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Causal Linkages in Supply Chain Management: An Exploratory Study of North American Manufacturing Firms

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ABSTRACT

In this paper we investigate the key causal linkages in supply chain management. We propose a conceptual framework and test this framework on data from 215 North American manufacturing firms using structural equation modeling techniques. Three major research issues are addressed in this study: Do sourcing decisions affect the degree to which firms achieve manufacturing goals of cost, flexibility, dependability, and quality? Does the degree of manufacturing goal achievement lead to higher customer responsiveness? Does the degree of manufacturing goal achievement lead to higher internal manufacturing performance? The study examines the relationship among sourcing decisions, manufacturing goals, customer responsiveness, and manufacturing performance. The results support the notion that an integrated supply chain involves aligning sourcing decisions to achieve manufacturing goals that are set to respond favorably to the needs of customers.

Subject Areas: Production/Operations Management, Strategy and Policy, and Structural Equation Modeling.

INTRODUCTION

Supply chain integration and management has recently received a great deal of attention from researchers and practitioners alike. Xerox, Hewlett Packard, Allied Signal, and Siemens are examples of firms that have attempted to operationalize supply chain integration with varying degrees of success in their respective industries (Leenders, Nollet, & Ellram, 1994). Research on supply chain management has tended to focus on individual functions (purchasing, manufacturing, logistics) and their responsibilities (Cavinato, 1992; Scott & Westbrook, 1991; Turner, 1993). This body of literature has not examined the causal linkages and processes that comprise the supply chain. Despite the growing use of the concept of supply chain management in many manufacturing firms, little empirical research dealing with aspects of supply chain integration exists.

This study is concerned with the content issues of supply chain management, the central question being: What are the relevant variables or key decisions that impact the effectiveness of supply chain management? To address this question, we propose a new framework of supply chain integration. The proposed "decisions-oriented" research framework is somewhat different from the ones used in other studies in the literature that focus on "materials flow" or "infrastructural integration" (see, e.g., Armistead & Mapes, 1993; and Stevens, 1990). In our view, the discussion of and inquiry into supply chain integration must center on causal linkages that exist among key strategic decisions along the supply chain. Accordingly, this paper identifies the key strategic decisions in the form of constructs. The causal structure among these constructs is presented as a conceptual model. The conceptual model is then tested using data from a sample of North American manufacturing firms.

This paper is organized as follows. First, the relevant literature is reviewed and a framework of supply chain integration is presented. Next, the conceptual model and the data used for testing the hypotheses are introduced. An overview of structural equations modeling (the technique used to test the model in this study) is provided. The results from the structural equation modeling analysis are presented and discussed. Finally, some suggestions are offered for future research.

LITERATURE REVIEW AND RESEARCH FRAMEWORK

Armistead and Mapes (1993) conducted a field study of managers in the U.K. to investigate the extent to which greater integration along the supply chain improves quality and operating performance. Strength of integration was measured as a composite index of ratings on five items: (1) extent of shared ownership of master production schedules; (2) level of adherence to manufacturing plans; (3) use of job titles that span traditional functions (e.g., supply chain manager); (4) extent of integration of information systems; and (5) level of visibility and spread of information. The results of their study indicated that increasing the level of integration does increase manufacturing performance. However, this study was based on a sample size of 38 firms and the authors did not formally test causal linkages. To our knowledge, this is the only article that has examined empirically the association between supply chain integration and performance. The research framework in our study is conceptually different from Armistead and Mapes. Our study utilizes a larger sample size, focuses on supply chain decisions, and differs in the statistical methodology employed.

Berry, Towill, and Wadsley (1994) discussed current practices of supply chain management in the U.K. electronics industry and developed a dynamic simulation model to estimate the benefits derived from successful implementation of supply chain management. Bleil (1993), in a practitioner-oriented article, laid emphasis on sourcing strategies, supplier management, and sole sourcing to reduce cycle time and costs. The relevance and importance of integrating the manufacturing and engineering capabilities of suppliers with that of the buying firm to achieve cost and quality targets and manufacturability of components was discussed by Burt (1989).

The recurring theme in these articles is the role of supply management in improving product quality and other aspects of manufacturing performance. Although the authors link supply management to product quality and cost, statistical validation of the linkage of supply management decisions to manufacturing goals of a firm and customer responsiveness has not been examined.

A somewhat different view of supply chain integration was given by Stevens (1990), who defined an integrated supply chain as a method for managing material flow from strategic, tactical, and operational perspectives by achieving a high degree of functional, internal, and external integration. Functional integration connotes the knitting together of the various departments across the supply chain; internal integration is viewed as the coordinated deployment of strategic goals down the levels of an organization to the supply chain; and external integration is viewed as the strategic use of suppliers to achieve the goals of the integrated supply chain.

Although the literature on supply management (Carter & Narasimhan, 1996; Schonberger & Ansari, 1984; Waller, 1993) and manufacturing strategy (Roth, DeMeyer, & Amano, 1989; Skinner, 1985) stress that supply management decisions are strategic and that cost, quality, dependability, and flexibility—the principal elements of manufacturing strategy—must be aligned with a firm's business strategy, few empirical studies have attempted to examine the causal linkages among them.

Sourcing Decisions

The role of purchasing in firms has changed from operational to strategic because effective management of suppliers and sourcing decisions are critical in today's manufacturing environment, where there are simultaneous pressures to reduce costs and time-to-market, and increase product quality and variety (Carter & Narasimhan, 1996; Nishiguchi, 1990). The strategic importance of purchasing derives from the conviction that suppliers and the way in which companies manage them can provide firm-specific competitive advantages. For example, Xerox has lowered material costs by 50% by effectively managing sourcing decisions (Bleil, 1993). Strategic use of supply management to gain flexibility, cost, dependability, and quality advantages over the competition has been underscored by several researchers (Burton, 1988; Dion, Banting, & Hasey, 1990).

Strategic Outsourcing

Outsourcing is often used by firms to pursue quality, flexibility, dependability, and cost objectives (Frazier, Spekman, & O'Neal, 1988; Higginson & Bookbinder, 1990). Outsourcing of activities that do not belong to the core business of a firm is becoming increasingly prevalent. A firm needs to continually evaluate the activities it performs in-house with a view to outsourcing activities that suppliers can perform better. A recent survey of U.S. chief executive officers (CEOs) shows that 42% of communication firms, 40% of computer manufacturers, and 37% of semiconductor companies rely on outsourcing from foreign firms (Burrill & Almassey, 1991). These CEOs predict that in the late 1990s the figures on outsourcing will increase to about 50%. Tully (1994) has also alluded to the increasing tendency of manufacturers to make less and outsource more.

