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Enterprise resource planning: Managing the implementation process

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Abstract

Over the past few years, thousands of companies around the world have implemented enterprise resource planning (ERP) systems. Implementing an ERP system is generally a formidable challenge, with a typical ERP implementation taking anywhere from one to five years. The story of the success of ERP systems in achieving the stated objectives is mixed. Some companies have had very successful implementations while others have struggled. This paper empirically investigates and identifies key differences in the approaches used by companies that managed their implementations on-time and/or on/under-budget versus the ones that did not using data collected through a survey of US manufacturing companies that have implemented ERP systems. Logistic regressions are used to classify on-time and on/under-budget firm groups based on the survey responses and to identify the significant variables that contribute to on-time and on/under-budget implementation performance. The results indicate that many different factors ranging from pre-implementation planning to system configuration influence performance, which managers should be sensitive about when implementing major systems like ERP.

Keywords: Enterprise resource planning; Survey methodology; Logistic regression models

1. Introduction

Since the mid-1990s, enterprise resource planning (ERP) systems have been installed in thousands of companies worldwide. ERP systems are enterprise-wide on-line interactive systems that support cross-functional processes using a common database. ERP systems are designed to provide, at least in theory, seamless integration of processes across functional areas with improved workflow, standardization of various business practices, and access to real-time up-to-date data. ERP systems are complex and implementing one can be a challenging, time consuming and expensive project for any company (Davenport, 1998). An ERP implementation can take many years to complete, and cost tens of millions of dollars for a moderate size firm and upwards of $100 million for large international organizations (Mabert et al., 2000). Even with significant investments in time and resources, there is no guarantee of a successful outcome.

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Despite the large installed base of ERP systems, academic research in this area is relatively new. Like many other new Information Technology (IT) areas, much of the initial literature in ERP consists of articles or case studies either in the business press or in practitioner focused journals. Many of these articles provide anecdotal information based on a few successes or failures. These publications have chronicled both some high profile failures and extensive difficulties at such companies as FoxMeyer and Hershey Food Corporation (Deutsch, 1998; Diederich, 1998; Nelson and Ramstad, 1999), and some model implementations (Kirkpatrick, 1998). Also, several authors (Piturro, 1999; Trunk, 1999; Zuckerman, 1999) emphasize that ERP is a key ingredient for gaining competitive advantage, streamlining operations, and having "lean" manufacturing. As a testimonial for this viewpoint, they point to tens of thousands of companies around the world who have implemented or are planning to implement ERP systems.

More recently, several academically oriented papers have dealt with various aspects of ERP (Davenport, 1998; McAfee, 1999; Stratman and Roth, 1999; Van Everdingen et al., 2000; Mabert et al., 2000, 2001). Davenport looks at the reasons for implementing ERP systems and the challenges of the implementation project itself. McAfee, and Stratman and Roth both look at operational performance. McAfee reports on a longitudinal experiment at a computer manufacturing facility to determine the impact of an ERP system on operational performance. His research shows that operational performance measures improve significantly on pre-ERP levels four months after implementation. McAfee proposes a longer time frame for such a study. Stratman and Roth propose an integrated conceptual model of "ERP Competence" which they define as comprised of several organizational aptitudes including strategic planning, executive commitment, project management, IT skills and change management. They argue that a firm's ERP Competence must be used effectively in order to truly harness the capabilities of an ERP system for competitive advantage. Van Everdigen et al. and Mabert et al. both use surveys to systematically study a variety of issues. Van Everdigen et al. in a survey of 2647 European companies across all industry types determined adoption and penetration of ERP by functionality. Mabert et al. surveyed manufacturing companies in the US to study penetration of ERP, motivation, implementation strategies, modules and functionalities implemented, and operational benefits in the manufacturing sector.

