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The Performance Effects of Complementarities Between Information Systems, Marketing, Manufacturing, and Supply Chain Processes

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Manufacturing firms are increasingly using advanced enterprise-level information systems to coordinate and synchronize externally oriented functions such as marketing and supply chain and internally oriented activities such as manufacturing. In this paper, we present a model of manufacturing performance that simultaneously considers the effects of a firm's integrated IS capability in conjunction with interfunctional and interorganizational coordination mechanisms. Consistent with the complementarity perspective, we view this specific form of IS capability as enhancing manufacturing's coordination with marketing and supply chain functions to drive manufacturing performance. Additionally, the theoretical model presented here introduces manufacturing-IS coordination, a form of coordination not considered in past research, as a key antecedent to integrated IS capability. The research thus provides a comprehensive framework for examining manufacturing performance in contexts that have been transformed by the use of advanced information systems. The theoretical model is tested using primary data collected from manufacturing firms and matched with objective manufacturing performance data from secondary sources. Results show that a firm's integrated IS capability, as well as the complementary effects of IS capability with manufacturing, marketing, and supply chain processes, are significant predictors of manufacturing performance. These findings are robust to concerns of endogeneity, unobserved heterogeneity, and alternative model specification.

Key words: manufacturing performance; coordination; integrated information systems; marketing and supply chain

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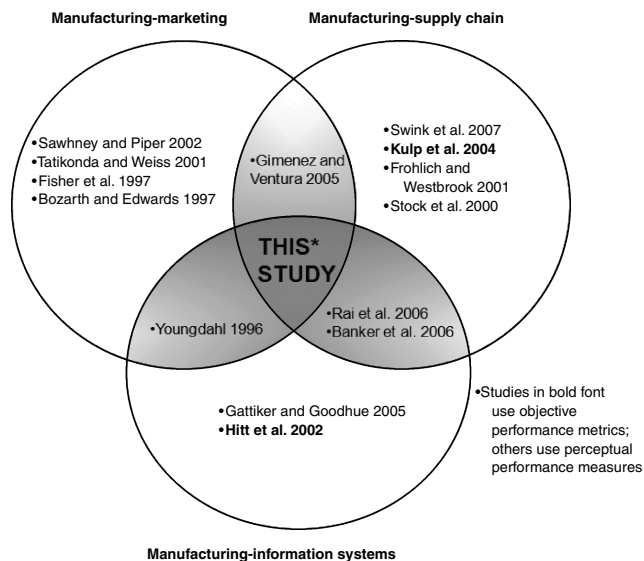
Introduction

The importance of intra- and interorganizational coordination in achieving superior manufacturing performance has been well established. For example, tighter coordination between the manufacturing and marketing functions and between manufacturing and supply chain partners has been shown to have a positive impact on several aspects of manufacturing performance, including cycle time reduction, on-time delivery, and new product development (e.g., Cheung and Lee 2002; Kulp et al. 2004; Hausman et al. 2002; Lee et al. 1997a, b; Montoya-Weiss and Calantone 1994; Sawhney and Piper 2002; Tatikonda and Montoya-Weiss 2001). Advances in information technology (IT) capabilities have also greatly altered the landscape within which such coordination processes occur (Lee et al. 1997a, b; Cotteleer and Bendoly 2006).

Increasingly, manufacturing firms are relying on integrated enterprise-wide information systems (e.g., resource-planning systems) for enhancing operating performance through improved information access and coordination across the various production and distribution stages (Markus et al. 2000, Davenport 2000, Banker et al. 2006, Gattiker and Goodhue 2005). An emerging recognition is that IT has become a critical enabler of business performance, and has led to calls for more systematic research that examines the interactions between a firm's information systems and other drivers of performance (Banker and Kauffman 2004, Steckel et al. 2004).

As shown in Figure 1, prior literature on coordination and manufacturing performance has primarily focused on the coordination between the manufacturing and marketing functions of the focal firm

Figure 1 Illustrative Empirical Studies in Manufacturing Performance



(Montoya-Weiss and Calantone 1994, Sawhney and Piper 2002, Tatikonda and Montoya-Weiss 2001) as well as the coordination between the focal firm's manufacturing function and its supply chain partners (Kulp et al. 2004, Frohlich and Westbrook 2001). Some recent empirical studies have also focused on a firm's information systems capability and its integration with supply chain capabilities (Banker et al. 2006, Rai et al. 2006). However, the increased role of IT in manufacturing performance, introduces a new dimension of interfunctional coordination that has hitherto not been considered, namely, between information systems (IS) and manufacturing functions. Dynamically changing business needs require manufacturing and IS functions to continually evaluate IT's support of business goals and develop new capabilities to support these goals (Stratman and Roth 2002, Segars et al. 1998). Additionally, the relative complexities of contemporary information systems require a level of training and support that extend much beyond the installation phase. Ongoing support and refinement of information systems are preconditions for effective use and require a high degree of coordination between the manufacturing and IS functions (Bancroft et al. 1998, Davenport 1998, Ettlie 1998).

In this paper we develop an integrative model of manufacturing performance that simultaneously considers the effects of *manufacturing-marketing* (Mfr-Mkt),

manufacturing-supply chain (Mfr-SC), and *manufacturing-IS* (Mfr-IS) coordination. In line with prior literature, we posit that manufacturing's coordination with marketing and supply-chain partners will directly influence manufacturing performance. Closer collaborations between the IS and manufacturing functions is expected to improve the firm's ability to provide integrated and consistent access to relevant information and to connect seamlessly with the firm's customers and supply chain partners. Our model therefore considers the effects of *integrated IS capability*, and consistent with the complementarity perspective espoused in the IS literature (Barua et al. 1996, Brynjolfsson et al. 1998), we propose that integrated IS capability will not only have a direct effect on manufacturing performance, but that it also acts as an enabler and complements the effects of the Mfr-Mkt and Mfr-SC coordination processes on performance.

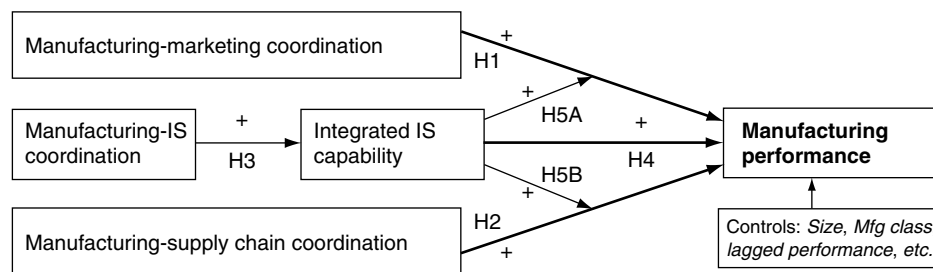
The model is tested using data collected from a national survey of manufacturers and archival manufacturing performance data from COMPUSTAT. Results from our study show that superior coordination between the manufacturing and IS functions leads to superior integrated IS capability, which in turn not only impacts manufacturing performance directly, but also plays a catalytic role in enhancing the positive effects of Mfr-Mkt and Mfr-SC coordination on manufacturing performance.

