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Review

Modeling the metrics of lean, agile, and leagility: An AHP-based approach

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The aim of this study was to develop a methodology for estimating whether an existing system can perform as a lean, agile, or leagile manufacturing system. We compared and identified the similarities and differences between leanness and agility, before developing leagility, by identifying the manufacturing features that were particularly affected by interdependent variables by preparing based on the conditions and characteristics that improved solutions to manufacturing practical operations in three case studies. The present article describes the three case studies and examines the three functions of lean, agile and leagile mechanisms by considering certain features. This study measured the available factors and characteristics to build a model based on the Analytical Hierarchy Process (AHP), which was sent to firms and factories to acquire their responses. We determined whether the functions were applicable to the manufacturing systems in the three case studies. The characteristics of the three case studies did not respond to the same functions, which suggests that more details or factors should be developed that might affect their operations to improve manufacturing systems to meet the requirements of customers. The leanness, agility, and leagility features were examined in the three case studies. Using these operations to acquire precise results; may require more tests in more highly developed conditions in certain locations.

Key words: Agility, analytical hierarchy process (AHP), leagility, leanness, supply chain.

INTRODUCTION

This study examines the difference between three systems based on the result sheets from selected companies, which were used to produce complete description of their criteria and functions used for testing and comparison on.

Lean production is highly suited to functional products and it is moving into the service industries (Robertson and Jones, 1999). Lean production has its roots in Toyota production systems (Ohno, 1988), but it has been suggested that leanness was first utilized during Spitfire production in the UK during World War II (Aikten et al., 2002).

The appropriate internal supply chain system is designed for a manufacturing system where leanness is achieved by eliminating redundant periods while agility requires greater reductions of the value-added time via production factors. Thus, lean and agile manufacturing features have been integrated into the leagile systematic supply chain (Stevens, 1989). In the present study, the system lead time, cost, quality, productivity, and service level were examined during the operations in three case studies.

The stable features considered by the manufacturing system are the lead time, service, costs, and quality level. The feature (lead time), that needs to be minimized in lean manufacturing is excess time wasting. Lean and agile systems have been studied by many researchers in various situations. The first of these manufacturing

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systems was the lean system of manufacturing, while the agile manufacturing principles emerged as a new system in companies. Lean was a reaction to old production systems, which were full of wastes and unsatisfactory quality, while the latter is a response to changing customer demands. Some researchers have suggested that agility is the next step after leanness. Thus, if lean principles are implemented in a system, agility is the best next step (Hormozi, 2001; Mason-Jones et al., 2000a), although lean and agile features have contrasting goals. However, they can be hybridized into total supply chain systems (Mason-Jones et al., 2000a). This idea resulted in the combined term, ”leagility”, which fuses these two manufacturing systems (Lean and Agile) in a total supply chain to ensure the enterprise’s performance.

The measurement of factors and their characteristics of these factors can be used to build a model with the Analytical Hierarchy Process (AHP). We identified the characteristics that were considered important by decision makers in different types of manufacturing systems in three companies, that is, case studies of Iran Mechanical Industries (IMI), Advanced Electronics Company (AEC), and Iran Lightening Company (ILC). The selection of the best alternatives that met all of the decision makers’ criteria attested how the firms performed.

The focus of this study was the applicability of the lean, agile, and leagile appropriate to the manufacturing systems used by these firms. First we deal with the concepts and definitions of lean, agile, and leagile features. Next, we provide some descriptions of the characteristics operations found in each firm.

Based on the factors and practical operations each company, we identified the best approach for their manufacturing systems. The strategies and policies utilized by the three companies were also different. We compared the results and performed statistical analyses of the best methods for the manufacturing systems in each company. This study considered only three companies, but a more accurate assessment of the appropriate manufacturing systems and methods used by more factory and company would be required to deliver a more precise and scientific analysis of the effects of these systems. Depending on the adaptations of each company and the functions used, the manufacturing system was examined to determine the most appropriate approach and policy.

ATTRIBUTES OF LEANNESS, AGILITY, AND LEAGILITY MANUFACTURING FRAMEWORKS

In recent years, many researchers have treated supply chain designs based on the relative merits of “lean” and “agile” philosophies. The focus of lean thinking is the reduction or elimination of wastes, which later led to the “lean management” or “lean manufacturing” concept (Womack and Jones, 1996).

