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Evaluation of Lean Manufacturing Factors in ATO Industries, Case Study: Rose Fireplace Industry

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Abstract

Manufacturers need to optimize operations. One of the best solutions for optimizing is achieving the highest possible degree of adaptability to lean manufacturing characteristics. The basic lean manufacturing elements include production flow, organizing, process control, measurement and supporting. Among these elements, measurement is of special significance. Measurement in lean manufacturing refers to determining the rate of adaptability in a system with lean manufacturing characteristics and hence, determining the degree of compatibility with criteria and characteristics of lean manufacturing, so manufacturers should constantly assess the degree of adaptability of their systems to lean manufacturing criteria. Purpose– The purpose of this paper is determining ATO systems leanness. Most previous studies have been done in Manufacturing to Order and Manufacturing to Stock industries, while the present study has been done in Assembly to Order or ATO industries. Design/methodology/approach– In this study, using dimensional analysis approach has been presented model that calculate degree of adaptability to lean manufacturing characteristic in Assembly To Order industries. Findings– The case study of this research is relevant to Rose Fireplace Industry. In this regard, lean manufacturing factors were divided into 6 main factors and 35 sub-factors. Findings indicate the degree of adaptability of Rose Fireplace Assembly Industry to lean manufacturing characteristics is 0.744. Originality/value– In this paper, ATO systems degree of adaptability to lean manufacturing characteristics is considered.

Keywords: Lean manufacturing, manufacturing to order (MTO), manufacturing to stock (MTS), assembly to order (ATO), leanness, dimensional analysis approach.

Introduction

The concept of lean production has been well spread as a conceptual framework popularized in many industrial companies since the early 1990s[1]. The concept of lean production is a multi-dimensional approach that encompasses a wide variety of management practices. Lean, or waste reduction efforts, has been a prominent business strategy in the past two decades[2]. Intensification of competitive forces limits the ability of companies to simply mark up prices based on cost increases. It has made cost control, rather than pricing power, the driving force behind corporate profit margins and earnings growth[3].

There is relatively published empirical and scientific evidence about the implementation of lean practices and the factors that may influence implementation. Most of the papers on the topic of lean production system focus on the relationship between implementation of lean manufacturing and the performance[4]. The core thrust of lean production is that these practices can work synergistically to create a streamlined, high quality system that produces final products at the pace of customer demand with little or no waste[5].

An investigation on implementation of practices related to Just-In-Time (JIT), Total Quality Management (TQM), and Total Preventive Maintenance (TPM) programs has shown their impacts on operational performance[6]. Other interesting methodologies are the ones used in some management prizes (Society of Manufacturing Engineers, 2006). Conceptual research continues to emphasize the importance of empirically examining the effect of multiple dimensions of the lean supply chain[7]. Lean production is not confined to the activities occurring in the manufacturing process of a company. Instead, it relates to activities ranging from product development, procurement and manufacturing and distribution, forming the lean enterprise, directly related to the lean consumption[8]. In all the processes, the main concern is to find the critical value streams, to assure that value is added and waste is eliminated[9].

Manufacturers need to optimize operations, supply chains and capitalassets[10]. Facilitated by advances in information technology, the pursuit of optimization has intensified the demand for speed, flexibility, waste elimination, process control, people utilization and global reach to gain competitive advantages[11]. Recently, achieving this goal has become increasingly complicated due to the fast moving global market, budget cuts and capacity downsizing[10]. Hence, lean manufacturing has become a key approach to manage this complexity[11]. Toyota Production System has become the basis for much of the optimization that has dominated manufacturers

in their developments since the last decade[12]. The objectives vary, overlap and differ in their emphasis on different firmse.g., on lean production versus lean behavior[13]. Several studies have defined a portfolio of tools or techniques to implement lean manufacturing[14].

The basic lean manufacturing elements include production flow, organizing, process control, measurement and supporting[15]. Measurement in lean manufacturing refers to determining the rate of adoptability in a system with lean manufacturing characteristics. Therefore, this measurement is aimed at determining the percentage of system adaptability with lean manufacturing criteria[16].