Supplier Capability Assessment and Management

Supplier capability assessment and management have been shown to influence cost, quality, and dependability (Lascelles & Dale, 1990; Schonberger & Ansari, 1984; Waller, 1993). Leenders and Fearon (1993) stressed that sourcing and supply management can contribute to reduced delivery lead times and defect-free products as part of a successful TQM implementation. Suppliers can also enhance the buyer's manufacturing flexibility. For example, Picanol and Mori Seiki design machines that require lower setup times with the aim of reducing cost to their customers and increasing their mix flexibility (Matthyssens & Van den Bulte, 1994).

In a supply chain environment, evaluating the capabilities of suppliers has a special role in that shared responsibility for the achievement of corporate targets is emphasized rather than internal performance measures (Anscombe, 1994). This trend marks a shift away from traditional price-based evaluation of suppliers. Increased involvement of suppliers in the design and manufacture of subsystems for the buyer (i.e., strategic outsourcing), and the use of JIT purchasing as a strategy to achieve cost, quality, and delivery performance targets have changed the way in which the capability of suppliers is assessed and developed. Hewlett Packard assesses the capability of its suppliers on multiple dimensions: technology, quality, responsiveness, dependability, and cost (Burt, 1989). Asea Brown Boveri expects from its suppliers error-free quality and delivery, compressed cycle times, a reasonable price, innovative engineering capability, and a portion of total cost improvement (Matthyssens & Van den Bulte, 1994).

To summarize, effective management of sourcing decisions requires attention to two strategic activities—outsourcing and supplier capability assessment and management. These strategic aspects of sourcing are of particular interest in this study.

Degree of Manufacturing Goal Achievement

The manufacturing strategy literature identifies cost, flexibility, quality, dependability, time, and innovation as principal competitive dimensions (Roth et al., 1989; Skinner, 1985). In a comprehensive literature review of manufacturing strategy, Adam and Swamidass (1989) found that cost, flexibility, delivery, and quality were most often mentioned in the literature. In another study, Maruchek, Pannesi, and Anderson (1990) found that most firms consider cost, quality, delivery, and flexibility as the content of manufacturing strategy. Swamidass (1986) reported that the most important manufacturing criteria in the opinion of manufacturing executives were: improving and maintaining quality, lowering manufacturing costs, and keeping delivery promises.

Besides being relevant to the competitive priorities of a firm, cost, flexibility, quality, and dependability are also important considerations in outsourcing and supply management decisions. Sourcing and supply management decisions can impact cost and product flexibility by enabling a firm to provide customized products and schedule flexibility to its customers, and by responding rapidly and in a coordinated way to schedule changes (Armistead & Mapes, 1993; Cavinato, 1992). Quality has long been an important consideration in a supply chain setting. Harrison (1990) advanced the concept of co-makership—closer relationship with the suppliers—as a technique to attain quality in manufacturing. Dependability has been shown to be important in a supply chain environment. Cameron Forged Products, which makes disks and shafts for Pratt & Whitney jet engines, improved dependability performance using synchronous manufacturing techniques involving its suppliers (Velocci, 1993).

The preceding discussion identifies quality, dependability, flexibility, and cost as elements of manufacturing strategy that link to customers and determine a firm's performance. Quality, dependability, flexibility, and cost also link to the supply base of a firm in that they influence strategic outsourcing decisions and the management of suppliers in pursuit of these manufacturing goals. It may be noted that having the right strategy is not enough; implementation effectiveness of goals is also important. If manufacturing goal achievement can be increased, it is expected that manufacturing and firm performance will also increase.

Performance Measures

In this work we investigated two performance measures—customer responsiveness and manufacturing performance.

Customer Responsiveness

Customer responsiveness has been recognized as one of the principal aims of supply chain integration. Hines (1996) proposed a pull model called Integrated Materials Value Pipeline designed to position the customer as a starting point for all intracompany and intercompany activities. In this model the customer defines the type of product, quality of the product, the price point, and the timing of when the product is needed. The designing of quality into the product, the incorporation of correct features, the optimization of cost, and delivery when required by the customer are viewed as the responsibility of all members in the supply chain.

Experiences of organizations like Caterpillar, General Motors, ICL, Philips, and Rank Xerox have shown that focusing on fast, reliable delivery and responsiveness to changing customer needs is important to achieve integration of the supply chain (Armistead & Mapes, 1993). One technique to achieve this integration is the use of synchronous manufacturing, which involves the flow of materials through the manufacturing process as quickly as possible, based on customer orders (Hammel & Kopczak, 1993). Using this technique, Pratt & Whitney reduced inventory and cycle time by 57%.

Hill (1994) argued that in world-class firms orders are won on delivery and variety (one of the flexibility dimensions) rather than price or quality, which are order qualifiers. Lee and Billington (1992) argued that the effectiveness of a supply chain must ultimately be measured by its responsiveness to customers. Maintaining superior customer service performance is becoming increasingly difficult because there are many types of customers, each served by different supply chains, each with its own needs, and each offering different opportunities. Therefore, finding and building strong positions in selected supply chains with selected customers will become the future focus for supply chain management (Anscombe, 1994). Consistent with these views, one of the performance measures of interest in the proposed conceptual model is customer responsiveness.

Manufacturing Performance

In addition to impacting customer responsiveness, it is expected that a well-managed and integrated supply chain will lead to internal benefits. The attainment of quality and flexibility lead to lower costs and productivity improvements due to reduced inventory, scrap and rework costs, and external failure costs. Lower costs, flexibility, and improved delivery dependability, in turn, lead to superior levels of customer satisfaction, resulting in better sales and profits. Manufacturing performance is operationalized in this study in terms of return on production assets and growth in productivity. This is consistent with the measures used by Vickery, Dröge, and Markland (1993), who used return on asset and growth measures in their study of manufacturing competence involving firms in the furniture industry, and the work of Snell and Youndt (1995).

The preceding sections lead to the research framework reflecting the "decisions-oriented" view of supply chain integration as shown in Figure 1. Supply chain integration is viewed as the confluence of "supplier integration," "strategic integration," and "customer integration."

