

# **Order Lead-time Improvement Following Enterprise-IT Implementation: An Empirical Study**

**Mark J. Cotteleer**

**Harvard Business School  
Boston, MA 02163**

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## **Abstract**

This paper investigates the influence of enterprise systems implementation on operational performance. It does so in the context of a study of order lead time performance improvement for a firm that implemented a common Enterprise Resource Planning (ERP) system simultaneously across each of its three geographic operating regions. The paper extends the literature on enterprise systems implementation by looking beyond the firm level to develop an understanding of how operational effects are realized across different operating units.

Findings suggest that the pattern of performance experienced by firm implementation regions is consistent, but that there are significant differences in the magnitude of initial improvement, and in the ongoing rates at which performance changes. Findings also indicate the presence of the “performance dip” that is often associated with implementations of new technology. However, in contrast to previous studies, the performance dip evidenced here is delayed. Field evidence is brought to bear on the analytical findings in order to offer insight into the factors that might drive differences between regional performances and between the conclusions of this study and the previous literature.

## **1. Introduction**

Enterprise systems represent one of the most important information technology categories to emerge in the last decade (Davenport 2000). These systems, best represented by Enterprise Resource Planning (ERP) applications, are the software products that support the wide array of work processes that firms rely on in their day-to-day business. Examples of the business processes commonly supported by enterprise systems include Order Management, Finance, Manufacturing, and Logistics (Davenport 1998; Escalle et al. 1999). Typical of these investments is an attempt to link these processes in the context of multiple geographically distributed operating sites (Markus et al. 2000).

ERP and other enterprise systems present an important phenomenon to be studied. From an economic perspective, these systems have attracted large investments by many firms. Investment in enterprise systems amounted to more than \$47 billion in 2001 (AMR 2001). This figure does not account for the billions of additional dollars of investment in computer hardware and services required to support these applications (Mabert et al. 2000; Willcocks et al. 2000). Reports further suggest that nearly 75 percent of U.S. manufacturing firms have made an ERP investment, or are considering making an investment in the future (Mabert et al. 2000). SAP, a leading enterprise systems vendor, reported that in 2001 it alone counted 17,500 organizations in more than 120 countries as customers (SAP 2001).

ERP implementations also provide examples of dramatic change efforts within firms. Many times these implementations represent unprecedented periods of tumult as firms grapple with the replacement of their core information systems across the distributed geographies in which they do business. More than 90 percent of firms that implement ERP do so for multiple process areas (Hitt et al. 2002), with in excess of 40 percent implementing “big bang”, meaning

that the entire change over to new systems and processes takes place in a single step (Mabert et al. 2000). Given the magnitude of the economic and organizational investments directed toward ERP implementation, efforts aimed at understanding their influence on firm performance stand to make significant contributions.

Previous firm-level studies of ERP have identified some benefits accruing to implementers. Research indicates that implementing firms realize benefits in terms of productivity and market capitalization (Hitt et al. 2002). Studies of operational performance have also revealed an ability of ERP to positively influence performance over time (McAfee 2002). In some cases operational improvement has been preceded by “performance dips” – periods of adjustment during which performance declines prior to improving. In other cases, improvements were immediate and uninterrupted.

While insightful, previous studies of post-ERP performance have fallen short of providing a full understanding of the influence of these technologies. ERP has been characterized as affecting performance at the process-level across multiple implementation sites (Austin et al. 2001; Markus et al. 2000). Yet prior research has looked only at firm-level outcomes. This leaves open the possibility that lower-level variation in performance is being masked by studies conducted at too high a level of analysis. Understanding whether there are significant differences in the way implementation outcomes are realized across lower levels within the firm can yield deeper insights into the drivers of such outcomes.

This paper investigates the influence that an enterprise system implementation had on the operational performance of a single firm with three geographic operating regions. It does so by evaluating the influence of an ERP implementation on order lead time performance within each region. Specifically, this paper asks whether the patterns of performance change across

operating regions vary. Where variation does occur, it seeks an understanding from field analysis as to what factors might be contributing to performance change.

Findings suggest that each of the operating regions realized significant lead-time improvements as a result of the implementation. However, the magnitude of the immediate implementation benefits, and the rate at which performance changed subsequent to implementation all differed significantly. The analysis also demonstrates the existence of a “performance dip” in the period following ERP deployment that is consistent in kind, but not in timing, with past research.

Following this analysis, the paper attempts to provide insight into regional performance patterns by drawing on field evidence and some theory on organizational learning. The paper illustrates not only the role that information technology can potentially play in the improvement of performance, but it also suggests some of the tactics that managers can employ to enhance the benefits they receive.

The rest of the paper proceeds as follows. Section 2 presents an overview of some of the literature that is relevant to a discussion of enterprise systems and their influence on operational performance. Section 3 presents the context, data, and analytic model used for the study. Section 4 provides a discussion of the statistical analysis and offers some potential explanations for its results. Section 5 provides some conclusions from the analysis and discusses several of the study’s limitations.

## **2. Influence of Enterprise System Implementation on Operational Performance**

Enterprise systems offer the potential to influence performance in three ways: through improved commonality, superior functionality, and increased visibility (McAfee 1999). First, by

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promoting *commonality* in data definitions, enterprise systems increase the opportunity for information sharing across the firm. The data standards promoted by enterprise systems allow for access to information by multiple constituencies across the firm. Increased sharing of data offers the prospect of tighter coordination between groups, leading to improved performance.

Second, improvements in *functionality* offer the potential for business process participants to become more effective in the conduct of work tasks. Software vendors attempt to provide this improved functionality by surveying the firms with whom they work to identify and embed “best practices” within their software products (Davenport 2000). Firms may attempt to draw on these embedded practices to improve performance.

Third, enterprise systems promise increased *visibility* on the part of users to the totality of the work processes in they support. Through integration of data and functionality, system users have the opportunity to follow up on transactions and investigate process exceptions. Improved visibility may work to reduce queue times for issues that would otherwise require addressing by traditionally non-integrated business functions. For example, the firm studied here sought to add “available to promise” (ATP) functionality through their ERP implementation. ATP functionality as it is embedded in many enterprise systems integrates order management, manufacturing, and inventory to allow order takers to identify and allocate products to customer orders from across multiple stages of the production process and across multiple inventory locations. Doing so immediately, while still in contact with the customer, offers the potential to both increase speed to delivery and to improve customer satisfaction.

