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AN INTEGRATIVE LEAN ASSESSMENT MODEL FOR DISTRIBUTION CENTRES

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ABSTRACT

It is hard to benefit fully from lean manufacturing without having an efficient distribution centre. Applying lean distribution concept helps to reduce distribution centres waste while maintains customer service level high. The purpose of this study is to develop a lean assessment model that enables distribution managers to measure and improve the leanness levels of their companies. A data driven analytical approach (i.e. factor analysis) is used to assess leanness quantitatively. A lean index score is calculated to benchmark the leanness level of four distribution companies based in Ireland and UK. Results recommend that special attention should be taken on simplifying distribution network structure, establishing long term suppliers' collaboration, managing customer demand, improving storage space utilisation, and managing distribution operations more efficiently.

Keywords Lean Distribution, Lean Assessment, Factor Analysis

1 INTRODUCTION

Over the last decade, competition between enterprises has become a matter not only of productivity but also of overall supply chain performance (Mahfouz and Arisha 2010). Distribution Centres, which are mainly concerned with storing, retrieving and connecting products through supply chain processes, play an instrumental role in leveraging supply chain performance in terms of time, quality and cost. Lean philosophy aims to achieve streamlined and waste-free operations by eliminating every negative aspects of resources consumption. Although the majority of lean publications have generally addressed production systems, lean thinking has stretched to encompass logistics and distribution activities. Lean distribution is defined as a logical extension of lean supply chain operations downstream from the manufacturing plant to create smooth product flows through the supply chain.

While many companies have applied lean concepts, more than 90% have failed to achieve measurable improvements in their system performance (Bhasin and Burcher 2006). This is largely due to the lack of lean assessment models that monitor, assess and compare leanness levels before and after applying lean practices (Soriano-Meier and Forrester 2002). Research on assessing leanness level over the last decade has focused on creating lean indices for manufacturing systems, but the problem of assessing leanness of distribution industry has not been addressed, as far as we are aware.

Hence, the paper aims to present a lean index that quantitatively evaluates the leanness performance in distribution companies. Three basic steps are followed through the paper to achieve these objectives; (1) Identify standard lean distribution performance metrics, (2) Develop an integrated lean assessment model to calculate a quantitative lean distribution index, and (3) Use the proposed lean index to indicate the effectiveness of the proposed improvement efforts, and as a benchmark for lean performance.

2 LEAN THINKING

2.1 Lean Distribution

Supply chain management literature reflected the importance of managing distribution centres to the efficiency of production systems as well as the whole supply chain performance (Yang *et al.* 2010). Each distribution function – from order planning and processing to supplier/customer relationship management, inbound and outbound operations, and orders delivery – can benefit from the lean principles. Myerson (2012) noted that, to make distribution centres lean, distribution managers should seek perfection, high customer value, efficient warehouse management, high process quality, optimal utilisation of storage space and minimum non-value added and waste activities.

2.2 Lean Assessment Process

Few attempts were made to evaluate the lean distribution process (Wu 2002). Based on a literature review, Table 1 shows a summary of different performance metrics that are utilised to evaluate the leanness level of the distribution industry.

Table 1: Summary of lean distribution performance metrics

Authors	Lean Distribution Performance Metrics
Myerson (2012)	Driver dwell time; Labour efficiency; Space utilisation; Customer satisfaction (on-time delivery, completed orders, no-damaged parts and low prices); Warehouse productivity
Bradley (2006)	Number of damaged parts; Percentage of on-time shipments; Shipment accuracy (delays in shipments)
Jaca *et al.* (2011)	Damage parts rate; Order lead times; Worker satisfaction
Frank (2004)	Order processing times; Order lead times
Crow *et al.* (2010)	Orders delivery time; Inventory total cost

3 METHODOLOGY

3.1 Identifying Lean Distribution Metrics

Given the hypotheses proposed by Ray *et al.* (2006) – that an indicator metric could be calculated for any common set of input variables and outcomes – a quantitative leanness index (i.e. a dependent metric) can be generated from the metrics that contribute to measuring leanness performance (i.e. independent variables). This can be accomplished via an integrated lean assessment model that starts by identifying the appropriate lean metrics, then standardises and normalises them, and finally calculates the leanness index.