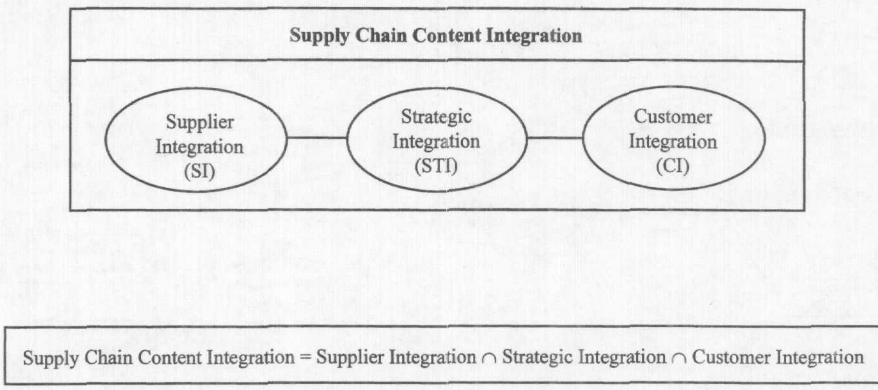
In this study, each of these components of integration is modeled in terms of "content variables" that are associated with key decisions in each of these areas. For example, supplier integration is characterized by decisions pertaining to outsourcing, and supplier capability assessment and management. Strategic integration and customer integration are captured in terms of the content variables—quality, flexibility, cost, and dependability targets—stemming from manufacturing strategy decisions and customer responsiveness, respectively. The causal linkages among these variables are hypothesized to influence manufacturing performance and customer responsiveness. This conceptualization views quality, flexibility, cost, dependability, and sourcing decisions as key drivers of effective supply chain integration that are linked to strategic priorities of firms. Although it is possible to assert additional dimensions to characterize these aspects of an integrated supply chain, we focus on these to study the combined effect of sourcing and manufacturing strategy on performance.

CONCEPTUAL MODEL

The preceding sections provide a basis for including sourcing decisions, degree of manufacturing goal achievement, external customer responsiveness, and internal manufacturing performance in the proposed conceptual model shown in Figure 2a. Figure 2b presents the structural equation model using standard conventions. This is included for the information that it provides to readers familiar with structural equation models.

Outsourcing and supplier capability management are the "observables" of the latent variable, strategic sourcing decisions. Strategic sourcing decisions are hypothesized to positively influence the degree of manufacturing goal achievement, a latent variable. Dependability, cost, flexibility, and quality are the observables of the latent variable, the degree of manufacturing goal achievement. As discussed earlier, the link between sourcing decisions and degree of manufacturing goal achievement is an operationalization of supplier integration. The proposed linkages in the model lead to the following hypothesis:

Figure 1: Research framework.



H1: Strategic sourcing decisions (strategic outsourcing and supplier capability management) positively influence the degree of manufacturing goal achievement (in terms of dependability, flexibility, cost, and quality).

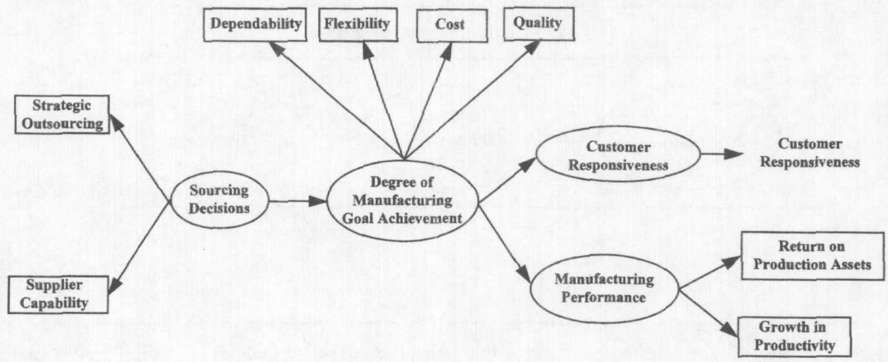
Just as supplier integration is important for an effective supply chain management effort, so are strategic integration and customer integration. These are driven by competitive considerations and are influenced by the requirements of customer responsiveness. The link between the degree of manufacturing goal achievement and customer responsiveness is an indication of strategic and customer integration. Thus, it is hypothesized that:

H2: The degree of manufacturing goal achievement (dependability, flexibility, cost, and quality) positively influences the level of customer responsiveness.

Another aspect of strategic integration in an effective supply chain management effort is the relationship between the degree of manufacturing goal achievement and manufacturing performance. Strategic integration relates to two aspects of the supply chain. The first aspect is the translation of competitive priorities into manufacturing goals. Quality, dependability, cost, and flexibility have been incorporated as components of the degree of manufacturing goal achievement to capture this aspect. The second aspect is the performance of the manufacturing function. Return on production assets and growth in productivity are proposed in the model as indicators of manufacturing performance. The hypothesis relating degree of manufacturing goal achievement and manufacturing performance is:

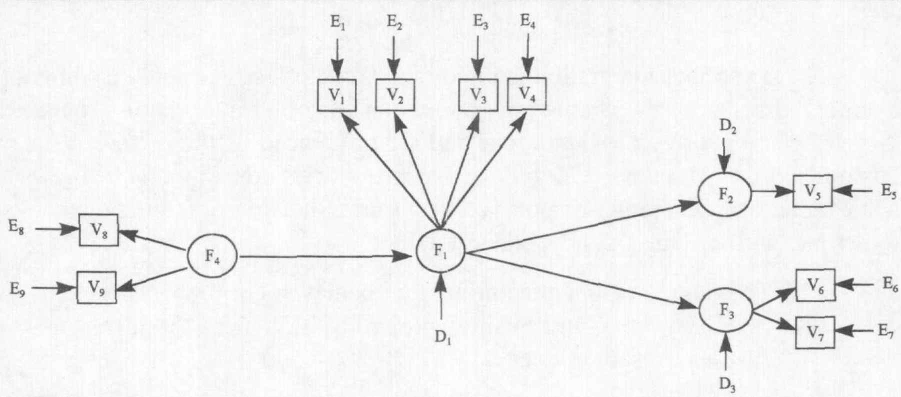
H3: The degree of manufacturing goal achievement (dependability, flexibility, cost, and quality) positively influences the degree of manufacturing performance (return on production assets and growth in productivity).

Figure 2a: Conceptual model.



Note: For the sake of brevity, errors and disturbance terms are not shown.

Figure 2b: Conceptual model—SEM representation.



Legend:

V_1: Dependability	F_1: Degree of Manufacturing Goal Achievement
V_2: Flexibility	F_2: External Customer Responsiveness
V_3: Cost	F_3: Internal Manufacturing Performance
V_4: Quality	F_4: Sourcing Decisions
V_5: Customer Responsiveness	E_1 to E_9: Error terms in measurement model
V_6: Return on Production Assets	D_1 to D_3: Error terms in structural model
V_7: Growth in Productivity	
V_8: Strategic Outsourcing	
V_9: Supplier Capability	

These three hypotheses together span the supply chain from supplier to customer. Our conceptual model sets the stage for empirical testing of the linkages among the key aspects of sourcing, degree of manufacturing goal achievement, customer responsiveness, and internal manufacturing performance. The method of structural equation modeling was used to test simultaneously the measurement model and the structural model. An overview of this technique follows.