Agility requires the use of market knowledge to exploit profitable opportunities in a volatile market place. Leanness means the development of a value stream to eliminate waste, including time, and to ensure a uniform schedule. When industries shifted their conventional supply chain model to an agile supply chain model, lean manufacturing was a prerequisite for agility (Richard, 1996). The market sensitivity of the agile supply chain was reported by Christopher and Towil (2000).

Further suggested that a much higher level of agility is required when the market place is volatile and the customer demand for variety is high. These studies observed that the agile supply chain is capable of handling an increased product variety, specialized fragmented customers, and markets.

Furthermore Naylor proposed the concept of leagility by integrating lean and agile principles factors (Hoekstra and Romme, 1992). The aim of the leagile supply chain is to postpone the products at the customer end, to handle the demand uncertainties. Various advantages have been pointed out by Hoek (1998) and many authors in recent years with respect to the postponement strategy, such as greater flexibility during production (Kidd, 1995).

The agile and lean approaches are complementary and, in many cases, there is a requirement for a “hybrid” lean/agile strategy (Christopher and Towil, 2000). In some cases, lean and agile can be brought together as a hybrid “leagile” solution (Naylor et al., 1999). There are three types of product: standard, innovative, and hybrid. Thus, there is a need for a comprehensive framework to categorize the supply chain types. According to the product characteristics and the stage of the product, this may require different characteristics and capabilities, particularly in the category of innovative production as the supply chain evolves from an agile focus (in the stages of introduction and growth) to a lean focus (in the stages of maturity).

A number of key characteristics of the two paradigms were also identified by Naylor et al. (1999) based on a comprehensive review of the available literature (Steven, 1989; Womack et al., 1990; Grunwald and Fortuin, 1992; Stalk and Weber, 1993; Goldman et al., 1994; Hayes and Pisano, 1994; Harrison, 1995; Kidd, 1995; Womack et al. 1996; Evans et al., 1997. These characteristics are described in Table 1.

Rating the importance of different characteristics of leanness, agility and leagility

Table 1 shows the importance of the metrics for each paradigm: three stars indicate a key metric or essential metric, two stars indicate secondary metrics that are also desirable, while one star is an arbitrary metric. These characteristics can be used to differentiate the paradigms. The paradigms pay particular attention to the

Table 1. The comparison in characteristics of the three manufacturing systems.

Characteristic	Lean	Agile	Leagile
Lead time	**	***	**
Costs	***	**	***
Productivity	***	**	**
Service	*	***	***
Quality	***	***	**

need to develop an integrated, seamless supply chain, where producers act as a virtual enterprise. The main difference between leanness and agility in terms of the value to customers is service, which is the most important factor for agility where cost and the sales fee is considerable to achieve leanness (Towil, 1996). Thus, there is only *one* necessary condition for enabling agile manufacturing systems.

They also require a minimum total lead time, which is defined as the time taken from a customer raising a request for a product or service until it is delivered. The total *lead time* has to be minimized to enable agility because the demand is highly volatile and fast moving. If a supply chain has a long lead time, it will not be able to respond quickly enough to exploit the marketplace demand. Furthermore, the appropriate engineering of the cycle time reduction always leads to significant bottom line improvements in the manufacturing costs and productivity (Towil, 1996).

Table 2 shows details of the main characteristics when comparing the paradigms and investigating their similarities and differences.

The tactics adopted may also be affected by whether the product is “standard” in scale (lean approach) or “special” in scale (agile approach). If the lead-time is long and demand is predictable, there is an opportunity for the pursuit of “lean” strategies.

Finally, if the demand is unpredictable but the lead-time is short, agile solutions will be required based on a rapid response. “Standard” products, on the other hand, will tend to be more stable and predictable.

It is possible to simplify the taxonomy in two dimensions: predictability and replenishment lead-time. In the volatile unpredictable conditions or stable conditions used by for manufacturing systems in companies, the stock out and obsolescence costs are wasteful.

After comparing lean and agile, we consider that the mixed attribute performance of leagile manufacturing system has special characteristics. Table 3 shows a comparison of the attributes of lean and agile supply. The purchasing policy moves from placing orders upstream for products moving in a streamline flow to assigning lean and agile supply during manufacturing.