While the above practitioner and academic research provides valuable insights into both ERP effective use and implementation process issues, we feel a more systematic empirical analysis of ERP implementations is essential for understanding key factors that lead to a successful implementation, as measured by on-time and on/under-budget performance. This paper addresses this issue by reporting on and analyzing the results of a survey of companies who have implemented ERP systems. More specifically, this paper empirically investigates whether there are key differences in the approaches by companies that managed their implementations "on-time" and/or "on/under-budget" versus the firms that did not. These are two success measures often cited by companies for ERP implementations (Mabert et al., 2000, 2001). Logistic regression models are used to classify companies that are able to accomplish their implementations on-time and then on/under-budget based upon a set of input variables. All results are based on the responses from this survey.

The rest of the paper is organized as follows: In the next section we discuss the research issues and framework employed to conduct the investigation, and the relevant research germane to this evolving area. Section 3 outlines the systematic data collection methodology in this study. In Section 4 we develop logistic regression models to classify companies based on on-time and on/under-budget measures and present our findings. Section 5 summarizes our observations and conclusions.

2. Research issues and research framework

The research reported in this paper is part of a long-term on-going project aimed at studying the state-of-the-art of ERP practice and implementations. This project has been carried out using a two-phased approach. In Phase I, a case study methodology was employed to study ERP implementations at 12 manufacturing firms using structured interviews of key managers, IT professionals, and users associated with each company's implementation. The size of these case study firms ranged from $30 million in revenues to over $35 billion. Five firms had revenues over $1 billion, three had revenues between $200 million to $1 billion and four were in the $30 million to $200 million range. These implementations involved four different ERP vendor packages. In addition to the case studies, senior consultants at six consulting firms specializing in ERP implementations were interviewed at length to get their perspectives on ERP (Mabert et al., 2000, 2001). Their expertise covered five different packages. The primary objective for conducting the case studies and the consultant interviews was to obtain reliable and detailed information on the current status of ERP practice and implementations. This research methodology has been used successfully in a number of studies (Orlikowski, 1992; Yin, 1993, 1994; Robey and Sahay, 1996), and was employed here to provide a foundation for our future efforts.

Several key findings emerged from the case studies. First, while most implementation projects are unique in many ways, there are still many underlying issues, activities and strategies that are common to all of them, irrespective of the package implemented. Second, the findings from the case studies strongly suggest that the overriding objective of most companies is to complete the project on-time and within the budgeted resources. Third, to meet on time and budget targets, ERP projects have to be planned very carefully and managed very efficiently. And fourth, the companies that stayed on-time and on/under-budget for their ERP implementation had many common characteristics. These include the following:

- Senior executives were very involved throughout the project, from the outset to completion, and also established clear priorities.
- A cross-functional ERP Steering Committee with executive leadership was established to oversee the project. The Steering Committee was empowered to make key decisions, both during the planning and implementing stages. In the larger firms the team members were fully dedicated to the ERP project and were often co-located in a "War Room".
- The implementation team spent extra time up front to define in great detail exactly how the implementation would be carried out. This included what modules and process options would be implemented and how the senior management priorities would be incorporated.
- These companies laid out clear guidelines on performance measurements. These metrics were not just technical ones but also included business operations.
- Modifications to the ERP system code were kept to a minimum.
- Organizational change and training strategies were developed in advance and were continually updated during the implementation.
- Implementations where several key modules were implemented at the same time took a shorter time (implementing several modules at the same time is usually referred to the Mini Big-Bang approach. Implementing the entire system at the same time is called the Big-Bang approach) than phasing in modules a few at a time (usually referred to as the phased-in approach).
- Key technology issues, such as data integrity and technology infrastructure, were addressed early.
- Only minor reengineering efforts were carried out up front.
- The implementation plan and subsequent progress was communicated regularly to employees, suppliers and customers.

