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# An empirical study of enterprise resource management systems implementation

## From ERP to RFID

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## Abstract

**Purpose** – The purpose of this paper is to determine the significant variables leading to successful implementation of enterprise resource management (ERM) and its predecessor concepts of enterprise resource planning, supply chain planning, electronic commerce, and radio frequency identification systems. An implementation roadmap is presented using four stages for implementing ERM systems: planning, development, implementation, and testing. The roadmap indicates when and where the significant success variables would appear and how a firm might manage the implementation process.

**Design/methodology/approach** – In the research, the key success criteria and key implementation drivers uncovered by literature, case studies, and interviews were used. A survey instrument was constructed and the survey hosted on a web site where practitioners from industry were invited to supply opinions. The data were analyzed by using correlation models and one-way analysis of variance (ANOVA) to develop cause-effect diagrams (CE) for overall ERM systems and each component of ERM. Based on the controlled error of the ANOVA process, the CE diagram was used to depict the degree to which variables influence implementation success.

**Findings** – The research results have helped uncover the key significant variables that contribute to successful ERM implementation.

**Originality/value** – The proposed implementation roadmap indicates when and where the significant success variables would appear and how a firm might manage the implementation process.

**Keywords** Manufacturing resource planning, Supply chain management, Electronic commerce, Resource management

**Paper type** Research paper

## Introduction

Technology has become one of the core components of business process reengineering (BPR) innovation. Implementing advanced information technology enhances the effectiveness and efficiency of business processes. Enterprise resource planning (ERP), electronic data interchange (EDI), supply chain planning (SCP), electronic commerce, and now radio frequency identification (RFID) are all technologies that have appeared on a continuum of improvement. All these advanced information technologies are helping business-trading partners to integrate their operations and strategies to lower the total system costs and to achieve a high customer service level. In this paper, we offer what we believe are the core components of enterprise resource management

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(ERM): ERP, SCP, electronic commerce, and RFID System. In Figure 1, we show the relationship between these core processes. It is important to note that a business may not deploy every component or even attempt to link the four components. We believe that these systems are distinctly different, serve specific functions, and may or may not "add up" to a comprehensive organizational capability.

ERP is a system for integrating internal business data and processes. It helps business processes be more flexible and responsive by breaking barriers between functional departments and by reducing duplication of effort. Currently, most ERP systems are only used in internal process integration – Finance & Accounting, Human Resources, Order Management (Sales), and Manufacturing, and these typically have not had significant collaboration with outsourcing suppliers and customers. However, ERP systems now are moving into advanced ERP, which is more focused on supply chain management instead of internal business processes. SCP is a process of collaborating with suppliers and customers for sharing, exchanging and moving information, and goods. SCM consists of activities associated with the flow and transformation of goods from the raw materials stage to the end-users, as well as the associated information flows. Material and information flow both up and down the supply chain. SCP is the integration of these activities to achieve cost reduction and customer satisfaction and to yield a sustainable competitive advantage.

RFID is a technology that is used to describe a system that transmits the identity of an objective wirelessly. The main components in RFID systems are the tag, the reader,

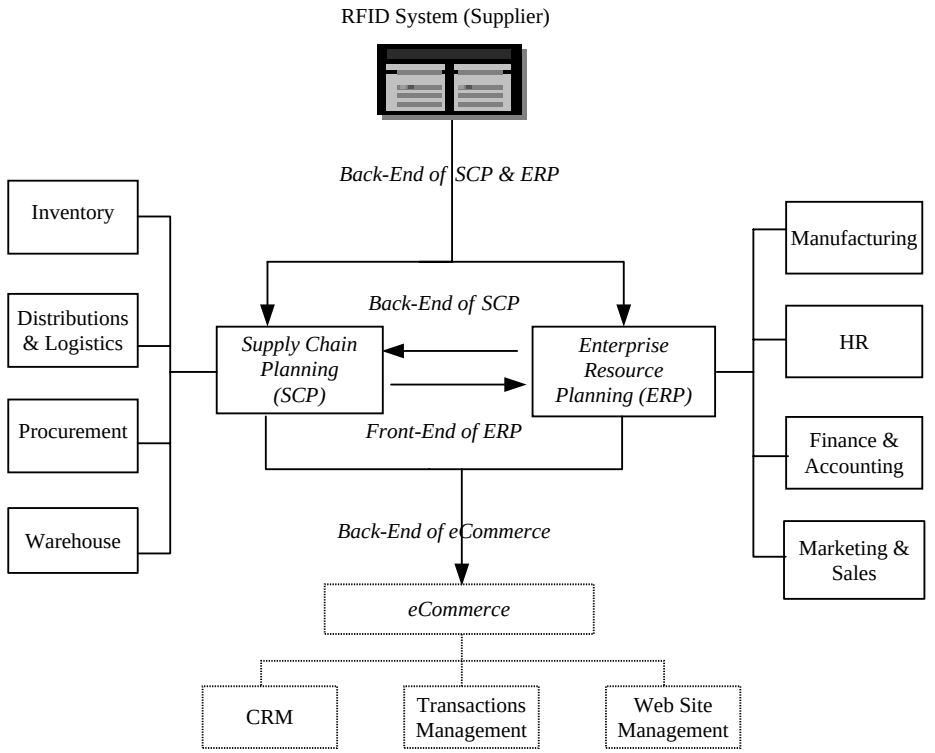


**Figure 1.**
The relationships between ERM

and the RFID middleware that translates and integrates data for enterprise applications such as ERP and SCP. RFID has been around for decades as an enabling technology. It does not provide much value on its own, but it enables companies to develop applications that do create value. Papers show RFID can help supply chain partners improve logistics efficiency, responsiveness, enhanced service, reduce labor costs, improve out-of-stock rate, and reduce inventory level (Angeles, 2005; Helders and Vethman, 2003; Ton and Stachowiak-Joulain, 2005; Shutzberg, 2004). In response to the growing number of RFID mandates from companies such as Wal-Mart, Target, Best Buy, Albertsons, and the Metro Group of Germany, suppliers now are developing skills and competencies with RFID.

