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Enterprise Resource Planning (ERP) Systems and the Manufacturing-Marketing Interface: An Information Processing Theory View

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ERP Systems and the Manufacturing-Marketing Interface: An Information Processing Theory View

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Abstract

The manufacturing-marketing (MM) interface has received substantial consideration in the operations management literature; however, relatively little attention has been paid to the role of information systems in facilitating MM integration. As integrated cross-functional systems, enterprise resource planning systems (ERP) are well-suited to provide MM integration. Based on information processing theory, the central proposition of this paper is the greater the interdependence between manufacturing and marketing, the greater the benefit of ERP. Specifically, H1 states that the greater ERP-enabled coordination between manufacturing and marketing, the greater the benefit of ERP to the plant. H2 states that the degree to which ERP-enabled manufacturing-marketing coordination improvements are realized, depends on the amount of interdependence between manufacturing and marketing. Using multiple regression, the model is tested on survey data from 107 manufacturing plants running ERP. The data support H1 and H2. These findings support the general proposition that interdependence between functions is one factor that influences the degree to which organizations reap benefits from their ERP investments. Based on the ERP literature, the model controls for the amount of time that ERP has been running in the plant; This factor was found to be insignificant in the model. However, exploratory analysis finds that time is associated with other ERP benefits.

Keywords: Enterprise systems (ERP); Manufacturing-Marketing interface; Interdependence; Information Processing Theory

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1. Introduction

Many companies are currently under pressure to be more responsive to shifts demand and to pressures for faster new product introductions and modifications. At the same time the manufacturing environment is increasing in complexity. For example, coordination has become challenging for many organizations as their operations have become increasingly distributed both geographically (i.e. across continents) and organizationally (i.e. across more suppliers and marketing channels).

Manufacturing companies can respond in a number ways (which are not mutually exclusive). One response is to increase capacity or inventory buffers (Thompson, 1967; Galbraith, 1973; Pagell, Newman, Hanna and Krause, 2000). However, many industries are finding that the viability of this option is decreasing. A second response is to simplify production and other processes (Schonberger, 1982; Krajewski, King, Ritzman and Wong, 1987; Huson and Nanda, 1995; Sakakibara, Flynn, Schroeder and Morris, 1997). A third is to increase integration, which may increase the amount of information available to one work unit about conditions in other work units or in the external environment (Lawrence and Lorsch, 1967; Wheelwright and Hayes, 1985; Adler, 1995; Ettlie, 1995; Hauptman and Hirji, 1996).

Companies considering pursuing this third option--increases in integration--face numerous decisions. Among the most basic of these are: *what to integrate* and *how to integrate*. Regarding the first question, many scholars have suggested that Manufacturing-Marketing (MM) integration increases performance-related outcomes. Regarding the second question, a majority of mid-size and Fortune 500 companies have turned to enterprise resource planning (ERP) systems (also known as enterprise systems) as a means of increasing integration among business functions (Scott and Shepherd, 2002; META Group, 2004). In spite of early evidence to the contrary, ERP systems do appear to yield benefits to the average firm (Hitt, Wu and Zhou, 2002; Anderson, Banker and Ravindran, 2003). However, how and where these benefits occur (and do not occur) within a company has not been as thoroughly researched. In thinking about the *how* and *where* issues, one place we might expect to see ERP deliver large payoffs is in the MM interface. After all, as a cross-functional system, ERP should increase performance by improving

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coordination between manufacturing and marketing—two functions that often occupied separate silos under most earlier transaction processing systems, such as MRP and some MRPII systems.

However, the operations management research community has yet to thoroughly investigate the effectiveness of ERP as a means of facilitating manufacturing-marketing integration. This paper attempts to fill this gap using information processing theory. After reviewing the empirical manufacturing-marketing interface literature, we argue that manufacturing-marketing interdependence is an important source of uncertainty. We suggest ERP may be effective in responding to this uncertainty by providing manufacturing-marketing integration. Specifically, we argue that *the greater the interdependence between manufacturing and marketing, the greater the benefit from ERP*. Next, we describe our test of the impact of ERP at varying levels of manufacturing-marketing interdependence. We use a survey methodology. After establishing the measurement validity of the data, we perform regression on data from 107 manufacturing plants. The data support the notion that interdependence is associated with greater ERP benefits. Finally we discuss the implications of this finding as well as limitations and future research.

2. Literature review

2.1 Manufacturing-marketing (MM) interface

A 2002 literature review noted that, although there are great number of conceptual and prescriptive articles describing the value of the MM interface, empirical studies are rare (O'Leary-Kelly and Flores, 2002). (Studies on new product development (e.g. Ettlie and Reza, 1992; Wheelwright and Clark, 1992; Adler, 1995; Ettlie, 1995; Hauptman and Hirji, 1996) are arguably the exception). A number of empirical papers have appeared since 2002. However, the ratio of empirical (and analytical) to conceptual papers is still low, suggesting the need for additional confirmatory research. According to Malhotra and Sharma (2002), this need may be especially great at the tactical and operational (rather than strategic) end of the decision spectrum.

Nevertheless, empirical evidence suggests a relationship between MM integration and performance-related outcomes. Hausman, Montgomery & Roth. (2002) find that cooperation between manufacturing and marketing is related to profit performance, competitive position and morale. Sawney and Piper (2002) report that the speed and quality of the MM interface positively affects defect rate,

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lateness and lead-time. Nahm,Vonderembse and Koufteros (2003) find that horizontal integration affects performance through its impact on time-based manufacturing. Other empirical work establishes conditions under which marketing-manufacturing integration is most (and least) valuable. These conditions include presence of a differentiation-integration business strategy (O'Leary-Kelly and Flores, 2002), demand uncertainty (Tatikonda and Montoya-Weiss, 2001; Calantone, Droge and Vickery, 2002; O'Leary-Kelly and Flores, 2002), competitor unpredictability (Calantone et al., 2002), frequency of new product introductions (Calantone et al., 2002), and novelty of products and internal processes (Tatikonda and Montoya-Weiss, 2001).