### **2.1. ES Influence on Firm Performance**

There is an emerging body of empirical research that investigates the influence of enterprise systems on objective measures of firm performance. Firm-level findings suggest that

ERP implementation is related to superior performance across multiple measures, including productivity and Tobin's  $q$ , a measure of surplus stock market returns (Hitt et al. 2002). These effects were strongest *during* the implementation period, diminishing somewhat “right at the end” of the deployment. Research suggests that better performance *during* deployment may result from a gradual phasing in of benefits prior to project completion, or from organizational “belt tightening” during implementation. The partial falloff in performance following the completion of ERP implementation is attributed to either a reduction in organizational flexibility or to offsetting increases in the long-term maintenance costs of the system (Hitt et al. 2002).

Firm-level evidence also exists regarding the ability of enterprise systems to positively influence operational performance. A longitudinal study of firm-level order lead-time and on-time shipping performance revealed significant long-term improvement (McAfee 2002). Findings for on-time shipping performance study were consistent with Hitt et al (2002) and with other studies of new technology implementations, in that they also demonstrated a post-implementation “performance dip” immediately following deployment. These dips are viewed as adjustment costs incurred by the firm as it learns to utilize the new technology and refines system and process characteristics to work well with one another (Chew et al. 1991; Hayes et al. 1986). In contrast, order lead-times did not demonstrate a performance dip. Instead, performance immediately improved and continued to improve over the length of the period studied.

Findings from research on operational performance have revealed ERP's ability to influence performance differentially across business processes (Davenport 2000). These results support a view of ERP as influencing performance at the process level . However, the breadth of ERP impact has also been characterized as reaching across multiple implementation sites

(Markus et al. 2000). As an enterprise-level technology, ERP is frequently implemented in multiple locations simultaneously (Austin et al. 2001). Empirical research has provided little evidence as to how these kinds of implementations influence performance across distributed sites.

## **2.2. The importance of understanding performance below the firm-level**

Where operational improvement is measured as gross change in performance, it seems unlikely that ERP would benefit all implementation locations equally over time. Differences in pre-deployment performance potentially leave sites with more or less opportunity to improve, causing implementation benefits to accrue disproportionately to implementation sites that performed less well prior to deployment. Alternatively, management skill may differ. Managers in some implementation sites may be more apt to leverage the capabilities offered by new technologies. Where this aptitude has been previously exercised, sites that performed better prior to ERP deployment may actually benefit more from its implementation. Finally, where implementation benefits are determined by the fit between the technology and its context, the unique characteristics of individual implementation sites may lead to unevenness in their distribution.

Geographic variation in ERP's influence on performance may have serious consequences in situations where the implementation is distributed across multiple operating regions. Dramatic performance improvements in one region might mask a lack of improvement, or a decline, in another. Initial dips in performance may occur unevenly across implementation sites, leading to a misinterpretation of the technology's specific impact. Importantly, a failure to understand how performance is differentially influenced below the level of the firm may cause managers (and researchers) to miss important factors that can affect implementation success.

Finally, since implementation sites are often managed independently, it seems appropriate to measure their performance independently as well.

This paper investigates the influence ERP implementation had on performance in the context of a multi-site implementation. At a general level it seeks to understand the influence ERP deployment had on the operational performance of the firm. Second, it investigates the way in which performance change was revealed across multiple geographically distributed business units within the firm. Third, through an examination of the firm's implementation approach, this paper seeks to identify some of the factors that moderate the relationship between ERP implementation and performance.

### **2.3. ES influence on Order Management process performance**

Order management has been a primary target of ERP implementations (Austin et al. 2001; Deloitte 1998; Mabert et al. 2000). There is also reason to expect that ERP implementation might affect order management process performance. First, ERP solutions explicitly target the order management process, including functionality for order generation, planning, production scheduling, inventory allocation, order picking, and shipping (Davenport 1998). Second, ERP applications are specifically intended to link together business processes and information in order to improve functionality, communication, and visibility (McAfee 1999). For example, at Tektronix, Inc. an ERP order management initiative was intended to provide global inventory visibility, unified customer identification, standardized credit approvals, and uninterrupted order flow for order creation through shipping (Westerman et al. 1999).

Order lead-time – the elapsed time between the date an order is received by the firm and the date the product is shipped to the customer – is a key measure for the evaluation of order management process performance. Lead-time has established roots as a measure of order

management and supply-chain performance, having been used in multiple studies of related phenomena (Hult et al. 2002; Mabert et al. 2000; McAfee 2002). The general importance of cycle time has been demonstrated in studies of customer service (Stalk et al. 1990) and manufacturing performance (Hayes et al. 1988). Customer service and timeliness have also been identified as primary reasons for IT investment (Brynjolfsson et al. 1996). Finally, order lead-time reductions are valuable to firms as a source of overall business cycle reduction and working capital release. For example, a reduction of one day in order lead-time was estimated to be worth approximately \$11 million in freed working capital for the studied firm.

### **3. Implementation Context and Measurement of Operational Performance.**

The study takes place at Tristen Corporation, a United States-based, \$4 billion producer of peripheral equipment for servers, desktop PCs, and other computerized equipment. In 1996, the firm employed nearly ten thousand people in 23 sales and manufacturing sites worldwide. The early 1990s saw corporate revenue grow 400 percent through a strategy of frequent new product introduction and technological leadership.

