

An Empirical Study on The Influence of Environmental Uncertainty on The Information Sharing of Firms- A Supply Chain Perspective

N Vivek ¹ - Dr Sudharani Ravindran ²

This research paper is one of the first attempts to study the supply chain practices of small manufacturing firms. The objective is to find out the impact of environmental uncertainty on the information sharing practices of the firms. The sample frame is small scale manufacturers (firms with less than 100 employees) listed with CODISSIA. A simple random sample of 75 firms is selected from the source list of 792 firms. These firms were administered a structured questionnaire containing pre validated scales to measure the environmental uncertainty and supply chain integration of firms.

After the data was collected, the scales were purified using CITC values and Cronbach's alpha. The resultant purified scales were then tested for convergent validity using PLS path modeling software (Visual PLS). Once the constructs were both reliable and valid, the impact of environmental uncertainty on information sharing was tested using bootstrapping method. The environmental uncertainty was found to have a significant positive impact on the information sharing practices of the firms.

Introduction

Supply chain initiatives over the last decade, while frustrating at times, have proved enormously beneficial to businesses; the most successful innovators viewed the supply chain as a strategic tool for changing the rules of the game (Anderson, J. C. And Narus, J.A.1990). As a result, supply chain management and shareholder value are closely linked, and supply chain management will continue to have a major role in corporate success.

Barratt, M.(2004) defines supply chain as network of facilities and distribution options that performs the functions of procurement of materials, transformation

of these materials into intermediate and finished products, and distribution of these finished products to customers. Balsmeier and Voisin (1996) states that supply chains exist in both service and manufacturing organizations, although the complexity of the chain may vary greatly from industry to industry, and from firm to firm.

In the 1990s, business leaders were inundated with new supply chain initiatives—from just-in-time inventory management to collaborative product commerce (Anderson, J. C. And Narus, J.A.1990). Most of those programs were well conceived, but their complexity and misalignment with corporate operating

1. Lecturer, PSG Institute of Management, PSG College of Technology, Coimbatore

2. Assistant Professor, PSG Institute of Management, PSG College of Technology, Coimbatore

models often produced conflicts, delays, and sub optimal results. Other times, competing or overlapping agendas led to inflated budgets and project terminations, leaving executives exhausted and discouraged.

During the same decade, however, supply chain programs saved thousands of companies billions of dollars. Successful initiatives made it possible for companies to meet customer needs more quickly, less expensively, and through more channels, better-quality, more-reliable goods also reached the market sooner. And for the first time, mass-customized products and services became a reality. (Anderson, J. C. And Narus, J.A. 1990)

Davis (1993) explains that today's ultra competitive world of short product life cycles, complex corporate joint ventures, and stiffening requirements of customers; it becomes necessary to consider the complete scope of supply chain management in the manufacturing sector. He further adds that successful businesses will need better visibility into their supply chains, they must be better at collaborating with suppliers to meet customer demands. Suppliers will be asked to react quickly to changes in the business environment and perform at higher levels than ever before.

Therefore to achieve optimal performance levels, manufacturers and distributors must have applications to help them communicate and collaborate efficiently, across the entire supply chain. Industries like electronics — with fragmented supplier communities and outsourced manufacturing—need supply chain applications that provide better visibility over multi tiered supply chain operations. Right now, this is not being managed efficiently; research firms

estimate that there are trillions of dollars lost to supply chain inefficiencies. (Banfield, E. 1999)

“A supply chain consists of all stages involved, directly or indirectly, in fulfilling a customer request. The supply chain not only includes the manufacturer and suppliers, but also transporters, warehouses, retailers and customers themselves”.

From the above definitions and discussions the supply chain definition given by Chopra *et al*, (2001) gives the good explanation of what a supply chain is, and a definition derived from all the above and closer to the ones of Chopra *et al*, (2001). According to this research defines supply chain as the chain of suppliers, manufacturers, wholesalers, distributors and stores that enable a product to be made, sold and delivered to the end user.

