ENTERPRISE RESOURCE PLANNING SYSTEMS IN OPERATIONS MANAGEMENT: A MODEL, AN INSTRUMENT AND AN EMPIRICAL TEST

by

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Enterprise Resource Planning Systems in Operations Management: A Model, an Instrument and an Empirical Test
(Under the Direction of Dale L. Goodhue and K. Roscoe Davis)

A model of certain costs and benefits arising from the implementation of Enterprise Resource Planning (ERP) systems is developed and tested. Organizational Information Processing Theory states that performance is influenced by the fit between coordination mechanisms and organizational context. ERP is such a mechanism–one that provides high levels of integration but requires considerable standardization. Two propositions follow regarding firms that implement ERP systems: Interdependence among a firm's sub-units is associated with positive business impacts from ERP. However, to the extent that sub-units are highly differentiated from one another, impacts will be less positive.

Using manufacturing plants running ERP systems as the domain, these two propositions are further refined based on four case studies. The resulting causal model is then tested using a questionnaire survey of 173 plants.

Structural equation modeling is used to purify the measurement model and to test the causal model. Interdependence between plants and the sales and distribution functions sharing their ERP system is positively associated with overall plant impacts of ERP; however, there is no statistically significant association involving interdependence with other plants in the organization. Differentiation among plants in the ERP implementation is associated with reliance on alternative (non-ERP) systems and with increased time required for managerial tasks. Finally, increased time for managerial tasks is associated with negative overall plant impacts of ERP. Thus the two central propositions are generally supported.

INDEX WORDS: Production planning and control, Manufacturing, Process choice, Enterprise resource planning systems (ERP), Management information systems (MIS), IS success, Task-technology fit, Data integration, Organization information processing theory, Interdependence, Differentiation, Uncertainty, Contingency theory, Survey, Case study

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by

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To Kim and Will

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CHAPTER 1
Introduction and Overview

Introduction

Enterprise Resource Planning (ERP) systems are one of the most important phenomena to have occurred in business over the past several years (Davenport, 1998). ERP systems arguably hold the key to enhancing integration across the traditional boundaries within and around an organization. Firms install ERP systems with goals such as improved coordination across areas of the company (and sometimes with customers and suppliers), administrative savings and reduced IT costs (Cooke & Peterson, 1998). However ERP's problems are reportedly as impressive as its benefits. For example, ERP systems are notoriously difficult to implement (Wilder & Davis, 1998), and the majority of these projects finish late or over budget (Martin, 1998).

Considered more broadly, ERP is an example of business systems integration, a trend that shows no signs of waning. Other fast-growing developments–supply chain management software and e-commerce–also have intra- or inter-organizational integration at their core. By the same token, the issue of integration extends back to early, fundamental thinking about business processes. This dissertation examines data integration through the ERP lens by tying it to a strong base of theory. In doing it so serves two purposes: It adds to our cumulative understanding of the theory and it guides current and future efforts at integration.

This dissertation presents a model that draws several propositions from organizational information processing theory and applies them to ERP. To test the propositions a survey was developed and administered. Results from the model are analyzed and implications for the model are discussed.

Defining the Problem Area

This research uses the following definition of ERP: *An Enterprise Resource Planning system (ERP) is a large, integrated, packaged computer software system handling business processes and data storage for a significant collection of business units and business functions. Such systems use a single, shared set of data bases and data definitions.* No commonly accepted definition has yet emerged (Holsapple & Sena, 1999). However this definition is consistent with those offered elsewhere (e.g. Cox & Blackstone, 1998; Deloitte Consulting, 1998).

As the definition makes clear, the *scope* of an ERP system has two dimensions: (1) the number and variety of business *units*, such as manufacturing *facilities* and *sales offices*; and (2) the number of business *functions* such as manufacturing, logistics, sales, and accounting. Although ERP systems are sometimes limited to single facilities, they are typically larger in scope than previous generations of systems such as MRP II (Manufacturing Resource Planning) systems. This dissertation uses the term *ERP implementation* to denote the portion of the organization across which the ERP system is implemented.

As the definition suggests, ERP systems require significant standardization. Shared data bases require data standards. Data standards often require the standardization of business processes, which also is often seen as making the software more expedient to install across multiple sub-units[1]. Finally, since ERP is packaged software, an organization must accept the assumptions and restrictions that the developers embed in the package.

Manufacturing Planning and Control (MPC)

This dissertation deals with the *manufacturing planning and control* portion of the manufacturing firm. Manufacturing planning and control includes three aspects

[1] The term *sub-unit* is used to refer to the parts that make up the organization, such as functional departments or physical locations–for example, a manufacturing plant.

(Vollmann, Berry, & Whybark, 1997): Developing a general manufacturing plan (production planning, master scheduling, resource planning), detailed material and capacity planning (MRP, capacity planning and scheduling, etc.), and execution (purchasing, shop floor). Tools for each function are generally included in a firm's *computerized manufacturing planning and control system*, which is a subset of the computerized applications that ERP systems provide.

Research Questions

Organization information processing theory states that firms process information in order to resolve uncertainty (Galbraith, 1973). Different sub-units deal with different tasks, technologies and environments. Various factors determine the level of integration that is required between these sub-units; therefore, a critical task in organizational design is matching an appropriate means of integration to organizational conditions (Galbraith, 1973; Lawrence & Lorsch, 1986; Thompson, 1967). ERP systems are one such device. Like any other device, these systems have characteristics that make them more appropriate for some conditions than others. One such feature of ERP is the relatively high degree of integration it provides; therefore, ERP should be beneficial for organizations with a high degree of interdependence among sub-units. On the other hand, ERP demands a relatively high level of standardization (data standards, process standards, and so on). Standardized systems may be a poor fit when sub-units differ from one another in their task environments (Goodhue, Wybo, & Kirsch, 1992).

Two research questions follow from these considerations:

1. Is differentiation among sub-units associated with ERP costs?

2. Is interdependence among sub-units associated with ERP benefits?

Overview of the Research Process

Figure 1.1 shows the conceptual model based on the discussion in this chapter. The model applies to the population of manufacturing plants running ERP systems. The unit of analysis is the manufacturing plant. Some organizations implement ERP systems in a single plant, but most ERP implementations include multiple plants.

Figure 1.2 presents an overview of the research process. The researcher's ultimate objective was testing hypotheses based on the model (Figure 1.1). However, the problem area was not well understood at the outset of this project, and little ERP-specific literature existed. Therefore the investigator undertook several exploratory case studies.

Based on the case studies and a review of the relevant literature, the researcher elaborated on the model in figure 1.1, eventually producing the model presented in Chapter 5. Based on this model, the researcher developed specific, testable hypotheses.

Choosing a research methodology for model testing is a matter of balancing the strengths and weaknesses of each in light of the task at hand (McGrath, 1982) and the resources available (Martin, 1982). The researcher chose the written survey format for the task at hand.

Conceptual definitions of the variables in the model were developed based on the literature and the case studies. Survey questions were written and refined based on these conceptual definitions. Where applicable, questions were adapted from previous instruments.

Next, the researcher developed a prototype questionnaire. Nine practitioners completed the questionnaire as a part of face-to-face interviews with the researcher. The process resulted in major changes to many items, as well as to the conceptual refinement of several construct definitions.

Although the plant is the unit of analysis in the model, the survey respondent is an employee in the plant's manufacturing planning and control area. Since the research questions involve understanding the effects of ERP systems, the domain is restricted to plants that are actually running ERP systems, as opposed to those whose ERP systems are in the implementation stage. In order to elicit completed questionnaires from individuals meeting these criteria, the researcher administered the questionnaire using the US mail and the internet. Sampling was highly opportunistic, and a variety of sample frames were used.

After administering the survey, the researcher evaluated the measurement properties of the instrument. He performed exploratory and confirmatory factor analysis, checked for violations of certain assumptions and calculated construct reliabilities. Based on these analyses the investigator *purified* the instrument by deleting problematic items and making other changes to the measurement model. Finally, the researcher used the survey data to evaluate the propositions in the research model.

Importance of the Research for Practice

Researchers have been criticized for not studying issues that are important to managers in operations management (Samson & Whybark, 1998), and to information systems field, as well (Ives, 1993). By all accounts, the ERP area is an important one. The ERP market exceeds 10 billion dollars (net of consulting fees and the like) and will surpass that figure in the future (Martin, 1998). Simply put, ERP is big. Furthermore, as the introduction to this chapter pointed out, success with ERP has been uneven. More broadly, previous generations of information technology in manufacturing have failed to produce all that they promised (Schroder, 1981; Swamidass & Kotha, 1998). This dissertation makes a significant contribution by identifying factors associated with the costs and benefits of ERP systems. Insights gained should make it possible to enhance benefits and avoid costs in future implementations of advanced manufacturing systems.

This research suggests several factors that affect whether or not IT integration yields benefits. The next five years will see the explosion of more highly integrative technologies. For example, expenditures on supply chain management software are projected to grow from $3.8 billion in 1999 to $20.3 billion by 2004– a full 26 percent of the total market for business software. Other types of packages which are considered to be *enterprise application software* by market research firms will grow by equally impressive amounts (Bradley, 2000). Figures like these suggest that research on integration will have large practical implications for some time to come.

Importance of the Research to Academics

Integration, interdependence and differentiation are time honored constructs in organization studies. This dissertation advances our understanding of these concepts by extending their application to a new area. Some leading academics (e.g.Samson & Whybark, 1998) have pointed out the need to balance traditional OM research, such as optimization models, which focus on narrowly defined situations, with more empirical research, especially as the diversity of operations environments grows. These scholars suggest that empirical theory-building and theory-testing research hold more promise because it deals with broader classes of phenomena and thus can be better generalized. The research presented here answers this call to arms.

Many published academic papers on ERP (e.g. Smethurst & Kawalek, 1999; Sumner, 1999; van Slooten & Yap , 1999), most practitioner articles (e.g. Althaus, 1999; Carr, 1999; Cooke & Peterson, 1998; Tate, 1999) and most popular discussion focuses on implementation. Specifically, many of these articles concentrate on implementers' attention to or knowledge of certain critical success factors, such as top management support and employee training. This dissertation provides a complimentary approach by suggesting that underlying organizational factors, not just implementation-related factors, affect ERP outcomes.

Leaders in MIS (Jarvanpaa, Dickson, & DeSanctis, 1985), OM (Malhotra & Grover, 1998) and other business disciplines have pointed out the need for reliable, valid measurement instruments. The researcher followed a rigorous process in developing and analyzing the questionnaire. This enables researchers in general to use the scales with confidence in the future. Such measures serve academics well because they allow cooperative efforts, such as follow-up confirmatory research and the accumulation of a body of knowledge. Furthermore, established measures can be used with confidence for testing or building *other* theories or frameworks.

Outline of the Dissertation

Chapter 1 defined and described ERP and manufacturing planning and control. It described the problem area; and it presented the research questions, an overview of the research process and the importance of the research. Chapter 2 discusses the methodological steps carried out in refining the model, developing the instrument, its administration, establishing its measurement properties and using it to test hypotheses. Chapter 3 presents relevant literature on ERP costs and benefits, on organizational information processing theory, on manufacturing process choice, various IS success constructs and other important concepts. Chapter 4 presents four exploratory case studies and describes how they affected the research model. Chapter 5 presents the model, defines the constructs, discusses their operationalizations and states the hypotheses. Chapter 6 uses the data to establish the instrument's measurement validity. Chapter 7 uses the data to test the substantial hypotheses. Chapter 8 discusses findings, conclusions and contributions. It also presents the limitations of the work and suggests future research directions.

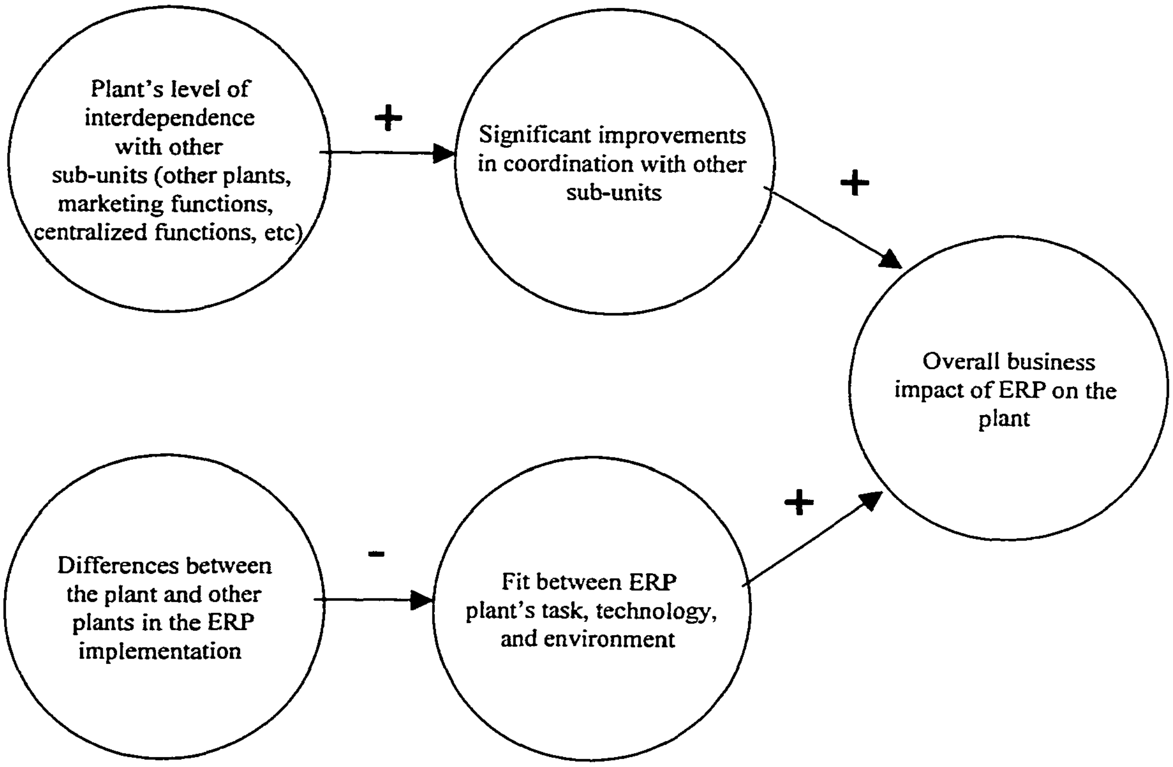

Figure 1.1: Conceptual Model-- Influence of Interdependence and Differentiation on a Manufacturing Plant's ERP Outcomes

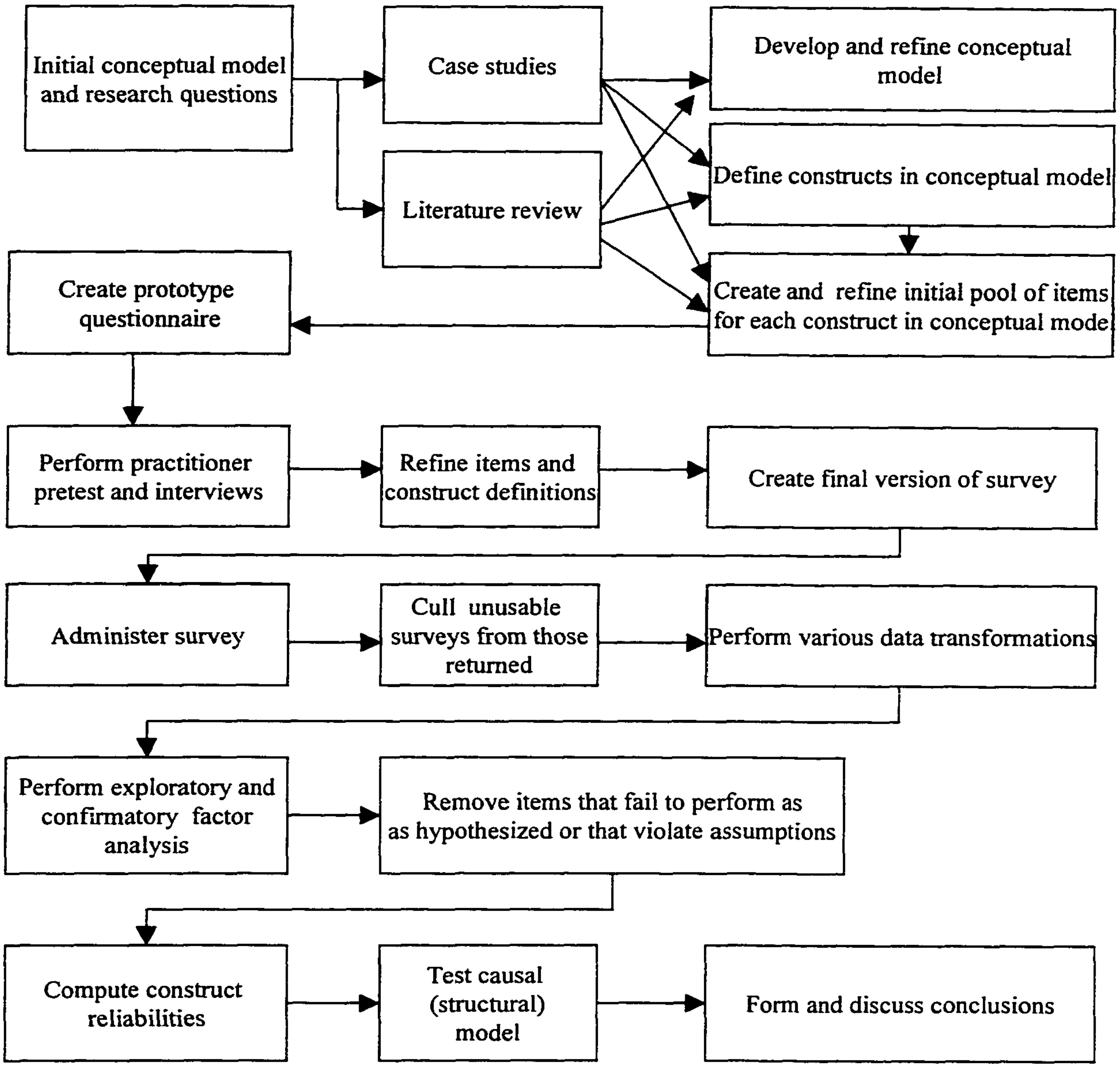

Figure 1.2: Dissertation Process Overview

CHAPTER 2
Methodology

Research Purpose and Methodological Sequence

The researcher began with the research questions stated in the previous chapter. These were based largely on prior exposure to the information processing and data integration literature discussed in Chapter 3. The researcher ultimately intended to test hypotheses based on the research questions. Methodologies that are the most appropriate for doing so include sample surveys, experiments and simulations (McGrath, 1982). However, these methods require a firm understanding of the domain to be studied–for example, the identification of important variables, a fairly well-developed conceptual model. A review of the ERP literature revealed that existing publications would not provide a sufficient level of understanding to proceed with a survey. Very few articles on ERP were in print, and these generally addressed implementation issues or took a high level (e.g. CIO, COO) perspective. None addressed the manufacturing plant level, *per se.*

Therefore, the researcher had to do considerable exploratory research. Case studies provide high levels of contextual realism and allow the study of many variables. Researchers often enter into case studies with a theoretical framework in mind. The case study process allows refinement of framework, and it typically provides unexpected insights, as well (Eisenhardt, 1989). On the other hand, weaknesses of field studies are lack of measurement precision, lack of control and lack of generalizability. Case studies are powerful for developing an understanding of phenomena, but relatively weak for hypothesis testing (McGrath, 1982).

The researcher performed four case studies during 1999. Focusing on single plants that are part of multi-plant ERP implementations, the cases were limited in scope. Cases consisted of on-site interviews with various personnel, tours and limited review of documents, reports and the like. Each case studied a particular plant at a single point in time; however, limited follow-up was conducted for several of the organizations. Chapter 4 presents more detail on the case study process.

The cases provided a strong understanding of the problem area. They also suggested additional areas of the literature for the researcher to review. Based on the cases and the literature, the researcher constructed the model presented in Chapter 5. The model suggested numerous hypotheses. Business research methodologies that are well-suited to testing hypotheses include surveys, lab experiments, and simulations. Given the still-limited knowledge of the area and the difficulty of studying the phenomena out of context, a survey was the most appropriate choice in spite of the fact that it sacrifices some of the precision of measurement and experimental control available with the other methods (McGrath, 1982).

Like case studies, surveys may be conducted longitudinally (with multiple measurements taken over time) or cross-sectionally. In cross-sectional studies the researcher takes a single measure on each subject. Longitudinal studies are superior for attributing causation; however, they require more time and other resources and are subject to attrition (Babbie, 1998). The costs of a longitudinal study were too great for the researcher to bear, but the phenomena of interest can be adequately studied cross-sectionally. Therefore a cross-sectional approach is employed.

Three modes exist for conducting surveys: face-to-face, telephone and written. Written surveys are generally less expensive and time consuming to conduct than are the other two modes (Dillman, 1978). Since the written survey enables asynchronous communication between researcher and respondent, it is particularly valuable when respondents are difficult to reach by telephone or in person. This type of difficulty is often encountered with the informants that would need to be used in this dissertation. For this reason and because of limits on resources, a written format was selected. In addition to the traditional pencil and paper approach, the survey was administered using e-mail in conjunction with the World-Wide-Web. This is discussed in greater depth in the next section. A variety of sample frames from a variety of sources was required in order to gain a sufficiently large sample.

In developing the survey scales, the researcher borrowed items from past instruments. Additionally he drew on the literature and on the case studies in order to develop items from scratch. The survey was then administered to nine practitioners. This resulted in refinement of some items and some construct definitions. Next the survey was administered to the individuals in the sample frames. The data were first analyzed to determine the instruments' measurement validity. Then the hypotheses from the research model were tested. These steps are discussed in Chapters 5 through 7. The remainder of this Chapter discusses some of the practical issues considered when administering the survey and the measurement validity issues that were considered.

Survey Administration

Questionnaire and packet construction

Individual questions were constructed according to recommendations of Babbie (1998). The researcher strove to create items that were brief, *single-barreled,* unbiased, and clear.

The survey itself was constructed according to the recommendations of Dillman (1978). The most important of these were:

- The front and back covers with copious white space
- Pages that do not appear crammed
- Alignment of the left most edge of response scales of items on a page
- Booklet format with each page being approximately 6.125 x 8.25 inches
- 9 point type
- Survey begins with an interesting question that applies to all recipients
- Demographic type information collected at end

The researcher followed Dillman's advice regarding the mail-out packet, as well. Dillman's overarching principal is that the survey packet should be a normal piece of business correspondence. Therefore, a cover letter was printed on laser printed letterhead and signed by the researcher. The packet weighed less than an ounce so it could be sent with normal first class postage, and a postage paid return envelope was included. The researcher followed Dillman's methodology in other matters from wording and organizing the cover letter to arranging and folding the items in the packet.

Early on, difficulties (described below) in convincing consulting firms and other groups to allow access to their clients and members suggested that securing participants would be problematic. The researcher felt that an electronic version of the survey might extend the study's reach. The survey resided on a WWW server and used cgi scripting so that respondents could take the survey using their web browser and so their responses would be written out to a data file accessible by the researcher. The electronic survey was identical to the paper version in terms of question wording, response scales, and question order. The researcher attempted to make the web experience as similar to the paper experience as possible.

Some individuals were notified electronically about the web survey and some were notified by a traditional letter (details appear in the next section and in Table 2.1). In general, the content of both mirrored the cover letter that accompanied the paper survey. E-mails were sent to several list-serves and to a mailing list provided by an ERP user group. The e-mails contained the URL for the survey. Letters were sent to other sample frames via US mail. Again, these contained the URL for the survey. (Because mailing only a letter is less expensive than mailing an entire survey packet, the researcher reasoned that letters referring recipients to the web would be allow him to stretch his resources. The results were mixed as described in Chapter 6).

It is more difficult to control access to a web-based survey than a paper one, especially if the survey is announced on list-serves. An item on the web-survey asked respondents how they were directed to the survey. Some respondents were given an authorization code to enter. Others simply listed how they were referred (e.g. APICS discussion list).

Following Dillman's advice, paper mailings were sent so that they would arrive early in the week. Dillman's advice regarding the timing and number of follow-up mailings was only partially followed. He recommends three follow-up mailings, the first being a postcard. Due to limits on resources, the researcher employed only a post-card, which was mailed as a follow-up to paper mailings 1 to 2 weeks after the initial mailing. The researcher attempted to send e-mails at the beginning of the week, although some of these were beyond his control. Follow-up emails were sent in some instances.

Description of Samples

Finding enough survey participants was a difficult ordeal. The researcher's original intent was to use contacts in consulting companies to assist in securing participants. The source of these consulting contacts was primarily the University of Georgia MIS advisory board. Approximately six consulting firms were contacted. Although most of these firms expressed some interest, none were ultimately willing to help.

This led to the execution of a number of *plan B's*. The researcher secured the cooperation of industry groups through extensive personal selling and networking. Each group has its own internal bureaucracy, priorities and resources. The support that various groups were willing or able to provide varied considerably. Of course, the researcher's resources were also limited. These realities led to a variety of strategies as described below and summarized in Table 2.1. Response rates and the like are provided in Chapter 6.

The Educational and Research Foundation of APICS (formerly the American Production and Inventory Control Society) provided three mailing lists. Two of these lists had already been compiled. The third was compiled especially for the researcher. Some individuals on the list were sent the paper version of the survey. This was supplemented by sending others only a cover letter with the Web survey's URL.

Several user groups were contacted, and two of these cooperated. Only one, Quest, the JD Edwards user group, provided a list of its members, most with email addresses. The American SAP User Group (ASUG) would not provide any type of member list and would not allow centralized access to its members. However, the chairman of the Manufacturing Planning and Execution (MPE) special interest group agreed to make surveys available to attendees of meetings of the group at an ASUG conference in Atlanta. Furthermore, the chairman of the ASUG purchasing special interest group agreed to announce (by forwarding an email drafted by the researcher) the existence of the web-version of the survey, along with its URL, on the group's email discussion group (or *list-serve*).

Table 2.1: Survey Sample Strategies

Sample Frame	Solicitation Medium	Survey Medium	Follow-up
APICS Member List 1	US mail	booklet	postcard
APICS Member List 1	US mail	web	postcard
APICS Member List 2	US mail	web	postcard
APICS Member List 3	US mail	booklet	postcard
APICS Member List 3	US mail	web	postcard
Quest Member List	e-mail individual	web	none
APICS Discussion Groups	e-mail list-serve	web	second e-mail
ASUG Purchasing SIG Discussion List	e-mail list-serve	web	none
ASUG MPE SIG Meeting	Announced at / pick-up at meeting	booklet	none
Misc. (personal contacts, etc.)	hand / US mail	booklet	none

APICS maintains approximately ten list-serves. The researcher sent email to nine of these announcing the survey and its URL. A second email was sent approximately thirty days later.

Finally, the researcher used personal contacts. Some contacts were manufacturing professionals to whom the survey was mailed. The researcher also asked several consulting contacts to pass on surveys to their clients.

The researcher attempted to limit method variance due to the means which the participants in the sample frame were solicited and the surveys were distributed. All paper surveys were distributed with a cover letter and return envelope, even if they were not distributed by mail. Minor variations in the cover letter were required for different groups, but the letter was substantially the same for all recipients. Similarly, all e-mail solicitations were done with an e-mail that was crafted to parallel the paper cover letter.

Validity and Reliability

Construct Validity

Construct validity concerns whether a measuring instrument "validly measures what it purports to measure" (Nunnally & Bernstein, 1994 p. 84). One cannot prove construct validity; one can only establish evidence for or against it. Construct validity is established by demonstrating evidence of content validity, discriminant validity, convergent validity and predictive validity (Nunnally & Bernstein, 1994).

Content validity

Content validity addresses, "How much a measure covers the range of meanings included within the concept" (Babbie, 1998, p. 134). Addressing this concern includes specifying the domain and its boundaries and creating or identifying a sample of items that tap the domain. Content validity exists when these items represent all elements of the domain and exclude extraneous elements (Carmines & Zeller, 1979).

Tools for establishing content validity include academic and practitioner literature reviews, focus groups, and interviews (Churchill, 1979). This project entailed literature reviews and case studies to inform the construct definition and item generation processes. Practitioners and academics reviewed items and construct definitions.

Discriminant Validity

Establishing discriminant validity means establishing that measures of multiple constructs do in fact diverge. If there is no difference in subjects' responses to scales that purport to measure two different things, then the instrument lacks discriminant validity (Kerlinger, 1979). Discriminant validity can be established by analysis of a correlation matrix, the multi-trait/multi-method technique, exploratory factor analysis (EFA), and/or confirmatory factor analysis (CFA). This dissertation uses EFA and CFA.

Convergent Validity

Convergent validity is agreement between two or more attempts to measure the same dimension or construct with different means (Campbell & Fiske, 1959; Kerlinger, 1979). This study relies primarily on a single method: the questionnaire survey. Therefore, rigorous evidence of convergent validity is not provided; however, the practitioner interview and pre-test phase of the survey development provided some evidence. During this process, the researcher questioned practitioners about various constructs in the model in order to determine whether the interviewees' assessments of the constructs were consistent with their responses to questionnaire items measuring the constructs.

Predictive Validity

Predictive validity exists when a construct measured by an instrument exhibits a logical statistical relationship to something else (a criterion). An example is a relationship between SAT scores and college performance. The measurement of the criterion may precede, follow or occur simultaneously with the administration of the instrument (Nunnally & Bernstein, 1994). When using predictive validity as evidence for construct validity, there should be a well-accepted relationship between the construct in question to the criterion (Nunnally & Bernstein, 1994). According to some authorities, measurement of the criterion should not be external: it should not be made by the same instrument that is being validated (Babbie, 1998). However, this is not the stance taken here. As discussed in chapters 2 and 3, all of the relationships in the conceptual model are based in theory. Since the model is theoretically defensible, evidence of predictive validity exists to the extent that the constructs as measured by the instrument behave as predicted by the model. The statistical evidence for and against each of these predictions is presented in Chapter 6.

External Validity

External validity is the extent to which findings can be generalized. Random selection from the entire population of manufacturing plants using ERP systems would be a major step towards ensuring external validity. However, sampling was opportunistic, not random. The representativeness of both the sample frame and the respondents from those frames is unclear. Generalizations to other populations are risky. On the other hand, a wide variety of samples frames was used. Furthermore, responses represented a wide range of industries, plant sizes, company sizes, and ERP packages.

Reliability

A subject's score on a measure (such as a questionnaire item or a scale of items designed to measure a single latent variable) is a function of that subject's *true score* and random error. Reliability (or its square root) is the estimate of the correlation between a subject's *true* score on a measure and the score that was actually observed. Moreover, the root of a measure's reliability forms the upper bound on the correlation that the measure can have with any other measure (Carmines & Zeller, 1979).

This study uses Cronbach's alpha to estimate reliability. Alpha values of 0.70 or more are acceptable (with lower values acceptable for new measures) (Nunnally & Bernstein, 1994); however values of 0.80 or better are preferable, especially for measures that are intended for reuse (Carmines & Zeller, 1979), such as those in this study. As presented in Chapter 6, the differentiation scale has an alpha of 0.74. All other scales have alphas above 0.80.

CHAPTER 3

Literature Review

Elements of ERP

Four key ideas for understanding ERP are *data standards, process standards, process restrictions* and *integration.* By definition, ERP systems employ a single database for the entire enterprise (Bancroft, Seip, & Sprengel, 1998; Curran & Keller, 1998; Davenport, 1998) (A company running separate databases for two divisions has two ERP systems). Such a single data base requires *data standards* ("the use of common field definitions and codes across different parts of the organization", Goodhue, Wybo and Kirsch 1992, p. 23) across the enterprise. In addition to requiring data standards, ERP also entails some standardization of business *processes* across operating entities (Ross, 1998). Since different business processes often result in different data about those processes, the requirement of data standards to a large extent requires *process standardization* across operating entities, as well. Furthermore, standardizing processes across the organization is often considered to be a key to implementing ERP expeditiously (McAffe, 1997).

Process restrictions require that a firm standardize its business practices with those that the ERP *package* can model. While the range of process configurations available in any major ERP package is wide, ERP systems are, nevertheless, typically unable to support a portion of a firm's existing procedures (McAffe, 1997), and often firms reportedly opt to modify the process instead of the software (Davenport, 1998). Exhortations not to stray from the options provided by one's ERP package can be found throughout the trade literature (e.g. Connoly, 1999; Wilder & Davis, 1998) and elsewhere (Curran & Keller, 1998).

Integration is the linking together of the information and processes of distinct operating entities and business functions of the organization. ERP systems link all (or many) business functions and operating locations together so all have access to all relevant information as transactions occur (Davenport, 1998).

ERP Benefits

Many firms install ERP systems to improve the flow of information across sub-units (Cooke & Peterson, 1998). Data standards eliminate the burden of reconciling or translating information that is inconsistently defined across two or more sub-units (Huber, 1982). Data standards also do away with the potential for translation or reconciliation errors as well as ambiguity about a field's true meaning (Sheth & Larson, 1990). The integration provided by ERP also reduces the administrative costs of sharing information, since many manual activities involved with keying and translating information from one system to another are eliminated. Finally, since the single database makes data universally available as it is updated, ERP improves the timeliness of information. Enhancing this flow enables the centralization of administrative activities, such as payroll and accounting (Davenport, 1998). Furthermore, it allows better operational coordination, such as improving material flows among plants or information flows from sales offices to plants (Davenport, 1998). ERP can also enhance centralized decision-making at the divisional or corporate level as information from various sub-units is centralized and standardized in a timely fashion (Davenport, 1998). Because it allows better coordination, ERP is sometimes credited with fostering an inter-functional process approach to business, rather than a functionally oriented one (Deloitte Consulting, 1998).

Many firms also install ERP systems to replace existing IT infrastructure as well as to reduce maintenance costs and the costs of future IT improvements. With ERP systems the vendor develops and maintains the software and thus spreads the costs of doing so among numerous customers. A single, standardized system also may reduce the cost of any maintenance and development that is done by the user firm, simply because these efforts are directed toward a single system rather than many (Ross, 1998).

Several other benefits are typically associated with ERP. However these benefits are not explicitly included as ERP benefits in this research because these benefits are not unique to ERP. In fact, they could be achieved with many other types of computer systems. For example, ERP systems replace non-Y2K compliant systems (Cooke & Peterson, 1998), but Y2K compliance could also be achieved by replacing local legacy systems with new local systems, such as MRP II. Also, an ERP may be instrumental in moving a firm away from inefficient business processes and toward accepted "best practice" (Cooke & Peterson, 1998). Implementing any new software provides an opportunity for re-examining and redesigning business processes. Furthermore, new systems often bring new functionality and faster processing. ERP certainly can provide these benefits; however, these benefits could also be achieved with a local system or a group of local systems spanning several business functions.

ERP Costs

ERP is packaged software, which allows limited customization. Firms (or more typically, certain sub-units of firms) implementing ERP often must change some business processes (Davenport, 1998; Sumner, 1999). Often these alterations have little significant effect or are improvements, but sometimes these changed processes are a poor fit with business needs (Davenport, 1998).

A related problem arises from the highly integrated nature of the systems coupled with ERP's standardization, complexity and wide scope. These factors can make ERP systems difficult or impossible to adapt to changing business conditions. One researcher referred to this as "pouring concrete on the business plan" (Lewis & Walley, 1999).

Organizational Information Processing Theory

ERP provides unprecedented levels of information systems integration, which this paper defines as *the linking together of the information and processes of distinct subsets of the organization*. Based on this observation, an appropriate lens for viewing ERP is Organizational Information Processing Theory.

Organizational Information Processing Theory states that in order to survive, organizations must process information to resolve uncertainty and thus make advantageous decisions (Thompson, 1967). Various coordination and control mechanisms remove uncertainty by allowing different parts or the organization to process and communicate information. In this view, organizations must choose the appropriate coordination and control mechanisms based on the level and types of uncertainty they face. These mechanisms include various organizational structures (such as standard operating procedures, matrices, committees) as well as integrative computer information systems (Galbraith, 1974), such as ERP.

Determining IS's Fit as a Coordination Mechanism

Uncertainty comes from a number of sources, including, *interdependence among sub-units* (Thompson, 1967). Interdependence is the degree to which the sub-units must exchange information or material in order to complete their tasks (McCann & Ferry, 1979). Interdependence increases the need for "mutual adjustment" and decreases the degree to which activities can be pre-planned. When interdependence is low, simple coordination modes like standard operating procedures suffice. By contrast, high interdependence increases the need for information about other entities, and thus it increases the appropriateness of information systems as a coordination mechanism (Daft & Lengel, 1986).

Similarly, both the *rate of change in the external environment* and the *complexity of individual sub-units' tasks* affect the degree and type of uncertainty and thus the appropriateness of IS as a coordination mechanism (Tushman & Nadler, 1978).

Finally, *differentiation among sub-units* decreases IS's effectiveness as a mode of coordination. Differentiation refers to the differences among sub-units in functional specialization, goals, and so on (Lawrence & Lorsch, 1986). Differentiation reduces the appropriateness of IS as a coordination mechanism because IS tends to be formal, rigid and standardized compared to other means of coordination (Daft & Lengel, 1986).

Organizational Information Processing Theory has been found to hold in a number of managerial situations (e.g. Van de Ven, Delbecq, & Koenig, 1976). This includes partially explaining the coordination mechanisms used to manage intra-company material exchanges among manufacturing facilities (Mascarenhas, 1984). In the information systems realm in particular, on the other hand, Wybo and Goodhue (Wybo & Goodhue, 1995) did not find a relationship between interdependence and data standards.

Applying the Theory to Enterprise Integration

Goodhue, Wybo and Kirsch (1992) apply this line of inquiry to understanding the costs and benefits of data integration. Their work is particularly relevant to ERP because it concerns the use of data *standardization* to achieve *integration*, two key elements of ERP. Goodhue, Wybo and Kirsch employ the constructs *differentiation* and *interdependence* from Organizational Information Processing Theory to explain the costs and benefits of integration. These include the ERP costs and benefits presented in the literature review in the beginning of Section 2. Goodhue, Wybo and Kirsch argue that the benefits of data integration increase with the interdependence among sub units, but the costs increase with differentiation.

These benefits arise from the fact that standardization increases the organization's ability to share data across sub-units. Furthermore, standardization allows data from multiple sub-units to be combined and compared without the constant need to translate, reconcile or remove ambiguities. Thus, standardization improves centralized (e.g. divisional or corporate-level) decision-making based on data from diverse sub-units. Moreover, data standardization facilitates coordination *among* operating sub-units, such as manufacturing facilities..

On the other hand, Goodhue, Wybo and Kirsch state that the costs of data standardization increase the more sub-units differ from one another in *tasks characteristics, technologies*, and *local environmental conditions*. If sub-units differ substantially from one another, it is likely that the integrated, standardized system will not be a good fit for all units. In other words, a standard system can diminish an individual unit's ability to respond to local conditions. Furthermore, once a system of data standards is in place, it is difficult to make changes for the benefit of one or a few sub-units because such changes extend to *all* sub-units.

This line of thinking applies well to ERP. ERP systems provide high levels of integration. It follows that they should be beneficial to the extent that interdependence among sub-units exists–for example, when a plant receives materials from another plant in the organization. However, as a standardized systems ERP may impose costs on plants whose task and environmental characteristics differ from those that the ERP designers assumed.