Much like an ERP system, RFID is a very complicated and costly technology. However, it is inevitable that RFID will be another breakthrough throughout the supply chain for manufacturing, packaging, logistics and distributions, and retailing (Figure 1).

Because of new information technology, such as the internet and the world wide web, businesses market and sell their products and services on the web in a trend called electronic commerce. Businesses are also using these technologies to improve their ability to provide service to customers and to improve their operational performance to gain competitive advantage through customer self-service, quick response to customers, reduced product lead time, and reduced inventory levels. electronic commerce is also quickly being adopted in internal functional areas such as procurement, R&D, and product design to leverage the knowledge and expertise of specialists within the organization.

When ERM vendors are launching their new products, they all claim their products can help businesses achieve several goals and gain competitive advantage. Businesses, either in manufacturing or servicing, know they have to implement ERM systems because of competition and customer requirements or they will lose market share (Baki *et al.*, 2004). However, when a vendor sells its products to businesses, does the vendor help the businesses evaluate and adjust their environments to gain the benefits from ERM systems? When a business decides to implement ERM systems into its organization, does it evaluate and prepare itself to make this big change? What are the factors that determine success? We have completed a survey of industry to help address these questions and provide the summary results in this paper.

## Case studies and interview insights

In order to better understand the implementation of ERM systems, we interviewed three manufacturing company managers who had implemented ERP and SCP systems. We combined these interview assessments with *Harvard Business School* and *RFID Journal* case studies that had been crafted to illustrate both successful and failed implementation examples of ERM system implementation (Escalle and Cotteleer, 1999; Westerman and Cotteleer, 1999; McAfee, 1997; Austin *et al.*, 1998; Stedman, 2000; Roberti, 2005, 2006). Based on these interviews and analysis of cases we crafted a survey instrument and used it to solicit quantitative assessments of the degree to which key implementation variables correspond with overall project success. Following are the insights gained from interviews, *Harvard Business School* and *RFID Journal* case studies (Escalle and Catteleer, 1999; Maselli, 2003; Roberti, 2005; Ton *et al.*, 2005).

*Insight from interviews*

(1) The reasons for implementing an ERP system included:
   - The companies grew too fast and their legacy systems could not support them. Also, it was costly to re-code the legacy system and it was difficult to maintain the old system.
   - Due to the Y2K problem, implementing ERP systems was much easier and less expensive than recoding legacy systems.
   - To accomplish BPR.
   - To improve the efficiency and effectiveness of internal communication.
   - To integrate data for internal functions such as sales, purchasing, and manufacturing.

(2) In each case, the ERP system did not meet all the interviewees' expectations and the BPR that was promised did not fully materialize.

*Insights from the Harvard Business School survey*

(1) In general, ERP technology could not support the survey respondents' businesses processes by itself.
(2) Their business organizations found it was difficult to make changes needed to extract benefits from the new systems.
(3) Some companies actually experienced damage to their businesses as a result of ERP implementation.
(4) Overruns on cost and schedule targets were common.
(5) Company managers expressed underachieved expectations and benefits.

*Insights from the RFID case studies*

(1) The collaborations between supply chain partners were significantly stronger than before.
(2) Considerable doubts exist in the ERM return-on-investment (ROI) especially in RFID implementation.
(3) RFID is still in a mandate-oriented stage today.
(4) One of the challenges of RFID implementation encountered by companies is how to shift RFID implementation from mandate driven to ROI drive.
(5) Tag cost is still a major issue.
(6) Upstream suppliers are concerned that retailers seem to have more benefits in a RFID implementation than suppliers do. It is not a mutual benefit between supply chain partners.

Critical issues affecting an ERM implementation have been discussed in several articles and cases, such as business processes reengineering, ERP-legacy integration, data management, implementation cost and schedule, ROI concerns, top management commitment, effective and strong project management, and project members' qualifications (Escalle and Cotteleer, 1999; Westerman and Cotteleer, 1999; McAfee, 1997; Austin *et al.*, 1998; Stedman, 2000; Margulius, 2004). According to the *AMR Research*,

Wal-Mart suppliers have spent $1-3 M each on RFID. Suppliers also have to integrate RFID into their applications, change existing software, and enable large volumes of data to be stored. *AMR Research* estimates this would cost each supplier $13-23 M. Some examples of successful implementations of ERM show that ERM could make businesses significantly more competitive while examples of failed implementations show that ERM could also cripple or kill a business (Escalle and Cotteleer, 1999; Westerman and Cotteleer, 1999; Austin *et al.*, 1998; Welti, 1999; Maselli, 2003; Ton *et al.*, 2005; Roberti, 2005). Understanding the underlying physical supply chain management problem and the characteristics of their products for deciding the right supply chain software is also discussed in some articles (Fisher, 1997; Walker and Alber, 1999).

## Success key criteria and variables for ERM

It is clear that the sources of information on ERM solutions differ regarding the descriptions of costs and benefits. Each vendor is carving out a niche where its technology strengths influence the type of software it deploys and the way the system is integrated into the host organization (www.sap.com; www.ibm.com; www.peoplesoft.com; www.oracle.com). It is worth to note that when we first started our ERM research in 2001, RFID systems had not been adopted widely. However, mega-retailer Wal-Mart and the other mandating companies see significant benefits in their own supply chains by implementing RFID technology and they believe that RFID will also benefit their suppliers in the long-term. The benefits of utilizing RFID technology for suppliers include reducing operations costs, optimization of inventory management, and increased information accuracy. However, it is not clear if these expectations are fully achieved. Zebra Technologies, an RFID tag producer, listed the top ten RFID concerns as cost, tag strength, reliability, resilience, data capacity, size, type, failure rate, data management and implementation. Many companies are taking a wait-and-see approach to RFID. According to *ABI Research*, only about 30 percent of Wal-Mart's top 100 suppliers had accomplished full-scale RFID implementations by January 2005. The remaining 70 percent have only been adding RFID tags at their distribution centres instead of integrating RFID technology early in the manufacturing processes (Bednarz, 2004).