The Supply Chain Operations References (SCOR model) is used to identify the lean metrics of the study. SCOR has come up with different performance attributes, all of which can be linked to various lean principles (Myerson, 2012). These includes: delivery reliability, perfect order measure, responsiveness, flexibility, cost, and asset management (www.supply-chain.org). The metrics of distribution cost and asset management are not defined due to the confidentiality of the financial information in some companies. Table 2 shows a map between SCOR performance attributes, and the identified lean metrics.

Table 2: The selected lean distribution performance metrics

SCOR Performance Attributes	SCOR Attributes Description	Distribution Metric	Description
Delivery Reliability	Delivery reliability focuses on the waste in terms of shipping the correct product to the correct place at the correct time. Failure of achieving that causes in	• Cancelled Orders	• The number of orders that are cancelled due to delays in shipment or delivering incorrect products.
		• On-Time	• The number of orders that arrived to their

	higher number of cancelled orders.	Delivery Orders	final destination at the agreed time.
Order Perfection	Order perfection measure the error-free rate of the orders. Error free orders contains orders that are delivered complete with zero damage items.	• Damage-Free Orders	• The number of orders that free of damages.
		• Order Fill Rate	• The portion of total orders delivered completely, i.e., all units shipped as agreed with customers.
Responsiveness	Responsiveness measurements relate how quickly orders can be delivered to the customer	• Order Lead Time	• The average time between customers setting and receiving the orders.
Flexibility	Flexibility measures distribution agility and response time for unexpected changes..	• Orders Processing Time	• The average time of distribution inbound operations (e.g. unloading, storing, picking, packaging, loading operations).

A significant field work has been carried out to investigate the practicality of the lean distribution metrics that were addressed in the literature. A senior member and a shaper of strategies in the Irish distribution industry was interviewed to gather general information about distribution companies and the characteristics of its supply chains, as well as an overview of the industry's current awareness of lean concepts and practices. A number of interviews were then held with seven distribution industry professionals from Ireland, UK and Portugal, followed by two observational visits of distribution companies in Ireland, aiming to study the appropriateness of the selected metrics. The managers have agreed that the six metrics can be effectively used to assess the leanness performance of their companies.

3.2 Data Collection

Quantitative data sets were collected for the selected metrics from four distribution companies based in Ireland and UK. In most cases this was a straightforward process, as all required data were available from the companies' ERP systems. Further data analysis and verification were conducted on a continuous basis through meetings and phone conversations with the responsible managers. Due to the diversity of the metrics' measurement units, as shown in Table 3, data standardisation phase became a necessity in order to reduce data bias before the application of factor analysis method.

Table 3: The measurement units of the selected metrics

Variable	Cancelled orders	On-time delivery Orders	Damage free orders	Order fill rate	Order lead times	Order Processing times
Measure Unit	Quantity/Month	Quantity/Month	Quantity/Month	Percentage	Hours	Hours

3.3 Data Standardisation and Normalisation

Data standardisation is a statistical approach that resets all data to equal ranges in order to ensure data consistency and comparability. Variables standardisation involving three main steps; (1) derive a common measurement unit represents the selected variables, (2) transform all model variables to a function of the selected common variable in order to minimise potential data bias, and (3) normalise the standardised variables for comparison purposes. Labour hour (i.e. the number of man hours required to deliver an order to the end customer) was selected as the common measurement unit that were used to standardise the studied lean distribution metrics (i.e. independent variables.