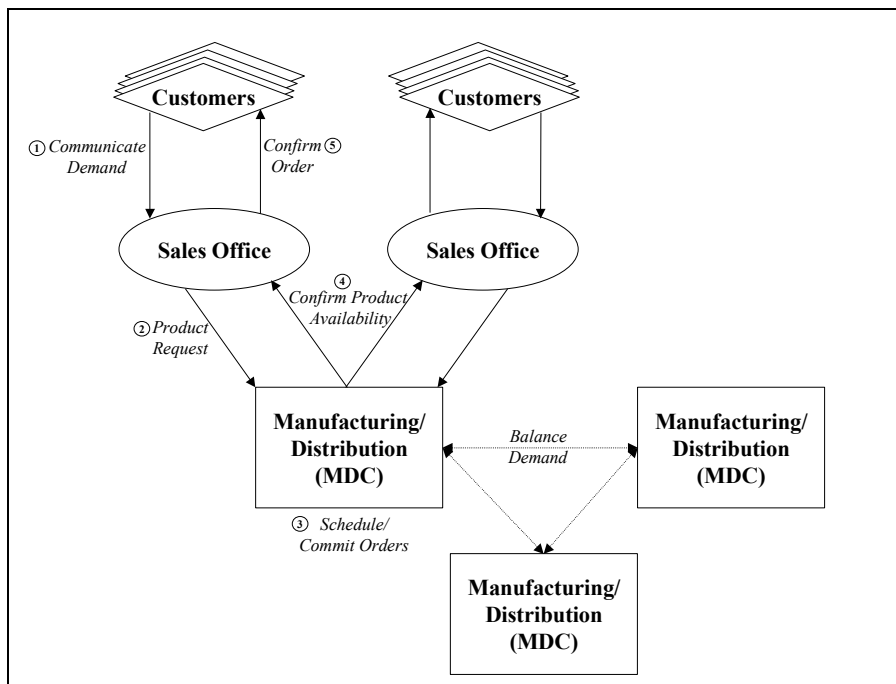
The data collection effort consisted of two complementary efforts. The first, described in the section 3.2, involved the collection of operational data from the target firm's information systems. The second included interviews with managers, implementation project participants, and users, and review of project documentation in order to form an understanding of the context within which the implementation took place. Interviews were semi-structured and included questions concerning system development, training, deployment, and post-implementation support. A description of the firm context in which the ERP implementation took place follows.

### 3.1. Context and motivation for ERP implementation at Tristen Corporation

As the late 1990s approached, Tristen management perceived an increasing trend toward commoditization of the company’s core products. In anticipation of this market change Tristen enacted a shift in strategy, relying less on technology innovation and more on the delivery of products with “high value-added”. In the company’s view, high value-add incorporated a dual emphasis on cost leadership and superior customer service.

Tristen served its core markets through a set of three manufacturing/distribution centers (MDCs), each supporting a single operating region – North America, Europe, or Asia. Product orders were gathered at sales offices scattered across the operating region and forwarded to the MDC for scheduling and commitment. Once committed at the MDC, product availability was signaled back to the sales office for confirmation back to the customer (see figure 1 for a depiction of the order process flow).

Figure 1: Pre-ERP order flow at Tristen Corporation.



Products were primarily manufactured to forecast, but held in a semi-finished state within each region in anticipation of future demand. Final configuration and testing of products was completed during order fulfillment. Despite the availability of good aggregated demand forecasts, Tristen faced difficulties balancing inventory at the region-level. One manager summarized:

Worldwide our customer's forecast might be accurate plus or minus 10%, but within geography it might be accurate plus or minus 70%. Customers might forecast heavy demand in Europe, but then for some reason demand would really be in Asia. We didn't have a good way to shuffle things around.

Tristen management suspected that the firm's inability to balance global demand in order to respond quickly to customer needs was becoming a competitive hindrance. The need to confirm every order through the MDC created delays of up to a week in the ability to begin the order fulfillment process, as logistics personnel had to manually track down inventory at other MDCs. Central to the difficulties faced by the firm was a lack of financial and operational information visibility across the firm. Instead of accessing common information systems, each region possessed its own, non-integrated information architecture. These systems had been in place for more than 15 years.

Lack of systems integration prevented Tristen from providing standard service levels to multi-national customers. In some cases, customers received different responses from the company, depending on the geography of the sales office they contacted or the location of the customer facility. The lack of integration frustrated customers' supply-chains management efforts and, by extension, Tristen's attempts to maximize customer satisfaction. Tristen managers concluded that in order to improve customer responsiveness they would need to

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implement new information systems. Key to this implementation would be the inclusion of ATP functionality. One manager characterized the situation: “We recognized that we needed ATP functionality, the ability to commit to orders in real time from anywhere in the world and to see inventory globally.” Another manager expanded upon this need:

From the operations side it was essentially about available-to-promise and being able to respond faster..., the reason we wanted worldwide ATP was that many of our customers are global. So, for example, a customer has operations in North America, Europe, and Asia. They expect each operation to be treated the same. Instead, the different regions were getting different levels of service.

The need for ATP and other operational improvements led in 1994 to the formation of a new initiative called the “Order-to-Fulfillment” project. The mission of the project was to “partner with customers to define and meet their evolving business needs for product availability, delivery, and integrated inventory management.”

Tristen’s information systems investment began with the selection of a software product to replace its aging legacy systems. The company chose a leading ERP application suite as its solution based on its overall fit with the company and the availability of the ATP functionality. In defining an implementation approach, Tristen held itself to three standards: 1) Minimization of package customization; 2) Minimization of business process change; 3) Simultaneous (“Big Bang”) implementation of all processes and locations. In situations where the first two standards conflicted, the bias of the implementation team was to accept the business process as it worked in the unmodified software. One manager described the company’s thinking on this matter:

So what’s the leap to understand that you ought to do the process the way the software package does it? If the package does it at least as well or better, as the

company currently does, then follow the package instead of modifying the software.<sup>1</sup>

Another decision made by managers of Tristen’s ERP implementation was the decision to collocate development at the firm’s North American headquarters. All aspects of the ERP systems and process development were located within a single building on Tristen’s headquarters campus in the United States. Project team members took up residence in the local community for the duration of the development process. Although dominated by North American personnel, an effort was made to include representation from other global sites. In particular, one representative was selected from each of the international MDCs.

Managers felt that collocation was required in order to increase the level of interaction between project team members. One manager described the importance of everyone being together:

Collocation was absolutely critical, absolutely key to this project because you got the interface in the hallway, you got the, “Hey, Bill, how do you do this?” and Bill would come over and sit down and show you.

Project team members from international sites returned to their home locations following deployment. Several information system specialists accompanied personnel returning to each MDC. These specialists were put in place to support the implementation during the first weeks following adoption of the new systems.

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<sup>1</sup> In rare cases where Tristen managers felt that the software did not match an important need of the business modifications were attempted. Most significant among these was the development of functionality to allow for financial processing in multiple currencies. No significant modifications to order management or logistics functionality were reported.