OVERVIEW OF STRUCTURAL EQUATION MODELING

Structural Equation Modeling (SEM), also known as latent variable analysis (Loehin, 1987) or causal modeling (Blalock, 1985), is similar to path analysis in that it provides parameter estimates of the direct and indirect links between observed variables. An important distinction between path analysis and SEM lies in the fact that the latter explains covariation in the data. SEM is also similar to regression techniques in that there is a quantification of relationship between dependent and independent variables. However, although regression parameters represent empirical associations, structural parameters represent causal associations. One of the unique features of SEM is the ability to provide parameter estimates for relationships among unobserved variables (i.e., the latent variables). A structural equation model implicitly asserts a covariance structure whose concordance with the observed covariance based on the data can be tested (Jöreskog & Sörbom, 1989). LISREL (Jöreskog & Sörbom) and EQS (Bentler, 1989) are the two most popular SEM software packages used by researchers. Although the parameter estimates, standard errors, and tests are essentially identical for both packages, EQS uses simpler terminology and notation (Brown, 1986). The goodness-of-fit test is carried out using chi-squared and other tests, which are available in EQS. The parameter estimates are derived using maximum likelihood estimation (MLE) or generalized least squares (GL) estimation methods. This research used EQS and generalized least squares (GL) estimation method to test the conceptual model. The mathematical equations corresponding to Figure 2b are shown in the Appendix.

DATA ANALYSIS

The test of the conceptual model was carried out using data from the Global Manufacturing Research Group (GMRG) Questionnaire II. A copy of this questionnaire can be found in Whybark and Vastag (1993). The database contains responses from a number of countries from Asia, Europe, South America, and North America. In this study, responses from firms in North America—U.S. and Mexico—were used (the GMRG data did not contain responses from Canadian firms). These firms belong to two industries—small machine tools and nonfashion textile manufacturing. Details of the process used to gather data can be found in Vastag and Whybark (1994). A summary of the data-gathering process follows.

Directories of trade association members from these industries were used to select a random sample of firms. A manufacturing executive from each of the selected companies was contacted by telephone. The executive was made aware of the trade association support and was invited to participate in the study. As an incentive, firms were told that if they participated in the study, the average responses for firms in their industry would be provided to them. Follow-up phone calls were made to answer questions and remind the participants to complete and return the questionnaires. A second wave of mailing was done to increase the sample size.

The data was collected in 1994. The final sample included 139 firms from the U.S., and 76 firms from Mexico. Completed questionnaires from firms in the U.S. came from executives in Illinois, New Hampshire, and Utah. A listwise deletion of missing values reduced the sample size to 127 firms. A scrutiny of the missing values revealed that most of the missing information was attributed to nonresponse to questions relating to financial measures.

Table 1 presents the descriptive statistics and correlations among all indicators used in our study. In Table 1, correlations that are statistically significant are shown in boldface. For example, the correlation between cost and dependability is statistically significant.

Gerbing and Anderson (1988) have emphasized that existing assessments of reliability, such as Cronbach's coefficient alpha, are only meaningful if the measures have an acceptable level of unidimensionality. Following their recommendations, the items comprising the various scales were subjected to two processes for scale purification. First, an exploratory factor analysis was conducted on the initial set of items to ensure the unidimensionality of the scales. Second, an assessment of reliability was made using Cronbach's alpha. Items that reduced the alpha value were eliminated. The Cronbach alpha values for the indicators are presented in Table 2. Typically, for an exploratory study in which the scales used have not been established through prior investigation, a minimum threshold alpha value of 0.6 is recommended (Nunnally, 1967). Based on the values in Table 2, the scales used in this study can be deemed reliable.

Besides ensuring that all indicators were unidimensional, a confirmatory factor analysis was done to verify if the measurement variables related to the latent variables—sourcing decisions, degree of manufacturing goal achievement, external customer responsiveness, and internal manufacturing performance. The results of the confirmatory factor analysis are presented in Table 3.

The principal components method with varimax rotation was used in the factor analysis. As can be seen from Table 3, the fit to a four-factor model was reasonably good. The only factor that did not have a "clean" loading was growth in productivity. However, a factor analysis of manufacturing performance items only yielded a reasonable fit to a two-factor model. This somewhat alleviated our concern with the "nonclean" loading of growth in productivity on manufacturing performance.

In this research the best possible scales were created by using the GMRG database. The high reliabilities of the items used in the different scales (see Table 2) were reassuring and indicative of the fact that the selection of scale items was adequate. The items used for the different constructs should be construed as an initial attempt at developing valid and reliable scales. Issues of reliability and content validity were kept in mind while selecting items from the GMRG database. For example, items relating to degree of manufacturing goal achievement were selected on the basis of previous literature in manufacturing strategy, which point to cost flexibility, quality, and dependability as key measures of manufacturing goal achievement. To the extent possible, we have included operationalization of indicators that are similar to those employed in other studies that have used the same GMRG survey questionnaire. For example, Wacker (1994) used the same

Table 1: Descriptive statistics and correlations.

Variables	1	2	3	4	5	6	7	8
1. Dependability	1							
2. Flexibility	.1034	1						
3. Cost	**.2369**	.0411	1					
4. Quality	**.2642**	.1207	.0804	1				
5. Customer Responsiveness	**.2284**	.0971	–.0080	.1356	1			
6. Return on Production Assets	–.0103	.0901	.0518	–.0448	.0697	1		
7. Growth in Productivity	.0743	.1182	–.0048	**.1648**	.0697	.0311	1	
8. Strategic Outsourcing	.0661	–.0162	**–.1471**	.0151	–.0408	.0381	–.1062	1
9. Supplier Capability	**.1963**	.1336	–.0267	.0659	.0944	–.0685	.0824	–.0044

$p < .10$. Statistically significant figures appear in boldface.

GMRG survey questionnaire to examine the relationships among manufacturing practices, technology, competitive advantage, and profitability. In Table 2, operationalizations of items of our model that are similar to those used by Wacker (1994) are highlighted.

RESULTS

The results from the SEM tests using EQS are presented in three parts. First, the results from the measurement model (see Table 4) are presented. Next, the results from the structural model are presented (see Table 5). Finally, overall validity of the model using fit criteria is discussed (see Table 6).