Interdependence

According to Pennings (1975), there are 4 types of interdependence: role, social, knowledge, and task. Task interdependence, which deals with the flow of work among entities, is the type of interdependence that is of interest in this research. Research on task interdependence has assessed both the patterns of workflows among individuals *within* a sub-unit, such as a department (e.g. Van de Ven et al., 1976)), as well as on workflows *among* sub-units (e.g. Mascarenhas, 1984). This research focuses on interdependence among sub-units (*inter-unit task interdependence*). McCann and Ferry (1979) define inter-unit task interdependence as "A condition where actions taken within one unit affect the actions and work outcomes of another unit" (114).

Numerous researchers (e.g. Aiken & Hage, 1968; Van de Ven, 1976) state that interdependence is best operationalized as transactions of resources, such as goods, services and information, among units. McCann & Ferry (1979) surveyed the literature and identified six dimensions of transactional interdependence:

1. Number of different resources involved
2. Amount of each resource exchanged (per time unit)
3. Frequency of transactions per unit of time
4. Slack, (Length of time before absence of the resource harms the unit).
5. Value of the resource (cost of substitution, cost of locating another source or user, etc.)
6. Direction of resource flow

For the first five dimensions, as the entity in question (number, amount, etc) increases within a relationship, so does the amount of interdependence in that relationship.

Thompson's (1967) classification of interdependence addresses dimension six, the flow of resources among entities. Thompson classifies interdependence into three types. The level of interdependence among sub-units increases as we move from type one through type three.

1. Pooled interdependence: "...Each part renders a discrete contribution to the whole and each is supported by the whole" (55).
2. Sequential interdependence: "Direct interdependence" between two or more entities where "the order of independence can be specified." Sequential interdependence is not symmetrical. For example, plant A must produce subassemblies before plant B can product the final product.
3. Reciprocal interdependence: Two entities both provide inputs to one another.

Differentiation in a Manufacturing Context

When implementing an ERP system, implementers make myriad configuration decisions, such as the level and frequency of shop floor reporting, the approach to and frequency of detailed material planning, the authorization of particular personnel to perform various functions, etc. A subset of these (including of those just listed) define the computerized manufacturing planning and control portion of the ERP system. As Figure 3.1 suggests, the quality of the fit of a particular manufacturing planning and control (MPC) system for a particular plant is not arbitrary. Instead, the MPC characteristics must be consistent with the processes and inputs employed (Hayes & Wheelwright, 1979; Hill, 1995; Safizadeh, Ritzman, Sharma, & Wood, 1996), which are in turn determined by characteristics of the products produced and markets served (Berry & Hill, 1992). In other words, there must be consistency between the markets a plant serves, its processes and its manufacturing planning and control system. If an MPC system that is inappropriate for a plant's products and markets is imposed on the plant, the plant's performance will suffer.

Table 3.1 lists characteristics of markets, of products and of inputs and processes from the literature. According to the literature, high performing firms make a consistent set of choices between the types of characteristics (e.g. a firm's choices can be described by a fairly vertical line down the second column, not a diagonal or zigzagging one). The left extreme of the column is often described as a job shop, followed by a batch shop, a repetitive environment and a continuous process on the right extreme. Hill (1995) refers to this distinction as one of *process choice*. Well performing hybrids, such as group technology, are documented (e.g. Safizadeh et al., 1996), and alternative typologies have been suggested (e.g. Umble, 1992). However, just as much as the classic typology, these hybrids and alternatives suggest the need for a plant's product and market characteristics to be supported by appropriate process and MPC characteristics.

Like process choice, the dominant manufacturing technology employed can have implications for the manufacturing planning and control system. In particular, processing (blending, refining, etc.) has certain characteristics that separate it from assembly and fabrication. These characteristics must be accommodated by the MPC system. These are listed in Table 3.2. The distinction between processing as a technology and the continuous process manufacturing choice should be noted. Processing (blending, refining, cooking, etc.) may take place as a continuous process or as a batch process (Taylor, 1980).

This line of thinking has important implications for ERP, as diagrammed in Figure 3.1. A particular ERP implementation imposes a particular set of computerized planning and control system characteristics (configuration decisions that are made when implementing ERP modules like material requirements planning, master scheduling and purchasing) on a manufacturing plant. As the above discussion points out, the best set of MPC characteristics are determined by a plant's process choice and process technology which, in turn, are constrained by characteristics of the products and markets a plant serves. The MPC choices imposed by ERP may or may not be a good fit. Since ERP is highly standardized, this dissertation argues that an organization's ERP implementation (say across a division or company) imposes a fairly homogeneous set of MPC characteristics across all plants in the implementation. If the ERP package has been wisely chosen and configured, this MPC configuration will be a good fit for the majority of plants in the system. However, a plant that differs from the majority in process choices will likely suffer a poor fit with the system imposed by ERP.

Table 3.1 Linking MPC Characteristics to Process and Product Characteristics

Source: Berry & Hill, 1992; Hayes & Wheelwright, 1979; Hill, 1995; Vollmann et al., 1997

Characteristics of Products and Markets Served	
Manufacturing volume per product or config.	Low..High
Product customization (to customer reqm't.)	Special...Standard
Price	High..Low
Variety of outputs	Wide..Narrow
Process characteristics (*Process choice*)	
Number of layers in the bill of materials	Many...Few
Variety of inputs (Number of raw matl. part numbers)	High..Low
Rate of design changes	High..Low
Rate of new design introductions	High..Low
Production lot sizes and flow type	Small batch..........Large batch...... Lotless............
Throughput time / Mfr. time	High..Low
Routing variability	High(Jumbled)................................Low(Fixed)
Priority control	Obvious....................................Non-obvious
Organization of layout	Functional.......................................Product
Equip. specialization	Low..High
Level of automation	Low.. High
Employee skill level	High..Low
Nature of material	Discrete——————| Non-Discrete
Amount of activity before customer order	None..All

Dependent Variables: Success of ERP System

This dissertation argues that the nature of ERP's impact (positive or negative) is affected by constructs such as interdependence and differentiation. The impact of an information system can be studied at several levels including the system, the information, the user and the organization (DeLone & McLean, 1992) (Table 3.3). Plant performance is this study's bottom line, so it makes sense to capture this organization-level variable. However, organization performance has shortcomings as an indicator because, for example, it can be influenced by many confounding factors (Ragowsky, Ahituv, & Neumann, 1996). Due to such problems, Delone and McClean (1992) suggest that researchers use multiple IS success variables aimed at multiple levels. However, others (e.g. Goodhue, 1995) have argued against studying the first three levels (system, information, user) *per se*. Instead, they point out that information systems contribute to organizational success by helping users perform tasks. Therefore, systems must be considered, not in and of themselves, but in light of the *tasks* users perform. Congruence between systems and tasks (called *task-technology fit* or TTF) is an appropriate success variable. TTF has been empirically linked to individual performance, which presumably contributes to organizational performance (Goodhue, 1995). In light of this evidence, it is appropriate to focus on aspects of task-technology fit through which differentiation and customization affect overall business impact.

Table 3.2: Process Technology Characteristics Affecting MPC System
(Present in batch processing and continuous processing)
Sources Taylor, 1980, Turner, 1998

Variable input characteristics are acceptable and routine
Multiple formulations/substitutability of raw materials
Production of co-products or by-products
Maintenance of multiple units of measure for a single item (e.g. produce in pounds but sell in square feet)
Unpredictability of processes (yield, output characteristics, processing times)
Variable output characteristics are acceptable and routine (e.g. grades)

Task-Technology fit has numerous dimensions, all of which are likely applicable to ERP. However, for this research it was necessary to identify the dimensions which would most likely be affected by differentiation. Clearly some dimensions, such as availability, would not be as affected as others. The case studies suggested that data relevance, data accuracy and data accessibility were highly affected. However, for reasons of parsimony, the researcher decided to include only two dimensions due to the need to limit questionnaire space and respondent burden. Data accessibility was eliminated. Additionally, the case studies suggested two other phenomena that indicated poor fit between ERP and the task at hand: (1) the reliance on informal or alternative systems and (2) the amount of time and other resources necessary to perform materials management and manufacturing management tasks.

Table 3.3: Categories of IS Dependent Variables

Source: DeLone & McLean, 1992

Categories of IS Success	Example of success measures
System Quality	Convenience, response time, down time
Information Quality	Accuracy, timelines, relevance, understandability
Use	Frequency of voluntary use, % of time used, nature of use, extent of use, use at intended level, type of business function used to support
User Satisfaction	User satisfaction
Individual Impact	Time taken to complete a task, # of alternatives considered, quality of decision or other outputs, changes in behavior, understanding of problem area
Organization Impact	Profit, costs, ROI, cost effectiveness of IS, productivity

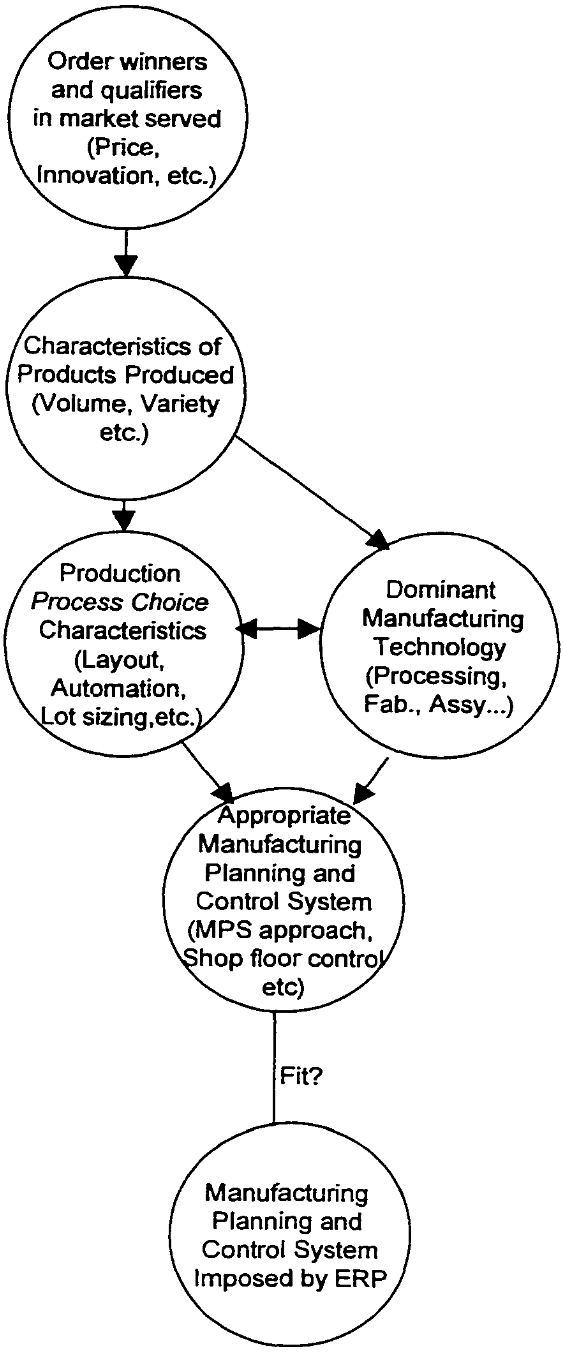

Figure 3.1: Relationship Among Markets, Products, Processes, Technologies and the MPC system

CHAPTER 4
ERP Case Studies

During 1999, four case studies were performed with the goals of gaining a better understanding of the costs and benefits of ERP at the plant level (a level of analysis that had received little attention at the time) and determining if an information processing theory-based approach might be a useful lens for approaching the issue.

The case study sites were chosen opportunistically through professional contacts. For the first two cases, no effort was made to select particularly unsuccessful or successful firms; however, after determining that the first two firms were largely unsuccessful, the researchers actively sought a successful case. Unfortunately, locating plants that were running ERP systems and convincing management to allow a case study was very difficult. Refrigeration, Inc. was a successful user of ERP; however, the number of business functions in its ERP system was limited compared to the other cases. Transportation, Inc. was also a less than ideal site because it had only partially rolled out ERP at the case-site plant, and ERP had not been implemented at other plants. This made assessing ERP impacts difficult. On the other hand, seeing a plant during the throes of design and implementation provided insights the researcher would not have gleaned elsewhere.

No research design is perfect, and the cases are no exception: The researcher could have developed confirming or disconfirming evidence of the insights that were gained (not to mention new insights) by including additional plants per organization, as well as by concentrating more on the organization-level situation. However, the strategy the researcher employed was consistent with the goal of the cases: learning about plant-level ERP impacts and the applicability of the research model.

All cases consisted mainly of on-site interviews, which were supplemented with phone interviews, tours, review of key documents, and the like. Most interviews lasted approximately one hour and followed a semi-structured format. Most interviews were taped and transcribed. Committee members Davis and Goodhue sat in on many of the interviews.

In the following section, this chapter presents a cross-case analysis with reference to the research model. The case write-ups themselves are in the appendix. Each case write-up begins with a discussion of the major issues in the case and ends with a limited analysis. The first two cases are presented and discussed in more detail than the second two because they embodied more of the characteristics that needed to be investigated (fully implemented system, large scale implementation, and so on).

The Cases and the Research Model

Interdependence and ERP Benefits

According to the *a priori* research model in Chapter 1, the degree to which an organization reaps ERP's integration-related benefits is influenced by the level of interdependence among sub-units in that organization. Firms studied all exhibited some interdependence and used ERP to manage this interdependence. All organizations used ERP to pool accounting and financial information. Presumably this led to greater efficiency and better centralized decision-making. Furthermore, through standardization, ERP reportedly increased the efficiency of the IT function, which was largely centralized in all cases (although to a lesser degree at Auto Products). However, by design the case studies concentrated at the plant level, and these benefits accrued at the organization-wide level. Thus the researcher was not in a position to thoroughly understand these (or other) global level benefits. Furthermore, such benefits are not much felt by the plants, even by their top managers.

Several organizations perceived that ERP would facilitate the transfer of materials among plants within the ERP implementation. However, these benefits did not materialize. Auto Products' Gainesville plant simply did not share common materials with other plants. Forest Products (FPC) used ERP to facilitate transfer of some MRO materials, but these are not an important part of the plant's financial picture. It appears that subjects were well aware that ERP could be used to manage such interdependencies, but they had not carefully considered the degree to which these interdependencies actually existed in their circumstances. Nevertheless, it appears that managing this type of interdependence is an important potential use of ERP– one that could substantially impact plants which depend upon their peers. Refrigeration, Inc. supplied the most material to other plants, but the situation is difficult to analyze because their SAP system was limited to purchasing and receiving.

Refrigeration, Inc. (RI) provided the best example of using ERP to manage interdependence in a way that affected the plants. The company created a centralized supply management function to leverage the fact that all plants used many common materials and common vendors. ERP provided the infrastructure to make the strategy work.

Forest Products planned use of ERP to centralize the order management function exploits interdependence. Since this has not yet been rolled-out, it is impossible to discern the extent of the impact on the plant; however it could be substantial. Currently, the system allows customer service representatives within plants to view other plants' inventories. According to plant personnel, this has had some benefit. By contrast, Auto Products ships a very limited range of items to only two customers. Its transactional interdependence with its sales and distribution function is minimal. In fact, the plant deals directly with customer plants. ERP has had little impact in this area. Finally, at Transport Inc., interdependence with sales and distribution appeared significant. Unfortunately, it was too early in the implementation to discern ERP's impact in this area.

The cases did uncover other laudable plant-level benefits, such as improved shop floor discipline at Forest Products. However, these cannot be considered ERP benefits *per se* because they could have been achieved with much simpler, less integrated systems, such as MRP.

Differentiation and ERP Costs

The research model predicts that ERP will impose costs when differentiation exists among entities in an enterprise, because differentiation increases the likelihood that the ERP will be a poor fit with the operational and informational needs of *some* local units. The cases provided support for and a richer understanding of this assertion.

The cases revealed that differentiation could be understood in light of the classic manufacturing product-process framework (e.g. Hayes & Wheelwright, 1979; Hill, 1995). Plants' manufacturing planning and control approaches were driven by their processes and layouts which in turn were driven by the characteristics (such as volume, variety and customization) or the products produced and markets served.

Forest Products' Augusta plant differs from other plants because of the wide variety of non-standard finished products it produces and the resulting need to make more extensive use of NSTOK part numbers and recovery/reclaim than its peers. When FPC configured SAP to handle N-STOK and recovery/reclaim, it assumed that non-standard cuts and non-standard products were rare. This was a valid assumption for most plants, but not for Augusta. The organization made a deliberate decision to accept the "ungraceful" manner in which the ERP system handled N-STOK and recovery-reclaim. This trade-off was worth putting up with at the other plants because of the infrequency with which most of them had to deal with non-standard business and thus with recovery-reclaim and NSTOK. But at Augusta this solution led to operational problems for the master scheduler and the finishing manager, as well as reporting problems that rolled up to the plant manager level. The Augusta plant has responded by relying on several manual systems, but these are resource intensive and still have not solved its problems regarding the accuracy of information.

Similarly, Auto Products' Gainesville plant differed from other plants in its division because of its product and process characteristics. The shop floor module that was implemented was appropriate for a plant producing a wide variety of models or models with a complex product structure. Each step in the production process (such as machining a metal blank into a housing) was controlled by a discrete work order and required numerous ERP transactions. Reporting the status of each work order allowed close tracking of work-in-process and intermediate component inventories. Such a system was a good fit for many of the plants in the division, but not for Gainesville. Gainesville makes only four major products from a handful of components. Cycle times are short and routings fixed. Therefore, there is little need to control production with work orders or for detailed inventory tracking.

With its twenty-some reporting points and awkward interfaces, the Gainesville ERP's shop floor system stifled production until Auto Products was able to decouple production from the ERP by interposing the "Streamline" system on the front end. Then the plant could use manual shop floor control systems that fit its needs, such as Kanban. In effect, the plant developed the coordination and control processes it needed and then retrofitted or jury-rigged Oracle so it would not be too disruptive.

Forest Products' Augusta plant and Auto Products' Gainesville plant suffered mostly because of differences between their production models and those assumed by the global (divisional of corporate) level ERP implementers. The Transport, Inc. situation was somewhat different. The Georgia facility did differ from other plants in the organization. However, the inability to change an order once released was reportedly built into the JD Edwards package itself, rather than being a configuration decision made at the corporate or division level as ERP was being implemented. Therefore, the problem is related in part to differences between the Georgia facility and the business model assumed by the *developers* of the JD Edwards package, not by those who configured the system at Refrigeration, Inc.. However, Georgia's differences from other plants in the company may also have played a role because Transport Inc.'s decision-makers presumably picked the package that best fits the majority of plants, and in the process of doing so they overlooked a critical business need that was particular to the Georgia facility.

Customization

The cases also suggested that organizations can accommodate the unique local needs of individual plants by customizing their ERP packages. Transport Inc. customized in order to allow changes to manufacturing orders after their release to the shop. In management's judgement, the system would not have been a viable fit with the plant's product and process characteristics (high customization, high process flexibility) without this change to the ERP package. Forest Products allowed no customization in its second (version 3) SAP implementation, but it highly customized SAP in the first (version 2) implementation. Employees there felt the version 2 system was a better fit for the plant. Similarly, Auto Products' Gainesville plant was able to add its own Lean-based front end to Oracle *after* the division implementation was cancelled and the Gainesville system became stand-alone.

Local Fit

The cases yielded a better understanding of how task-technology fit manifests itself at the plant level. Numerous dimensions of TTF exist. The three that were the largest issues in the cases were data relevance, data accuracy and data accessibility.

Several other indicators of poor fit were striking. The researcher had the in-going assumption that the gap between required business processes and those modeled in ERP would result in either changing business processes or changing the software. By contrast, the cases showed many examples of employees *bridging the gap* themselves by using alternative systems or by simply working harder and longer.

Forest Products and Auto Products both utilized alternative information systems. The Forest Products plant had an elaborate spreadsheet-based system for decision analysis and performance reporting. It was used in each department and was rolled up to the plant level. Similarly, Auto Products used a visual system (kanban), instead of Oracle, to coordinate production on the shop floor.

Plants also bridged the gap by working more hours. This was particularly true at Forest Products. For example, the master scheduler spent extra hours managing NSTOK orders, and a position was added to interface between SAP and the finishing department.

Culture and Resistance to Change

To be sure, some of the negative reaction we observed to the ERP systems at both plants can be attributed to work culture and resistance to change. For example, Auto Products was expected to change their part numbers to accommodate the ERP system, and they fought against (and managed to postpone) it. This change created some short term problems, but there was no fundamental business reason to favor one part numbering system over another. At Refrigeration, Inc. the "old-timers" used the legacy system when they had the option while the newer employees preferred SAP. Clearly, employees' years of service appears to explain the difference in usage better than task-technology fit in this instance.

However, resistance to change does not explain all the issues. As discussed earlier, many problems were caused by each plants' task, technology and environmental characteristics (for example, markets served, production volume and product variety) not fitting with the way their ERP systems were configured.

Conclusion

The case studies resulted in the following findings that relate directly to the research model. Of course, the degree to which they can be generalized is far from certain.

- Both interdependence with other sub-units and differentiation among sub-units affect plant level ERP costs and benefits.

- Organizations can use ERP to exploit interdependence involving plants and finance/accounting, as well as plants and the IS function. However, the benefits of doing so are not highly visible at the plant level.

- Organizations reportedly can use ERP to exploit interdependence involving plants and other plants, plants and sales/distribution functions, and plants and centralized purchasing. Only benefits resulting from interdependence with centralized purchasing were observed; however, it is likely that the other types of benefits could have been observed if they existed at the case sites.

- The characteristics considered in the product-process manufacturing strategy framework is a good lens for examining differentiation among plants.

- Manifestations of local fit at the plant level include data accuracy, data relevance, data accessibility, time and resources required for tasks, and use of alternative/informal systems.

CHAPTER 5

Hypotheses and Operationalizations

Introduction

An intermediate research model and a final model appear in Figures 5.1 and 5.2. A number of hypotheses are developed from the final model and stated in this chapter. This chapter then discusses operationalizing the concepts in the model with specific survey questions. Special considerations, such as scale transformations and developing interaction scores, are discussed in this section. The third major section discusses the practitioner pretest and its results. For reference, Table 5.1 summarizes the construct definitions.

Research Model and Hypotheses

Based on the literature review and the case studies, the initial research model (Figure 1.1) was developed into the intermediate model in Figure 5.1. The initial model and the final model show that interdependence among sub-units is associated with a positive overall business impact of ERP on the plant. However, this relationship depends on ERP's improving coordination with other sub-units. In reality, ERP may not improve such relationships because of poor implementation or other factors. Therefore, this assumption is made explicit by incorporating the interaction between improvements and coordination improvements in the intermedite model. As discussed in the next section, the final model (Figure 5.2) distinguishes between the two types of sub-units that are considered.

The intermediate model adds the local fit construct. This recognizes that differentiation affects overall ERP plant impact by influencing the fit between users needs and the data and computerized business applications that ERP provides. The final model breaks down local fit into four dimensions.

The initial model also stated that differentiation between a plant and its peers is associated with negative business impacts on that plant. The intermediate model recognizes that organizations may be able to accommodate some differences by customizing ERP to meet special needs of plants that are very different from the norm. The differentiation-customization interaction implies that ERP impacts with be the greatest under either of two sets of circumstances: low differentiation coupled with low customization or high differentiation coupled with high customization.

Improvements in Coordination and Interdependence

The literature and the cases suggest some of the interdependencies that manufacturing organizations seek to manage with ERP are relationships with the sales and distribution function, with other plants (with whom materials and information are exchanged), and with centralized support functions such as divisional accounting or centralized purchasing. Adequately treating all of these interdependencies in a single survey would leave room for little else. Therefore, relationships with centralized functions were dropped. Compared to the other functions, little variance on interdependence with accounting was expected. The use of centralized purchasing or supply management is far from universal, so items dealing with this topic would not apply to the majority of respondents. Furthermore, interdependencies with plants and sales and distribution are likely to involve physical goods and thus are likely more tangible to survey respondents. Therefore, the final model includes only interdependence with other plants and interdependence with sales and distribution functions. In the research model, the hypotheses regarding both types of interdependence are completely parallel to one another.

Chapters 3 and 4 argued that ERP facilitates such coordination among sub-units because, as a standardized, integrated system, it makes information about one sub-unit available to another in a timely, usable and unambiguous fashion. Therefore:

> H1: There is a significant positive relationship *between improvements in coordination with other plants in an ERP implementation* and *overall business impact of ERP*

H2: There is a significant positive relationship between *improvements in coordination with the sales and distribution functions within an the ERP implementation* and *overall business impact of ERP*

Table 5.1: Construct Definitions

Interdependence	The degree to which a particular plant must exchange information or materials with other sub-units within an ERP implementation in order to complete its tasks. This dissertation considers plants' relationships with two types of other sub-units: (1) other manufacturing plants and (2) sales and distribution sub-units.
Improvements in Coordination	A particular plant's ability to adjust to changing conditions in other sub-units within an ERP implementation
Differentiation	The degree of difference between a particular plant and the average plant within an ERP implementation in tasks, technologies employed and environmental characteristics
Local Level Customization	Changes made to the ERP system to meet the needs of a particular plant
Local Fit	The degree to which ERP technology as implemented matches a particular plant's task requirements
Overall Business Impact	The net effect of the ERP system on the business performance of a particular plant

However, the impact of a plant's improvements in coordination with another sub-unit may well be trivial unless the relationship with that sub-unit is an important one for the plant– in other words, the impact of coordination improvement varies with the level of interdependence. Interdependence is defined as *the degree to a which particular plant must exchange information or materials with other sub-units within an ERP implementation in order to complete its tasks.* Interdependence between sub-units increases the need for one department to adjust to changing conditions (changing requirements, changing abilities, etc.) in another. Therefore interdependence increases the need for coordination among sub-units. Because ERP presumably improves coordination (H1 and H2), hypotheses 3 and 4 follow:

> H3 (interaction hypothesis): *Interdependence with other plants in an ERP implementation* significantly increases the effect of *improvements in coordination with other plants* on *overall business impact of ERP*

> H4 (interaction hypothesis): *Interdependence with the sales and distribution functions within an the ERP implementation* significantly increases the effect of *improvements in coordination with sales and distribution* on *overall business impact of ERP*

Differentiation and Local fit

Chapters 3 and 4 argued that, as standardized systems, ERP systems are typically configured to meet the needs of the average plant in an implementation. The notion of differing from the average is captured by the construct *differentiation.* For this research, differentiation is defined as *the degree of difference between the plant of interest and the "average" plant in the ERP implementation in tasks, technologies employed and environmental characteristics.* This definition is based on Daft and Lengel (1986).

Any implementation of a computerized manufacturing planning and control (MPC) system (including ERP) imposes certain MPC characteristics on a plant or department. These MPC characteristics may or may not be the best fit with that plant or department's manufacturing processes. This research hypothesizes that the particular MPC characteristics imposed by the ERP will be those that best fit the majority or the "average" plant or department in the implementation. Therefore, a plant or department that differs significantly from the average will suffer a poor fit between its manufacturing process characteristics and its ERP.

As discussed in the previous chapter and summarized in Table 5.2 there are numerous dimensions of local fit, and four were selected for this project. One hypothesis for each dimension follows:

> H5: There is a significant negative relationship between *differentiation* and *data accuracy.*

H6: There is a significant negative relationship between *differentiation* and *data relevance.*

H7: There is a significant positive relationship between *differentiation* and *time and other resources required for materials and production management.*

H8: There is a significant positive relationship between *differentiation* and *the use of alternative systems.*

Table 5.2: Dimensions of Local Fit

Data Accuracy	Whether the ERP data are sufficiently correct for performance of required tasks
Data Relevance	Whether the ERP system provides the information needed for performance of required tasks
Time and other resources required for materials and production management	Time and other resources required for production planning and scheduling, material planing, purchasing and production supervision
Use of Alternative Systems	Use of alternative or informal systems for functions the ERP system was intended to perform

Customization

The cases suggested that firms willing to dedicate resources to customizing ERP to meet the needs of an individual plant before or during implementation can accommodate differences between that plant and standard business practices (including manufacturing planning and control practices) imbedded in the ERP system. In other words, for a particular plant, the impact of differentiation on local fit depends on the level of customization performed to meet that plant's unique local-level needs. The following four hypotheses apply this notion to the model:

H9 (interaction hypothesis): *Customization* significantly decreases the negative relationship between *differentiation* and *data accuracy.*

H10 (interaction hypothesis): *Customization* significantly decreases the negative relationship between *differentiation* and *data relevance.*

H11 (interaction hypothesis): *Customization* significantly decreases the positive relationship between *differentiation* and *time and other resources required for materials and production management.*

H12 (interaction hypothesis): *Customization* significantly decreases the positive relationship between *differentiation* and *the use of alternative systems.*

Local Fit and Overall Business Impact

The model posits that the local fit variables lead to an overall positive business impact on the plant. Plant performance occurs through individual performance. The effect of individual performance is influenced by the degree to which information systems provide the right data with a sufficient level of accuracy. Each local fit dimension reflects an individual's perception of ERP's effect on certain work processes in the plant. These should be indicative of ERP's impact on work processes in the plant in general. Overall plant performance is influenced by individual work processes. Therefore:

H13: There is a significant positive relationship between *data accuracy* and *overall business impact of ERP.*

H14: There is a significant positive relationship between *data relevance* and *overall business impact of ERP.*

H15: There is a significant negative relationship between *time and other resources required for materials and production management* and *overall business impact of ERP.*

H16: There is a significant negative relationship between *the use of alternative systems* and *overall business impact of ERP.*

Additional Hypotheses

The model suggests that local customization improves local fit by accommodating differentiation. However, there is evidence that some companies customize ERP simply for the sake of making ERP resemble legacy systems. This ranges from the appearance of reports to the configuration of business processes. Researchers have suggested that this is not worthwhile because customization should occur only when there is an underlying business reason, if at all (Haines, 2000; Ross, 1998). This dissertation has argued that differentiation among sub-units is a valid reason for ERP customization. This was stated earlier in hypotheses 5 through 12. However, an alternative explanation is that local customization *always* improves ERP fit– *regardless* of the level of differentiation. This notion is worth testing. Therefore the following hypotheses are included (it is expected that they will not be confirmed):

> H17: There is a significant positive relationship between *local level customization* and *data accuracy.*
>
> H18: There is a significant positive relationship between *local level customization* and *data relevance.*
>
> H19: There is a significant positive relationship between *local level customization* and *time and other resources required for materials and production management.*
>
> H20: There is a significant positive relationship between *local level customization* and *the use of alternative systems.*

Correlated Error Variances Among the Local Fit Constructs

The error variances for the four local fit constructs are inter-correlated. The assumption of the general LISREL model is that all of the variation in the endogenous variables is explained by the constructs in the research model. However, this is not the intent of the research model in this study, especially with regard to the local fit constructs (data accuracy, time, use of alternative systems). Specifically, ERP implementation related factors, such as user training and top management support, explain much of the variance in the local fit. Therefore, the model is specified to allow the errors of prediction to correlate among the local fit constructs. Conceptually, this acknowledges that constructs that are not included in the model affect local fit.

Operationalizing the Latent Variables

The latent variables were defined (Tables 5.1 and 5.2 above) based on applicable literature and the case studies. The researcher generated an initial pool of questionnaire items based on the definition of each latent variable. When adequately validated items were available from the literature, there were adapted. Numerous items were developed from scratch. Then the investigator culled and refined this initial pool of items with the help of other researchers. After several rounds of such initial refinement, the researcher pre-tested the items with 9 practitioners. This process is described in greater depth below.

The following sections discuss the development of the initial pool of items. The practitioner interview process itself is then discussed. Tables 5.3 through 5.9 list the pool of items that was presented in the original practitioner interviews, their sources (if any), reasons for revisions, and the final items version of each scale.

Interdependence Items

Crafting a questionnaire scale to measure interdependence was a formidable task. Few survey items for measuring inter-unit transactional interdependence occur in the literature and these are generally domain-specific.

Wybo & Goodhue (1995) argued that in addition to concerning themselves with the characteristics and patterns of resources exchanged (e.g. the six dimensions of transactional interdependence identified by McCann and Ferry), researchers should measure perceptions of interdependence, as well. Following this advice, the investigator chose to develop scales both for transactional interdependence and for perceptions of interdependence.

Characteristics and Patterns of Resource Exchanges

Because an objective of the dissertation was the creation of a limited number of single factored scales, it was necessary to concentrate on only a few of the dimensions of transactional interdependence that were presented in the literature review. The researcher chose frequency of exchange and tolerance for slack because these dimensions already existed in a single-factored scale with known measurement properties (Wybo & Goodhue, 1995) . Wybo's two items were part of a three item scale that showed discriminant validity and a reliability (Cronbach's alpha) of 0.71. Presumably supplementing these two items (which required some rewording) with others would bring the reliability to 0.71 or higher.

Several scales (e.g. Mascarenhas, 1984)) include an item in which participants are asked to describe what portion of their total information or material flow fits within each of Thompson's 3 categories of interdependence. However, the researcher concluded that these entailed both too high a burden on the respondents and too much potential for error. Furthermore, translating the information into a usable score is problematic.

Perceptions of Interdependence

Rather than asking about characteristics of exchanges, items tapping perceptions of interdependence focus more directly on the definition of interdependence: *A condition in which actions taken within one unit affect the actions and work outcomes of another unit*. For the perceptions of interdependence scale, the researcher used Wybo's (1995) three item scale almost verbatim and supplemented it with several additional items. In Wybo's study, the scale had an alpha of 0.91 and showed evidence of discriminant validity.

Customization

The researcher reviewed the end-user participation (e.g. Bergeron, 1986; Doll & Torkzadeh, 1989; Franz & Robey, 1986; Gottschalk, 1999; Hwang & Thorn, 1999; Jarvenpaa & Ives, 1991; Leonard-Barton & D.K.Sinha, 1993; McKeen & al, 1994; Olson & Ives, 1981; Robey & Farrow, 1982; Sioukas, 1995) and IS maintenance (e.g. Swanson, 1999)) literature in hopes of finding scales that could be used to measure ERP customization. Neither search was fruitful, so the majority of items were written from scratch. However, the researcher did base one item on Doll & Torkzadeh's (1989) *perceived user involvement* scale. Doll estimated that this scale had a reliability of 0.92 and adequate construct validity. Yoon (1995) changed the response scale to agree/disagree (the type of scale used in this dissertation scale) and found the reliability to be 0.94.

Improvements in Coordination

Items that could be appropriated for this project could not be identified in the literature. However, the researcher conducted an earlier (unpublished) small scale survey in which the coordination benefits construct was measured with two items. The estimated Cronbach's alpha for these items was 0.72. The items also showed good evidence of discriminant validity. Therefore these items were included. Several additional items were written for the survey.

Response Variables

Goodhue (1998) developed scales for data accuracy and data relevance (4 items for data relevance and 3 items for data accuracy), each with reliability of approximately 0.83. Two of the three data accuracy items and all of the data relevance items were used in the survey after they were reworded somewhat to fit the ERP topic. One accuracy question could not be reworded satisfactorily Additionally, the researcher adapted two data accuracy items from Wang and Strong (1996). Although the Wang and Strong items were the result of several studies to establish the dimensions of data accuracy, no quantitative evidence of reliability and discriminant validity had been developed. Items for the local fit dimensions *time and resources* and *alternative systems*, as well as the construct *overall business impact,* were developed from scratch.

Table 5.3: Original Survey Items and Revisions Based on Practitioner Interviews

Gray-scale items are included on the final survey

	Construct: Data Accuracy	Source	Item Number-Final Version	Problem/Issue
Item on original version	There are accuracy problems in the ERP data that plant employees use or need (R)	1		There are always inaccuracies in production and inventory data so even a respondent who feels data accuracy is excellent will agree strongly with this item.
Revision	The information from the ERP system has numerous accuracy problems that make it difficult for employees to do their jobs		ACC1	

Item on original version.	[redacted]	[redacted]	[redacted]	Responses were inconsistent with others in scale. Several respondents stated they do not interpret *believable* in the same fashion as *accurate* or *true.* The statement, *the information that the ERP system provides to this plant is believable* also performed poorly.
Revision	[redacted]		[redacted]	
Item on original version	Plant employees generally accept the data they receive from the ERP system as true	2		Some plant employees will (unwisely) accept the data as true regardless of the level of data accuracy.
Revision	[redacted]		[redacted]	
Item on original and final versions (No revision)	[redacted]	[redacted]	[redacted]	

1 Modified from Goodhue's *data accuracy* scale
2 Modified from Wang and Strong's *data quality* proto-scale

Table 5.4: Original Survey Items and Revisions Based on Practitioner Interviews

	Construct: Use of Informal/Alternative Information Systems	Item Number-Final Version	Problem/Issue
Item on original and final versions (No revision)	[redacted]	[redacted]	
Item on original version	Plant employees depend on unofficial systems (such as excel spreadsheets or whiteboards) to get the information they need		Assumes ERP is designed to provide *all* information, which is not the case. Non-ERP systems are used *by design.*
Revision	[redacted]	[redacted]	
Item on original version	Plant employees do not need to use unofficial information systems (such as spreadsheets or logbooks) to		The word *not* makes the item confusing/ hard to answer on an agree/disagree scale

	supplement the information that ERP provides (R)		
Revision	[redacted]	[redacted]	
Not on original version. On revised survey only	[redacted]	[redacted]	
Item on original version	Plant employees use alternative systems (such as excel spreadsheets) to get information that they should be getting with from the ERP		Regardless of the quality of the ERP, a few recalcitrant employees will use informal or legacy systems to get information even though they *should* be getting the information from the ERP because it is indeed available from ERP
Revision	[redacted]	[redacted]	
Item on original and final versions (No revision)	[redacted]	[redacted]	

Table 5.5: Original Survey Items and Revisions Based on Practitioner Interviews

	Construct: Data Relevance	Source	Item Number-Final Version	Problem/Issue
Item on original and final versions (No revision	[redacted]	[redacted]	[redacted]	
Item on original version	It is difficult for plant employees to do their jobs effectively because some of the data they need is not available from the ERP system (R)	1		The word *not* makes the item confusing/ hard to answer on an agree/disagree scale
Revision	[redacted]	[redacted]	[redacted]	

Item on original version	The reports that are available from the ERP system are missing critical data that would be very useful to plant employees (R)	1		
Revision	[redacted]	[redacted]	[redacted]	
Item on original and final versions (No revision)	[redacted]	[redacted]	[redacted]	

1 Modified from Goodhue's *right data* scale

Table 5.6: Original Survey Items and Revisions Based on Practitioner Interviews

	Construct: Time & Resources Required to do tasks	Item Number-Final Version	Problem/Issue
Item on original and final versions (No revision)	[redacted]	[redacted]	
Item on original version	[redacted]	[redacted]	
Revision	Now that we have ERP it is more difficult to do work like purchasing and production control (R)		Difficulty is harder to interpret than time expended or productivity
Item on original version	[redacted]	[redacted]	
Revision	ERP has generally resulted in fewer hours worked for plant personnel, like buyers, planners, production supervisors		Unclear whether item refers to hours per person or total; also during or post implementation.
Item on original and final versions (No revision)	[redacted]	[redacted]	
	Construct: Significant Business Impact on Plant		
Item on original and final versions (No revision)	[redacted]	[redacted]	
Item on original version	As far as this plant is concerned, ERP has met important business needs		Even if the overall business impact on the plant is negative, the system may have met *some* business needs.