Therefore, the main question of the research is "What is the rate of compatibility to lean manufacturing criteria and features in Assembly to Order industries? "In this article, using dimensional analysis method has been presented model that calculate degree of adaptability to lean manufacturing characteristic in Assembly to Order industries. As a case Study, to demonstrate the application of model, Rose Fireplace Industry which is one of the largest and most advanced leaders in fireplace industry is investigated.

The Research Literature

After publishing the results of "Int. Motor Vehicles Program" by Massachusetts Institute Technology, other studies have been introduced on the measurement of lean manufacturing factors. Here, some of the major research works are briefly reviewed.

Organizational assessment is another name that conducted by Padova University [17]. In this study, factors and characteristic of organizing labor has been studied from the perspective of lean manufacturing. One of the research works on lean manufacturing has been conducted by Archie Lockamy. This research shows the effect of performance measurement systems in selecting factories and manufacturing companies in the world. According to this research, the most important factor in failure of lean production is the lack of a standard performance measurement system. Repair and maintenance, logistic and support systems have been considered as important tools to reduce waiting time for product delivery to customer[18].

Another study has been performed in this field refers to the model for measuring the degree of leanness in manufacturing companies. This model is used for operationalization of lean manufacturing principals. In this research; variables such as removing waste, continuous improvement, zero defect, on time delivery, multi-function teams, decentralization and integration of activities, have been known as variables of lean manufacturing. The purpose of this study is to operationalize the concepts of lean manufacturing. This model evaluates the degree of leanness in manufacturing companies by focusing on management's commitments[19].

Among other research can be pointed to Machado and Pereira researches that a practical model has been presented to assess the rate of leanness supply chain at organizations by them. To evaluate the rate of leanness supply chain, the presented model focuses on 3 elements: designing manufacturing systems, controlling production systems and managing improvement at production systems. The presented model in this research has considered six factors including lean development factors, lean logistics, lean manufacturing, lean distribution, lean enterprise and lean consumption factor to determine the rate of leanness of supply chain. In this model, the emphasis is on customer participation, lean delivery and flexibility. In addition to customer participation, zero inventory principle is especially emphasized in implementing the principles of just in time manufacturing[20]. Also a consolidation model was proposed for small and medium sized systems to improve lean enterprises by Wilson and Roy. The purpose of this model has been indicated as cost saving, increasing production efficiency and reducing inventory levels in the small and medium-sized systems to improve lean logistics. This purpose finally leads to present a model called Double Freight Consolidation Model (DFCM). This model has been recognized as a profitable model to increase efficiency and reduce cost in the supply chain. In this research, full participation and corporation of customers, vendors, carriers and supporters have been introduced as essential elements for improving lean logistics and achieving successful lean logistics in small and medium-sized systems. Successful lean logistics depend on factors such as long-term participation, rapid exchange of information and knowledgeable salespeople[21].

Another study has been performed in this field refers to fuzzy systematic method. This method has been introduced to determine the leanness of manufacturing system by Bayou and Korvin. The proposed method is based on seven characteristics: being dynamic, objective, comprehensive, integrative, relative, and based on fuzzy logic. The main objectives of this research have been configured in two goals, determining the leanness of manufacturing system as well as developing a systematic method for measuring the leanness of manufacturing system. In this research, a case study has been done to determine the leanness of Ford Motor and General Motors. The results of this study demonstrate a 17% superiority of Ford Company compared to General Motors Company[22].

Among other research can be pointed to William M. feld researches. M. feld divided primary elements of Lean Manufacturing into 5 groups: production flow, organizing, documentation, procurement, process control and introduced overall 33 constituent elements of lean manufacturing. William M. feld discussed 25 main questions to evaluate companies and based on this scale, he evaluated the rate of adaptability to lean manufacturing characteristics in these systems.