After analyzing the set of characteristics relative to their nature and timing during the implementation process, we chose to group these characteristics into three categories consisting of planning effort, implementation decisions, and implementation management. *Planning effort* refers to all factors that have to be addressed in the planning stages before the start of the project. These include such variables as executive support and involvement in the planning of the project, the makeup of the implementation team, and addressing key

Table 1
Key planning and implementation management variables

Planning variables	Implementation management variables
Development of a business case	Strong executive involvement
Defined very clear desired outcomes	Strong executive support
Defined performance metrics	Communicated progress regularly
Strong executive sponsorship	Benchmarked implementation progress
Strong executive involvement	ERP committee able to make key decisions
An empowered ERP steering committee	Communicated with personnel impacted
An ERP implementation team	Created "Super-Users" and "Trouble-Shooters"
Clear organizational change strategies	Trained all users
Clear education and training strategies	Kept suppliers/customers informed
Communicated ERP plan to the enterprise	
Addressed data conversion and integrity	
Technology infrastructure in place	

technology issues. *Implementation decisions* refer to strategic options on how to conduct the implementation. These include such decisions as whether to implement using the Big-Bang approach or the phased-in approach, and the amount of software customization and reengineering to complete. The third critical area is *implementation management* itself, referring to all variables/actions during the implementation. The key variables identified by the case studies in each of these three categories are listed in Tables 1 and 2.

While the case studies proved useful in understanding the general nature of implementations, it was based on a small sample. To confirm our initial finding of the differences and commonality of ERP implementations, a survey instrument was developed in order to obtain a broader perspective of ERP practice and experiences relating to planning, customization, managing, costs, time-lines, performance, and success factors. More specifically, the primary objective of the project is to study the individual and/or collective impact of the planning variables, strategic decision variables, and implementation management variables on ERP implementation costs and timelines.

Table 2
Key strategic decision variables

Implementation decision variables
Single ERP package versus multiple packages
Big-Bang or mini Big-Bang versus a phased-in approach
Number of modules implemented
Order of implementation
Modifications to system
Major reengineering upfront versus limited reengineering
An accelerated implementation strategy

The proposed methodology of studying key factors behind ERP implementations is very similar to the approach used in a variety of studies in Information Technology (IT) implementation research. Some of these proposed factors are the ones that have been found to be significant in other IT implementations. These include top management support, IT design, and appropriate user training interaction and understanding (Fuerst and Cheney, 1983; Schultz, 1984; Sanders and Courtney, 1985; Kwon and Zmud, 1987). Other studies of IT implementation also provide some guidelines for the current study (Ginzberg, 1981; McFarlan, 1981) but much of this deals with legacy systems. The technology closest to ERP systems for manufacturing firms is MRP II. ERP systems have evolved from MRP and MRP II and can be considered as extensions of MRP II with enhanced and added functionalities. In the MRP literature, several authors have studied implementations (Schroeder et al., 1981; White et al., 1982) using different key variables and regression based modeling.

While IT and MRP II research sheds some light on ERP implementations, there are significant differences between both legacy systems and ERP, and MRP II and ERP. For example, many legacy systems, like early MRP, were custom-designed requiring unique designer–user interactions. ERP systems, on the other hand, are package systems that usually require organizational or process changes for implementation. Further, legacy systems usually operated in functional silos whereas ERP systems are integrative and require significant changes to processes across the entire organization for successful implementation. The key difference between MRP II and ERP systems is that ERP includes functionalities, such as human resources planning, decision support applications, regulatory control, quality, elements of supply chain management and maintenance support that are beyond the traditional focus of MRP II (Yusuf and Little, 1998).

3. Methodology

The survey questionnaire asked for information on implementation in six key areas: The respondent's and the company's characteristics, the ERP planning process, implementation decisions, management of the implementation process, timelines and, budgets and costs. It was four pages long and had a total 26 questions. Most questions in the survey required multiple responses. The responses were encoded using a mix of check boxes, open-ended answers, and a binary scale with Yes or No responses. The case studies provided the guidance for the encoding scheme in terms of what type of questions required what responses. For example, the total cost was segmented into buckets because the interviews showed that respondents were more comfortable with providing approximate figures instead of exact values. The planning and managing variables were encoded using a binary scale (Yes or No) because either the companies used these approaches or they did not. After the initial development of the survey questionnaire, it was sent to two ERP project leaders from our case study companies. The primary objective was to test whether the instrument provided consistent and accurate information. Their responses were checked against the information collected during the case studies. In addition, the questionnaire was checked by two ERP consultants. Based on the information provided by these experts, the instrument was fine-tuned and finalized.