2.1.1 Mechanisms for achieving MM integration

In addition to testing the conditions under which MM integration may be valuable, the literature examines a number of *mechanisms* for integrating manufacturing and marketing (i.e. for managing the MM interface). These include lateral relations between functions--for example the degree to which functions work together (Hausman et al., 2002; McAfee, 2002; O'Leary-Kelly and Flores, 2002) or consult with one another (Sawhney and Piper, 2002). Lateral relations are also an important interface mechanism used in concurrent design (Ettlie, 1995; Tatikonda and Montoya-Weiss, 2001). Companies may also institute integrative job positions (Van Dierdonck and Miller, 1980; Germain, Droge and Daugherty, 1994), such as an employee who reports to the materials area but works full time with marketing. Empirical MM studies have also examined committees (Germain et al., 1994) and hierarchical control (Van Dierdonck and Miller, 1980).

However, the MM interface literature pays less attention to information technology as an integrative mechanism. Certainly the literature published by IT vendors, such as SAP, positions integrated IT as a way to effectively integrate production and marketing. Moreover expenditures on integrated systems (including ERP, supplier relationship management, and customer relationship management) over the past 15 years have been huge. Thus it seems worthwhile to investigate the effectiveness of an IT-based approach to MM integration—especially because the existing ERP literature raises some concerns about ERP's value in this area, as the next section discusses.

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2.2 Enterprise resource planning (ERP) systems

A defining characteristic of ERP is its level of cross-functional integration. The proto-typical ERP implementation, such as that described by Davenport (1998), is a single database and set of business applications. In practice, ERP implementations sometimes consist of multiple “instances” and process models (Jacobs and Whybark, 2000; Markus, Tanis and vanFenema, 2000). Nevertheless, in terms of the number of business functions and locations linked together, ERP tends to be well-integrated, especially with respect to earlier generations of systems (Gattiker and Goodhue, 2002). As an integrated system, ERP may be well-suited for managing the interface between two business functions—e.g. the manufacturing-marketing interface.

ERP research can be divided into two broad categories: implementation-oriented research, which investigates factors that contribute to system implementation success, and performance-oriented research, which seeks to explain differences in ERP’s effect on performance (Staehr et al. 2002). According to Staehr et al. (2002), implementation research (e.g. Ng et al., 1999; Umble, Umble and Von Deylen, 2001; Weston, 2001; Akkermans and van Helden, 2002; Gefen, 2002; Abdinnour-Helm, Lengnick-Hall and Lengnick-Hall, 2003; Al-Mashari, Al-Mudimigh and Zairi, 2003; Craighead and LaForge, 2003; Mabert, Soni and Venkataramanan, 2003; Muscatello, Small and Chen, 2003; Schrnederjans and Kim, 2003; Somers and Nelson, 2003; Umble, Haft and Umble, 2003; Sheu, Chae and Yang, 2004) is the more developed of the two.

Although smaller, the existing body of performance-oriented research has also yielded some important firm level findings. Hitt et al. (2002) demonstrate that ERP adopters outperform non-adopters on productivity, financial and stock market metrics. They also show that, among adopters, performance increases when ERP is implemented. Anderson et al. (2003) find a large stock market valuation multiple from ERP investments. These studies demonstrate that the benefits of ERP systems are positive on average when we look at aggregated, firm-level performance.

By contrast, operations management performance-oriented results are somewhat more equivocal. Gattiker and Goodhue (2002) reported that the majority of APICS (commonly known as the American Production and Inventory Control Society) members surveyed reported that ERP was an improvement over predecessor systems. Similarly, Mabert Soni and Venkataramanan, (2000) found favorable general perceptions among APICS members. However the researchers also noted that the type of benefits being reported the most were related to increased timeliness and availability of information. By contrast, "traditional cost / operational-based" (p. 56) benefits, such as cost and inventory measures, lagged. Similarly, respondents to Stratman and Roth's (2002) *improved business performance* scale reported positive ERP improvements related to overall functional efficiency and process re-engineering; however, they reported neutral to negative ERP impacts on control of operating expenses and customer satisfaction. In a 2001 survey of APICS members, IT user groups and others, approximately 70 percent of respondents reported that their ERP systems were "successful" or "very successful," however 30 percent self-described as "neutral" or "disappointing" (Mabert, Soni and Venkataramanan, 2001). A 300-day longitudinal study of a single company's archival data (McAfee, 2002) found that operational performance indicators initially dipped but eventually exceeded the levels that existed when ERP was implemented (although it is important to note that only 30 days of pre-ERP performance data were captured). Rabinovich, Dresner & Evers (2003) compared the effects of ERP, JIT, MRP and mass customization approaches on inventory speculation, lead time and inventory turnover. Controlling for the other approaches, ERP had no positive effects and actually unfavorably affected inventory speculation.

Taken together, the Hitt and Anderson firm level-studies (mentioned above) coupled with the operations studies suggest an interesting contradiction. The firm-level studies suggest an overall positive effect of ERP. However, the operations studies discussed above are relatively lukewarm. Moreover, they suggest that in manufacturing operations, ERP may underperform JIT and other approaches—approaches that cost quite a bit less to implement. One clue to resolving this apparent contradiction comes from Ragowsky Stern and Adams (2000). This study found that the benefit of particular MRPII modules increased with the complexity and uncertainty of the manufacturing environment (e.g. number of suppliers, product complexity). The broader implication is that one cannot discern the value of integrated IT by generalizing across a diverse sample of plants. Rather, the value of an IT investment may *depend* on operating and environmental characteristics. Likewise, Gattiker and Goodhue (2004, 2005) find that value of ERP varies, depending organizational structure. Similarly, Bendoly and Jacobs (2004) find that, while ERP can be configured to perform profitably under a wide variety of conditions, ERP delivers the most to companies whose processes are centralized and relatively homogeneous. One way to link information system impacts to organizational characteristics is through information processing theory, as the next section explains.