Another study has been performed in this field refers to Nestle Company researches in United Kingdom[23]. This research points

to operational complexity of a lean manufacturing process. Continuous improvement and reformation of organizational culture has been announced as the most important factors in successful implementation of lean manufacturing. Another study confirming the findings of this research is the research work of Murray. Murray dissected the impact of training and team participation in continuous improvement. He suggested that the changing nature of the work is another important factor in achieving lean manufacturing [24]. Also another research work conducted by Warwick University and Massachusetts Institute Technology[25] provided self-assessment for lean enterprises. This method has emphasized on three factors: leadership, process lifetime, capability of foundation. In the next section will be to introduce dimensional analysis method as a method of determining the system degree of adaptability to lean manufacturing characteristics.

Presenting dimensional analysis approach: In this approach, presented by Willis and Houston, different features and characteristics of various sizes and significance convert to a single unit. Reforming this technique into the standard form, it can be used to assess the lean manufacturing main factors.

The initial model of this method was used by Willis and Huston in 1990 for choosing some suppliers as in equation-1

$$DA = \prod_{i=1}^{n} \left(\frac{x_i}{y_i} \right)^{wi} \quad (1)$$

Where W_i is the weight of each factor, X_i is performance criterion score of supplier No. 1, Y_i indicates performance criterion scoreof supplier No. 2 and n is the number of factors. Willis and Huston used the technique as a mathematical technique to compare two suppliers. If the result of the above equation is greater than 1, supplier No.1 will be selected, otherwise the choice is supplier No.2. In this model, to compare n suppliers of the model, n-1 comparisons should be made to identify the best supplier. In 1993, Willis improved the model and introduces equation-2 as follows:

$$DA = \sum w_i \sqrt{\prod_{i=1}^{n} \left(\frac{X_i}{Y_i} \right)^{w_i}} \quad (2)$$

In the equation above, the variables are the same as the initial model, except for Y_i which is the performance criterion score (Y_i=9). So, in this model, each supplier would be compared to the standard criterion. For determining the degree of adaptability of entire system, formula-3 is presented as follows:

$$DALean = \left(\frac{DOA_1}{DOA_{1s}} \right)^{w1} \times \left(\frac{DOA_2}{DOA_{2s}} \right)^{w2} \times \left(\frac{DOA_3}{DOA_{3s}} \right)^{w3} \times \left(\frac{DOA_4}{DOA_{4s}} \right)^{w4} \times \left(\frac{DOA_5}{DOA_{5s}} \right)^{w5} \times \left(\frac{DOA_6}{DOA_{6s}} \right)^{w6} \quad (3)$$

In the next section, as Case Study, rate of leanness for Rose Fireplace Industry is calculated by dimensional method.

Case Study: Calculation of rate of leanness for Rose Fireplace Industry

The case study of this research has been conducted in Rose Fireplace Industry. This industrial unit produces a variety of fireplaces and its subsets. Rose Fireplace Industry is supplier of various types of cast iron designed fireplaces and different types of stone fireplace. Assembling the three components of fireplace is provided based on customer's order, so Rose Fireplace Industry is an Assembly to Order Industry.

After several meetings with effective experts and managers, a questionnaire consisting of main criteria and sub criteria of lean manufacturing was designed. To determine the leanness of Rose Fireplace Industry, 6 main criteria and 35 sub criteria were set. The main factors include information technology, supply chain management, purchasing and logistics system, organization and leadership, marketing and sales system and quality management system factors and 35 sub criteria of subsets were configured as described in table-1 to 6.

Table-1
Sub factors of information technology system

Evaluation factors of " information technology system"
intelligence of information system
Internet and network services
Information transmission with suppliers
Centralization of customers information and suppliers at a point
Information transmission with suppliers

Table-2
Sub factors of supply chain management system

Evaluation factors of "supply chain management system"
Organization relationship with suppliers
Coordinating power of suppliers
Stable cooperation of suppliers
Number of suppliers
Self-inspection of suppliers
Suppliers interval

Table-3
Sub factors of purchasing and logistics systems

Evaluation factors of "purchasing and logistics systems"
Despite the technical specification for purchasing items
Quality control of items and product method
Preferred quality over price
Material and products transport system
Commodity classification system
Integration supplier system

