Measuring the degree of leanness in logistics service providers

Overboom, M.A.; de Haan, J.A.C.; Naus, A.J.A.M.

Published in:
Proceedings of the 17th International Annual EurOMA Conference

Publication date:
2010

Document Version
Peer reviewed version

Measuring the degree of leanness in logistics service providers: development of a measurement tool

Mark Overboom (m.a.overboom@uvt.nl)
Tilburg University

Fons Naus
Tilburg University

Job de Haan
Tilburg University

Abstract

Logistic service providers and their customers benefit from leanness, but how lean are they? We adapted the lean measurement instrument developed by Shah and Ward (2007) to make it suitable for a logistic service environment. We removed some items, and added new ones on the basis of the triadic nature of relationships between LSPs, outsourcers, and their clients, and on the basis of the content of processes. The modified instrument was tested with two LSPs that claimed to apply the lean philosophy in their processes, and demonstrated a valid measurement of leanness of LSPs.

Keywords: Lean, Logistics, Measurement

Introduction

Lean production has been developed in the automotive industry in Japan (MacDuffie and Pil, 1996) and has come to be applied in various manufacturing industries. Nowadays also the service industry has started to show interest in lean management practices (Landsbergis, Cahill and Schnall, 1999 in Parker, 2003). More specifically in the field of logistics companies are trying to upgrade their operations using lean management practices (Disney, Naim and Towill 1997; Jones, Hines and Rich, 1997; Wu, 2003, De Haan et al., 2009). However, it is unclear to what extent logistics has become lean. Over the years a large number of definitions, tools, and practices somehow related to the idea of lean were introduced. Shah and Ward (2007) were the first to develop an instrument measuring the degree of leanness. Their instrument was developed for the manufacturing environment, but could this be used for logistics as well?

A prevailing trend in logistics is that manufacturers outsource warehousing functions to logistics service providers (LSPs) in order to focus more on their core businesses (Lee and Elsayed, 2005). LSPs can perform tasks ranging from traditional logistics activities (such as storing, transporting, warehousing, and packaging) to less-conventional activities (such as customs clearance, billing, and tracking and tracing) (Chen, 2007). However, due to global competition companies are forced to improve their logistics service level while keeping costs at a minimum (Chen 2007). As a result, many manufacturers and retailers are seeking to outsource their logistics activities to

logistics service providers, since they are more capable to bring the company's products and services to the market rapidly and efficiently (Chen, 2007). Implementing lean management practices is often seen as a good way to achieve this. This raises the question what lean practices can be used in LSPs and, how the level of leanness of LSPs can be measured?

To answer these questions a three-step approach has been applied. First a literature review was carried out to identify the character(s) of lean and its measurements as well as the content of the services the LSPs offer to shippers in the triad with receivers (Bask, 2001). Then the results of these reviews were combined to adapt the questionnaire Shah and Ward developed to reflect the character of services instead of production.

Finally, to revalidate the revised questionnaire, it was applied in two case studies and triangulated with data from websites and other (internal) documents describing the lean procedures, and a warehouse tour to observe lean practices as applied on the shop floor.

Lean practices

Lean deals with producing twice as much with only half of the inputs (Womack and Jones, 1996), providing exactly what the customer needs (Kerr, 2002). Production processes should only consist of activities adding value to the customer. All other activities are considered to be waste to be removed from the production process, through continuous improvement. The lean philosophy can be summarized in bundles. Shah and Ward (2003) and Bayou and Korvin (2008) distinguish, based on quantitative analysis of literature, four internal-oriented bundles, i.e. Just-In-Time (JIT), Total Quality Management (TQM), Total Preventive Maintenance (TPM) and, Human Resource Management (HRM), and two external-oriented bundles, i.e. Supplier Communication Management (SCM) and Customer Involvement (CI) (Olsen, 2004).

Shah and Ward (2007) divided lean production in 3 constructs ('Supplier related', 'Customer related' and 'Internally related'). These are further divided in 10 operational constructs ('Supplier feedback', 'JIT delivery', 'Developing suppliers', 'Involved customers', 'Pull', 'Flow', 'Low setup', 'Controlled processes', 'Productive maintenance' and 'Involved employees').