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2.3 Information processing theory (IPT)

2.3.1 Overview of IPT

IPT can help us make sense of the above findings and it is a valuable lens for examining the manufacturing-marketing interface. According to IPT the key task for organizations is managing uncertainty, such as task complexity and the rate of environmental change (Galbraith, 1973; Galbraith, 1977; Tushman and Nadler, 1978). To do so, organizations must deploy the information processing mechanism (or combination of mechanisms) that is most appropriate for managing the uncertainty (amount and type of uncertainty) that the organization faces. Galbraith (1973; 1977) suggests that simple coordination mechanisms (e.g. standard operating procedures, hierarchical referral) are appropriate for low uncertainty environments. However, as uncertainty increases, firms must respond with some combination of four more complex modes. In particular, information processing capacity can be increased by (1) facilitating lateral relations between sub-units, or by (2) implementing an integrated computer information system, such as ERP. The need for information processing can be reduced by (3) creating self-contained tasks or by (4) accepting greater inefficiency or "slack". Focusing on options 1 and 2, figure 1 summarizes the theory.

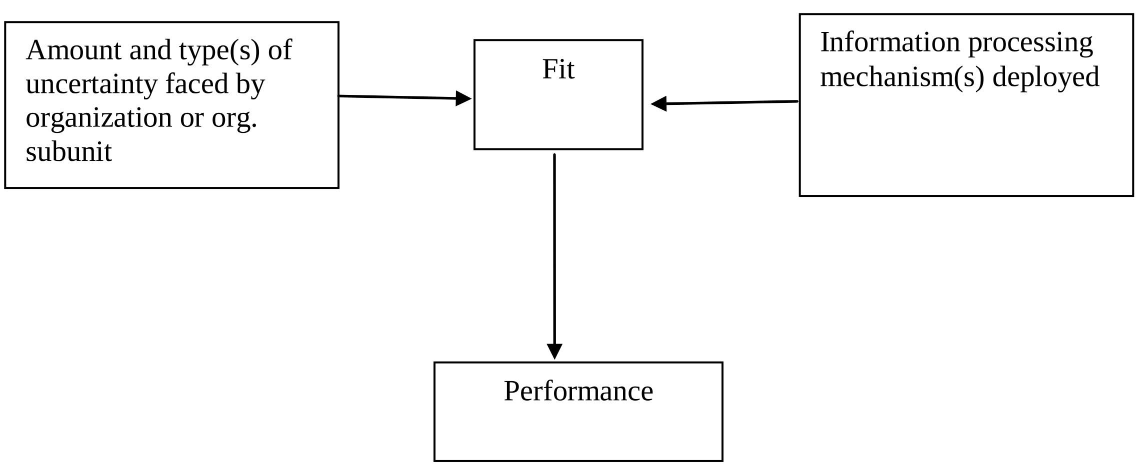

Figure 1. Overview of information processing theory

Applying IPT to manufacturing plants, Flynn and Flynn (1999) examined a variety of information processing approaches. Their results support the theory for the most part: Uncertainty was associated with lesser performance, but several uncertainty management mechanisms moderated this relationship. Notably however, investments in information technology did not have a positive impact. Benasou &

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Venkatraman (1995) find support for IPT in the supply chain management arena: Matching the level of uncertainty (complexity, interdependence, variety and so on) in supply relationships with information processing capacity (number of communication channels, scope of IT use, frequency of interpersonal contact, and so on) increases performance-related outcomes. Several of the MM interface papers mentioned in the previous section also draw on IPT. For example, O'Leary-Kelly & Flores (2002) and Tatikonda & Montoya-Weiss (2001) conceptualize market volatility and process novelty as uncertainty, and they examine several information processing mechanisms for dealing with it.

2.3.2 IPT perspective on using ERP to manage the MM interface

From an IPT point of view, ERP can be conceptualized as a particular type of information processing mechanism. Thus, IPT suggests that the impact of ERP (like the impact of any information processing mechanism) will vary from company to company (or plant to plant) because the relevant uncertainties typically vary from company to company and plant to plant. Establishing the particular uncertainties that ERP is well suited to handle may help explain some of the varying results practitioners and academics have reported with ERP.

Tushman and Nadler (1978) discuss uncertainty from the perspective of the subunits that make up the firm (e.g. manufacturing plants, marketing, R&D). The researchers suggest three important sources of uncertainty: the nature (e.g. complexity, instability) of the core task that the subunit is responsible for executing, the nature of the environment facing the subunit (a subset the environment of the company overall), and the degree to which the subunit's activities are interdependent with other subunits.

Since the MM interface deals with interactions between organizational subunits (manufacturing and marketing), Tushman and Nadler's subunit perspective is potentially quite useful. Numerous MM studies (as discussed above) find that the value of the MM interface increases with the amount of uncertainty faced by the company. This suggests that an integrated information system will be a particularly good solution when manufacturing and marketing need to coordinate tightly (Goodhue, Wybo and Kirsch, 1992). In other words, since a hallmark of ERP is integrating the data and processes of a company's different business functions, ERP might be a good fit when interdependence between business functions is an important source of uncertainty. McCann and Ferry (1979; p.114) define interdependence as "a condition where actions taken within one unit affect the actions and work outcomes of another unit." Interdependence between two units increases the likelihood that changing conditions in one unit require

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another unit to adjust (Thompson, 1967). As an integrated information system, ERP facilitates this type of adjustment by making each function aware of information about other functions. Thus the central research proposition of this paper is:

Greater interdependence between manufacturing and marketing is associated with greater benefits from ERP.