Environmental Uncertainty

Environmental uncertainty means those events and variables that have a random and unpredictable variation, impacting the very existence of a business (Lenz, 1980; Turner, 1993). Today's markets are becoming hyper competitive and include players from all corners of the globe who are increasingly more demanding in their requirements (Thomas and Griffin, 1996), product life cycles are getting compressed and new manufacturing technologies are cropping up (Krause *et al*, 1998). This has resulted in the great outsourcing wave (Krause *et al*, 1998; Ellram, 1990; Fliedner and Vokurka, 1997). Environmental Uncertainty has become the major force impacting the supply chain.

Most of Environmental Uncertainty research is based on the work of Aldrich (1979). Aldrich proposes five sub

dimensions of environmental uncertainty- 1) capacity, 2) homogeneity-heterogeneity, 3) stability- instability, 4) concentration- dispersion, and 5) turbulence. A later work by Achrol and Stern (1988), Paswan et al. (1998) came up with four sub dimensions- diversity (among consumers), dynamism, concentration, and capability. Still later works by Milliken (1987) and Oswald et al. (1997) classified environmental uncertainty into seven sub dimensions- stable-turbulent, simple-complex, predictable-unpredictable, static-dynamic, non-threatening- threatening, exciting-dull, and certain-uncertain

Some researchers classify uncertainty on the basis of the source of the uncertainty. Miller and Droge (1986) have classified uncertainty into the following five sub dimensions - volatility in marketing practices, product obsolescence rate, unpredictability of competitors, unpredictability of demands and tastes, and change in production or service modes. Gupta & Wilemon (1990) proposed four uncertainty factors- 1) increased global competition, 2) continuous development of new technologies that quickly cause existing products to be obsolete, 3) changing customer demand needs and requirements which truncate product life cycles, and 4) increasing need for involvement of external organizations such as suppliers and customers. Ettlle & Reza (1992) and Zhang's (2001) envision uncertainty as unexpected changes in customers, suppliers, competitors, and technology.

Information Sharing refers to the amount of sensitive information that is willingly shared among partners (Monczka et al., 1998). Information is to be shared with both upstream and downstream partners. Free information sharing is

critical if the entire supply chain is to function seamlessly (Towill, 1997; Turner, 1993; Balsmeier and Voisin, 1996). Free information sharing among partners can be a source of competitive advantage for the firm (Novack et al., 1995; Jones, 1998). Partners exchanging information freely tend to work as a single unit cohesively (Stein and Sweat, 1998). The evils of the bull whip effect can be nullified by free information sharing (Yu et al. 2001). The key factor that leads to better performance in the 20th century is information sharing (Tompkins and Ang ,1999). However organizations view information as a sensitive resource and a source of competitive advantage and refuse to share it with anyone. (Vokurka & Lummus, 2000). Organisations feel that competitors will steal their customer orders or perform more effectively if the secrets of the firm are leaked out (Lancioni et al., 2000; Ballou et al. 2000; Croom et al., 2000). Many researchers (Kwan, 1999; Pagel, 1999) have noted that information sharing in the supply chain can play an important role in reducing the inventory level as it allows the companies to quickly respond to market changes thus requiring minimum inventory across the supply chain. He observed that average inventory level had an inverse relationship with the frequency and volume of information sharing. However, besides information sharing there are some other enablers of inventory reduction in a supply chain, e.g. reduction of suppliers base in the supply chain (Pagel, 1999), and reduced order fulfilment time (Mohanty & Deshmukh, 2001). Regarding order fulfillment, Sahay et al (2003) observed that it was the second most important supply chain issues in Indian companies and companies were paying maximum time and attention to improve order fulfillment

Theoretical Framework and Hypothesis

Uncertainty in the environment will affect the ability of a firm to work properly. Constantly changing customer needs, supplier schedules, etc will affect the ability of the firm to schedule and deliver products. To offset any uncertainty, firms must start sharing more information with their trading partners. Only an increased flow of information will make supply chains more transparent. This leads us to the following hypothesis

H1: The higher the environmental uncertainty of a firm, the greater will be the information shared between the firm and its partners.