The survey, cover letter and response envelope were mailed to 270 firms that were randomly drawn from a list of approximately 2700 US companies that have or are implementing ERP systems. This list has been developed from a variety of sources including ERP user-group companies, customer lists provided by ERP vendors, consultant clients and through research of company Web sites. The contact names at these 270 companies were developed from APICS members, ERP user-group participation lists, and a subscriber database list from InfoWorld, a technical trade journal. The mailing was sent out in the first week of October 2000. By mid-December 2000, 78 responses had been received, for an overall response rate of 28.8%. Given the length and comprehensive nature of the survey, this response rate was concluded to be reasonable. Respondents were not asked to provide company-identifying information to enhance sharing of company performance based information. Of the 78 responses, 77 had already implemented ERP systems. One was in very preliminary stages of implementation and, consequently, had only minimal information. Another two had contradictory information and were thrown out, leaving 75 usable responses.

The size of the responding companies ranged from \$30 million to \$32 billion in annual revenues. The number of employees ranged from 140 to 60,000. Eighty percent of the respondents were at the manager or above level, with over 35% listing their job titles to be director or vice-president. Approximately 25% had some form of ERP designation in their title (Director—SAP Applications, Director of ERP Systems, etc.). A more detailed breakdown of the statistics from the responding companies is presented in Table 3.

4. Results

The data show there are distinct differences in what the sample companies have done in terms of their implementations. Just over 89% of the companies have implemented a single ERP system, of which just over half have other systems attached to their ERP system. The rest had implemented modules from multiple ERP systems. A total of

Table 3
Basic data of responding companies

Respondent's position	Percent (%)	Annual revenues	Percent (%)	Number of employees	Percent (%)
Executive/VP	10.0	<$500 million	28.5	<1000	22.8
Director	25.7	$501 million to $1 billion	10.2	1000–2500	14.3
Manager	44.3	$1 billion to $5 billion	32.8	2501–5000	21.4
Other	20.0	>$5 billion	28.5	>5000	41.5

65% of the sample were SAP companies. Given its market share is approximately 33%, SAP is represented disproportionately in the sample. However, our case study and consultant analysis indicates that the type of system implemented is not a factor in determining implementation outcomes, time lines, and success rates. The strategy used for the implementation is one of the most important factors in determining the outcome of an ERP project. Fifty-two percent (52%) of the sample companies chose to implement several key modules at the same time. Only two of these 52% could be truly classified as Big-Bang implementations. The rest were Mini Big-Bang. Twenty-nine percent (29%) of the companies chose to do significant reengineering up front. The rest either did minimal reengineering or left it till after the system was installed. Approximately 55% chose to use an accelerated implementation methodology such as ASAP.

To evaluate the impact of the planning, decision and implementation management variables on the costs and the timelines, all the companies are first separated into two timeline categories, "on-time" and "late" based on their response to the question whether their ERP implementation was completed on-time. Next, the companies were separated into two budget/cost categories, "on/under-budget" and "over-budget", again based on their response on whether their implementation was on/under-budget or over-budget. Separating the companies into these categories provides an easy but useful way of determining if there is a relationship between the *planning*, *decision* and *implementation* variables and whether the project was on-time or late, and whether it is on/under-budget or over-budget. This analysis is presented below for each set of planning, decision and management variables.

4.1. Planning variables

For the 12 planning variables, the respondents were asked to answer either a 'Yes' or a 'No' depending on whether their company undertook this planning task. The results are summarized in Table 4. The interpretation of the sample statistics in this table is as follows: Of the companies that were on-time, late, on/under-budget or over-budget, the percentage statistic shows the proportion of companies that completed that task. Thus, of all the on-time companies, 83% had developed a business case. Similarly, of all the companies that were late, 78% had developed a business case. The results for both the timeline categories and the budget/cost categories show similar trends. While the data suggest that both sets of categories are very similar for such dimensions as "Defined Performance Metrics" and "Had an ERP Implementation Team/War Room", there are a number of very striking contrasts for tasks such "Had Strong Executive Involvement", "Developed Clear Education and Training Strategies" and "Had Technology/Infrastructure in Place". These descriptive comparisons are further supplemented statistically using contingency tables. There are several significant differences, as indicted by the reported p-values. (An 'NS' indicates a non-significant value.) Overall, these results indicate that the companies who are on-time and on/under-budget do a better job in planning for their ERP project.