The results show that operationalization of degree of manufacturing goal achievement was valid as shown by the parameter estimates and their statistical significance. The latent variable, sourcing decisions, was not statistically significant; however, the construct was shown to have content validity and unidimensionality. For the other constructs, unidimensionality and face validity were shown, but the construct validity could be better. These results are attributable to the fact that an available database was used to test the conceptualized model in the best possible way. The intent of GMRG was to gather data on manufacturing practices. Quite a few of these practices can be classified as "tactical" or shop-floor oriented. We have picked those practices that have been shown in the literature to be "strategic" in nature and statistically tested the measurement properties (face validity, convergent validity, and unidimensionality) of these items in a rigorous manner. We were fairly successful in demonstrating the robustness of the measurement properties of the key construct of degree of manufacturing goal achievement.

The measurement model results reveal that flexibility, cost, and quality have a statistically significant relationship with the "degree of manufacturing goal

Table 2: Description of the items and reliabilities of the indicators.

Indicator	Standardized Alpha	Representative Items	Question Number in GMRG Survey*
1. Depend-abiity	.8441 (2 items)	Performance, as compared to competitors, on:	
		a) delivery speed	1.18 (item 4)
		b) delivery reliability	1.18 (item 5)
2. Flexibility	.6493 (3 items)	Performance, as compared to competitors, on:	
		a) mix flexibility	1.18 (item 6)
		b) volume flexibility	1.18 (item 7)
		c) product design time	1.18 (item 8)
3. Cost	1.0000 (1 item)	Performance, as compared to competitors, on:	
		a) unit cost of manufacturing	1.18 (item 1)
4. Quality	1.0000 (1 item)	Performance, as compared to competitors, on:	
		a) quality of products	1.18 (item 2)
5. Customer Responsive-ness	.9695 (2 items)	a) Minimum days to future delivery promised date (Reverse coded)	4.08 (item 1)
		b) Minimum days from cus-tomer order to shipment date (Reverse coded)	4.18 (item 1)
6. Return on Production Assets	.9936 (2 items)	a) Ratio of gross margin to investment in production equipment	Gross margin = 1 – (Qn. # 1.16) Investment = Qn # 1.14
		b) Ratio of sales to investment in production equipment	Sales = Qn. # 1.06 (item 1 + item 2) Investment = Qn # 1.14
7. Growth in Productivity	.9126 (2 items)	a) Percentage change in output	4.22 (item 1)
		b) Percentage change in productivity	4.22 (item 2)
8. Strategic Outsourcing	.7843 (4 items)	Use of subcontracting for strategic reasons:	
		a) lower costs	3.11 (item 5)
		b) higher quality	3.11 (item 6)
		c) lower delivery lead times	3.11 (item 4)
		d) production difficulty	3.11 (item 2)
9. Supplier Capability	.7845 (2 items)	Evaluation of suppliers on the basis of:	
		a) higher quality	5.01 (item 11)
		b) delivery reliability	5.01 (item 12)

*GMRG survey can be found in Whybark and Vastag (1993), pp. 435-455.

Table 3: Rotated factor loadings for the four structural factors.

Variables	Factor 1	Factor 2	Factor 3	Factor 4
1. Dependability	**0.7684**	-0.0383	0.1118	0.0632
2. Flexibility	**0.7219**	0.0748	-0.1384	-0.0764
3 Cost	**0.5042**	-0.1806	0.1286	0.2287
4. Quality	**0.6674**	0.2007	0.0205	-0.1097
5. Strategic Outsourcing	-0.0729	**0.7843**	-0.1131	0.0320
6. Supplier Capability	0.1317	**0.6372**	0.1344	-0.0112
7. Customer Responsiveness	-0.0363	-0.0066	**0.9326**	0.0348
8. Return on Production Assets	0.0474	0.0609	0.0001	**0.9362**
9. Growth in Productivity	0.2819	0.0927	0.2992	**-0.2569**
Eigenvalue	1.9560	1.1121	1.0227	0.9970
Cumulative proportion of total variance explained	0.2170	0.3410	0.4550	0.5650

achievement" construct. The link between the variables "strategic outsourcing" and "sourcing decisions" was not found to be statistically significant. A plausible explanation for this result is that the operationalization of the construct "strategic outsourcing" is lacking in content definition. The use of outsourcing related to fast delivery, cost, quality, and production difficulty, in our operationalization. This operationalization is not complete in that it does not capture the important flexibility dimension. Also, this result pertaining to the measurement model suggests that perhaps the strategic use of outsourcing has not been emphasized in North American manufacturing firms.

The results from the structural model confirmed H1 and H2, but did not lend support for H3. The causal link between sourcing decisions and the degree of manufacturing goal achievement was statistically significant, confirming prior expectation (Table 5). In the sample of firms analyzed, sourcing decisions do impact the level of manufacturing goal achievement in terms of quality, cost, flexibility, and dependability. Strategic outsourcing was operationalized as the use of subcontracting for strategic reasons such as low cost, high quality, and fast delivery. The degree of manufacturing goal achievement was operationalized as the comparative evaluation of a firm's performance on dependability, cost, quality, and flexibility. It is conceivable that some components of the scales comprising the latent variable "sourcing decisions" might have a strong influence on (i.e., structurally related to) the components of the degree of manufacturing goal achievement construct, thus leading to a statistically significant relationship in the structural model.

The causal linkage between degree of manufacturing goal achievement and external customer responsiveness was statistically significant. This result underscores the importance of the degree of manufacturing goal achievement to achieving superior customer satisfaction. Also, it points to the importance of actual achievement versus goal setting pursuant to a specific manufacturing strategy. However, the link between the degree of manufacturing goal achievement and internal manufacturing performance was not statistically significant. An explanation for this

Table 4: Measurement model results.

Indicator	Construct	Parameter Estimate	Standard Error	*t*-value
Strategic Outsourcing	Sourcing decisions	0.043	0.378	0.1138
Supplier Capability	Sourcing decisions	1	n.a.	n.a.
Dependability	Degree of manufacturing goal achievement	1	n.a.	n.a.
Flexibility	Degree of manufacturing goal achievement	0.298	0.167	1.784*
Cost	Degree of manufacturing goal achievement	0.368	0.178	2.068**
Quality	Degree of manufacturing goal achievement	0.380	0.169	2.250**
Customer Responsiveness	Customer responsiveness	1	n.a.	n.a.
Return on Production Assets	Manufacturing performance	-0.051	0.518	0.271
Growth in Productivity	Manufacturing performance	1	n.a.	n.a.