### **3.2. Operational Data Collection**

Lead-time data was collected for sales orders booked before and after ERP deployment.<sup>2</sup> Data were collected for three operating regions within the firm. All regions implemented the same ERP solution, on the same date. As such, factors related to implementation timing and resources, and global economic climate are well controlled for in the study.

Approximately 113,000 pre- and post-deployment order records were used in the analysis. These records cover a period beginning 12 months prior to deployment and extend 24 months following deployment.<sup>3</sup> The data included information necessary to calculate order lead-time, as well as related information that allowed transactions to be sorted by operating region and classified in other ways including transaction date, order quantity, and order value.

The variables used in the analysis are defined in Table 1. Summary statistics are provided in Table 2. Order quantity (**units**) and dollar value (**value**) are included in order to account for managers' prioritizations based on alternative measures of order size. The total number of orders taken on a particular day (**daycount**) is included in order to account for possible performance changes on high volume days. An index of time (**month**) and its square (**month2**) facilitate an analysis of how lead-time performance changed over time. Finally, regional indicator variables (**europe**, and **asia**) provide order-level identification of the operating region in which an order transaction was created. Variables enter the model both as main effects, and in interaction with regional indicator variables in order to account for differences in the

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<sup>2</sup> These data have been used in related work in (Cotteleer 2002).

<sup>3</sup> Order transactions are excluded for the three months prior to ERP deployment. Data is excluded in order to avoid bias in estimates of order lead-time performance. This bias would have arisen because at the time of ERP implementation, all outstanding orders were reentered into the new system with order dates corresponding to the first week of ERP operation. As a result, information was not available on the full set of orders processed in the quarter prior to implementation (i.e., only orders that were taken and shipped prior to implementation would have been included in the data set). In addition, the first five days of operation following ERP deployment are excluded as all outstanding pre-deployment records were converted to the new system with booking dates during that time.

effect each has on regional order lead-time performance. Thus, analysis of elapsed order lead-time was conducted using the following model.

$$\begin{aligned} \text{leadtime}_i = & \alpha + \beta_1 \text{daycount}_{ij} + \beta_2 \text{reqqty}_i + \beta_3 \text{examt}_i + \beta_4 \text{europe}_i + \beta_5 \text{asia}_i + \\ & \beta_6 \text{europe}_i * \text{daycount}_{ij} + \beta_7 \text{asia}_i * \text{daycount}_{ij} + \beta_8 \text{europe}_i * \text{reqqty}_i + \beta_9 \text{asia}_i * \text{reqqty}_i + \\ & \beta_{10} \text{europe}_i * \text{examt}_i + \beta_{11} \text{asia}_i * \text{examt}_i + \beta_{12} \text{month}_i + \beta_{13} \text{europe}_i * \text{month}_i + \beta_{14} \text{asia}_i * \text{month}_i + \\ & \beta_{15} \text{month2}_i + \beta_{16} \text{europe}_i * \text{month2}_i + \beta_{17} \text{asia}_i * \text{month2}_i + \varepsilon \end{aligned}$$

Where “*i*” represents in customer order and “*j*” represents the operating region from which the order was placed.

**Table 1: Model variable definitions**

Variable Name	Definition
<b>leadtime</b>	Elapsed time between the order booking date and the date it was recorded as shipped to the customer.
<b>month</b>	A time index variable used to capture the number of months prior to, or after ERP deployment that a transaction was executed.
<b>europe, asia</b>	Indicator variables that identify the operating region in which a sales order was generated. Transactions that originated in North America were identified where both <b>europe</b> and <b>asia</b> were set equal to zero.
<b>daycount</b>	The total number of order transactions that were processed within the operating region on the day the order was taken. A measure of business intensity.
<b>units</b>	The total number of product units (in thousands) associated with the order. A measure of order size.
<b>value</b>	The total dollar value (in thousands) of the sales order. A measure of order value.

**Table 2: Summary of Analysis Variables**

Variable	N	Mean	Std. Dev.	Min	Max
leadtime	112818	33.44	35.65	0	434
month	112818	9.39	9.90	-12	24
europe	112818	0.29	0.45	0	1
asia	112818	0.19	0.40	0	1
daycount	112818	94.58	90.29	1	833
units	112818	0.64	1.86	0	116
value	112818	262.61	1728.00	0	126000

Model selection was theoretically motivated by the literature on learning curves, which posits that performance following the implementation of new process and/or technology will improve nonlinearly but monotonically with time or experience as a function of learning-by-doing (see Dutton et al. 1984; Yelle 1979 for comprehensive reviews of the learning curve literature). Typical learning curve specifications utilize models that relate the log of performance to the log of either elapsed time or cumulative experience. In this case, however, the existence of

zero values for the performance measure (i.e., when the order was booked and shipped on the same day) prevented the use of the log specification.

Visual inspection of the data, however, still raised the possibility the improvement function was non-linear. Specifically, it appeared that a performance dip might exist following initial ERP deployment. In order to capture this characteristic of the data, and to accommodate zero values in the dependent variable, various exponential functions were tested for use in the model. These alternatives included transformations of the dependent and independent variables according to Neter (1990).

The final functional form was selected based on model fit and use in prior, related research (see, McAfee 2002). Models were also evaluated that controlled for calendar month, quarter, and quarter ends. Finally, analysis was completed using an enhanced model for the post-deployment period. This model included data on sales channel, distribution site, and product type. Different modeling alternatives reported similar results. The model presented was selected on grounds of fit, parsimony, and interpretability. As a final test, models were run assuming both constant and differing levels variation across operation regions. Findings were identical using both models.

OLS results for the analyses are presented in Table 3. Models 1a and 1b include only the main effects for the combined pre- post-deployment periods. These models establish baseline lead-time performance over the entire study period and the contribution of the control variables to the explanatory power of the model. Model 1a does so by assuming a linear relationship between lead-time and operating month. Model 1b repeats this analysis with the addition of the square of operating month (**month<sup>2</sup>**), which accommodates an apparent non-linear relationship

between lead-time and operating month. We note the significance ( $p < .001$ ) for each of the variables in the main effects models.