Data collection methodology and instrument administered

The instrument consisted of two constructs environmental uncertainty and information sharing

The information sharing construct was measured using an already validated instrument developed by Suhong Li (2002). The environmental uncertainty construct was measured using an already validated instrument developed by Aldrich (1979)

A list of manufacturing firms was obtained from Coimbatore District Small Scale Industries Association (CODISSIA). Companies with less than 100 employees were considered. The resultant list contained 792 firms. A random sample of 75 firms was requested to fill in the questionnaire

Analysis Methodology

After the data is collected the scales are analysed to achieve the following objectives-Purification of scales, reliability

of scales, unidimensionality of scales and validity of the scales. Purification is one using Corrected Item Total Correlation (CITC), Reliability is tested using Cronbach's alpha, Validity and unidimensionality are tested using PLS Path modeling.

Before any type of factor analysis is done (EFA or CFA), it is essential to purify the measuring instruments of variables that do not correlate to the constructs (Churchill 1979). Purification is carried out by inspecting the CITC values of each variable with respect to the construct to which it belongs. CITC indicates whether the variable actually belongs to the construct or not. Variables showing scores lower than 0.5 are deleted, unless there is a compelling reason to keep them in the construct. Some items with CITC values over 0.5 can also be removed if the overall reliability of the construct in question improves as a result of the deletion (Obtained by checking the "alpha if deleted" scores).

Reliability of constructs refers to the accuracy with which the constructs repeatedly measure the same phenomenon without much variation. The reliability of each construct in question was examined using Cronbach's alpha (Cronbach, 1951). An alpha score larger than 0.7 is generally acceptable as sufficient accuracy for a construct (Nunnally 1978). After purifying the constructs one by one, we arrive at purified scales for the constructs. Each construct should display sufficient reliability before being used in a structural equation model.

Unidimensionality is a common trait exhibited by all the indicator variables of any given construct (McDonald, 1981; Hattie, 1985). Unidimensionality is best

measured by Confirmatory Factor Analysis (CFA). A combination of CFA and path analysis is Structural Equation Modelling. This is the best method of measuring the unidimensionality of any construct. In this research we will use structural equation modeling to test the unidimensionality of the constructs. There are two approaches to structural equation modeling- Covariance methods and PLS path modeling. Covariance methods make rigid assumptions about the distribution of variables (multivariate normality) and the sample size (at least 200). Another criterion is the degrees of freedom, which means that each construct should have at least three indicators for it to be identified. This makes them unsuitable to use in this research. PLS methods on the other hand are non parametric in nature. They do not make any assumptions about the distribution of the data and the sample size needed is much smaller for model validation and testing (five to ten times the largest number of indicators/construct in the model). The convergent validity of each construct is checked by examining the "Average variance extracted (AVE)" values. Constructs which have AVE values greater than 0.5 are said to have convergent validity or unidimensionality. In some cases values upto 0.4 are also considered if they are central to the model (Chin W W 1995, Chin et al 2003, Chin W W 1998, Chin et al 1999)

The following section will present the large scale validation results on each of the constructs- environmental uncertainty and information sharing. For each construct the instrument assessment methodology described above has been applied.