Note: In order to define the measurement scales for the constructs, one of the links from the indicator to the construct has to be set equal to one. Consequently, for these links the standard errors and *t*-values have been marked as "n.a." (not applicable).
*$p < .10$
**$p < .05$

result could be that the particular measure used for productivity was inappropriate. It is possible to postulate several ways for measuring productivity. For example, instead of labor productivity, an alternative measure of productivity, asset or investment productivity could be considered. Also, it is not clear whether there was uniform understanding across the respondents as to the precise definition of productivity used in the survey instrument. Recognizing possible measurement errors for this measure, the structural equation model was tested by specifying 10% to 20% error, a priori, for the error terms of ε_6 and ε_7. This approach has been suggested by researchers in SEM (see, e.g., Hayduk, 1987). This analysis also failed to yield a statistically significant result for this linkage.

The overall validity of the conceptual model was tested using multiple-fit criteria. The results of these criteria are reported in Table 6. The chi-squared value for the model is 64.2730 for a degree of freedom of 54. This chi-squared value yields a *p*-value of .1598, which is much higher than the minimum threshold of .05, a value required for an adequate fit of the overall model (Bagozzi & Yi, 1988; Bentler, 1989). Another way of assessing the fit of the overall model is by computing the ratio of chi-squared to the degree of freedom. According to Matsueda (1982), a ratio of χ^2 to *df* of no more than four-to-one is considered a good fit. Our value of 1.1902 is indicative of a good fit of the model. The EQS output provides three other goodness-of-fit indices. These are the Bentler-Bonett normed fit index (NFI), Bentler-Bonett non-normed fit index (NNFI), and the comparative fit index

Table 5: Structural model results.

(Predicted Sign)	Regression from	Coefficient to	Parameter Estimate	Standard Error	*t*-value
H1 (+)	Sourcing decisions	Degree of manufacturing goal achievement	0.175	0.066	2.668**
H2 (+)	Degree of manufacturing goal achievement	Customer responsiveness	0.235	0.102	2.313**
H3 (+)	Degree of manufacturing goal achievement	Manufacturing performance	0.192	0.155	1.243

$^{*}p < .10$
$^{**}p < .05$

(CFI). CFI is the preferred index to be used in models of small sample sizes. Bentler (1989) suggested that the CFI index value be at least 0.95 for confirmed models. As can be seen from Table 6, our model yielded a CFI value of 0.9910, which exceeds the minimum criterion of 0.95. When these fit statistics are considered together, the above results lend support to the overall validity of the conceptual model.

DISCUSSION

The results of data analysis lend empirical validity and credence to the conceptual issues incorporated in the hypothesized model. The overall fit of the model to the data suggest that supplier integration, strategic integration, and customer integration as components of supply chain integration merit further exploration. As suggested in our research framework (see Figure 1), the interaction among the components of supply chain integration—customer integration, strategic integration, and supplier integration—could proceed as follows. Customer integration could take place through a deployment process that translates customer requirements into specific manufacturing objectives to be pursued. Further, the delineation and refinement of these manufacturing goals is achieved through the strategic integration process. This responsibility is typically vested in the executive management and is communicated through a top-down approach to the functional levels, including manufacturing. The professed manufacturing goals as dictated by strategic integration could be pursued by conducting a "capability requirements analysis." Such an analysis would identify whether a particular capability should be developed in-house or provided by the supply base. The decision to utilize the capabilities of suppliers that are compatible with the manufacturing goals and customer requirements (i.e., outcome of strategic and customer integration) would be part of what we have termed "the supplier integration process in our research framework." The supplier integration process takes into account two critical sourcing decisions: strategic outsourcing, and supplier capability assessment and management. As a result of the capability requirements analysis, strategic outsourcing

Table 6: Goodness of fit summary results.

Fit Indices/Statistics	Value
Degrees of Freedom (*df*)	54
Sample Size	127
χ^2	64.2730
χ^2/df	1.1902
p-value (Overall model)	0.1598
Bentler-Bonett Normed Fit Index	0.9470
Bentler-Bonett Non-Normed Fit Index	0.9890
Comparitive Fit Index	0.9910

decisions would identify activities that suppliers can perform more effectively than the buyer. Another aspect of sourcing decisions is an ongoing assessment of supplier capabilities. The interactions described above are suggestive of the three types of integration conceptualized in Figure 1, which lends credence to the research framework. A detailed exploration of the processes suggested above using multiple case studies should prove fruitful. For example, the deployment process that translates customer requirements to professed manufacturing goals merits attention. Likewise, details of the capability requirements analysis can be studied and evaluated in the light of our conceptual model.

In the structural model, the links between sourcing decisions and degree of manufacturing goal achievement was shown to be statistically significant. The link between degree of manufacturing goal achievement and customer responsiveness was also shown to be statistically significant. In the measurement model, quality, dependability, flexibility, and cost links to the degree of manufacturing goal achievement were shown to be statistically significant. Together they imply that supplier integration, strategic integration, and customer integration across the supply chain determine customer responsiveness. To the extent that customer responsiveness dominates competitive priorities of firms, supply chain integration will be a dominant and effective competitive strategy. We have proposed that supply chain integration impacts customer responsiveness and performance via the key linkage between sourcing and degree of manufacturing goal achievement. Existing concepts relating to supply chain integration are based primarily on case studies and anecdotal evidence from individual companies. In contrast, the results of this study represent the first attempt at empirical validation of key causal linkages in a supply chain.

RESEARCH METHODOLOGICAL ISSUES

This research study used an existing database, Global Manufacturing Research Group (GMRG) data to develop and test hypotheses. In general, the use of existing databases for theory building raises several research and methodological issues: (1) unit of analysis and the associated frame of inference; (2) measurement issues; (3) validity and generalizability issues; and (4) theory building via replication studies. We discuss each of these issues in the ensuing section.

Use of Available Data Sets in Research

Several studies have used existing databases for theory building and testing purposes (Chowdhury & Menon, 1995; Bucklin, Ramaswamy, & Majumdar, 1996; Kumar & Balasubramanian, 1997). The most widely known Profit Impact on Marketing Strategies (PIMS) database has been used by researchers from several disciplines such as marketing, strategy, organization theory, finance, and management science. Ramanujam and Venkatraman (1984), in a critical review of research that used existing databases, identified six research streams in disciplines such as marketing, industrial organization economics, strategy, and finance, for which the PIMS database was the foundation. These research streams have stimulated research on various strategic issues. Examples of research based on existing databases include: identification of factors that influenced business performance, integration of different research approaches, discovery of contingency relationships, and empirical validation of strategic typologies (see, e.g., Craig & Douglas, 1982; Hambrick, MacMillan, & Day, 1982; and Prescott, 1983).

