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IDENTIFICATION OF MEASUREMENT ITEMS OF DESIGN REQUIREMENTS FOR LEAN AND AGILE SUPPLY CHAIN-CONFIRMATORY FACTOR ANALYSIS

Abstract: *This study examines the consistency approaches by confirmatory factor analysis that determines the construct validity, convergent validity, construct reliability and internal consistency of the items of strategic design requirements. The design requirements includes use of information technology, sourcing procedures, new product development, flexible manufacturing functions and demand management supply chain net work design, management, commitment and inventory management policies among manufacturers of volatile and unforeseeable products in Andhra Pradesh, India. This study suggested that the seven factor model with 20 items of the leagile supply chain design requirements had a good fit. Further, the study showed a valid and reliable measurement to identify critical items among the design requirements of leagile supply chains.*

Keywords: *leagile supply chain, confirmatory factor analysis, sourcing, product development*

1. Introduction

Companies seeking to survive in the business world need to identify new competitive advantages to distinguish them from the competitors. With the onset of globalization, the competition has increased, demanding more efforts from the companies. The ability to meet the customer demands for time, variety, quality and price, has been the biggest challenge for companies. Achieving world-class performance levels requires continuous attention and efforts to ensure the survival of business in moments when demand fluctuates. The paradigm involving lean and agile creates a virtually brand new management framework named as leagile. The leagile framework allows firms and networks to shape an appropriate profile to face successfully the volatility of markets and fight to gain competitive advantages.

Christopher (2005) defines supply chain as the set composed by a particular leader company and all the other companies with whom they interact, directly or indirectly, through its suppliers and customers, upstream and downstream, that is, from the point of origin of the basic materials and/or services, to the point of effective consumption of the products and/or services. According to Moura *et al*. (2008), a supply chain can be defined as a set of organizations that maintain relations with each other from the beginning to the end of the logistic chain, creating value in the form of products and

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services from the suppliers to the final consumer.

Lean manufacturing represents a collection of practices that "work together synergistically to create a streamlined, high-quality system that produces finished products" (Shah and Ward, 2003)**,** a lean supply chain attempts to streamline the whole chain in a similar manner. Improving the efficiency of a supply chain depends, directly, on the demand, and requires the reduction of uncertainty within the supply chains to improve its predictability (Rudnicki, 2001). The ability to achieve this level has been called the agile supply chain (White *et al*., 2005).

The term leagile is a combination of "lean" and "agile" and can be united for optimizing the management of the supply chain (Bruce *et al*., 2004; Kundu and Manohar, 2012). A supply chain is sensitive to the market and it is ready to respond to real demand (Christopher and Towill, 2000). The typical logistics goals of a leagile supply chain include short response, feasible deadlines, ability to change the volume and the mix of production, among others (Christiansen *et al*., 2007).

Narasimhan and Jayaram (1998), conducted exploratory factor analysis for each construct to ensure the unidimensionality of the scales in respect of supply chain management practices. The indicator items are deleted if they are loaded on more than two factors or their factor loadings are smaller than 0.5. Craig and Jennings (2000) examined the factors that drive purchasing social responsibility (PSR), barriers to PSR, ways of overcoming those barriers, and outcomes of PSR through CFA. Tracey and Tan (2001) employed Confirmatory Factor Analysis (CFA) and path analysis to examine empirically the relationships among supplier selection criteria (quality, delivery reliability, product performance and unit price). Handfield and Bechtel (2002), suggested that buyer-dependence, supplier human asset investments, and trust are all positively associated with improved supply chain responsiveness, defined in their study as the supplier's ability to quickly respond to the buying party's needs by conducting confirmatory factor analysis. Ngai *et al*., (2004) conducted an empirical study using an exploratory factor analysis of the survey data and revealed five major dimensions of the critical success factors for web based supply chain management system implementation. Chen *et al*. (2006) developed three constructs of e - Supply chain capability (procurement, make and delivery) and tests the relationships between e-Supply chain capability, competitive advantage, and organizational performance. Hallgren and Olhager (2009) proposed the model that incorporates a wide perspective on factors related to lean and agile manufacturing, to be able to identify similarities and differences. Bozarth *et al*. (2009) presented a conceptual model that formally states the relationship between supply chain complexity (Downstream complexity, internal manufacturing complexity and upstream complexity) and plant performance through multiple regression modeling. Mashayekhi *et al*. (2011) conducted the study using factor analysis, inner effective factors (enablers) and agile capability factors were identified and clarified to some extent through confirmatory factor analysis method so that these factors agreed with literature and researchers experiences. Agus (2011) investigated relationship between SCM, supply chain flexibility and business performance and these associations are analyzed through statistical methods such as Pearson's correlation and structural equation modeling (SEM). Whitten *et al*. (2012) developed scales based on descriptive items listed by Lee for the Triple-A supply chain strategy dimensions of agility, adaptability, and alignment and assess the complete model using a structural equation methodology. The overall result suggests that supply chain management has significant correlations with supply chain