Measurement results

Environmental Uncertainty

The environmental uncertainty construct was initially represented by 18 variable indicators. The analysis began with purification using CITC values. The CITC values corresponding to each variable are shown in table 1. At the end of the purification process 11 variables are left. All except one variable have CITC values greater than 0.5. The resulting reliability of the dimension is 0.9313. The indicator variables left out are unpredictable customer needs, changing customer product preferences, unpredictable supplier engineering level, unpredictable supplier product quality, competition from different industries and competition from different countries. Unpredictable customer needs and changing customer preferences seem to be out of the final list because the number of products produced by the manufacturers is very few in number. Unpredictable supplier engineering level seems to be out because the suppliers to these companies are supplying low tech products to these companies and do not need high degree of technology. Unpredictable supplier quality seems to be out because the quality supplied may be adequate for the industries. Competition from other industries seems to be out because these are niche players. Competition from foreign players seems to be out because the scale of operation of these companies does not warrant international competition. The unidimensionality of the construct is tested in VisualPLS by considering the AVE value. The results are tabulated in table 5. The AVE value of 0.659158 (shown in table.5) shows a good convergent validity and hence unidimensionality for the construct.

Table 1 Environmental Uncertainty Purification

	CITC	
	1	2
Customers' needs are unpredictable	0.3839	
Customers' requirements regarding product features are difficult to forecast	0.9027	0.8886
Customers order different product combinations over the year	0.166	
Customers' product preferences change over the year	0.3935	
The properties of materials from suppliers can vary greatly within the same batch	0.6365	0.6948
Suppliers' engineering level is unpredictable	-0.4818	
Suppliers' product quality is unpredictable	-0.9596	
Suppliers' delivery time can easily go wrong	0.942	0.9635
Suppliers' delivery quantity can easily go wrong	0.7984	0.8018
Competitors' actions are unpredictable	0.7577	0.821
Competition is intensified in our industry	0.5761	0.6055
Competitors are from different industries	0.14	
Competitors are from different countries	0.3075	
Competitors often introduce new product unexpectedly	0.5196	0.4985
Technology is changing significantly in our industry	0.6542	0.6944
Technological changes provide opportunities for enhancing competitive advantage in our industry	0.916	0.9655
Technological breakthrough results in many new product ideas in our industry	0.6438	0.6488
Improving technology generates new products frequently in our industry	0.5413	0.5724
Cronbach's alpha	0.8012	0.9313

Table 2 Environmental Uncertainty Final Measurement Scale

Customers' requirements regarding product features are difficult to forecast	ALPHA=0.9313
The properties of materials from suppliers can vary greatly within the same batch Suppliers' delivery time can easily go wrong	
Suppliers' delivery quantity can easily go wrong	
Competitors' actions are unpredictable	
Competition is intensified in our industry	
Competitors often introduce new product unexpectedly	
Technology is changing significantly in our industry	
Technological changes provide opportunities for enhancing competitive advantage in our industry	
Technological breakthrough results in many new product ideas in our industry	
Improving technology generates new products frequently in our industry	

Information sharing construct was purified by observing the CITC values (shown in table 3). The sub-construct was left with three indicators at the end of the purification process. Indicators measuring proprietary information transferred to partners was eliminated from the construct. This could be because the concept of small firms do not have too much of proprietary knowledge to share with their partners. The reliability of the sub-construct was 0.7982, which was adequate for the analysis. The unidimensionality was tested using Visual PLS. The AVE value of 0.7133 (shown in table 5) indicates good convergent validity and hence unidimensionality for the sub-construct.

Table 3 Information Sharing Purification

	CITC 1	CITC 2
Our trading partners		
are informed in advance of our changing needs	0.6911	0.6911
share proprietary information with us	0.778	0.778
share business knowledge of core business processes with us.	0.4839	0.4839
receive proprietary information from us	0	
Cronbach's alpha	0.7095	0.7982

Table 4 Information Sharing Final Measurement Scale

Our trading partners	ALPHA=0.7982
are informed in advance of our changing needs	
share proprietary information with us	
share business knowledge of core business processes with us.	