Revision	[redacted]	[redacted]	
Item on original and final versions (No revision)	[redacted]	[redacted]	
Item on original and final versions (No revision)	[redacted]	[redacted]	

Table 5.7: Original Survey Items and Revisions Based on Practitioner Interviews

	Construct: ERP Customization	Source	Item Number-Final Version
No revisions to any items in this scale	[redacted]	[redacted]	[redacted]
	[redacted]	[redacted]	[redacted]
	[redacted]	[redacted]	[redacted]
	[redacted]	[redacted]	[redacted]
	[redacted]	[redacted]	[redacted]

1 Based on items from Doll's *perceived end-user involvement* scale

Table 5.8: Original Survey Items and Revisions Based on Practitioner Interviews

Note: The survey also contains a set of parallel items that refer to *sales and distribution.*

	Construct: Perceptions of Interdependence	Source	Item Number-Final Version
No revisions to any items in this scale	[redacted]	[redacted]	[redacted]
	[redacted]	[redacted]	[redacted]
	[redacted]	[redacted]	[redacted]

	[redacted]	[redacted]	[redacted]
	Construct: Frequency of Exchange & Tolerance for Slack		
Not on original version. On revised survey only	[redacted]	[redacted]	[redacted]
All item on original and final versions (No revisions)	[redacted]	[redacted]	[redacted]
	[redacted]	[redacted]	[redacted]
	[redacted]	[redacted]	[redacted]
	[redacted]	[redacted]	[redacted]

1 Modified from Wybo and Goodhue's *perceptions of interdependence* scale
2 Modified from Wybo and Goodhue's *patterns and characteristics of interdependence* scale

Table 5.9: Original Survey Items and Revisions Based on Practitioner Interviews

Note: The survey also contains a set of parallel items that refer to *sales and distribution.*

	Improvements in Coordination *	Source	Item Number-Final Version	Problem/Issue
Items on original and final versions (No revisions)	[redacted]	[redacted]	[redacted]	
	[redacted]	[redacted]	[redacted]	
	[redacted]	[redacted]	[redacted]	
	[redacted]	[redacted]	[redacted]	

No revisions. Deleted from final version.	Because of ERP, this plant has been hurt by problems related to poor synchronization with these other plants (R)			Item is designed to measure presence amount of improvement. However, an absence of harm does not imply and improvement.
	ERP has harmed this plant's coordination with these other plants (R)	1		Same as above: Absence of harm does not imply and improvement.

1 From an earlier unpublished survey by Gattiker, Goodhue and Kwak. These two items had a reliability of approximately 0.72 and showed evidence of discriminant validity.

Operationalizing Differentiation

The literature review stated that differentiation is best assessed by comparing a plant to others within its ERP implementation on various product characteristics, manufacturing *process choice* characteristics, and manufacturing technologies employed. The ideal method would be to measure the level of each characteristic at each plant in the ERP implementation, compute an average and then compare the plant of interest to that average. However, researchers must often settle for less than the ideal. As discussed in this section, this project required compromises on both the number of criteria included and on the question format.

Deciding on the format of the scale was a matter of eliminating alternatives based on practical considerations until the best workable one was found. Requiring the participation of more than one informant (and thus more than one plant) per ERP implementation would make it impossible to obtain a sufficiently large sample given the resources available to the researcher. Asking a single informant to provide values for numerous characteristics for numerous plants would be burdensome and would likely result in poor reliability. Another alternative considered was a pair of questions for each characteristic: one for which the respondent would characterize his or her plant and a second in which he or she would report on the average plant. However, this method creates problems in identifying appropriate response scales and in computing difference scores. Moreover, it still imposes a considerable burden on respondents.

Therefore, the researcher determined that the best alternative is a single questionnaire item per characteristic. Each of these items asks the respondent to compare his or her plant to the average plant in the ERP implementation on a scale ranging from *much more* to *much less.* This format has several advantages. First, it requires only one question per dimension assessed. Second, it avoids asking for specific numbers (such as the number of layers in the bill of materials or the portion of products made to stock). The practitioner pretest confirmed the soundness of this approach: Interviewees stated that they felt confident reporting on other plants but also stated they could more accurately assess *general* levels of difference or sameness rather than providing hard numbers.

Even with this compromise, including all the product characteristics and dimensions of manufacturing process choice from the literature review would make the survey unacceptably long. Several criteria were employed for selecting which elements to include. First, a subset of items that is reasonably representative of the whole was selected. Next the researcher considered that the differentiation scale requires informants to compare their plant to the typical or average plant in their ERP implementation. This is cognitively more demanding than many other types of survey items because it requires a comparison. Moreover, it requires knowledge of the situation not just in a respondent's plant, but in other plants as well. Therefore, criteria were chosen from the list that would be easily known not just to an employee of the plant but to an employee of *another* plant in the same company. Furthermore, it is stylistically awkward and confusing to ask the responder to make a comparison between some things. For example, items asking a respondent to compare plant A with plant B on *the fixedness of routings* or *the obviousness of priority control* are awkward and thus might be easily be skipped or misinterpreted. On the other hand, it is not awkward to ask respondents to compare *amounts* or *numbers* of things, so dimensions that could be characterized this way were included.

Table 5.10 lists each dimension that was included and the item designed to tap it. The dimensions came from the review of the literature discussing manufacturing typologies and manufacturing strategy (Chapter 3). The items along with the scale and instructions are in Appendix B.

Table 5.10: Differentiation Items

Characteristic	Item on Survey
Product Volume	Number of units produced monthly *per* model or configuration or formulation.
Product Variety	Variety: The number of different model numbers, configurations or formulations produced
Number of Part Numbers in System	The number of different active part numbers or material code numbers, excluding finished goods part numbers or finished goods code numbers
Product Complexity	Product complexity: Number of levels in the typical bill of materials
MTO	The degree to which products are made to customer specifications, instead of to stock
Rate of Design Change	The average number of design changes per month
Rate of New Product Intros.	The number of new design introductions per month
Throughput Time	The average amount of time that passes between the time an order is put into production and the time it is completed
Need for Lot Control	The need to identify or segregate material by individual piece or lot rather than merely by part number
Technology	Amount of production activity dedicated to processing (blending, purifying, converting, etc.) as opposed to assembly or fabrication

Modeling the Conceptual Definition of Differentiation

For each of the dimensions in Table 5.10, the response scale runs from -4 *(extremely less)* to +4 *(extremely more).* The midpoint of the scale (zero) indicates no differences. In other words, the center of the scale reflects no differentiation, while moving away from this midpoint, toward either end indicates progressively higher differentiation. (Examining Section 3 of the survey itself in the appendix may make this more clear).For differentiation to affect an ERP implementation the researcher assumes that differences must be large. That is, small differences between a plant and its fellow plants are not expected to have negative effects on local fit. Only when a plant differs significantly from its peers is it expected that the imposition of a standard system will cause problems. In order to operationalize this notion, the researcher dichotomized each of the ten item scores (to either a one or a zero). Large differences are indicated by raw scores at either end of raw scale. Therefore, any raw item score between -4 and -3 or +3 and +4 was converted to a dichotomized score of one[2]--all other item scores were converted to zeros. (This is also shown in Table 5.11).

Table 5.11: Transformed Differentiation Scale (Primary Method)

Raw Score (Original Scale)	Transformed (Dichotomized) Score
-4	1
-3	1
-2	0
-1	0
0	0
+1	0
+2	0
+3	1
+4	1

Although the conceptualization and operationalization just discussed are considered the most appropriate, this dissertation will consider an alternative--one that is arguably more conventional. This is the conceptualization of differentiation as the *average* level of difference between the respondent plant and other plants across all ten dimensions. Operationalizing this also requires transforming the scale. The scale is "folded on its midpoint" into a one through five scale with one indicating no differentiation and five indicating extreme differentiation. The exact transformation is in Table 5.12.

[2] Because observations from the same plant were combined, fractional scores on any dimension/item could occur. Therefore, more precisely, the score is the count of scores

Regardless of whether the primary or alternative method is used, each of the ten indicator scores must be combined into a score for the differentiation construct. This is accomplished by simply summing the indicator scores (and dividing by the number of indicators for the alternative operationalization). Thus with the primary operationalization, the overall differentiation score can simply be thought of as a count of the number of dimensions on which the plant of interest differs significantly from its peers in its ERP implementation. In this case the maximum possible score is equal to ten and the minimum is zero[3]. With the alternative operationalization, the overall score is the mean of the ten indicator scores. The overall score could range from one to five.

Table 5.12: Transformed Differentiation Scale (Alternative Method)

Raw score (original scale)	Transformed Score
-4, +4	5
-3, +3	4
-2, +2	3
-1, +1	2
0	1

LISREL is often used to combine indicator scores into an overall construct score (in fact, it is used this way for other constructs in the dissertation). However the researcher had to create the construct score (as described in the previous paragraph) and specify it to LISREL because the differentiation indicators are causal indicators. This is discussed in the following sections, after discussion of reliability for the construct.

Reliability and TD Calculation

LISREL incorporates reliability in estimating a model's goodness of fit to the empirical data a researcher provides. However, since a single indicator is used for differentiation in the LISREL model, the program cannot compute the reliability for the

between -4 and -3 and between +3 and +4.

[3] One item was dropped as a result of the analysis of measurement validity (described later) so there were ultimately nine items and a maximum possible dichotomized score of nine.

differentiation construct. Therefore the researcher estimated the reliability of the differentiation scale (using SPSS's Cronbach's alpha routine) and he specified this estimate to the LISREL program according to the single indicator method (Vandenberg & Scarpello, 1990). Using this method the researcher specifies the variance of the indicator measurement error (theta delta or TD) for the differentiation indicator and the relationship between the indicator and the construct (λ). Both TD and λ are based on the reliability as follows:

$\lambda = \sqrt{\alpha}$

$TD = (1 - \alpha) \times$ scale variance

The reliability was calculated as Cronbach's alpha (or α) for the nine differentiation indicators taken together. The researcher used the original 1-9 scale, (with zeros, or *don't know* responses, treated as missing values) because this untransformed scale has more information than the folded scale.[4] The reliability of either of the transformed scores described above could not be higher than this estimate. It may be lower, but, since lower reliabilities *increase* statistical significance in LISREL, the estimate is a conservative one.

The variance was calculated based on the folded scale that is actually used in the structural analysis. Because the variance depends on which of the two methods are used to score differentiation (discussed above), there are two variance estimates and thus two TD estimates.

The sensitivity of the causal model to various reliability estimates is described in the next chapter. In general, the model is insensitive to changes in reliability.

Causal Versus Effect Indicators

Several decisions had to be made about scoring the differentiation construct because the indicators of differentiation are *causal* (also known as composite or formative), rather than the more traditional *effect* indicators. When causal indicators are

[4] Taken together, the 9 indicators had a reliability (Cronbach's alpha or α) of 0.74.

used some of the usual assumptions made in assessing measurement validity are not valid (Bollen, 1991). An effect indicators' score is caused by a latent variable (and error). We expect that a change in the latent variable will cause a *simultaneous* change in all of the effect indicators intended to measure it. On the other hand, instead of being influenced by a latent variable, values of causal indicators determine the value of the latent variable. When one causal variable increases, thus creating an increase in value of the latent variable, we do *not* expect simultaneous increases in the other causal variables measuring the latent variable. In other words, for a single latent variable, we expect to observe high correlations or covariance among effect indicators, but causal indicators may have no correlation with one another (Bollen, 1991). Table 5.13 sums up some of the differences between the two types of variables.

Table 5.13: Overview of Effect Versus Causal Indicators

Effect Indicators	**Causal Indicators**
Change in response to changes in the state of the construct	Create the state of the construct
Vary simultaneously with a change the construct	*Ceteris paribus*, a change in any one indicator changes the state of the construct
Ideally, correlate perfectly with one another	Need not correlate with one another

Differentiation Indicators as Causal

The differentiation construct is conceptualized and defined as being caused by individual differences on a number of dimensions, where there is no expectation that all the dimensions will be correlated. In other words, the differentiation indicators *cause* the construct. Differentiation is *caused by* differences between manufacturers in characteristics like product complexity, need for lot control, rate of new product introductions, product variety, and so on, which are the differentiation indicators in this study. Furthermore, the indicators do not change simultaneously upon a change in any indicator or a change in the underlying latent variable. This criterion is posited by Bollen & Ting (2000), who note that a common method for establishing whether indicators are causal or effect is to perform "mental experiments" where the researcher envisions changes in a latent variable and then imagines whether *all* of the indicator variables will change in response. Although some of the differentiation variables used here will move together some of the time, we would not expect them all to co-vary most of the time. For example, the need for lot control can be just as great in an environment with low product complexity, such as pharmaceutical ingredients, as it is in an environment with higher product complexity, such as aircraft electronics. Further, examination of the correlation matrix of the differentiation indicators (Table 6.20, Chapter 6) shows generally low correlations and numerous insignificant ones.

Modeling Causal Indicators in Structural Equation Models

Constructs measured with causal indicators require an "alternative" to the classical measurement model in which in indicator score (x) is a function of a latent variable plus error such that[5]:

$$x=\lambda\eta + \varepsilon \qquad (1)$$

When indicators cause the state of the latent variable the model takes the form (Bollen, 1991):

$$\eta=\gamma_1 x_1 + \gamma_2 x_2 + \ldots + \zeta \qquad (2)$$

Since there is no theoretical reason for assuming that the weight should differ from one another (i.e. $\gamma_1=\gamma_2=\ldots$), the simple count of extreme item scores (-4, -3, +3, +4) was used as the primary operationalization. The mean of the "folded" item score was used as the alternative operationalization. The values actually specified for γ and the error estimate were assigned based on the estimated reliability of the indicators as discussed above.

Several other methods exist for modeling causal indicators in structural equation models. However, these are not feasible for this study's causal model and operationalizations. Jeffrey Edwards of the University of North Carolina Department of

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[5] In LISREL notation, a *y*, not an *x*, would normally be used here.

Sociology suggested an approach in a personal communication. This model identifies the formative latent variable by fixing one of the path coefficients to or from it to one. However, this method did not allow the identification of the interaction term (differentiation X customization).

Bollen (1989) suggests another method. However it requires the causal indicators to be supplemented with at least one effect indicator. By contrast, effect indictors for the differentiation latent variable were not included in the current study.

Interactions

The research model contains three interactions. The investigator created a latent variable for each interaction. Each interaction has a single manifest variable, which is the product of the two scale means corresponding to the latent variables that comprise the interaction. All indicator scores were centered first. For example, the researcher calculated a *plant interdependence X plant coordination improvement* interaction score for each observation by multiplying the mean of the observation's *plant interdependence* indicators by the mean of its *plant coordination improvement* indicators. This required reverse scoring the customization scale so that high scores on both customization and differentiation would have the same hypothesized effect. All indicator scores were centered before computing interactions.

Reliability of each interaction term is the product of the scale reliabilities (Cronbach's alpha computed using SPSS) of each main effect involved in the interaction (Jaccard, Turrisi & Wan, 1990). For example, the researcher calculated the reliability for the *plant interdependence X plant coordination improvement* interaction by multiplying the reliability of the *plant interdependence* scale by the reliability of the *plant coordination improvement* scale. Error variances (theta delta terms) were computed based on the reliability according to the single indicator method discussed above. Model sensitivity to these reliability estimates is discussed in Chapter 7.

Pre-testing And Refinement Based On Practitioner Interviews

The researcher conducted individual face-to-face interviews with nine practitioners in order to identify possible problems with the questions and to give a preliminary sense of the construct validity of the instrument. All interviewees were employees in manufacturing plants in the Athens, Georgia area. Interviewees' job functions were representative of those to whom the survey would later be mailed. Interviewees' job titles included plant manager, materials manager, purchasing manager, production supervisor, warehouse manager, buyer and planner. Five plants, representing a wide variety of manufacturing contexts were included. Technologies employed included fabrication, assembly, molding, processing and packaging. Layouts included small batch, large batch, JIT and repetitive. The plants served business to business and consumer markets.

Each interviewee was asked to complete the questionnaire. The researcher was present during this time. However, interviewees were asked to behave as if they had received the survey in the mail. The investigator asked interviewees to note any items which they felt were confusing or vague or that they did not know how to answer. Additionally, the researcher sat where he could observe the respondent (and the respondent's answers) as the subject filled out the survey. Using his own color-coded copy of the questionnaire, the researcher could identify questions that the respondent answered inconsistently (i.e. answers on two questions intended to measure the same thing should be similar). The researcher and the participant then discussed items that the participant felt were problematic as well as those for which the participant's responses lacked internal consistency.

The interviewees were asked to comment on the adequacy of the items representing various constructs and whether or not those constructs captured the issues practitioners felt perceived as important *vis a vis* ERP. In general, interviewees expressed the sentiment that the items captured the content represented by the constructs. When the investigator asked more generally if the questionnaire "left out anything important," several practitioners expressed surprise that the questionnaire did not deal with user training issues. While this underscores the importance of training and of implementation issues in general, these are beyond the scope of this study.

The researcher also looked for inconsistencies on the differentiation items (for example, firms that have lower volume than their peers should have higher variety). The researcher also questioned each interviewee about product and process characteristics at his facility and at other plants in his organization. The investigator compared this information to the written answers to the differentiation questionnaire items. Inconsistencies were discussed with practitioners to discover their causes.

The interview process was revealing. For example, approximately half of the items measuring customization, local fit, overall business impact were revised or completely replaced. Two of the nine original differentiation items were changed (one item was split into two) and several were reworded. Two of the interdependence/coordination improvement items were changed and one discarded. Many of the revisions were to replace vague or confusing wording. However, some key conceptual refinements were made, and these doubtlessly improved the quality of the instrument. Tables 5.3 through 5.9 (above) list the original items and the revisions and deletions along with the reason for each.

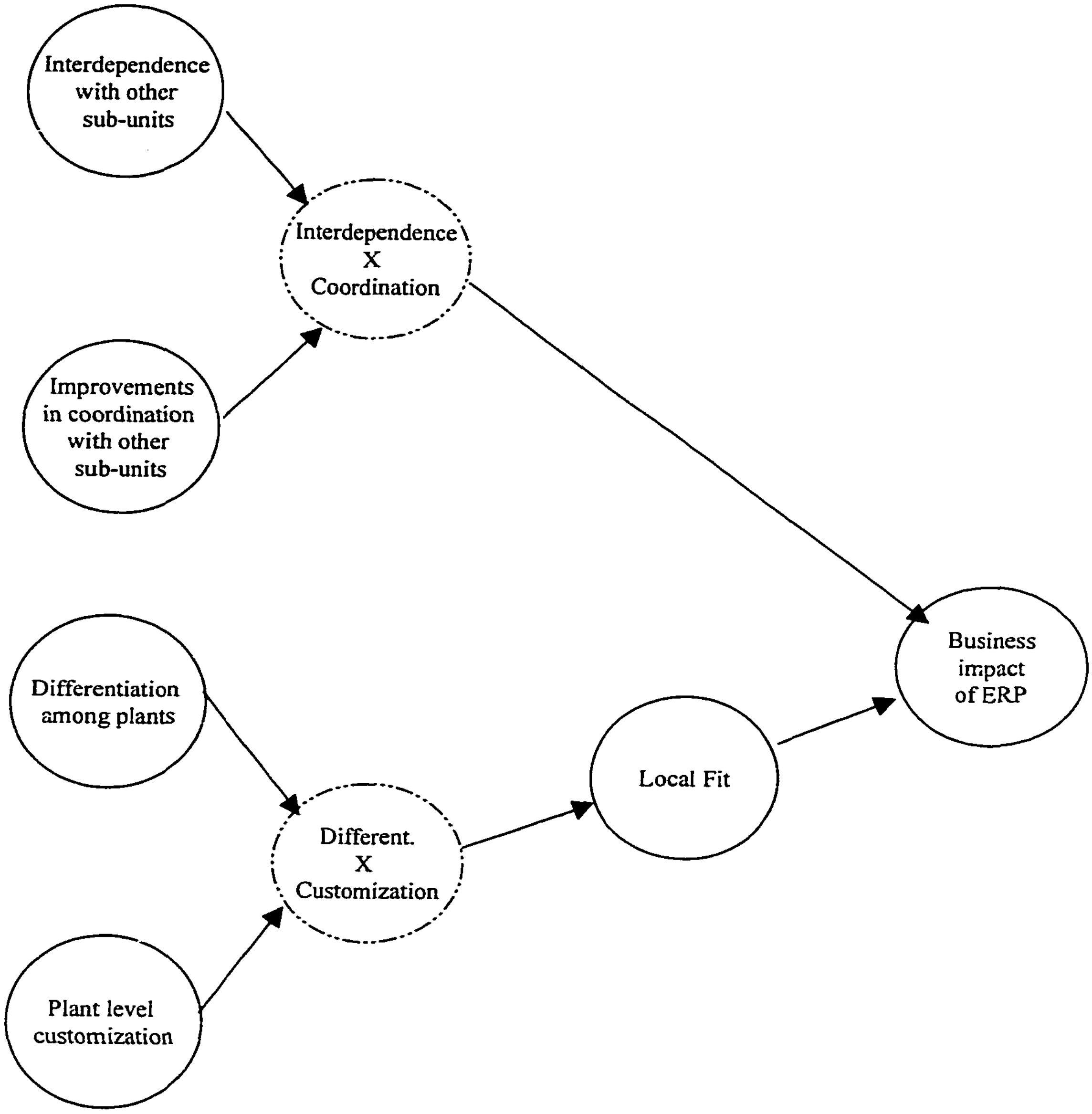

Figure 5.1: Intermediate Research Model

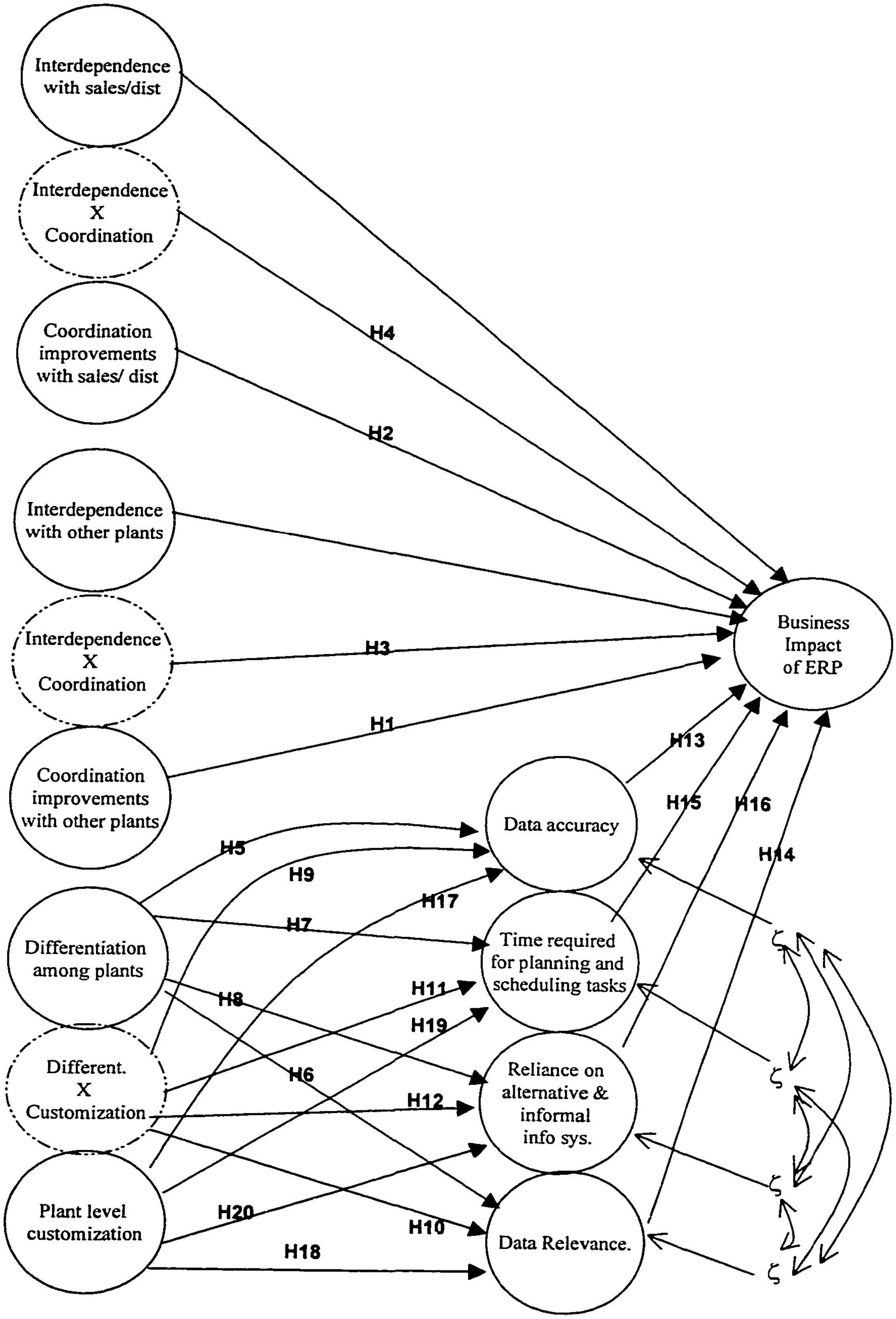

Figure 5.2: Final Research Model

CHAPTER 6

Survey Response and Quantitative Analysis of Measurement Validity

Overview

This chapter discusses the survey responses that were received. Then the establishment of measurement properties using survey responses is discussed for all constructs in the conceptual model presented in the previous chapter. Next, because not all ERP implementations represented in the study have the same characteristics, some respondents were instructed to skip sections dealing with some characteristics. The treatment of this is reviewed. Figure 6.1 presents a chronological overview of the data analysis steps.

Survey Response

Table 6.1 lists the sample frames that were employed. These were introduced in Chapter 2. The sources have various shortcomings because they contain potential respondents who are not appropriate. This makes it difficult to state a meaningful response rate, and it required substantial culling of the surveys received. The reader may recall from Chapter 2 that the target population is manufacturing plants running ERP systems. The target respondent was an employee working in manufacturing planning and control (as it is defined in Chapter 1) in the plant.

By contrast, all frames that the researcher used contained non-manufacturing business organizations (e.g. services, consulting firms, software companies). Some of these could be culled out of mailing lists that were provided; however, some slipped through. No screening of email discussion groups (or list-serves) was possible. Even among the manufacturing plants represented, all of the frames contained plants that were in the planning and implementation stages of ERP, as opposed to running ERP, and

Table 6.1: Source of Final Sample

Sample Frame	Solicitation Medium	Survey Medium	Sent out	Un-deliv.	Net sent	Usable	Non mfg job	> 6 years	Final Sample
APICS Member List 1	US mail	booklet	642	34	608	39	1	1	37
APICS Member List 1	US mail	web	266	7	259	23	3	3	17
APICS Member List 2	US mail	web	775	40	735	41	3	3	35
APICS Member List 3	US mail	booklet	100	7	93	9	0	0	9
APICS Member List 3	US mail	web	100	8	92	1	0	0	1
Quest Member List	e-mail individual	web	1230	135	1095	43	29	1	13
APICS Discussion Groups	e-mail listserve	web	4800	n/a	4800	71	20	3	48
ASUG Purcasing SIG Discussion List	e-mail listserve	web	300	na	300	11	7	0	4
ASUG MPE SIG Meeting	Announced at / pick-up at meeting	booklet	25	n/a	25	4	3	0	1
Misc.	hand / US mail	booklet	35	n/a	35	13	0	0	13
Total			8258		8027	255	66	11	178

the APICS frames contained plants that were neither running ERP nor in the planning and implementation stages. In other words, they were not even considering ERP.

Problems with inappropriate respondents existed as well. Many individuals on all of the lists provided are not employed in the manufacturing planning and control area. Other fields represented include MIS and engineering. Furthermore some people have multi-plant responsibility.

All of these problems existed with all the frames to some degree, but strengths and weakness of each can be identified. The APICS member lists generally represent manufacturing businesses, but many are not running ERP systems and many employees are above the plant level. The ERP user groups generally represent organizations running ERP systems, but many are non-manufacturing and the majority of individuals do not appear to be working in manufacturing planning and control jobs. Representing a large number of consultants, non-MPC employees, service businesses and companies not running ERP live, the APICS list-serves were the most problematic source.

These factors presumably affected the response rates from all sources. The survey invited individuals representing plants to respond to the first two items regardless of whether they were running ERP. Nevertheless, individuals who represent an organization that is outside the sample frame (because of implementation status or being non-manufacturing) would probably be less likely to respond to the survey. The same is likely true of individuals who are not target respondents.

In addition to affecting the response rate, problems with the wide sample frames also resulted in some culling of the surveys that were actually received. For example, completed surveys were received from service businesses. These issues are discussed below.

Surveys were omitted from the final sample for a number of reasons. Many surveys, especially from the web, were incomplete and were not used. As mentioned, the second questionnaire item identifies plants that are not running ERP *live*. Approximately 150 surveys received fell into this category and were discarded. Surveys from non-manufacturing businesses were also omitted. Furthermore, some respondents had multi-plant responsibility. If these respondents did not identify a particular plant about which they were responding, the survey was disqualified. Furthermore, since it was necessary to identify when multiple surveys were received from a single plant, surveys from list-serves that did not include plant and company name were discarded. The APICS list-serves are available to people world-wide. Since a major purpose of the research was scale development, the researcher thought it prudent to omit responses from individuals whose plant location or domain name was from a non-English speaking country (The researcher monitors several of the lists and has noted the extremely limited English proficiency of many participants).

Culling surveys for the reasons just listed left 255 surveys. From this group 66 more were eliminated because they were completed by informants who were not employed in manufacturing planning and control jobs. Eleven additional surveys were eliminated because they describe computer systems that were more than six years old. This left 178 cases. Several of these cases were combined in the structural analysis (but not the exploratory and confirmatory factor analysis) because they were from the same plant. This yielded 173 cases for the structural analysis.

Beyond culling surveys based on system age and the components in the system, the investigator relied on the respondents' judgement regarding whether a computerized business system at his or her facility was an ERP system. To facilitate this judgement, page 1 of the survey provided a definition of ERP and the names of some of the more popular ERP systems. Tables 6.2 through 6.6 present some characteristics of the plants in the final sample, their informants and their ERP systems.

Exploratory Factor Analysis

EFA has two purposes in this study. First, it provides initial confirmation or disconfirmation of the hypothesized measurement model structure. Second, it suggests potential problems with or alternatives to the hypothesized measurement model. The hypothesized measurement model and any "suggestions" posited by EFA are later tested using Confirmatory Factor Analysis in order to arrive at a valid measurement model for use in testing the structural model.

Table 6.2: Frequency Breakdown by Company Size in Employees

Company Size	Freq.	Percent of total
1-500	50	28
500-1,500	22	12
1,500-5,000	24	14
5,001-10,000	28	16
10,000+	52	29
missing	2	1

Table 6.3: Frequency Breakdown by Industry

Industry	Freq.	Percent of total
Automotive	8	5
Chemicals	10	6
Consumer	7	4
Defense/Aero.	10	6
Electro-Mechanical	21	12
Electronics	30	17
Food	6	3
Job Shop	9	5
Other Discrete	60	34
Pharmaceutical	1	1
Other Processing	7	4
Textile	4	2

Table 6.4: Frequency Breakdown by Respondent's Job Function

Job Function	Freq.	Percent of total
Production Supervisor	4	2
Scheduler/Planner/Buyer	28	16
Materials Manager/ Purchasing Manager	74	42
Operations Manager	31	17
Plant Manager	15	8
Other Manufacturing Job	19	11

Table 6.5: Frequency Breakdown by Components Included in Plant's ERP System

Function or Component	Freq.	Percent of total
MRP/Scheduling	168	94
Purchasing	173	97
Shop Floor	138	78
Sales & Distribution	148	83
Accounting	169	95
Human Resources	46	26
Engineering	89	50

Table 6.6: Frequency Breakdown by Plant's ERP Package Vendor

Package	Freq.	Percent of total
SAP	46	27
JD Edwards	26	15
Baan	14	8
Oracle	14	8
QAD	9	5
Peoplesoft	7	4
Other	77	43

Several factor analyses were performed using the principal components method. Although the constructs meet the conceptual criterion (correlated factors) for oblique rotation, the more conservative orthogonal rotation (SPSS Varimax rotation) was used.

Because response variables are expected to co-vary with their predictors, variables were divided into several groups and independent factor analyses were performed on each group. Group 1 (the "dependent" group) consisted of variables intended to measure data accuracy (ACC prefixed variables), data relevance (REL), time required for planning and scheduling (TIME), and reliance on informal systems (ALT). Group 2 (the "independent" group) consisted of variables intended to measure perceptions of interdependence (P_GI and S_GI), coordination improvements (P_CB and S_CB prefixed variables), and plant level customization (CUSTOM). Finally, variables measuring *overall business impact,* the model's ultimate response variable, were placed in a third group. The reader may wish to refer to Table 6.7, which lists the items sorted by construct.

Table 6.7: Items on Final Version of Survey

		Data Accuracy
acc1	R	The information from the ERP system has numerous accuracy problems that make it difficult for employees to do their jobs
acc2		The information that the ERP system provides to employees in this plant is accurate
acc3		The data plant employees receive from the ERP system is true
acc4		The ERP data that plant employees (planners, supervisors, etc.) use or would like to use are accurate enough for their purposes
		Use of Alternative and Informal Information Systems
alt1		Since we implemented ERP, plant employees have not had to resort to alternative systems (such as spreadsheets or homegrown PC systems) in order to get the information they require
alt2	R	To get the information they need, plant employees depend on unofficial systems (such as spreadsheets or homegrown PC systems) instead of ERP
alt3	R	Employees use unofficial systems (such as spreadsheets or homegrown PC systems) for needs the ERP system was intended to fulfill
alt4		ERP provides the bulk of the information this plant needs
alt5	R	Plant employees must use alternative/informal systems (such as spreadsheets or homegrown PC systems) to get information they should be getting from ERP
alt6	R	If plant employees could not substitute informal systems (such as spreadsheets or homegrown PC systems) for ERP, working effectively would be more difficult
		Data Relevance
rel1		The data that the ERP system provides is exactly what plant employees need to carry out their tasks
rel2	R	It is difficult for plant employees to do their jobs effectively because some of the data they need is missing from the ERP system
rel3	R	The data accessible from the ERP system lacks critical information that would be useful to plant employees
rel4		The ERP system provides the right data to meet plant employees' needs

Time Required for Materials and Production Management Tasks		
time1		Since we implemented ERP, plant employees such as buyers, planners and production supervisors need less time to do their jobs
time2		ERP saves time in jobs like production, material planning and production management
time3	R	Now that we have ERP it is more time-consuming to do work like purchasing, planning and production management
time4		ERP helps plant employees like buyers, planners, and production supervisors to be more productive
Overall Business Impact of ERP on the Plant		
impact 1		In terms of its business impacts on the plant, the ERP system has been a success
impact 2		ERP has seriously improved this plant's overall business performance
impact 3	R	From the perspective of this plant, the costs of ERP outweigh the benefits
impact 4		ERP has had a significant positive effect on this plant
ERP Customization To Meet Local Plant Needs Note: As discussed below, these items were reverse scored before being input into the *causal* model so that high scores refer to a lack of customization. This allowed high scores on the differentiation-customization interaction to indicate high differentiation and low customization.		
custom 1		The ERP system was altered to improve its fit with this plant
custom 2		The ERP implementation team was responsive to the needs of this plant
custom 3		Individuals from this plant had a great deal of influence on how the ERP system was set-up.
custom 4	R	A standard version of the ERP software was implemented without changes being made to fit the particular requirements of this plant
custom 5		When the ERP system was being implemented in this plant, the package was changed to better meet the needs of this plant
Frequency and Tolerance for Slack in Exchanges with other Plants (Survey contains a set of parallel items dealing with sales and distribution instead of plants)		
p_fs1		To be successful, this plant must be in constant contact with these other plants

p_fs2		If this plant's communication links to these other plants were disrupted things would quickly get very difficult.
p_fs3		Frequent information exchanges with these other plants are essential for this plant to do its job
p_fs4		In general, how long can information received from or provided to these plants be delayed before operations at your plant are seriously affected?
p_fs5		What time period best describes the frequency with which your plant needs to send or receive information to/from these plants?
Perceptions of Interdependence with other Plants (Survey contains a set of parallel items dealing with sales and distribution instead of plants)		
p_gi1		Close coordination with these other plants is essential for this plant to successfully do its job
p_gi2		Information provided by these other plants is critical to the performance of this plant
p_gi3	R	This plant works independently of these other plants
p_gi4		The actions or decisions of these other plants have important implications for the operations of this plant
Improvements in Coordination with other Plants (Survey contains a set of parallel items dealing with sales and distribution instead of plants)		
p_cb1		ERP helps this plant adjust to changing conditions within these other plants
p_cb2		ERP has improved this plant's coordination with these other plants
p_cb3		ERP makes this plant aware of important information from these other plants
p_cb4		ERP helps this plant synchronize with these other plants

Group One

The hypothesized group 1 measurement model is depicted in Figure 6.1. With the exception of the variable ALT4 and the variables intended to measure data relevance (REL), group 1 EFA supported the hypothesized factor structure. Factor analysis using pairwise deletion produced 3 eigenvalues over one, all of which are clearly interpretable. Table 6.8 shows that variables intended to measure ACC, ALT and TIME all load on the appropriate factors, with the exception of variable ALT4. Furthermore, with the exception of ALT4 and the REL variables, the difference between the each variable's primary loadings and all other loadings is greater than .10.

Table 6.8: Group One Factor Analysis Results

(Values below .15 are not printed)

	1	2	3
ACC1R	.213	**.682**	.229
ACC2	.218	**.839**	.190
ACC3	.243	**.827**	.174
ACC4	.237	**.760**	.270
REL1	.399	.359	.453
REL2R	.627	.516	
REL3R	.561	.420	.212
REL4	.466	.582	.304
ALT1	**.544**	.166	.340
ALT2R	**.781**	.255	
ALT3R	**.757**	.253	.218
ALT4	**.290**	.430	.559
ALT5R	**.812**	.214	.312
ALT6R	**.783**		.229
TIME1	.275	.224	**.769**
TIME2	.158	.209	**.818**
TIME3R	.281		**.748**
TIME4	.153	.434	**.678**

By contrast, the loadings for most individual data relevance (REL) variables are not as clean. Two of the four REL variables load on the same factor as ALT. This makes conceptual sense and suggests that there is some redundancy between the two. There are additional causes for concern regarding the REL variables. First, REL4 loads most highly on the factor associated with data accuracy and REL1 loads on the TIME factor. Third, the differences between each variable's highest and second highest loadings are not nearly as great for the REL variables as for the other variables in the analysis.

Dropping ALT4 did not change the behavior of the REL variables substantially. The researcher also tried dropping various data accuracy and time variables in attempt to cause the data relevance variables to load more cleanly. However this was not successful. Dropping the REL variables, in addition to ALT4, yields a clean solution (Table 6.9). When a four-factor solution is specified, the additional factor is not interpretable.