flexibility and business performance. Ezutah (2011) made a study involves statistical tests using 16 measures and 72 corresponding metrics. These statistical tests include exploratory factor analysis to investigate the construct validity of the measures and their metrics, a confirmatory factor analysis to test the model fitness and a multiple regression analysis to test the criterion validity of the measures in respect of Green Supply Chain Performance Measures in the Automotive Industry.

Leagile supply chain management has emerged as a proactive approach for improving performance of business processes and products in accordance with the requirements of the customer. Various approaches for implementing leagile supply chain management practices has been proposed and recognized in previous literatures, yet little investigation has identified the reliability and validity of such approaches particularly in manufacturers of volatile and unforeseeable products. This study examines the consistency approaches by confirmatory factor analysis that determines the adoption and implementation of items for leagile supply chain management.

2. The conceptual model

The proposed model is based on seven main constructs- (i) product development (PD); (ii) sourcing (SOU), (iii) Manufacturing (MFG), (iv) Demand management (DM) (v) Information Technology (IT) (vi) Supply chain Network Design (SCN) (vii) Inventory Management (INV). In this study, in order to determine the domain that encompasses SCM dimensions for lean and agile, exhaustive theoretical, empirical and practitioner literature were reviewed (Agus, 2011; Vipul Chalotra, 2012; Romana Kohlberger, 2012). Incorporating ideas, theories and studies from literature, the above constructs operationalised by its indicators are explained below.

Product Development (PD): Due to short period of product life cycle new product introduction to market as an appropriate and successful strategy. Hybrid products tend to have a long product life cycle with a certain degree of improvement or innovation offered periodically. A product design strategy that shifts product differentiation closer to the consumer by postponing identity changes, such as assembly or packaging. The indicators of the constructs are Involving suppliers in product development stage, Involving customers in product development stage and Application of computer technology in product design (e.g. CAD, CAE, CAPP).

Sourcing (SOU): The superior criteria for selection should be: speed, flexibility, price and quality. There should be minimum and reliable suppliers. Just in time (JIT) supply processes ensure that certain parts of the product arrive on the assembly line just in time to be fitted to the particular product. The indicators of the constructs are sourcing strategy, Multi-criteria supplier selection, supplier integration and development.

Manufacturing (MFG): Flexible manufacturing concept may be adopted. Flexible manufacturing strategies are incorporated by a business to make a factory capable of producing multiple products/models. The strategy makes use of manufacturing tactics that can work to increase a company's bottom line profits by reducing overhead costs. The indicators of the constructs are Production type & control, production system, product structure etc.

Demand Management (DM): The customer's demand is uncertain; products design may also need to be reconsidered several times. When there is an unpredictable demand leagile supply chain is best suitable by deciding the decoupling point. The indicators of the constructs are Demand planning, planning intensity, capacity planning etc.