Model 2 and Model 3 facilitate the analysis of operating region effects through the inclusion of **europa** and **asia** and their interactions with each of the variables in the main effects models. The models focus respectively on pre- (Model 2) and post-deployment (Model 3) periods in order to facilitate the interpretation of operating region effects through avoidance of three-way interactions. Table 4 presents prototypical order lead-times based on these results for each month using median values for each of the other independent variables. Also included in Table 4 are calculations of the instantaneous rate of lead-time performance change for each operating month.<sup>4</sup> Prototypical lead-time performance is graphically depicted in Figure 1. The figure presents prototypical plots for all regions overlaid with actual monthly performance data for each region.

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<sup>4</sup> Instantaneous rate of change is calculated for each region/month by taking the F.O.C. with respect to month. The calculations are used to assess the rate at which performance is converging or diverging within any given month.

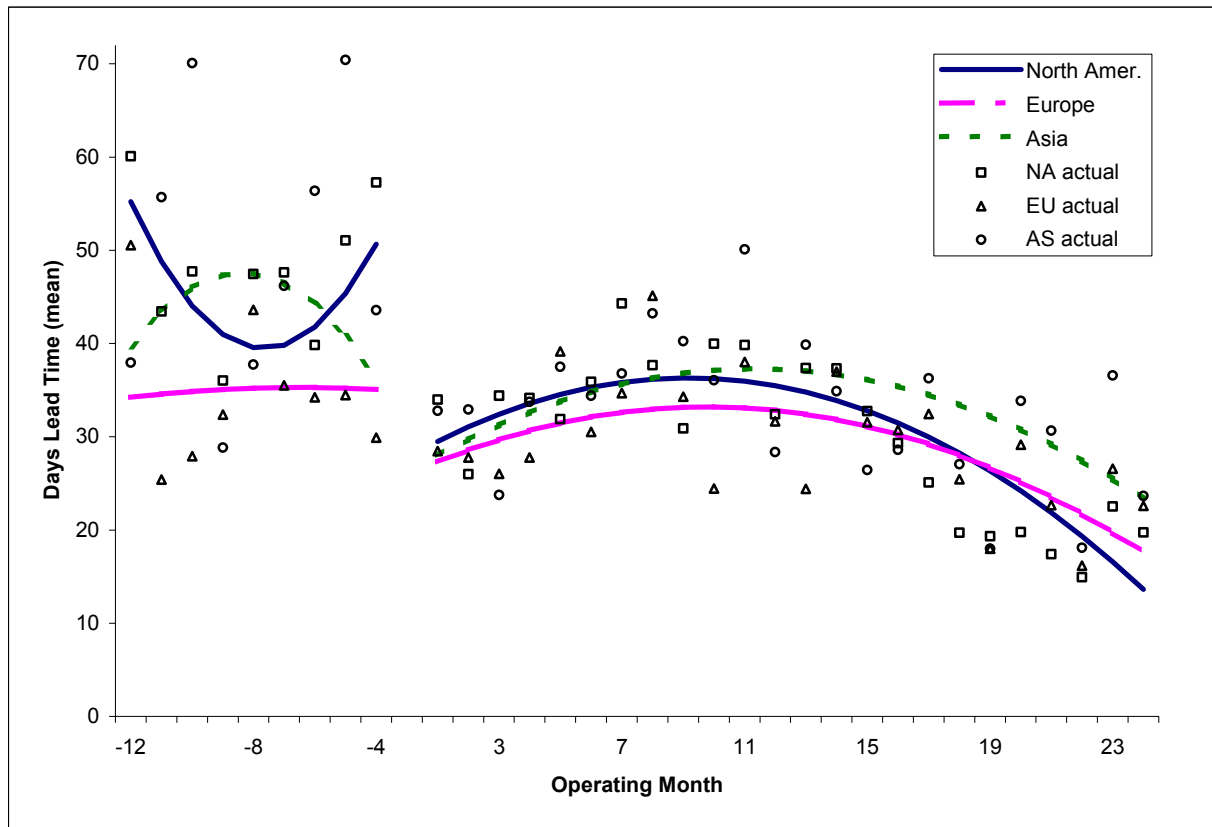
**Table 3: Summary of OLS pre- and post-deployment lead-time performance (standard errors in parentheses).**

Deployment Period: Model:	Pre- & Post- Model 1a	Pre- & Post- Model 1b	Pre- Model 2	Post- Model 3
constant	36.6418*** (0.1915)	36.8841*** (0.2017)	72.1573*** (3.3427)	25.7695*** (0.6215)
daycount	0.0348*** (0.0012)	0.0347*** (0.0012)	0.1595*** (0.0055)	0.0246*** (0.0015)
units	-0.4160*** (0.0559)	-0.4214*** (0.0559)	-0.7090*** (0.2296)	-0.5222*** (0.1069)
value	-0.0002*** (0.0001)	-0.0002*** (0.0001)	0.0174*** (0.0015)	-0.0044*** (0.0009)
month	-0.6585*** (0.0106)	-0.6052*** (0.0175)	12.8035*** (0.8679)	1.8776*** (0.0979)
month2		-0.003883*** (0.0010)	0.8358*** (0.0540)	-0.1027*** (0.0037)
europa			-49.1323*** (13.5041)	-7.5153*** (0.9576)
asia			-78.0025*** (24.6277)	-1.3665 (1.0482)
europa*daycount			0.6629*** (0.1063)	0.0882*** (0.0040)
asia*daycount			1.7929*** (0.1676)	0.0132*** (0.0029)
europa*units			-1.6593 (5.9740)	0.3818* (0.2083)
asia*units			-24.8945* (14.6772)	0.4077*** (0.1420)
europa*value			-0.0123 (0.0177)	-0.0033** (0.0016)
asia*value			0.1307 (0.0861)	0.0040*** (0.0009)
europa*month			-13.2358*** (3.3564)	-0.3707*** (0.1508)
asia*month			-22.8255*** (6.1189)	0.0886 (0.1699)
Europe*month2			-0.8692*** (0.2011)	0.02562*** (0.0058)
Asia*month2			-1.4350*** (0.3629)	0.01599*** (0.0065)
R-Square (adj.)	0.0459	0.0461	0.0807	0.0456
N	112818	112818	18277	94541
Prob. > F	0.0000	0.0000	0.0000	0.0000