Some critical milestones have been suggested when implementing RFID. Researchers and practitioners suggest firms should start from a pilot RFID infrastructure and make sure the infrastructure is scalable. Getting the trading partners involved is also a key point in RFID implementation. Other key success factors are: top management support, validation and measuring of goals, taking the time to analyze and plan, building ones own test lab, and keep testing (Morrison, 2006). A RFID implementation survey shows the top five reasons for adopting RFID are: mandates from customers, inventory visibility, supply chain visibility, efficiency gains, and labor efficiency (Vijayaraman, 2005). World Kitchen and NYK Logistics have implemented RFID systems in their supply chain systems successfully (Roberti, 2006; Maselli, 2003). World Kitchen formed a cross functional team that included three members from IT, two from distribution centre operations, and one from the Wal-Mart sales account team. The implementation team had full support and commitment from top management. Metro Group, Germany's biggest retailer, worked with third party vendor consultants on RFID functionality. Its suppliers were fully involved in the implementation process (Ton *et al.*, 2005).

How then does a company determine what type of system they need; and once this decision is made, how is a vendor selected and the implementation process managed? We suggest that the literature and case studies do support a set of key success criterion that might guide the answers to these questions. Also it appears that a relatively small collection of variables seems to influence significantly the degree to which the success criteria are achieved and these variables tend to be the same regardless of the type of ERM system. In Table I, we summarize an interpretation of our literature research to suggest the key success criteria for each ERM component and the underlying common variables that influence successful implementation (Bingi *et al.*, 1999; Simchi-Levi and Kaminsky, 2003; Crisler, 2000; Tsai, 1997; Connolly, 2000; Lewis, 2000; Lapide, 2004; Vijayaraman, 2005; Morrison, 2006).

*Key success criteria*

It is evident from the literature that the success criteria are quite different for each type of system (Table I). The reader has to be careful to distinguish what is promised for the business user versus what is promised in terms of technology. It is not a simple task to convert the software providers' advertising claims into strategic business objectives. We believe that some degree of accomplishment is necessary in each success criteria in order to claim a genuine system level success.

*Key independent variables*

Several variables appear to drive successful ERM implementations. A critical component is the support of the executive level management group. This group should

| ERP | SCP | RFID | eCommerce |
|---|---|---|---|
| Business Processes Reengineering | Information sharing between partners | Information sharing between partners | Customer satisfaction |
| Reduced inventory level | Reduced inventory level | Reduced inventory level | Online product catalog |
| Reduced logistics cost | Reduced logistics cost | Reduced out-of-stock rate | Tight integration between ERP & SCP systems |
| Reduced procurement costs | Reduced procurement costs | Reduced human errors | Secure electronic payment |
| Order fulfillment & replenishment performance | Order fulfillment & replenishment performance | Order fulfillment & replenishment performance | Reduced costs (e.g, printing, postage) |
| Increased productivity & flexibility | Collaborations between supply chain partners | Improve logistics efficiency | Online customer service |
| Standardization of computing platforms | Response to market changed efficiently and effectively | Improved responsiveness to the customer | Improved responsiveness to the customer |
| Global sharing of information | Creation of new market opportunities | Reduced labor cost | |
| Improved responsiveness to the customer | More reliable and ocurate demand forecast | Reduced shrink | |

**Table I.**
Success criteria for ERM systems

be committed to the change process that implementing ERM systems is sure to cause. It appears that a combination of software vendor consultants and third party consultants are used by most implementers of ERM systems. The success of the system is likely influenced by the selection of the consulting team. Successful implementation tends to share the property that the initial budget and schedule predictions are feasible. Most implementations report significant cost and schedule overruns but the successful ones appear to be able to justify the errors and work around the resource issues. Finally, the implementation team composed of functional members and technology members seems to appear frequently in successful implementations. We show in Table II the list of key variables that our research indicates are the drivers for implementation success.

## Methodology

In our research, we used the key success criteria and key implementation drivers uncovered by case studies and interviews and documented in Tables I and II and from those constructed a survey instrument and hosted the survey on a web site where we could invite practitioners from industry to supply opinions. It is important to note that the survey participants only had ERP, SCP, and electronic commerce implementation experiences when we conducted this survey in 2001. We analyzed the data we collected from our survey by using correlation models and one-way analysis of variance (ANOVA) to develop cause-effect diagrams (CE) for overall ERM systems and each

| Key variables for ERM implementation | Variable name |
|---|---|
| *Core issues* | |
| Schedule reliability | SCHEDULE |
| Budget reliability | BUDGET |
| Realistic business expectations | EXPECT |
| Sufficient implementation time | IMPLMNT |
| Vendor-consultant relationship | V-RELATN |
| Compatibility with legacy systems | COMPTBLE |
| Management support | MGT-SPT |
| *Implementation team skills* | |
| Communication skills | CON-INTP |
| Full time assignment | FT-COMM |
| Cross functional skills | CRS-FC |
| Interpersonal trust | MU-TRUST |
| Project management skills | PRO-MGMT |
| Experience | EXPER |
| *Vendor consultant skills* | |
| Business process knowledge | VEN-BPK |
| Experience | VEN-EXP |
| Interpersonal skills | VEN-INTP |
| Communication skills | VEN-COMM |
| *Outside (Third-party, 3P) consultant skills* | |
| Software product knowledge | CON-SPK |
| Experience | CONS-EX |
| Interpersonal skills | CON-INTP |
| Communication skills | CON-COMM |

**Table II.**
Key success variables uncovered by interviews and case studies

component of ERM. Based on the controlled error of the ANOVA process we used the CE diagram to depict the degree to which variables influence implementation success. It is noteworthy that the overall results tended to be carried into the component models but not with the same intensity.