Table 6.9: Group One Factor Analysis after Removing Problem Variables

(Values below .15 are not printed)

	1	2	3
ACC1R	.225	**.736**	.233
ACC2	.221	**.857**	.182
ACC3	.253	**.841**	
ACC4	.239	**.742**	.265
ALT1	**.569**	.191	.302
ALT2R	**.791**	.275	
ALT3R	**.783**	.289	.193
ALT5R	**.831**	.229	.283
ALT6R	**.785**		.223
TIME1	.283	.245	**.762**
TIME2	.178	.206	**.815**
TIME3R	.296		**.765**
TIME4	.161	.429	**.690**

In sum, for group 1, EFA suggested investigating whether the following changes to the hypothesized measurement model result in a better fit:

- Drop the variable, ALT4
- Combine the constructs, data accuracy and data relevance, or omit the construct, data relevance

There were 18 variables in the factor analysis and 178 observations. As a result there were 9.9 observations per variable in the analysis. This meets commonly accepted criteria of 5 to 10 cases per variable.

Group Two

Group 2 (Table 6.10) contained the constructs based on interdependence with other plants and with sales and distribution as well as improvements in coordination with other plants and with sales and distribution. Observations that were single plant ERP systems or that excluded sales and distribution functions were instructed to skip items tapping these constructs. Therefore these observations were excluded from the group 2 exploratory factor analysis. Including these observations by basing the covariance matrix on pairwise deletion created a matrix that was not positive definite.

Table 6.10: Group Two Factor Analysis

(Values below .15 are not printed)

	1	2	3	4	5	6
P_FS1	**.892**					.154
P_FS2	**.750**					
P_FS3	**.851**					
P_FS4	**.639**	-.159			.561	
P_FS5	**.743**				.538	
P_GI1	**.884**					
P_GI2	**.883**					
P_GI3R	**.761**					-.186
P_GI4	**.831**	.249				
P_CB1	**.733**		.432	.164		.158
P_CB2	.499		**.663**			
P_CB3	.598		**.617**			
P_CB4	**.725**		.485			
S_FS1		**.871**	.172			
S_FS2		**.668**			.216	
S_FS3		**.767**	.317		.259	
S_FS4		.320			**.844**	
S_FS5		.304	.185		**.796**	
S_GI1		**.828**	.166			
S_GI2		**.810**	.205			
S_GI3R		**.679**	.204		.204	
S_GI4	.278	**.728**				
S_CB1		.362	**.747**			.207
S_CB2		.300	**.808**			.206
S_CB3		.310	**.804**		.227	
S_CB4		.208	**.843**		.176	
CUSTOM1				**.857**		
CUSTOM2			.345			**.757**
CUSTOM3						**.862**
CUSTOM4				**.882**	.181	
CUSTOM5				**.899**		

Figure 6.2 shows the group 2 measurement model as originally hypothesized. The group 2 factor analysis yielded six eigenvalues over one and a very interpretable solution (Table 6.10). However, the analysis also raised several issues.

The researcher hypothesized that interdependence with other plants would exhibit two dimensions and that interdependence with sales and distribution would evidence the same two parallel factors. These dimensions are frequency of exchange and tolerance for slack (FS) and perceptions of interdependence (GI). By contrast, the factor analysis suggests that, in fact, there is in one, not two, dimensions of interdependence with other plants, as well as only one dimension of interdependence with sales and distribution. In other words, for plants the FS and GI variables appear to be measuring the same underlying construct in the minds of respondents, and the same is true for interdependence with sales and distribution. This suggests using CFA to check whether the instrument can discriminate between perceptions of interdependence and tolerance for slack/frequency of exchange.

The items measuring improvements in coordination with sales and distribution (S_CB) formed a factor that is separate from items measuring interdependence with sales and distribution (S_FS and S_GI). By contrast, two of the items measuring improvements in coordination with *other plants* loaded with the factor that appears to be interdependence with other plants. The other two items loaded with the S_CB items. This suggests using CFA to check

- whether the instrument can discriminate between plant coordination improvements (P_CB) and sales/distribution coordination improvements (S_CB).
- whether the instrument can discriminate between interdependence among plants (P_FS and P_GI) and plant coordination improvements.

P_FS4 and P_FS5 loaded highly on the plant interdependence factor and factor five, which appears to be a "scale type" factor, while S_FS4 and S_FS5 loaded on factor five. These 4 questions are the only ones that do not use an agree-disagree scale. Their scale is in time (from "quarter" to "minute"). Thus factor five likely represents the type of response scale employed. This interpretation is buoyed by deleting P_FS4, P_FS5, S_FS4 and S_FS5, which produces a 5 factor solution identical to the original 6 factor one except that the *scale type* factor disappears. This suggests trying a *scale type* factor in CFA with the expectation that P_FS4, P_FS5, S_FS4 and S_FS5 would load significantly on both this factor and on the intended interdependence factor.

The CUSTOMIZATION variables split into two factors. Furthermore, the CUSTOMIZATION variables do not reduce to one factor when fewer factors are specified in SPSS. Closer examination of the items provides the explanation. Items CUSTOM1, CUSTOM4 and CUSTOM5 deal specifically with customization of the ERP package. By contrast, items CUSTOM2 and CUSTOM3 deal with the implementation process– more specifically with the relationship between the ERP implementation and the plant. This suggests using CFA to check the unidimensionality of the CUSTOM items.

Group Three

The ultimate dependent manifest variables (IMPACT) in the model are those measuring the construct overall business impact of the ERP system on the plant. Because they are expected to co-vary with other families of variables, these 4 variables were put into their own factor analysis. This analysis yielded one eigenvalue over one–evidence of unidimensionality of the *impact* construct.

Confirmatory Factor Analysis

Confirmatory factor analysis using the LISREL structural equation modeling program allowed testing of the hypothesized measurement model and testing of improvements suggested by the exploratory factor analysis. Table 6.11 shows items that were discarded based on the following analysis. All of these are discussed below. Appendix C presents the LISREL output for the group 1 and group 2 confirmatory factory analysis final models.

Evaluating Model Quality Using SEM

SEM provides several criteria for judging the model quality. Indicator loadings are estimates of the strength of the relationship between a questionnaire item and a latent variable. All indicator loading should be statistically significant.

LISREL also provides numerous goodness of fit indices. Measures of absolute fit indicates the degree of similarity between the covariance matrix produced by the data and the one implied by the model (Hair, 1998). The chi square statistic is the most common of these measures. Since good models are characterized by small differences between actual and predicted matrices, *small* chi squares (with *in*significant p-values) are desirable. However, for evaluating structural equation models, the chi square test has several flaws including sensitivity to sample size. Therefore, authorities encourage researchers to use other indicators of fit. (Hair, 1998; Vandenberg & Lance, 2000). In this dissertation, none of the models had insignificant chi-squares, so they are not reported for the purposes of determining absolute model fit. However, chi squared difference tests are employed to compare nested models, a technique which is discussed later.

Table 6.11: Items Deleted from Measurement Model After CFA

Survey Item		Reason for Deleted
alt4	ERP provides the bulk of the information this plant needs	Insufficient alignment with construct definition. Loaded higher and with more significance with ACC, REL and TIME constructs than with ALT construct in alternative CFA models.
rel1	The data that the ERP system provides is exactly what plant employees need to carry out their tasks	Instrument does not adequately discriminate between data relevance and the other local fit constructs.
rel2	It is difficult for plant employees to do their jobs effectively because some of the data they need is missing from the ERP system	
rel3	The data accessible from the ERP system lacks critical information that would be useful to plant employees	
rel4	The ERP system provides the right data to meet plant employees' needs	
custom 2	The ERP implementation team was responsive to the needs of this plant	Insufficient alignment with construct definition. Do not measure same content as other items in the customization scale.
custom 3	Individuals from this plant had a great deal of influence on how the ERP system was set-up.	
p_fs3 s_fs3	Frequent information exchanges with these other plants are essential for this plant to do its job	Item does not discriminate between frequency and tolerance for slack construct and coordination improvement construct.
p_fs4 s_fs4	In general, how long can information received from or provided to these plants be delayed before operations at your plant are seriously affected?	Errors of measurement not independent of FS5 probably due to question order on survey.
p_fs5 s_fs5	What time period best describes the frequency with which your plant needs to send or receive information to/from these plants?	Errors of measurement not independent of FS4 probably due to question order on survey.
p_gi1 s_gi1	Close coordination with these other plants is essential for this plant to successfully do its job	Errors of measurement not independent of FS1 probably due to question order on survey.

Based on their review of the literature, Vandenberg and Lance (2000) recommend 2 absolute fit measures: Root Mean Square Error Of Approximation (RMSEA) and

Standardized Root Mean Square Residual (SRMR). They recommend that RMSEA not exceed 0.08 and the SRMR not exceed 0.10.

By contrast, incremental fit measures compare the improvement that the specified model makes over a *null* model, such as a model consisting of one latent variable with all the model's indicator variables linked to it. Vandenberg and Lance recommend the Non-normed Fit Index (or Tucker Lewis Index) and the Relative Non-Centrality Index with a minimum acceptable value of 0.90 for both.

Group One

The hypothesized group 1 measurement model was tested using LISREL. Figure 6.3 shows the modifications to the hypothesized model that were made based on CFA. As shown in Table 6.12 column 1, all four fit indices for the hypothesized model were sufficient, with the exception of the RMSEA, which was .008 over the acceptable threshold. Furthermore, all indicator loadings were above the .05 significance level (t=1.96). In fact, the minimum t-statistic was above 6.0. 178 observations were used for this analysis. The following sections address the issues raised by EFA.

Table 6.12: Goodness of Fit Statistics Group One Measurement Model

		Target	1	2	3	4
1. Non-normed Fit Index (AKA Tucker Lewis Index)	NNFI TLI	.90	.897	.921	.886	.944
2. Root Mean Squared Error of Approximation	RMSEA	$\leq$0.08	.091	.080	.098	.076
3. Relative Non-Centrality Index	RNI	.90	.913	.935	.903	.955
4. Standardized Root Mean Square Residual	SRMR	$\leq$0.10	.067	.053	.070	.051

Does item ALT4 Measure The Construct Use of Alternative and Informal Systems?

Comparing ALT4 to the other items intended to measure the ALT construct does suggest that ALT4 is tapping a different, albeit related, concept. Clearly ALT4 asks the respondent about whether most of the data he or she requires comes from ERP. On the other hand, the remaining ALT items get at the need to substitute or augment in order to get *some* key data, regardless of the *proportion* of the required data that ERP does provide. The items ALT1, 2, 3, 5 and 6 are more consistent with the construct definition than ALT4. Therefore conceptual reasons exist for dropping ALT4. CFA provides empirical support for this notion.

To investigate the concerns that EFA raised about ALT4, an alternative model (model 2) was run with ALT4 deleted. Improvements in fit of at least of .02 are sometimes used as the criterion for model improvement (Vandenberg & Lance, 2000). Model 2 improves the Relative Non-Centrality Index and the Non-normed Fit Index by over .02. This provides some empirical justification for dropping the variable. Additionally, the researcher ran 3 alternative models. Instead of being an indicator of the ALT construct, ALT4 was modeled as an indicator of the construct TIME in the first of these models; of REL in the second; and of ACC in the third. ALT4 loaded higher and with greater significance in all 3 of these alternative models than it did in the hypothesized model. These findings suggest that ALT4 is not successfully measuring the construct *use of alternative systems.* In light of the conceptual and empirical evidence ALT4 was dropped.

Does The Instrument Measure Data Relevance As A Separate Concept From The Other Local Fit Measures?

Exploratory factor analysis of the local fit measures (group 1 above) suggested a three factor solution. Variables measuring the local fit constructs data accuracy (ACC), use of alternative systems (ALT), and time (TIME) each load on "their own" factor. However, two data relevance (REL) items loaded with ALT, one with ACC and one with TIME. This suggests respondents consider REL and ALT to be the same concept or that REL is not a concept distinct from ACC, ALT and TIME that in the minds of respondents.

Conceptually, it is easy to see how respondents might not distinguish between the idea of data relevance and the use of alternative or informal systems. If the ERP system does not "provide the right data to meet plant employees' needs," or if "some of the data they need is missing from the ERP system," which are representative wording of the data relevance items, then it is likely (perhaps mandatory) that employees will turn to alternative systems.

Therefore, a chi squared difference test was run to determine whether combining the constructs Data Relevance and Use of Alternative Systems was warranted. This test compares the model fit to the data of two "competing" models. In this case, the target model contains the constructs Data Relevance and Use of Alternative Systems as hypothesized. In other words, the model consists of two latent variables (REL and ALT). The REL indicators (REL1, REL2R, REL3R, and REL4) are linked to the REL latent variable and the ALT indicators are linked to the ALT latent variable (See Figure 6.4). In the alternative model, the correlation between the two constructs is fixed at one. (Conceptually this is the same as a one-construct model with all indicators loading on the same construct). Both models produce a chi square statistic and an associated number of degrees of freedom. The alternative model is *nested* in the target model. In other words, the alternative model is a more restrictive version of the target model. Because they are nested, the difference between the models' chi squares and df's is itself a chi square statistic with an associated df. This difference in chi squared has its own level of significance. If there is no significant difference then the more parsimonious alternative model is accepted at the expense of the target model. (Note that in structural equation models larger chi squares indicate poorer fits and more degrees of freedom indicate more parsimony). If the difference is significant, the alternative model is rejected in favor of the target model.

The chi square statistics for the REL-ALT models are in Table 6.13. The alternative model is a worse fit and this worsening is significant (chi square=18.0, df=1, $p<.01$), which provides no justification for combining the REL and ALT constructs.

Even though the chi square test proves the REL questions are not collectively measuring the concept ALT, EFA still raises questions about REL because the REL indicators fail to form a separate factor from the other local fit items and because they fail to load on any single factor. The researcher ran model 3– a 3-factor CFA model in which the REL indicators are assigned to the constructs, ALT, ACC, and TIME according to the way they loaded in EFA. The significances of these loadings are almost identical to model 2, in which the REL items load on their own construct as originally hypothesized. On the other hand, model 2's fit exceeds that of model 3. Finally, the researcher ran model 4 which differs from model 2 only in that it lacks the REL construct and its indicators. Compared to model 2, model 3 improves the Relative Non-Centrality Index and the Non-Normed Fit Index by .02. These are large differences.

Table 6.13: Chi Square Difference Test for Data Relevance and Use of Alternative Systems

	Target	Alternative	Difference
Chi sqr.	43.1	82.6	39.5
df	26	27	1
Signif.			p<.01

Ultimately the researcher dropped the REL construct and its indicators. As discussed above, the empirical evidence of discriminant validity is mixed. Conceptually, the items 2, 3 and 4 assume that the ERP system is designed to provide all or most of the information users need. As discussed in the practitioner interview section, interviewees pointed out that this is often not the case. Instead, the system must be judged with reference to functions it was intended to fulfill and data it was intended to provide. The researcher incorporated this modification into the revised ALT items but did not do so for the REL items. Additionally, REL may be subsumed in part by ALT and TIME. When data relevance is lacking, users will turn to other systems (or invent them) or simply work longer and harder. This is confirmed by the highly significant loadings of REL items on the ALT and TIME constructs in CFA, although the data do demonstrate high discriminant validity between ALT and the REL items considered together. Finally, there is the issue of parsimony, without REL, the instrument has 3 local fit constructs (TIME, ACC and ALT) with rock solid measurement properties. The ratio of questionnaire items to respondents is a concern, and including REL reduces it while providing questionable benefits.

Group Two Confirmatory Factor Analysis

To avoid identification problems in the covariance matrix, this analysis included only observations from plants whose ERP systems included multiple plants and sales and distribution. This file contained 98 cases. Figure 6.5 shows all of the refinements that were made to the group 2 measurement model.

Column 1 (Table 6.14) gives the fit indices for the hypothesized model. While the fit is poor, all indicator loadings are significant except CUSTOM2 and CUSTOM3. Fortunately, EFA suggested some actions that might improve the fit.

Do the Customization Items Measure a Single Construct?

EFA suggested that the CUSTOMIZATION variables CUSTOM2 and CUSTOM3 actually measured a different concept than CUSTOM1 CUSTOM4r and CUSTOM5. This notion is reinforced by the non-significant indicator loadings of variables CUSTOM2 and CUSTOM3 in the initial CFA. Because the evidence of this problem is so strong, the researcher investigated it first in the hope that confirming and fixing this problem would bring the measurement model's fit statistics within acceptable ranges.

Table 6.14: Fit Indices for Group 2 Measurement Models

			1	2	3	4	5
Non-normed Fit Index (AKA Tucker Lewis Index)	NNFI TLI	$\geq$.90	.751	.779	.835	.876	.892
Root Mean Squared Error of Approximation	RMSEA	$\leq$0.08	.108	.109	.092	.086	.081
Relative Non-Centrality Index	RNI	$\geq$.90					.908
Standardized Root Mean Square Residual	SRMR	$\leq$0.10	.100	.085	.072	.075	.076
Comparative Fit Index	CFI		.779	.806	.863	.895	.910

To investigate, a test of a one construct versus two construct model was run[6]. As seen in Table 6.15, the difference in chi squared was significant (p<0.001), which implies that the 2 construct model is a better fit. This provides empirical support for the notion that CUSTOM2 and CUSTOM3 measure something different than the variables CUSTOM1, CUSTOM4r and CUSTOM5.

Table 6.15: Chi Square Difference Test for Customization

	Target model	Alternative model	Difference
Chi sqr.	56.3	12.8	43.5
df	5	4	1
Signif.			p<.001

Conceptually, examining the items shows that items 2 and 3 do tap a different construct than items 1, 4 and 5. Items 1, 4 and 5 deal specifically with changes to the ERP system for the benefit of the local plant. While items 2 and 3 tap related subjects, they deal with the characteristics of the implementation process and the relationship between the plant and the implementers. Therefore, because CUSTOM1, CUSTOM4r and CUSTOM5 are more precisely aligned with the concept of customization at the local level, they were retained while CUSTOM2 and CUSTOM3 were not.

After dropping the variables CUSTOM2 and CUSTOM3, the researcher re-ran the group 2 CFA model. The results are in column 2 of Table 6.14 (above). Dropping these items improves both TLI and RNI by over .02.

Are Correlated Error Variances A Problem?

Purging the two wayward customization items improves the model fit, but it remains very poor. This poor fit suggested looking for violations of assumptions before answering additional questions raised by EFA. Examining the modification indices

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[6] Because all respondents were instructed to complete the customization items, missing items and thus identification of the covariance matrix were not an issue. Therefore all 178 observations were used for this test.

suggests seriously correlated error variances for the following pairs of items: P_FS4 and P_FS5; S_FS4 and S_FS5; P_FS1 and P_GI1; S_FS1 and S_GI1.

Examining the survey booklet shows that each pair of items appears side by side. Furthermore each pair is the *first two* items in each section. This suggests that the correlated error variances are due to anchoring and adjusting. Because the errors are not independent, at least one item in each dyad should be dropped. However, as discussed below, scale type also influences responses to items FS4 and FS5. Therefore the scale type issue is discussed before final judgement on these items is rendered.

What is the Effect of the Type of Response Scale Used?

Instead of using agree/disagree, the response scales for FS4 and FS5 employed as scale that was denominated in time units. EFA suggested that the type of scale was influencing the way in which participants answered these items. This can be investigated by adding a *scale type* factor for questions for these items (P_FS4, P_FS5, S_FS4, S_FS5). The results of this model appear in column 3 of Table 6.14 (above). Adding the scale type factor does indeed improve model fit substantially.

The scale type issue must be considered in tandem with the anchoring and adjustment problem discussed above. As discussed under the previous heading, correlated error variances due to anchoring and adjusting require the elimination of one item from each pair (The reader should recall that the survey employs parallel FS and GI items– one set for interdependence with other plants and the other for interdependence with sales and distribution):

- P_FS4 or P_FS5
- P_FS4 or P_FS5
- S_FS1 or S_GI1
- S_FS4 or S_FS5

Either FS4 or FS5 must be dropped, leaving only two items that would be linked to the scale type factor if it is included in the model. However, identification problems ensue if only two items are linked to this factor. Furthermore, including a scale type factor reduces model parsimony. Therefore the researcher deleted from the model both items from the pair S_FS4 or S_FS5 and both from the pair P_FS4 or P_FS5. This eliminates both the scale type issue and the correlated error variances problem.

The remaining issue is which item to drop from the pair FS1 and GI1. Dropping GI1 leaves an equal number of FS and GI items in the model so GI1 was eliminated.

Dropping the above items does not reduce the conceptual gestalt of the scales. The FS items were designed to tap frequency of contact and the amount of slack (tolerance for delay) in communication. The remaining items adequately include both concepts. Furthermore, the necessity of "close coordination," which GI1 taps, is well-represented in the other GI items, particularly GI3.

The fit indices for model with these modifications appears in column 4 of Table 6.14 (above). They are substantially improved.

Does The Instrument Discriminate Between Two Dimensions Of Interdependence?

EFA also suggested combining the 2 hypothesized dimensions of interdependence for both plants and sales and distribution, resulting in one construct for plants and one for sales and distribution. To test this, a chi square difference test was run (Tables 6.16 and 6.17). The target model consists of two latent variables (*perceptions of interdependence* and *frequency of exchange/tolerance for slack*) and their indicators. In the alternative model, these two are combined. For *interdependence with sales and distribution,* there appears to be evidence that the *perceptions of interdependence* (GI) questions are measuring something different than the *frequency of exchange/tolerance for slack* (FS) questions. However the situation is the opposite for the questions dealing with interdependence with other plants. There is insufficient evidence that the GI questions and FS questions are measuring two distinct constructs.

Table 6.16: Chi Square Difference Test – Interdependence with Sales and Distribution

	Two LV's	One LV	Difference
Chi sqr.	5.5	15.7	10.2
df	8	9	1
Signif.			p<.005

Table 6.17: Chi Square Difference Test – Interdependence with Other Plants

	Two LV's	One LV	Difference
Chi sqr.	15.3	15.8	0.5
df	8	9	1
Signif.			p>.05

This presents a bit of a dilemma because, as discussed earlier, the *interdependence with sales and distribution* items and the *interdependence with other plants* items are exactly parallel. The most conservative approach would seem to be to assume that discriminant validity is lacking in the sales and distribution items as well as the other plants items. Thus the P_FS and P_GI items should be combined and linked to a single *interdependence with other plants* latent variable. As a parallel, the S_FS and S_GI items should be combined and linked to a single *interdependence with sales and distribution* latent variable. On a procedural level, using a single construct simplifies the conceptual model, especially because interactions are included. Therefore, the two constructs were combined.

Does The Instrument Discriminate Between Interdependence and Improvements in Coordination?

EFA raised questions regarding the instrument's ability to discriminate between the construct *interdependence with other plants* and the construct *improvements in coordination with other plants*. Therefore the researcher ran a chi square difference test (Table 6.18). The target model consists of 2 latent variables: interdependence and coordination improvements, as hypothesized. In the alternative model, the *interdependence* and *improvement* items are made to load on a single latent variable. The test clearly shows that the target model is a better fit, thus demonstrating discriminant validity between the two constructs. Therefore these constructs were not combined.

Can the Goodness of Fit be Brought Within Acceptable Parameters?

Column 4 of Table 6.14 (above) shows the fit statistics for the group 2 measurement model after all changes justified by CFA were made. The fit is not acceptable. However, testing the dissertation's substantive hypotheses requires a strong measurement model. In hopes of further purifying the model, the researcher examined the model's modification indices.

Table 6.18: Chi Square Difference Test – Interdependence and Coordination Improvements

	Target 2 LV's	Alternative 1 LV	Difference
Chi sqr.	91.4	192.9	101.5
df	34	35	1
Signif.			p<.001

The modification indices revealed that the model fit would be improved if S_FS3 were allowed to load on the *improvements in coordination with sales and distribution* construct, rather than on the *interdependence with sales and distribution* construct. (This is the case even though the analysis above demonstrates that the instrument can discriminate between the constructs *interdependence* and *improvement.*) Eliminating this problematic item would not unduly compromise the richness of the interdependence scale. After all, the concept, frequency of exchange is also represented by question FS1.

To investigate empirically, the researcher ran a model in which S_FS3 loaded on the *improvements in coordination with sales and distribution* construct and in which P_FS3 loaded on the *improvements in coordination with other plants* construct. Both of these loadings were statistically significant (t=6.73 and t=7.53 respectively).

Based on these results, deleting S_FS3 and P_FS3 seemed like a sound solution for bringing model fit to acceptable levels. The model was run with these variables discarded. The results are in column 5 of Table 6.14. While the NNFI and RMSEA just miss their target values, the researcher considered the fit sufficient.

Summary of Group Two CFA

In summary, the following changes were made to the group 2 measurement model based on confirmatory factor analysis:

- Drop variables CUSTOM2 and CUSTOM3 because they do not appear to be measuring customization.
- Dropping the variables P_FS4, P_FS5, S_FS4, S_FS5, P_GI1 and S_GI1 due to correlated error variances.
- Combine the constructs *perceptions of interdependence with other plants* and *tolerance for slack/frequency of exchange with other plants* into the construct *interdependence with other plants.*
- Combine the constructs *perceptions of interdependence with sales and distribution* and *tolerance for slack/frequency of exchange with sales and distribution* into the construct *interdependence with sales and distribution.*
- Drop S_FS3 and P_FS3 based on significant loadings on other factors.

Construct Reliability

After purifying the measures as described above, the investigator estimated the reliability using Cronbach's alpha in SPSS. The alphas for each construct are in the following Table 6.19.

Table 6.19: Construct Reliabilities

Construct	Alpha	No. of items	Item abbrevs.
Time and Other Resources Required	.85	4	TIME
Use of Alternative Systems	.87	5	ALT
Data Accuracy	.88	4	ACC
Differentiation	.74	9	various
Customization	.87	3	CUSTOM
Interdependence with other plants	.91	5	P_FS, P_GI
Interdependence with sales & distribution	.84	5	S_FS, S_GI
Improvements in coordination with other plants	.91	4	P_CB
Improvements in coordination with sales & distribution	.91	4	S_CB
Overall business impact of ERP on plant	.85	4	IMPACT

Construct Validity of Differentiation Indicators

Because formative indicators do not conform to all of the assumptions of classical test theory, it is dangerous to automatically assume the applicability of traditional algorithms for establishing construct validity. However, ascertaining good evidence of construct validity is possible in this context: For the indicators under examination here, theory enables the *a priori* specification of relationships that should manifest themselves among the indicators. The degree to which these are or are not exhibited in the data provides evidence for or against the validity of the indicators. These relationships are discussed below.

The researcher expected total manufacturing volume to be negatively associated with product variety, the proportion of output that is made to order, rate of new product introductions and the rate of bill of material changes. However, examining the "vol." column of Table 6.20 reveals that the data did not reflect this pattern. Only one of these expected relationships is negative, and it is weak. The other correlations are positive, which is the opposite of the hypothesized direction. Furthermore, *volume's* correlations with *variety* and *rate of new product introductions* are significant, positive and relatively large.

This problem is probably due to confusion about the meaning of the *volume* item. In the pretest, several practitioners interpreted prototype volume items to mean overall manufacturing volume, not volume per unit. Although the researcher reworded and tested the item, the strange correlations in the data suggest he did not do so satisfactorily. (In retrospect, perhaps having an item on overall volume adjacent to the item on volume per unit would solve the problem). Because the volume item does not appear to be measuring what was intended it was dropped.

The researcher also expected to find relatively high positive correlations among product complexity (number of BOM layers), product variety (the number of different models, configurations or formulations produced), number of active part numbers, product customization (portion of output that is made to order), throughput time, rate of new product introductions, and rate of design changes. Large scores on the aforementioned variables are indicative of a job shop or small batch shop making relatively complex, customized products in lower volumes, whereas low scores suggest a large batch or repetitive manufacturer with lower variety, higher volume and less customization. Examining the correlation matrix shows that, 18 of the 21 correlations

Table 6.20: Correlations Among Differentiation Indicators

	BOM	Var	PN	MTO	Lot	Time	New	Change	Pro	Vol
No. of BOM layers	1.00	**0.42**	**0.52**	**0.35**	0.03	**0.27**	**0.27**	**0.24**	(0.08)	0.12
Product variety	**0.42**	1.00	**0.71**	**0.37**	0.02	0.16	**0.48**	**0.34**	0.16	**0.53**
Number of active part numbers	**0.52**	**0.71**	1.00	**0.46**	0.02	**0.28**	**0.48**	**0.40**	0.06	**0.36**
% of output that is MTO	**0.35**	**0.37**	**0.46**	1.00	0.07	0.15	0.32	**0.39**	**0.04**	0.06
Need for lot control	0.03	0.02	0.02	0.07	1.00	**0.35**	0.11	0.15	0.17	0.08
Ave. throughput time	**0.27**	0.16	**0.28**	0.15	**0.35**	1.00	0.17	**0.28**	(0.00)	(0.07)
Rate of new product intros.	**0.27**	**0.48**	**0.48**	**0.32**	0.11	0.17	1.00	**0.64**	0.09	**0.28**
Rate of BOM change/ECN	**0.24**	**0.34**	**0.40**	**0.39**	0.15	**0.28**	**0.64**	1.00	(0.14)	0.16
Amt. processing vs assy/fab	(0.08)	0.16	0.06	0.04	0.17	(0.00)	0.09	(0.14)	1.00	0.24 *
Vol. per model/formulation	0.12	**0.53**	**0.36**	0.06	0.08	(0.07)	**0.28**	0.16	0.24 *	1.00

Bold correlations are significant at 0.01
Asterisked correlation is significant at 0.05

among this group are positive, significant and relatively large. This is good evidence of the validity of these measures.

The need for *lot control* was not expected to correlate highly with any of the other indicators. After all, some job shop and some complex manufacturers, such as producers of aircraft parts, require lot control. On the other hand many do not. Similarly, some processors, such as food and drug processors, require lot control, however many others do not. Over all, the data met this expectation. The correlation between processing time and lot control, while not expected, makes sense: The longer material spends as work in process the greater the need for factory floor control in general, and lot control is, among other things, a special case of shop floor control.

The researcher did not expect the *processing* item ("pro") to group with other items. This was the case. Some processors, such as petroleum refiners, are characterized by high volume, low variety, and low complexity. Others, such as producers of health and beauty products, tend toward the other end of the spectrum.

Special Coding for Cases with Only a Single Plant or No Sales and Distribution Function

Note that some surveys reported on plants that did not have other plants as a part of their ERP implementations. These groups were instructed to skip the section on interdependence and coordination improvements with other plants, as well as the section on differentiation from other plants. Similarly some cases reported not having sales and distribution functions that were a part of their ERP systems. These groups were instructed to skip the section covering interdependence and coordination improvements with sale and distribution. Table 6.21 classifies the observations.

Observations representing plants that are part of a single plant ERP implementation (skipped Section 4a) were assigned the lowest observed score for each item measuring interdependence with other plants in the ERP system and for items measuring improvements in coordination with other plants in the ERP system. The minimum score for each item was 1 so 1 was assigned.

These observations were also assigned a score of *same* (5 on the 1 to 9 scale) for the items in the differentiation section (Section 3a).

Table 6.21: Response Characteristics

	ERP Excludes Sales/Distrib.	**ERP Includes Sales/Distrib.**	
ERP is Single Plant	19	26	**45**
ERP is Multi Plant	30	103	**133**
	49	**129**	**178**

Similarly, observations that lacked sales and distribution sub-units in their ERP system (skipped Section 4b) were assigned the lowest observed score for each item measuring interdependence with sales and distribution sub-units in the ERP system and for items measuring improvements in coordination with distribution sub-units in the ERP system. The minimum score for each item was 1 for most items and 2 for the other items.

Interaction Construct Reliabilities

As discussed in the previous chapter, reliability of each interaction term is the product of the scale reliabilities (Cronbach's alpha computed using SPSS) of each main effect involved in the interaction. For example, the researcher calculated the reliability for the *plant interdependence X plant coordination improvement* interaction by multiplying the reliability of the *plant interdependence* scale by the reliability of the *plant coordination improvement* scale. Error variances (theta delta terms) were computed based on the reliability according to the single indicator method (Vandenberg & Scarpello, 1990) discussed above. Table 6.22 shows the calculations.

Note that the scale for customization was reversed. This was necessary to create consistency in *customization* and *differentiation* between the direction of the scale and hypothesized effect on the response variables (High scores in either variable decrease local fit and overall business impact. Low scores increase them.) Without this transformation, the interaction term would be meaningless.

Descriptive Statistics

Table 6.23 presents the descriptive statistics for the constructs in the model after the measurement model was refined as outlined in this chapter. These descriptives do not include the special coding for cases with no sales and distribution or single plant ERP's that is described in the above. Means, standard deviations, minimums and maximums are given. For data accuracy, use of alternative info. systems these and time & resources required for planning and scheduling tasks, items are scaled so that high scores indicate ERP is a good fit. For example, high scores on alt. sys. mean the ERP, not alt. sys. are being used.

Table 6.22: Reliabilities Of Interactions And Their Components

	Reliab.	Indicator Loading (λ)	Scale Variance	Error Variance
	α	$\sqrt{\alpha}$	σ^2	$(1-\lambda)*\sigma^2$
Interdep. w/ other plants (A)	0.908			
Improvements in coord. w/ other plants (B)	0.905			
Plants Interdependence X Improvement (A*B)	0.822	0.906	9.02	1.61
Interdep. w/ sales and distribution	0.844			
Improvements in coord w/ sales and distribution	0.912			
Sales & Dist. Interdep. X Improvement	0.770	0.877	11.94	2.75
Differentiation (number of 4 to 5 scores)	0.742			
Customization (reverse scaled)	0.869			
Differentiation X Customization	0.639	0.799	12.98	4.69
Differentiation (mean of 1-5 scores)	0.742			
Customization (reverse scaled)	0.869			
Differentiation X Customization	0.639	0.799	2.87	1.04

Table 6.23: Descriptive Statistics

Factor	Mean	Std. Dev.	Min.	Max.
Data Accuracy *	4.75	1.32	1	7
Use of Alternative Info. Systems *	3.48	1.40	1	7
Time & Resources *	4.57	1.41	1	7
Overall Impact on Plant	4.65	1.34	1	7
Coord. Improv. w/ Other Plants	4.48	1.57	1	7
Interdependence w/ Other Plants	4.11	1.76	1	7
Coord. Improv. w/ Sales & Dist.	5.25	1.28	1	7
Interdependence w/ Sales & Dist.	5.59	1.13	1	7
Local Customization	4.33	1.77	1	7
Differentiation (Dichotomized Scores)	1.79	2.11	0	7
Differentiation (Mean Scores)	2.12	1.02	1	5