**Table 4: Summary of predicted lead-times and First Order Conditions, by operating month.**

Operating Month	Predicted Values			FOC		
	NA	EU	AS	NA	EU	AS
-12	55.19	34.24	39.67	-7.26	0.37	4.36
-11	48.77	34.57	43.43	-5.58	0.30	3.16
-10	44.03	34.84	45.99	-3.91	0.24	1.96
-9	40.95	35.04	47.36	-2.24	0.17	0.76
-8	39.54	35.18	47.52	-0.57	0.10	-0.43
-7	39.81	35.25	46.49	1.10	0.04	-1.63
-6	41.75	35.25	44.25	2.77	-0.03	-2.83
-5	45.36	35.19	40.82	4.45	-0.10	-4.03
-4	50.64	35.06	36.19	6.12	-0.16	-5.23
1	29.49	27.28	28.00	1.67	1.35	1.79
2	31.06	28.56	29.71	1.47	1.20	1.62
3	32.42	29.68	31.24	1.26	1.04	1.45
4	33.58	30.65	32.60	1.06	0.89	1.27
5	34.53	31.46	33.79	0.85	0.74	1.10
6	35.28	32.12	34.80	0.65	0.58	0.93
7	35.83	32.63	35.64	0.44	0.43	0.75
8	36.16	32.98	36.30	0.23	0.27	0.58
9	36.30	33.18	36.80	0.03	0.12	0.41
10	36.22	33.22	37.12	-0.18	-0.03	0.23
11	35.94	33.11	37.26	-0.38	-0.19	0.06
12	35.46	32.84	37.23	-0.59	-0.34	-0.11
13	34.77	32.42	37.03	-0.79	-0.50	-0.29
14	33.88	31.85	36.66	-1.00	-0.65	-0.46
15	32.78	31.12	36.11	-1.20	-0.80	-0.63
16	31.47	30.24	35.39	-1.41	-0.96	-0.81
17	29.96	29.21	34.50	-1.61	-1.11	-0.98
18	28.25	28.02	33.43	-1.82	-1.27	-1.15
19	26.33	26.67	32.19	-2.02	-1.42	-1.33
20	24.20	25.17	30.78	-2.23	-1.57	-1.50
21	21.87	23.52	29.19	-2.43	-1.73	-1.67
22	19.33	21.72	27.43	-2.64	-1.88	-1.85
23	16.59	19.76	25.49	-2.84	-2.04	-2.02
24	13.64	17.64	23.39	-3.05	-2.19	-2.19

Figure 2: Prototypical lead-time values and plot by month (median values of daycount, units, and value).



## 4. Discussion

### 4.1. Changes in Operational Performance

Lead-time performance trends *prior to* ERP deployment are described using Model 2. Findings suggest that, controlling for daily volume, order quantity, and order value, North American lead-time performance was getting worse while European and Asian performance were improving. Europe was estimated to have a small performance edge over Asia at the data cutoff date four months prior to ERP deployment. However, Asian performance was improving more rapidly at a rate of 5.2 days per month, rather than a nearly stable 0.2 days per month.

Performance trends *following* ERP deployment are described in Model 3. Findings indicate that all three operating regions realized immediate lead-time improvements following

ERP deployment. However, rapid changes in estimated pre-deployment order lead-times for North America and Asia make it difficult to interpret the magnitude of this improvement with high confidence. Nonetheless, it is clear that North America improved more dramatically than the other regions. In North America, prototypical lead-time performance improved 41.7 percent (21.2 days) between pre- and post-deployment periods. Europe realized a smaller improvement of 22.2 percent (7.8 days) while Asia improved 22.6 percent (8.2 days). Relative to one another, the regions stayed the same in their performance rankings, with Europe leading (27.3 days), followed by Asia (28.0 days) and North America (29.5 days).

Performance also converged significantly between the time periods immediately before and after deployment (see, Cotteleer 2002). For example, comparing the last monthly estimate prior to deployment with the first monthly estimate following deployment reveals a reduction of 85.9 percent in the gap between North American and European lead-time performance. Over time, the North American region also improved significantly faster than the other regions ( $p < .01$ ), eventually surpassing both regions in lead-time performance.

Differences in the extent to which performance improved following implementation may be a byproduct of relatively worse pre-implementation performance. The more poorly performing regions might simply have had a greater opportunity to improve. The convergence in performance following deployment is suggestive of that explanation. Alternatively, it may be that aspects of the implementation approach favored some regions over others. Evidence of favorable implementation conditions is apparent in the case of the North American region. For the firm studied, the ERP deployment project was executed primarily from the company's North American headquarters. In addition, 60 percent of the personnel allocated to the project came from North America.

Heavy North American representation may have helped the region in two ways. First, it might have increased the acceptance of the system by North American users. Managers reported that having a credible, locally based source that supported the implementation was key to system acceptance. One representative stated: “People saw that I had gotten over it, and I had more to lose than anyone because supporting the old systems was my job. That was pretty symbolic.”

Second, managers reported that low representation from other regions reduced their level of project input. Beyond user acceptance, poor representation was seen to increase implementation risk at geographically distributed sites in two ways – first, by reducing the system’s fit with local requirements; second, by hindering the ability of local users to understand the logic of the new systems and business processes. As one project manager coarsely put it “if you did not send somebody to the project, you were not represented, you were S.O.L.”.

#### **4.2. Delayed performance dip following ES implementation**

Lead-time performance gains were immediate and for the most part maintained during the study period. However, each of the regions did experience a delayed “performance dip” over a period of several months following deployment. During their declines, both Asia and Europe saw performance diminish to the point where it was roughly equal to or, in the case of Asia, slightly worse than what was experienced in the months prior to deployment. Lead-time performance began to improve once again for the regions in the tenth (North America and Europe) and twelfth (Asia) months.<sup>5</sup> Following the performance dip, all regions displayed lengthy improvement trends, lasting through the end of the 24-month post-deployment study period.