It is also necessary to point out that the correlation models are measuring a fundamentally different relationship than the ANOVA. Correlation measures the degree of agreement between our key variable scale and the overall success score reported by the respondents. ANOVA is used to determine if there are significantly different success scores explained by categories of independent variables. While significant and similar findings in both models are possible, it is also possible that the models will reveal slightly different results that must be researched more carefully. We acknowledge that repeatedly using the bivariate correlation model reduces the power of the test but our goal here was not a test of hypotheses as much as a simple indication of association between the success criteria and the key drivers. ANOVA is a much more controlled experimental procedure for this research and we combine the indications of correlation with the statistically significant relations from ANOVA to build a database of "votes" that summarize the number of times a key implementation variable is found to be related to each of the three ERM components. We show the CE models for both the correlation and ANOVA methods for the overall data in this paper. We use the tallied "votes" to recommend whether or not a key implementation variable is truly on the implementation roadmap. We summarize the results for overall ERM systems below.

*Analysis methods*

We analyzed these data by using correlation models and one-way ANOVA from SPSS software and then developed CE for overall ERM systems and each component of ERM. The goal of this process was to identify the key success variables that should appear in the implementation roadmap.

*Correlation model*

We used a simple bivariate correlation model to measure the degree of agreement between our survey key dimension scale and the overall success reported by the respondents. Organizations can adopt and modify the following equation when they have more advanced information technologies to implement. The equation for a correlation model is:

$$Y_i = f(X_{ij}),$$

where $Y$ = ratio of reported success criteria to total criteria for each group $i$; $i$ = overall, ERP, SCM, electronic commerce, RFID… ($i = 1,2,3,4,5\ldots$); and $X_{ij}$, $j$ = variables (schedule, budget, management support, consultant skills…, etc.)

As Table I indicates the number of key success criteria between ERP, SCM, electronic commerce, and RFID are different. ERP, for example, has nine success criteria and electronic commerce has seven criteria. Since we have a different number of implementation success criteria for ERP, SCM, RFID, and electronic commerce in our survey, we used ratios instead of binary sums for our overall score of success – so an ERP system that achieved 4 of the list of ERP success criteria was scored as 4/9.

When analyzing the data by using a correlation model we determine whether or not the variables have either positive or negative correlation with success scores. Our goal with correlation models is simply to uncover potential relationships-we used the significance levels of each test to determine the strength of a relationship. The strength is depicted on the CE model as the width of the fish-bone diagram connector. We did not seek an overall set of hypotheses tests so we used the correlation model as a preliminary indicator.

*One-way analysis of variance (ANOVA)*

The ANOVA approach evaluates whether the group means of the dependent variables differ significantly from each other. In other words, an overall analysis of variance test is conducted to assess whether means of a dependent variable are significantly different among groups of explanatory variables. ANOVA is used in our research to determine if there are significantly different success scores explained by our suspected key variables in Table I.

The hypothesis for our study is as follows:

*H0.* There is no significant variability in the ERM systems success scores explained by key independent variables defined by our model.

The existence of significant relationships from either a correlation model or ANOVA perspective allows us to reject this hypothesis and suggests relationships that form the basis of an implementation roadmap. Once again, we use the significance level of each variable as an indicator of the strength of the relationship and render these relationships in a CE graphic. When using ANOVA the overall experiment error is controlled so these results are in some ways more definitive than the correlation model.

## Result

We first used one-sample *t* tests to evaluate the average of success scores reported in the survey for overall E-Business and each individual component. Table III shows the *t* test results.

The Success Score is calculated as the ratio of success criteria to total criteria for each type of implementation. Therefore, the minimum would be zero and the maximum would be one. Zero indicates that implementing E-Business systems did not help the company improve its performance based on any success criteria. One means that E-Business systems helped the company achieve all success criteria. For Overall, and ERP the average success scores are 0.46 and 0.43, respectively. There are a total of nine success criteria for ERP. A score of 0.43 means that implementing ERP system benefited companies about four out of ten of the success criteria. For SCM and

| System | Number of cases | Mean | SD | SE of mean | 95 percent CI Lower | 95 percent CI Upper | *t*-value | df |
|---|---|---|---|---|---|---|---|---|
| Overall | 43 | 0.44 | 0.33 | 0.05 | 0.35 | 0.56 | 9.05 | 42 |
| ERP | 30 | 0.43 | 0.32 | 0.06 | 0.31 | 0.55 | 7.25 | 29 |
| SCM | 7 | 0.62 | 0.38 | 0.16 | 0.22 | 1.01 | 3.96 | 5 |
| eCommerce | 6 | 0.52 | 0.30 | 0.12 | 0.21 | 0.83 | 4.28 | 5 |

**Table III.**
*T*-test results for ERM system success

electronic commerce, the average success scores are 0.62 and 0.52, respectively. We have nine success criteria for SCM and seven success criteria for electronic commerce. Therefore, SCM system benefits our respondents up to six out of nine of success criteria. electronic commerce, on the other hand, helps them four out of seven of success criteria.

Table IV shows the findings of the survey analysis that link key implementation variables in Table II with success criterion in Table I.