Certainly manufacturing and marketing always share some degree of interdependence, and, over the last 20 years, this interdependence has often increased as companies have reduced inventories and lead time buffers. Nevertheless, it is reasonable to expect the level of interdependence with sales and marketing to *vary* from company to company and from plant to plant within a company. For example, plants that produce many product configurations or that serve new markets or that have unpredictable competitors may well need to coordinate manufacturing and marketing decisions tightly. By contrast, a mature market for standard products may change relatively little from day to day or month to month and thus would not require frequent re-allocations of manufacturing resources based on market conditions. Manufacturing-Marketing interdependence-related uncertainty is higher for the first type of plant than for the second.

3. Research model

In order to investigate the research question we developed a conceptual model (figure two). Noting that researchers have experienced difficulty detecting organization-level information systems impacts (when they exist), Barua, Kriebel and Mukhopadhyay (1995) suggest several guidelines. One of these recommendations is to focus at lower levels of the organization (e.g. the individual business function or business unit), rather than the entire firm. Following this advice, our ultimate dependent variable is the overall plant-level ERP impact (rather than, say, company-wide impact). This plant-level focus is consistent with a great deal of other operations management literature including (Anderson, Rungtusanatham, Schroeder and Devaraj, 1995; Flynn, Schroeder and Sakakibara, 1995; Flynn, Schroeder and Sakakibara, 1996; Flynn and Flynn, 1999; Ketokivi and Schroeder, 2004; Rungtusanatham, Forza, Koka, Salvador and Nie, 2005). A plant focus may be particularly appropriate for ERP research because ERP configurations may differ from plant to plant within a firm (Hitt et al 2002). Furthermore, operations characteristics often differ substantially across the plants in a firm

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<u>(Skinner, 1974) potentially resulting in plant-to-plant differences in the impact of an ERP within the company (Gattiker and Goodhue, 2004).</u>

Barua et al also recommend capturing "intermediate variables" that may lead to the overall effect of the information system. This paper's focus on the manufacturing-marketing interface suggests that the appropriate intermediate benefit to examine should be ERP-enabled MM *coordination improvements*. We define *coordination improvement* as the degree to which ERP helps a plant adjust to changing conditions relating to sales and distribution. Our model suggests that these coordination improvements are an important part of ERP's overall plant level impact. Thus our first hypothesis is:

> *H1: Greater ERP-enabled <u>coordination improvement</u> (improvement in coordination with marketing) is associated greater overall plant-level ERP benefit.*

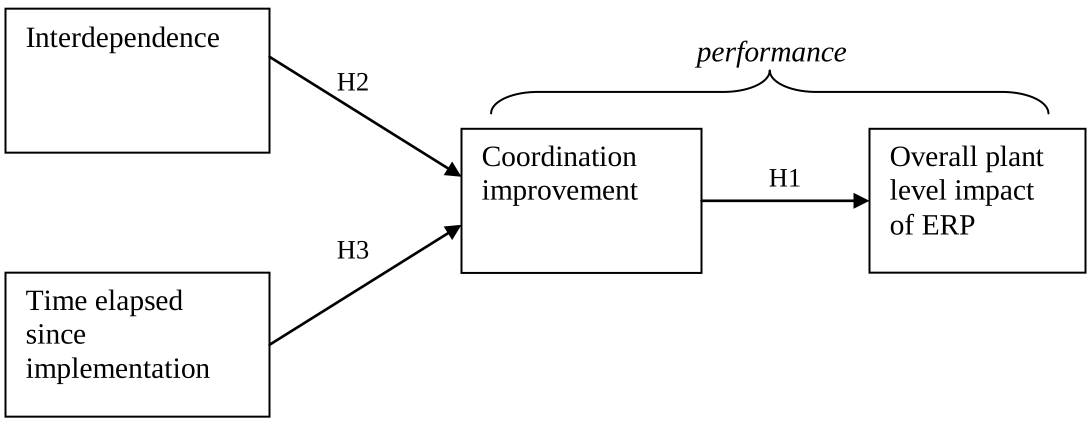

Figure 2: Research model of the effect of interdependence on plants running ERP

3.1 Interdependence

As an integrated system, ERP provides manufacturing with information from marketing applications. As discussed in the section 2.3, information processing theory suggests that the greater the level of interdependence between the two functions, the greater the benefit of such information. Thus:

> *H2: Greater manufacturing-marketing <u>interdependence</u> is associated with greater ERP-enabled <u>coordination improvement</u>.*

Note that, our objective is to explain variation in results among firms who have implemented ERP. Since most larger companies have already installed ERP, we believe ours is a more practical objective than attempting to provide guidance on whether or not to adopt the software in the first place.

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Thus our model applies to plants that are running ERP. If, by contrast, we were interested in the adopt/no adopt decision, we would examine an interaction between ERP and interdependence (or find a way to hold interdependence constant) among firms that have and have not implemented ERP. However, since our focus is on the companies that have implemented ERP, we examine varying levels of interdependence among a sample of firms that have all implemented ERP (i.e. interdependence is a main effect as depicted in figure 2 above).

3.2 Time since implementation

Case study research has suggested that some impacts of ERP may improve with time as unforeseen problems are solved and users move up the learning curve (Markus and Tanis, 1999; Ross and Vitale, 2000; Ash and Burn, 2003). Thus time might mask or amplify any effect of the substantive variables in the research model. Thus, it is necessary to control for the effects of time elapsed, and we introduce the following control hypothesis to do so:

H3 (control hypothesis): The greater the time elapsed since ERP implementation, the greater the ERP-enabled coordination improvements.