Table 5 Validity of constructs (AVE scores)

Construct	AVE
Environmental uncertainty	0.662263
Information sharing	0.706527

Causal Model and Hypothesis Test

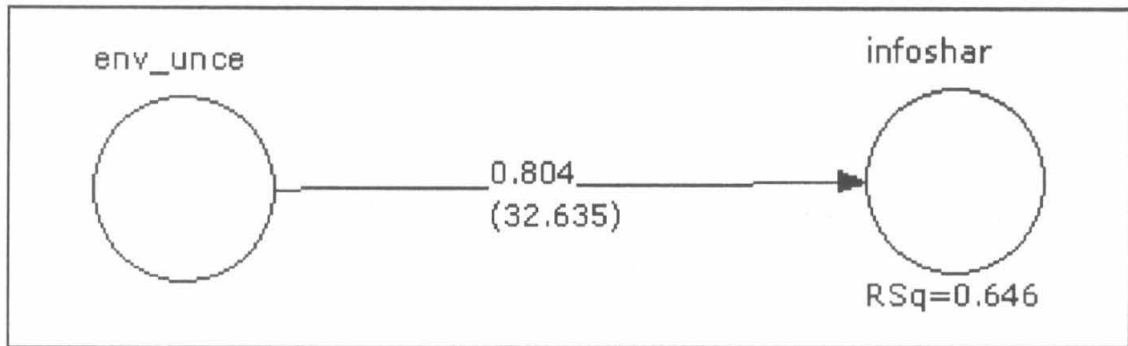
A causal effect of environmental uncertainty on the information sharing of the firms is tested using Visual PLS path modeling software. A rigorous test of the significance of various proposed relations can be tested using the bootstrap function in Visual PLS. PLS path modeling is a non parametric method, and as such cannot be used for performing a t-test. But it is possible to use resampling methods (bootstrap and jack knife) to obtain the significance of the various paths in the model. Bootstrap is more reliable in estimating the significance of paths (Chin W W, 1995). So this research has considered and used bootstrap for the purpose of determining causal relations proposed in the model. In boot strap used in this research, random samples sized 75 (the respondent number) were taken, and 500 such samples were taken (to get best estimates a resample number of 500 is

recommended although in theory an infinite resample is needed for the purpose). The Results were examined for significance. At 5% level of significance the cutoff t-statistic is 1.96. In general we assume that if the t-statistic is more than 2, the path is significant.

H1: The higher the environmental uncertainty of a firm, the greater will be the information shared between the firm and its partners

The hypothesis was found to be highly significant (beta= 0.805, t= 32.635). This proves our presumption that the environmental uncertainty of a firm has an impact on the supply chain integration of the firm. A high R Sq value of 0.646 indicates that environmental uncertainty has a high negative impact on the supply chain integration of the firm.

Model Tested



Implications and Summary

This research paper has identified and tested the reliability and validity of two constructs—environmental uncertainty and information sharing. It has also tested the impact of environmental uncertainty on the information shared by small manufacturing firms. The environmental uncertainty was found to have a significant positive impact on the information shared by the firm with its trading partners as proposed.

This means that as the environment throws challenges, firms become more forthcoming with information to reduce the impact of uncertain conditions. This also means that, to survive in uncertain conditions, firms should start sharing more information with their partners and stake holders.

Keywords Used

Average variance extracted
Bootstrap
CODISSIA
Construct Validity

Construct Reliability
Corrected Item total correlation (CITC)
Cronbach's alpha
Indicators
Information Quality
Just in time
Logistics practices
PLS Path modeling
Purified scale
Supply chain integration
Unidimensionality
Visual PLS

References

- Achrol, R. S. and Stern, L. W. (1988), "Environmental Determinants of Decision-Making Uncertainty in Marketing Channels", *Journal of Market Research*, 25(1), pp.36-50
- Aldrich, H. E. (1979), *Organizations and Environments*, Prentice-Hall, Inc., Englewood Cliffs, NJ
- Anderson, J. C. And Narus, J.A. 1990. A Model of Distributor Firm and Manufacturing Firm Working Partnership. *Journal of Marketing*, 54(1), pp.42-58