Table-4
Sub factors of organization and leadership systems

Evaluation factors of "organization and leadership systems"
Strategic planning
Staff participation
Perspective of human resource management
Power of concentrating and decision making
Integration of operations
Continuous Improvement
Management attitude to training

Table-5
Subfactors of marketing and sales system

Evaluation factors of "marketing and sales system"
Sales force automation
Marketing automation
Customer satisfaction evaluation
Customer relationship management
Customer service management
Product development(a structure to development and marketing growth)

Table-6
Subfactors of quality management system

Evaluation factors of " quality management system"
Inspection of items and products method
Inspection during assembly
Using statistical process control technique
Utilizing the ISO series of standards
Applying the principles of quality assurance

In the next step, the paired comparisons and scoring are developed to determine weight and also the score of main and sub factors by all managers and effective experts. Table-7 indicates the weight of sub factors and table-8 indicates the weight of main factors. Average scores of sub-factors are shown in table-9, too. It should be noted that weight of sub factors is determined based on paired comparisons done by experts and efficient managers and average score of sub factors is presented by all experts and effective managers. The average score for each sub factor has been applied as X_i in Willis method. To determine the higher or lower priority of each sub factor, paired comparison has been performed with the scale of respectively 9 to 1/9.

In the final step, the degree of adaptability of main factors to lean manufacturing characteristics has been calculated based on the equation-2, using tables-7,9 as follows:

DA (Information Technology) = 0.700, DA (Supply Chain Management) = 0.733, DA (Organize and Leadership) = 0.749
DA (Procurement Management) = 0.735, DA (Quality Management) = 0.746, DA (Marketing and Sales) = 0.764

Also, the degree of adaptability of entire system to lean manufacturing characteristics has been calculated based on the equation-3, using table-8 as follows:

DA Total =0.744

It should be noted that in equation-2, the total weight of sub factors for a main factor equals 1. In the next section, the validation of model is discussed.

Model validation: Model validation is an important process coming before analyzing the outputs of a model. If the model is invalid, decisions made based on the outputs could not be valid[26]. There are many techniques to validate models, such as: degenerate tests, event validity, face validity, internal validity, validation by comparing with a previously validated model, Experts validation and etc.[27]. In this study, as validation method, experts would determine the validity of the model. After determining the compatibility of lean manufacturing factors in Rose Fireplace Industry, marketing and sales system, organization and leadership system, quality management system, procurement management system, supply chain management system and information technology system were respectively ranked first to sixth[28]. For determining the validation of model, these results were presented to experts and effective managers. Expert group opinion demonstrates the accuracy and validity of results[29]. This means, from the view of expert group, marketing and sales system, organization and leadership system, quality management system, procurement management system, supply chain management system and information technology system are the first to sixth place of importance in achieving lean manufacturing characteristics[30]. Expert group opinion exactly confirms the results of implementing dimensional analysis model in Rose Fireplace Industry. Most important results of the study are presented as conclusions and future research suggestions in next section.

Conclusion

The results of dimensional analysis method have been developed based on main factors in Rose Fireplace Industry Indicate the degree of adaptability of this system to lean manufacturing characteristics is 0.744.