The rest of the paper is organized as follows. In the next section, we develop the research model and key hypotheses. Next, we describe the survey measures and data collection, followed by the empirical analysis and results. Finally, we conclude the paper with a discussion of implications for research and practice, as well as directions for future work.

Conceptual Framework

In developing our conceptual framework we integrate perspectives from the theories of coordination (cf. Malone and Crowston 1994) and complementarity (cf. Milgrom and Roberts 1995). A substantial body of work in organization theory emphasizes the importance of interdependencies (e.g. Galbraith 1977, Lawrence and Lorsch 1967, Pfeffer 1978), and coordination has been defined as *managing the dependencies among activities* (Malone and Crowston 1994). Organizational interdependencies arise due to a number of

Figure 2 Research Model



factors such as shared resources, access to information, and specialization of knowledge and expertise. Whang (1995) develops taxonomy of coordination in manufacturing operations and identifies three types of coordination: (a) coordination within operations, such as when manufacturing plants coordinate production activities, (b) cross-functional coordination, such as between manufacturing and marketing, and (c) interorganizational coordination, such as that with supply chain partners. Our focus in this paper is on firm-level manufacturing performance, and therefore with manufacturing as the focal function, we examine the key cross-functional and interorganizational coordination between manufacturing and other units. Specifically, we identify three major coordination-related antecedents to manufacturing performance: (a) manufacturing's coordination with marketing; (b) manufacturing's coordination with supply-chain partners;¹ and (c) manufacturing's coordination with IS. Whereas Mfr-Mkt and Mfr-SC coordination are expected to impact manufacturing performance directly, Mfr-IS coordination is posited to impact the firm's integrated IS capability.

Complementarity theory suggests that the value of an organizational resource can increase in the presence of other complementary resources (Milgrom and Roberts 1995). Because manufacturing-marketing interactions and boundary-spanning collaborations with supply chain partners are increasingly enabled through the use of information systems, we posit that the firm's integrated IS capability will be complementary to these coordination processes and thus accentuate the positive effects of Mfr-Mkt and Mfr-SC coordination on manufacturing performance.

¹ We use the term supply chain to include a firm's suppliers as well as its customers.

Prior research has emphasized the importance of measuring manufacturing performance along different dimensions (e.g., cost, speed, quality, productivity, etc.) due to the existence of important trade-offs between improvements in these measures (Banker et al. 2006, Miller and Roth 1994). We therefore conceptualize manufacturing performance as a composite construct made up of several performance indicators. In the following subsections, we develop the study's main hypotheses flowing from the conceptual model depicted in Figure 2.

Manufacturing-Marketing Coordination

Interactions between manufacturing and marketing units have received considerable attention in recent years (for contemporary reviews, see Parente 1998, Malhotra and Sharma 2002). In a global marketplace characterized by hypercompetition and rapidly shortening product life cycles the need for greater interaction and coordination between manufacturing and marketing functions has been repeatedly emphasized (e.g., Hauser and Clausing 1998, Hausman et al. 2002, Moorman 1995). Conversely, it has also been suggested that a lack of coordination between the two functions leads to a mismatch in demand and supply, and then, consequently, to manufacturing inefficiency and spectacular business failures (Fisher et al. 1997, Ho and Tang 2004).

We define manufacturing-marketing coordination as the extent to which the manufacturing and marketing functions develop a mutual understanding of each other's capabilities and align their respective goals and activities based on such understanding. Close alignment between the two functions is expected to have a positive impact on manufacturing performance because it leads to: (a) reduced task uncertainty for both functions (Galbraith 1977, Sethi

2000) (b) greater understanding by marketing of manufacturing's constraints, objectives, and motivations (Hausman et al. 2002); (c) greater understanding by manufacturing of customer preferences, marketing promotional plans, and competitive activity (Kohli and Jaworski 1990); (d) anticipation, mitigation, and elimination of potentially dysfunctional problems that undermine manufacturing efficiency (Lee et al. 1997a, b; Sethi 2000; Tatikonda and Montoya-Weiss 2001); and (e) closer alignment of objectives of both functional areas (Crittenden 1992, Shapiro 1977). The impact of these various issues is fairly well established in the operations literature. Joint planning, reciprocity and trust across these business functions fosters improvements in manufacturing scheduling that can significantly reduce two of the most often-cited costs for operations managers: namely, idle resource (poor productivity and opportunity costs) and inappropriate inventory (costs associated with having the wrong kind of inventory in the wrong place at the wrong time) (Goldratt et al. 2000). High levels of such coordination further allows capabilities and opportunities to be leveraged to these ends in a timely and nondisruptive manner, and hence avoid the kind of schedule "firefighting" that only prolongs or displaces the cost of manufacturing adjustments (Bozarth and Edwards 1997).

HYPOTHESIS 1 (H1). *Coordination between a firm's manufacturing and marketing functions will be positively associated with manufacturing performance.*

Manufacturing-Supply Chain Coordination

In recent years, many manufacturing firms have adopted practices that not only promote internal coordination, but also facilitate external coordination with supply chain partners (Kulp et al. 2004, Frohlich and Westbrook 2001). We define manufacturing-SC coordination as the extent to which a firm's manufacturing unit and its supply chain partners develop a mutual understanding of each other's capabilities and align their respective goals and activities based on such understanding. In the supply chain context, coordination can be viewed as having processes in place to ensure that resources and actions are coordinated based on partner inputs, capabilities, economies, and needs. Because of this, greater coordination aids not

just in incidental problem solving, but in the development of problem-solving routines that facilitate tactical flexibility both within and among coordinating firms (Frohlich and Westbrook 2001). Greater coordination and the development of interfirm routines also engender trust, reciprocity, and effective relational governance, and in turn augments manufacturing's extended capabilities and the ability to excel in both resource productivity and inventory efficiency (Dyer and Singh 1998, Swink et al. 2007). An example of such coordination would be the retailer and manufacturer sharing joint responsibility for implementing the initiative of quick customer response. The benefits include greater efficiencies in lead time and inventory management (Clark and McKenney 1994, Kulp et al. 2004, Aviv 2001, Stock et al. 2000). Thus,