4. Instrument development and data analysis

4.1 Instrument development

To define the constructs and ensure content validity of our measures, we reviewed the literature and conducted case studies of ERP systems in manufacturing plants of four companies. This enabled us to define and operationalize the constructs accurately and in a way that is relevant to the domain. When possible we adapted questionnaire items from existing scales. Especially with regards interdependence, which has been the topic of many other papers, the depth of our scale is consistent with other recent attempts to measure the construct (i.e. Ranganathan, Dhaliwal and Teo, 2004; Martínez Sánchez and Pérez Pérez, 2005; Kim, Umanath and Kim, 2005/2006).

To further establish whether the survey items corresponded to the theoretical constructs, we interviewed nine managers in local manufacturing facilities. (The jobs of these individuals were consistent with the job titles of the respondents who later completed the survey.) Interviewees filled out a prototype questionnaire and were asked to explain their interpretation of the items, especially when a participant answered items within a single scale inconsistently. We also elicited informal verbal descriptions from interviewees and we checked these for consistency with their responses to the

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questionnaire items. Numerous refinements resulted. The end product was the survey instrument in appendix one. We discuss the unidimensionality, reliability, convergent and discriminant validity of the instrument in the data analysis section.

4.2 Data collection

The target survey respondent was someone working in a manufacturing job. Therefore we surveyed a sample provided by APICS, as well members of user associations of two of the major ERP packages. Unfortunately, the user groups consisted mostly of IT staff but did include some operations people. Potential participants were either sent or given a paper survey and cover letter, or were given an email solicitation inviting them to visit a web site with a parallel version of the survey. IT, consultants and non-operations people were removed from the pool of surveys returned as were individuals who indicated that their plant had not implemented ERP. Further, based on our definition of ERP as a functionally integrated system, we omitted respondents representing systems that were not integrated—systems that lacked MRP, accounting and marketing functions (see table1). Surveys with missing values were also culled. This left 124 usable responses. Surveys from APICS mailing lists and APICS list serves accounted for about 80 percent of the usable responses.

Computing an overall response rate is problematic because email solicitations were sent to list-serves and the composition of the list serve subscribers (practitioners, academics, consultants, manufacturing versus service, and so on) is unknown and because even a substantial number of manufacturing plant personnel in the pool were in plants that had not implemented ERP. We do know that our response rate on pencil and paper surveys sent to mailing lists (which included plants that had not implemented ERP) was approximately 10 percent. When sending the survey, we could not filter out plants that had not implemented ERP (although we did filter out non-ERP plants from the *responses*, as described in the preceding paragraph). Respondents in these plants presumably had little motivation to fill out the survey and return it (although the survey provided a space for then to indicate that there plant had not implemented ERP). Thus, it is logical to assume that our response rate among plants that had implemented ERP was much higher than our overall response rate, but we have no way of establishing this.

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4.3 Sample characteristics

Case study evidence suggests that ERP impacts are typically negative immediately after implementation but improve with time and eventually become positive (Markus and Tanis, 1999; Ross and Vitale, 2000; Ash and Burn, 2003). Larger sample research provides some confirmation of this (Cosgrove Ware, 2003). We are interested in the sustained effects of ERP, not implementation related problems (which other researchers have studied relatively thoroughly as we point out in the literature review). Therefore we sought to exclude observations for which little time had elapsed to work out the inevitable implementation-related difficulties (e.g. user resistance to change, technical problems, and so on). A recent study (Cosgrove Ware, 2003) suggests that a year is sufficient time for such problems to be resolved. Therefore we excluded 17 observations representing plants that had been running ERP for less than one year. This left 107 observations. The sample does not contain more than one plant per company.

The following industries were represented by at least five percent of the sample: automotive, chemicals, consumer, electronics, and other processing. All the companies in this sample had implemented manufacturing, marketing (sales and distribution) and accounting modules as part of their ERP system (table 1); and the majority had shop floor and engineering modules. The size of the average implementation was six plants. Tables 2 through 5 provide further information about the sample. As table 4 indicates, 18 percent of the plants had implemented ERP systems that are not "big names" like SAP. Respondents did list the names of these packages/vendors the survey. We looked these up on a manufacturing software directory to ensure that they really were ERP systems. This incidence of smaller market-share ERP packages is consistent with data collected by other researchers (Mabert et al., 2000).

Table 1: Modules in ERP implementation

Size of ERP implementation (number of plants in company running the system)	**Percent of Plants running this function**
MRP	100
Purchasing	100
Accounting	100
Sales/Distribution	100
Shop Floor	77
Engineering	53
Human Resources	33

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Table 2: Frequency breakdown by company size (no. of employees)

Company Size	Percent of plants in companies of this size
1-1,500	40
1,500-10,000	35
10,000+	25

Table 3: Frequency breakdown by respondent's job function

Job Function	Percent of total
Scheduler/Planner/Buyer	20
Materials Manager/ Purchasing Manager	44
Operations Manager	16
Plant Manager	11
Other Manufacturing Position	9

Table 4: Frequency breakdown by software vendor

Software Vendor	Percent of total
SAP	37
JD Edwards	17
QAD	7
Oracle	7
BPICS/SSA	5
PeopleSoft	5
Baan	4
Other	18

Table 5: Time elapsed ERP since implementation at plant (since “go-live”)

Time Elapsed (months)	Percent of total
12 to 17	42
24 to 35	26
36 to 47	15
48 to 59	11
60	11
72	2

4.3.1 Measurement validity

All latent variables (i.e. all variables except Time Elapsed Since ERP Implementation) were measured with multi-item scales in order to allow each scale’s unidimensionality, discriminant validity,

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convergent validity and reliability to be assessed. Establishing these properties helps assure researchers and research consumers that the scales actually measure the phenomena that they purport to measure (Churchill, 1979; O'Leary-Kelly and Vokurka, 1998). Several refinements to the scales were made during this process (i.e. several items were dropped). Appendix one shows the original and final sets of items.