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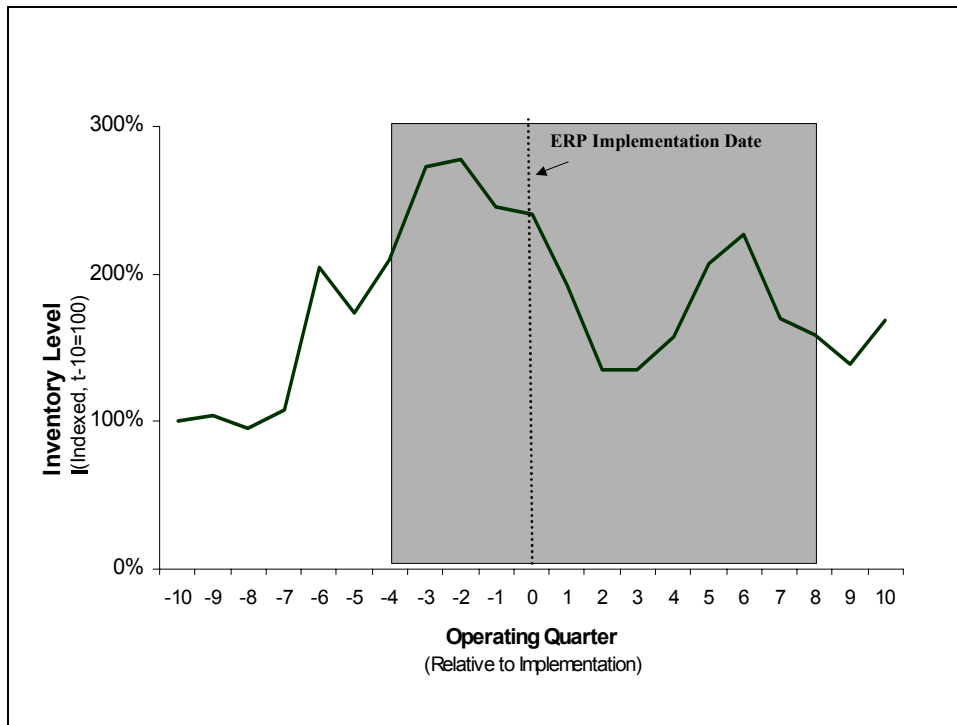
<sup>5</sup> Recognizing that a quadratic turns over at  $x=-b/2a$ , and substituting for values of **month**, **month2**, and their region-level interactions, we find that North America begins improving once again at month 9.14, followed by Europe I month 9.78, and Asia in month 11.33.

Findings with regard to the timing of the performance dip contrast with those of previous studies (Hitt et al. 2002; McAfee 2002). Those studies revealed performance dips in the period immediately following implementation. The timing of the decline is most evident in McAfee (2002) because of the longitudinal approach adopted in that study. Evidence from the field suggests two tactics employed by the studied firm – buffering with inventory and employing local support teams –that may have delayed, but not avoided, a temporary performance decline. Field data also reveals one set of behaviors – uncontrolled local adaptation – that may have contributed to the decline when it occurred.

#### **4.2.1. Buffering Performance with Inventory**

Inventory is frequently used as a buffer for system shocks (Hayes et al. 1988). In the course of normal business, these shocks may come in the form of unexpected demand changes or disruptions to the supply chain. In the case of preparation for the implementation of an ERP solution, shocks may come in the form of disrupted business processes as employees learn to use the new information systems to execute normal business. The studied firm attempted to buffer the initial shock of ERP deployment to its production and delivery capability by significantly increasing inventory levels in the months prior to deployment. Figure 2 illustrates this build-up at the firm level using quarterly data. Although the figure shows a regular pattern of inventory buildups to coincide with the end of each calendar year (periods -10, -6, -2, 2, 6, and 10), inventory increases in the quarters leading up to the implementation were significantly higher and of longer duration.

Figure 3: Firm Level Inventory (indexed), by quarter, relative to ERP implementation date.



Inventory levels fell rapidly in the quarters that immediately followed implementation. To the extent that inventory levels fell faster than the firm learned to effectively use the new systems and business process, deteriorating performance may be an expected result. A comparison of Figure 1 and Figure 2 suggests that lead-time performance ceased its decline between the third and fourth quarters (months 9 – 12) of post-implementation operation, the same time in which the firm once again began to build inventory levels. It may be further noted that performance improvement continued past the sixth quarter of operation, when inventory again began to fall. From an organizational learning perspective it may be that by the eighteenth month of post-implementation operations, the firm had learned enough about the new systems to work well without the addition of inventory buffers.

#### 4.2.2. Local User Support

The firm also prepared for implementation by stationing key project team members in the operating regions during and immediately after the ERP deployment. The action provided the distributed implementation sites with highly qualified workers who were well down their individual learning curves with respect to the new process and technology. Perhaps more important, these team members also provided local-level resources for the rapid resolution of user issues. One project team member commented on her experience: “... there was nowhere for us to go, nowhere for us to hide. We were going to implement this thing to work the best we knew how, and if it didn’t {work}, we were going to be here to fix it”. Other team members also had strong feelings about the impact of having experienced personnel available as local resources, noting:

They had somebody who had worked on the project for more than a year and knew the software very well. So they had a sort of built-in escalation path that the other people at the site could go ask about how things worked.

From an organizational learning perspective, these local resources provided a source of “vicarious learning” for end users in each of the regions. Vicarious learning represents knowledge obtained by others but which is available for the organization’s use (Chew et al. 1991). In this case, vicarious learning was embedded in the project team members that participated in the ERP development project, training, and deployment. When disbursed to the operating regions, these resources were seen to buffer the organization from the initial shock of the implementation, thus promoting the early gains that were evident from the analysis.

Despite the acknowledged value of local end-user support by project team members, its availability turned out to be short-lived. The firm experienced a high level of attrition among project team members in the months following the ERP deployment. Turnover was attributed to

two factors. First, the highly publicized success of the implementation led to extensive “raiding” by outside employers interested in acquiring experienced ERP implementers. Second, the company did a poor job of reintegrating personnel back into the business. Where backfilling took place due to the extended full-time involvement of team members, there was sometimes no position to move back into. In cases where support positions were created for former team members, they were poorly defined and not well accepted in the organization. As a result, many implementation team members left the company to pursue opportunities in consulting or with other firms.

Loss of key project team members had the potential to adversely affect performance in two ways. First, through their expertise developed during the implementation effort, these individuals potentially represented the most effective users of the new system. Thus, their loss led to a decline in the average effectiveness of all users. Second, to the extent that project team resources left the operating regions before users in those regions had sufficiently mastered the new information technology and business process, the loss of vicarious knowledge might have induced declines in operational performance until such time as the user community at large could learn from their own experiences.