HYPOTHESIS 2 (H2). *Coordination between a firm's manufacturing function and its supply chain partners will be positively associated with manufacturing performance.*

Manufacturing-IS Coordination

A long tradition of IS research has maintained that one of the most critical roles of the IS function is ensuring continuous interactions with business users to ensure responsiveness to emerging business needs and opportunities (cf. Clark et al. 1997, Sambamurthy and Zmud 2000). In manufacturing industries, investments in enterprise systems for coordinating and aligning various production functions have become increasingly prevalent (O'Leary 2000). Manufacturers are rapidly replacing older technologies (such as MRP) that provide support for discrete production planning and manufacturing tasks with integrated enterprise-wide systems that provide a level of interoperability difficult to achieve with stand-alone systems (Gattiker and Goodhue 2005, O'Leary 2000). However, a key challenge lies in making the information from these systems truly available—not only from a technological feasibility standpoint but also from that of user efficacy. Research dealing with user perceptions during IS implementation shows that critical obstacles, especially those concerning inaccurate configurations, may be related to the nature of the social exchange between manufacturing and IS staff (Gefen and Riddings 2002). The complexity of the business processes involved, the uniqueness of each

company's processes, and the need to adapt existing work processes require ongoing and continuous interactions between manufacturing and IS staff (McKinley 2000). Prior research also shows that the nature of such interactions during and after implementation influences user assessments of the system and ultimately their ability to effectively use it (Gefen and Riddings 2002). Robey et al. (2002) argue that successful implementation of complex information systems (such as ERP) is contingent on effective interactions between IS and other functional areas. For example, ERP software allows customization only through "built-in tables," which serve as pre-designed templates, and need to be reconfigured to reflect the firm's business rules. This is usually a formidable task that end users can seldom accomplish without significant help from trained IS staff. Closer linkages with the IS function allow manufacturing to reconfigure the system so as to provide up-to-date information and ensure that the information system capabilities are aligned with manufacturing needs.² Therefore,

HYPOTHESIS 3 (H3). Coordination between a firm's manufacturing and IS functions will be positively associated with integrated IS capability.

Integrated IS Capability

Many organizations lack the system-level integration necessary to access information easily and coordinate work processes (Frie et al. 1999). Integrated IS capability, in the manufacturing context, refers to the degree to which the focal firm's information systems provide integrated data and process integration. Manufacturers with integrated IS capabilities can provide seamless and consistent access and visibility to relevant customer, production, order, and market data and can facilitate process integration with supply chain partners. The functionality provided by an integrated information system is specifically intended to link business processes together to improve visibility and information flow (McAfee 2002). For example,

the entry of a new customer order can immediately flow through the entire system and trigger the necessary changes in production plans, inventory stock levels, employee schedules, and can even lead to the automated generation of invoices, credit evaluations for customers, and purchase orders for suppliers. In addition to process automation and visibility, which reduce errors and delays associated with manual processes, integrated information systems for manufacturing enable improved decision making as well as improved interactions with supply chain partners (Hitt et al. 2002). Such improvements accrue as a result of improved information flow, standardization and integration of activities, and centralization of administrative services, thereby leading to fewer delays and errors in order processing as well as to adoption of accepted best-of-practice business processes that replace inefficient processes (Gattiker and Goodhue 2005). Conversely, in firms stymied by a lack of integrated information systems, there is a corresponding inability to support coordinated activities with other functional areas and partners, thereby leading to ineffective decisions and poor overall performance. Therefore,

HYPOTHESIS 4 (H4). Integrated IS capability will be positively associated with manufacturing performance.

Complementary Effects of Integrated IS Capability

In addition to the independent effects of manufacturing-marketing coordination, manufacturing-SC coordination, and integrated IS capability on manufacturing performance, there are likely to be interaction effects as well. The use of information systems to support and enhance coordination processes can be theoretically linked to the notion of *complementarities*, or the idea that "doing more of one thing increases the returns to do more of another" (Milgrom and Roberts 1995, p. 181). Increasingly, scholars are beginning to view information systems as complementary resources that enhance the value of other organizational resources and capabilities (Brynjolfsson and Hitt 2000, Barua et al. 2001, Tippins and Sohi 2003, Tanriverdi and Ruefli 2006). Mfr-Mkt and Mfr-Sc coordination represents an alignment of goals and behaviors contingent on mutual understanding, trust, and partnership. Although non IT-based coordination mechanisms such as team meetings and face-to-face

² We recognize that firms might have different coordination structures in place to achieve manufacturing-IS coordination, including highly distributed arrangements where the IS staff may be embedded within the manufacturing function. Although the study of coordination structures is beyond the scope of this paper, we are grateful to an anonymous reviewer for this important observation.

communication can be used, integrated information systems greatly facilitate interfunctional exchanges and promote joint understanding. Whereas the direct effects of an integrated IS capability enable managers to search for, retrieve, analyze, and store real-time data, the built-in communication capabilities of these systems (e.g., built-in e-mail and conferencing capabilities) serve as complementary functionality that enables richer forms of asynchronous and geographically dispersed communication sustained over longer periods of the day (Hinds and Keisler 2002). For example, Mfr-Mkt coordination requires the two functional groups to actively exchange information about market demands, customer needs, and manufacturing plans for joint planning and alignment of goals. An integrated information system greatly facilitates these interactions and effectively complements other traditional interpersonal exchanges. Further, the systems impose a standard grammar for communication that limits the need for other governance mechanisms to ensure that coordination goals are being met (Argyres 1999). Because information exchanged via the system can be traced back to the provider (e.g., e-mail history), it leaves the provider vulnerable to repercussions if the information is perceived as inadequate, irrelevant, or wrong. Under these circumstances, the receiver of the information also has the incentive to use the information, because nonuse of the information is verifiable, and managers are more easily held responsible for either inaction or actions taken that are contrary to the information provided (Maltz and Kohli 1996). Thus, marketing and manufacturing managers, as senders and receivers of market and production related have greater incentives to provide and access accurate and timely information. The information transparency enabled by these systems not only serve as built-in governance mechanisms, but also facilitate marketing and manufacturing personnel to make decisions based on accurate expectations about each others' plans and to provide timely and relevant information to each other, thereby promoting greater convergence to strategic plans. The use of an integrated information system for coordination can therefore be interpreted as a set of routines around which these managers synchronize their activities (Schelling 1978).