*Success row*. The numbers shown in success row indicates the correlation between success scores and variables. Two results are revealed from this number. First, a positive number means the higher the level of variables, the higher the success scores. Second, the larger the correlation number, the stronger the correlation between success scores and variables. On the other hand, negative numbers indicate higher level of variables and lower success scores. For instance, on the budget column, the correlation number between budget and success score is 0.438. Therefore, we know the correlation between success scores and budget reliability is a moderately positive correlation. Specifically, the more accurate the budget reliability in our survey questionnaire (1 – Significantly over budget, 2 – Moderately over budget, 3 – On budget, 4 – Moderately under budget, 5 – Significantly under budget), the bigger the success scores. In other words, when companies' E-Business systems implementation budget is either moderately or significantly under budget, their success scores for implementing E-Business system would be higher.

*Cases row*. Cases row indicates how many respondents answered the question.

| *Variables* | *EXPECT* | *IMPLMNT* | *HOW LONG* | *SCHEDULE* | *BUDGET* | *MGT_ SPT* |
|---|---|---|---|---|---|---|
| SUCCESS | −0.3731 | −0.3944 | −0.1346 | −0.4471 | 0.438 | −0.0522 |
| Cases | (41) | (39) | (39) | (39) | (36) | (40) |
| Correlation One-Way ANOVA | $P = 0.016$ $P = 0.080$ | $P = 0.013$ $P = 0.048$ | $P = 0.414$ $P = 0.679$ | $P = 0.004$ $P = 0.017$ | $P = 0.008$ $P = 0.0005$ | $P = 0.749$ $P = 0.833$ |
| | *CON_COMM* | *CON INTP* | *CON_SPK* | *CONS_SPK* | *COMPTBLE V* | *RELA TN* |
| SUCCESS | −0.3066 | −0.0771 | −0.5254 | −0.2163 | −0.1351 | 0.1824 |
| Cases | (23) | (23) | (24) | (24) | (37) | (12) |
| Correlation One-Way ANOVA | $P = 0.155$ $P = 0.207$ | $P = 0.726$ $P = 0.571$ | $P = 0.008$ $P = 0.031$ | $P = 0.310$ $P = 0.0159$ | $P = 0.425$ $P = 0.654$ | $P = 0.570$ $P = 0.243$ |
| | *VHN_BPK* | *VEN COMM* | *VEN_EXP* | *VEN_INTP* | *MU_TRUST* | *FT_COMM* |
| SUCCESS | −0.3386 | −0.0282 | −0.139 | −0.0485 | −0.0134 | 0.0675 |
| Cases | (25) | (25) | (22) | (25) | (37) | (38) |
| Correlation One-Way ANOVA | $P = 0.098$ $P = 0.251$ | $P = 0.894$ $P = 0.414$ | $P = 0.537$ $P = 0.622$ | $P = 0.818$ $P = 0.943$ | $P = 0.937$ $P = 0.537$ | $P = 0.687$ $P = 0.443$ |
| | *PRO_MGMT* | *CRS_FC* | *COMMUN* | *EXPER* | | |
| SUCCESS | −0.1888 | 0.1012 | −0.1205 | 0.1881 | | |
| Cases | (38) | (38) | (37) | (38) | | |
| Correlation One-Way ANOVA | $P = 0.256$ $P = 0.638$ | $P = 0.546$ $P = 0.833$ | $P = 0.477$ $P = 0.331$ | $P = 0.258$ | | |

**Table IV.**
Overall relationship of success factors and key variables

*Correlation row*. On correlation row, *p*-value reveals our level of confidence in saying that the variables are correlated with success scores. In our research, we set the significant level = 10 percent, in the other words, *p*-value = 0.10 for the overall guide to interpret our result. Therefore, when the variable's *p*-value is less than 0.1, we could say that we have more than 90 percent confidence that the variable has a strong correlation with success score in our correlation model. When *p*-value is less than 0.20 or 0.30, the correlation between the variable and success score are either moderate or weak. For instance, the *p*-value = 0.004 between schedule and success score. Therefore, we have 99.6 percent confidence that there is correlation between schedule and success. However, the correlation model only revealed a correlation between the variable and success score, it did not reveal if there are significantly different success scores explained by variables. This is why we used one-way ANOVA analysis to find out if there are significantly different success scores explained by variables.

*One-way ANOVA row*. In one-way ANOVA analysis, we used the same significant level as our guide to reject or accept our hypotheses. The hypotheses we made on our research are that there is no significant variability in E-Business success criteria explained by key independent variables defined by our model. When the variable's *p*-value is less than 0.10, we reject the hypotheses. In other words, there is significant variability in E-Business success criteria explained by key independent variables.

## Overall results

The analysis of all ERM survey data lumps all types of implementations into a single model. Table II provides the statistical summary of correlation and ANOVA analysis. We use *p*-values to indicate the level of confidence that a variable is in fact related to overall project success. A *p*-value of 5 percent indicates that there is 5 percent or less chance that this variable is not significantly related to our overall implementation success scores. We use the significant level = 10 percent, in other words, *p*-value=0.10, to set the threshold for significant results. Therefore, when the *p*-value of a variable is less than 0.10, we could say that we have more than 90 percent confidence that the variable has a strong relationship in either the correlation or ANOVA models. When the *p*-value of a variable is greater than 0.1 but less that 0.2 or 0.3, the correlation between the variable and the success score is either moderate or weak (Table V).

The overall ERM correlation CE diagram in Figure 2 reveals that six significant variables have strong correlations with success score (*p*-value $< 0.05$). These six significant variables are schedule reliability, budget reliability, 3P consultant system process knowledge, vendor's business process knowledge, systems implementation time, and companies' expectations. The communication skill of the 3P consultant shows moderate correlation with success score (*p*-value $< 0.20$). In Figure 3 the ANOVA CE model has one more significant variable, implementation team's ERM experience, which does not show up in the correlation analysis.

Figures 2 and 3 depict graphically what was found to be statistically significant and provide the basis of the proposed implementation roadmap. Details for the components of ERM that are not depicted in this paper can be found in the paper we published in *Engineering Management Journal*.