4.2. Management variables

The questions in the survey for the nine management variables were very similar to the planning variables and required 'Yes' and 'No' responses. The results for these variables are tabulated in Table 5. The trends here are very similar

Table 4
Impact of planning variables

Planning variables	On-time (%)	Late (%)	*p*-value	On/under-budget (%)	Over-budget (%)	*p*-value
Developed a business case	83	78	NS	87	72	NS
Defined very clear desired outcomes	83	61	0.075	77	56	0.073
Defined performance metrics	56	51	NS	50	53	NS
Had strong executive sponsorship	94	80	NS	93	75	0.047
Had strong executive involvement	89	47	0.002	77	42	0.004
Had an empowered ERP steering committee	94	80	NS	100	69	0.001
Had an ERP implementation team/war room	100	94	NS	100	92	NS
Developed clear organizational change strategies	67	55	NS	67	50	NS
Developed clear education and training strategies	94	76	0.075	97	67	0.002
Communicated ERP plan to the enterprise	100	88	NS	93	92	NS
Addressed data conversion and integrity issues early	100	75	0.019	87	78	NS
Had technology/infrastructure in place	100	63	0.002	97	50	0.000

Table 5
Impact of implementation management variables

Management variables	On-time (%)	Late (%)	*p*-value	On/under-budget (%)	Over-budget (%)	*p*-value
Had strong executive involvement	89	51	0.003	73	50	0.026
Had strong executive support	100	84	0.065	100	78	0.006
Communicated progress regularly across the company	100	84	0.065	93	86	NS
Benchmarked implementation progress against clear milestones or performance metrics	83	67	NS	87	56	0.006
Allowed ERP committee to make key decisions	100	88	NS	100	83	0.019
Communicated regularly with all who would be impacted	94	76	0.075	93	72	0.027
Created "Super-Users" who served as trouble-shooters	89	94	NS	93	92	NS
Trained all who would be using the system	94	86	NS	100	78	0.006
Kept suppliers/customers informed	78	63	0.070	87	63	0.001

between the on-time and the late companies, and the on/under-budget and the over-budget companies, with the on-time and on/under-budget companies managing their implementations better. These descriptive comparisons are also supplemented statistically using contingency tables. There are several significant differences, as shown by the reported *p*-values. Overall, these results suggest that the companies that managed their implementations more systematically were more likely to complete their implementations on-time and on/under-budget.

4.3. Decision variables

The impact of the decision variables is summarized in Table 6. While the differences for both sets of categories are not as striking as the ones for the planning and the management variables, the impact of these variables can be potentially much more significant. For example, our case studies indicate that the amount of modifications to the system can significantly increase both implementation times and costs. This shows up very clearly in these results. Only 11% of the on-time companies undertook major modifications versus 53% of the late companies. The results are very similar for the budget categories. One obvious result is for the accelerated implementation strategy. Companies that use these strategies are more likely to complete their implementations on time.

4.4. Logistic regressions

While the above planning, decision and implementation variables provide valuable insights into