Just In Time (JIT)

JIT is a disciplined approach to improve overall productivity and eliminate waste, using cost-effective production and delivery of only the necessary quantity of parts at the right quality, at the right time and place, while using a minimum amount of facilities, equipment, materials and human resources (De Haan and Yamamoto, 1999; Slack et al., 2004; Harrison and Van Hoek, 2005). Companies that apply JIT focus on minimization of delay, inventory, number defects, and downtime, and an increase in simplicity and visibility and value creation.

Total Quality Management (TQM)

TQM focuses on continuous improvement and sustainability (Shah and Ward, 2003) and it emphasizes that everyone within an organization needs to be involved to succeed (Slack, et al., 2004). An important tool of TQM is the kaizen event which is "a focused and structured continuous improvement project" (Farris et al., 2009: pp. 42). Continuous improvement projects are typically implemented by adopting Plan-Do-Check-Act (PDCA) and Standardize-Do-Check-Act (SDCA) as cycles of change management (Taylor and Brunt, 2001).

Total Productive Maintenance (TPM)
TPM is defined as: "the productive maintenance carried out by all employees through small group activities" and productive maintenance is defined as: "maintenance management which recognizes the importance of reliability, maintenance and economic efficiency in plant design" (Nakajima, 1988 in Slack et al., 2004, pp. 704). TPM starts with 5S, a systematic process of housekeeping to achieve a working environment in which employees commit themselves to implementing and doing the housekeeping - clean and organize workstations.

Human Resource Management (HRM)
Lean production practices aims to achieve job autonomy, skill utilization and participation of shop-floor employees in decision making (Parker, 2003). Shah and HRM practices in lean most commonly cited are: job rotation, job design, job enlargement, formal training programs, cross-training programs, work teams, problem solving groups and employee involvement as well as) a flexible, cross functional workforce, and self-directed work teams (Shah and Ward 2003). Managing collaboration, participation, training and development, and continuous improvement are important aspects of lean HRM and includes the use of performance measurement and incentive programs (Deppe, 1994)

Supplier Communication Management (SCM)
Lean suppliers' sides amplify improvements (e.g. TQM) for its customers which are in turn passed on to the next stage in the supply chain (Bhasin and Burcher, 2006). A lean supply concept means that there is frequent and close contact among suppliers and their customers. Suppliers can learn from their customers, which would result in a better match between the requirements of customers and the actual deliveries of suppliers (Owen and Kruse, 1997 in Wu, 2003). Suppliers should get feedback on the quality of their products and their delivery performance to reduce the probability of repeatable defective deliveries (Olsen, 2004). Suppliers should be invited during the development processes of new products to let them know the exact requirements of the inbound goods and delivery requirements and to provide valuable information about the feasibility of the new product (Bhasin and Burcher, 2006).

Customer Involvement (CI)
Just like suppliers, customers should be involved in managing lean supply chain processes, relevant information can be shared and products and processes can be better improved using feedback inputs (e.g. Wu, 2003; Olsen, 2004). Sharing information would enhance supply chain competitiveness (e.g. better quality or higher efficiency) in that transparency of, for instance, unnecessary inventories and process bottlenecks can be observed more appropriately and consequently be solved (Bagchi and Skjøtt-Larsen, 2003).

Logistics Service Providers
Logistics is a primary process for LSPs, it aims to get the right products in the right place, at the right time and at the lowest costs (Rutner and Langley, 2000; Yong, Xiao and Feilong in De Haan et al., 2009). Logistics is considered to be of vital importance for a company (e.g. Vasiliauskas and Jakubauskas, 2007; Fugate, Stank and Mentzer, 2008). Many definitions and interpretations of "logistics service providers" (LSPs) or "third party logistics" (TPLs) can be found in literature (Marasco, 2008). In some cases

the term TPL is used as a label for traditional "arm's length" sourcing of transportation and/or warehousing, whereas in other instances it is used to describe more complex outsourcing activities that can encompass the entire logistics process (Van Laarhoven, Berglund and Peters, 2000). While more and more companies reap the benefits of using LSPs, the number of tasks outsourced to these companies increases as well (Michel, 2003).

LSPs always function in a triad of shipper-LSP-client. LSPs can be argued to be part of outsourcers, since they perform logistics activities for outsourcers. The relation between LSP and receiver consists of the outbound flow of materials and information. Both relationships are important within the supply framework. In the logistics relationship between outsourcer and receiver only information is exchanged.