In contrast, in firms with disparate or nonintegrated systems the system features do not naturally promote information exchange and coordination capabilities across business functions. By failing to provide such features as automatic updates of data records through systemwide triggers, a single point for data entry, a consistent view of the data, and facilities for quickly reporting and sharing relevant information across functional boundaries, these systems are more likely to hamper or render ineffective other marketing-manufacturing coordination mechanisms that are put in place. Therefore,

HYPOTHESIS 5A (H5A). *The relationship between manufacturing-marketing coordination and manufacturing performance is moderated by integrated IS capability: the greater the integrated IS capability, the stronger the positive association between Mfr-Mkt coordination and manufacturing performance.*

The complementary effects of integrated information systems are also anticipated with respect to inter-organizational coordination between manufacturing and supply chain partners. Connectivity throughout the supply chain enables each member of the chain to identify and respond more effectively to dynamic customer needs and facilitates coordinated responses (Ettlie 1995, Rai et al. 2006, Ross 2002). This allows firms to synchronize their manufacturing activities and to build greater commitment to joint plans (Kulp et al. 2004). Therefore,

HYPOTHESIS 5B (H5B). *The relationship between manufacturing-SC coordination and manufacturing performance is moderated by integrated IS capability: the greater the integrated IS capability, the stronger the positive association between Mfr-SC coordination and manufacturing performance.*

Research Design

Sample

Production and inventory managers (PIMs) from an e-mail contact list provided by APICS (American Production and Inventory Control Society) Education and Research Foundation served as key informants for this study. This process provided a list of valid e-mail addresses for 1,023 PIMs representing 386 unique manufacturing firms. The initial e-mail

explained the importance of their participation and promised them a summary of the research findings as well as a comparison of their firm with other firms in their industry. Two follow-up e-mails were sent, spaced a week apart. Complete responses were received from 169 firms, and the response rate was 43.8% of all firms contacted. The sample consisted of a set of firms with a median of \$1.76 billion in annual sales and 7,800 employees. Industry representation in the final sample consisted of approximately 14% in chemicals and pharmaceuticals, 23% in industrial equipment, 20% in electronics, 10% in instruments, and the remainder in miscellaneous industries such as metals, textiles, and furniture. Secondary data on performance and other relevant control variables was available from COMPUSTAT for 126 firms, and consequently this served as the effective sample size for subsequent analysis. Comparisons of the responding and nonresponding firms with regard to size (sales and number of employees) as well as industry representation (four-digit SIC codes) showed no significant differences, indicating that responses were representative of the original sample.

Two additional checks for nonresponse bias were also performed. First, incomplete surveys were compared to complete surveys. A second check compared late respondents (after the second follow-up e-mail was sent) with early respondents (after the initial mailing). No systematic differences were identified in either check, suggesting the absence of response bias.

Scale Development

Existing scales were either adapted to fit the study context or new scales were developed based on relevant literature. The preliminary survey instrument was pretested in two phases: (1) telephone interviews with a convenience sample of members from a local chapter of APICS and (2) through an initial pilot study of PIM participants from an e-mail list service hosted by APICS. Two hundred forty-three active participants (as measured by the number of messages each posted over a 12-month period), were contacted via e-mail, and 79 of them provided complete responses to the pilot version of the survey. In the first phase, participants were requested to identify items that were confusing, to assess the language used, and to evaluate in general the face validity of

the items used to measure the constructs. The pilot pretest survey data was then used to examine the psychometric qualities of the refined scales. An analysis of these 79 responses using exploratory factor analysis and tests of reliability indicated that the scales performed adequately.

The manufacturing-marketing coordination scale was developed based on the literature in marketing on the manufacturing-marketing interface (e.g., Gupta et al. 1986; Ayers et al. 1997; Fisher et al. 1997; Maltz and Kohli 1996, 2000). The Mfr-SC coordination scale items were designed to mirror the style of items in the Mfr-Mkt coordination scale, but were modified to reflect coordination with external supply chain partners. The Mfr-IS coordination construct was developed to reflect the interactions between the two groups to ensure mutual understanding of manufacturing requirements and technology capabilities. The items measure the extent to which the IS staff understood manufacturing's requirements, effectively communicated the information system's capabilities to end users, and worked with them to customize the system, design suitable reports, and provide ongoing training (Kettinger and Lee 1995, Pitt et al. 1995). The integrated IS capability construct was contextualized to manufacturing firms and developed based on discussions with production managers. The items tap into the ability of the firm's information systems to provide integrated access to relevant data, including customer-, production-, order-, and market-related data and coordinate its activities with SC partners.

Because manufacturing performance is a multidimensional construct, any single performance metric may not be able to provide a comprehensive understanding of the performance relationship relative to the constructs of interest. We therefore use an industry-adjusted (four-digit SIC industry) composite index made up of multiple manufacturing performance metrics (Lee 1992, Chen et al. 2003, Vastag and Whybark 2005, Montoya-Torres 2006). Following prior research, the objective performance index was composed of operating margins, on-time (backlog) ratios, and inventory turns derived from COMPUSTAT data. The composite manufacturing index demonstrated good reliability (Coefficient – Alpha = 0.76, Composite Reliability = 0.77 and average variance extracted = 0.55), providing support for

Table 1 Common Use of Objective Performance Metrics in Contemporary Literature

Objective metrics	Past use in operational performance research
Inventory turns	David et al. (2002), Ragowsky et al. (2000), Lieberman et al. (1999) Flynn and Flynn (1999), Huson and Nanda (1995), Flynn et al. (1994)
Backorder, out-of-stock, & similar availability measures	Kulp et al. (2004), Schroeder et al. (2002), Cua et al. (2001), Narasimham and Das (2001) Flynn and Flynn (1999)
Operating margins	Jack and Raturi (2003), Schroeder et al. (2002), Cua et al. (2001), Ragowsky et al. (2000) Huson and Nanda (1995), Schmenner and Vollman (1993), Hendricks and Singhal (2005)

the use of a composite measure. Table 1 provides an abbreviated list of contemporary manufacturing research studies that have made use of these items.

Our specific indexing approach involved standardizing each set of industry-scaled measures across our respondents and then constructing an average of these standardized items for each respondent (cf. Schroeder et al. 2002). Appendix A lists the final measurement scales. Other additional controls, that were added to account for heterogeneity in the data, include an index of JIT activity, firm size (measured as log of sales), and manufacturing process dummy variables (cf. Fullerton and McWatters 2001, Benton and Shin 1998).