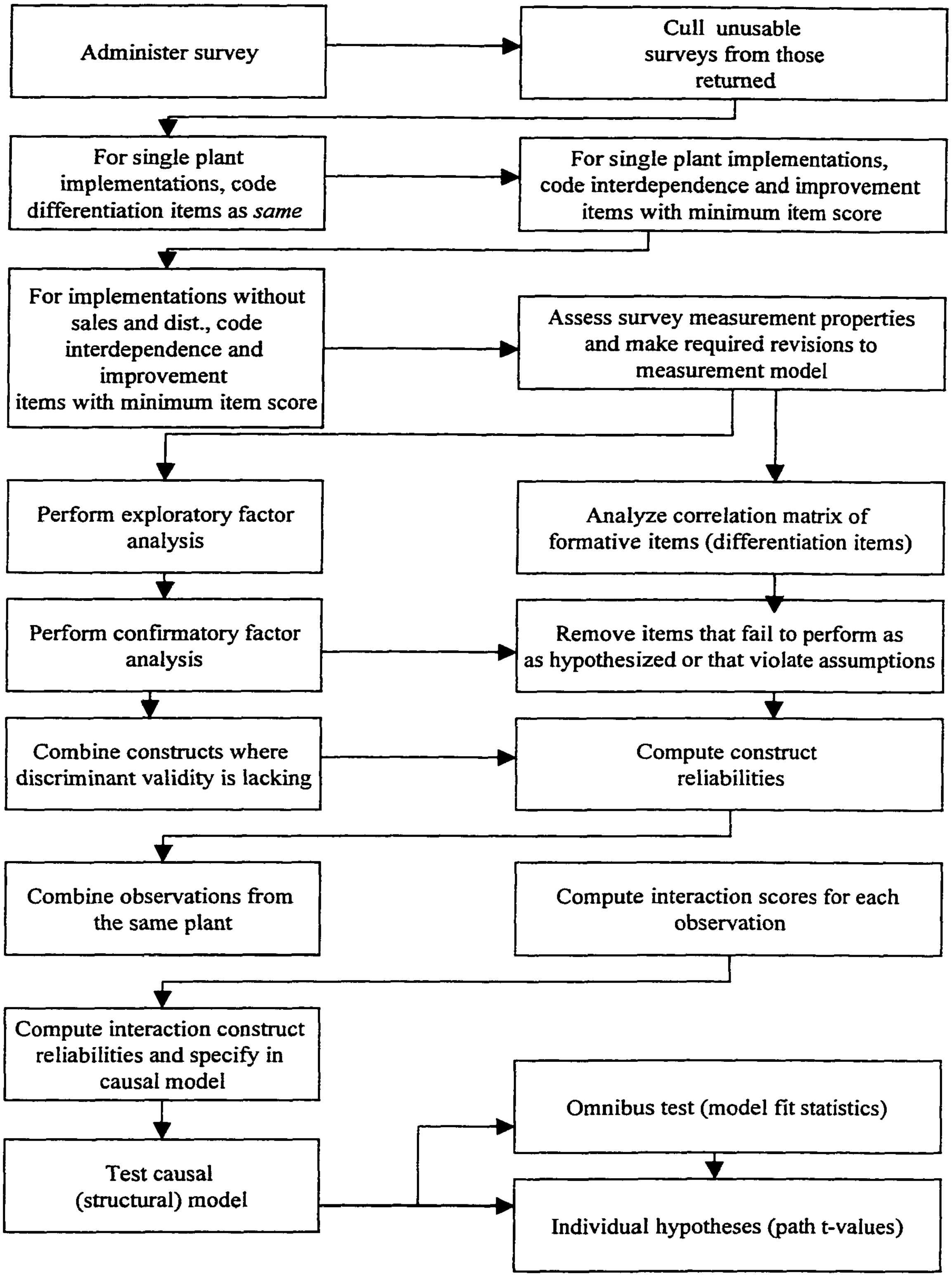


Figure 6.1: Data Analysis Overview

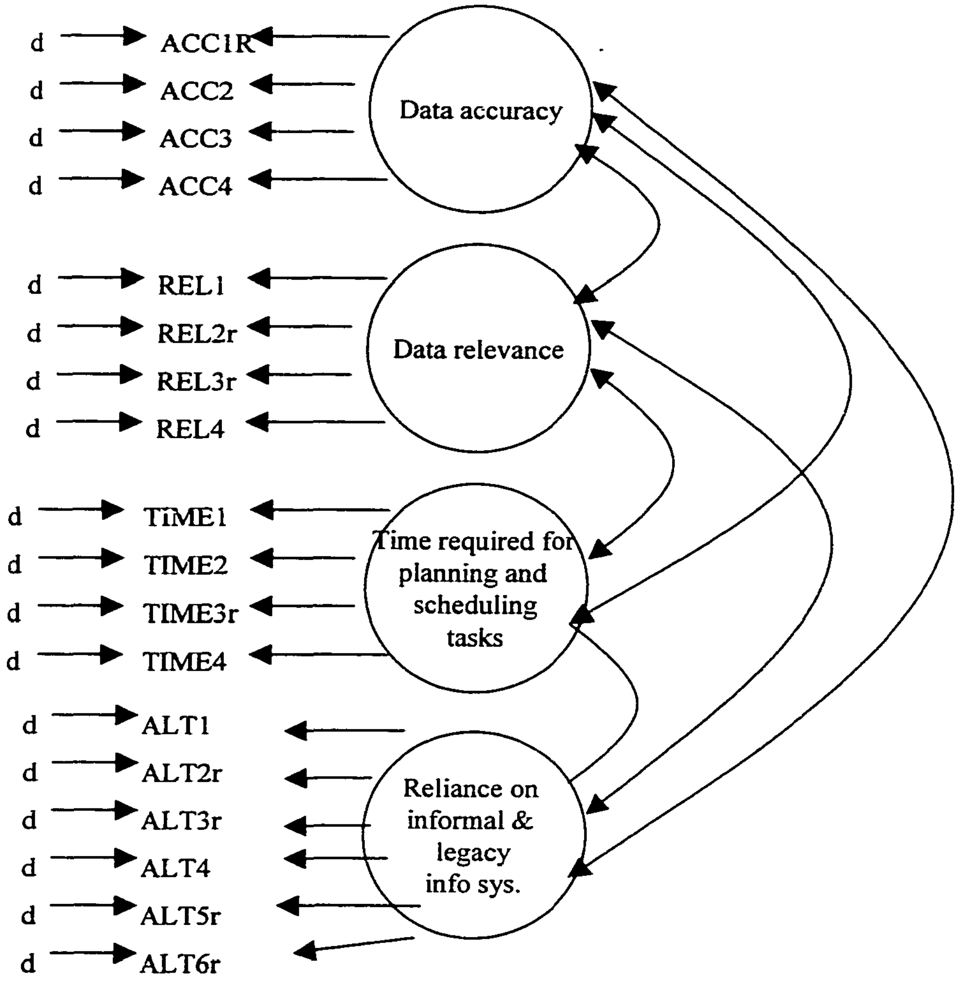


Figure 6.2: Group 1 Measurement Model as Originally Hypothesized

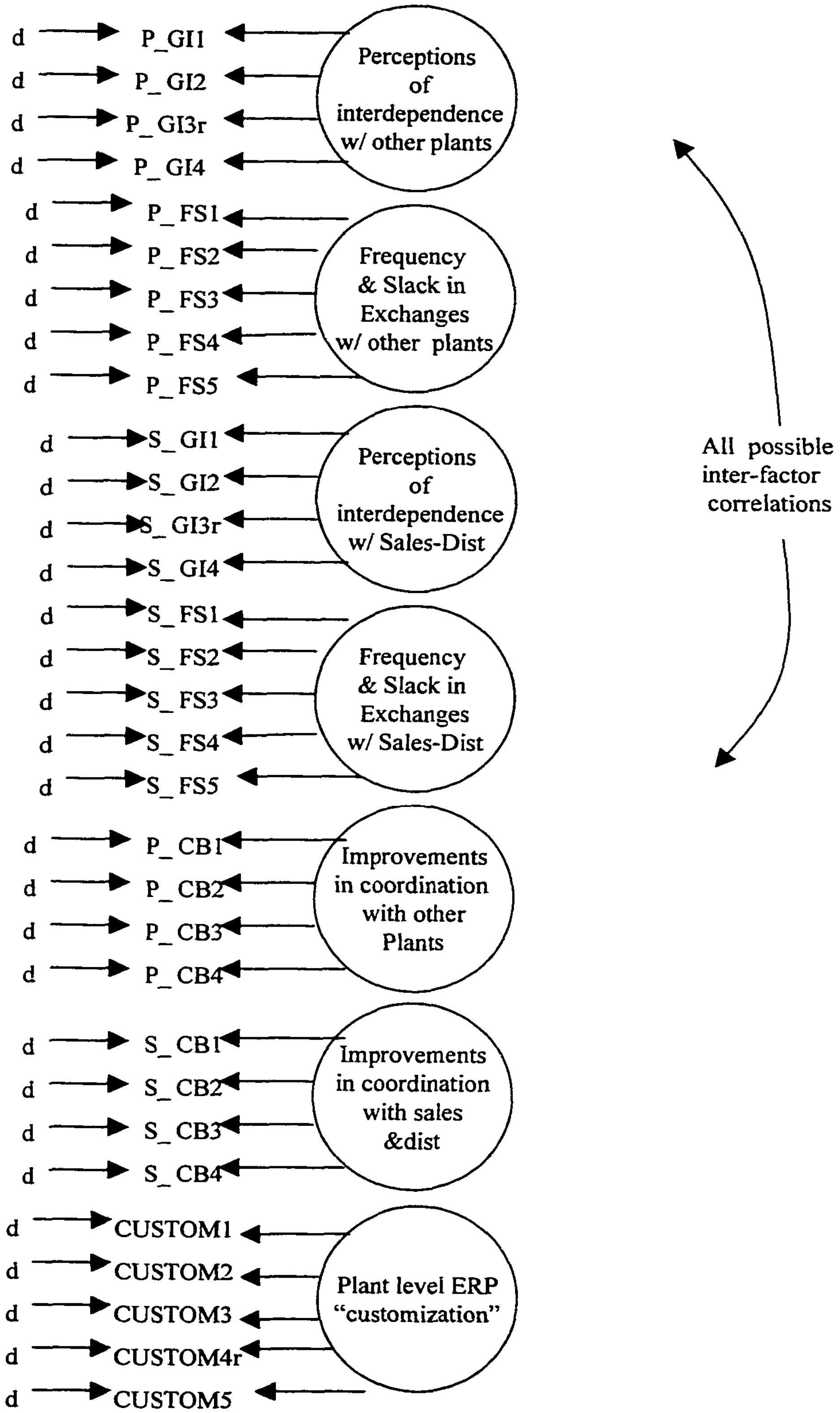


Figure 6.3: Group 2 Measurement Model as Originally Hypothesized

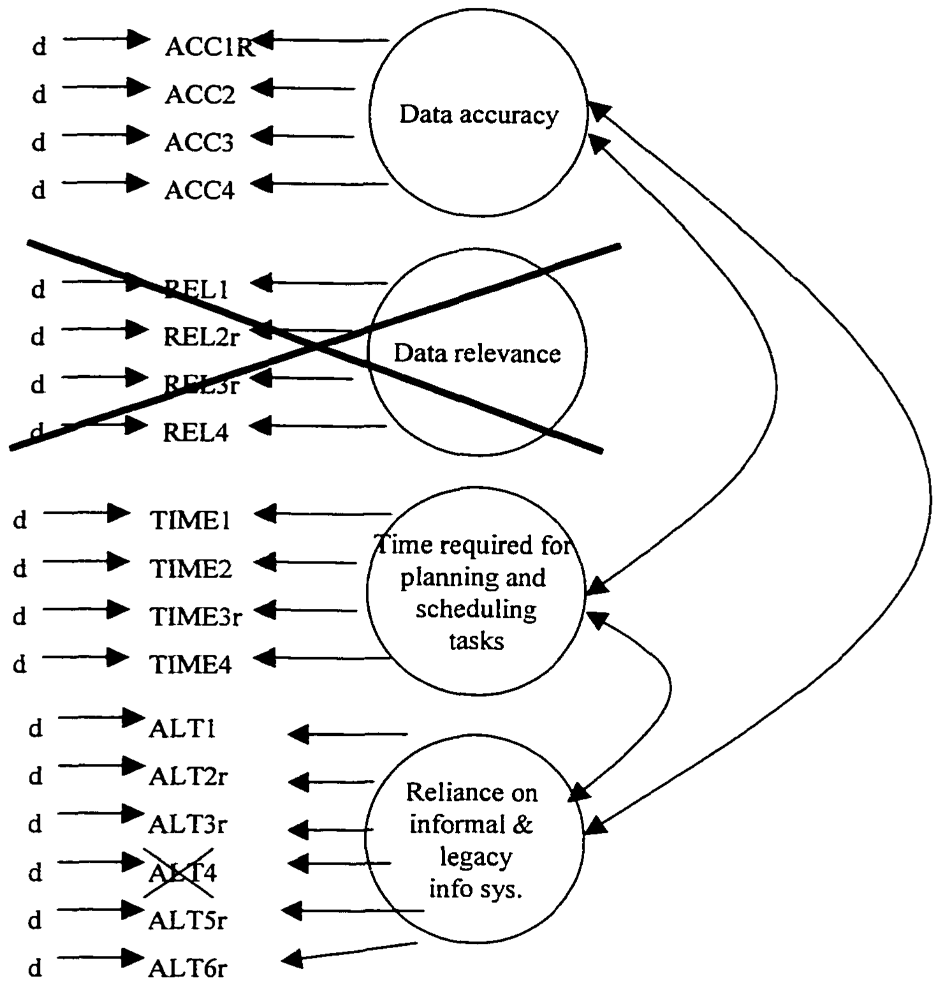
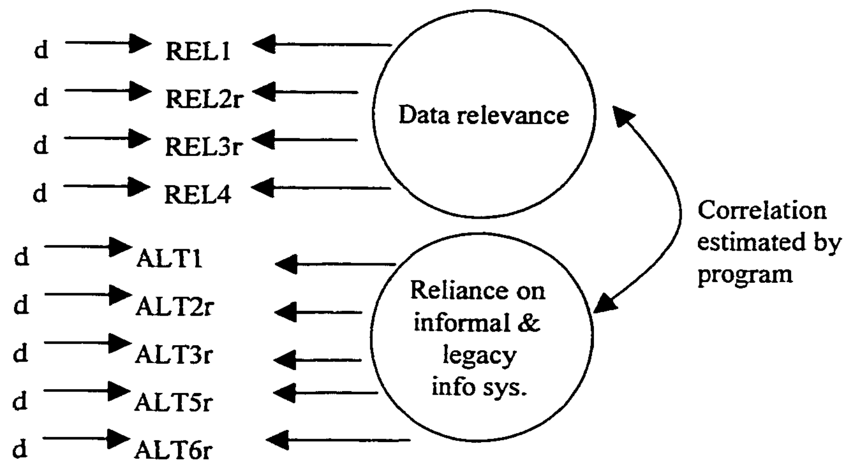


Figure 6.4: Group 1 Final Measurement Model

Target Model



Alternative Model

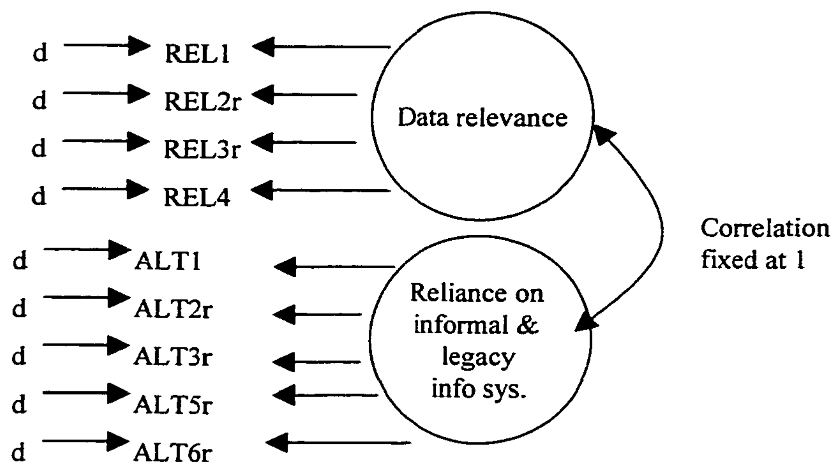


Figure 6.5: Illustration of Chi Square Difference Test of Competing Models

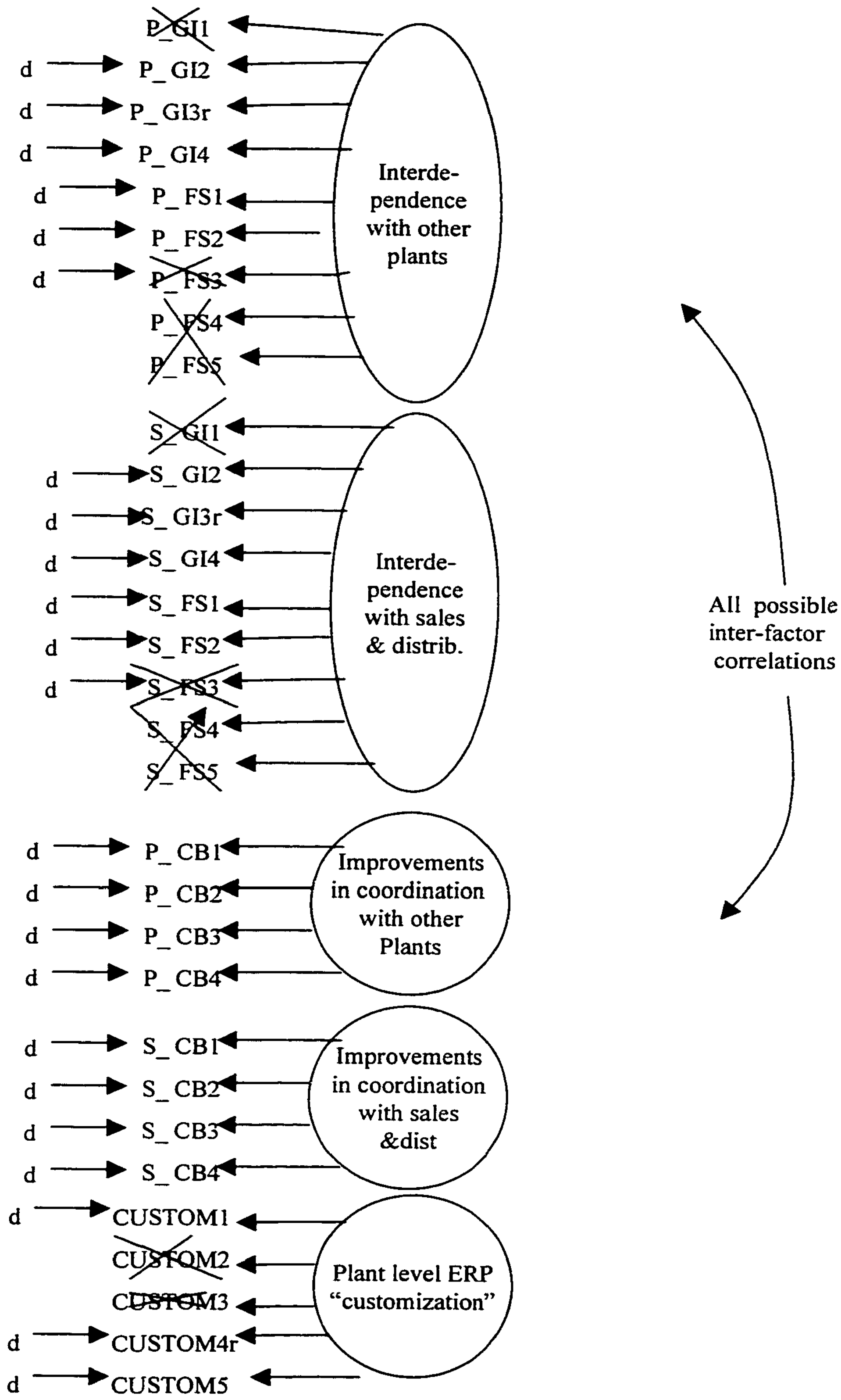


Figure 6.6: Group 2 Final Measurement Model

CHAPTER 7

Analysis of the Causal Model

Overview

This chapter presents analysis of the causal, or structural, model. Two models are presented. The difference between the two is the way in which the differentiation construct is modeled. The first analysis presented uses the primary method of scoring the differentiation construct. This is followed by analysis using the alternative method. The conceptual and methodological difference between the two was presented in Chapter 5.

Results Using Primary Method of Modeling Differentiation

This section presents the results when the 9 differentiation scores are dichotomized. The model fit statistics, which appear in Table 7.1 all fall within acceptable parameters. Table 7.2 presents the variance explained in each of the endogenous constructs.

Table 7.1: Model Fit Statistics for the Model

Non-normed Fit Index (AKA Tucker Lewis Index)	NNFI TLI	≥ 0.90	.911
Root Mean Squared Error of Approximation	RMSEA	≤ 0.08	.062
Relative Non-Centrality Index	RNI	≥ 0.90	.920
Standardized Root Mean Square Residual	SRMR	≤ 0.10	.081

Examining the Model

Hypotheses Regarding Interdependence with Sales and Distribution

Figure 7.1 displays the standardized path coefficient and statistical significance (t-values) for the each relationship in the model. The interaction *interdependence with sales and distribution X improvement in coordination with sales and distribution* is significantly associated with the *overall business impact of ERP on the plant.* This means that the magnitude of the effect of *improvements in coordination* depends on the level of *interdependence*. This also requires interpreting the interaction and its two main effects as a group.

Table 7.2: Variance Explained In Endogenous Constructs

Data Accuracy	.026
Time and other resources required for materials and production management	.048
Use of Alternative & Informal Systems	.041
Overall Business Impact	.870

According to Schoonhoven (1981) an interaction can be interpreted by examining the first partial derivative of the equation for *overall business impact of ERP on the plant* (or *impact*). LISREL estimated the predictors' relationship to *impact* according to:

impact = .043*s_inter + .206*s_impr + .124*s_inter*s_improv - .055*p_inter - .063*p_impr - .021*p_inter*p_improv + .323*accuracy + .529time + 0.049alt

where *s_inter* is interdependence with sales and distribution, *s_impr* is improvements in coordination with sales and distribution, *p_inter* is interdependence with other plants, and so on. The first partial derivative with respect to improvement in coordination with sales and distribution is:

δ impact / δ s_improv = .206 + .124*s_inter

The first partial derivative shows the effect of a change in improvements in coordination (*s_improve)* on overall business impact of ERP (*impact*). We can see from the above equation that the effect of a change in improvement depends on the level of interdependence. Graphing the equation, as shown in Figure 7.2 demonstrates that an increase in coordination always enhances the business impact of the ERP system. More importantly, the positive slope of the line indicates that as interdependence increases, the effect of a unit change in coordination improvement increases. This provides evidence supporting hypotheses 2 and 4.

Hypotheses Regarding Interdependence with Other Plants

By contrast, impact is not significantly related to interdependence with other plants, coordination improvements with other plants, or their interaction. Therefore this study does not provide support for hypotheses 1 and 3.

Hypotheses Regarding Differentiation and Customization

Neither differentiation, customization nor the interaction of the two has a statistically significant relationship to data accuracy. Therefore there is no evidence to support hypotheses 5, 9 and 17.

The only main effect that is significantly associated with local fit is differentiation as a predictor of time and other resources required for planning and scheduling tasks (*time*). However, neither customization nor the differentiation-customization interaction are significantly associated with *time*. Thus the data support the notion that differentiation negatively affects *time*, but there is no evidence customizing the ERP system moderates this relationship. In terms of the research model, there is support for hypothesis 7, but not for 11 or 19. Removing the customization-differentiation interaction has a negligible effect on the differentiation-time relationship (the t-statistic decreases only slightly), on the other structural relationships and on model fit.

The interaction of differentiation and customization is significantly associated with the use of informal and alternative systems ($p<.05$). This coefficient can be interpreted by taking the first partial derivative of the equation for *alt,* using the same procedure described for the interdependence-improvement interaction above. The equation for *alt* is:

$$alt = .020*generic - .060*differentiaion - .051*generic*differentiaion$$

The first partial derivative, graphed in Figure 7.3, is

$$\delta\ alt / \delta\ differentiation = -.060 - .051*generic$$

In interpreting the equation for *alt*, the reader must remember that high scores on the *alt* scale indicate use of the ERP system, to the exclusion of alternative and informal systems, in applications for which the implementers intended for ERP to be used. Thus the reader may find it helpful to think of *alt* as "the use of the ERP for everything for which it was intended." Low *alt* scores can be conceptualized as using non-ERP information systems for purposes for which the ERP was designed. Furthermore, since *generic* is scaled as the reverse of customization, high values on the *generic* scale indicate low ERP customization. In other words, customization decreases as one moves to the right along the horizontal axis of Figure 7.3.

Examining Figure 7.3 shows that δ alt / δ differentiation is always negative. This indicates that differentiation increases the use of alternative and informal systems (it decreases "the use of the ERP for everything for which it was intended") at all levels of customization. The negative slope of the line indicates that increasing ERP customization moderates the relationship between differentiation and the use of alternative and informal systems. In other words, in the presence of differentiation, customization decreases the degree to which users will turn to alternative and informal systems. The data support hypotheses 8, 12 and 20.

As the previous chapter discussed, data relevance was removed from the model due to measurement issues. Therefore, no judgement can be made on hypotheses 6, 10 and 18.

Hypotheses Regarding the Effect of Local Fit on Overall Business Impact of ERP on the Plant

Both *data accuracy* and *time and other resources required for materials and production management* are significantly associated with *overall business impact of ERP*. On the other hand *use of alternative systems* is not significantly related to *overall business impact.* In other words, there is support for hypotheses 13 and 15, but not for 16. No judgement can be made on hypothesis 13, which involves *data relevance.*

Sensitivity of the Model

A variable's reliability forms the upper limit on the association one can observe between that variable and any other variable. It follows that the lower the reliability, the lower the chances of detecting a statistically significant relationship when regression is used. However, LISREL adjusts for reliability so that when reliability of a variable is poor, less of an effect is required for a significant relationship between that variable and any other.

A researcher can specify reliabilities or allow LISREL to calculate them. The latter option is the usual one when multiple indicators of a latent variable are used in the LISREL model. However, as discussed in Chapter 4, the LISREL model in this study contains only one indicator for the differentiation construct (It was measured using multiple indicators, which were combined into a single composite score). Since the reliability for differentiation was calculated outside of LISREL and since low reliability estimates increase significances, it seemed wise to test the model using alternative reliabilities in order to determine the sensitivity of the model to the reliability estimate.

In terms of statistical significances, variance explained and goodness of fit indices, the model is fairly insensitive to estimates of reliability for the differentiation construct (Table 7.3). Note that this estimate also affects the reliability of the differentiation-customization interaction construct. However, raising differentiation's reliability from .74 to .81 (which raises the reliability of the differentiation-customization interaction from .64 to .70) moves the significance of the relationship between alternative systems across the threshold from significant at .05 to insignificant. This is an increase in the p-value of only .007 (from .048 to .056).

Table 7.3: Sensitivity to Reliability Estimate

Reliability		t-value for...		R^2 for...			NNFI	SRMR
Differ.	Differ X cust	Differ on time	Differ X cust on alt	Acc	Time	Alt		
.74	.64	-1.97	-1.66	.026	.048	.041	.911	.089
.81	.70	-1.90	-1.59	.022	.042	.035	.911	.081
.87	.75	-1.85	-1.55	.020	.039	.031	.911	.081

Results Using Alternative Method of Modeling Differentiation

As discussed above, the alternative for scoring differentiation is to take the mean of the scores for the 9 indicators of differentiation. Doing so produced results that were mostly parallel to those in the model that uses the primary method, which is discussed above. Standardized path coefficients (Figure 7.4) are close to one another for both methods. The same is true of variance explained by each structural equation and the goodness of fit indices (Table 7.4). There is a statistically significant relationship between overall ERP impact and the interdependence-coordination improvement interaction. Its interpretation (the way in which interdependence moderates the relationship between coordination improvements and overall ERP impact) of the interaction is the same. However, one major difference exists between scoring methods: When the mean is used, neither the relationship between the differentiation-customization interaction and use of alternative systems nor the relationship between differentiation and time is statistically significant. This is discussed in the next chapter.

Table 7.4: Model Fit Statistics Using Alternative Differentiation Model

Non-normed Fit Index (AKA Tucker Lewis Index)	NNFI TLI	≥0.90	.912
Root Mean Squared Error of Approximation	RMSEA	≤0.08	.061
Relative Non-Centrality Index	RNI	≥0.90	.922
Standardized Root Mean Square Residual	SRMR	≤0.10	.081

In sum, when differentiation is scored as the mean of each indicator's 1-5 score, hypothesis 8 is supported. However, the data do not provide evidence for any of the other hypotheses.

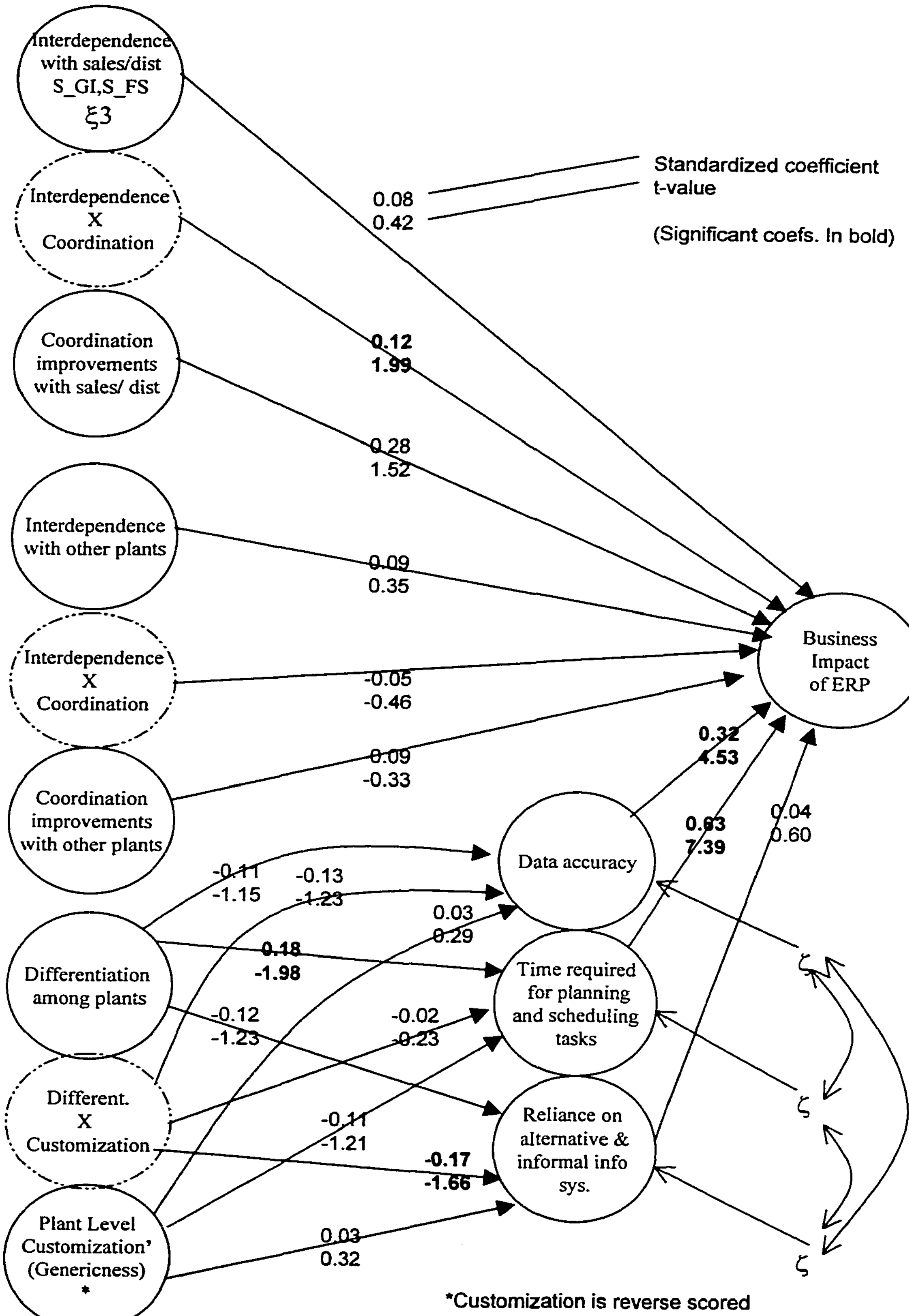


Figure 7.1: Structural Model (Primary)

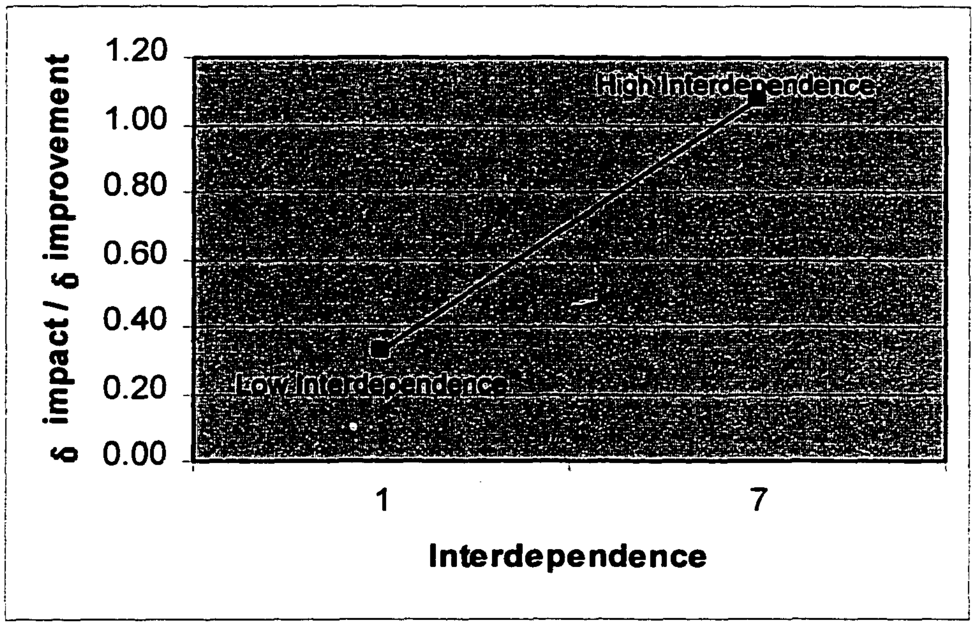


Figure 7.2: Interdependence's Moderating Effect on the Relationship Between Coordination Improvements and Overall ERP Impact

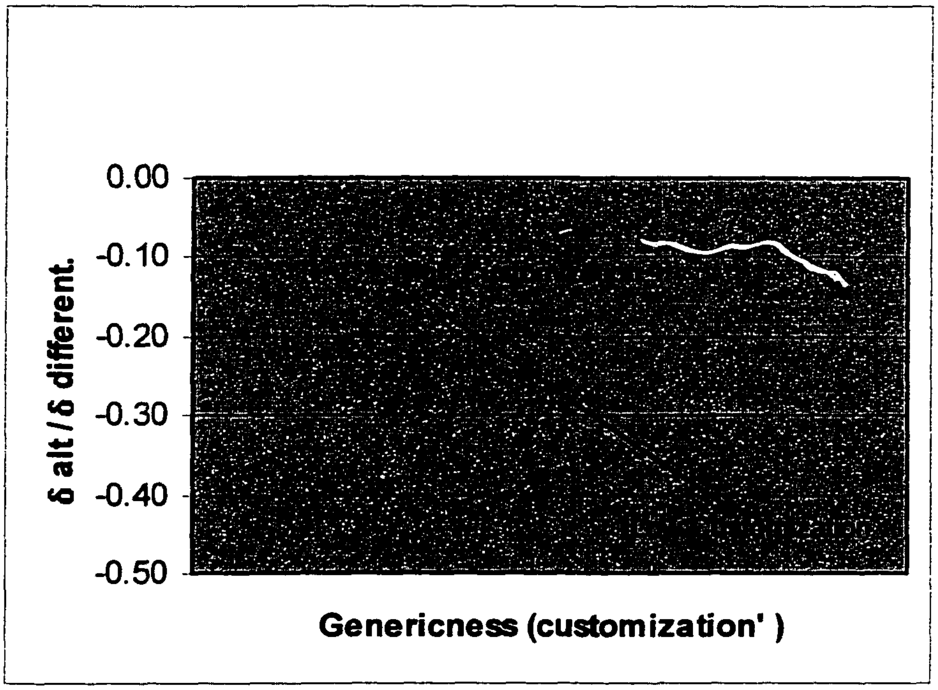


Figure 7.3: ERP Customization's Moderating Effect on the Relationship Between Differentiaion and the Use of Alternative Systems

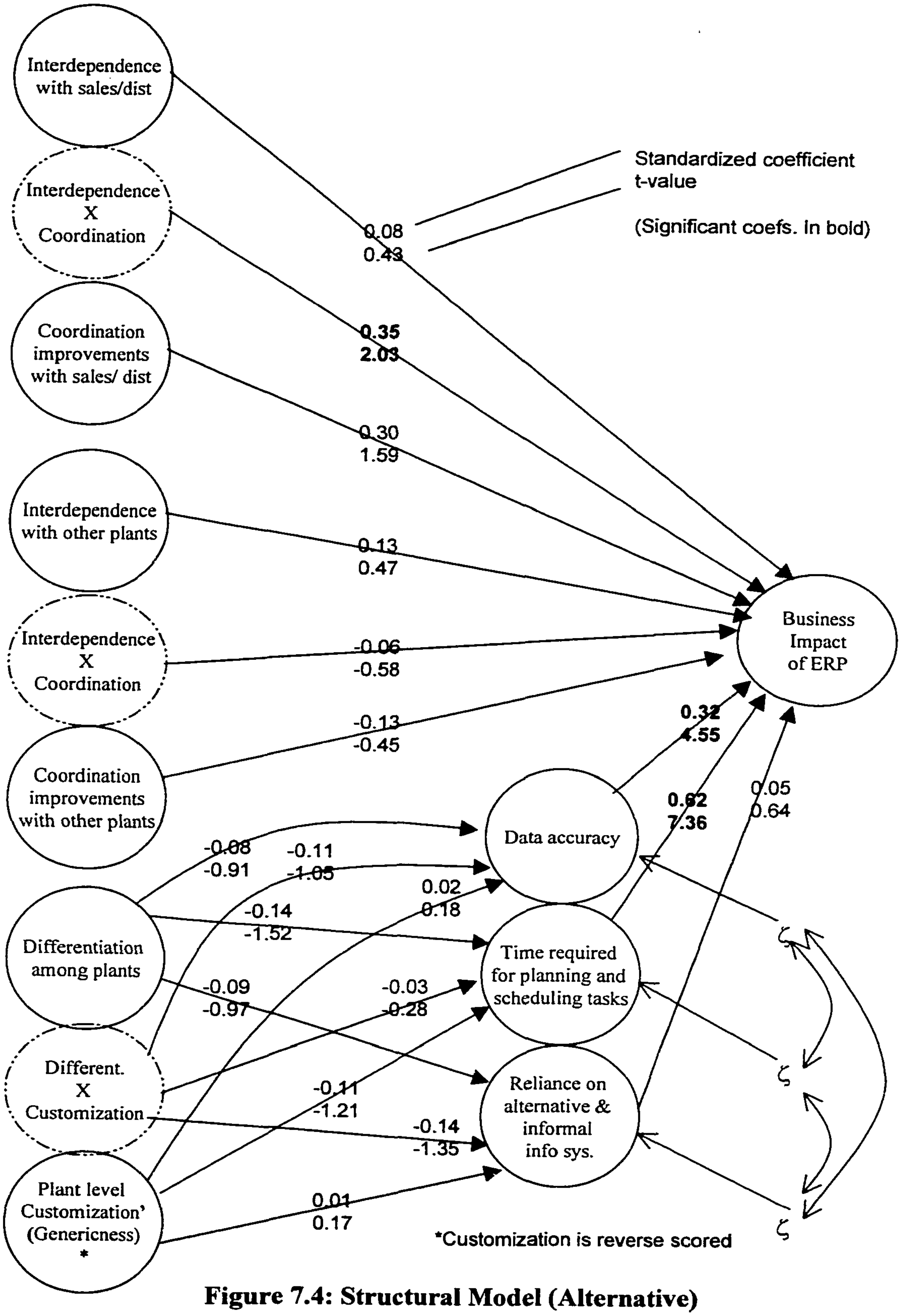


Figure 7.4: Structural Model (Alternative)

CHAPTER 8

Discussion, Conclusions, Limitations and Contributions

Conclusions and Discussion

Overall Findings

When this research was begun the dominant practitioner thinking, at least as evidenced by the trade press, was that ERP is universally good. During the project the ERP pendulum swung. By late 1999, several notable firms (Hershey, Whirlpool, Allied Waste and others) had gone public blaming ERP for some substantial business problems. The voices clamoring "ERP is bad" drowned out those extolling its virtues.

By contrast, the research suggests that *it depends*. In other words, certain factors will determine the appropriateness of any technology for any organization. The empirical research presented here provides some confirmation of this, and it identifies some of those factors for ERP. As discussed in the literature review, both the practitioner and academic literature suggest that ERP success depends in part on certain implementation critical success factors. However, this dissertation shifts the focus by suggesting that there are also certain fundamental organizational characteristics that influence the impact of ERP. Two of these factors are interdependence among sub-units and differentiation among sub-units. Both of these influence the effect that ERP systems have on the overall business performance of individual manufacturing plants.

Table 8.1 summarizes the empirical results of the 20 hypotheses based on the analysis presented in the previous chapter. The research results clearly suggest that both interdependence and differentiation affect the overall business impact of ERP on the plants that were studied. The model explained roughly 87 percent of the variation in overall business impact (Table 7.2, above). The interaction of *improvements in coordination* and *interdependence with sales and distribution* was significantly

Table 8.1: Summary of Hypotheses

	Hypothesis	Support
1	There is a significant positive relationship between *improvements in coordination with other plants in an ERP implementation* and *overall business impact of ERP*	no
2	There is a significant positive relationship between *improvements in coordination with the sales and distribution functions within an the ERP implementation* and *overall business impact of ERP*	yes (in interaction)
3	(interaction hypothesis): *Interdependence with other plants* in an ERP implementation significantly increases the effect of *improvements in coordination with other plants* on *overall business impact of ERP*	no
4	(interaction hypothesis): *Interdependence with the sales and distribution functions* within an the ERP implementation significantly increases the effect of *improvements in coordination with sales and distribution* on *overall business impact of ERP*	yes
5	There is a significant negative relationship between *differentiation* and *data accuracy.*	no
6	There is a significant negative relationship between *differentiation* and *data relevance.*	n/a (omitted)
7	There is a significant positive relationship between *differentiation* and *time and other resources required for materials and production management.*	yes
8	There is a significant positive relationship between *differentiation* and *the use of alternative systems.*	yes (in interaction)
9	H9 (interaction hypothesis): *Customization* significantly decreases the negative relationship between *differentiation* and *data accuracy.*	no
10	(interaction hypothesis): *Customization* significantly decreases the negative relationship between *differentiation* and *data relevance.*	n/a (omitted)
11	(interaction hypothesis): *Customization* significantly decreases the positive relationship between *differentiation* and *time and other resources required for materials and production management.*	no
12	(interaction hypothesis): *Customization* significantly decreases the positive relationship between *differentiation* and *the use of alternative systems.*	yes
13	There is a significant positive relationship between *data accuracy* and *overall business impact of ERP.*	yes
14	There is a significant positive relationship between *data relevance* and *overall business impact of ERP.*	n/a (omitted)
15	There is a significant negative relationship between *time and other resources required for materials and production management* and *overall business impact of ERP.*	yes
16	There is a significant negative relationship between *the use of alternative systems* and *overall business impact of ERP.*	no
17	There is a significant positive relationship between *local level customization* and *data accuracy.*	no (as expected)
18	There is a significant positive relationship between *local level customization* and *data relevance.*	n/a (omitted)
19	There is a significant positive relationship between *local level customization* and *time and other resources required for materials and production management.*	no (as expected)

20	There is a significant positive relationship between *local level customization* and *the use of alternative systems.*	yes (in interaction)

associated with ERP's overall business impact on the plant. Local fit is strongly associated with overall impact; and differentiation and customization account for about five percent of the variation in local fit.