Lean management practices in logistics

The main challenge in lean logistics is to improve control of movement of goods. Paradoxically, storing and transportation are two primary processes of LSPs (Gu et al., 2007; De Haan, et al., 2009), but in the lean philosophy they are often considered as wastes. De Haan et al. (2009) identified waste types for inbound and outbound processes in LSPs, which are summarized in Table 1.

Table 1: Waste in warehouse processes

Type of waste	Inbound process	Outbound process
Overproduction		Packing of products not yet needed
Waiting time	Unloaded goods wait for check and transport to storing	Picked goods wait for packing and shipping
Transport	Inadequate routing from reception to storing	Inadequate routing from storing to packing and to shipping
Processes	Look for empty slots to store if fixed slot is occupied	Put picked goods next to packing table, packer takes goods from floor
Inventory	Goods waiting for next process occupy space in reception area	Goods waiting for next process occupy space in packing and shipping area
Motion		
Defective goods	Defective goods are stored	Defective goods are shipped

In a typical lean warehouse all processes should be based on end-customer demand, hence pull based (Hawkey, 2008). LSPs should strive for a continuous flow of goods. In warehouses typically two major processes can be distinguished in which continuous flow can be achieved: the inbound flow of goods and the outbound flow of goods (De Haan et al., 2009). To enable a flow of goods, materials and equipment should be matched to goods to be available when and where needed, and in the right quantities. Also, human labor should be matched to the flow of goods via dedicated planning systems (Ballard and Howell, 1997). Thus variations in lead-time are reduced.

For LSPs to create a continuous inbound flow, goods ready to be unloaded, should not have to wait (e.g. for paperwork and checking) to be stored but need to be transported immediately to storage (De Haan et al., 2009). Creating a flow implies stabilizing the output rate (i.e. level scheduling) making labor- and material scheduling much easier). Elimination of waste (e.g. long set-ups and unreliable processes) and unevenness enable lower inventories without impeding material flow (Stratton and Warburton, 2003).

Adjustments

The description of the LSPs' processes indicates that various adjustments have to be made in the content of the lean bundles as described earlier because of the specific character of the processes and triadic relationship an LSP is in. the adjustments are summarized in Table 2.

Table 2: Items lean management measurement instrument LSPs

Just In Time
- Continuous and uninterrupted flow of materials (De Haan et al., 2009) - Removal of bottlenecks (Harrison and Van Hoek, 2004; Slack et al.,2004) - Clever picking, shipping and storing, routing and warehouse lay-out (De Haan et al., 2009) - Flexibility, batch size= 1 (De Haan et al., 2009) - Production is pulled by shipment of orders (Baudin, 2005; Womack (2005)
Total Quality Management
- Plan-do-check-act and Standardize-do-check-act (Taylor and Brunt, 2001) - Focused and structured improvement projects/ Kaizen (Farris et al., 2009) - Quality control (Taylor and Brunt, 2001) - Emphasis on training employees in quality issues (Montgomery, 2005)
Total Preventive Maintenance
- Improve equipment effectiveness by examining losses which occur (down-time loss, speed loss, defect loss) (Nakajima, 1988) - Recognize importance of reliability, maintenance and economic efficiency in plant design (Nakajima, 1988) - Facilitate production flows (De Haan et al., 2009) - Train staff in relevant maintenance skills (Nakajima, 1988)
Human Resource Management
- Self-directed work teams (Shah and Ward, 2003) - Autonomous problem solving teams (Parker, 2003) - Shop-floor employees drive suggestion programs (Deppe, 1994; Parker, 2003) - Shop-floor employees lead improvement efforts (Deppe, 1994; Parker, 2003) - Cross-functional training and development (Deppe, 1994) - Frequent communication of special events (Worley and Doolen, 2006) - Employees have quality targets (Deppe, 1994) - Poka Yoke (Shinto, 1986)
Supplier Communication Management
- Frequently close contact with suppliers (Lamming, 1993 in Slack et al., 2004) - Feedback on delivery of inbound goods (Bruun and Mefford, 2004; Olsen, 2004) - Suppliers are involved in new service development (Bruun and Mefford, 2004; Olsen, 2004)
Customer Involvement
- Frequently close contact with customers (Wu, 2003; Olsen, 2004) - Feedback on outbound goods (Bruun and Mefford, 2004; Olsen, 2004) - Customers share current and future demand information (Harrison and Van Hoek, 2004)

The above changes in the content of the lean bundles cause changes in the measurement tool Shah and Ward (2007) developed, as this focuses on manufacturing and not on LSPs. Shah and Ward collected Data were from a large database (obtained from Productivity Inc.), which holds manufacturing executives from a diverse set of manufacturing companies, i.e.. Furthermore, Shah and Ward solely focus on managers. In the database they used, only high-level and mid-level manufacturing managers. Contents of lean (e.g., TQM) however, require new behaviors, roles and responsibilities for all organizational members, including shop-floor employees (Victor, Boyton and Stephens-Jahng, 2000).