Research using available data sets in the operations management literature are beginning to emerge. Bozarth and Berry (1997) used available market and manufacturing data to propose a methodology to measure market-manufacturing congruence for evaluating the congruence between market needs and manufacturing plant capabilities. Wathen (1995) examined the relationship between production process focus and performance at the business unit level using the PIMS database and found partial support for the relationship between production process focus and financial performance for business units using return-on-sales, and no support while using return-on-assets and return-on-income as indicators of financial performance. The results of our study are similar in that we failed to show a significant relationship between degree of manufacturing goal achievement and return of production assets as an indicator of financial performance. Wathen's "production focus" construct is similar to the degree of manufacturing goal achievement in our study.

Research, Methodological Issues, and Limitations in the Use of Available Data Sets

Unit of Analysis

The unit of analysis as well as dispersion of data across firms, industries, products, and markets for which data are collected is important. For example, PIMS and GMRG databases have data from a sample of businesses across different firm sizes, products, and markets. The unit of analysis for the GMRG database is the manufacturing business unit or plant level. Consequently, the issue of generalizability of results is mitigated by the comprehensiveness of the databases. However, a focused analysis using a different data set will strengthen the validity of the results reported in this paper.

Measurement Issues

Data limitations may also affect the operationalization of constructs. In some instances, the operationalization may be forced or unduly narrow (Ramanujam &

Venkatraman, 1984) because the researcher was restricted to the items in the database. On the other hand, the use of available databases has promoted the increased inclusion of objective measures in the operationalization of constructs, which were otherwise not amenable to data collection in dedicated survey instruments because of lower response rates. Items used in the questionnaire of the available data set have to be carefully selected by using the literature as support for using the existing scales. This has implications for model testing and, in particular, comparing findings across studies. It is also important to purify scales through the use of techniques such as exploratory factor analyses and reliability analyses, as was done with the GMRG-based data and scales in our study.

Validity and Generalizability Issues

Previous studies have highlighted additional concerns with the accuracy and validity of available data sets. For example, in the case of PIMS, Jacobson and Aaker (1985) noted the potential for biases, because data may originate from single informants. Phillips, Chang, and Buzzell (1983, p. 31) discussed the general lack of independent checks on informant-provided data, such as the use of other informants or sources. The measures may be indirect and based on industry press and public information. Because of this constraint, the measures and their corresponding labels may not fully capture the phenomena that is being studied. In addition, the primary information from which the measures are developed, like most research using secondary data, may not be immune from reporting bias with respect to focus, company, and event, however credible and objective the data source may be.

In order to ensure valid and comparable results, attempts to replicate earlier studies should use the same data, variable transformations, and estimation procedures, to obtain model estimates. If there are extenuating circumstances for diverging from earlier studies, the reasons for the unique treatment should be documented. The use of available data sets is considered as "exploratory" research because the user of the data set did not control the choice of sample and population that were investigated. In the realm of the philosophy of science, this approach is called the "discovery" mode of creating knowledge (Platt, 1964). Consequently, care must be taken while inferring from the results of data analysis. Particular attention must be paid to issues such as: unit of analysis or level of inquiry, operationalization of constructs, and population frame. Moreover, if the research method involves causal modeling, attention must be paid to the choice of using reflective indicators versus causal indicators for model specification and data analysis (see Bollen & Lennox, 1991, for a discussion). In our study, the context and content of the proposed conceptual model acknowledges of the specification of a reflective model only. In general, the research intent of the study dictates the use of reflective versus causal indicators. In most circumstances, indicators "reflect" on constructs, that is, the constructs are operationalized in terms of the indicators.

Theory Building

To facilitate theory building, it is important to use different operationalizations of the same construct for the purpose of convergence of findings. Note that this is not the same as replication. In replication, the same items are used to generate similar or identical findings. However, for convergence, different items should be used to arrive at similar or identical findings. Consistent and cumulative findings aid in theory-building efforts.

The coefficient of determination (R^2) in models that use available data sets may be lower because the dependent variable may be influenced by several independent variables that are not controlled, as they are not explicitly measured. This does not necessarily invalidate such models. For example, important mediating relationships can still be discovered. In a similar way, unobserved, firm-specific factors that include items measured in the data set may be used as control variables for assessing the impact of other independent variables on the dependent variable(s).

Limitations of Using Available Databases

The potential for measurement error in the variables is high. The existence of limited control variables for capturing observable heterogeneity, the composition of the sample, and the subjectivity of some of the key variables all contribute to the measurement error. As indicated earlier, certain variables that are known (through past research) to influence the dependent variable, may not be included in the model because they are not measured. This can cause specification errors or low R^2. The findings, therefore, must be interpreted in the context of model specification.

Issues relating to validity are also important when using established data sets. Terms must be clearly defined and the frame of reference used by the respondents for the survey questions should be the same across firms for valid operationalizations of variables. This also has implications of comparability of parameter estimates across different studies. Missing data is another important issue because the number of observations available for model estimation is reduced. The number of observations available also may differ across different studies using the same database because of changes in the database and/or data preparation errors.

Limitations of This Study

The following limitations of this study are worth noting. Degree of manufacturing goal achievement is influenced by a number of factors including manufacturing planning and control, integrating mechanisms such as access to highly integrated databases, and managing for innovation. These influences were not included in our study, which is a limitation stemming from the use of an existing database. However, the significance and validity of the hypothesized relationship cannot be rejected due to this limitation. As is common in studies utilizing existing databases, R^2 values would tend to be low as is the case in our study. The significance of the results must rest on the rigor of statistical analysis and demonstration of the validity and reliability of the scales. This issue has been investigated by Murthi, Srinivasan, and Kalyanaram (1996) using the PIMS database. They extended existing empirical research on pioneering advantage (which had established a strong association between pioneering and market share) by suggesting that managerial skills may account for this relationship. Murthi et al. also developed efficiency measures to represent a firm's managerial skills. In addition, unobserved, firm-specific factors including unobserved managerial skills were used as control variables and the impact of pioneering on market share was then examined. They found that the results were robust even after controlling for managerial skills. This lends credence to the robustness of the statistically significant results reported in this paper. Also, the operationalization of the constructs in this study was somewhat narrow, dictated by the availability of data in the GMRG database. Richer conceptualization of the factors mentioned above and more refined scales for the latent variables should yield better insights.

FUTURE RESEARCH

Empirical validation of the conceptual model of supply chain integration in this research raises two key questions: What are the key decision linkages in supply chain integration? and, How do firms make these decisions effectively? Our study suggests some answers to the first question. The role of process technology and innovation and information technology as an integrating mechanism need to be researched within the context of the proposed model. Future research should also be directed towards understanding how the decisions identified in this study are being made in firms. For example, a possible research question that can be investigated is, "How do firms manage the outsourcing decision?" Another research issue that can be investigated is, "how do firms integrate supplier capabilities in setting targets for quality, flexibility, and dependability so as to achieve customer responsiveness?" Multiple case studies can be useful in developing answers to these questions.