The manufacturing process dummy variable classifications were based on the Hayes and Wheelwright product-process matrix (eg. Hayes et al. 2005, p. 48) and the dominant processes characterizing the firms in the sample as: (a) highly standardized continuous-flow manufacturing, (b) high-volume mass production, (c) midvolume assembly line, (d) midvolume disconnected line and batch production, or (e) specialized, low-volume job shops (the last category serving as a baseline). Thus, distinctions relating to industry standards regarding SC-relationships, technology, and outcomes are adequately accounted for by industry scaling and by the inclusion of various control measures. Finally, to serve as a proxy for other omitted unobservables, we include a one-year lagged performance measure for the objective manufacturing performance model.

Scale Validation

Confirmatory factor analysis techniques (CFA) were used to estimate the measurement models. Overall, the measurement model of all four multi-item perceptual constructs showed acceptable fit level as judged by goodness-of-fit indicators (TLI = 0.98, CFI = 0.98, RMSEA = 0.05), and only 4.3% of the items (as opposed to 5% by chance alone) had significant cross loadings. A separate CFA of the four individual constructs also provided evidence of convergent validity (minimum TLI = 0.98; minimum CFI = 0.99, and maximum RMSEA = 0.04). Moreover, average variance extracted (AVE) for each construct was greater than 0.50, and the square root of the AVE was greater than the correlations among the constructs demonstrating discriminant validity (Fornell and Larcker 1981). Convergent validity was supported by all the item loadings on respective constructs being statistically significant (minimum $t = 5.85$, $p < 0.05$). Scale evaluation yielded positive results with composite reliability estimates for all constructs being greater than 0.70 and averaging 0.92 (see Table 2).

Although the utilization of multiple informants has been repeatedly recommended (Phillips 1981, John and Reve 1982), the use of multiple informant designs remains an exception. The availability of multiple complete responses representing individual firms provided the opportunity to test the reliability of views provided by the managers surveyed. Fifty-four of the 126 single-business firms in the final sample had complete responses provided by at least two separate PIMs. These 54 firms formed the basis for a subsample examination of interrater reliability.

Because aggregating responses across multiple informants is predicated on demonstrating perceptual agreement among the informants, we calculated an index of interrater agreement that demonstrates this shared assignment of psychological meaning among multiple informants of a firm³ (James et al. 1984, 1993). For all seven scales, the interrater agreement values were acceptable and ranged from 0.41 to 0.79.

³ Interrater reliability ($\gamma_{WG(I)}$) is calculated as $J[1 - (S_{xj}^2/\sigma_{Eu}^2)] / \{J[1 - (S_{xj}^2/\sigma_{Eu}^2)] + (S_{xj}^2/\sigma_{Eu}^2)\}$ where J = Number of items reflecting the construct, S_{xj}^2 = the mean of observed variances on the J items, and $\sigma_{Eu}^2 = (A^2 - 1)/12$ and refers to the expected error variance, and “ A ” corresponds to the number of alternatives in the response scale X_j .

Table 2 Descriptive Statistics, Composite Reliabilities, Model Fit and Correlations

Variables	Mean (S.D.)	Model fit	1	2	3	4	5	6	7	8	9	10	11
1. Objective manufacturing performance	4.06 (6.11)	NA	0.55 0.77										
2. Manufacturing-IS coordination	2.93 (1.34)	$\chi^2 = 0.026$ ($p = 0.09$, $df = 5$), TLI = 0.99, CFI = 0.99, RMSEA = 0.01	0.003	0.82 0.96									
3. Manufacturing-marketing coordination	4.50 (0.84)	$\chi^2 = 6.62$ ($p = 0.36$, $df = 9$), TLI = 0.99, CFI = 0.99, RMSEA = 0.02	0.03	0.15	0.66 0.92								
4. Manufacturing-SC coordination	3.63 (1.15)	$\chi^2 = 7.72$ ($p = 0.10$, $df = 9$), TLI = 0.99, CFI = 0.99, RMSEA = 0.015	0.04	0.08	0.002	0.52 0.84							
5. Integrated IS capability	3.27 (1.04)	$\chi^2 = 1.03$ ($p = 0.39$, $df = 9$), TLI = 0.99, CFI = 0.98, RMSEA = 0.01	0.09	0.28	0.22	0.15	0.61 0.95						
6. JIT	0.54 (0.19)	NA	0.13	−0.03	0.17	−0.02	−0.24	NA					
7. Firm size (Log of sales)	7.70 (1.72)	NA	−0.35	−0.06	0.14	−0.01	−0.07	0.05	NA				
8. Highly standardized/ high-volume continuous- flow dummy	0.16 (0.37)	NA	−0.08	0.09	0.12	0.003	−0.06	−0.20	0.15	NA			
9. High-volume/mass production dummy	0.17 (0.37)	NA	−0.03	0.01	−0.23	−0.03	0.03	−0.001	0.04	−0.02	NA		
10. Midvolume assembly line dummy	0.19 (0.39)	NA	−0.05	0.17	0.03	−0.12	−0.003	0.13	0.02	−0.04	−0.05	NA	
11. Midvolume discontinuous line/batch dummy	0.31 (0.47)	NA	−0.12	−0.03	0.04	0.25	−0.10	0.07	−0.14	−0.15	−0.16	−0.19	NA

Notes. All correlations greater than 0.15 are significant at 0.05. Numbers on diagonal are average variance extracted and composite reliabilities (Fornell and Larcker 1981).

Additionally, following James et al. (1984), we calculated the intraclass correlation coefficient (ICC2) to assess reliability when perceptions are aggregated. These results, taken together, suggest that the measures consistently tap shared perceptions among firm members rather than merely aggregating radically diverse individual perceptions. The respondents also reported their perceived knowledge of manufacturing activities on a single seven-point Likert scale. This was used to evaluate informant competency (Kumar et al. 1993). Furthermore, the competence assessment also served as a weighting factor in aggregating the multiple responses from a firm, thereby improving the quality of the data utilized in subsequent analysis (Van Bruggen et al. 2002).