Findings Regarding Interdependence

The case studies–Auto Products is the best example–and the practitioner literature suggest a belief among many practitioners that tightening coordination among sub-units always provides significant benefits. Thus many firms implement ERP systems to facilitate coordination. In reality, sometimes companies' efforts are rewarded with improved business performance but often they are not. The research model provides an explanation: ERP-enabled coordination benefits themselves may not deliver the business impact. Instead, the effect of improvements in coordination depends on the level of interdependence between the plant and other sub-units.

The research findings provide support for this assertion in the area of plants' relationships with the sales and distribution functions with whom they share the ERP system (hypotheses 2 and 4). The researcher found evidence that ERP is associated with improvements in coordination with sales and distribution and that such improvements do have a positive impact on the plant (hypotheses 2). Most importantly, the investigator also found evidence that this relationship is moderated by interdependence (hypotheses 4).

However, there was not support for the hypotheses (1 and 3) regarding plants' interdependence with other plants. Neither interdependence with other plants nor improvements in coordination with other plants nor the interaction of the two was significantly associated with ERP's overall business impact on the plant. Why the difference? Both interdependence and coordination improvements are higher for plants' relationships with sales and distribution than for relationships with other plants (Table

7.23). Nevertheless there should be at least some plants that have high interdependence with other plants. However, it is possible that the survey samples did not capture them adequately. Examining the descriptive statistics reveals that the mean interdependence and coordination improvements scores are lower for *other plants* than for *sales and distribution.* However, the variance for interdependence with other plants is actually greater than for interdependence with sales and distribution.

On the other hand, the explanation may not be methodological. Perhaps before ERP, plant personnel managed material flows and the like with other plants by using non-ERP means of coordination, such as telephone or fax, and perhaps these means were fairly effective. ERP may have improved plants ability to manage their interdependencies with other plants as the descriptive statistics suggest. However, if the non-ERP means were effective, the introduction of ERP may not have had an improvement that is significant enough to have a detectable impact on overall plant performance.

The conceptualization and operationalization of interdependence may play a role in this finding as well. A plant that is a receiver of materials or other resources may realize a greater impact from improvements in coordination to does a plant that is a supplier to other plants (Thompson, 1967). By contrast, the study did not take into account this *direction* of the exchange.

Findings Regarding Differentiation and Customization

The researcher hypothesized that differentiation (hypotheses 5 through 8) or the differentiation-customization interaction (hypotheses 9 through 12) would affect each of the three local fit dimensions in the model: data accuracy, time and other resources required for materials and production management, and the use of alternative systems. The data showed significant associations for two of the three.

One of the researcher's in-going assumptions–based on the practitioner and early academic literature–was that when ERP systems are not a good fit for local task conditions, companies either change business processes or change the ERP software (through customization). By contrast, most employees in the case studies could not change the software. Furthermore, they could not alter certain fundamental business processes because these were tied to the nature of the products manufactured and markets served. Perhaps as a result of these realities, employees *bridged the gap* between the business model embedded in the ERP software and the business model demanded by local conditions. Examples of bridging the gap are working longer or harder and developing alternative information systems. Of course, these are embodied in this study's local fit dimensions *time and resources* and *use of alternative systems.*

Both dimensions–*time and resources* and *use of alternative systems*–are significantly associated with differentiation (hypotheses 7 and 12). Differences between the plants studied and others within their ERP implementations result in both more time and more resources being required for materials management and manufacturing management tasks. Similarly, such differences are associated with greater use of alternative or informal systems for functions the ERP system was intended to perform.

As with differentiation, customization does not play a uniform role. Customization appears to moderate differentiation's impact on the *use of alternative systems*. However, only differentiation, not customization, affects *time and resources required for materials and production management.* This result may be caused by insufficient statistical power: More power is required to detect interactions than main effects. Alternatively, customization simply may not compensate for differences in sub-units in some instances. As expected, independent of differentiation, customization had no effect on local fit (hypotheses 17 through 20).

However, the more significant finding by far is that customization *does* matter in some cases (hypothesis 12). After all, as the literature review pointed out, common wisdom and a wealth of (mostly practitioner) literature supports the "no customization" strategy. There can be little doubt that customization must be pursued judiciously; however, the results of the survey suggest that customization is warranted in some instances. The case studies compliment these findings. Customization apparently improved local fit in several ERP implementations, most notably Refrigeration, Inc. By contrast, the results of Forest Products' first SAP implementation points out the folly of unfettered, across-the-board customization.

By most accounts a fairly high level of data accuracy is required to run an organization using ERP. The data from this study suggest ERP data accuracy does vary from plant to plant, and data accuracy is strongly associated with the overall plant-level impact of ERP (hypothesis 13). However, it appears that differentiation does not explain these differences in data accuracy. Plant employees are aware of the importance of data accuracy, particularly for applications like MRP (that 95% data accuracy is required for MRP to run successfully is an article of faith in the materials management field). Therefore, acceptable data accuracy in spite of the level of differentiation may well be a result of employees bridging the gaps as mentioned earlier.

Indeed, the cases revealed examples of employees going to great lengths to ensure that poor fitting applications do not result in poor quality data. For instance, department supervisors complained that they spent too much of their time doing routine transactions because doing them was too complicated for most of their employees to do well (in other words without making erroneous transactions that would result in inaccurate data). Forest Products also added a person in the finishing department to serve as a human interface between the SAP reporting system and the system that was actually used to control activity in the department. Again, one role of this individual was to take data from the shop floor (in a format useful to the shop floor) and convert it so that it could be entered into SAP. Feeding SAP without this person probably would have resulted in problematic data being entered.

Differentiation does not explain a huge amount of the observed differences in local fit in the study. In fact, differentiation and customization explain less than five percent of the variance in each local fit dimension (Table 7.2). This was expected. In other words, the researcher hypothesized that differentiation would be significantly associated with local fit, but he had no expectation that it would account for all the variance (thus the correlated error variances in the research model). Instead, there is plenty of conceptual and empirical evidence outside of this study suggesting that local fit is affected by a host of other variables, such as management support and user training. It is unlikely that any of these variables *alone* would explain a huge amount of the variation in local fit. The same is true of differentiation and customization.

The researcher hypothesized that all three local fit dimensions would be significantly associated with ERP's overall business impact on the plants in the study (hypotheses 13 through 16). The data do not support the existence of one of the relationships. However, the findings make sense, and they cast light on the results of different approaches to bridging the gap. Data accuracy is strongly linked to overall impact (hypothesis 13), although differentiation and customization do not appear to impact data accuracy (hypotheses 5, 9, and 17). On the other hand, there is a strong connection between differentiation and the *time and resources* dimension; and there is a strong association between time and resources and overall impact (hypotheses 7 and 15). By contrast, the use of alternative and informal systems does not appear to affect overall impact (hypothesis 16).

This difference between the impact of the use of alternative systems and the impact of time and resources is logical: When employees develop and use an alternative or informal information system they are using alternative technologies to fill a business need that ERP was intended to fulfill. However, the need *is* presumably being fulfilled, regardless of the means. If needs are being met without a big increase in the resources required to do so, plant performance should not be affected. Developing the system may require some resources, but once developed the system may fill its purpose admirably. The spreadsheet-based performance monitoring used throughout the Forest Products plant is a good example. On the other hand, when employees fulfill plant needs by working longer hours or expending other resources, plant performance may suffer. This may simply be a result of planners and supervisors being paid by the hour. Or it may go deeper: For example, two managers in the case studies mentioned that employees' working longer on the basics reduces the time and energy available for continuous improvement.

Measurement Findings

The effort to develop a valid measurement instrument was successful. In general this project demonstrated that the constructs in the theoretical model can be measured well. Several noteworthy findings emerged from analysis of the *a priori* measurement model.

There is mixed evidence that data relevance exists as a separate construct from data accuracy and other dimensions of local fit in the minds of respondents. Further examination as to whether it deserves a place in the task-technology fit framework may be in order.

Similarly the evidence that the instrument could discriminate between perceptions of interdependence and patterns and characteristics of resource exchanges was mixed. Wybo and Goodhue, hypothesized that these are separate dimensions of interdependence, and they presented some empirical evidence to back their claim. They warned that the dimensions should not be used interchangeably. The evidence that managers distinguish between the two is not as strong in this study: It appears that subjects make the distinction when the topic is interdependence with sales and distribution, but not for interdependence for other plants.

Limitations

The research model is limited in scope. It concentrates on the plant level and therefore the ultimate dependent variable in the study is ERP's overall business impact on *the plant*. It is risky to make the assumption that positive or negative impacts on a plant translate to positive or negative impacts for the organization as a whole. For example, in cases in which a firm's constraint does not lie within a particular plant, a negative ERP impact on the plant may have no effect on that company's ability to make money. In fact, top management may wisely choose to "take a hit" in the performance of one plant if doing so allows ERP to uplift a constraint elsewhere. This limitation does not mean that understanding local level-effects of ERP are not important. It simply means that not all local-level effects translate to global ones.

Another limitation is the assumption in the research model that objectives of implementing ERP are fairly consistent across firms. In reality, some firms do not implement ERP to improve coordination among sub-units, or, for that matter, to save cost, provide better information, or to accomplish any number of other objectives for which ERP is credited. Some firms may well have other objectives. Furthermore, the main motivation for some organizations is simply replacing current infrastructure Differing goals may explain some of the findings regarding the role of interdependence and coordination improvements with sales and distribution versus with other plants. Incorporating goals into a study would likely be beneficial. However, it may be infeasible because objectives are often not clearly stated and they can change considerably over time.

Finally, the assumption that ERP systems are configured to best meet the needs of the "average" plant may not hold in all cases. In at least some circumstances, the global ERP configuration is heavily influenced by the pilot plant. In other implementations, plants with the most influential or most vocal representatives have disproportionate influence. However, operationalizing these concepts would be difficult if not impossible.

In addition to these conceptual limitations, the dissertation has several methodological limitations. Many of these are a function of the trade-offs that were made and the limits on resources that were available.

Generalizing the results of any research is a dangerous proposition. Generalizability is improved by random sampling from the population. By contrast, this research used a number of sample frames that were generated opportunistically. The difficulty in securing participation resulted in using many sources of respondents. This fact may actually temper some selection biases. Nevertheless, it is far from certain whether the plants in the sample represent the general population of plants running ERP systems.

When it became apparent that it would be difficult to obtain an adequate sample size through the channels that were originally intended, the researcher elected to supplement the pencil and paper approach with an email/web approach. The researcher attempted to minimize the differences between the paper and electronic surveys (in terms of question order, cover letter/cover email wording, etc.). However, it is possible that the electronic format introduced methods biases. Furthermore, although the researcher took steps to limit and monitor access to the web-based survey, it is possible (although unlikely) that individuals outside of the intended sample frame could have accessed and completed the instrument.

The differentiation construct presented several complications. Differentiation was measured with causal indicators. Modeling with causal indicators is not well-developed compared to modeling with effect indicators. This was further complicated in this dissertation because the differentiation construct was also involved in an interaction. This required the use of a simple count, and alternatively a simple mean, as a differentiation indicator. One of this approach's limitations is its failure to provide insights on *which* elements of differentiation (product complexity, rate of product change, volume, etc.) affect ERP outcomes the most. Another weakness is the possibility that the estimate of reliability for the differentiation construct is incorrect.

The survey used perceptual measures. This is common practice in management research. Nevertheless, managers' perceptions of both qualitative and quantitative phenomena are not perfect reflections of reality. However, collecting objective measures on a large scale would be prohibitively costly for the phenomena under consideration here. Moreover such measures are unavailable for many elements in the research model. This project did attempt to operationalize most variables with multiple measures, which provides some evidence of their reliability and validity.

Contributions

Contributions to Academia

This work provides some confirmation of information processing theory, particularly as applied to the area of data integration. The survey data and cases provide evidence that the best choice of integrating technology does indeed depend. In particular, this study found strong evidence that the level of interdependence in an organization does affect the degree to which ERP– a highly integrative, highly standardized technology– will be beneficial. To a lesser degree, this project presented evidence that differentiation within an organization will reduce the appropriateness of a standardized integrating technology.

This research also increases our understanding of the manufacturing process choice framework. According to this literature, a requirement for high performance is a fit between market characteristics, product characteristics, and manufacturing processes. This research extends the evidence for this line of thinking into the computerized manufacturing planning and control systems area: It provides a conceptual basis and some empirical support for the notion that choices regarding the configuration information systems should be influenced by a manufacturing entity's product and process characteristics.

Contributions to Practice

This chapter began by describing the dramatic shift in the business community's overall attitude toward ERP over the past few years. The chapter presented evidence that ERP is neither a faddish monstrosity nor a universal elixir. It is neither good nor bad. Rather it makes good business sense under many circumstances but is inappropriate in others. This study identifies some of these circumstances. Firms can consider these factors as they continue to implement ERP and as they evaluate existing implementations. What's more, some of the same factors likely influence the success of newer, integrative information technologies, such as customer relationship and supply chain software. The maxim, *it depends*, almost certainly applies.

More specifically, this dissertation presents evidence that differentiation does affect ERP outcomes: Differentiation affects the fit of the ERP system with local plant conditions, and this influences the plant level business impact of ERP. The results suggest that ERP implementers should not dismiss out of hand managers who claim, "We are different." To disregard such claims is to risk saddling production and inventory management personnel with systems that require burdensome amounts of time and other resources to operate–an outcome which the survey links to a negative business impact on the plant. Differentiation also may mean that employees will work around the ERP system by using alternative systems, such as spreadsheets, or legacy systems. The survey data suggest that use of these systems may not harm plant performance. However, by the same token, such an outcome hardly justifies spending thousands of dollars on ERP. Furthermore, reliance on alternative systems instead of ERP at the plant level may mean that needed data are not captured by the ERP and made available elsewhere. Therefore, the use of alternative systems may have negative affects that are most visible, not in the plants, but in other levels or other functional areas of the business.

The research results suggest that, when differentiation is significant, firms should consider options besides ERP. Organizations have long used humans to interface between two or more loosely coupled systems. However, new technologies such as component-based architectures allow various sub-systems to operate independently of others. Both strategies have a potential place in any organization's arsenal.

Similarly, when ERP *is* the integrative method of choice and differentiation exists, the results suggest that firms should consider customizing ERP to meet the needs of plants whose needs differ significantly form those that can be met with the organization-wide ERP configuration. In particular, customization moderated the impact of differentiation on the use of alternative and legacy systems in the survey data. On the other hand, customization should be considered judiciously. Other literature points out the costs and risks associated with changing ERP source code. There are less drastic options; however, allocating the resources required to accommodate the needs of idiosyncratic sub-units though these other means still can be costly. Regardless of the approach, the costs must be considered in tandem with the benefits, and this research suggests that while the benefits exist, they may not be overwhelming: The relationship between the differentiation-customization interaction and the use of alternative systems is not as strong as other links in the dissertation, and the alternative systems construct is not associated with plant performance–at least not in the minds of this survey's participants. Furthermore, customization is not involved in any other significant relationships in the model.

The differences in the findings between the primary and alternative operationalizations of differentiation are also instructive to those wishing to apply this research. It is *large* differences from other plants on one or a few factors that plays a role in determining the appropriateness of ERP. By contrast, when the researcher operationalized differentiation so as to take into account small differences on all factors that were considered, differentiation played no significant role in determining local fit. This underscores an observation made in the Forest Product case, and in other researchers works: Attempting to accommodate all of a plants idiosyncrasies is a fool's errand. Instead, this dissertation suggests that special arrangements to meet the unique needs of one or a few plants should be carefully targeted to situations where major differences exist.

Many firms decided to implement (or not implement) ERP based on an comparison of the expected costs and benefits. The foregoing discussion explains how this dissertation casts light on the realization of certain ERP costs. However, the dissertation also provides guidance to those considering ERP's benefits. Specifically, the plant level benefits of ERP are affected by the level of interdependence between plants and their sales and distribution functions. Some manufacturing facilities do not share a great deal of interdependence with sales and distribution. For example, some plants produce to a master schedule that is frozen for many weeks or months into the future. It is possible that the projected benefits of ERP may be overestimated in these situations. On the other hand, in situations where there is a great deal of interdependence between plants and sales and distribution, organizations should plan to fully exploit ERP's ability to better manage the relationships.

Organizations also implement ERP systems to better manage interdependence among plants. This dissertation suggests that these firms proceed with caution. ERP systems may improve plants' ability to coordinate with other plants; however, this study found no link from improvements in coordination to overall business impact on the plant.

Future Research

The study suggests a number of future directions. Additional ERP case studies would provide a richer understanding of the phenomena considered here and a better sense of the context in general. One weakness of the case studies presented in the dissertation is the consideration of only one plant per ERP implementation. The researcher plans to study at least one additional plant in the Forest Products organization. This dissertation contended that many benefits associated with ERP's managing interdependence occur at the global level, not in the plants. Combining the local, plant perspective with the global perspective would be valuable. Another investigator has tentative plans to study Forest Products' ERP at the corporate level. Of course those findings would be combined with the other Forest Products cases.

To advance our understanding of Organizational Information Processing Theory it would be worthwhile to further explore why the findings regarding interdependence with other plants differed from the findings regarding interdependence with sales and distribution. The discussion section earlier in this chapter presented several possible explanations for the differences in findings. Each of these could be feasibly tested.

Finally, refining the operationalization of the differentiation construct as presented here would be valuable. This should be supplemented with additional work on modeling it in a structural equation context.

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APPENDIX A
Case Studies

1. Auto Products, Inc., Gainesville Plant

1.1 Overview

Over several days in March of 1999, the investigator interviewed the following employees of a single manufacturing facility: Plant Manager, IT Manager, Purchasing Manager, Industrial Engineer, Manufacturing Manager, Purchasing Manager, Scheduling Manager, and Controller. During the same period the researcher also interviewed 2 non-plant personnel: The former head of the division ERP implementation team and a former member of the team. Note also that the current plant IT Manager and Scheduling Manager served on the division ERP implementation team before they were hired at the Gainesville plant. Thus they participated in the Gainesville implementation. The researcher conducted face-to-face follow up interviews with the IT Manager and the Purchasing Manager and informal follow-up phone interviews with several other personnel.

1.2 Company Background

The corporation has approximately 200 manufacturing facilities with six billion dollars in annual sales. Most products are sold to OEMs and are highly engineered. Products include controls, hydraulic products and engine components. Gainesville, the plant studied, was 1 of 7 in the Engine Components Division (ECO), which reports to the Automotive Components Group. Most plants in the division were tier one suppliers to the major auto manufacturers.

1.3 ERP Background

Before the ERP initiative, each plant in the Engine Components Division, with the exception of Gainesville, ran its own MRP II-type system on an AS400. The systems were based on packaged software. However, over the 15 years that they had been installed, each plant's system had been highly customized to meet its particular needs.

IT Case for ERP:

Throughout the corporation, divisional IT traditionally reported to the division controller. However 1995 saw a corporate push to make IT more strategic. At this time, Engine Components IT began to report to the worldwide VP of Engine Components.

In the mid-1990's personnel at both the Engine Components IT Group and at Corporate began to realize that continuing to run current systems was becoming increasingly untenable. The systems were not Y2K compliant, and the fact that each system was unique would have made fixing Y2K problems very costly. An internal study suggested Y2K updates would have taken 10 man-years of programming time with no value added.

One feature that made fixing the Y2K problem difficult was the unstandardized nature of systems in the division. The lack of standards also made updates and maintenance costly; and updates seemed to be required at an ever-increasing rate. The Engine Components IT department's backlog of maintenance and upgrade requests was approximately 2 years long and growing. Furthermore, the industry was placing increasing demands involving IT on the plants. For example, meeting an upcoming bar-coding requirement by modifying the software in each plant separately would have been very expensive. IT personnel gradually realized that maintaining one standardized package instead of numerous packages would be easier. Indeed some felt it was the only practical option, given that current systems were getting older and the need for change was happening faster. Furthermore it was felt that having a software vendor do the general maintenance and updates would be more economical than continuing to do them in house because costs would be spread it over numerous firms.

At the same time, a number of corporate teams were re-establishing the IT "menu" of software and hardware items from which the divisions could choose. For example, one team was evaluating email packages, one was examining engineering vaulting systems, one servers, and so on. One of these groups was evaluating business control systems. (Business control encompassed the main business functions, such as manufacturing and accounting, but not engineering). They evaluated many packages, such as BPICS, MAPICS and Oracle. Their final menu was a limited one, as they chose BPICS for UNIX environments and Oracle for client-server. There was manufacturing representation on the groups in the form of internal consultants.

The ECO Division team that was charged with picking a new business system for their division was called the SLAM team. The team was led by a former plant manager and composed of functional/manufacturing people an division IT representatives. All plants in ECO were represented. One team member stated that she felt the team was "being pushed toward Oracle and BPICS," and this push probably came from the corporate level.

During this time, 2 other divisions both made the decision to install Oracle. Neither of these divisions were part of the Automotive Components Group. Each division would have its own data base instance.

Manufacturing case for ERP:

Manufacturing did not traditionally get involved in the selection of software. Manufacturing specified what functionality they needed, and IT and accounting chose the software.

However, there was at least some sentiment in manufacturing that new systems were needed. Manufacturing was aware of the increasing IT backlog; and some initiatives that manufacturing wanted to undertake were simply not feasible with existing IT.

There was also a "general feeling" that the current systems were outdated and that forward thinking companies were moving toward graphical user interfaces and client server architecture. The implementation manager characterized upper management's thinking as, "This [the current systems] is really old stuff. We need to do something different." The plant manager also stated that there was a general feeling that ERP systems were the "world class" way to go and that adopting ERP was in keeping with the more general continuous improvement mentality of the Group. According to the plant manager there was a "general feeling" that the system would produce advantages such as centralized purchasing, however, these were not explicit objectives.

Accounting: Centralized Financial Services

At roughly the same time the Engine Components group was considering ERP, the corporate accounting group was contemplating an initiative to centralize accounts payable, accounts receivable, and the general ledger. This initiative was a result of benchmarking that determined the corporation's accounting expenses were too high relative to similar companies. Centralizing accounting at the corporate level was viewed as a way to become more efficient and achieve "best in class" status.

The initiative to centralize was called Centralized Financial Services. Centralizing functions that had been performed in the plants required a significant IT investment. Revamping systems in accounting would also solve impending Y2K problems in that area. Accounting originally chose SAP. However, since 3 major operating divisions, including Engine Components, had chosen Oracle, Accounting decided to go with Oracle as well.

Instead of working off of the Oracle instance in each operating division, Accounting decided to operate its own instance of the Oracle database. This instance would contain all of each division's payables, receivables, and general ledger data. According to the manager of the Engine Components Division implementation, accounting was uncomfortable not having its own database with all of the accounting detail on it. Accounting decided to maintain its own instance in spite of being advised not to do so by Oracle, consultants and various internal groups. (A conversation with the IS manager after the case study revealed that this strategy was being reversed.)

1.4 Division ERP Players

The division's core implementation team, called the SLAM team, was formed in December 1996. The team manager had been the controller at the Hastings, Nebraska plant. The team contained representatives from all of the division's six plants, as well as divisional IT people. All members were assigned full time to the team. The assignment required 70 to 100 percent travel.

There were several other key groups. An Oracle Integration Team (OIT) was formed at each plant. Additionally, a group of consultants was hired.

During the life of the project, Oracle was installed in Gainesville. Installation work had also begun at the Hastings and Sioux Falls plants in January of 1998. Afterward, the SLAM team decided to put the Sioux Falls implementation on hold so that it could concentrate solely on the Hastings plant. When a new Division head took office in September 1998, he cancelled the entire Oracle project. The Hastings implementation was still in process at this time but reverted back to its legacy system.

1.5 The Gainesville Plant

Background on Gainesville Plant

The plant is a tier one supplier to several foreign and domestic auto manufacturers. Prior to 1996, the product made in the plant was not well accepted by the market. The plant shipped low volumes and was not a significant source of manufacturing revenue for the division. Instead the plant focused on improving the design of its major product and on refining the manufacturing technology to make it.

The product is made by machining 4 types of metal parts (gears, housings, rotors and shafts) each in its own cell, and then assembling them together along with some electrical components. (The generic product structure is described in the appendix). The average end item consists of fifteen to twenty components. Four finished goods models comprise over eighty percent of shipments. All of these major end items are produced continuously. Most of the materials management and manufacturing activity involves a total of only one hundred or so part numbers.

The Gainesville plant differed somewhat from many of the other plants in the division. For example, compared to Gainesville, many of the other plants produced a greater variety of end items in smaller volumes, less regularly. Furthermore, Gainesville was less mature than other plants.

The Gainesville Implementation

Because Gainesville was a low volume, low revenue plant in 1996, it was considered to be a low risk environment in which to install Oracle. Furthermore Gainesville did not have a working system installed. Therefore Gainesville was chosen as the first plant to install Oracle. Modules to be installed were:

- Manufacturing Package: Cost, Purchasing, Work In Process, Inventory, Order Entry, Quality (quality was abandoned);
- Finance Package: Accounts Payable, Accounts Receivable, and General Ledger
- Human Resources Package: Payroll.

In the months between the decision to make Gainesville the first Oracle site and the beginning of the Gainesville implementation, Gainesville's business began to surge as two auto manufacturers drastically increased their use of the plant's product. Unfortunately, the plant had an extremely difficult time meeting this new level of demand. The plant spent $10,000 per week in air freight to its customers. Its customers had representatives "camped out" full time in at the plant to make sure that their interests were looked after.

The Gainesville implementation began in Spring 1997 and went live in October 1997. However, while Oracle was running after October 1997, it was not really used to plan and control plant operations. Furthermore the system failed to produce inventory numbers and financials that were believable. A member of the SLAM team observed:

> ***If the system [Oracle] gave them bad information, they did not look to see what caused the bad information; they just went back to their spreadsheets.***

In the Summer of 1997, about three months into the Gainesville implementation, the Gainesville plant manager was replaced, largely because of the plant's difficulties in meeting its commitments to its customers. The new plant manager's first priority was shipping product to meet customer needs, not business control systems. She said:

We were able to get the point that we didn't let it [Oracle] impact our customers, we made products and shipped products and did what we needed to do to catch up with the system.

By August 1998 the plant was reliably getting product out the door in a fashion that met customer needs. At this time the plant manager began a program, called Lean, to simplify its logical and computerized systems. As a part of this program, the original Oracle shop floor module was replaced with a customized module that had been written by Oracle and Deloitte-Touche for another facility in the corporation. Another important (and ongoing) part of Lean was correcting bills of material and routings.

The Lean initiative also involved four to eight hours of training for all management people and "Anyone that has anything to do with the material on the floor or actually touching a part." The training included basic materials management and accounting concepts, as well as how these concepts related to Oracle. Individuals had to pass a test on the subject matter after the training. However, according to one interviewee, the training was not taken seriously enough by some individuals because they had such low regard for the system at the time.

Around this time a number of key personnel were replaced including the controller (in June), the IT manager (in August), the scheduling manager, and the Materials Manager (September). The IT manager and the scheduling manager had served on the SLAM team (the team that executed the Gainesville implementations).

Today the system is not used to plan and control manufacturing and materials functions. The Lean shop floor module makes the shop floor invisible to Oracle. Actual shop floor activity is controlled by the Kanban system (a simple control system that coordinates activities using visual signals). The current configuration is described in more depth below. Production and material planning are done on spreadsheets. The purchasing module is in use, but not without some consternation on the part of plant personnel and some "workarounds," which are described below. The plant manager characterized the situation as follows:

I would strongly disagree [with the statement 'you are running your plant using Oracle']. We are running our plant based off of our manual systems, and we have simplified Oracle to a point to be able to use it to accurately reflect our financial status that I find out at the end of the month how we did.

Similarly, accounting runs Oracle and its legacy system in parallel. However, unlike in other functional areas, the controller is confident that the accounting information in Oracle is correct (it matches the legacy data). The systems are run in parallel because the legacy system is still the official system of record for the division. Furthermore, Oracle will not generate many reports that are needed, such as standard margin reports because the financial (revenue) and manufacturing (cost) data are on two separate instances.

ERP Impacts on the Gainesville Plant

The Gainesville installation did not result in a system that was used to plan and control the plant. The following sections describe some of the problems that were associated with the ERP implementation.

Shop floor reporting

The manufacturing module was configured as a work-order based system with extensive shop floor control. The system was designed to track the quantity and location of all material that was in process. It would also track the amount of material in intermediate inventories (For example, when a metal blank was machined into a gear, it would be put back into inventory under new part number). Jobs were released to each cell in the form of manufacturing orders. A cell received numerous manufacturing orders each day. Each manufacturing order would specify information such as the part number and quantity to be made and the material from which it should be made. When work began on a manufacturing order, the quantity would be transacted in Oracle. The transaction removed material from inventory or a queue and placed it in process. When a job was completed at a cell, the quantity complete and quantity scrapped would be reported. Normally, this transaction would put the material back into inventory as a the new part number.

Plant personnel believed the this reporting system was too complicated and burdensome and that it was not a good fit with Gainesville's product structures and manufacturing flow. Completing a finished product required 26 reporting transactions in the shop. Furthermore, although he or she would typically run the same part all day, an operator might do so under 5 separate (but identical) manufacturing orders, each with its own reporting requirements.

This situation was aggravated by the user interfaces which were cumbersome. The current IT manager described them as "terrible, slow at best."

Prior to Oracle implementation, little shop floor reporting was done, and the Gainesville shop floor was notoriously "undisciplined" from a reporting standpoint. After the Oracle implementation, it is generally felt that operators did not conscientiously report production and scrap. There was also a attitude among plant personnel that the plant was not being run by the numbers that Oracle provided, which were inaccurate, so "why bother" entering correct data into the system.

To eliminate some of the reporting burden, at the beginning of the implementation, management decided that operators would report on paper. These reports would be put into log books, which were put into spreadsheets, which were put into another spreadsheet; and finally the information was entered into Oracle by one person for the entire shop. Thus, original reporting errors were compounded by the four opportunities for transcription errors.

The system was not a good fit. The Plant Manager described the situation:

> ***The group that was putting the system in place for Gainesville I think were pretty short sighted in that they had this ERP system, and they were going to implement it, and then we would adjust everything we were doing to fit the system. And so what we ended up putting in place was something that was order driven [and] required a lot of transactions from the shop floor portion of it.***

The new plant manager implemented a visual Kanban-based shop floor control system as part of the LEAN initiative. At this time, Gainesville replaced the Oracle shop floor module with a demand flow module as described above. The Kanban system coordinates activities on the shop floor. The new shop floor module essentially decouples the shop from Oracle or makes it "invisible" to Oracle. An Oracle transaction is done on the floor to release material from the raw material inventory into work in process inventory (WIP) on twenty-six critical parts. Other parts are never transacted into WIP. All parts are relieved from inventory (from WIP for the critical twenty-six and raw material inventory for the rest) when a product is shipped. Shipping, scrap reporting and entering the critical twenty-six parts into WIP are the only production transactions that are performed manually. This is essentially a *backflush* system. No other Oracle transactions are done on the floor to reflect inventory transactions or manufacturing operations, such as the machining of metal blanks into gears or the assembling of several components into one. Instead, the customized Oracle module automatically generates all such shop floor transactions when a product is shipped.

The Production Manager states that as a result of the new module he does not get some of the information he would like. This mostly pertains to productivity data on individual work centers. He has found some other ways to get the data using spreadsheets. He has also changed the way he manages the individual work centers.

Part numbers

Gainesville was expected to change its part numbers to standard ones in order to accommodate the ERP. According to the plant manager, changing part numbers would have affected data accuracy and the time it required to do transactions. More importantly, the burden involved in making the change would have been too great:

> ***The bigger issue in my mind is we have got light years of time that we have spent in our shop for documentation that is all part number driven. Everything we do is driven by a part number. And, tons of stuff on the shop floor as well as all of our prints and just all of our records that are around these part numbers. – Plant Manager***

The shop floor reporting problem and the part number problem were not allowed to persist. Perhaps because they affected production the most, the plant manager and others did not tolerate them. However, other problems are still being experienced today. These include purchasing-accounts payable issues, not getting information from the system and post-implementation inflexibility.

Purchasing System

The purchasing-accounting interface was also a problem. Oracle encompassed both accounting and purchasing/receiving applications. Purchasing was also affected by the centralizing of the payables function away from the plant to headquarters. The ERP implementation created major problems in the process of receiving and paying for component inventories. Resolving these problems required a tremendous amount of time particularly in purchasing. Buyers were spending fifteen to twenty-five percent of their time resolving purchase order/invoice problems.

Purchasing uses techniques from the JIT (Just-in-Time) philosophy. Purchase orders specify a total quantity to be purchased over a duration, such as a month or quarter. The timing and quantity of daily deliveries is specified weekly with a *release.* Daily deliveries are called *shipment numbers.* Daily requirements are often are often variable and unpredictable because they are based largely on plant consumption (which is base on an auto-maker customers consumption). Therefore, because of the difficulty in keeping up with this variable demand, it is typical and acceptable for actual daily quantities delivered by vendors to vary somewhat from the quantity specified on the release. Thus, before Oracle, receiving personnel were authorized to over- or under-receive a daily delivery within established tolerances. Discrepancies were resolved after the fact because the payables clerk had to get the buyers' approval before authorizing payment of any overages or underages.

To centralize and streamline the payables process, the Oracle implementation eliminated the local clerk and thus this step. Thus he Oracle configuration required that a precise match between quantities specified and quantities actually received at the time the goods were actually received. It required that each daily delivery match precisely the amount called for on the release. All physical receipts had to perfectly match the quantities specified (by the shipment number). Any mis-matches would go on payment hold

The problem was made worse because of the way the system handled over or under receipts at the back dock. If an overage was received, the "extra" was applied against the next open shipment number (usually the next day's quantity). If a shortage was received, the current day's shipment number was kept open and part of the next physical delivery would be used to complete it. Having overages from one shipment number applied to the next open shipment number in this fashion causes *all subsequent* shipments to not match the quantities specified. The purchasing manager refers to this as the "trickle down effect."

Because, after ERP, dock personnel had no authority to over or under receive a shipment, the only way to prevent the " trickle down effect" was for a buyer to change the shipment number quantity after the goods were physically received but before the receipt was transacted on the Oracle system. However, given the pace at the back dock, the number of receipts each day and the nature of the buyer job, this was not practical.

During Spring of 1999, purchasing *worked around* the problem, but the solution created some problems of its own. To prevent mismatches between deliveries and invoices and to prevent invoices from going on payment hold, purchasing abandoned the practice of specifying the quantities of individual (usually daily) deliveries. Instead, purchasing issues an order with only a single weekly quantity specified. The actual daily delivery quantities are specified outside of Oracle. To further prevent mismatches, purchasing overstates each weekly release when it issues the release. At the end of the week (after all deliveries on the release have been received) the buyer then adjusts the release quantity to match the quantity actually received. For example, if the plant needs a weekly quantity of, say 2,500, purchasing issues a weekly release without specifying the daily quantities. Furthermore, the weekly release will be for a quantity more than is actually needed, say 3,000. At week's end, the buyer adjusts the release to the quantity actually received, ideally 2,500.

However, this "workaround" solution has some significant negative impacts on the business. First, It is time consuming. Second, it creates performance measurement problems. For example, the plant needs to measure vendor performance, including whether vendors ship correct quantities. If the vendor ships 2,400 total or does not ship accurate daily quantities, the plant has problems detecting and tracking it.

Interfacing with the ERP

Interviewees expressed near unanimous frustration with the interfaces. This included:

- entering data, such as a purchase order or new item master
- getting ad hoc information from the system
- regular reports

Results include doing one's job with less data, developing alternative sources for the information, or more time spend on gaining information. The following statements characterize typical sentiments:

> ***Maybe it would get easier for me once I get a better handle on the system itself, but looking at certain applications that you want particular information, again, you're looking at, you go into one screen so that you can go into another one, to another one, to another one, to finally get what you need. And, it's not like there's a shortcut. – Purchasing Manager***

> ***I may be putting in a bill of materials, and I'm inputting the information, but I can't see everything on one screen, so I have to go from one screen to the next to get information that I need. When I'm putting in a part number, I put in the description, but I have to go to another screen to put in the effective due date, go to another screen to put in the materials control type, and things of that nature, so it takes a while to do certain things because you can't see everything on one screen. That's frustrating, and I think that, you know, if I knew that it wouldn't have such a negative impact on everything, I probably would just whiz through it.—Industrial Engineer***

On the other hand, better reports and interface screens are beginning to be developed now that data accuracy and reporting issues are being solved. However, several managers pointed out that the expertise required to write the reports does not reside within the corporation.

Ongoing flexibility

Many of the people interviewed expressed concern that the plant would not be able to continually adapt Oracle as conditions change and modifications to business practices (and thus the ERP) are needed. However, the researcher had a difficult time eliciting examples of this; however, the following quotes provide a sense of the nature of the concerns:

> ***Based on what I've seen so far, I don't see Oracle changing that much. It's a matter of our adapting the changes to Oracle, and that's the way I see it. It's not like we can take the system and adapt it around what we're using anymore; from now on, it's our adapting around the system. –Purchasing Manager***

> ***New business [practices] as I see it has to be put in and we have to work with new business based on what we use in Oracle and you've got to adapt that to the system, the system's not going to adapt to us..... Right now that would have to be tailored to Oracle. It's not like we could take Oracle and ...mold it around what we want it to do. - Purchasing Manager***

Some reasons for the impacts

Lack of pre-existing systems

Prior to 1996, the focus at the plant was on engineering the product itself and on refining manufacturing techniques. One observer stated, "The plant was run by engineers." Materials management and production planning and control were not critical to the plant's success because production itself was not critical. Therefore the plant did not have well-developed production planning and control systems in use. For example, bill of material and routing accuracy was poor; and few procedures for reporting existed. The SLAM team leader described the lack of use of control systems by saying, "If they wanted to know how much they had in production or in inventory they just went out and counted them."

This situation had several implications. First, the plant was not in the habit of following the dictates of any system. Second, the SLAM team found themselves in the position of modeling processes that did not exist. The IT manager (who was a SLAM team member) said:

> ***The biggest reason why it [using Oracle] did not stick is because the software wasn't part of their processes. Their business processes were not nailed down to the point where 'this is what this person does every day and this is how they feed data into the system.' And because there were no business processes and no discipline put in place, they just quit using it.***

The plant manager also noted the lack of materials management expertise at the plant and the inability of the plant to ensure that the configuration met its needs:

> ***We did not have the resources in this plant that had any experience to be able to ask the right questions or to even know what they need. They were expecting the solution to come from above and it would fit our operations.... In terms of the material control [expertise] we didn't have any***

Implementation Related Issues

No doubt, the surge in plant business at same time as the implementation had an impact on the implementation. Two such impacts were Gainesville people's not getting involved in the implementation and a lack of time for training on the part of Gainesville people. According to one source Gainesville personnel were simply "spread too thin." The decision was made to give people a minimal amount of training, which was limited to how to perform transactions. Training did not include an overview of the system or the relationship between business processes and Oracle. Furthermore, the SLAM team made many decisions about business process to incorporate into the system without input from Gainesville personnel because Gainesville personnel were often unavailable for consultation.

SLAM team personnel note several other factors that affected the implementation:

- Many of the Gainesville personnel that SLAM team involved heaviest in the implementation left the company.
- Division management had little tolerance for slowing down or moving the pilot to another location because of the Y2K and because strategic use of IT had become a major focus at corporate.
- Inexperienced Deloitte & Touche Oracle consultants, who were "too green."
- The software was "too new" with "too many bugs and patches"
- Separate instances for accounting and the division. Many manufacturing implementation decisions were contingent on Accounting decisions which had not been made. The SLAM team did no understand what accounting transactions are

driven when a manufacturing transaction is made or the effect on the general ledger. The IT manager stated "We honestly did not understand the accounting side at all."