Unidimensionality refers to whether the items in a scale measure a single latent variable. Unidimensionality can be assessed using confirmatory factor analysis or exploratory factor analysis on all constructs individually or simultaneously—a more conservative approach (O'Leary-Kelly and Vokurka, 1998). Using SAS v. 8.0 PROC FACTOR (oblique rotation because of the assumption that factors are correlated), we conducted exploratory factor analysis (EFA) on all variables together. (Please see Hair, Anderson, Tatham and Black (1998) for an excellent explanation of this technique.) Since we had a well-defined expectation as to the number of latent variables and the indicators that would tap them, we specified the number of factors (3) to be extracted *a priori*. At almost nine to one, the ratio of items to sample size is very adequate (Hair, Anderson, Tatham and Black, 1998). The factor analysis results on the final scales appear in Table 6 . Evidence of unidimensionality is excellent: All items within scales load together with large primary factor loadings (Hair et al., 1998); and each item's primary loading is substantially elevated over its loadings on other factors.

Reliability, which can be thought of as a scale's repeatability or signal to noise ratio (Nunnally and Bernstein, 1994), was assessed using Chronbach's alpha. The reliability for each scale is given in table 7. At .83 or above, all reliabilities exceed common thresholds of .60 to .80 (Nunnally and Bernstein, 1994).

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Table 6
PROMAX rotation; 4 eigenvalues>1

	Overall Plt. Impact	Interdep.	Coord. Improv.
Impact1	**0.87976**	0.07242	0.30547
Impact2	**0.89215**	-0.03884	0.20222
Impact4	**0.89421**	0.09476	0.26580
Coord1	0.41594	0.32984	**0.68934**
Coord2	0.48876	0.20955	**0.68795**
Coord3	0.32867	0.26729	**0.74104**
Coord4	0.22483	0.12416	**0.85230**
Inter2	0.16723	**0.76555**	-0.21324
Inter3	0.17003	**0.74955**	0.42181
Inter4	-0.02959	**0.73057**	0.28983
Inter5	0.02414	**0.69469**	0.40080
Inter7	-0.02225	**0.73533**	0.17000

Table 7 Standardized Cronbach's alphas

Scale	Alpha
Overall plant level ERP impact	.93
Coordination Improvements	.89
Interdependence	.83

Discriminant validity refers to whether different scales do indeed measure different constructs (Bagozzi, 1980). Following O'Leary-Kelly & Vokurka (1998), Stratman & Roth (2002) and Venkatraman (1989), discriminant validity is demonstrated with chi square difference tests. This consists of creating and comparing two CFA models (a hypothesized model and an alternate model) for every pair of constructs in the study. In each alternate model, the correlation between the two constructs (Φ) is constrained to be one. In other words, the alternative model assumes that the survey designed to measure two constructs items actually measure the same construct (i.e. that discriminant validity is lacking). Since the alternate model is nested in the hypothesized model, the fit of the two models can be compared by determining the statistical significance of the difference in chi squared and degrees of freedom between the two models. Figure 3 gives an example for one of the pairs of constructs in the study. In this study, the hypothesized and alternate models were compared for all three possible pairings of latent variables using LISREL version 8.52. In every case, the hypothesized models were rejected in favor of the hypothesized models at the .001 confidence level.

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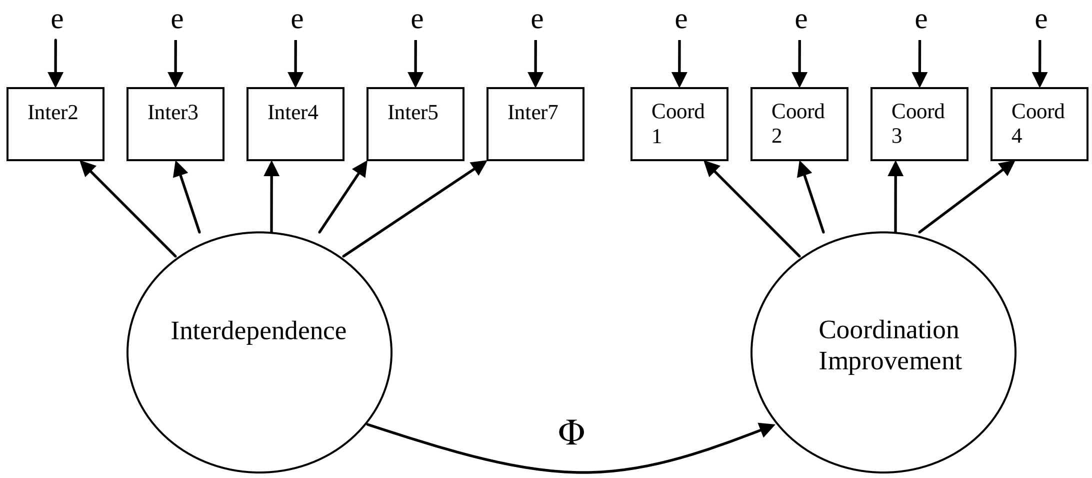
Convergent validity refers to whether two methods of measuring the same phenomenon agree with one another (Bagozzi, 1980). In our practitioner interviews we compared practitioner responses to the prototype questionnaire to their verbal descriptions. This provides limited subjective evidence of convergent validity (i.e. the scale items and the unstructured verbal descriptions generally were consistent with one another).



Model	Model Fit		Sig of A-H
	chi^2	d.f.	
Alternate (Φ fixed at 1)	148.6	44	
Hypothesized (Φ free)	100.2	43	
A-H	48.4	1	*p*<.001

Figure 3. Example of chi square difference test of discriminant validity

4.4 Tests of hypotheses

Table 8 displays the descriptive statistics for each construct.