We aggregated the significant variables for each component by indicating how many times they appear in CE diagrams. Figure 2 shows the frequency of key factor intensity. The intensity is the count of the times the factor was significantly related to

| Variables | Cases | Correlation $p$-value | One-way ANOVA $p$-value |
|---|---|---|---|
| Company expectations | 41 | *0.016* | *0.0800* |
| Implementation time | 39 | *0.013* | *0.0480* |
| Running time | 39 | 0.414 | 0.6791 |
| Schedule reliability | 39 | *0.004* | *0.0179* |
| Budget reliability | 36 | *0.008* | *0.0005* |
| Top management support | 40 | 0.749 | 0.8363 |
| Third party consultant communication skills | 23 | 0.155 | 0.2073 |
| 3P interpersonal skills | 23 | 0.726 | 0.5711 |
| 3P system process knowledge | 24 | *0.008* | *0.0318* |
| 3P experience | 24 | 0.310 | *0.0595* |
| System compatibility | 37 | 0.425 | 0.6542 |
| Vendor and consultant relationship | 12 | 0.570 | 0.2433 |
| Vendor business process knowledge | 25 | *0.098* | 0.2510 |
| Vendor communication skills | 25 | 0.849 | 0.4154 |
| Vendor experience | 22 | 0.537 | 0.6224 |
| Vendor interpersonal skills | 25 | 0.818 | 0.9439 |
| Implementation team mutual trust | 37 | 0.937 | 0.5371 |
| Team full-time commitment | 38 | 0.687 | 0.4430 |
| Team project management skills | 38 | 0.256 | 0.6387 |
| Team cross-function knowledge | 38 | 0.546 | 0.8330 |
| Team communication skills | 37 | 0.477 | 0.3316 |
| Team ERM experience | 38 | 0.258 | *0.0879* |

**Note:** Italic items are significant with $p < 0.10$

**Table V.**
Summary of statistical results

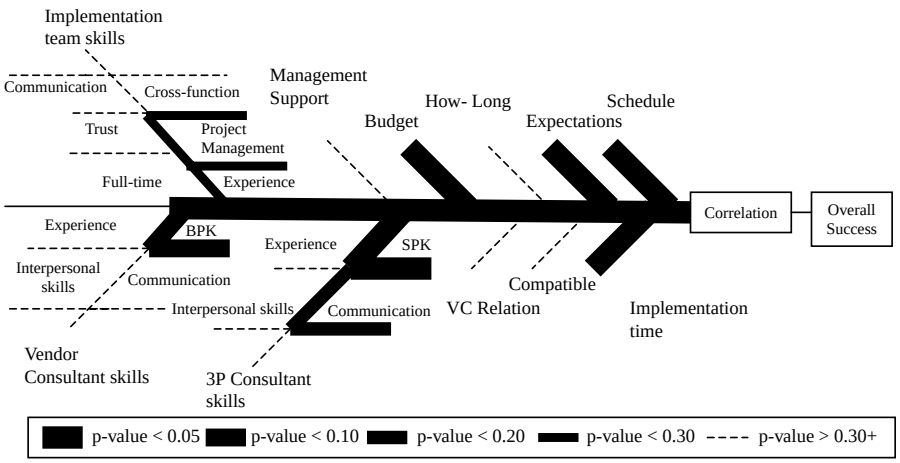


**Figure 2.**
Overall ERM correlation CE diagram

implementation success in the survey when overall, supply chain, electronic commerce, and ERP systems were analyzed. The maximum intensity would be two tests times four samples to yield an eight. These key factors are now used to construct the overall implementation roadmap.

Pareto analysis helps to identify the most important effects and causes so that we can prioritize and focus on the main causes. In this research, we use Pareto analysis to

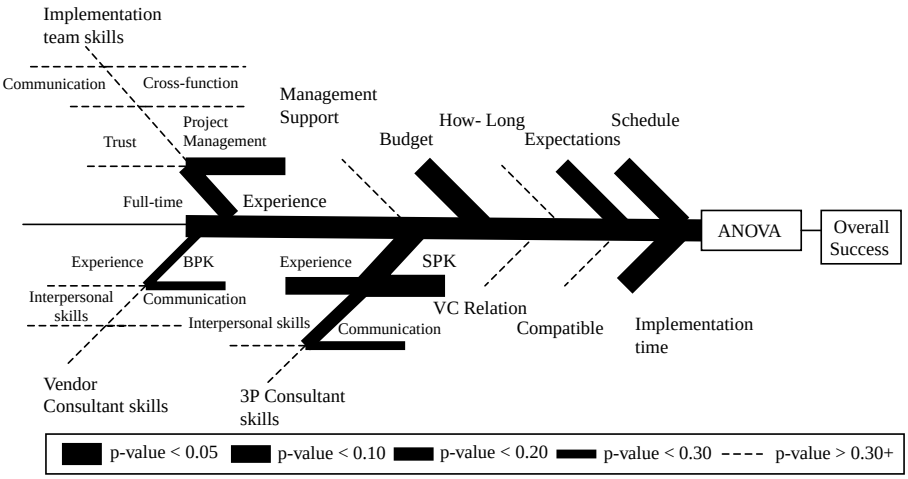


**Figure 3.**
Overall ERM ANOVA CE diagram

interpret the relationship between significant variables and overall success scores. We can see that budget reliability, the system process knowledge of third party consultants, companies' expectations, implementation time, schedule reliability, and the experience and competence of third party consultants constitute 80 percent of the overall success scores. We suggest that the majority of the overall success scores depend on these six significant variables. Figure 4 shows six significant variables.

After we identified these six significant variables, we compared them to the key variables of RFID implementation found in the literature. We found that most of them would overlap. Table VI shows the key variables for RFID, ERP, SCP, and electronic commerce.