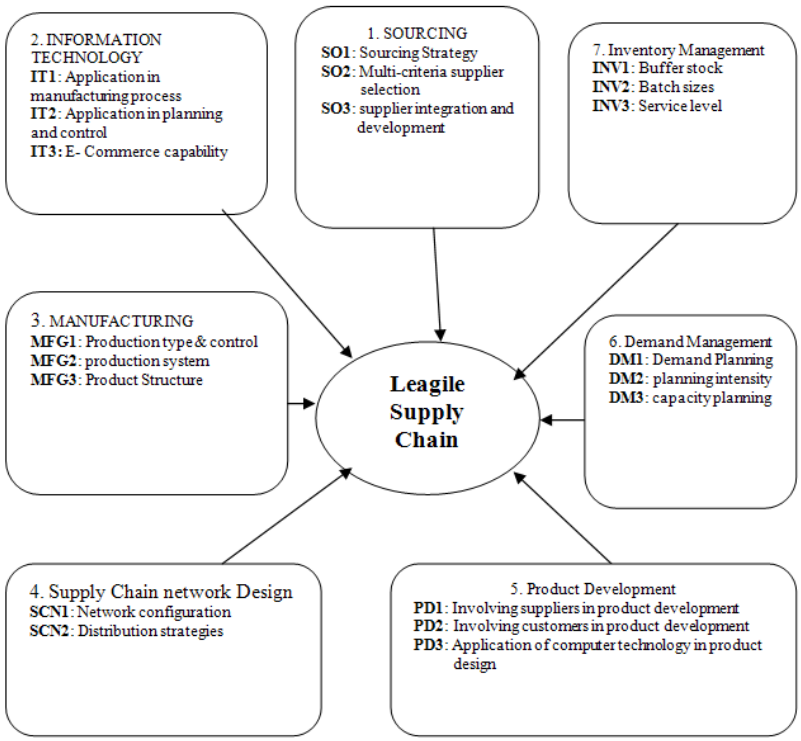

Figure 1. The Conceptual Frame work

Information Technology (IT): IT has greatest influence on lead time, quality and service level. Information technology applied to logistics inbound and outbound increases the speed of the information, providing faster and more accurate data for decision making. Delivery / service on time and communication system for customer service qualify the chain as order winner. The information technology applied to the production justifies the use of lean tools in a productive environment, making the material and the information itself to flow faster. The indicators of the constructs are Application of computer/information technology in manufacturing process, Application of computer/information technology in manufacturing planning and control, E-Commerce capability.

Supply Chain Network Design (SCN): The considered strategy is based on the both principles of Lean and agility, beside push and pull of materials. Here, the tradeoff between positioning of decoupling point throughout an exemplary network, and reduction of inventory level along throughput time is possible. In order to achieve leagile supply chain, the upstream of the decoupling point should be designed to be lean while downstream should be agile. Customers expect quality service defined as reliable product deliveries of the right amount, at the right time with no damage to product and at a low cost. The company, however, must balance customer satisfaction with the need for profitability. Supply chain network design in upstream side should be based on minimizing cost and maximizing quality where as Supply chain network design in downstream side should be based on maximizing service level and minimizing lead time. The indicators of the constructs are: Network configuration and Distribution strategies.

Inventory Management (INV): Customer service, as measured by order-to-ship time, will be best in the lean system. This hypothesis should hold true as long as sufficient quantities of the right inventory are on hand at the appropriate stock keeping locations. If backorders exist in the lean system, considerable time may be required to acquire supplies and realign production priorities. Enterprise-wide inventory will be lowest in the agile system. In lean & agile supply chain network Vendor Managed Inventory (VMI) played a vital role. The indicators of the constructs are: Buffer stock, Batch sizes and Service level.

The hypotheses regarding strategic design requirements of leagile supply chain are presented in the study's research questions are given below.

Hypotheses

Research Question: What are the Dimensions of strategic design requirements of leagile supply chain?