Table 3 shows the main points when attributing systems. We present a comprehensive framework for modeling the performance of lean, agile, and leagile supply chains by analyzing the variables that affect market sensitivity, elimination of waste, information technology, and flexibility to assess the performance improvement in three cases of supply chains with fast moving consumer goods business.

We used the Analytical Hierarchy Process (AHP) approach. By using AHP in a supply chain (SC) context, we can evaluate the effects of various performance dimensions on the specified objectives of SC, such as a timely response to meet the customer demand (lead-time). We also explicitly consider the effects of the performance determinants on each other. The dimensions and determinants of the supply chain performance have systematic characteristics, so they may be integrated into one model. These systematic relationships can portray the true linkages and interdependencies more accurately for these determinants (Saaty, 1996).

Supply chain performance

Hult et al. (2004) and Ketchen and Hult (2011) described supply chains as characterized by reciprocal interdependence, meaning that each SC factor depended on adjoining participated components to perform its tasks. The supply chain is described as a chain linking each shared level from up-streamed and down-streamed via manufacturing operations and services. Thus, requests for the essential amount of material, cost, and information can be managed effectively to meet the market requirement. Most companies and factories realize that in order to evolve an efficient and effective supply chain, SCM needs to be assessed to determine its performance. Lee and Billington (1995) believed that a supply chain is the network of facilities that processes raw materials, which transforms and delivers the products to customers through a distribution system. The management of this network requires the mastery of optimization logistics because a specific quantity of goods needs to be supplied at a particular time and price. The successes and failures of supply chains are ultimately determined in the marketplace by the end users.

SCM can be defined as the design and management of seamless, increased value process across organizational boundaries to face the volatile and real needs of the end user (Fawcett et al., 2007). However, its role in the system is manipulating and handling the tasks, operations, and costs.

The purpose of SCM is to maximize value in the supply chain. SCM competes for value by, collaborating with users and applicants to create an atmosphere based on value to improve efficiency by decreasing the costs, or increasing the benefits by promoting market effectiveness.

The goal of the SC is not limited to desirable products or services because it is also directed at increasing value

Table 2. Comparison of Lean and Agile Manufacturing System.

Agile Manufacturing	Lean Manufacturing
High Profit margin	Low profit margin
High product variety	Low product variety
Marketability dominant cost	Physical dominant cost
Market driven	Customer driven
Emphasis on thriving in a market environment	Emphasis on efficient use of resources
Unpredictable market demand	Predictable market demand
Orders based on changing the market	**Orders based on customers**
Greater flexibility for customized products	Flexible production for product variety
Checking samples on the line by **workers**	**Checking samples on the line by workers**
Obligatory enrichment	**Highly desirable enrichment**
Focused on enterprise-wide operations	**Focused on factory operations**

Table 3. Comparison of metrics used for leanness, agility, and leagility in manufacturing systems.

Distinctive attributes	Lean supply chain	Agile supply chain	Leagile supply chain
Market demand	Predictable	Volatile	Volatile and unpredictable
Product variety	Low	High	Medium
Product life style	Long	Short	Short
Customer drivers	Cost	Lead-time and availability	Service level
Profit margin	Low	High	Moderate
Dominant costs	Physical costs	Marketability	Both
Stock out penalties	Long term contractual	Immediate and volatile	No place for stock out
Purchasing policy	Buy goods	Assign capacity	Vender managed inventory
Information enrichment	Highly desirable	Obligatory	Essential
Forecast mechanism	Algorithmic	Consultative	Both/either
Typical products	Commodities	Fashion goods	Product as per customer demand
Lead time compression	Essential	Essential	Desirable
Eliminate waste	Essential	Desirable	Arbitrary
Rapid reconfiguration	Desirable	Essential	Essential
Robustness	Arbitrary	Essential	Desirable
Quality	Market qualifier	Market qualifier	Market qualifier
Cost	Market qualifier	Market qualifier	Market qualifier
Lead-time	Market qualifier	Market qualifier	Market qualifier
Service level	Market qualifier	Market qualifier	Market qualifier

Sources: Naylor et al. (1999), Mason-Jones et al. (2000a), Olhager (2003), Bruce et al. (2004).

and absorbing more users into systems or activities. Next, we describe the method used to determine the best manufacturing system for each sector.