Table 8. Descriptive statistics (1=strongly disagree; 7=strongly agree)

Variable Name	**Mean**	**Standard Dev.**	**Minimum**	**Maximum**
Overall plant level ERP impact	4.8	1.4	1.0	7.0
Coordination Improvements	5.4	1.1	1.8	7.0
Interdependence	5.7	1.0	2.0	7.0
Time since ERP Implementation (months)	30.0	16.2	12	72

To test the hypotheses, we created a variable for each construct by averaging the indicators for that construct. (Due to our sample size, we elected not to use structural equation modeling (e.g. LISREL)

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to test the whole model). We evaluated the hypotheses using two multiple regression models—one for each outcome variable (using SAS 8.0 PROC REG). The results appear in tables 9 and 10.

Table 9. Regression results for hypothesis one (n=107)

Outcome Variable	Signif. of regression model (*p*)	Adjusted R^2	Independent Variable	Std. Regression Coef.	Signif. of Coef (*p*)
Overall plant level ERP impact	<.0001	.38	Coordination improvement **(h1)**	.63	<.0001

Table 10. Regression results for hypotheses two and three (n=107)

Outcome Variable	Signif. of regression model (*p*)	Adjusted R^2	Independent Variable	Std. Regression Coef.	Signif. of Coef (*p*)
Coordination Improvement	<.0001	.25	Interdependence **(h2)**	.51	<.0001
			Time elapsed **(h3)**	-.02	n.s.

4.5 Discussion of results

H1 posited that the overall ERP impact on the plant would be influenced by ERP-driven improvement in manufacturing-marketing coordination. As the significant regression coefficient in table 9 indicates, the data support H1. H2 stated that manufacturing-marketing coordination improvement is positively influenced by manufacturing-marketing interdependence. Table 10 indicates that the data support this hypothesis. Finally, H3 stated coordination improvements would increase with the time elapsed since ERP implementation in the plant. Table 10 indicates that the data do not support this hypothesis.

4.6 *Post Hoc* Exploratory analysis

The finding that coordination improvements do not improve with time in our data was unexpected. Since a number of case study and prescriptive articles have stated that ERP performance improves with time, confirming this with cross-sectional data is an important undertaking. In order to explore this further, we investigated the possibility of non-linear effects of time by adding a quadratic term to the model for coordination improvements. However, this term did not even approach significance. We also examined the residuals of regressing coordination improvements on time, but no pattern emerged. Finally we added time to the regression for overall impact; however it was insignificant.

However, since we collected data on several other intermediate variables besides coordination improvements, we were able to do some additional investigation by checking the correlations of time with these variables. *Task Efficiency* is the degree to which ERP makes business processes in the plant more efficient (e.g. the ERP system saves supervisory and planning and control employees time). *Data quality* is the accuracy and relevance of the information provided by the ERP system. Task efficiency is fairly highly correlated with elapsed time (r=.26, p<.01), however data quality (along with coordination improvement) is not (r=-.05, $p>.10$). This makes sense. Task efficiency is the most likely to be subject to learning effects. As time elapses we would expect employees to learn how to best utilize the system's new capabilities. On the other hand, messy data is something that most companies clean up as ERP is implemented or very soon after it goes live (Vosburg and Kumar, 2001), especially since early problems resulting from not doing so were well publicized (e.g. Deutsch, 1998). Therefore we would not see data quality continuing to change systematically as years pass with ERP in place. Similarly, the results from H2 suggest that coordination improvements are a function of opportunities provided (or not provided) by organizational structure, which we would not expect to see change systematically across companies through time. In sum, the exploratory analysis suggests that time is an important antecedent of some ERP outcomes, as asserted by other papers; but, the results also suggest time is not a predictor of all outcomes.

It is also likely that the survey would have benefited from a more nuanced measure of the time variable. The survey (appendix) asked respondents how many months had elapsed since ERP had gone live at their plant. However, some organizations implement ERP on a module-by-module basis. Therefore, it is possible that in some plants ERP "went live" with a module such as accounting, but not the manufacturing and marketing modules. For these plants, the "time since ERP has gone live" is not an accurate representation of how long the manufacturing and marketing modules had been live. Future research interested in the time variable should probably collect data on how long each individual module (rather than ERP as a whole) has been running. The fact that we did not do this limits our work.

5. Implications, limitations and future research

5.1 Implications for academe

5.1.1 Manufacturing-marketing interface

The manufacturing-marketing (MM) interface has received substantial consideration in the literature; however, compared to other means of coordination, relatively little attention has been paid to the role of *information systems* in facilitating the MM interface. This study finds that ERP's overall plant level impact is neutral to positive (μ= 4.8 on 7-point scale, table 8 above). More significantly, the study finds that improvements in coordination between marketing and manufacturing are an important antecedent of this overall plant-level impact (standardized β = .63, table 9). In other words, ERP's facilitation of MM coordination does indeed account for an important part of ERP's favorable impact on manufacturing. In fact, MM coordination improvements explain 38 percent of the plant-to plant-variation in overall impact in this study (adjusted R^2, table 9).

Much of the empirical MM interface literature suggests that the greater the uncertainty, the greater the value of MM integration. These results extend this finding to IT-enabled MM integration in particular: Interdependence among subunits is an important source of uncertainty (Tushman and Nadler, 1978). Interdependence explains approximately 25 percent of the variation in coordination improvements. There is a direct pathway from MM interdependence to ERP-enabled MM coordination improvements (standardized β = .51, table 10) and from these coordination improvements to overall plant level ERP impact (standardized β = .63, table 9).

5.1.2 Information processing theory

Based on the work of Galbraith (1973; 1974; 1977) and Tushman and Nadler (1978), this paper posited that interdependence among subunits is an important potential source of uncertainty. Thus, the greater the interdependence between marketing and operations, the greater the benefit of a highly integrative coordination mechanism such as ERP. The results of this study support this notion.