IS's understanding of the ERP

The current IT Manager (who served on the SLAM team) said that the SLAM team lacked a sufficient understanding of the software. Most of their training had been on an Oracle demonstration database. They did not test Oracle's "basic functionality" as part of their conference room pilot. The IT Manager maintains that because of this the SLAM team never thoroughly understood the intricacies of the system.

A SLAM team member who trained Gainesville personnel in one of the modules stated that he knew how to "push the buttons," but did not really understand the underlying logic of ERP.

The IT Manager and SLAM team manager both pointed out that a particular weakness among the consultants was that they did not understand the interrelationships between different modules of Oracle.

2. Forest Products, Inc., Augusta Plant

2.1 Overview

In March and April 1999, the researcher interviewed the following individuals in the Augusta manufacturing facility of Forest Products Corporation: Plant Manager, Senior Plant Accountant, Accounting Clerk, Purchasing Manager, Master Scheduler, Customer Service Representative, Master Scheduler, Shipping Supervisor and two Department Managers. The researcher conducted several follow-up interviews with the plant manager and other personnel.

2.2 Company and ERP Background

Forest Products Corporation (FPC) manufactures construction materials such as joists, beams, plywood and engineered lumber. Logs are the primary raw material. FPC has approximately $1.2 billion in sales annually, generated from approximately 20 manufacturing facilities, all in North America. Finished goods are stocked at the plants and shipped directly to customers and distributors. Our focus in this case is on FPC's Augusta plant.

In the early 1990's management felt Forest Products systems were inadequate for several reasons. Current systems were not Y2K compliant. Furthermore, the plants were running various systems that did not communicate with one another. Thus customers had to place and track orders with multiple plants. In fact, it was difficult to even find out how much inventory FPC had for a particular item without making telephone calls to numerous plants.

In 1993 it was decided to implement a number of SAP modules (version 2.1) across all plants. The modules chosen were manufacturing and materials, finance and accounting, and sales and distribution. Access to and control of the SAP system were to be maintained at the corporate IT level. Most plants, including Augusta, did not have IT on staff.

Along with outside consultants, a project team from corporate IT began implementing SAP beginning with the Augusta plant. Because of the differences among plants, they implemented a different configuration of SAP at each plant. This included significant customization of the SAP code.

The approach created several unforeseen problems. The high levels of customization required considerable resources. In fact, the team spent the entire implementation budget on just 4 plants, and the project was then put on hold. Shortly thereafter SAP began releasing revisions to version 2.1, some of which enabled SAP to better handle the 3 dimensional nature of Forest Products' items. Unfortunately, having customized the code to meet the needs of different plants during implementation, Forest Products found that installing the upgrades was not feasible.

At this point a new IS vice president was hired for ERP implementation. He pointed out the problems in implementing a unique configuration of SAP at each plant, and he stressed the importance of developing one business "vision" for the entire company prior to moving forward with ERP. In 1996, the *Blueprint Team* (which included the manager of the Augusta plant) was formed to develop this vision. A group of mid and top level managers was assigned to this team full time for six months. A consulting group was also used. The focus was on manufacturing planning and control One result was the creation of the master scheduler position at all plants.

After the company-wide blueprint was created, SAP 3.1 was to be implemented in all 20 plants in 2 years (prior to the year 2000), this time with the help of a different outside consultant. In contrast to the approach taken during the first round of implementations, FPC did not allow its plants to modify SAP code. In fact, to facilitate implementing the software on the tight two-year timetable, a "fast-track" template-based approach to implementation was used. This approach stressed standardization and allowed for little configuration to meet individual plants' needs.

At the plant level, most of the differences between the 2.1 and 3.1 implementations were in materials management, shipping, and customer service.

The first implementation occurred at the Augusta plant and was completed August 1998. Now about 20 office staff plus 20 operating managers and associates use the SAP system at Augusta.

A shop-floor data collection system called FACE was also implemented company wide at this time. FACE provided a more user friendly interface that uploads data to SAP.

2.3 The Augusta Plant

The plant has approximately 350 employees. It produces engineered beams and other similar materials. The plant has four departments: green, dryer, press and finishing. In the green department trees are received, prepared, and "unrolled" into sheets of veneer. In the dryer department veneer is dried and then stored in bundles. In the press department, bundles of veneer are cut into strips and mixed with glue before being fed into a press. The press runs one continuous length of material. As material exits the press it is cut into fifteen to fifty foot billets. In finishing, these are cut into finished lengths, which are bundled and sent into the finished goods storage yard.

There are a number of stock items (standard depth, width and length) but many products are sawed to order. Lower volume sawed-to-order material is referred to as configurable material or *NSTOK*. After being cut and bundled in finishing, stock and non-standard (NSTOK) products go into finished inventory. Off-cuts (leftover sections of billets from finishing) and rejects containing some usable material go into *recovery-reclaim* inventory for use later. Partially complete orders (partial bundles of identical items) are also stored in *recovery-reclaim,* since from this point onward the organization only keeps track complete bundles.

Each plant's customer service department takes orders. Stock orders that cannot be filled from finished goods inventory are promised against future production. Non-standard orders are sawed to order (from recovery/reclaim inventory material or new production).

The wide variety of finished goods configurations it ships sets the Augusta plant apart from other facilities in the company. In its product line, it is the only plant that handles non-stock lengths. For example, Augusta manufactures all European (metric) orders which is a significant business segment, but is still treated as NSTOK.

2.4 Benefits from ERP

According to the interviewees, the system has produced several important benefits at the plant level. SAP maintains perpetual inventories of finished goods and of some intermediate materials. These increase the plant's ability to make and keep customer commitments. Additionally, several interviewees stated that SAP improves accountability and self-discipline within the plant. SAP provides visibility of production orders that are open in the plant and it provides accurate inventories of intermediate materials, such as veneer.

At the company level, SAP improves coordination among plants for filling customer orders. A customer service representative in one plant can view all other plants' inventories using the SAP system; and some plants can enter finished goods orders against one another's inventories. Before SAP, both of these activities were conducted via telephone, which was more time-consuming and error prone. By providing increased inventory visibility, SAP has improved order promising capability. It does not appear that SAP is being used to consolidate master schedules and provide true "available to promise" capability. This will be brought on-line in the future.

The first three of Augusta's four production departments (green, dryer, and press) are satisfied with SAP. Unlike the finishing department, these production areas are very straightforward in terms of manufacturing planning and control, and typical of most operations in FPC. The reaction of the manager of the dryer department is representative of these departments. He stated that the simplicity of their processes has a lot to do with their satisfaction:

> ***When you take a log and you peel it, and you make a stack of 4 x 8 veneer, all SAP is doing is tracking: that's worth 90 cubes, 90 cubic feet. Then***

when the dryer uses it, through the FACE system, we withdraw that from inventory and it minuses out and it gets added to the next stuff along the line.

Furthermore, SAP has eliminated many reporting and data entry chores. For example, prior to the first SAP implementation, the dryer department employees had to calculate the cubic feet of each bundle of veneer removed from green inventory and the cubic feet of veneer entered into dry inventory. This involved measuring bundle height and multiplying by a factor. At one hundred to two hundred bundles per shift, this practice resulted in a lot of mathematical errors and, ultimately, in poor inventory accuracy. The first SAP implementation eliminated the math errors by performing the calculations automatically, and the second implementation went even further by all but eliminating data entry through bar-coding each bundle.

The dryer department manager states that SAP is now a “piece of cake,” and that, “Bottom line, it’s saving us an enormous amount of time now not having to do all those hand calculations.” However, there were some valuable reports he received under the previous version of SAP that he does not receive now.

Finally, the system produces real-time cost per unit information, whereas previous systems produced it only periodically (at month end). However, plant personnel raised serious concerns about the validity of this data.

2.5 Problems from ERP

Many problems stem from the poor visibility of information regarding NSTOK orders and *recovery-reclaim* inventory. The accuracy and understandability of performance measurement and accounting data are also issues. The problems often result in the use of informal systems or "going without."

NSTOK Part Numbers

One goal of the SAP 3.1 implementation was to enable *available to promise* calculations. Doing so without adding unacceptable levels of complexity and IS staff required drastically reducing FPC’s number of *stock* model numbers. The biggest part of the problem came from the many stock model numbers used for non-standard products. Since most plants had little actual volume of non-standard products, a compromise solution was found. Starting with the SAP 3.1 implementation, FPC instituted "configurable material" or *NSTOK* part numbers for all non-standard products. A given NSTOK number is used for all non-standard products with a given width and depth, *regardless of length.* For example, all non-standard items that are 3.5 inches wide and 14 inches deep are assigned part number 897686, regardless of their length. Since NSTOK part numbers do not indicate length they cannot be used as a way to identify what has been ordered on a particular sales order. The only way to determine that is to pull up the individual line item of the sales order and look at the text description. Nor is it clear what "quantity on hand" or "quantity produced" means for NSTOK items. Finally, a bundle of NSTOK product in the plant cannot be fully described by its part number. The only way to fully identify the configuration of product in such a bundle is to indicate its order number and line number.

According to plant personnel, for other plants in Forest Products, this way of handling non-standard products worked well enough. However, because of its heavy volume of non-standard business, relative to other plants, Augusta is experiencing problems related to NSTOK. For example to create the schedule, the master scheduler needs to know what orders have been placed, and what recovery-reclaim is available for cutting. For any planned order related to NSTOK, the SAP standard reports he receives indicate the quantity, depth and width of the material needed, but not the length. To discern the length he needs to open up the appropriate line item of the specific sales orders. As a result the master scheduler spends approximately 30 minutes per day looking up NSTOK requirements in sales orders. NSTOK creates similar visibility problems in the customer service department.

Making changes to customer orders is difficult. Using sales order number as part of the identifier means that identical items are not interchangeable. For example, when orders are being physically assembled, the picker must locate the distinct package of NSTOK that is associated with the order being picked, even if there are numerous identical packages in inventory, which is often the case. For many products this is no great inconvenience, but it greatly complicates operations at Forest Products' Augusta plant because the size of the items (often fifty feet or more in length) makes moving them difficult. Furthermore because NSTOK is identified by sales order, a bundle of NSTOK material cannot easily be moved from one sales order to another. A customer service representative explains:

> ***It's locked in, all the way down to that package number. You might have 9 packages out there that are 39 foot, the same size and everything, but each one is assigned to a specific order and it has to ship with that order. So, if the customer calls and wants to change his mind or, let's just say he wants to take that same package and move it to another one of his trucks, that is chaos. It's a nightmare.***

Recovery-Reclaim Inventory

Off-cuts and partial bundles are stored in recovery-reclaim inventory until they can be used on new orders or completed. Because of its high variety of configurations, Augusta has some of the "toughest cuts" in the company. This results in a lot of leftover billet sections and thus a lot of recovery-reclaim inventory to manage.

Since FPC's ERP system is part-number driven, the only way to track the exact contents of recovery reclaim inventory would be to assign a part number to every piece that was placed into recovery reclaim. FPC management feels this is not worthwhile because of the sheer (potentially infinite) variety of lengths of off-cuts and rejects. Therefore, all material that is placed into recovery-reclaim is inventoried under a single part number, and SAP only "knows" the total cubic feet in recovery-reclaim.

This poor visibility into recovery-reclaim causes problems for the plant. As mentioned earlier, to avoid wasting usable material, the master scheduler needs to schedule cuts from material in recovery-reclaim whenever possible, instead of cutting into "fresh" billets. To have better visibility, he would like to keep a perpetual recovery-reclaim inventory in Excel; however, doing so would require a full-time clerk which the plant cannot afford. Therefore making the best use of recovery-reclaim is difficult, and the master scheduler estimates it has added five to ten hours to his work week.

NSTOK also creates visibility-related problems in the customer service, where orders are entered. Once an order is entered, the customer service representatives have poor visibility of NSTOK materials that are on order. This creates problems in situations where a customer inquires about materials he has previously ordered. The only way for customer service to identify NSTOK materials is to drill down to the line item of the actual sales order.

The finishing department, must do manual calculations in order to manage the daily material flow into and out of recovery-reclaim and the associated reporting. This activity consumes about 1 man-day *everyday,* and the department recently hired a clerk solely to work on it. This problem has gotten progressively worse as more standardized ERP software has been implemented. The department manager spent sixty to ninety minutes per day on such tasks when the initial, customized version of SAP was installed, and approximately 30 minutes per day using their old, totally customized system before any ERP was installed.

Performance Reporting

In addition to visibility problems for critical information, there is also a problem with the meaningfulness and accuracy of SAP reports. This surfaces in a number of different areas and is often addressed by maintaining alternate reporting systems.

In the finishing department, production and cost numbers generated by SAP are not useful to the finishing manager. The key performance indicator for the finishing department manager is *recovery* (net finished good production divided by billets received into the department to be sawn into finished goods). However because of recovery-reclaim, SAP does not provide a meaningful recovery metric that the department manager can use to gauge performance on a daily basis. The problem with SAP (as it was implemented at FPC) is that it only considers as production those completed bundles placed into finished goods inventory. It does not count material in recovery/reclaim, including partial bundles even though from the standpoint of measuring the department's efficiency they are finished production. As a result yield is understated some days and overstated on others. Because the SAP daily production report is not managerially meaningful, the Finishing Department Manager and other managers use a manually generated Department Production Report maintained on Excel. One department manager states:

> ***Really, SAP, even though that's eventually what the plant's performance is based on, I don't really use a lot of the numbers that we're entering. Number one, they're not easy to get to. I know my way around the system, but they're not easy to get to and I don't trust the numbers that it gives me.***

Similarly, the senior plant accountant and the plant manager have concerns about the accuracy of SAP generated reports. Some problems are inherent in FPC's SAP configuration. For example, because an NSTOK part number does not signify length, it is difficult to track the cost per cubic foot produced. This creates problems valuing certain business segments, such as European sales. Other deficiencies are due to errors in the logic implemented. The plant manager and accountant have noted many discrepancies between SAP-based performance reports and both historical averages and manually generated reports. Corporate has investigated some of these and the plant's internal figures or estimates have been found correct.

As a result, the plant manager and his team make many decisions based on a manually generated plant production report. This report draws data from the FACE system, and from various departmental reports, some of which are generated from tally sheets on the shop floor.

Compared to other systems, the SAP system is unforgiving from an accounting point of view. On several occasions, the accountant has literally spent days undoing the effects of errant transactions.

Complexity and Understanding

Even though the Senior Plant Accountant has years of experience in a variety of manufacturing environments, he has difficulty comprehending how costs are calculated and passed on from one department to another in the current system. Furthermore, because SAP limits his access to information and because it restricts the format into which this information is organized, SAP makes it more difficult to investigate and understand.

The Senior Plant Accountant feels that eventually the problems will be fixed and that reports will be better tailored to the needs of the plant but that right now resources are a problem. However, he points out that in previous systems he would have done much of this customization himself. Now, because of the integration of plants and associated complexity, he is dependent on the corporate SAP team. He states:

> ***If you tinker with something, you're tinkering with something that 19 other plants are using, too, and you just can't do that. Not all the plants are exactly the same, so you don't know what you'll screw up somewhere else.***

2.6 Analysis

2.6.1 Compromise Costs

Product variety and the degree of product customization are two fundamental characteristics of manufacturing tasks. Forest Products' Augusta plant differs from other plants due to the wide variety of non-standard finished products it produces. As discussed above, Augusta's need to make more extensive use of NSTOK part numbers and recovery/reclaim than its peers is a result its relatively high variety and low volume (per configuration). When rolling out SAP version 3 (in contrast to the version 2 project), FPC used a fast-track implementation strategy that left no room for customizing ERP to meet an individual plant's needs. As a result costs were incurred. When FPC configured SAP to handle NSTOK and recovery/reclaim, it assumed that non-standard cuts and non-standard products were rare. This was a valid assumption for most plants, but not for Augusta. The organization made a deliberate decision to accept the "ungraceful" manner in which the ERP system handled NSTOK and recovery-reclaim. This trade-off was worth putting up with at the other plants because of the infrequency with which most of them had to deal with non-standard business and thus with recovery-reclaim and NSTOK. But at Augusta this solution led to operational problems for the master scheduler and the finishing manager, as well as reporting problems that rolled up to the plant manager level. The Augusta plant has responded by relying on several manual systems, but these are resource intensive and still have not solved its problems regarding the accuracy of information.

Because of a desire to economize on time and personnel costs, Forest Products decided not to attempt to accommodate the differences of the Augusta plant. However, the plant acknowledged this possibility that the SAP system *could* meet the plant's needs. Unfortunately, because of the complexity of their ERP system, neither the plant manager nor anyone on his staff has the necessary understanding of the system to *even know if there is* a more sophisticated global configuration that meets his needs while also being compatible with the needs of other plants. What's more, corporate IS personnel who might have the knowledge are busy elsewhere. In general, such knowledge is in short supply and costly. Even more resources are required to actually implement such a configuration.

While Forest Products made a *deliberate* decision not to accommodate differentiation, several interviewees suggest that uniqueness also determines which *unanticipated* problems go untreated, as well. For example, one interviewee stated:

> ***Nobody's going to back you up now because you're the only plant with a problem. The problems that are getting fixed are problems that are pretty similar throughout all plants. The problems that aren't getting fixed are the ones that are individual problems, specific to plants.***

This suggests that given enough resources, Forest Products may have been able to improve their SAP configuration's fit with the Augusta plant, but it also underscores the scarcity of such resources and thus the magnitude of potential design costs.

2.6.2 Benefits

One hallmark of ERP is its high level of integration among plants and other business units and functions. This can have significant benefits in terms of centralizing information for corporate decision-making, improved operational coordination among sub-units and the elimination of administrative redundancies.

We saw some impressive benefits at Forest Products. Some of these were related to ERP's integrative nature. For example, at Forest Products the ERP provided better coordination among plants by allowing customer service reps to see inventory across multiple plants and to place customer orders against other plants' finished inventories.

3. Refrigeration, Inc., Duluth Plant

3.1 Overview

In May 1999, the researcher interviewed the materials manager, several buyer planners, the receiving supervisor the a receiving clerk.

3.2 Company & plant background

Refrigeration, Inc. (RI) is a $1.2 billion company in the transport refrigeration business. Major lines are container and truck refrigeration units (Duluth does both of these) and bus air conditioning (produced in Duluth's sister plant in Valdosta). The company has 3 divisions: North American Division, International Division, and Service Parts. Service Parts Division is not part of the SAP implementation, but the other divisions are.

All plant functions that use SAP report to the Materials Manager. He also has materials responsibility for the Valdosta plant. The Production Control Supervisor reports to the Materials Manager; 10 planners report to the Production Control Supervisor. Three of these are buy/planners for container products, three for trailer products, two for the Valdosta plant, one for MRO; and one does production planning. The MRO buyer/planner and the production planner do not use SAP. The materials manager and several of his people have participated in implementations at other plants.

Manufacturing planning and control

The plant uses the traditional manufacturing planning and control framework and kanban. Most purchases are planned and controlled using the MRP and procurement systems. Some shop floor activity is controlled by MRP and some by kanban. The materials manager would like to move more purchasing to kanban.

Most of the system administration is done at headquarters. For example, running jobs to interface SAP and the legacy system. Also the report writing capability is at HQ. The Duluth plant does not have IS staff. Master Scheduling is also done at corporate.

ERP Background

The company is implementing SAP's procurement and MRP packages in all plants. However they are continuing to run a legacy MRP system in parallel with SAP in each plant and interfacing the two systems (this is discussed further below). Duluth was the pilot plant for the SAP/Legacy plant level implementation. It went live July 4, 1997. The Valdosta Plant went live November 1997. Today 7 of the 14 manufacturing plants are on the SAP/legacy configuration. The company has also implemented SAP's financial/accounting module. This began in early 1996.

A consulting firm assisted in the Duluth implementation. Currently, implementations are handled by an internal team.

SAP was chosen because the parent company already used it, and thus RI could acquire SAP for very little cost. The business unit controller and two vice presidents and general managers made the decision to go with SAP and what modules to implement. One interviewee described the decision to implement only the procurement portion of the production module, not the whole manufacturing and logistics module, as "purely financial"—it was to save the costs of buying and implementing other modules of the software.

The company will probably to implement more of the SAP production software in 2000, but that depends somewhat on the blessing of the new company president. (The company was sold to another parent after the SAP implementation was underway). A major upgrade was planned for Spring1999. It has been postponed and is now scheduled for September or October.

Objectives for ERP

SAP was part of an overall restructuring of the purchasing organization. ERP enabled purchasing to be split into centralized *supply management* and plant level *buying/planning*. Supply management is centralized at headquarters. Supply managers are responsible for negotiating and administering contracts with vendors. Supply managers develop in depth knowledge of a limited number of commodities. This includes a knowledge of the market and individual vendors, as well as well as a thorough understanding of how the commodities are used in the company. At the local level buyer/planners determine the need for material to support production and they issue and manage PO's for material to support that production. They are also responsible for planning production.

In 1994, a prestigious consulting firm pointed out to company management, that the information to effectively carry out the centralized supply management concept was not available with the old system. At the company-wide level, the legacy purchasing system made it very difficult to roll-up and access information from multiple plants. Examples of such information include system-wide purchases of a particular commodity or quality problems for a particular vendor. The legacy system also made rolling up forecasts of component usage across plants difficult. A better system was also needed to make centralized information, such as the details of contracts for each part, available to the buyer/planners in the plants.

A former buyer described the pre-ERP situation:

> ***Our supply managers in Minneapolis, to try and get the information that they needed to go out and try and get some [better contracts and so forth]. They didn't have the information. They'd be e-mailing us down here, and we'd have to dig through paper files to get what they wanted, and now they can just run a report and get what they need.***

ERP would also provide better control of payables. Furthermore, SAP was the corporate standard and putting Refrigeration, Inc. on this system would facilitate corporate level accounting and financial decision-making.

3.3 The Refrigeration, Inc. ERP System

Duluth's manufacturing planning and control system combines a legacy MRP II system (an old AS400 MAPICS-type system) and several SAP modules. The Duluth plant (and the other plants in the implementation) run the following SAP modules: Receiving, purchasing and MRP. The legacy MRP module is run in parallel with SAP. Some companies run parallel legacy and ERP MRP systems solely because of concerns about the validity or reliability of SAP. However, at RI running both systems is required because of the fact that shipping and production functions are performed on legacy systems by design.

The following activities are still performed in the legacy system: Shipping, master scheduling, shop scheduling, interplant material transfers and shop floor reporting, such as material movement transactions and production reporting. The following table indicates the system on which each purchasing and materials management activity is run.

Table A.3.1 Refrigeration, Inc. SAP and Legacy Functionality for Purchasing and Materials Functions

	SAP	Legacy
Master Scheduling		X
MRP	X	X
Purchasing	X	
Production Scheduling		X
Shop floor reporting		X
Receiving	X	
Shipping		X

Running 2 parallel manufacturing planning and control systems requires extensive data transmission across these systems. This requires extensive bridge programming and the careful sequencing of data processing jobs in IT at headquarters.

The system in practice

This section describes in how SAP (and Legacy) are being used in the plant. Since the use of SAP or Legacy is discretionary for the buyer/planners and materials manager, details of actual use provide clues about the effectiveness of each system.

Buyer/Planners

One of the two primary user groups at the plant are buyer/planners. They use the SAP/Legacy system to receive information and to perform transactions, such as preparing and issuing a purchase order. The following table summarizes the uses of legacy and SAP for the buyer/planner role.

Table A.3.2: Refrigeration, Inc. SAP and Legacy Functionality for Buyer-Planner Job

	SAP	Legacy	Manual
Job Functions			
Material Planing (Determine whether/when to issue/reschedule PO, etc.)	X	X	
Prepare/issue PO	X		
Correct invoice discrepancy	X		
Track vendor performance	X		X
Information Sources			
MRP record	X	X	
Master Schedule		X	
Bills of Materials/Item masters	X	X	
Invoice discrepancy report	X		

The buyer/planners use SAP for preparing and issuing purchase orders. They also review and process invoice discrepancies using SAP. Buyer/planners use both the SAP and legacy systems for material planning (comparing planned usage with scheduled receipts, reviewing historical usage, pegging, etc.).

Generally, each time an MRP system is regenerated (e.g., weekly), the system produces a material planning record for each part for which action (e.g., placing or rescheduling a purchase order) is needed. Determining whether and how to act on these "action messages" is a central function of the buyer-planner. At Duluth, buyer/planners receive *two* sets of material planning records– one generated by legacy and one generated by SAP. In general, buyer/planners conduct a cursory review of both sets of records for two reasons: First, inconsistencies, such as differing on-hand balances among the two, indicate an interface glitch and must be resolved. Second, SAP and legacy have slightly different criteria for whether planner action is required so both systems print out a slightly different set of records.

The need to do a cursory review of both sets of records notwithstanding, whether a buyer/planner primarily depends on the SAP records or the legacy records is a combination of both personal preference and fundamental differences between the two systems. The more senior buyer planners are more accustomed to the layout of the legacy system planning record, and they therefore prefer using it as much as possible. Operating in this mode, they "toggle" between legacy and SAP, which they must use to act on their decisions (by placing or rescheduling PO's, etc.). Legacy presents the planning record and ancillary information such as historical usage and lot sizes on the same page, whereas SAP requires moving to other screens for such information. Furthermore, legacy presents the MRP record in a format that is more like one would find in most other systems and general training materials.

All planners use legacy for *pegging*, which cannot be performed on SAP as it is configured at RI. Pegging is the ability to determine what upper level (e.g., finished goods) requirements are driving planned requirements for lower level parts (e.g., compressors). In the researcher's judgement, pegging would be possible on SAP if master scheduling, interplants and other functions were running on SAP.

In practice, individuals who were employed before the SAP installation prefer legacy, while both buyer/planners hired later prefer SAP. Several interviewees (both "old timers" and newer hires) stated using legacy instead of SAP is largely a matter of personal comfort and reluctance to change. The Materials Manager stated:

> ***It's like Charlie Brown and his blanket ,so to speak, but they still like to have the ability to go back and look at the mainframe and look at MRP, because that's what they were raised with and it still has the right data and they would trust it before they would trust SAP.***

SAP meets most of the Material Manager's information needs. These include purchasing commitments for a period, material received for a period, production problems and their causes, invoice price discrepancies, vendor on time performance.

There are a some shortcomings in SAP generated reports, however, personnel are generally satisfied. Two reports that buyer/planners are not receiving are vendor performance by planner code and MRO receipts. Neither of these are forthcoming and their absence appears to be a result of configuration decisions and limitations in SAP. However satisfaction with reports is generally good. The materials manager reports that it has taken time to develop the reports that plant personnel want and that personnel find useful, but they are "most of the way there." According to the Materials Manager, users can get whatever they want on a report in whatever format. However, since the reports are written centrally, this can and does take time.

Receiving

In receiving, whether to use SAP or legacy is not discretionary. Both receiving department clerks use SAP to "receive" shipments. In other words, after package contents are verified against packing slips, the clerk enters the purchase order and line number and the quantity from the packing slip into the SAP system so that the system reflects the receipt. The inventory control system is designed so that subsequent transactions, such as move and put-away transactions are done on legacy, which controls the shop floor.

The receiving supervisor receives two reports from SAP. One lists discrepancies between SAP and legacy. The other is simply a list of all receiving transactions that have been completed. Furthermore, for troubleshooting, the supervisor can do transactions that generate information like receiving history for a part, or the status of a purchase order.

Problems benefits and other impacts

Interfacing 2 systems- technical problems and data accuracy effects

Interfacing SAP with legacy causes two categories of problems: First, sometimes there are significant problems with the way in which data processing jobs are run by system administrators at headquarters. Usually this means the entire run, such as an MRP regeneration, must be repeated. Sometimes this results in data being lost. The second type of problem occurs when only some parts, not an entire run, are affected. For example, a transaction done for a single part on one system does not transfer correctly to the other system. As a result elements, such as on hand balances or part number revision levels, differ between the two systems. Sometimes these smaller problems are a result of the way in which transactions are completed at the plant level.

Both types of problems occurred frequently and had a significant impact on the plant during the first eighteen months after going live; however, the number of inconsistencies between legacy and SAP has diminished. The Materials states that during the first 12-18 months, researching and correcting discrepancies between the 2 systems was a full time job for someone in the purchasing and materials area. But now it only requires 30 minutes per day at most. Nevertheless, he does not feel that interfacing the legacy and SAP systems was the right approach because of problems with the interfaces over the first 18 months of the system.

While the problem has diminished, having to "plan twice" as a result of having to screen inconsistencies between the two systems is still a beef for the planners. One planner stated that, "It's annoying, but there's generally not something that you just can't work around." Another planner states that he is "amazed" at how well the bridge programs work but he is still annoyed by inconsistencies between SAP and legacy MRP records. He goes on to say

> ***Refrigeration, Inc. has done a good job with the bridge programs. But I think it makes it a lot more complex at the lower levels [of the organization] with two systems.... I would prefer one software package. There is a lot of toggling back and forth to get the information that you need.... My druthers are put one package in and throw the rest away.***

In contrast to the "small inconveniences" associated with inconsistencies between the two systems, problems associated with botched MRP runs are "a big hassle" because when legacy MRP is not right, planners simply do not have the information needed to do their jobs. This type of problem costs each planner one day per month or less.

System Complexity and User Understanding

The buyer/planners stated that they understand the logic of the purchasing and MRP modules themselves. One interviewee stated that their system's logic is like the logic of any other system. In other words, it follows basic manufacturing planning and control principles. On the other hand, integration with other functions (accounting and receiving) and integration of the SAP and legacy manufacturing planning and control systems complicates the overall business control systems and makes the impacts of some transactions hard to predict.

This distinction can be made by comparing two statements from one of the plant's more sophisticated buyer/planners. The first statement is her response to the interviewer's statement that in many cases personnel find ERP systems confusing:

> ***I mean I know the steps to take to make my purchase order come off at night, and I know where my requisition came from. I understand where that came from, and I understand where it ties in and all that, and yeah, I would have to say that if you pick any one of the people out there, they know where their requisition came from and they know how to make that requisition generate their purchase order and all that, I mean I'm kind of confused as to why anybody would think it was so hard.***

In contrast, she expressed less confidence in her understanding of the overall *enterprise-wide* system:

> ***So, there are some things going on there that we don't understand and we don't know how not to make them look like we just lost $65,000 worth of inventory. There are some things there. To tell you right off the bat what they are, I don't know, but yeah, there is some basic understanding of the stuff on the receiving side that we, we do some things but we probably aren't quite as sure why we're doing them.***

Similarly the Materials Manager indicated that undoing problems or incorrect transactions is difficult, both because a transaction immediately affects accounting and manufacturing systems and because many transactions affect both SAP and Legacy.

> ***If I fix it here what's it cause over here. I don't think there's enough awareness of this. If I am cycle counting and I make an inventory adjustment, that transaction goes right to the bottom line. –Materials Manager***

His reference to the *bottom line* refers to the closer integration between accounting and manufacturing which means that transactions are reflected on the general ledger more quickly with SAP than with the previous system. Early in the implementation, problems with the implementation caused the plant to make some very large inventory adjustments. In order to keep these from going to accounting immediately, plant management "did some jury rigging" to correct inventories in a manner that kept their effects off of the general ledger while the details of the inventory inaccuracies could be investigated. However this ultimately caused worse data accuracy problems and discrepancies between SAP and legacy.

By contrast, the receiving clerk and supervisor expressed satisfaction with their overall understanding of the system. For them the impacts of series of complicated transactions, such as undoing a receipt, are generally not a problem.

Hiring policy

The materials manager stated that the biggest local impact of the system is in the kind of people he hires for purchasing and material planning jobs. He states

> ***ERP caused us to look at qualities of our people. Better data causes you to want people who can analyze that data to make better decisions.***

The Materials Manager now hires college educated people with better computer skills. A seasoned buyer planner agreed:

> ***Legacy was relatively simple. It was easy. SAP is a more complex system with more abilities... You need a more educated workforce to understand, to effectively use SAP.***

Quality and availability of reports and information

SAP provides better information for resolving problems and avoiding guesswork in receiving. For example, if a shipment arrives without a purchase order number, SAP provides ad hoc reporting capability to help resolve the problem. For example users on the dock can generate a list of all PO's issued on a certain date or PO's open for a certain vendor. SAP allows receiving to document the conditions surrounding receiving exceptions, such as who authorized them. According to the receiving manager, SAP also facilitates resolution of problems after the fact:

> ***I like it a lot better, too. Like I say, you've got a lot more information and history there, so if you have to re-trace anything or do some digging, you can generally find out what caused what to happen.***

The Materials Manager states that SAP enables better management of supplier quality. For example, warranty problems and rejections within the plant can be tied back to individual shipments from specific vendors. SAP allows the plant and corporate supply management to make judgements on "whether we have the right suppliers." Furthermore, the system facilitates finding and fixing discrepancies in accounts payable. The receiving supervisor agreed:

> ***If there ends up being an invoice discrepancy sometimes, you can go way back if you have to and try and see what went wrong because, now in SAP you've got exact packing slip numbers. In the past, you had nowhere to put a packing slip number, so sometimes you'd be receiving against the wrong order. You've got a packing slip number, normally it identifies the PO, so you don't have a lot of the matching problems that you had with the old system.***

While several interviewees were hard pressed to think of information they needed that SAP was not delivering, others pointed out that they are not receiving reports that are needed. In several, cases they do without. While in others they compile their own reports, often using estimates. Examples of information personnel would like but do not get from SAP are price breaks, delivery performance by planner code, and receipts of MRO (maintenance, repair and operating) materials (Many MRO supplies are hazardous and require close monitoring).

Many of these reports were not available with the old system. Furthermore, some reports are becoming available although the process is slow because reports must be written at headquarters. Over all, SAP provides some useful information that was unavailable or less convenient to get under legacy. Furthermore, there does not seem to be a serious problem with information needs not being met by the SAP system.

Better control

SAP provides more precision in ensuring that invoices, purchase orders and packing slips all agree, and thus that the plant get what it pays for. Furthermore, the system provides more control on the back dock. The receiving clerk appreciates that SAP makes in harder to inadvertently over-receive a packing slip

Speed and ease of use

The SAP user interface is marginally faster for many personnel who use it. Several planners stated that it is slightly less cumbersome to cut a purchase order and that

SAP automates some non-value-added tasks. For example SAP automatically faxes PO's instead of generating hard copies to be faxed manually. Another interviewee appreciates SAP's faster processing speed.

On the other hand, some interviewees do not appreciate the format in which SAP presents information, such as the MRP record, and the fact that one must drill down through menus to obtain information. One user stated

> ***The old system was much faster. There wasn't nearly as many click, click, click, click, click, click, click, click. You know, when SAP first came, I think someone may have even counted how many mouse clicks I had to do just to generate an order.***

In the case of both the pros and the cons, savings or losses are minutes per person per week, not hours or days. Several interviewees stated that SAP and legacy are approximately equal in speed ease of use. Any differences in speed and ease or use between SAP and legacy are marginal.

Overall evaluation on costs and benefits

The study did not focus on the corporate level (or global) benefits of the SAP/legacy system. However, in the interviewees' opinions the company is receiving substantial global benefits as a result of the system. The best recognized global benefits are better financial control and centralized information for corporate supply management. Both these benefits "trickle down" to the plant. For example, the plant benefits from the minimization of overpayment of invoices. Furthermore, the plant reaps lower costs and other advantages that centralized supply managers can provide with SAP-generated information.

Moving beyond the plant's share in the global benefits, the plant-level benefits appear to be roughly equal to the costs and neither is very substantial. For example, in receiving the system provides improved information for troubleshooting problem receipts, but it does not provide other information, such as MRP receipts.

Differentiation and Interdependence

The materials manager stated that there are not significant differences among plants in the company when it comes to purchasing. Most plants are using the same types of purchased materials under similar conditions, even though the products themselves vary somewhat. Similarly, one planner stated:

> ***I would have to say we all do it basically the same way. I've been to Minneapolis..... And I have had contact with people in our Hastings plant, and on a general, and of course I've been to Puerto Rico, I know how they plan, on a general rule, I would have to say we all do it basically the same way. We follow the same steps and do it the same way.***

One planner plans for the Valdosta plant. He states that this plant differs from Duluth because it ships a greater variety of products and because design changes are made to these products frequently. He quips that in fact they are often engineered on the assembly line. "We're engineering systems on the line... One week my plan will look very good, the next thing I know, I've got parts that I need because they are changing, for example, some sort of tubing." He states that the system meets Duluth's needs better than Valdosta's but that the same is true of any system. He stated, most of the changes that would improve the situation (engineering's flattening bills of materials and his being on the ECN distribution list) are not SAP specific. On the other hand he agreed with the interviewer's statement that a system could be designed that was better tailored to Valdosta. At this point, it is unclear whether a better system could be designed (perhaps with more frequent regeneration) or whether Valdosta is just a tougher environment. And it is unclear whether SAP could accommodate such a system *along with* the SAP configuration that is being run in other plants.

There are some significant interdependencies at RI. All of the plants in the company use the same commodities which can be purchased from the same vendors. Pooling supply management is beneficial under these conditions, and the ERP system provides the infrastructure to facilitate it. An ERP system provides centralized supply management with information that is generated in the plants. Furthermore it provides information from supply management back to the plants in so that the plants have the information they need to effectively purchase against centrally negotiated vendor contracts.

3.4 Analysis

The purchasing application is a good example of using ERP to manage interdependence. The limited scope of the implementation makes it somewhat anomalous and difficult to compare to other cases. The exclusion of production and production scheduling makes it difficult to assess the impact on differentiation, but several buyer/planners suggested that "purchasing is purchasing"– in other words, from their perspective the plants are fairly homogeneous. Following up more on the Valdosta plant, would have provided some confirmation (or disconfirmation) of this, but doing so was beyond the research scope.

4. Transport, Inc., Georgia Plant

4.1 Overview

Transportation, Inc. (TI) generates one billion dollars in revenue annually making rolling stock. It has about 5000 employees at 5 manufacturing sites, 22 after market sales and replacement sites, 3 distribution and 50 dealerships.

The researcher interviewed the following individuals during the Fall of 1999: CIO, Senior VP of Finance, Vice President of Engineering, Assistant Plant Manager Factory Operations Manager, a production department supervisor, Materials Manager, a senior buyer, Inventory Control Supervisor, Production & Sales Engineering Supervisor, Manufacturing Engineer, Cost Accounting Supervisor, Industrial Relations Clerk.

Their pre-ERP systems consisted of a number of legacy systems and databases– a situation which led to a number of problems. For example, interfacing systems and managing duplicate part numbers was labor intensive. They also had no central vendor files and thus no ability to leverage their buying power across plants. Y2K was a factor, but not a motivating one. Management chose to implement the JD Edwards (JDE) system. Another system was actually their first choice but its supplier chose to stop supporting certain applications that TI desired.

They have installed financial, payroll and HR materials and purchasing modules. Order entry and shop floor control have been partially rolled out in two out of the five plants: Midwest and Georgia. These systems went live early in the winter of 1999. The CIO described these installations as "MRP not ERP," since they have not made the effort to link up the plants. That is, they do no cross-location reporting or planning. They do have centralized databases, but they have not tried to utilize data from across locations because it would require some significant programming.