AHP MODEL

Initially, we explained the effective items on the model used by this method, so we describe its classifications and main levels. AHP is a fundamental approach for decision making, which is a major multi-criteria decision model for systems that use processes. AHP was introduced by Saaty in the 1970's (Saaty, 1977). AHP is utilized to identify problems and to solve them. Thus, the problem is modeled as a hierarchical structure based on the viewpoints of decision makers' from the objectives through intermediate criteria at various levels. Firstly, we find the objectives, then the criteria or characteristics followed by effective alternatives to solve the problem, as shown in the Figure 1.

By these three hierarchical stages, there are link between the goals, the major criteria, and the alternatives solutions. After finding these three hierarchical levels of the process, the decision maker evaluates every criterion compared with the alternatives. Finally, the decision makers must identify the main priorities, which are arranged to classify or rank the alternatives to make a decision, where the decision makers have to limit their choices by considering the priority goal. The inconsistency ratio is calculated during the hierarchical process. The overall criteria are analyzed using three functions: the first function structures the complexities at the top level of the hierarchical process in Figure 1; the second function measures the ratios in a reciprocal or pair-wise comparison matrix; and the third function synthesizes the scales and calculates the result. This level of structure or principle refers to the lowest level elements, that is, the alternatives based on all of the scales ranked by the decision makers. Each priority is weighted based on the higher stage priorities in steps. The aim is to synthesize the estimates of the majority for each alterative. The priority ranking of the decision alternatives can be acquired from the synthesized priorities. This produces different values. However, Liu et al. (1999) considered that the level of hierarchy should be divided into a four level-hierarchy which comprises the goal level, criterion level, sub-criterion level, and scheme or alternatives level (Liu et al., 1999).

In this paper we briefly discuss the use of this multi-criterion decision making method to find the best strategy for manufacturing systems based on characteristics of the three case studies. We begin by defining the pair-wise priorities.

AHP MODELS OF THE THREE CASE STUDIES

In this study, there are three decision makers in the three case studies. The decision makers’ use their knowledge and experience to calculate the scales for each characteristic, before then prioritizing them using 5 × 5 matrices. The scales used for the main characteristics depend on elements such as flexibility, elimination of waste, information technology, market sensitivity. We can determine the effects of different elements, such as flexibility, which is affected by the source flexibility, delivery flexibility, and manufacturing flexibility, as well as other elements elimination of waste which is affected by knowledge disconnects, inventory transportation waiting, and over-production. The effective items related to information technology include electronic data interchange, types of information, data accuracy, knowledge bases, and market sensitive elements related to the delivery speed, new product introduction, and customers' responsiveness. However, the current results and scales were based on these main characteristics.

The main aim is to identify the most suitable manufacturing system or the best strategy for each company based on various levels and characteristics. Figure 2 shows the model used in this study.

The aims of this research were to obtain the sequences, subsequences, or alternatives estimated from the overall characteristics of the three case studies. We considered the scales at four levels to determine the appropriate manufacturing system in each case. The experts (decision makers) were informed by alternative supply chain then the experts give the relative weights between alternative sequences during the process to identify the relative weights for the functional operations in companies.

MUTUAL INTERDEPENDENCE OF CRITERIA IN MANUFACTURING SYSTEMS

The overall goal of this study was to find the manufacturing system for a supply chain, which would make it more professional when responding to market requests. The lead time, cost, quality, service level and productivity were the major determinants in the proposed model. The effects are shown in a pair-wise comparison matrix (1 to 9) in Table 4, which aims to find the most suitable manufacturing system for each firm. We begin with the three manufacturing systems. We compared the manufacturing systems used by each of the three enterprises from the upper levels down to the sub-factors to determine the functions and operations.

The scales were based on expert' opinions of the supply chain performance. Next, we illustrate the performance using scales and functions for a supply chain case with interdependencies.