Managers and researchers have made progress in understanding the contribution of suppliers to the strategic flexibility goals of the buyer. This understanding is reflected in the supplier capability and assessment decisions. The role of strategic outsourcing in furthering the flexibility goals of an organization deserves additional investigation. Likewise, goals relating to quality, cost, dependability, and flexibility have important implications for sourcing decisions in general. Contemporary practices in supply management such as supplier development, supplier partnering, and buyer-supplier relationships in achieving manufacturing goals should be investigated in future research. The results are representative of the current practice of supply chain management in North America. An interesting subject for future research would entail international comparison of supply chain management practices (e.g., North American, European, and Pan-Pacific regions). In addition, future research should focus on extending this framework to consider the impact of supply chain management practices on firm performance.

In the area of research methodology, this research points to the distinction of selecting a reflective indicator model as opposed to a formative indicator model. This choice is principally dependent on the research intent of the study. In this paper, each latent variable is hypothesized to reflect the stated observed variables. For instance, the latent variable of sourcing decisions was reflected by two observables—strategic outsourcing and supplier capability. This conceptualization is based on existing theories and research. The main thrust of this paper is to investigate the linkages among the latent variables of interest. Future research should consider alternative conceptualizations of the stated relationships.

It is imperative to make use of existing databases, to make rapid and significant progress in advancing empirical research in SCM and manufacturing strategy. In fact, research of this ilk is very common in marketing. For example, the existence of numerous studies based on the PIMS database has been noted earlier in this paper. Although collecting data specifically tailored to the conceptual model may be the "best" approach in most contexts, practical considerations such as the difficulties in data collection may tilt the scales towards the use of available data sets for developing and testing theories.

This study's contributions to the existing literature on supply chain integration are sixfold. First, the paper has proposed supply chain integration as being comprised of supplier integration, strategic integration, and customer integration. The framework provides a basis for assessing the effectiveness of supply chain integration. This view differs from a purely material flow-based conceptualization of the supply chain. The key decision linkages along the supply chain were then identified in terms of content variables and the resulting model was tested using the structural equation modeling technique. To our knowledge, previous research has not tested the causal linkages along the supply chain. Second, the paper has demonstrated the usefulness of focusing attention on latent variables and their covariance structure. The structural equation modeling technique is well suited to capturing the linkages among the multifarious decisions that are made across the supply chain. Third, this study has developed scales for measuring the constructs that have content validity. The measurement model was shown to be statistically significant, thus providing a foundation for additional research in this area. Fourth, the results show that the conceptual model has statistical validity, providing empirical evidence for the importance of supply chain integration to customer responsiveness and manufacturing performance. Fifth, general methodological and research guidelines for the use of available data sets are provided. Finally, this paper has extended other works based on GMRG (e.g., Wacker, 1994) by developing a conceptual model based on extant literature and testing it using the GMRG database. [Received: May 1, 1996. Accepted: September 11, 1997.]

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APPENDIX

Structural Model

$$\eta = \beta\eta + \Gamma\xi + \zeta,$$

$$\begin{bmatrix} \eta_1 \\ \eta_2 \\ \eta_3 \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 \\ \beta_{21} & 0 & 0 \\ \beta_{31} & 0 & 0 \end{bmatrix} \begin{bmatrix} \eta_1 \\ \eta_2 \\ \eta_3 \end{bmatrix} + \begin{bmatrix} \gamma_{11} & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} \xi_1 \\ 0 \\ 0 \end{bmatrix} + \begin{bmatrix} \zeta_1 \\ \zeta_2 \\ \zeta_3 \end{bmatrix},$$

where

η_1 = Degree of manufacturing goal achievement,
η_2 = Customer responsiveness,
η_3 = Manufacturing performance,
ξ_1 = Sourcing decisions, and
ζ_1 to ζ_3 = Error terms in structural model.

A structural model depicts the postulated direct effects among the concepts or latent variables or "unobservables." The entries in β and Γ are structural coefficients that express the endogenous concepts as linear combinations of all the other concepts.

Measurement Model

$$\mathbf{y} = \Lambda_y \eta + \varepsilon,$$

$$\mathbf{x} = \Lambda_x \xi + \delta,$$

where

y is a (7 x 1) matrix of observed *y* variables
x is a (2 x 1) matrix of observed *x* variables.

A measurement model depicts the links between the conceptual variables (unobservables) to their observed indicators. The values of observed indicator variables (*x*s and *y*s) are thought to arise from the underlying (latent) concepts, so we express the observed *x* and *y* variables as linear combinations of the conceptual variables.

$$\begin{bmatrix} y_1 \\ y_2 \\ y_3 \\ y_4 \\ y_5 \\ y_6 \\ y_7 \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ \lambda_{21} & 0 & 0 \\ \lambda_{31} & 0 & 0 \\ \lambda_{41} & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & \lambda_{63} \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \eta_1 \\ \eta_2 \\ \eta_3 \end{bmatrix} + \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \varepsilon_3 \\ \varepsilon_4 \\ \varepsilon_5 \\ \varepsilon_6 \\ \varepsilon_7 \end{bmatrix},$$

where

ε_1 to ε_7 = Error terms in the measurement model.

$$\begin{bmatrix} x_1 \\ x_2 \end{bmatrix} = \begin{bmatrix} \lambda_{11} \\ 1 \end{bmatrix} [\xi_1] + \begin{bmatrix} \delta_1 \\ \delta_2 \end{bmatrix},$$

where

δ_1, δ_2 = Error terms in the measurement model.

Variance-Covariance Matrices

$$\Phi = \begin{bmatrix} \psi_{11} & 0 & 0 \\ 0 & \psi_{22} & 0 \\ 0 & 0 & \psi_{33} \end{bmatrix}.$$

Covariance matrix of ξ, is $\phi = (\phi_{11})$.
Covariance matrix of ζ is Ψ (3 x 3).

$$\Psi = \begin{bmatrix} \psi_{11} & & \\ \psi_{21} & \psi_{22} & \\ \psi_{31} & \psi_{32} & \psi_{33} \end{bmatrix}.$$

Covariance matrix of ε, is θ_{ε} (7 x 7)

where

$$\theta_{\varepsilon} = \text{diag}(\theta_{11}^{\varepsilon}, \theta_{22}^{\varepsilon}, \ldots, \theta_{77}^{\varepsilon}).$$

Covariance matrix of δ, is θ_{δ} (2 x 2)

where

$$\theta_{\delta} = \text{diag}(\theta_{11}^{\delta}, \theta_{22}^{\delta}).$$

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