Table 6
Impact of implementation decision variables

Implementation decision variables	On-time	Late	*p*-value	On/under-budget	Over-budget	*p*-value
Implemented single ERP package	61%	41%	NS	53%	39%	NS
Used a mini Big-Bang implementation	65%	47%	NS	59%	44%	NS
Average number of modules implemented	8.24	8.51	NS	8.66	8.31	NS
Made major modifications to system	11%	53%	0.002	23%	56%	0.008
Undertook limited reengineering upfront	67%	51%	NS	63%	50%	NS
Used accelerated implementation strategy	89%	47%	0.005	53%	56%	NS

completion of implementations on-time or on/under-budget, a more systematic statistical analysis is necessary to determine which of these variables are individually or collectively significant. Also, it will be useful to explore if some composite variables created using combinations of variables are better predictors of success. For example, would a composite variable representing all planning factors be better at predicting on-time or on/under-budget implementations than the individual planning variables. The composite variables would reflect a collective set of things that need to be done rather just a few individual ones. A number of statistical tools are available for such analysis including discriminate analysis and regression. Discriminate analysis would help a researcher classify variables whereas regression allows for more rigorous analysis by providing an overall predictive model and a significance level for the chosen variables. Since our response variables are dichotomous (on-time versus late, and on/under-budget versus over-budget), we chose to use the binary logit model of logistic regression analysis.

Green et al. (1977) first proposed the application of logit analysis. Since then numerous researchers have used it to analyze categorical data (Robinson and Satterfield, 1998; White et al., 1999). To use a logistic regression, the response variable needs to be coded as 0 or 1. For the study reported here, two sets of logistic regressions are executed. The first uses completion of an implementation on-time as the response variable. Completion times are coded as 0 if the implementation was completed on-time, and 1 if it was late. The second logit regression uses completion of the implementation on/under-budget (coded 0) or over-budget (coded 1) as the response variable.

The coefficients of the logistic regression model are determined as maximum likelihood estimators, i.e., by maximizing the likelihood functions (Fienberg, 1983). A negative sign for a coefficient means that the variable is more likely to increase the probability of achieving an on-time or an on/under-budget implementation. In regression analysis, the modeler has the flexibility to specify the functional form of the independent variables, with several open-ended options available. One strategy is to use all available independent variables. Another is to collapse some of the variables into "composites" reflecting total effort. For this analysis, we use both these options. For the latter, two "composite" independent variables are created. The first is a composite variable for the planning variables. It is set up by adding all the "1" responses to the 12 planning variables. The objective here is to capture the overall amount of the planning effort. Thus, if a company used all the 12 planning variables, its composite score would be 12. The second composite variable is for the implementation management variables. It is also set up by adding the "1" responses to the nine implementation management variables to capture the overall management "effort". A similar composite variable is not feasible for the decision variables since the impact of each decision variable is individual in nature and not collective.

4.5. Logistic regressions for on-time versus late implementations

A stepwise tool was used to develop the logistic regression models. For each response variable, two logistic regressions are shown, one using at least one composite variable and the other using all the

Table 7
Significant variables for the on-time vs late logistic regression (with at least one composite variable)[a] (*Panel A*) and classification table for on-time vs late (with at least one composite variable) (*Panel B*)

Panel A

Variables	Coefficient	Standard error	*p*-value
Composite of planning variables	−1.820	0.682	0.008
Modifications to the system	7.590	2.751	0.006
Accelerated methodology	−3.492	1.748	0.046
Strong executive involvement during implementation	−2.292	1.270	0.071
Training all users	8.319	3.431	0.015
Keeping suppliers and customers informed	−3.117	1.793	0.082
Constant	15.651	6.131	0.011

Panel B

	Predicted on-time	Predicted late	Total	Percentage correct (%)
Actual on-time	12	4	16	75.0
Actual late	1	46	47	97.9
Overall percentage				92.1

[a] −2 log(likelihood) model: Marginal = 74.706, Full = 29.815, Diff = 44.891, Sig = 0.000.

individual variables. The results obtained from the fit of these logistic regression models for on-time implementations using the planning composite variable are summarized in Table 7 (Panel A) with the resulting classification analysis in Table 7 (Panel B). The analysis was performed on 16 on-time and 47 late implementations. Of the 63 cases used to fit the model, 75% of the on-time companies were classified correctly and 97.9% of the late companies were classified correctly, for an overall accuracy of 92.1%. The significant variables in the logit model are two decision variables, the composite planning variable and three implementation management variables. The model predicts that extensive planning in advance of the implementation, an accelerated implementation strategy, strong executive involvement during implementation, and keeping customers and suppliers informed all contribute positively to an on-time implementation. On the other hand, the model indicates modifications to the systems and training users are likely to result in delays. While training can add to the implementation time, it must be pointed out that this function is critical to the eventual success of the project. Like several of our case study companies, it is quite possible that our sample companies did not estimate the extent of the time required for training.