Model Estimation and Results

The general system-form of the model used to test the hypotheses was:

Integrated IS Capability

$$= \beta_0 + \beta_{m0}(\text{Manufacturing-IS Coordination}) \quad (1)$$

Manufacturing Performance

$$\begin{aligned}
 &= \beta_1 + \beta_{m1}(\text{Manufacturing-Marketing Coordination}) \\
 &+ \beta_{m2}(\text{Manufacturing-Supply Chain Coordination}) \\
 &+ \beta_{m3}(\text{Integrated IS Capability}) \\
 &+ \beta_{i1}(\text{Integrated IS Capability}) \\
 &* (\text{Manufacturing-Marketing Coordination})
 \end{aligned}$$

$$\begin{aligned}
& + \beta_{i2}(\text{Integrated IS Capability}) \\
& * (\text{Manufacturing-Supply Chain Coordination}) \\
& + \beta_{c1}(\text{JIT}) + \beta_{c2}(\text{Firm Size}) \\
& + \beta_{c3}(\text{HighStdz/vHighVolContFlow Dummy}) \\
& + \beta_{c4}(\text{HighVolMassproduction Dummy}) \\
& + \beta_{c6}(\text{MidVolAssemblyLine Dummy}) \\
& + \beta_{c5}(\text{MidVolDisconLine/Batch Dummy}) \\
& + \beta_{c6}(\text{Lagged Objective Performance}) + e_1 \quad (2)
\end{aligned}$$

Specification and Diagnostics Tests

It is likely that a firm's propensity to coordinate across functions to achieve organizational goals may be endogenously determined. Consequently, failing to account for endogeneity in manufacturing performance could lead to potentially misspecified and biased results (Greene 2003). When panel data is available, the use of instrumental variables is one approach to account for endogeneity. An alternative approach to control for this potential bias is to use the two-step econometric procedure originally described by Heckman (1979) and developed for business research by Shaver (1998). In the first step, we separate our responding firms into two groups: firms with scores above the mean on the sum of the three coordination variables (manufacturing-marketing, manufacturing-IS, and manufacturing-supply chain—i.e., the high-coordination group) coded as one and firms that were below the mean on the sum of the three coordination variables (i.e., the low coordination firms) coded as zero.

Following Shaver (1998), we estimate a probit model using maximum likelihood to assess the effects of environmental dynamism (a proxy for industry environment; items from Fisher et al. 1997), the four industry dummies (serving as proxies for different manufacturing conditions), and firm size, all of which were expected to influence the decision of the firms to coordinate across functions internally and with the supply chain to achieve organizational goals (Banker et al. 2006). Endogeneity is accounted for by creating a control variable "lambda" using estimates obtained from the first stage. Lambda (λ_i), or the "inverse Mill's ratio," is calculated as $\hat{\lambda}_i = \phi(\hat{\gamma}_i w_i) / \Phi(\hat{\gamma}_i w_i)$, where ϕ is the standard normal density function, w_i

and $\hat{\gamma}_i$ are the vector of independent variables and coefficients from the first stage probit model, and Φ is the standard normal distribution function (Greene 2003). In the second step, both IS capability and manufacturing performance are estimated as a function of their appropriate determinants, and via the inclusion of lambda as an additional predictor variable. Because the manufacturing performance model includes the integrated manufacturing-IS construct, which may also be endogenously determined, we use three-stage least-squares analysis for those models because it provides reliable and more efficient estimates of parameters (Kennedy 1998). We first examined whether the analysis met the overidentifying restrictions. The Sargan $N * R^2$ test ($\chi^2_1 = 0.083$, $p = 0.77$), and the Basman test ($\chi^2_1 = 0.07$, $p = 0.78$), indicate a nonrejection of the joint-null hypothesis that equation is overidentified (Baum et al. 2003, Woolridge 2002).

Overall, the manufacturing performance model provided a systemwide R^2 of 0.28, with, more specifically, 39% of variance in the objective performance measure accounted for. While the analysis reported above used a three-stage least-squares approach, we also conducted hierarchical regression analysis to examine whether the incremental variance explained by the interaction effects was significant. The model with the main effects and controls only (the reduced model) explained 23% of the variance, the addition of the interaction terms (full model) explained a significant level of additional variance beyond that explained by the reduced model ($\Delta R^2 = 0.04$, $F_{13,113} = 3.70$, $p < 0.05$).

To test the interaction hypotheses, we followed the standard guidelines for moderated regression analysis suggested in the literature (Cohen et al. 2003, Jaccard et al. 1990). Consequently, to minimize multicollinearity among interaction terms and their component main-effect terms, we first mean-centered all the independent variables involved in creating the interaction terms. The variance inflation factors in all cases were substantially below the critical value of 10, indicating that multicollinearity was not an issue (Neter et al. 1995).

It is important to note here that, in the presence of an interaction term, a mean-centered simple or main effect is interpreted as the effect of a given exogenous predictor when the moderator it interacts with is at

its mean value (Irwin and McClelland 2001). In contrast, in a main-effects-only model of the form $Y = \alpha_0 + \beta_1 X_1 + \beta_2 X_2 + \varepsilon$, the coefficient of X_1 represents the effect of variable X_1 on Y , holding all other variables in the model constant. In fact, main effects in the interaction model can be considered the weighted average effect across all observed values of the other predictors (Cohen et al. 2003). Following this interpretation, we refer to the main effects as centered main effects.

Hypotheses (H1 and H2) relating to the centered main effect of the Mfr-Mkt and Mfr-SC coordination on manufacturing performance were both supported. As proposed, manufacturing-IS coordination revealed a significant positive effect on integrated IS capability (H3). Furthermore, the centered main effect of integrated IS capability on manufacturing performance (H4) was also well supported. In testing the complementary effects, we found that integrated IS capability amplifies the effect of marketing-manufacturing coordination (H5A) as well the effect of manufacturing-supply chain coordination (H5B) on manufacturing performance. In summary, all the hypothesized relationships were statistically significant.

Robustness Checks

We conducted several robustness checks to examine the sensitivity of the results obtained. In order to account for the possibility that random fluctuations or anomalies could influence a single year's performance, we created two-year averages (year t and year $t + 1$ as well as year $t - 1$ and year t) as well as three-year averages (year $t - 1$, t , and $t + 1$) of the objective performance index. The model was reestimated with all three versions of the dependent variables and provided results that were consistent with the results reported in Table 3.

To account for the possibility that the effects of coordination initiatives in year t are realized in year $t + 1$, we reestimated the model with performance in year $t + 1$ as the objective performance measure. Complete data was available for only 90 firms for the period $t + 1$. Although the pattern of results for the model estimated with this dependent variable was similar, the levels of significance were lower for some of the estimated parameters.