The results from our literature review the following hypotheses are introduced.

Ha:Issues relating to the Product Development (PD) constitute dimension of strategic design requirements of leagile supply chain.

Hb:Issues relating to the Sourcing (SOU) constitute dimension of strategic design requirements of leagile supply chain.

Hc:Issues relating to the Manufacturing (MFG) constitute dimension of strategic design requirements of leagile supply chain.

Hd:Issues relating to the Demand Management (DM) constitute dimension of strategic design requirements of leagile supply chain.

He:Issues relating to the Information Technology (IT) constitute dimension of strategic design requirements of leagile supply chain.

Hf:Issues relating to the Supply Chain Network Design (SCN) constitute dimension of strategic design requirements of leagile supply chain.

Hg:Issues relating to the Inventory Management (INV) constitute dimension of strategic design requirements of leagile supply chain.

3. Confirmatory factor analysis

CFA requires the specification of a factor model, including the number of factors and the pattern of zero and nonzero loadings on those factors. A small number of theory-driven competing models might be specified as well. CFA provides information on how well the hypothesized model explains the relations among the variables. CFA has the advantages of allowing hypothesis testing on the data. The confirmatory factor analysis was done using LISREL 8.52. The measurement model fit with the data was checked with model chi-square goodness-of-fit, and approximate fit indexes. Insignificant model chi-square goodness-of-fit (set at 0.05) signifies model fit. For approximate fit indexes, Goodness of Fit Index (GFI), Adjusted Goodness of Fit Index (AGFI), Normed fit index (NFI), Relative fit index (RFI), Incremental fit index (IFI), Tucker-Lewis fit index (TFI) and Comparative fit index (CFI) of above 0.9 would indicate model fit . For another Approximate fit index, Root mean square error of approximation (RMSEA), a value less than 0.08 Root Mean Squared Residual (RMR) value less than 0.05 would signify reasonable model fit. Significance of standardized regression weight (standardized loading factor) estimates signifies that the indicator variables are significant and representative of their latent variable.

4. Results and analysis

Survey Questionnaire

Survey questionnaire is developed from an extensive literature review which examined a number of streams of research, including lean and agile supply chains, supply chain

strategies, design requirements for various supply chains, confirmatory factory analysis. Twenty questions on the constructs such as (i) product development (PD); (ii) sourcing (SOU), (iii) Manufacturing (MFG), (iv) Demand management (DM) (v) Information Technology (IT) (vi) Supply chain Network Design (SCN) (vii) Inventory Management (INV) are developed. The survey was sent to the medium and small organizations of Andhra Pradesh. The survey was addressed to personnel involving purchasing, production, marketing & sales, logistic providers with mailing and personal contacts. A total of **259** out of 3**00** usable surveys were received. Another **20** surveys were returned and were not applicable because the respondent was no longer with the company. This resulted in an effective response rate of 86.3 percent.

Descriptive Statistics

A summary of the demographic characteristics of the sample is presented in Table 1.

Table 1. A summary of the demographic characteristics

Feature	Category	Frequency	Percentage
Business function	Production	75	29
	Purchasing	62	24
	Sales & Distribution	122	47
Type of Industry	Apparel	18	42.85
	Automotive	10	23.81
	electronics	14	33.34
Size of the Firm	<50	10	23.81
	50-100	18	42.85
	100-200	14	33.34
Customer Type	Retailer	09	21.43
	Bulk Manufacturer	10	23.81
	Distributor	15	35.71
	Customer direct	08	19.05
Experience of Employees	< 2 years	85	32.82
	3-5 Years	67	25.87
	>5 years	107	41.31

Of the 259 responses received from three types of medium and small scale industries, namely (i) apparel manufacturing (ii) automotive spare parts and (iii) electronic components indicates that their interest in leagile supply chains. Responses indicate that people from important business are involved. Customer types namely Retailer, Bulk Manufacturer, Distributor and Customer direct are involved in the study. Approximately 77% had more than three years of working experience. This highlights the importance of working experience in the implementation of leagile supply chain management systems.