## Proposed roadmap

We use these findings of significant variables to formulate a graphical roadmap that indicates when and where these success factors may appear and how a firm might manage the implementation process (Figure 5). Four principle stages appear in our

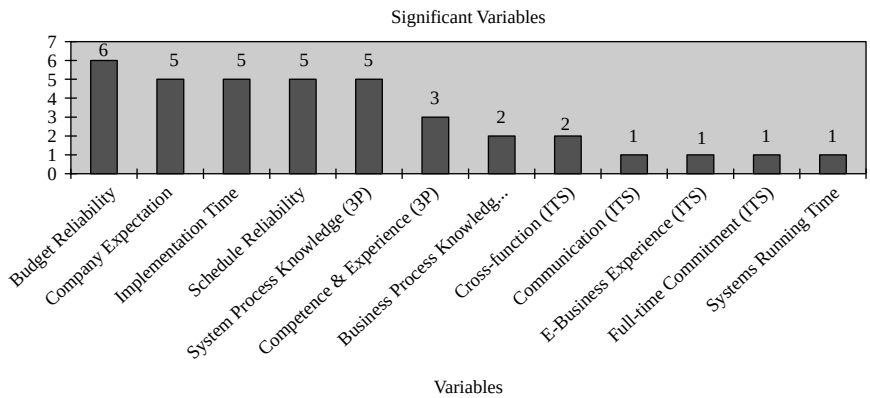


**Figure 4.**
Significant variables for implementation success

ERM systems roadmap: planning, development, implementation, and testing. The average ERM system's implementation time is 9-18 months (AMR, 2001). The solid lines with arrows show the flow of the roadmap. An end sign is not shown in the roadmap because ERM system implementations are endless projects. Firms need to frequently monitor and maintain their ERM systems as their business processes change.

*Companies' expectations and trading-partners' involvements*

Companies' expectations and trading-partners' involvements appear in the planning and testing stages. Five out of eight of our ERM CE diagrams show that the company's realistic expectations are a significant variable to overall success scores. In the planning stage, the first things a firm should examine carefully are its expectations. It should consider organizational needs above organizational wants. Trading-partners' involvement is also a significant variable especially in RFID system implementation. In recent RFID implementations, some upstream suppliers felt they were required

| ERP, SCM, ERM (based on our survey) | RFID (based on literature) |
|---|---|
| Budget reliability | Budget variables (costs, ROI) |
| Company expectation | Company expectation/commitment |
| Implementation time | Implementation time |
| Schedule reliability | Technology reliability |
| System process knowledge | System process knowledge |
| Vendor's competence and experience | Trade partners involvements |
| Business process knowledge | Business process knowledge |
| Cross-functional team | Cross-functional team |
| | Customer's mandate |

**Table VI.**
Key independent variables for RFID and other ERM systems

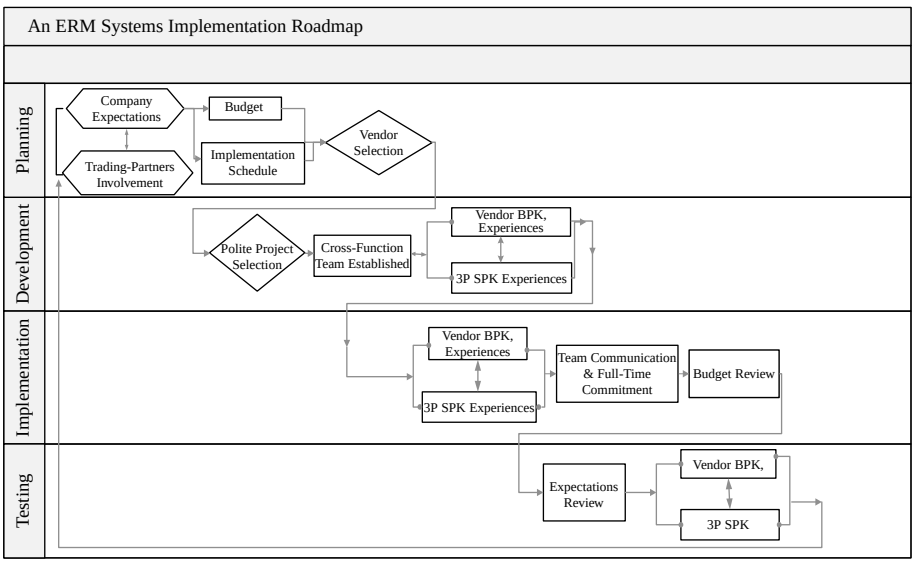


**Figure 5.**
An ERM implementation roadmap

to invest money to implement advanced technology to satisfy their powerful retail customers. In most supply chains, one entity saves costs at the expense of others. Companies need to provide a clear picture of long-term mutual benefits to their partners. Moreover, they need to have a direction for where they are going and how ERM systems may help. A firm should seek clear and unambiguous answers from ERM system vendors. According to the interviews with some companies, a system vendor typically promises results far exceeding the product's capability and design.

One of the main reasons for implementing ERM systems is to gain competitive advantage. A firm should understand the benefits of ERM and then evaluate its organization to determine its desired organizational benefits. A firm should list its expectations and establish a clear initial vision. System vendors should not dictate company goals and objectives; rather these things need to be developed internally. Therefore, a company's expectations appear in the testing stage again because the company will evaluate and check if the system meets its expectations that were set in the early planning stage. The expectations are expectations that the company develops based on its needs, not the expectations defined by the system vendor.