After variables had been converted, they were transformed into a standard score so that data from different operational processes, with different orders of magnitude, could be normalised and thus compared on an equivalent basis (Dubes and Jain 1980). A standard score (i.e. Z score) for each variable was calculated using the formula $z = \frac{x-\mu}{\sigma}$ where Z is the standardised independent variable, X is the original data value, μ is the sample mean and σ is the standard deviation. The normalised data sets were then processed statistically, and the outputs examined to determine the best model for the proposed leanness index.

3.4 Factor Analysis (FA)

Factor analysis (FA) is used in describing patterns of relationships between quantifiable variables that cannot be measured directly (Pett *et al.* 2003), and is composed of a multivariate group of methods that enable various measurement dimensions in data sets (Hair *et al.* 1987). It seeks to derive interpretable common factors from extensive sets of data and then evaluate variables that cannot be measured quantitatively or collected directly from the companies involved (e.g. leanness levels, product evaluation indices, and competitive strategies) (Zhang and Ray 1995).

FA starts with deriving common factors by amalgamating the number of independent variables into a smaller number of factors, whose numbers are determined using a component matrix. The component matrix showed that a 2-factor model was used as it accounted for 73.8% of total data variance. A 3-factor model is not feasible since the third factor had a variance less than 1.

The significance of the lean distribution metrics and their correlation with the extracted factors, from the component matrix, is shown in Table 4. Determining the loading of each variable on the factors helped to identify variables' magnitude: any variable loading less than 0.4 on all factors should be eliminated (Tabachnick and Fidell 2007). Given that all variables' loaded at over 0.4 on at least one of the two selected factors, as shown in Table 4, they were retained for the next analysis step.

Table 4: Pattern and structure matrix for FA

Variables	Pattern Coefficient	
	Factor 1	Factor 2
Cancelled orders	.465	.816
On-Time delivery orders	.369	.817
Damage free orders	.924	
Orders fill rate	.755	-.409
Order lead times	.90	
Order processing times	.502	

To obtain reasonable definitions for the leanness factors, the variables were grouped according to their loadings on the factors. Factor 1 had the highest loading on 'Damage free orders', 'Order fill rate', 'Order processing time', and 'Order lead times' suggesting these variables could be grouped into a single factor labelled '*Distribution quality and flexibility'*. In the same way, the second factor, which had significant loading values with 'Cancelled orders' and 'On-time delivery orders' is more associated with '*Distribution Accuracy'*. Once the two factors were defined, the factor scores (i.e. weights) were calculated using the component score coefficient matrix (Julie 2007), Table 5.

Table 5: Factor score matrix

Component Score Coefficient Matrix		
Independent Variables	Factors	
	Distribution Quality and Flexibility	Distribution Accuracy
Cancelled orders	0.114	-0.498
On-time delivery orders	0.185	0.552
Damage free orders	0.323	-0.25
Order fill rate	0.244	-0.216
Order lead times	-0.332	-0.149
Order processing times	-0.192	0.158

The selection of a variable's factor score in Table 5 is related to its loading in Table 4 – pattern coefficient columns. The coefficients of 'Cancelled orders' and 'On-time delivery orders' are highly correlated to the second factor in Table 4, so their factor scores can be obtained from 'Distribution Accuracy' column in Table 5: the same applies for 'Damage free orders, 'Order fill rate', 'Order processing times', and 'Order lead times' which are highly correlated with the first factor in Table 4, so the factor scores in 'Distribution quality and flexibility' column at Table 5 can be used. Table 6 illustrates the final factor scores of the six leanness variables.

Table 6: Factor scores for the studied variables

Variables	**Factor Scores**
Cancelled orders	-0.498
On-time delivery orders	0.552
Damage free orders	0.323
Order fill rate	0.244

Order lead times	-0.332
Order processing times	-0.192

To assess companies' leanness levels and prioritise the proposed efforts to improve their performance, an individual lean index for each variable is calculated by multiplying variable's score by its factor score, and the overall leanness index by summing the variables' lean indices as illustrated in Equation 1.

$$\text{Lean Index} = -0.498 * \text{Cancelled orders} + 0.552 * \text{On-time delivery orders} + 0.323 * \text{Damage free orders} + 0.244 * \text{Order fill rate} - 0.332 * \text{Order lead times} - 0.192 * \text{Order processing times} \quad (1)$$

Since the interpretation of the variables' factor scores is 'the higher the score, the more impact the variable has on the company's leanness', increasing the number of on-time delivery orders, damage free orders and orders fill rate contribute significantly to increasing leanness score, and larger number of cancelled orders and longer order processing and lead times will detract from its leanness value.