The results for an on-time logit model with all singular variables are shown in Tables 8 (Panel A) with the classification table in Table 8 (Panel B). The stepwise analysis only brings three variables into the equation, two planning and one decision. Both the planning variables, strong executive involvement and defining very clear desire objectives, contribute positively to an on-time implementation whereas modifications result in delays. This model is not as powerful as the one with the planning composite variable.

4.6. Logistic regressions for on/under-budget versus over-budget implementations

For the budget logit model, the response variable is set equal to 0 for an on/under-budget implementation and equal to 1 for an over-budget implementation. The analysis for on/under-budget versus over-budget was performed on 29 on/under-budget and 33 over-budget companies for a total of 62 cases. The results for this logistic regression with composite variables are presented in Table 9 (Panels A and B). The significant variables in this logit model include the planning composite variable, one decision, and two implementation management variables. The model indicates that the planning composite variable contributes positively

Table 8
Significant variables for the on-time vs late logistic regression (without composite variables)[a] (*Panel A*) and classification table for on-time vs late (without composite variables) (*Panel B*)

Panel A

Variables	Coefficient	Standard error	*p*-value
Strong executive involvement during planning	−3.520	1.177	0.003
Defining very clear desired objectives	−1.766	0.931	0.058
Modifications to the system	3.025	0.977	0.002
Constant	3.953	1.294	0.002

Panel B

	Predicted on-time	Predicted late	Total	Percentage correct (%)
Actual on-time	10	6	16	62.5
Actual late	3	44	47	93.6
Overall percentage				85.7

[a] −2 log(likelihood) model: Marginal = 74.706, Full = 41.154, Diff = 33.552, Sig = 0.000.

Table 9
Significant variables for on/under-budget vs over-budget logistic regression (with at least one composite variable)[a] (*Panel A*) and classification table for on/under-budget vs over-budget implementations (with at least one composite variable) (*Panel B*)

Panel A

Variables	Coefficient	Standard error	*p*-value
Composite of planning variables	−0.963	0.269	0.000
Modifications to the system	3.954	1.210	0.001
Communicated progress regularly	4.516	1.790	0.012
Kept suppliers and customers informed	−2.385	1.005	0.018
Constant	4.951	2.048	0.016

Panel B

	Predicted on/under-budget	Predicted over-budget	Total	Percentage correct (%)
Actual on/under-budget	24	5	29	82.8
Actual over-budget	6	27	33	81.8
Overall percentage				82.3

[a] −2 log(likelihood) model: Marginal = 90.949, Full = 43.599, Diff = 47.350, Sig = 0.000.

to an on/under-budget implementation. As one would expect, modifications impact budgets adversely. Just like the model without the composite variables, this regression shows that keeping suppliers and customers informed has a favorable impact on implementations that are completed on or under-budget whereas communicating progress regularly to the entire company impacts budgets adversely. It is also interesting to note that the implementation management composite variable was not significant in any of our models.

The results for this logistic regression without composite variables are presented in Table 10 (Panels A and B). The classification table shows that 96.6% of the on/under-budget companies are classified correctly and 84.8% of the over-budget companies are classified correctly, for an overall percentage of 90.3%. The significant variables in the logit model include three planning, one decision, and two implementation management variables. The model indicates that the three planning variables all contribute to an on/under-budget implementation. Modifications impact budgets adversely. Of the two management variables, keeping suppliers and customers informed has a favorable impact on budgets whereas communicating progress regularly to the entire company impacts budgets adversely. Since our case studies

Table 10
Significant variables for on/under-budget vs over-budget logistic regression (without composite variables)[a] (*Panel A*) and classification table for on/under-budget vs over-budget implementations (without composite variables) (*Panel B*)