#### **4.2.3. Local Adaptation**

A third potential explanation for the pattern of declining performance seen in each of the regions relates to a spate of uncontrolled localized configuration that occurred in the months following deployment. During this time, users acted on their own behalf to modify parameter settings in order to more closely match the way they felt local business should be conducted. One project manager described the problem and its consequences.

I think one of the areas where we fell short was recognizing that once you implemented, users started customizing for how they got their work done. In a global ERP environment, one site starts saying, “I’m going to set my parameters or my offsets for transit time this way...” but another one sets it differently, your assumption about product that may be available to commit against an order may not be valid.

She further elaborated:

We didn’t really have a good process in place to make sure that there was consistency where there needed to be. We had some issues specifically with the logistics sites. Once they got into the system, they started making changes and there wasn’t a good process to either prevent that from happening or to monitor it until we started seeing metrics that got out of whack.

Local adaptation created an uncertain environment within distributed firm locations in which users could no longer anticipate the results of system use. Uncertainty or ambiguity in the operating environment has been identified as an inhibitor of organizational learning in that it obfuscates the relationship between action and performance, causing improvement to come less quickly and less often (Bohn 1995; Lant et al. 1990).

Following the realization that local configuration was inhibiting performance, firm management imposed a change control process. Managers reported that this stabilization allowed for improved realization of the benefits promised by the ERP applications.

## **5. Conclusion**

Enterprise systems represent a huge area of investment of global firms. They also represent major change for the firms that embark on these efforts. The purpose of this paper has been to examine the influence of one such implementation on operational performance. This

paper has sought to move beyond prior work to investigate this influence at the level of the operating region.

Findings revealed significant improvement in the lead-time performance of each operating region. However, these improvements differ both in initial magnitude and in the rates at which performance evolved over the two years following ERP deployment. Possible explanations for these differences include relative differences in the improvement opportunity available to each operating region and the possibility that some aspects of the deployment approach (e.g., domination of the implementation team by members of one region) provided unique advantages for some regions.

Findings with regard to the existence of a “performance dip” contrasted earlier studies. Although performance dips did occur in each region, they were delayed in their appearance. Evidence from the field offers three potential explanations for this occurrence and, by extension, three tactics that managers might use to avoid similar performance dips in their firms.

First, managers might consider using buffers to shield performance from the shock of implementing new systems and business processes. In the case of this study, the firm used inventory to buffer lead-time performance. This tactic apparently insulated product delivery performance for a time. It might be imagined that other kinds of buffers could be used with equal effectiveness in different process areas. For example, additional staffing might be employed to support the ERP transition in service related activities such as customer service and financial processing.

Despite the potential to enhance implementation benefits, a buffering strategy is not free. Where inventory is used as a cushion, managers must take into account the offsetting costs driven by the need for extra working capital and the potential for increases in shrinkage and

obsolescence. Buffering tactics that include the addition of personnel may incur costs related to employee recruitment and severance, and to the inherent difficulties involved in shifting human resources around the firm. Firms that use buffers as part of their implementation strategy should consider making these offsetting costs an explicit part of the business cases they use to justify the overall project. Future research should consider the appropriateness of different buffer strategies in order to maximize the effectiveness of this approach.

Second, post-deployment performance may be enhanced when the firm disburses experienced implementation personnel to distributed sites. These “super users” can become important sources of vicarious learning for regular users during the time they are learning to use the new system. Managers who employ this tactic should develop retention strategies to keep super users in place following implementation. The implementation process can be long, often lasting a year or more. Former roles will often either be backfilled or eliminated. Implementation personnel need to be properly reinserted into the organization in roles that are both fulfilling and that leave them available to the rest of the firm for insights on how best to use the system. Future research might consider alternative retention strategies to understand which might be most effective at achieving retention goals.

Finally, managers should consider limiting the adaptation of new enterprise systems in the period immediately following deployment. Certainly there will be unanticipated issues that need resolution in order for the system to properly function. These should be addressed. However, where the system is “good enough”, managers should resist local adaptation until firm members develop a good understanding of the logic behind new practices. Future research might investigate the tradeoffs between early adaptation and organizational learning following implementation. Insights into what types of system changes are most beneficial (or least costly),

and the amount of time typically required for adequate learning before adaptation may be particularly helpful to firms.

The evidence presented here suggests that managers can play an active role in influencing operational performance following implementation. By managing process buffers, deploying vicarious knowledge resources, and minimizing early local adaptations it may be possible to realize early performance gains without subsequent performance dips. Future research should consider the effects of these tactics, and others, in additional enterprise systems contexts so that the exact nature of their influence can be evaluated.

### **5.1. Limitations of the study**

Several limitations of this study should be kept in mind when interpreting the results. First, the data do not exhaustively cover the entire study period. Characteristics of the firm's data conversion strategy led to the elimination of data for the three months prior to deployment of the ERP applications. It is therefore possible that the estimated initial performance gains are off by a considerable margin. This limitation is particularly relevant to the evaluation of the Asian region, which was estimated to be improving significantly in months prior to the data cutoff. The concern is less troubling for Europe and North America, whose performance trajectories were either stable or falling. Future research should seek out performance data that is not subject to the limitations of the current data set. Using such data, the immediate performance change attributable to ERP deployment might be more precisely estimated.

Second, this study uses a single performance measure to gauge the influence of the information technology on operational effectiveness. Other performance measures are certainly important and may have exhibited different patterns of performance improvement. Future research should include other measures to see if similar patterns emerge. Nevertheless, the

current study still makes a contribution in that these patterns are investigated for at least one important performance dimension. To the extent that order lead-time contributes to the competitive success of firms, the findings suggest that the deployment of enterprise-level information technologies can contribute to performance improvement.

Third, regional affiliation, although significant in both a statistical and managerial sense, account for a relatively small proportion of the variation in lead-time performance. It is reasonable to suspect that many other factors contribute to the determination of order lead-time performance. It is possible that in addition to explaining more about lead-time performance, these other factors may be correlated with operating regions or countries. Such a correlation could lead to a bias in the estimates of the relationship between deployment site and lead-time.

Future research should consider using other sets of explanatory variables in order to verify the robustness of the findings in these areas. In addition, future research should consider the specification of more robust statistical models. Tests of the data using alternative model specifications yield similar results with regard to general patterns of operational performance improvement. However, other models may still yield improved results.

## Endnotes

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