Obtaining the weights based on expert' opinions

The weights were obtained based on the supply chain system in each of the three case studies, according to decision makers and experts who had experience in the area of supply chain management. They generated the ranks by asking questions relate to the supply chain, e.g., they asked the question: what is the importance of market demand based on cost when cost is compared to quality?, which they ranked as 2 in the ranking of 1 to 9, as shown in the second line of Table 4. Saaty (1980) suggested a scale of 1 to 9 for comparing two components. In this ranking one implies equal effects whereas nine implies the stronger effect of row elements compared with column elements. If experts felt that the column element had a higher effect than the row element, the reciprocals of numbers from 1 to 9 were used.

Table 4 shows the ranks and criteria for a case study when analyzing its manufacturing system, as well as other manufacturing mechanisms. The second level in Table 5 shows that there is a comparison of the main characteristics of the supply chain of the selected case studies.

The ratios were determined by calculating the weights and the pair-wise consistency by comparing the scales of the main indices with each other (Tables 5 to 9); the second calculation compared the pair-wise scales for the

Table 4. Pair-wise comparison matrix showing the importance of interdependence among indices.

Criteria	Lead time	Cost	Quality	Productivity	Service level	e. Vector
Lead time	**1**	3-Jan	5-Jan	3	4-Jan	0.0866
Cost	3	**1**	4-Jan	6-Jan	3	0.1022
Quality	5	4	**1**	7-Jan	6	0.252
Productivity	3-Jan	6	7	**1**	5-Jan	0.246
Service level	4	3-Jan	6-Jan	5	**1**	0.184
Sum	13.33	11.66	8.616	9.306	10.45	

$\lambda_{max} = 0.1$; CI= - 1.225; CR= -1.09 < 0.1.

Table 5. Characteristics of factors used to rate the lead time.

Factor	Elimination of waste	Flexibility	Information technology	Market sensitivity	e. Vector
Elimination of waste	**1**	3-Jan	6-Jan	4-Jan	0.005
Flexibility	3	**1**	2	5-Jan	0.25
Information technology	6	2-Jan	**1**	6	0.61
Market sensitivity	4	5	6-Jan	**1**	0.305

Table 6. Characteristics of factors used to rate Cost.

Factor	Elimination of waste	Flexibility	Information technology	Market sensitivity	e. Vector
Elimination of waste	**1**	5-Jan	7-Jan	3	0.18
Flexibility	5	**1**	4-Jan	2-Jan	0.16
Information technology	7	4	**1**	3-Jan	0.32
Market sensitivity	3-Jan	2	3	**1**	0.27

Table 7. Characteristics of factors used to rate quality.

Factor	Elimination of waste	Flexibility	Information technology	Market sensitivity	e. Vector
Elimination of waste	**1**	7	7-Jan	3-Jan	0.05
Flexibility	7-Jan	**1**	3	5-Jan	0.2
Information technology	7	3-Jan	**1**	2	0.3
Market sensitivity	3	5	2-Jan	**1**	0.31

sub-factors in the remaining hierarchical levels, as shown in Table 5, which were based on the opinions of the decision makers' (ranking).

There were three main sub-factors in the third level (Tables 6 to 9); so the identification of the most suitable manufacturing system was based on all three weighted attributes or components scales for each company based on the rankings of the decision makers or experts'.

The three rows and four columns of the scaled weights (three alternatives and four sub-criteria) are shown in Tables 10 to 13, which were generated by multiplying the matrix of four by five (four sub-criteria for five indices or main factors), and these in turn, were calculated from the third and fourth levels of the model to yield in a matrix of three rows and five columns, as follows;

$$\begin{pmatrix} 0.59 & 0.65 & 0.26 & 0.39 \\ 0.263 & 0.183 & 0.08 & 0.08 \\ 0.121 & 0.15 & 0.613 & 0.47 \end{pmatrix} \text{X} \begin{pmatrix} 0.05 & 0.18 & 0.05 & 0.14 & 0.05 \\ 0.25 & 0.16 & 0.2 & 0.2 & 0.26 \\ 0.61 & 0.32 & 0.3 & 0.19 & 0.15 \\ 0.305 & 0.27 & 0.31 & 0.45 & 0.4 \end{pmatrix} =$$

$$= \begin{pmatrix} 0.44 & 0.395 & 0.373 & 0.42 & 0.36 \\ 0.11 & 0.1 & 0.08 & 0.166 & 0.09 \\ 0.546 & 0.354 & 0.629 & 0.63 & 0.3 \end{pmatrix}_{3x5}$$

Table 8. Characteristics of factors used to rate productivity.