5.3 Implications for practice: understanding pathways to ERP benefits

The introduction of this paper stated that, in response to a variety of pressures, managers need to know what to integrate and how to integrate. Statements from the IT vendor and consulting community suggest great faith in the notion that greater information systems-enabled integration yields greater

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business benefits. For example, a white paper provided by Microsoft Business Solutions (Industry Directions, 2003) states:

> Real-time integrated systems streamline processes, transactions, communication and reporting across the organization and out to trading partners. These directly improve employee and operating efficiencies and effectiveness, driving up overall corporate productivity potential for years to come.

Based on this logic, more and more integration everywhere in the business might seem like a logical objective. For example, an SAP white paper (SAP, 2003) states:

> Adaptive manufacturing must be managed as an end-to-end, closed loop process with tight linkages between the manufacturing applications [and] other adjacent enterprise applications….

Indeed ERP-driven integration among business functions has had a positive effect on the average business. However, it is also important to note (as managers are certainly aware) that results vary from company to company—and across business functions and plants within companies. When ERP yields less than is expected in a plant or location, typical attributions include employee resistance to change, unrealistic promises by vendors, and so on.

However, this paper suggests another explanation: Simply put, integrated information systems will not have equal payoffs under all conditions. Interdependence is one condition that appears to influence payoffs. Rather than accepting generalizations about the benefits of information technology, operations decision-makers must think logically about the pathways by which the benefits will accrue in their particular organizations.

5.4 Limitations and future research

The unit of analysis in this paper is the manufacturing plant. We focused on the individual plant because of our interest in *how* the impacts of ERP occur. According to Barua et al., answering this question requires focusing at the operations level. In most manufacturing organizations, most operations occur in the plants. The plant level impact essentially "add up" to the company level impact. Because the manufacturing strategy (Skinner 1974) and ERP literature (Gattiker and Goodhue 2004) suggest that ERP may affect different plants within a company differently due to plant specific factors (such as plant-to-plant differences in manufacturing volume, levels of customization and so on), focusing only at the firm level may obscure some variables that contribute to ERP's success or failure. Therefore, our plant-level focus—while certainly not capturing the whole picture—provides a compliment to the many excellent firm-level studies in the extant ERP literature.

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The scope of this paper is fairly limited. Thus the study differs from many earlier papers (on MRP and ERP) which comprehensively examine a great number of potential antecedents to success. Although quite high already, the explained variance in this paper would no doubt be higher if a comprehensive approach were employed. However, this project's objective was to explore one theoretical construct—interdependence—with respect ERP's role in the manufacturing-marketing interface. Because the importance of interdependence in a number of organizational theories, including ITP, and because of the importance of manufacturing-marketing coordination, "going deeper rather than broader" seems justified. Indeed, our rather parsimonious model explains a substantial amount of the plant to plant variation in ERP impact.

This study analyzes the impact of ERP-driven cross functional integration in manufacturing from the perspective of the manufacturing plant. Conducting a similar study using marketing sub-units as units of analysis would be a worthwhile endeavor. Technologies such as SAP Netweaver (SAP, 2004) are allowing closer integration with suppliers and customers. Extending the research model to the external supply chain is a future agenda item.

The goal of this paper was to determine whether certain theoretically-predicted relationships exist in the real world. This required collecting data from real plants either through a survey (our approach) or from archival databases. In either case, a weakness of collecting data from real settings is the lack of control (McGrath, 1982). In other words, we cannot rule out the possibility that non-ERP-related company actions or other phenomena influenced our dependent and independent variables and thus caused us to incorrectly assess the impact of ERP.

6. Conclusion

Whybark (1994, p. 50) concluded, "There is not a sufficient understanding of what mechanisms for coordinating sales, marketing and manufacturing currently exist and how they are used. A study that would identify the mechanisms being used today and the conditions under which they were successful would be of great value." Using Information Processing Theory, this study investigates one coordination mechanism—ERP—and finds that the degree to which plant achieves benefits from the mechanism is affected by interdependence-related uncertainty. This finding is consistent with other manufacturing-marketing interface research, which generally finds that the value of MM integration is affected by

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uncertainty. It is also consistent with other IPT research. Thus the paper advances both of these bodies of knowledge.

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Appendix: Questionnaire items

Overall business impact of ERP on the plant	
impact1	In terms of its business impacts on the plant, the ERP system has been a success
impact2	ERP has seriously improved this plant's overall business performance
impact3 R	From the perspective of this plant, the costs of ERP outweigh the benefits (Item deleted due to discriminant validity problems)
impact4	ERP has had a significant positive effect on this plant
Interdependence uncertainty	
Inter1	To be successful, this plant must be in constant contact with sales and distribution (Item deleted due to discriminant validity problems)
Inter2	If this plant's communication links to sales and distribution were disrupted things would quickly get very difficult.
Inter3	Frequent information exchanges with sales and distribution are essential for this plant to do its job
inter4	Close coordination with sales and distribution is essential for this plant to successfully do its job
inter5	Information provided by sales and distribution is critical to the performance of this plant (based on Wybo and Goodhue 1995) (Wybo and Goodhue, 1995)
Inter6 R	This plant works independently of sales and distribution (Item deleted due to discriminant validity problems)
Inter7	The actions or decisions of sales and distribution have important implications for the operations of this plant (based on Wybo and Goodhue 1995)
Improvements in coordination	
Coord1	ERP helps this plant adjust to changing conditions within sales and distribution
Coord2	ERP has improved this plant's coordination with sales and distribution
Coord3	ERP makes this plant aware of important information from sales and distribution
Coord4	ERP helps this plant synchronize with sales and distribution
Time elapsed since ERP implementation	
	How long (in months) has ERP been running live at your plant? _____