4 FINDINGS AND ANALYSIS

The developed leanness index is used as a scale for the leanness performance of the four studied distribution companies. The results showed that company D is the leanest, with an overall Lean Index score (LI) of 1.03; the next leanness is company B (Lean Index score 0.47), followed by companies A (LI -0.07), and C (Li -0.48). Analysing such leanness scores is important, especially in terms of identifying the challenges that these companies face and the impact of their characteristics on their leanness performance.

4.1 Analysis of Companies' Leanness Scores

Company D: Several factors contributed to the high leanness score of the company - including the robust long term relationships it has with its customers, the efficiency of its ordering process and the standardisation of its warehouse operations. These factors resulted in significant improvements in the values of 'On-time delivery orders', 'Damage-free orders' and 'Cancelled orders' metrics. Despite that, the company still has room to improve, as the complex structure of its distribution network and being far-distance of its suppliers cause long 'Orders lead time'.

Company B: The firm sets up standard agreements with its suppliers, resulting in faster 'Order processing time' and more accurate supplier delivery process which increase the 'Orders fill rate'. SKU's are usually stored in random locations in the warehouse, causing longer storing and picking times, which in turn increase the 'Order lead time'. Operational times and costs, and the numbers of damage free items, can be significantly improved if class-based storage practices are applied and warehouse floor is more logically organised. Although the company has its own fleet for deliveries, optimal vehicle routing plans are needed in order to improve the 'On-time delivery' and 'Cancelled orders' metrics.

Company A: The Company scored short 'Order processing times' and 'Order lead times' due to the efficient management of customer demand, the error-free transaction of information (via its advanced ERP system), and the close locations of its suppliers. Being a part of a wider network of depots for a big brand name in the tire industry, its supplies can be controlled by strict central logistics policies which sometimes conflict with customer requirements. The restrictions imposed by manufacturing or economic constraints on supplying specific items to the depot cause frequent stock-outs, significantly increasing the numbers of 'Cancelled orders' and lowering the 'On-time delivery orders' and 'Orders fill rate' scores. To mitigate the negative influences of these challenges, the company is advised to create new collaborations and partnerships with alternative sources (e.g. suppliers or bigger distribution centres) and efficiently manage its inventory levels.

Company C: Looking at the company's conditions gives a better understanding of its lean metrics scores. SKUs are usually replenished after long price negotiations with suppliers, making for longer 'Order processing time'. The company expects its 'Order processing time' will be greatly reduced when a standard agreement with suppliers is created. Another problem is that the warehouse floor is disorganised, with items usually stored in random locations, resulting in inefficient picking operations and in turn longer 'Order lead times' and higher 'Numbers of damaged parts'. Its suppliers are far away, and the structure of its distribution network is complex, both contributing to increased 'Orders lead time' and lower 'On-time delivery orders' scores.

5 CONCLUSION

Lean in manufacturing has reached its maturity phase however in distribution centres it is still in the introduction phase. Finding ways to successfully implement and assess leanness in distribution centres are urged by operations and supply chain managers. The calculated leanness levels of the studied companies have indicated that the better and more efficient the management of customer demand, error-free information transaction, long term collaboration with suppliers, and organised storage space the more the positive impacts are on orders perfection, delivery reliability, responsiveness and flexibility. There are a good potential to extend this research work to include more distribution companies within supply chain networks. The number of companies that contributed to this study is considered a limitation. Increasing sample size and include more companies in the benchmark exercise will add value to the verification of the index and the recommendations for improvement.

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