Factor	Elimination of waste	Flexibility	Information technology	Market sensitivity	e. Vector
Elimination of waste	**1**	6-Jan	3	5-Jan	0.14
Flexibility	6	**1**	4-Jan	3-Jan	0.2
Information technology	3-Jan	4	**1**	4-Jan	0.19
Market sensitivity	5	3	4	**1**	0.45

Table 9. Characteristics factors used to rate of the service level.

Factor	Elimination of waste	Flexibility	Information technology	Market sensitivity	e. Vector
Elimination of waste	**1**	2-Jan	6-Jan	9-Jan	0.05
Flexibility	2	**1**	8	4-Jan	0.26
Information technology	6	8-Jan	**1**	3-Jan	0.15
Market sensitivity	9	4	3	**1**	0.4

Table 10. Expert' rating scales for manufacturing supply chain system with respect to the elimination of waste.

Scale	Leagility	Agility	Leanness	e. Vector
Leagility	**1**	5	3	0.59
Agility	5-Jan	**1**	4	0.263
Leanness	3-Jan	4-Jan	**1**	0.121

Table 11. Expert's rating scales with respect to the flexibility of the system.

Scales	Leagility	Agility	Leanness	e. Vector
Leagility	**1**	6	5	0.65
Agility	6-Jan	**1**	3	0.183
Leanness	5-Jan	3-Jan	**1**	0.15

Table 12. Expert's rating scales with respect to the information technology in the system.

Scales	Leagility	Agility	Leanness	e. Vector
Leagility	**1**	4	3-Jan	0.26
Agility	4-Jan	**1**	6-Jan	0.08
Leanness	3	6	**1**	0.613

Table 13. Expert's rating scales with respect to the market sensitivity in the system.

	Leagility	Agility	Leanness	e. Vector
Leagility	**1**	7	2-Jan	0.39
Agility	7-Jan	**1**	4-Jan	0.08
Leanness	2	4	**1**	0.47

According to the weighted scales of the attributes, the matrix comprised sub-factor scales of three by five (alternatives and sub-criteria with five indices) where the upper level indices were used to estimate the weights for these two levels based on the ranking scales to the factors given by decision makers or experts.

$$\begin{bmatrix} 0.44 & 0.395 & 0.34 & 0.42 & 0.36 \\ 0.11 & 0.1 & 0.08 & 0.106 & 0.09 \\ 0.546 & 0.354 & 0.629 & 0.63 & 0.3 \end{bmatrix} \mathrm{X} \begin{bmatrix} 0.08 \\ 0.1 \\ 0.25 \\ 0.24 \\ 0.18 \end{bmatrix} = \begin{bmatrix} 0.3145 \\ 0.079 \\ 0.4404 \end{bmatrix} \longrightarrow \textbf{\textit{Leanness Manufacturing System}}$$

The measures generated by the three stages of values were considered by experts or decision makers to be the main elements of each manufacturing system with respect to the lean, Agile or Leagile Supply Chain. This allowed us to find the most suitable manufacturing system based on the company performance so we could recommend suggested systematic improvements to the operation in each factory. (0.4404) was determined by multiplying the upper and lower levels and, finally, the last numerical rates, which related to the leanness factors for the company. This indicated the manufacturing system that should be focused on as the most important items, which could improve the efficiency of the manufacturing system and the structure of the company.

We applied this method to the other two enterprises as well. The final calculations for the second enterprise are as follows;

$$\begin{bmatrix} 0.33 & 0.26 & 0.68 & 0.53 \\ 0.53 & 0.61 & 0.21 & 0.11 \\ 0.093 & 0.069 & 0.092 & 0.313 \end{bmatrix} \mathrm{X} \begin{bmatrix} 0.5 & 0.44 & 0.53 & 0.53 & 0.3 \\ 0.16 & 0.31 & 0.11 & 0.2 & 0.2 \\ 0.19 & 0.058 & 0.18 & 0.139 & 0.12 \\ 0.09 & 0.172 & 0.1 & 0.06 & 0.18 \end{bmatrix} =$$

$$= \begin{bmatrix} 0.365 & 0.349 & 0.373 & 0.343 & 0.326 \\ 0.41 & 0.44 & 0.38 & 0.43 & 0.302 \\ 0.094 & 0.115 & 0.103 & 0.092 & 0.101 \end{bmatrix}_{3\mathrm{x}5}$$