*Budget reliability*

Budget reliability appears in the planning and implementation stages and is a most significant success factor. Fifty-seven percent of our respondents indicated their actual implementation budgets were either significantly or moderately over projection. The key seems to be reliable cost estimates rather than low cost projects. Firms quickly lose faith in implementations with significant cost overruns. It appears that many organizations jumped onto the ERM parade with minimal financial metrics. Even the use of simple net present value and ROI criteria when formulating budgets would be a major step forward. One challenge companies encounter during RFID implementation is how to shift RFID implementation from mandate driven to ROI drive. Considerable doubts exist in the RFID and other ERM systems ROI. Evidence suggests companies will not be able to see ERM systems ROI for the first two or three years. Amazingly, few companies in our analysis invested much time with even basic financial planning! Budget reliability appears in the implementing stage because the firm will need to review cost estimates and changing technology. Funds will also be allocated for training and education during this stage and these requirements tend to evolve and change as the system implementation matures.

*Pilot project selection*

Researchers and practitioners suggest firms should start from a pilot ERM infrastructure and make sure the infrastructure is scalable especially for RFID implementation. Companies can start from functional integrations and carry the implementation experiences and benefits to the next level of integration such as business units and inter-company integrations. Companies should build their own test labs if needed since they understand their business processes more than any other party in the implementation process.

*Third party (3P) consultant's system process knowledge*

Third party consultant's system process knowledge appears in the developing, implementation, and testing stages. After deciding which ERM vendor the company is

going to use, the company might consider hiring 3P consultants who have a strategic alliance with the system vendor. Some companies use either a vendor consultant or 3P consultant to help them implement systems (some companies hire both). Companies hire 3P consultants to reengineer their business processes to fit the software system they intend to implement. One of the advantages of using 3P consultants is the familiarity associated with the vendor's software system.

In the implementation stage, companies will need 3P consultant system process knowledge even more than in the development stage. The 3P consultant may need to modify the company's business processes to match the ERM software systems. When poor test results materialize, strong commitments from 3P and vendor consultants are essential. Both the company and 3P consultants should understand that implementing an ERM system successfully is a win-win situation.

*Vendor consultant business process knowledge*

Vendor consultant's business process knowledge appears in the development, implementation and testing stages. Companies first need to select an ERM systems vendor. Companies should understand that high market share ERM vendors may not guarantee that they can implement the systems successfully. In the Hershey and SAP case (Stedman, 2000), Hershey used top-rated vendors for every ERM component. They used SAP for ERP, Manugistics for Supply Chain and Siebel for Customer Relationship Management. However, the ERM system failed and caused Hershey's profit to drop 19 percent in the third quarter of 1999. Therefore, we suggest that companies examine a vendor's core product to determine if requirements are met. Careful construction of a requirements document is essential and a business process consultant can be a wise investment early in the implementation lifecycle. The company should also examine the vendor's business process knowledge. According to our case studies and interviews with industry, the vendor consultant who lacks business process knowledge will dramatically increase implementation difficulties.

Although vendors claim their products can be customized during the implementation stage, the majority of our respondents suggest to "keep the system clean and standard." The more customization that is allowed, the more complications arise in the system. Customization also increases the difficulties when upgrading the system. Vendor consultants play an important role in the implementation stage not only for their technical skills, but also for their advice on business processes.

The role that the vendor consultant plays in the testing stage is more important than 3P consultants or the internal company team. Technical obstacles with either hardware or software need to be overcome. Additionally, the vendor consultant is responsible for understanding the system specifications completely. Requirements traceability becomes critical if performance features are modified or if key design decisions are altered.

It is noteworthy to consider the ownership of an ERM's implementation. Usually, managers from the IT department and other related departments own the ERM implementation project. However, due to lack of either ERM software or cross-functional knowledge of managers, the vendors take charge of the ERM implementation instead of the internal company team. It is important that the internal company team create a learning environment that encourages the team members to continue learning and adapting during the change process.

## Conclusion

Our research results have helped uncover the key significant variables that contribute to successful ERM implementation. It is clear that some variables, like companies' expectations, budget reliability, and schedule reliability are major factors that consistently appear in all components and across both CE modeling techniques. It is also clear that each component of ERM can be quite distinct in its implementation and consequently in its success factors. We suggest taxonomy where ERM components can be related to one another and a simple implementation roadmap. We indicate when and where significant variables appear and how a firm might manage the implementation process. Clearly, the research hypothesis is rejected and we conclude that several of the independent variables in Table I significantly explain the success of an ERM implementation.

Our research is clearly constrained by survey data obtained at a particular time. Costs of RFID components change rapidly and the business environment fluctuates due to economic and market pressures. Our goal has been to craft a generic model that has some degree of universal appeal. Clearly a generic model overlooks conditions unique to each industry where RFID might be deployed. Such a research constraint suggests future research to observe the evolution of RFID technology, the impact of RFID on business processes and the migration of RFID business practices throughout the supply chain. We believe that our baseline model is suitable for general use and robust enough to allow for follow-on improvements and refinement.

Recently, there has been some research to support our conclusion. A case study at Texas Instruments points out the standardization of internal processes, user expectations, and important information technology systems is the foundation for the success of ERP implementation (Sarkis and Sundarraj, 2003). Another research paper indicates ERP implementation variables such as system adaptation, complexity, and organization adaptation did support our research result in independent variables (company expectation, system process knowledge) that significantly explain the success of an ERM implementation (Luo and Strong, 2004).

It is convenient to think of ERM system implementation as a change process on a large-scale. The implementation of an ERM system touches just about every aspect of a firm's operations even when small individual components are put into place. The adoption of one component tends to lead to others over time until most firms are intricately dependent on the underlying information technology to operate. The emergence of RFID, customer relation management, strategic enterprise management, data warehousing, and online analytic processing depend on lower level ERM implementation. We foresee a time when an ERM system will not be a collection of components as suggested in Figure 1 but rather a pyramid of layers of implementation that build upon one another. Certainly, ERM implementations are costly and complex undertakings. We conclude that the evidence generated by successful and failed experience can be used to understand this management challenge so that a method of implementation that minimizes risk can be shared.

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