Table-7
Weight of sub factors of main factors based on paired compressions

Sub factors of information technology system	Weight of the factor based on paired compression	Sub factors of supply chain management system	Weight of the factor based on paired compression	Sub factors of purchasing and logistics system	Weight of the factor based on paired compression	Sub factors of organization and leadership system	Weight of the factor based on paired compression	Sub factors of marketing and sales system	Weight of the factor based on paired compression	Sub factors of quality management system	Weight of the factor based on paired compression
Intelligence of information system	.245	Organization relationship with suppliers	.291	Despite the technical specification for purchasing items	.372	Strategic planning	.388	Sales force automation	.297	Inspection of items and products method	.423
Internet and services via network	.334	Coordinating power of suppliers	.045	Quality control of items and product method	.131	Staff participation	.057	Marketing automation	.251	Inspection during assembly	.169
Information transfer with suppliers	.217	Stable cooperation of suppliers	.330	Preferred quality over price	.283	Perspective of human resource management	.082	Customer satisfaction evaluation	.077	Using statistical process control technique	.069
Focusing customers information and suppliers at a point	.091	Number of suppliers	.039	Material and products transport system	.063	Power of concentrating and decision making	.269	Customer relationship management	.102	Utilizing the ISO series of standards	.169
Information transfer with customers	.114	Self-inspection of suppliers	.075	Commodity classification system	.031	Integration of operations	.096	Customer service management	.079	Applying the principles of quality assurance	.170
		Suppliers interval	.321	Integration supplier system	.122			Continuous Improvement	.055	Product development(a structure to development and marketing growth)	.193
								Management attitude to training	.051		

Degree of adaptability of marketing and sales factor is 0.764 and this factor has the maximum rate of adaptation to lean manufacturing characteristics and information technology factor has the minimum rate of adaptation. Also organization and leadership, quality management, purchasing and sales management and supply chain management factors with adaptation rate of .749, .746, .735, .733 are respectively in second to fifth place of adaptability to lean manufacturing characteristics. Result of this research proves high accuracy, validity, efficiency and delicacy of model in determining the rate of leanness in a system. Case study of the research has been done in Rose Fireplace Industry relevant to Assemble to Order (ATO) industries. Future researches works can use the current method to determine the rate of leanness in Make to Stock (MTS), Make to Order (MTO) and Engineer to Order (ETO) industries.

Table-8
Weight of main factors based on paired comparisons

Main factors	Weight of factors
Information technology system	.048
Supply chain management system	.203
Purchasing and logistics system	.159
Organization and leadership system	.248
Marketing and sales system	.216
Quality management system	.217

Table-9
Average scores of sub-factors

Sub factors of information technology system	**Weight of the factor based on paired compression**	**Sub factors of supply chain management system**	**Weight of the factor based on paired compression**	**Sub factors of purchasing and logistics system**	**Weight of the factor based on paired compression**	**Sub factors of organization and leadership system**	**Weight of the factor based on paired compression**	**Sub factors of marketing and sales system**	**Weight of the factor based on paired compression**	**Sub factors of quality management system**	**Weight of the factor based on paired compression**
Intelligence of information system	5.75	Organization relationship with suppliers	7.75	Despite the technical specification for purchasing items	7.33	Strategic planning	6.75	Sales force automation	7.67	Inspection of items and products method	6.33
Internet and services via network	7.25	Coordinating power of suppliers	5.25	Quality control of items and product method	8.67	Staff participation	8	Marketing automation	8.33	Inspection during assembly	8
Information transfer with suppliers	6.25	Stable cooperation of suppliers	7.5	Preferred quality over price	7.33	Perspective of human resource management	5.25	Customer satisfaction evaluation	6.67	Using statistical process control technique	2.67
Focusing customers information and suppliers at a point	4.5	Number of suppliers	5	Material and products transport system	5.67	Power of concentrating and decision making	8	Customer relationship management	3.33	Utilizing the ISO series of standards	7.67
Information transfer with customers	6.75	Self-inspection of suppliers	8.25	Commodity classification system	7.67	Integration of operations	7	Customer service management	3.67	Applying the principles of quality assurance	8.33

Sub factors of information technology system	**Weight of the factor based on paired compression**	**Sub factors of supply chain management system**	**Weight of the factor based on paired compression**	**Sub factors of purchasing and logistics system**	**Weight of the factor based on paired compression**	**Sub factors of organization and leadership system**	**Weight of the factor based on paired compression**	**Sub factors of marketing and sales system**	**Weight of the factor based on paired compression**	**Sub factors of quality management system**	**Weight of the factor based on paired compression**
		Suppliers interval	4.5	Integration supplier system	3	Continuous Improvement	7.5	Product development(a structure to development and marketing growth)	8.67		
						Management attitude to training	2.75				

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