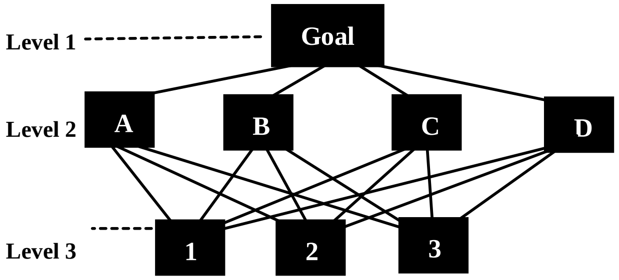

Figure 1. A Three-level AHP model.

After multiplying the matrix of sub-factors by the weighted index matrix, the results for the manufacturing system are as follows

$$\begin{bmatrix} 0.365 & 0.349 & 0.373 & 0.343 & 0.326 \\ 0.41 & 0.44 & 0.38 & 0.43 & 0.302 \\ 0.094 & 0.115 & 0.103 & 0.092 & 0.101 \end{bmatrix} \text{X} \begin{bmatrix} 0.038 \\ 0.162 \\ 0.23 \\ 0.14 \\ 0.34 \end{bmatrix} = \begin{bmatrix} 0.293 \\ 0.327 \\ 0.09 \end{bmatrix} \rightarrow \textit{Agile Manufacturing System}$$

After comparing the three manufacturing system, the best choice was the highest amount. The second scale indicates the agility of the system during manufacturing. For the third company, this was calculated in the same way as the first and second, as follows:

$$\begin{bmatrix} 0.643 & 0.575 & 0.158 & 0.6823 \\ 0.226 & 0.3428 & 0.56 & 0.216 \\ 0.1003 & 0.0785 & 0.263 & 0.0923 \end{bmatrix} \text{X} \begin{bmatrix} 0.27 & 0.5925 & 0.52 & 0.054 & 0.5 \\ 0.505 & 0.2275 & 0.245 & 0.505 & 0.305 \\ 0.129 & 0.2975 & 0.124 & 0.156 & 0.09 \\ 0.0425 & 0.11 & 0.056 & 0.26 & 0.087 \end{bmatrix} =$$

$$= \begin{bmatrix} 0.247 & 0.632 & 0.531 & 0.518 & 0.563 \\ 0.309 & 0.38 & 0.272 & 0.325 & 0.28 \\ 0.093 & 0.164 & 0.106 & 0.1074 & 0.1055 \end{bmatrix}_{3\text{x}5}$$

This was then multiplied by the weighted index matrix, as follows:

$$\begin{bmatrix} 0.247 & 0.632 & 0.531 & 0.518 & 0.563 \\ 0.309 & 0.38 & 0.272 & 0.325 & 0.28 \\ 0.093 & 0.164 & 0.106 & 0.1074 & 0.1055 \end{bmatrix} \text{X} \begin{bmatrix} 0.177 \\ 0.42 \\ 0.08 \\ 0.03 \\ 0.2 \end{bmatrix} = \begin{bmatrix} \mathbf{0.477} \\ \mathbf{0.298} \\ \mathbf{0.116} \end{bmatrix} \rightarrow \textit{Leagility Manufacturing System}$$

These results evaluated each enterprise's manufacturing system based on the analysis of various factors that affected the manufacturing systems in a hierarchical manner. The derived scales of the main elements in the adjacent cluster were based on the priority ranking for the manufacturing system used by each company. The Expert Choice Software generated the AHP results shown in Figure 3 where the leagile manufacturing system(0.477) for IMI had the best performance of the supply chain manufacturing systems tested (Agile and Lean Supply Chain).

DISCUSSION AND CONCLUSION

In this paper, we compared major indices such as the lead time, cost, quality, productivity and service level to analyze manufacturing system performance. These were the main criteria tested but other factors could test to determine their effects on performance in a systematic manner. We assessed the effects of these measures based on the opinions of decision makers and experts.

Our analysis allowed us to find the most suitable manufacturing system and to identify the needs of companies to promote their growth and survival in a supply chain system. These values were based on the opinions of decision maker so these factors were particularly relevant to the companies.