- Ballou, R. H., Gillbert, S. M. and Mukherjee, A. (2000), "New Managerial Challenge from Supply Chain Opportunities", *Industrial Marketing Management*, 29, pp.7-18
- Balsmeier, P. W. and Voisin, W. (1996), "Supply Chain Management: a Time-Based Strategy", *Industrial Management*, 38(5), pp. 24-27
- Banfield, E. (1999), "Harnessing Value in the Supply Chain", John Wiley and Sons, New York, NY
- Chin, W. W. (1998). The partial least squares approach for structural equation modelling. In George A. Marcoulides (Ed.), *Modern Methods for Business Research*, Lawrence Erlbaum Associates
- Chin, W. W., and Newsted, P. R. (1999). Structural Equation Modeling analysis with Small Samples Using Partial Least Squares. In Rick Hoyle (Ed.), *Statistical Strategies for Small Sample Research*, Sage Publications.
- Chin, W. W. (1995). Partial Least Squares Is To LISREL As Principal Components Analysis Is To Common Factor Analysis. *Technology Studies. Technology Studies*, volume 2, issue 2, 315-319
- Chin, Wynne W. and Marcolin, Barbara L. and Newsted, Peter R., 2003, "A Partial Least Squares Latent Variable Modeling Approach for Measuring Interaction Effects. Results from a Monte Carlo Simulation Study and an Electronic-Mail Emotion / Adopion Study", *Information Systems Research*, volume 14, number 2, June. p 189-217
- Chopra, S. And Meindl, P. 2001. *Supply Chain Management: Strategy, Planning and Operations*, Upper Saddle River, NJ: Prentice-Hall, Inc
- Churchill, G. A. (1979), "A Paradigm for Developing Better Measures of Marketing Constructs", *Journal of Marketing Studies*, Vol.16, pp.12-27.
- Cronbach, L. J. (1951), "Coefficient Alpha and Internal Structure of Tests", *Psychometrika*, 16, pp.297-334
- Croom, S., Romano, P., and Giannakis, M (2000), "Supply Chain Management: an Analytical Framework for Critical Literature Review", *European Journal of Purchasing and Supply Management*, 6, pp. 67-83
- Davis, T. (1993), "Effective Supply Chain Management", *Sloan Management Review*, 34(4), pp.35-46
- Ellram, L. M. (1990), "The Supplier Selection Decision in Strategic Partnerships", *Journal of Purchasing and Materials and Management*, Fall, pp.8-14
- Ettl, J. E. and Reza, E. M. (1992), "Organizational Integration and Process Innovation", *Academy of Management Journal*, 35(4), pp.795-827
- Fliedner, G. and Vokurka, R. J. (1997), "Agility: Competitive Weapon of the 1990's and Beyond", *Production and Inventory Management Journal*, 38(3), pp.19-24