In essence three types of changes were made in the questionnaire adaptations with limited impact and modifications of a more radical character and new questions on issues Shah and Ward did not cover

Adaptations appear in particular with respect to internal processes which differ in character in an LSP environment either because they don't exist or they have a different content. Set ups are not relevant in an LSP as they are in manufacturing. Defect rates in manufacturing refer to products whereas in LSPs they refer to problems with orders, such timelines of delivery.

Modifications appear in particular with respect to the external processes which differ in character in an LSP environment as the relationship with the other parties is not simply supplier or customer. A manufacturer may require annual cost reductions from its supplier, but an outsourcer ('supplier') requires annual cost reductions by an LSP. Customers inform their suppliers about their satisfaction about the latter's' performance, but don't consider an LSP as supplier as they don't have a contract them.

Additional question were on issues like standardization and employee involvement as in particular standardization was not really covered in the questionnaire and the autonomy aspect of employee involvement was not included.

These changes resulted in a questionnaire of 63 questions in total of which 8 were identical, 9 did not apply anymore, 6 were changed marginally, 17 had to be adapted and 23 were added.

Methodology of the empirical study

The companies for the empirical study were selected by purposeful sampling. From an on line database (Chainlogistics.com) a list of LSPs was created, from 52 were selected because of the content of the mission statement. Then these were analyzed further by looking for relevant elements of lean on the site. 24 mentioned one aspect and 11 more than one. Finally, the two companies with a lean webpage: Menlo and CEVA were selected.

These companies agreed to participate in the test of the adapted questionnaire. In the test not just the questionnaire was filled in by managers of the companies, but several other sources and methods were used as well to avoid respondent-bias. Before the visit the webpage's of the companies were analyzed by two researchers independently of each other to see which items of the questionnaire were covered. During the visit the questionnaire was used for a structured interview by the two researchers. In addition to that company tour was made to observe what was visible of lean on the shop floor. Finally, relevant documents were analyzed.

Based on all this information the researchers prepared a report summarizing the results of the analysis of the webpage, the documents and observations during the company tour as well as the calculated scores on the various constructs based on those for the individual questions. The results from these various methods and sources were consistent with each other. This report was fed back to the interviewees for comment and discussion. In the feedback session some issues had to be clarified as some questions and answers appeared to be unclear as the signal words had not been effective or terms had multiple interpretations. Then the overall score was compared with the results of the confidential measurement tools the companies use internally. These scores and the result of the questionnaire were pretty similar. Another issue that drew attention was that scores for the various constructs differed from the companies' overall average, but in line with experiences the interviewees shared.

Results

From the feeback sessions we concluded that a number of items from the original instrument were perfectly usable, indicating the value of the original instrument developed by Shah and Ward (2007). However, our respondents indicated that a limited number of items were not usable because they were specifically tailored for the manufacturing environment. For example the Supplier Communication Management (SCM) item "Charts showing defect rates are used as tools on the shop floor" was changed into "Charts showing delivery problems are used as tools on the shop floor." On the other hand, we also added new items to capture the triadic relationship between the logistic service provider, the shipper and its client. For instance, Shah and Ward's three setup times items Setup_01, Setup_02, and Setup_03) were substituted by three items involved with speed of operations: "We unload items for easy storing," "We store items for easy picking" and "We pick items for easy shipping." Furthermore, the findings from the interviews were confronted with information from the company websites, on-site observations, and internal measurements. We found that these additional datasources were consistent with the image of lean from the interviews.

Next, we used the instrument to measure the degree of leanness of the two participating companies. The results are shown in Table 3.