Panel A

Variables	Coefficient	Standard error	*p*-value
Strong executive involvement during planning	−4.586	1.986	0.021
Clear education and training strategies	−2.815	1.582	0.075
Technology and infrastructure in place	−6.278	2.707	0.020
Modifications to the system	7.244	2.803	0.010
Communicated progress regularly	6.043	2.563	0.018
Kept suppliers and customers informed	−4.457	1.753	0.011
Constant	4.668	2.555	0.068

Panel B

	Predicted on/under-budget	Predicted over-budget	Total	Percentage correct (%)
Actual on/under-budget	28	1	29	96.6
Actual over-budget	5	28	33	84.8
Overall percentage				90.3

[a] $-2\log(\text{likelihood})$ model: Marginal = 90.949, Full = 27.794, Diff = 63.155, Sig = 0.000.

indicated that communications is a critical function in the success of ERP implementations, this counter-intuitive outcome is discussed later.

5. Discussion and conclusions

Our case studies suggest that because of the investment required for an ERP project, both in terms of the resources and the resulting organizational changes, companies are very sensitive about implementation times and budgets, going to great lengths to set realistic timelines and budgets. One indicator of this phenomenon is the case study companies that started their implementations later. Such companies tended to have shorter completion times and smaller budgets, reflecting that implementations have become more "efficient" over time because of the learning curve effect. While the authors recognize that both the timelines and the budgets are set by the companies and self-reported in the survey, there is no reason to believe they are not representative of actual experience. The logistic regression equations provide a valuable mechanism for identifying significant input variables in classifying whether a particular ERP implementation is likely to be on-time and within budget based on the survey data. Many of the results from this more comprehensive investigation confirm analytically what we had learned through the case studies.

First, all of the companies in our case studies stressed that upfront planning is a key element for a successful implementation. This is confirmed by the composite planning variable being highly significant in our models. At a more detailed level, planning of education and training programs, and having a technology infrastructure are two of the significant individual planning variables common to successful implementation. Several companies in our case studies indicated that planning educational and training programs had given them a much better understanding of the magnitude of costs involved in this process.

Second, the case study companies also emphasized keeping modifications to the source code to a minimum. Because the integrative design of ERP systems increases the complexity involved in source code modifications, most companies significantly underestimate the effort required for modifications. Modifications not only lead to increased costs and implementation times, they also make future upgrades of the system difficult to implement. Every model in this study determined modifications to be a highly significant variable with adverse impact.

Third, the case study companies emphasized the importance of the implementation management effort itself. Surprisingly, those variables, individually and collectively, are not as significant in predicting on-time and on/under-budget implementations as anticipated. This could be due to the fact that since an ERP implementation is a key project, companies who put in significant up front planning continued to do a good job with the management of the implementation process. For example, the correlation between the planning composite variable and management composite variable is 0.72 (p-value < 0.01). The data does suggest that keeping suppliers and customers informed was one significant implementation management variable, which was identical to our earlier study. For three of the case study companies involving their suppliers and customers in the implementation process led to two key outcomes. One, they were able to design the inter-firm interaction processes better, leading to fewer modifications to the system. And two, they were able to "stress-test" the likely volume and types of transactions to be handled.

Finally, we noted a counter-intuitive outcome as identified by the positive sign on the regression coefficient for the communication of progress, which suggests that more communication tends to increase the likelihood of cost overruns. One possible explanation is that the communications might cause reexamination of processes as well as necessitating more customization. Unfortunately, the collected data do not allow for a more systematic evaluation of this issue. This does suggest that further research is needed in this area. However, all of our case study companies felt this is a critically important step for user acceptability of the system as well as its productive use.

This study provides valuable insights towards understanding ERP implementations and important factors influencing success. In particular, it analytically verified the importance of planning, execution and strategy on implementation time and budgets. While the findings have some common elements with other IT implementation studies, there are many that are unique to ERP implementations because of the integrative characteristics of ERP systems. However, the research to find answers to complex processes often creates new questions. The authors note some counter-intuitive outcomes that require future exploration.

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