- Gupta, A. K. and Wilemon, D. L. (1990), "Accelerating the Development of Technology-based New Products", *California Management Review*, 32(2), pp.24-44
- Hattie, J. (1985), "Methodology Review: Assessing Unidimensionality of Tests and Items", *Applied Psychological Measurement*, 9, pp.139-164
- Jones, C. (1998), "Moving beyond ERP: Making the Missing Link", *Logistics Focus*, 6(7), pp.2-7
- Krause, D. R., Handfield R. B., Scannel, T. V. (1998), "An Empirical Investigation of Supplier Development: Reactive and Strategic Processes", *Journal of Operations Management*, 17(1), pp.39-58
- Kwan, A. T. W. (1999). The use of information technology to enhance supply chain management in the electronics and chemical industries. *Production and Inventory Management Journal*, (Third quarter): pp.7-15
- Lancioni, R. A., Smith, M. F. and Oliva, T. A., (2000), "The Role of the Internet in Supply Chain Management", *Industrial Marketing Management*, 29, pp.45-56
- Lenz, R. T. (1980), "Environment, Strategy, Organization Structure and Performance: Patterns in One Industry", *Strategic Management Journal*, 1(3), pp.209-226
- Li, Suhong, 2002, An Integrated Model for Supply Chain Management Practice, Performance and Competitive Advantage, Doctoral Dissertation, University of Toledo, Toledo, OH
- McDonald, R. P. (1981), "The Dimensionality of Tests and Items", *British Journal of Mathematical and Statistical Psychology*, 34, pp.100-117
- Miller, D. and Droge, C. (1986), "Psychological and Traditional Determinants of Structure", *Administrative Science Quarterly*, 31(4), pp.539-560
- Milliken, F. J. (1987), "Three Types of Perceived Uncertainty about the Environment: State, Effect, and Response Uncertainty", *Academy of Management Review*, 12, pp.133-143
- Mohanty, R. P. And Deshmukh, S. G. 2001. Essentials of supply chain management. New Delhi: Phoenix Publishing House Private Limited
- Monczka, R. M., Petersen, K. J., Handfield, R. B., and Ragatz, G. L. (1998), "Success Factors in Strategic Supplier Alliances: the Buying Company Perspective", *Decision Science*, 29(3), pp.5553-577
- Nunnally, J. C. (1978), *Psychometric Theory*, McCraw-Hill, New York, NY
- Novack, R. A., Langley, C. J. Jr, and Rinehart, L. M. (1995), "Creating Logistics Value: Themes for the Future", Oak Brook, IL: Council of Logistics Management.
- Oswald, S. L., Mossholder, K. W., and Harris, S. G. (1997), "Relations

- Between Strategic Involvement and Manager's Perceptions of Environment and Competitive Advantage Strengths", *Group and Organization Management*, 22(3), pp.343-365
- Pagel, D. 1999. Managing for optimal performance through effective coordination of the supply chain. *Production and Inventory Management Journal*, (First quarter): pp.66-70
 - Paswan, A. K., Dant, R. P. and Lumpkin, J. R. (1998), "An Empirical Investigation of the Linkage among Relationalism, Environmental Uncertainty, and Bureaucratization", *Journal of Business Research*, 43(3), pp.125-140
 - Sahay B.S., Ramneesh Mohan. 2003. Supply Chain Management Practices in India. *International Journal of Physical Distribution and Logistics Management*, 33(7), pp. 583-606
 - Stein, T. and Sweat, J. (1998), "Killer Supply Chains", *Informationweek*, 708 (9), pp.36-46
 - Tan, K. C., Kannan, V. R. and Handfield, R. B. (1998), "Supply Chain Management: Supplier Performance and Firm Performance", *International Journal of Purchasing and Materials Management*, 34(3), pp.2-9
 - Thomas, D. and Griffin, P. M. (1996), "Coordinated Supply Chain Management", *European Journal of Operational Research*, 94(1), pp.1-15
 - Tompkins, J. and Ang, D. (1999), "What are Your Greatest Challenges Related to Supply Chain Performance Measurement?", *IIE Solutions*, 31(6), pp. 66
 - Towill, D. R. (1997), "The Seamless Chain- the Predator's Strategic Advantage", *International Journal of Technology Management*, 13(1), pp 37-56
 - Turner, J. R., (1993) "Integrated Supply Chain Management: What's Wrong with This Picture", *Industrial Engineering*, 25(12), pp. 52-55
 - Vokurka, R. J. and Lummus, R. R. (2000), "The Role of Just-in-Time in Supply Chain Management", *International Journal of Logistics Management*, 11(1), pp.89-98
 - Yu, Z.X., Yan, H. and Cheng, T. C. E. (2001), "Benefits of Information Sharing with Supply Chain Partnerships", *Industrial Management and Data Systems*, 101(3), pp.114-119
 - Zhang, Q. Y. (2001), *Technology Infusion Enabled Value Chain Flexibility: a Learning and Capability-Based Perspective*, Doctoral Dissertation, University of Toledo, Toledo, OH.