Table 3 Three-Stage Least-Squares Regression Results

Predictors	Hypotheses	DV: Integrated IS capability	DV: Objective manufacturing performance index
Intercept		2.44*** (0.39)	12.57** (5.35)
Manufacturing-marketing coordination	H1 (+)		1.48** (0.57)
Manufacturing-supply chain coordination	H2 (+)		0.76* (0.43)
Manufacturing-IS coordination	H3 (+)	0.21*** (0.06)	
Moderator			
Integrated IS capability	H4 (+)		0.94*** (0.46)
Interactions			
Integrated IS capability × Manufacturing-marketing coordination	H5A (+)		1.43** (0.60)
Integrated IS capability × Manufacturing-supply chain coordination	H5B (+)		0.63* (0.33)
Controls			
JIT			4.72 (2.53)
Size of firm (Log of sales)			−0.93** (0.31)
Industry dummy1			−0.06 (1.25)
Industry dummy2			1.65 (1.76)
Industry dummy3			−0.01 (1.33)
Industry dummy4			−2.90* (1.36)
Lagged objective performance index			0.77*** (0.16)
Lambda (inverse mills ratio)		0.25 (0.43)	−7.04 (4.19)
Maximum VIF		1.07	4.33
System R^2			0.28

***Significant at $p \leq 0.001$; **Significant at $p < 0.01$; and *Significant at $p < 0.05$ (directional one-tailed test). All parameter estimates are unstandardized estimates. Numbers within parentheses represent the standard errors.

We also tested for an alternate model specification to determine whether the coordination mechanisms (Mfr-Mkt and Mfr-SC) mediate the impact of Integrated IS capability on manufacturing performance. Although there are no direct comparisons of moderator and mediation models, the overall fit as represented by the system R -squared for the mediation model ($R^2 = 0.20$) was lower than our proposed moderator model (system $R^2 = 0.28$). Furthermore, following Barron and Kenny's (1986) three-step procedure to test for mediation, we did not find a significant relationship between Integrated-IS capability and Mfr-SC coordination, thereby ruling out mediation. Also, the relationship between integrated-IS capability and manufacturing performance is not fully

mediated by the coordination mechanisms. These empirical results, along with our theoretical arguments provided strong support for the moderated model espoused in our study.

Finally, to account for the limitation that all data used to test Hypothesis H3, positing the association between Mfr-IS coordination and integrated IS capability, came from a single respondent, we used the data from a second respondent to test H3 separately. fifty-four of the 126 single-business firms in the final sample had complete responses provided by at least two separate key informants; data from one respondent was used for the independent variables and data from the second respondent for the dependent variable. Because this data set was too small for complete analysis, Hypothesis H3 alone was tested with this data set through simple regression analysis. Again, the results were consistent with the reported results, and support was found for H3.

Supplementary Analyses

We carried out additional analyses to explicate the complementarity effects of integrated IS capability on manufacturing performance. As shown in Figure 3 (panel 1), there is a marked contrast in manufacturing performance achieved with high levels of Mfr-Mkt coordination (one standard deviation above the mean) when integrated IS capability is high (one standard deviation above the mean) than when it is

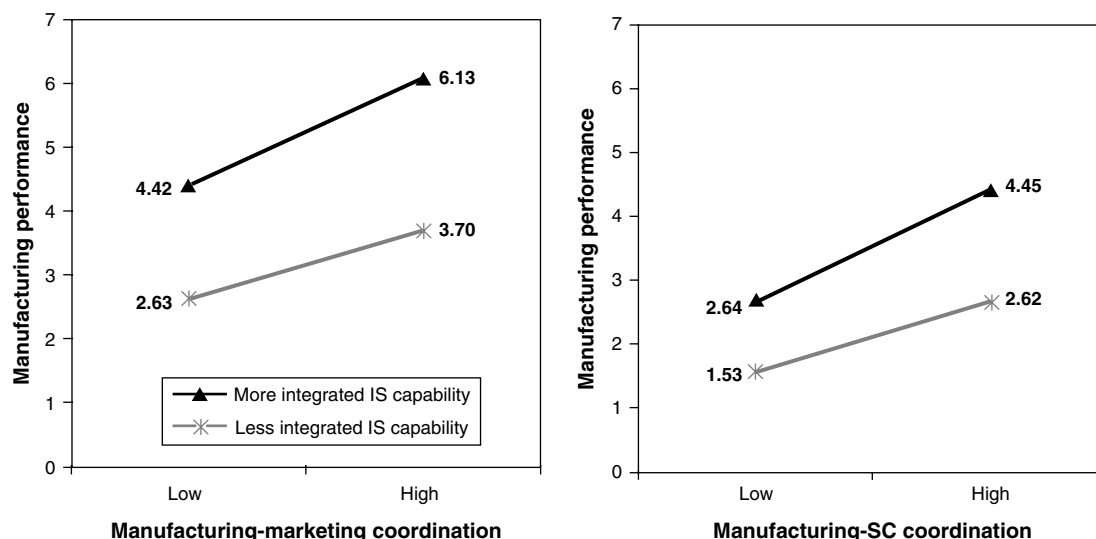
low (one standard deviation below the mean). Firms that have high Mfr-Mkt coordination appear to utilize the high manufacturing-IS capabilities synergistically to become more operationally effective. In contrast, for firms with low coordination, although a more integrated information system improves performance, the full extent of benefits are not captured.

Panel 2 of Figure 3 presents results of the effects of manufacturing-supply chain coordination. Again, firms with high levels of Mfr-SC coordination (one standard deviation above the mean) and a *high* integrated IS capability outperform firms with high levels of Mfr-SC coordination and *low* integrated IS capability. In contrast, when Mfr-SC coordination is low, we find that even a high level of integrated IS capability cannot adequately compensate for poor coordination to appreciably improve performance. As evident from the figure, it is only the firms with high Mfr-SC coordination that are able to leverage the integrated IS capability to achieve superior performance.

Discussion

Although this study took considerable care to address the concerns of endogeneity, heterogeneity, and unobservables as well as alternative model specification in the empirical analysis, the results should be interpreted in the context of other potential limitations. The study suffers from some of the general limitations of survey research such as respondent bias

Figure 3 Coordination Effects on Performance at High and Low Levels of Integrated IS Capability



and perceptual scales. Although 32% of the sample was from multiple informants, the use of single informants for the rest of the sample was less than ideal. However, our use of objective manufacturing performance measures, various secondary source controls, the checks performed with our multisource subset, and additional robustness analyses suggested that the associations posed in our theoretical model were not driven purely by perceptual or halo effects (not prone to common method bias).