Table 3. Scores for lean concepts

Lean concepts	Number of items	Menlo	Ceva
Outs. Comm.	6	4.1	3.7
Outs. Agreem.	4	3.4	3.3
Rec. Comm.	3	2.1	1.7
Pull	5	3.4	3.2
Flow	8	4.3	4.3
Standardization	4	4	3.3
Speed	3	3.9	4.3
SPC	7	2.7	4.1
Empl. Involv.	9	4.2	4
TPM	6	4.5	1.3

Table 3 shows that for most lean concepts the measurements yield fairly consistent results, except for Receiver Communication (Rec.Comm), indicating the special triadic nature of the relationships between shipper, client and LSP. For SPC and TPM we see deviating results for one, but not for both organizations.

Conclusions

Shah and Ward (2007) are to be commended for developing their tool to measure the degree of leanness. However, although very useful, the instrument is not generally applicable because it was developed for a production environment and not for a service environment. In the present study we modified this instrument to make it suitable for logistic service providers (LSP). The lean philosophy has been embraced by LSPs because margins are meagre and results need improvement. A complicating context variable in this case is that logistic service providers are engaged in a complex web of relationships with their clients (outsourcers) and receivers. Clients are both suppliers and principle to the LSP as well supplier to the receiver. The LSP can play different roles in this triad.

The results of our research demonstrate that, with some minor adaptations and a number of new items added, the Shah and Ward instrument can be used in a logistic services context as well. Conceptually, results from interviews and observations were in agreement with results from internal lean measurements. Thus, we are confident that the modifications are truly reflective of lean practices of logistic service providers. Empirically, the results suggest that for both companies involved, the lean concepts measured show a fairly consistent picture. A limitation of this study is that neither Shah and Ward nor we used the insights from shop floor employees to further validate the instrument. This suggests an important direction for further development of the instrument.

References

Bagchi, P.k., and Skjøtt-Larsen, T. (2003), Integration of information technology and organizations in a supply network. *International Journal of Logistics Management*, Vol. 14, pp. 89-108.

Ballard, G., and Howell, G., (1997), Shielding Production: An Essential Step in Production Control. Technical Report no. 97-1, Construction Engineering and Management Program, Department of Civil and Environmental Engineering, University of California.

Bask, A. H. (2001), Relationships among TPL providers and members of supply chains – a strategic perspective. *Journal of Business and Industrial Marketing*,Vol. 16, No. 6, pp. 470-486.

Baudin, M. (2005), *Lean Logistics: The Nuts and Bolts of Delivering Materials and Goods* (First ed.) Productivity Press Inc.

Bhasin, S., and Burcher, P. (2006), Lean viewed as a philosophy. *Journal of Manufacturing Technology Management*, Vol. 17, No. 1/2, pp. 56-72.

Bruun, P., Mefford, R.N. (2003), Lean production and the Internet. *International Journal of Production Economics*,Vol. 89, pp. 247-260.

Chen, C.C. (2008), A model for customer-focused objective-based performance evaluation of logistics service providers. *Asia Pacific Journal of Marketing and Logistics*, Vol. 20, No. 3, pp. 309-322.

Deppe, J. (1994), *HRM heeft een katalyserende functie bij invoering van lean management*. HRM- select, nr. 1.

Disney, S.M., Naim, M.M., and Towill, D.R. (1997), Dynamic simulation modelling for lean logistics. *International Journal of Physical Distribution and Logistics Management*, Vol. 27, No. 3, pp. 174-196.

Farris, J.A., Aken, van, E.M., Doolen, T.L., and Worley, J. (2009), Critical success factors for human resource outcomes in Kaizen events: an empirical study. *International Journal of Production Economics*, Vol. 117, pp. 42–65.

Fugate, B.S., Stank, T.P., and Mentzer, J.T. (2008), Linking improved knowledge management to operational and organizational performance. *Journal of Operations Managemen* , Vol. 27, No. 3, pp. 247-264.

Gu, J., Goetschalckx, M., McGinnis, L.F. (2007), Research on warehouse operation: A comprehensive review. *European Journal of Operational Research*, Vol. 177, No. 1, pp. 1-21.

Haan, de J., and Yamamoto, M. (1999), Zero inventory management: facts or fiction? Lessons from Japan. *International Journal of Production Economics*, Vol. 59, pp. 65-75.

Haan, de J., Overboom, M., and Naus, F. (2009), *Lean Logistics Service Providers: Option or Utopia? Experiences from the Netherlands.* The 5th International congress on Logistics and SCM Systems. Seoul.

Harrison, A., and Hoek, van R. (2005), *Logistics Management and Strategy* (Second ed.). Essex: Pearson Education Limited.