Analysis of Reliability and Validity

The study tested the measurement properties of the constructs by confirmatory factor analysis. CFA was used to evaluate how well the measurement items reflect latent variables in the hypothesized structure, due to the fact that this study is based on the theoretical basis from the previous research.

Table 2. Reliability and validity analytical results of measurement model

Latent Variable	Item	Standardized Factor Loadings	SMC	Composite Reliability (C R)	AVE
Product Development (PD)	PD1	0.73	0.47	0.75	0.5
	PD2	0.68	0.53		
	PD3	0.71	0.50		
Sourcing (SOU)	SOU1	0.60	0.64	0.77	0.54
	SOU2	0.72	0.48		
	SOU3	0.86	0.26		
Manufacturing (MFG)	MFG1	0.83	0.31	0.89	0.74
	MFG2	0.88	0.22		
	MFG3	0.86	0.27		
Demand Management (DM)	DM1	0.86	0.26	0.90	0.74
	DM2	0.88	0.22		
	DM3	0.85	0.28		
Information Technology (IT)	IT1	0.75	0.44	0.85	0.65
	IT2	0.81	0.34		
	IT3	0.86	0.26		
Supply Chain Network Design SCN)	SCN1	0.86	0.34	0.80	0.69
	SCN2	0.80	0.35		
Inventory Management (INV)	INV1	0.82	0.21	0.89	0.72
	INV2	0.89	0.32		
	INV3	0.84	0.30		

Average Variance Extracted of each latent variable was more than 0.7 which showed that latent variables had reliability and convergence validity. The data of Average Variance Extracted (AVE) of Squared Multiple Correlation (SMC), Construct Reliability (CR) and latent variables are presented in Table 3. The above overall propriety test of measurement model and reliability and validity analytical results showed that 20 questions of Leagile Supply chain capability in this research could actually efficiently measure the design requirements of leagile supply chain.The fit indices of the structure model of confirmatory factor analysis are shown in table 4. The value of χ^2/d.f is 3.9 indicates the close fit of the model (Carter and Wu, 2010). As to the propriety of model, GFI value was 0.82, AGFI was 0.74, CFI was 0.98 indicates the moderately close fit. Therefore, there were enough evidences to accept all the propositions (Ha, Hb….Hg) were supported.

It is an established fact that root mean square error of approximation (RMSEA) and standardized root mean square residual (SRMR) are also measures for model fitness. SRMR values less than 0.08 and RMSEA values less than 0.06 imply very good

models (Brown, 2006; Hu and Bentler, 1999). The values of RMSEA (0.106) and SRMR (0.047) obtained in the study indicates the satisfactory fitness of the model. Therefore, generally speaking, the measurement model of this Leagile Supply chain suggesting a reasonably acceptable fit to the data.

Table 3. Fit indices of structure model

	Propriety Indicators	**Research Findings**
Absolute Propriety Indicators	χ^2/d.f	**3.9**
	GFI	**0.82**
	AGFI	**0.74**
	SRMR	**0.047**
	RMSEA	**0.106**
Relative Propriety Indicators	NNFI	**0.97**
	NFI	**0.97**
	CFI	**0.98**

5. Conclusion

The path loadings of items of Product Development, sourcing, Manufacturing, Demand management, Information Technology, Supply chain Network Design and Inventory Management are above 0.7 and are significant for design requirements of leagile supply chain suggesting that these areas are dimensions of above constructs. Hence, this study suggested that the seven factor model with 20 items of design requirements of leagile supply chain had a good fit. It is a valid and reliability measurement to identify items of design requirements of leagile supply chain. The present findings provide evidence to support that this is a valid instrument to determine strategic design requirements among the organizations implementing lean and agile supply chains. This study can be extended to identify sensitivity of the factors and their relative weights basing on the dimensions of the respective constructs.

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