The study's main contribution lies in exploring the role of Mfr-IS coordination and integrated IS capability in conjunction with the traditional coordination drivers in explaining manufacturing performance. In describing the expanding role of information systems in contemporary organizations, Hayes et al. (2005, p. 175) remark that "...IT's role for many years was simply to *support* operations; today it is at the *heart* of operations" (italics in the original). As noted at the outset, prior research on manufacturing performance has emphasized the importance of both interfunctional and interorganizational coordination. However, these studies have, at best, only noted the role of IS in passing and have not directly incorporated an integrated information systems construct in the conceptual or empirical models. By including integrated IS capability in the model, we find that it not only directly and positively impacts manufacturing performance, but plays a significant complementary role as well. The transparency, visibility, and communication capabilities provided by advanced information systems enable manufacturing planners, and the groups with which they interact, to share information and coordinate planning and fulfillment activities. Although these effects have been indicated in case studies of successful companies such as Dell and Walmart, this study provides richer empirical evidence using a larger sample and robust measures of manufacturing performance. The interaction results strongly suggest that even in the case of firms with superior Mfr-Mkt and Mfr-SC coordination, an integrated IS capability is important for synergistic benefits. Conversely though, when there is a lack of alignment and mutual commitment to shared goals across functional areas, simply putting in place an integrated information system (such as an ERP or

SCM system) will not impact manufacturing performance significantly. In fact, under conditions of low Mfr-SC coordination, there is no change in performance as firms move from low to high level of integration capability in their manufacturing information systems. Therefore, firms investing in information systems without putting in place the commitments with partners to align and impact their mutual manufacturing goals are likely incurring only the cost of IT without reaping any of the benefits. Given the important role played by integrated IS capability, future research should examine the aspects of these systems at greater granularity to understand if different facets of integrated manufacturing-IS (for example, internal integration versus supplier or customer facing integration functionality) differentially impact manufacturing performance.

Another significant contribution of this study is its examination of the role of manufacturing-IS coordination in contemporary manufacturing firms. The importance of coordination between IS and end user departments has been emphasized in the IS literature and shown to positively impact several outcome variables such as IS development success, end user satisfaction, etc. The literature on interfunctional coordination has thus far only considered the effects of manufacturing-marketing coordination on manufacturing performance. The results obtained in this study emphasize the general need to augment future manufacturing performance models by explicitly considering the role of manufacturing-IS coordination. Such coordination must extend well beyond the system implementation stage, and ongoing coordination between the two functions is critical for achieving more integrated information systems. We expect this to be particularly critical as the complexity of organizational informational needs increases and in light of the corresponding increase in the sophistication of its information systems. Improved coordination between IS and other business functions might well be expected to serve as an imperative for superior organizational performance.

Conclusion

Drawing on the literature in the areas of manufacturing-marketing coordination, manufacturing supply chain, and information systems, we developed a

model that explained substantial manufacturing performance variance in a cross-sectional sample of manufacturing firms. Our study integrates perspectives from studies that have considered manufacturing performance in the context of interfunctional and interorganizational coordination, but hitherto have proceeded as parallel literature streams. We close this gap by developing a model that includes an integrated information systems construct and manufacturing-IS coordination in conjunction with manufacturing-marketing and manufacturing-supply chain coordination, thereby providing a more complete picture of the true drivers of manufacturing performance. Given advances in information systems and the diffusion of these advances across manufacturing industries, future assessments of operational performance cannot afford to neglect the effects of superior information systems capability. While it may be possible for all firms to acquire the latest information systems, our results indicate that not all firms are equally successful in extracting the full potential of these advanced information systems. For companies that can seize and master the challenges of developing superior integrated IS capability, the synergistic benefits with superior coordination can provide tremendous performance gains.

Although the present study has been limited to focusing on operational manufacturing performance measures, it is reasonable to assume that other forms of benefits, such as increases in new product development capabilities and manufacturing flexibility, can be identified. Future work should consider these alternative benefits as well.

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Appendix A. Questionnaire Factors and Items

Manufacturing-Marketing Coordination[§]

*We have processes to ensure that...

(1.a) ...our manufacturing plans/solutions are marketing aligned

(1.b) ...marketing input is used in developing manufacturing plans and solutions

(1.c) ...our marketing plans/solutions are manufacturing aligned

(1.d) ...manufacturing input is used in developing marketing plans and solutions

*Employees engaged in...

(1.e) ...marketing understand the importance of manufacturing to our business

(1.f) ...manufacturing understand the importance of marketing to our firm

Manufacturing-IS Coordination[§]

*In our firm, the IS (information systems) area coordinates frequently with manufacturing area...

(2.a) ...to increase manufacturing's understanding of the production/resource-planning system's capabilities

(2.b) ...to help develop an understanding of manufacturing's technical req.s for the production/resource-planning system

*In our firm, the IS (Information Systems) staff...

(2.c) ...work with us to customize the production/resource-planning system to our needs

(2.d) ...helps us obtain information and reports from the production/resource-planning system relevant to us

(2.e) ...provide ongoing training on the use of the production/resource-planning system

Manufacturing-Supply Chain Coordination[§]

*We have processes to ensure that...

(3.a) ...our manufacturing plans/solutions are supply chain aligned

(3.b) ...supply chain partner input is used in developing manufacturing plans and solutions

(3.c) ...our supply chain partners' plans and solutions are manufacturing aligned

(3.d) ...manufacturing input is used in developing our supply chain partners' plans and solutions

*To what extent would you agree that...

(3.e) ...our supply chain partners understand our manufacturing capabilities

(3.f) ...our manufacturing personnel understand the capabilities of our supply chain partners

Integrated IS Capability

*Our production/resource planning system allows us integrated access to...[§]

(4.a) ...all customer-related data (eg. Service contracts, feedback, etc.)

(4.b) ...all order-related data (e.g., order status, handling requirements, etc.)

(4.c) ...all production-related data (e.g., resource availability, quality, etc.)

(4.d) ...all market-related data (e.g., promotion details, future forecasts, etc.)

*To what extent does your resource-planning system facilitate the following coordinated activities with your suppliers?[¥]

(4.e) Knowledge of the maintenance of inventory mix/levels

(4.f) Delivery scheduling and tracking

*To what extent does your resource-planning system facilitate the following coordinated activities with your buyers?[¥]

(4.g) Knowledge of the maintenance of inventory mix/levels

(4.h) Delivery scheduling and tracking

JIT[£]

For each of these three functions, approximately what percentage (%) of all practice at your firm is best described as just in time?

(6.a) Purchasing

(6.b) Production

(6.c) Delivery

§: 1 = Strongly Disagree, 7 = Strongly Agree

¥: 1 = Not at All, 7 = Extensively

£: 0–10%, 11–20%, etc

Objective Manufacturing Performance (from COMPUSTAT)

(a) Inventory Turns: 1/Days.Inventory

(b) Operating Margin: [Sales – COGS]/Sales

(c) On-Time Ratio: Sales/Backlog

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