The most important goal was identifying the use of the functions and operations in the hierarchy of the model and determining how the main criteria were affected by alternatives. The rank of each criterion was evaluated and aggregated based on its importance to supply chain management depending on the expert opinions.

Thus, changes in the hierarchy or opinions would lead to changes in the outcomes. We used AHP to find the most suitable manufacturing system for each chosen company (according to expert opinions of the available factors and equipment, during the overall comparison). However, the results also indicated conflicts between the three manufacturing systems used by the companies. The general outcome was that the first system lost its agility by reducing some effective factors, although the lean supply chain was improved. In the second and the third companies, the service level was an important criterion that affected agility and leagility in the manufacturing systems. The lead time was reduced, which decreased the cost and improved the quality of products. However, reducing the lead time also eliminated more waste in the manufacturing supply chain.

Our model allowed us to identify the most suitable attributes for a manufacturing system to improve the supply chain management performance, while it is also identified the main elements and factors that could further affect the supply chain management. After considering the importance of each of the main criteria for the manufacturing system in supply chain, we found that the most important factors for lean manufacturing systems were cost, quality, and productivity Lead time was an important criterion in agile manufacturing systems and the service level was an important criterion in leagile manufacturing systems. To analyze the combined effects of the three supply chain performance determinants on the selection of the three alternatives we performed clustered by calculating the weightings of the supply chain system because the number of tables included four more matrices with additional pair-wise comparison, that is, one for each upper level determinant. The alternatives and determinants were also evaluated to determine their importance for improving the supply chain performance.

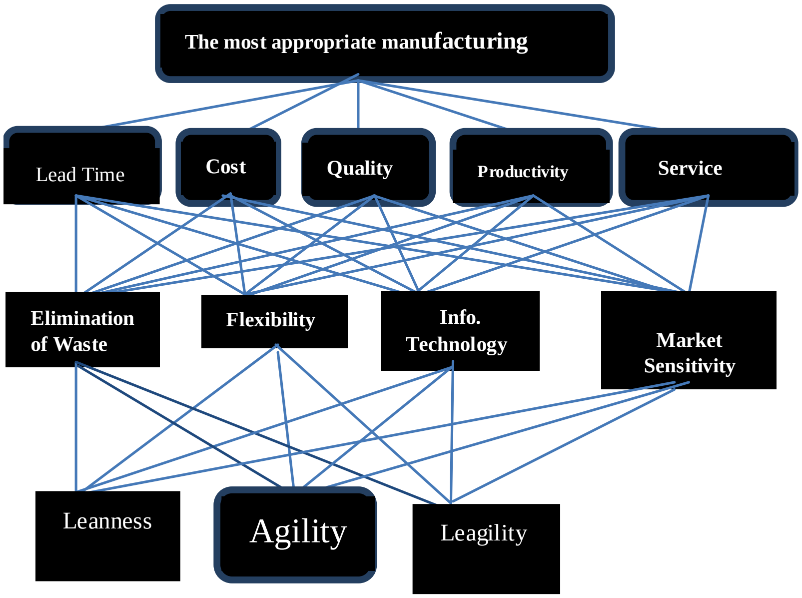

Figure 2. The three-level hierarchical model used in this study.

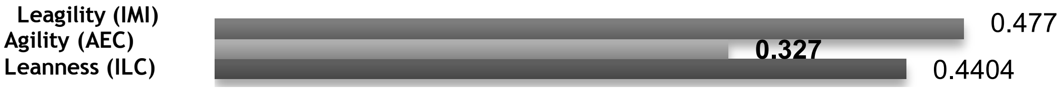

Figure 3. The results obtained using the Expert Choice Software.

The overall goal was to reduce the lead time and its score in lean was lower than that in the agile manufacturing system in the supply chain. Our analysis identified changes that would affect the supply chain manufacturing system with respect to the lean, agile, and leagile supply chain elements. Reducing the lead time meant that the lean supply chain had a lower score than the agile supply chain. The strategy used to decrease the cost and improve the quality meant that the lean supply chain was better than the other supply chain manufacturing systems. A leagile supply chain was more desirable for improving the service level and it had a higher rating than the agile supply chain.

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