4.2 Implementation Difficulties

They have tried to avoid customizing the systems: They require anyone wanting customization to make a case to the steering committee; however, they have customized the system in certain situations.

The no customization policy was harder to maintain in the Georgia plant than in the Midwest plant. The Midwest plant produced a small variety of items, mostly to stock. Like JD Edwards, the Midwest plant's legacy system was based on discrete bills of material, so the shift to JDE was not terribly disruptive.

On the other hand, Georgia produced a wide variety of models with an almost infinite variety of combinations of options available and some engineering done on many orders. In contrast to the Midwest plant, all of Georgia's possible end-item configurations could not feasibly have their own bills of material. Therefore, Georgia use a configured bill of materials approach. Order entry personnel used various selection charts prepared by engineering to develop a BOM for each order. Before JD Edwards, this was handled manually and fairly informally, not with a formal computerized system (in fact Georgia had no computerized MRP system). The longevity and skill of Georgia's employee's enabled this system to work. Employees' expertise allowed the right decisions to be made problems to be recognized without many formal rules or controls.

The CIO mentioned one deficiency of the Georgia system: *You put it together with the hope that it would all fit and you wouldn't be hit with a product liability problem down the line.*

An example of this is the *per print* system employed in the plant. Often a customer would asked for something that required a standard part to be modified slightly. Atlanta would create these on the fly, without standard drawings and without part numbers. Someone in engineering would take a standard drawing and mark it along with a description, and then send this to manufacturing. There were hundreds of "per print" parts generated every week. The plant kept a separate set of books for these, which caused problems with reporting and pricing.

Instead of an informal configuration management system, the new ERP system uses rules based software to develop the BOM from the customer order. Making the transition has been difficult. Because the previous system had many informal elements, it was difficult to duplicate. For example, there were numerous errors in bills of material;

however, everyone "just knew" how to compensate. By contrast, JDE is a closed loop system, so if data are not entered correctly and bills of materials and the like are not followed, problems such as inventory inaccuracies ripple through the system. Similarly, the "per print" system was not viable in JD Edwards because all parts had to be entered on the system. During the changeover to JDE the documentation for these parts was a huge bottleneck which caused the revision of the entire implementation schedule.

A different issue centered on changes to customer orders. High variety, high flexibility and product sophistication are order winners in the market segment that Georgia serves. A key to satisfying this market is a flexible manufacturing process that is capable of handling changing specifications, even after production on a order has begun. However, with the JDE system, there could be no changes as soon as the order had been released and the first stages of manufacturing had begun. To change the order at this point would have required backing out all transactions done on the original order, then entering the new order, and re-entering on the system all steps that had already be completed. Since the policy direction from management was that the system would be implemented with minimal or no customization, manufacturing and sales had to accept the fact that they would no long be able to change orders after fabrication had begun. However, shortly after the ERP system went live, a major customer asked for exactly this type of change. He was told that it was impossible. Manufacturing was adamant that such changes could no longer be done. The customer went to top management, and shortly after the directive came down that the changes *would* be done, and the system would have to be modified accordingly. At this point the ERP implementation was halted, and the plant_back to the old system until the customization was complete.

4.3 Summary

Though the transition has been somewhat difficult, the system operates effectively in the Georgia and Midwest plants. Additional plants are scheduled to come on line soon. Interestingly, the discussion with stakeholders in the Georgia plant, there was not a lot of discussion of benefits from implementing JDE, even when individuals were asked directly. Those benefits that were cited tended to be easier access to data, but there was no mention of major improvements over the old systems. Rather, the sense was that many difficult implementation problems had been overcome and the company had succeeded in doing what top management had asked– but with few benefits at the plant level.

APPENDIX B

Survey and Cover Letter

Survey 1

sur2

surv3

surv 4

surv5

surv 6

surv7

surv8

surv9

surv 10

surv11

surv12

surv13

APPENDIX C

Lisrel Output

Group One Measurement Model

```
Number of Iterations = 49

 LISREL Estimates (Maximum Likelihood)

        LAMBDA-X

           ACCURACY   SAVETIME    ALT_SYS
           ----   ----   ----
   ACC1R     1.272      - -        - -
           (0.112)
            11.305

    ACC2     1.325      - -        - -
           (0.094)
            14.073

    ACC3     1.220      - -        - -
           (0.092)
            13.221

    ACC4     1.131      - -        - -
           (0.096)
            11.783

   TIME1      - -      1.462       - -
                     (0.120)
                      12.202

   TIME2      - -      1.331       - -
                     (0.112)
                      11.845

  TIME3R      - -      1.251       - -
                     (0.119)
                      10.477

   TIME4      - -      1.176       - -
                     (0.103)
                      11.447

    ALT1      - -       - -       1.073
                                (0.129)
                                  8.285

   ALT2R      - -       - -       1.288
                                (0.111)
                                 11.615

   ALT3R      - -       - -       1.324
                                (0.103)
                                 12.808

   ALT5R      - -       - -       1.553
                                (0.103)
                                 15.046

   ALT6R      - -       - -       1.304
                                (0.113)
```

11.511

PHI

	ACCURACY	SAVETIME	ALT_SYS
ACCURACY	1.000		
SAVETIME	0.633 (0.056) 11.214	1.000	
ALT_SYS	0.618 (0.055) 11.170	0.651 (0.054) 12.050	1.000

THETA-DELTA

ACC1R	ACC2	ACC3	ACC4	TIME1	TIME2
1.249 (0.156) 8.016	0.560 (0.094) 5.980	0.641 (0.094) 6.848	0.860 (0.110) 7.800	1.180 (0.173) 6.833	1.094 (0.154) 7.109

THETA-DELTA

TIME3R	TIME4	ALT1	ALT2R	ALT3R	ALT5R
1.458 (0.185) 7.896	0.965 (0.131) 7.378	2.164 (0.243) 8.923	1.197 (0.148) 8.112	0.888 (0.118) 7.523	0.546 (0.103) 5.296

THETA-DELTA

ALT6R
1.265 (0.155) 8.152

Squared Multiple Correlations for X - Variables

ACC1R	ACC2	ACC3	ACC4	TIME1	TIME2
0.564	0.758	0.699	0.598	0.644	0.618

Squared Multiple Correlations for X - Variables

TIME3R	TIME4	ALT1	ALT2R	ALT3R	ALT5R
0.518	0.589	0.347	0.581	0.664	0.815

Squared Multiple Correlations for X - Variables

ALT6R
0.573

Goodness of Fit Statistics

Degrees of Freedom = 62
Minimum Fit Function Chi-Square = 121.498 (P = 0.000)
Normal Theory Weighted Least Squares Chi-Square = 125.907 (P = 0.000)
Estimated Non-centrality Parameter (NCP) = 63.907

90 Percent Confidence Interval for NCP = (35.677 ; 99.912)

Minimum Fit Function Value = 0.686
Population Discrepancy Function Value (F0) = 0.361
90 Percent Confidence Interval for F0 = (0.202 ; 0.564)
Root Mean Square Error of Approximation (RMSEA) = 0.0763
90 Percent Confidence Interval for RMSEA = (0.0570 ; 0.0954)
P-Value for Test of Close Fit (RMSEA < 0.05) = 0.0144

Expected Cross-Validation Index (ECVI) = 1.039
90 Percent Confidence Interval for ECVI = (0.880 ; 1.242)
ECVI for Saturated Model = 1.028
ECVI for Independence Model = 8.105

Chi-Square for Independence Model with 78 Degrees of Freedom = 1408.623
Independence AIC = 1434.623
Model AIC = 183.907
Saturated AIC = 182.000
Independence CAIC = 1488.986
Model CAIC = 305.179
Saturated CAIC = 562.542

Root Mean Square Residual (RMR) = 0.141
Standardized RMR = 0.0510
Goodness of Fit Index (GFI) = 0.901
Adjusted Goodness of Fit Index (AGFI) = 0.855
Parsimony Goodness of Fit Index (PGFI) = 0.614

Normed Fit Index (NFI) = 0.914
Non-Normed Fit Index (NNFI) = 0.944
Parsimony Normed Fit Index (PNFI) = 0.726
Comparative Fit Index (CFI) = 0.955
Incremental Fit Index (IFI) = 0.956
Relative Fit Index (RFI) = 0.891

Critical N (CN) = 133.283

REL const deleted. compare to file m_gl_2c

Standardized Solution

LAMBDA-X

	ACCURACY	SAVETIME	ALT_SYS
ACC1R	1.272	- -	- -
ACC2	1.325	- -	- -
ACC3	1.220	- -	- -
ACC4	1.131	- -	- -
TIME1	- -	1.462	- -
TIME2	- -	1.331	- -
TIME3R	- -	1.251	- -
TIME4	- -	1.176	- -
ALT1	- -	- -	1.073
ALT2R	- -	- -	1.288
ALT3R	- -	- -	1.324
ALT5R	- -	- -	1.553
ALT6R	- -	- -	1.304

PHI

	ACCURACY	SAVETIME	ALT_SYS
ACCURACY	1.000		
SAVETIME	0.633	1.000	
ALT_SYS	0.618	0.651	1.000

The Problem used 25304 Bytes (= 0.2% of Available Workspace)

Time used: 3.508 Seconds

Group Two Measurement Model

Note GI prefixed variables are for construct *perceptions of interedependence.* RESOUR prefixed variables are for construct *time and other resources required...* CB prefixed variables are for *coordination improvements.* P_ denotes other plants S_ denotes sales and distribution.

_g2_14C.SPL

Number of Iterations = 15

LISREL Estimates (Maximum Likelihood)

LAMBDA-X

	PLT_INTR	S&D_INTR	RESOURCE	P_CB	S_CB
P_FS1	1.670 (0.168) 9.963	- -	- -	- -	- -
P_FS2	1.577 (0.185) 8.516	- -	- -	- -	- -
P_GI2	1.760 (0.160) 11.028	- -	- -	- -	- -
P_GI3R	1.430 (0.175) 8.190	- -	- -	- -	- -
P_GI4	1.585 (0.159) 9.971	- -	- -	- -	- -
S_FS1	- -	1.081 (0.125) 8.670	- -	- -	- -
S_FS2	- -	0.826 (0.148) 5.583	- -	- -	- -
S_GI2	- -	1.223 (0.108) 11.295	- -	- -	- -
S_GI3R	- -	1.432 (0.170) 8.435	- -	- -	- -
S_GI4	- -	0.826 (0.099) 8.348	- -	- -	- -
RESOUR1	- -	- -	1.631 (0.189) 8.612	- -	- -
RESOUR4R	- -	- -	1.525 (0.187) 8.174	- -	- -
RESOUR5	- -	- -	1.616 (0.174)	- -	- -

			9.269		
P_CB1	- -	- -	- -	1.370 (0.149) 9.210	- -
P_CB2	- -	- -	- -	1.273 (0.140) 9.125	- -
P_CB3	- -	- -	- -	1.445 (0.140) 10.332	- -
P_CB4	- -	- -	- -	1.531 (0.149) 10.294	- -
S_CB1	- -	- -	- -	- -	1.233 (0.118) 10.489
S_CB2	- -	- -	- -	- -	1.317 (0.124) 10.609
S_CB3	- -	- -	- -	- -	1.186 (0.108) 11.029
S_CB4	- -	- -	- -	- -	1.221 (0.111) 10.974

PHI

	PLT_INTR	S&D_INTR	RESOURCE	P_CB	S_CB
PLT_INTR	1.000				
S&D_INTR	0.208 (0.107) 1.932	1.000			
RESOURCE	0.038 (0.115) 0.328	0.024 (0.116) 0.205	1.000		
P_CB	0.711 (0.061) 11.627	0.242 (0.107) 2.264	0.184 (0.113) 1.623	1.000	
S_CB	0.143 (0.108) 1.324	0.487 (0.087) 5.605	0.186 (0.111) 1.671	0.636 (0.071) 9.022	1.000

THETA-DELTA

P_FS1	P_FS2	P_GI2	P_GI3R	P_GI4	S_FS1
1.170 (0.209) 5.589	1.872 (0.302) 6.191	0.781 (0.166) 4.698	1.742 (0.277) 6.279	1.050 (0.188) 5.584	0.797 (0.136) 5.842

THETA-DELTA

S_FS2	S_GI2	S_GI3R	S_GI4	RESOUR1	RESOUR4R

1.591	0.280	1.537	0.528	1.520	1.657
(0.240)	(0.088)	(0.258)	(0.088)	(0.337)	(0.328)
6.631	3.180	5.948	5.984	4.504	5.047

THETA-DELTA

RESOUR5	P_CB1	P_CB2	P_CB3	P_CB4	S_CB1
1.035	1.072	0.958	0.739	0.845	0.517
(0.292)	(0.181)	(0.161)	(0.140)	(0.159)	(0.093)
3.542	5.922	5.956	5.286	5.315	5.545

THETA-DELTA

S_CB2	S_CB3	S_CB4
0.558	0.367	0.400
(0.102)	(0.072)	(0.077)
5.462	5.114	5.166

Squared Multiple Correlations for X - Variables

P_FS1	P_FS2	P_GI2	P_GI3R	P_GI4	S_FS1
0.704	0.571	0.799	0.540	0.705	0.594

Squared Multiple Correlations for X - Variables

S_FS2	S_GI2	S_GI3R	S_GI4	RESOUR1	RESOUR4R
0.300	0.842	0.572	0.563	0.636	0.584

Squared Multiple Correlations for X - Variables

RESOUR5	P_CB1	P_CB2	P_CB3	P_CB4	S_CB1
0.716	0.636	0.628	0.738	0.735	0.746

Squared Multiple Correlations for X - Variables

S_CB2	S_CB3	S_CB4
0.757	0.793	0.788

Goodness of Fit Statistics

Degrees of Freedom = 179
Minimum Fit Function Chi-Square = 311.316 (P = 0.00)
Normal Theory Weighted Least Squares Chi-Square = 292.106 (P = 0.000)
Estimated Non-centrality Parameter (NCP) = 113.106
90 Percent Confidence Interval for NCP = (70.190 ; 163.930)

Minimum Fit Function Value = 3.243
Population Discrepancy Function Value (F0) = 1.178
90 Percent Confidence Interval for F0 = (0.731 ; 1.708)
Root Mean Square Error of Approximation (RMSEA) = 0.0811
90 Percent Confidence Interval for RMSEA = (0.0639 ; 0.0977)
P-Value for Test of Close Fit (RMSEA < 0.05) = 0.00244

Expected Cross-Validation Index (ECVI) = 4.126
90 Percent Confidence Interval for ECVI = (3.679 ; 4.656)
ECVI for Saturated Model = 4.813
ECVI for Independence Model = 17.550

Chi-Square for Independence Model with 210 Degrees of Freedom = 1642.816
Independence AIC = 1684.816
Model AIC = 396.106

Saturated AIC = 462.000
Independence CAIC = 1759.885
Model CAIC = 581.991
Saturated CAIC = 1287.758

Root Mean Square Residual (RMR) = 0.219
Standardized RMR = 0.0755
Goodness of Fit Index (GFI) = 0.775
Adjusted Goodness of Fit Index (AGFI) = 0.710
Parsimony Goodness of Fit Index (PGFI) = 0.601

Normed Fit Index (NFI) = 0.810
Non-Normed Fit Index (NNFI) = 0.892
Parsimony Normed Fit Index (PNFI) = 0.691
Comparative Fit Index (CFI) = 0.908
Incremental Fit Index (IFI) = 0.910
Relative Fit Index (RFI) = 0.778

Critical N (CN) = 70.671

m_g2_14C.SPL

Standardized Solution

LAMBDA-X

	PLT_INTR	S&D_INTR	RESOURCE	P_CB	S_CB
P_FS1	1.670	- -	- -	- -	- -
P_FS2	1.577	- -	- -	- -	- -
P_GI2	1.760	- -	- -	- -	- -
P_GI3R	1.430	- -	- -	- -	- -
P_GI4	1.585	- -	- -	- -	- -
S_FS1	- -	1.081	- -	- -	- -
S_FS2	- -	0.826	- -	- -	- -
S_GI2	- -	1.223	- -	- -	- -
S_GI3R	- -	1.432	- -	- -	- -
S_GI4	- -	0.826	- -	- -	- -
RESOUR1	- -	- -	1.631	- -	- -
RESOUR4R	- -	- -	1.525	- -	- -
RESOUR5	- -	- -	1.616	- -	- -
P_CB1	- -	- -	- -	1.370	- -
P_CB2	- -	- -	- -	1.273	- -
P_CB3	- -	- -	- -	1.445	- -
P_CB4	- -	- -	- -	1.531	- -
S_CB1	- -	- -	- -	- -	1.233
S_CB2	- -	- -	- -	- -	1.317
S_CB3	- -	- -	- -	- -	1.186
S_CB4	- -	- -	- -	- -	1.221

PHI

	PLT_INTR	S&D_INTR	RESOURCE	P_CB	S_CB
PLT_INTR	1.000				
S&D_INTR	0.208	1.000			
RESOURCE	0.038	0.024	1.000		
P_CB	0.711	0.242	0.184	1.000	
S_CB	0.143	0.487	0.186	0.636	1.000

The Problem used 66072 Bytes (= 0.8% of Available Workspace)

Structural Model

Note: Differentiation is modeled using primary method

LISREL Estimates (Maximum Likelihood)

LAMBDA-Y

	ACCURACY	SAVETIME	ALT_SYS	IMPACT
ACC1R	1.000	- -	- -	- -
ACC2	1.038 (0.086) 12.006	- -	- -	- -
ACC3	0.951 (0.082) 11.654	- -	- -	- -
ACC4	0.889 (0.083) 10.703	- -	- -	- -
TIME1	- -	1.000	- -	- -
TIME2	- -	0.875 (0.078) 11.251	- -	- -
TIME3R	- -	0.829 (0.082) 10.148	- -	- -
TIME4	- -	0.790 (0.069) 11.382	- -	- -
ALT1	- -	- -	1.000	- -
ALT2R	- -	- -	1.186 (0.152) 7.804	- -
ALT3R	- -	- -	1.228 (0.151) 8.147	- -
ALT5R	- -	- -	1.456 (0.167) 8.719	- -
ALT6R	- -	- -	1.222 (0.154) 7.917	- -
IMPACT1	- -	- -	- -	1.000
IMPACT2	- -	- -	- -	1.008 (0.063) 15.948
IMPACT3R	- -	- -	- -	0.578 (0.102) 5.665
IMPACT4	- -	- -	- -	1.018

(0.058)
17.525

LAMBDA-X

	P_INTERD	P_COORD	S_INTERD	S_COORD	GENERIC	DIFFERN
P_FS1	1.000	- -	- -	- -	- -	- -
P_FS2	0.860 (0.051) 16.698	- -	- -	- -	- -	- -
P_GI2	1.011 (0.041) 24.551	- -	- -	- -	- -	- -
P_GI3R	0.824 (0.046) 17.907	- -	- -	- -	- -	- -
P_GI4	0.977 (0.047) 20.849	- -	- -	- -	- -	- -
P_CB1	- -	1.000	- -	- -	- -	- -
P_CB2	- -	1.074 (0.054) 19.892	- -	- -	- -	- -
P_CB3	- -	1.144 (0.051) 22.573	- -	- -	- -	- -
P_CB4	- -	1.093 (0.050) 21.945	- -	- -	- -	- -
S_FS1	- -	- -	1.000	- -	- -	- -
S_FS2	- -	- -	0.911 (0.042) 21.674	- -	- -	- -
S_GI2	- -	- -	0.831 (0.031) 26.727	- -	- -	- -
S_GI3R	- -	- -	0.947 (0.045) 20.921	- -	- -	- -
S_GI4	- -	- -	0.821 (0.031) 26.199	- -	- -	- -
S_CB1	- -	- -	- -	1.000	- -	- -
S_CB2	- -	- -	- -	0.991 (0.041) 24.383	- -	- -
S_CB3	- -	- -	- -	1.003 (0.038) 26.319	- -	- -
S_CB4	- -	- -	- -	1.226 (0.044) 27.736	- -	- -

GENERIC1	- -	- -	- -	- -	1.000	- -
GENERIC4	- -	- -	- -	- -	1.175 (0.112) 10.515	- -
GENERIC5	- -	- -	- -	- -	1.153 (0.109) 10.583	- -
D_4TO5_9	- -	- -	- -	- -	- -	0.860
P_IXB	- -	- -	- -	- -	- -	- -
S_IXB	- -	- -	- -	- -	- -	- -
GENX45_9	- -	- -	- -	- -	- -	- -

LAMBDA-X

	P_IxB	S_IxB	GENRxDIF
P_FS1	- -	- -	- -
P_FS2	- -	- -	- -
P_GI2	- -	- -	- -
P_GI3R	- -	- -	- -
P_GI4	- -	- -	- -
P_CB1	- -	- -	- -
P_CB2	- -	- -	- -
P_CB3	- -	- -	- -
P_CB4	- -	- -	- -
S_FS1	- -	- -	- -
S_FS2	- -	- -	- -
S_GI2	- -	- -	- -
S_GI3R	- -	- -	- -
S_GI4	- -	- -	- -
S_CB1	- -	- -	- -
S_CB2	- -	- -	- -
S_CB3	- -	- -	- -
S_CB4	- -	- -	- -
GENERIC1	- -	- -	- -
GENERIC4	- -	- -	- -
GENERIC5	- -	- -	- -
D_4TO5_9	- -	- -	- -
P_IXB	0.910	- -	- -
S_IXB	- -	0.880	- -

GENX45_9	- -	- -	0.800

BETA

	ACCURACY	SAVETIME	ALT_SYS	IMPACT
ACCURACY	- -	- -	- -	- -
SAVETIME	- -	- -	- -	- -
ALT_SYS	- -	- -	- -	- -
IMPACT	0.323 (0.071) 4.534	0.529 (0.071) 7.394	0.049 (0.082) 0.597	- -

GAMMA

	P_INTERD	P_COORD	S_INTERD	S_COORD	GENERIC	DIFFERN
ACCURACY	- -	- -	- -	- -	0.022 (0.077) 0.285	-0.064 (0.056) -1.147
SAVETIME	- -	- -	- -	- -	-0.110 (0.091) -1.205	-0.131 (0.066) -1.979
ALT_SYS	- -	- -	- -	- -	0.020 (0.064) 0.319	-0.060 (0.047) -1.283
IMPACT	0.055 (0.157) 0.352	-0.063 (0.192) -0.331	0.043 (0.103) 0.419	0.206 (0.136) 1.520	- -	- -

GAMMA

	P_IxB	S_IxB	GENRxDIF
ACCURACY	- -	- -	-0.045 (0.036) -1.234
SAVETIME	- -	- -	-0.010 (0.043) -0.231
ALT_SYS	- -	- -	-0.051 (0.031) -1.661
IMPACT	-0.021 (0.046) -0.463	0.124 (0.063) 1.986	- -

Covariance Matrix of ETA and KSI

	ACCURACY	SAVETIME	ALT_SYS	IMPACT	P_INTERD	P_COORD
ACCURACY	1.646					
SAVETIME	1.252	2.292				
ALT_SYS	0.862	1.081	1.163			
IMPACT	1.234	1.670	0.907	1.640		
P_INTERD	-0.072	-0.152	-0.062	0.020	4.574	
P_COORD	-0.061	-0.140	-0.050	0.116	3.695	3.543

S_INTERD	-0.016	-0.079	-0.014	0.162	1.285	1.189
S_COORD	0.006	-0.018	0.010	0.292	1.123	1.351
GENERIC	0.010	-0.253	0.003	-0.220	-0.265	-0.344
DIFFERN	-0.275	-0.607	-0.256	-0.344	1.429	1.426
P_IxB	0.034	0.138	0.023	0.508	0.858	0.187
S_IxB	-0.006	0.085	-0.003	0.412	-1.291	-0.749
GENRxDIF	-0.547	-0.158	-0.628	-0.426	-0.570	-0.842

Covariance Matrix of ETA and KSI

	S_INTERD	S_COORD	GENERIC	DIFFERN	P_IxB	S_IxB
S_INTERD	5.130					
S_COORD	3.599	3.116				
GENERIC	0.228	-0.056	2.073			
DIFFERN	0.419	0.223	0.145	4.539		
P_IxB	0.719	0.792	0.053	-1.172	8.946	
S_IxB	-5.904	-3.683	-0.756	0.008	3.078	11.842
GENRxDIF	-0.136	-0.484	0.596	-0.264	0.947	-0.250

Covariance Matrix of ETA and KSI

	GENRxDIF
GENRxDIF	12.911

PHI

	P_INTERD	P_COORD	S_INTERD	S_COORD	GENERIC	DIFFERN
P_INTERD	4.574					
	(0.566)					
	8.077					
P_COORD	3.695	3.543				
	(0.452)	(0.457)				
	8.170	7.752				
S_INTERD	1.285	1.189	5.130			
	(0.397)	(0.351)	(0.611)			
	3.235	3.383	8.399			
S_COORD	1.123	1.351	3.599	3.116		
	(0.313)	(0.287)	(0.433)	(0.377)		
	3.595	4.715	8.316	8.263		
GENERIC	-0.265	-0.344	0.228	-0.056	2.073	
	(0.257)	(0.228)	(0.270)	(0.210)	(0.387)	
	-1.030	-1.511	0.844	-0.268	5.350	
DIFFERN	1.429	1.426	0.419	0.223	0.145	4.539
	(0.427)	(0.380)	(0.434)	(0.338)	(0.290)	(0.660)
	3.346	3.750	0.965	0.661	0.499	6.877
P_IxB	0.858	0.187	0.719	0.792	0.053	-1.172
	(0.553)	(0.483)	(0.581)	(0.455)	(0.386)	(0.628)
	1.550	0.388	1.237	1.741	0.136	-1.866
S_IxB	-1.291	-0.749	-5.904	-3.683	-0.756	0.008
	(0.661)	(0.577)	(0.832)	(0.611)	(0.462)	(0.733)
	-1.953	-1.298	-7.099	-6.024	-1.638	0.010
GENRxDIF	-0.570	-0.842	-0.136	-0.484	0.596	-0.264
	(0.747)	(0.660)	(0.786)	(0.613)	(0.530)	(0.849)
	-0.763	-1.277	-0.173	-0.789	1.123	-0.311

PHI

P_IxB	S_IxB	GENRxDIF

P_IxB	8.946 (1.174) 7.618		
S_IxB	3.078 (1.015) 3.034	11.842 (1.659) 7.138	
GENRxDIF	0.947 (1.130) 0.838	-0.250 (1.326) -0.189	12.911 (2.182) 5.916

PSI

	ACCURACY	SAVETIME	ALT_SYS	IMPACT
ACCURACY	1.603 (0.278) 5.761			
SAVETIME	1.211 (0.211) 5.727	2.183 (0.346) 6.318		
ALT_SYS	0.818 (0.165) 4.956	1.041 (0.199) 5.240	1.115 (0.269) 4.143	
IMPACT	- -	- -	- -	0.213 (0.060) 3.521

Squared Multiple Correlations for Structural Equations

ACCURACY	SAVETIME	ALT_SYS	IMPACT
0.026	0.048	0.041	0.870

THETA-EPS

ACC1R	ACC2	ACC3	ACC4	TIME1	TIME2
1.131	0.583	0.598	0.813	1.078	1.192
(0.143)	(0.092)	(0.087)	(0.105)	(0.154)	(0.154)
7.885	6.329	6.864	7.741	7.001	7.718

THETA-EPS

TIME3R	TIME4	ALT1	ALT2R	ALT3R	ALT5R
1.521	0.931	2.088	1.236	0.946	0.512
(0.186)	(0.122)	(0.237)	(0.152)	(0.124)	(0.101)
8.187	7.647	8.796	8.109	7.610	5.065

THETA-EPS

ALT6R	IMPACT1	IMPACT2	IMPACT3R	IMPACT4
1.184	0.458	0.546	2.596	0.360
(0.148)	(0.065)	(0.074)	(0.284)	(0.057)
7.976	7.020	7.362	9.146	6.285

Squared Multiple Correlations for Y - Variables

ACC1R	ACC2	ACC3	ACC4	TIME1	TIME2

0.593	0.753	0.713	0.616	0.680	0.596

Squared Multiple Correlations for Y - Variables

TIME3R	TIME4	ALT1	ALT2R	ALT3R	ALT5R
0.509	0.606	0.358	0.570	0.650	0.828

Squared Multiple Correlations for Y - Variables

ALT6R	IMPACT1	IMPACT2	IMPACT3R	IMPACT4
0.595	0.781	0.753	0.174	0.825

THETA-DELTA

P_FS1	P_FS2	P_GI2	P_GI3R	P_GI4	P_CB1
0.694	1.489	0.546	1.124	0.983	0.735
(0.096)	(0.173)	(0.082)	(0.133)	(0.124)	(0.093)
7.237	8.585	6.626	8.435	7.915	7.903

THETA-DELTA

P_CB2	P_CB3	P_CB4	S_FS1	S_FS2	S_GI2
0.857	0.530	0.566	0.540	1.054	0.442
(0.108)	(0.078)	(0.079)	(0.078)	(0.127)	(0.060)
7.919	6.758	7.127	6.948	8.298	7.315

THETA-DELTA

S_GI3R	S_GI4	S_CB1	S_CB2	S_CB3	S_CB4
1.260	0.465	0.391	0.470	0.354	0.414
(0.150)	(0.062)	(0.053)	(0.061)	(0.049)	(0.063)
8.393	7.458	7.400	7.750	7.190	6.605

THETA-DELTA

GENERIC1	GENERIC4	GENERIC5	D_4TO5_9	P_IXB	S_IXB
1.738	1.064	0.818	1.170	1.610	2.750
(0.227)	(0.207)	(0.188)			
7.659	5.128	4.347			

THETA-DELTA

GENX45_9
4.690

Squared Multiple Correlations for X - Variables

P_FS1	P_FS2	P_GI2	P_GI3R	P_GI4	P_CB1
0.868	0.694	0.895	0.734	0.816	0.828

Squared Multiple Correlations for X - Variables

P_CB2	P_CB3	P_CB4	S_FS1	S_FS2	S_GI2
0.827	0.897	0.882	0.905	0.801	0.889

Squared Multiple Correlations for X - Variables

S_GI3R	S_GI4	S_CB1	S_CB2	S_CB3	S_CB4
0.785	0.881	0.889	0.867	0.898	0.919

Squared Multiple Correlations for X - Variables

GENERIC1	GENERIC4	GENERIC5	D_4TO5_9	P_IXB	S_IXB
0.544	0.729	0.771	0.742	0.821	0.769

Squared Multiple Correlations for X - Variables

GENX45_9
0.638

Goodness of Fit Statistics

Degrees of Freedom = 766
Minimum Fit Function Chi-Square = 1338.418 (P = 0.0)
Normal Theory Weighted Least Squares Chi-Square = 1264.392 (P = 0.0)
Estimated Non-centrality Parameter (NCP) = 498.392
90 Percent Confidence Interval for NCP = (404.641 ; 600.029)

Minimum Fit Function Value = 7.781
Population Discrepancy Function Value (F0) = 2.898
90 Percent Confidence Interval for F0 = (2.353 ; 3.489)
Root Mean Square Error of Approximation (RMSEA) = 0.0615
90 Percent Confidence Interval for RMSEA = (0.0554 ; 0.0675)
P-Value for Test of Close Fit (RMSEA < 0.05) = 0.00119

Expected Cross-Validation Index (ECVI) = 8.944
90 Percent Confidence Interval for ECVI = (8.399 ; 9.535)
ECVI for Saturated Model = 10.500
ECVI for Independence Model = 47.334

Chi-Square for Independence Model with 861 Degrees of Freedom = 8057.432
Independence AIC = 8141.432
Model AIC = 1538.392
Saturated AIC = 1806.000
Independence CAIC = 8315.870
Model CAIC = 2107.393
Saturated CAIC = 5556.422

Root Mean Square Residual (RMR) = 0.309
Standardized RMR = 0.0809
Goodness of Fit Index (GFI) = 0.741
Adjusted Goodness of Fit Index (AGFI) = 0.695
Parsimony Goodness of Fit Index (PGFI) = 0.628

Normed Fit Index (NFI) = 0.834
Non-Normed Fit Index (NNFI) = 0.911
Parsimony Normed Fit Index (PNFI) = 0.742
Comparative Fit Index (CFI) = 0.920
Incremental Fit Index (IFI) = 0.921
Relative Fit Index (RFI) = 0.813

Critical N (CN) = 111.518

Standardized Solution

LAMBDA-Y

	ACCURACY	SAVETIME	ALT_SYS	IMPACT
ACC1R	1.283	- -	- -	- -
ACC2	1.332	- -	- -	- -
ACC3	1.220	- -	- -	- -

ACC4	1.141	- -	- -	- -
TIME1	- -	1.514	- -	- -
TIME2	- -	1.325	- -	- -
TIME3R	- -	1.256	- -	- -
TIME4	- -	1.196	- -	- -
ALT1	- -	- -	1.078	- -
ALT2R	- -	- -	1.279	- -
ALT3R	- -	- -	1.324	- -
ALT5R	- -	- -	1.570	- -
ALT6R	- -	- -	1.318	- -
IMPACT1	- -	- -	- -	1.280
IMPACT2	- -	- -	- -	1.291
IMPACT3R	- -	- -	- -	0.741
IMPACT4	- -	- -	- -	1.304

LAMBDA-X

	P_INTERD	P_COORD	S_INTERD	S_COORD	GENERIC	DIFFERN
P_FS1	2.139	- -	- -	- -	- -	- -
P_FS2	1.839	- -	- -	- -	- -	- -
P_GI2	2.161	- -	- -	- -	- -	- -
P_GI3R	1.762	- -	- -	- -	- -	- -
P_GI4	2.089	- -	- -	- -	- -	- -
P_CB1	- -	1.882	- -	- -	- -	- -
P_CB2	- -	2.022	- -	- -	- -	- -
P_CB3	- -	2.153	- -	- -	- -	- -
P_CB4	- -	2.057	- -	- -	- -	- -
S_FS1	- -	- -	2.265	- -	- -	- -
S_FS2	- -	- -	2.063	- -	- -	- -
S_GI2	- -	- -	1.881	- -	- -	- -
S_GI3R	- -	- -	2.145	- -	- -	- -
S_GI4	- -	- -	1.860	- -	- -	- -
S_CB1	- -	- -	- -	1.765	- -	- -
S_CB2	- -	- -	- -	1.750	- -	- -
S_CB3	- -	- -	- -	1.771	- -	- -
S_CB4	- -	- -	- -	2.163	- -	- -
GENERIC1	- -	- -	- -	- -	1.440	- -
GENERIC4	- -	- -	- -	- -	1.692	- -
GENERIC5	- -	- -	- -	- -	1.661	- -
D_4TO5_9	- -	- -	- -	- -	- -	1.832
P_IXB	- -	- -	- -	- -	- -	- -
S_IXB	- -	- -	- -	- -	- -	- -
GENX45_9	- -	- -	- -	- -	- -	- -

LAMBDA-X

	P_IxB	S_IxB	GENRxDIF
P_FS1	- -	- -	- -
P_FS2	- -	- -	- -
P_GI2	- -	- -	- -
P_GI3R	- -	- -	- -
P_GI4	- -	- -	- -
P_CB1	- -	- -	- -
P_CB2	- -	- -	- -
P_CB3	- -	- -	- -
P_CB4	- -	- -	- -
S_FS1	- -	- -	- -
S_FS2	- -	- -	- -
S_GI2	- -	- -	- -
S_GI3R	- -	- -	- -
S_GI4	- -	- -	- -
S_CB1	- -	- -	- -
S_CB2	- -	- -	- -
S_CB3	- -	- -	- -
S_CB4	- -	- -	- -
GENERIC1	- -	- -	- -
GENERIC4	- -	- -	- -
GENERIC5	- -	- -	- -
D_4TO5_9	- -	- -	- -

P_IXB	2.722	- -	- -
S_IXB	- -	3.028	- -
GENX45_9	- -	- -	2.875

BETA

	ACCURACY	SAVETIME	ALT_SYS	IMPACT
ACCURACY	- -	- -	- -	- -
SAVETIME	- -	- -	- -	- -
ALT_SYS	- -	- -	- -	- -
IMPACT	0.323	0.625	0.041	- -

GAMMA

	P_INTERD	P_COORD	S_INTERD	S_COORD	GENERIC	DIFFERN
ACCURACY	- -	- -	- -	- -	0.025	-0.106
SAVETIME	- -	- -	- -	- -	-0.105	-0.184
ALT_SYS	- -	- -	- -	- -	0.027	-0.118
IMPACT	0.092	-0.093	0.076	0.284	- -	- -

GAMMA

	P_IxB	S_IxB	GENRxDIF
ACCURACY	- -	- -	-0.125
SAVETIME	- -	- -	-0.023
ALT_SYS	- -	- -	-0.169
IMPACT	-0.049	0.334	- -

Correlation Matrix of ETA and KSI

	ACCURACY	SAVETIME	ALT_SYS	IMPACT	P_INTERD	P_COORD
ACCURACY	1.000					
SAVETIME	0.644	1.000				
ALT_SYS	0.623	0.662	1.000			
IMPACT	0.751	0.861	0.657	1.000		
P_INTERD	-0.026	-0.047	-0.027	0.007	1.000	
P_COORD	-0.025	-0.049	-0.024	0.048	0.918	1.000
S_INTERD	-0.005	-0.023	-0.006	0.056	0.265	0.279
S_COORD	0.003	-0.007	0.005	0.129	0.298	0.407
GENERIC	0.005	-0.116	0.002	-0.119	-0.086	-0.127
DIFFERN	-0.101	-0.188	-0.111	-0.126	0.314	0.356
P_IxB	0.009	0.031	0.007	0.133	0.134	0.033
S_IxB	-0.001	0.016	-0.001	0.094	-0.175	-0.116
GENRxDIF	-0.119	-0.029	-0.162	-0.093	-0.074	-0.125

Correlation Matrix of ETA and KSI

	S_INTERD	S_COORD	GENERIC	DIFFERN	P_IxB	S_IxB
S_INTERD	1.000					
S_COORD	0.900	1.000				
GENERIC	0.070	-0.022	1.000			
DIFFERN	0.087	0.059	0.047	1.000		
P_IxB	0.106	0.150	0.012	-0.184	1.000	
S_IxB	-0.757	-0.606	-0.153	0.001	0.299	1.000
GENRxDIF	-0.017	-0.076	0.115	-0.034	0.088	-0.020

Correlation Matrix of ETA and KSI

	GENRxDIF
GENRxDIF	1.000

PSI

ACCURACY	SAVETIME	ALT_SYS	IMPACT

ACCURACY	0.974			
SAVETIME	0.624	0.952		
ALT_SYS	0.591	0.638	0.959	
IMPACT	- -	- -	- -	0.130

Regression Matrix ETA on KSI (Standardized)

	P_INTERD	P_COORD	S_INTERD	S_COORD	GENERIC	DIFFERN
ACCURACY	- -	- -	- -	- -	0.025	-0.106
SAVETIME	- -	- -	- -	- -	-0.105	-0.184
ALT_SYS	- -	- -	- -	- -	0.027	-0.118
IMPACT	0.092	-0.093	0.076	0.284	-0.056	-0.154

Regression Matrix ETA on KSI (Standardized)

	P_IxB	S_IxB	GENRxDIF
ACCURACY	- -	- -	-0.125
SAVETIME	- -	- -	-0.023
ALT_SYS	- -	- -	-0.169
IMPACT	-0.049	0.334	-0.062