Hawkey, B. (2008), Discovering the Lean Supply Chain I: Transforming Supply Chain Operations into a Lean Differentiator. Article published by Lean Horizons Consulting.

Jones, D., Hines, P., and Rich, N. (1997), Lean logistics. *International Journal of Physical Distribution and Logistics Management*, Vol. 27, No. 4, pp. 153-182.

Kerr, J. (2002), What does "lean" really mean? *Logistics Management*, Vol. 4, No. 5, pp. 31-34.

Laarhoven, P. van, Berglund, M., and Peters, M. (2000), Third-party logistics in Europe – five years later. *International Journal of Physical Distribution and Logistics Management*, Vol. 30, No. 5, pp. 425-442.

Lee, M.K., and Elsayed, E.A. (2005), Optimization of warehouse storage capacity under a dedicated storage policy, *International Journal of Production Research*, Vol. 43, No. 9, pp. 1785-1805.

Macduffie, J.P., and Pil, F.K. (1996), The Adoption of High-Involvement Work Practices. *Industrial Relations: A Journal of Economy and Society,* Vol. 35, No. 3, pp. 423 - 455.
Malhotra, M.K., and Grover, V. (1998), An assessment of survey research in POM: from constructs to theory. *Journal of Operations Management,* Vol. 16, No. 4, pp. 407–425.
Michel, K. (2003). *The Modern Logistics Service Provider, A case for expanding the scope of your warehouse, operations and connecting to the rest of the world*. Michel Distribution Services. Cadre Technologies, Inc.
Montgomory, D.C. (2005), *Introduction to Statistical Quality Control* (Fifth ed.). New York: John Wiley and Sons, inc.
Nakajima, S. (1988), Introduction to TPM: Total Productive Maintenance (Translation) - Productivity in Slack, N., Chambers, S., and Johnston, R. (2004), *Operations Management* (Fourth ed.). Essex: Pearson Education Limited.

Niepce, W. and Molleman, E. (1998), Work design issues in Lean Production from a Sociotechnical Systems Perspective: Neo-Taylorism or the Next Step in Sociotechnical Design. *Journal of Human Relations*, Vol. 51, No. 3, pp. 259–287.
Olsen, E. (2004), Lean manufacturing management: the relationship between practice and firm level financial performance. Dissertation. The Ohio State University.
Parker, S.K. (2003), Longitudinal Effects of Lean Production on Employee Outcomes and the Mediating Role of Work Characteristics. *Journal of Applied Psychology*, Vol. 88, No. 4, pp. 620-634.
Rutner, S.M. and Langley Jr, J. (2000), Logistics Value: Definition, Process and Measurement. *The International Journal of Logistics Management,* Vol. 11, No. 2, pp. 73-82.
Slack, N., Chambers, S., and Johnston, R. (2004), *Operations Management* (Fourth ed.). Essex: Pearson Education Limited.
Shah, R., and Ward, P.T. (2003), Lean manufacturing: context, practice bundles, and performance. *Journal of Operations Management,* Vol. 21, No. 2, pp. 129-149.
Shah, R., and Ward, P.T. (2007), Defining and developing measures of lean production. *Journal of Operations Management,* Vol. 25, No. 5, pp. 785-805.
Stratton, R., and Warburton, R.D.H. (2003), The strategic integration of agile and lean supply. *International Journal of Production Economics*, Vol. 85, No. 2, pp.183-198.
Taylor, D., and Brunt, D. (2001). *Manufacturing Operations and Supply Chain Management* (First ed.). London: Thomson Learning.
Vasiliauskas, A.V., and Jakubauskas, G. (2007), Principle and Benefits of Third Party Logistics Approach When Managing Logistics Supply Chain. *Transport Journal*, Vol. 22, No. 2, pp. 68-72.
Victor, B., Boynton, A., and Stephens-Jahng, T. (2000), The Effective Design of Work Under Total Quality Management. *Journal of Organization Science,* Vol. 1, No. 1, pp. 102-117.
Womack, J.P., and Jones, D.T. (1996), *Beyond Toyota: How to Root Out Waste and Pursue Perfection.* Harvard Business Review. September-October, pp. 4-16.
Wu, Y.C. (2003), Lean manufacturing: a perspective of lean suppliers. *International Journal of Operations and Production Management,* Vol. 23, pp. 1349-1376.