# 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.

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**Key words:** 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 (Womack et al. 1990; Womack and Jones, 2003). 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 (Ohno, 1988; Standard and Davis, 1999; Womack et al. 1990). 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 (Cooper, 2007).

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 (White et al. 1999; Dahlgaard, 2006; Samson and Terziovski, 1999; McKone et al. 2001; Flynn et al. 1995). 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 (Shah and Ward, 2003).

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 (Cua et al. 2001). 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 (Mistry, 2005; Womack and Jones, 2005). 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 (Achanga et al. 2006; Womack and Jones, 2005). In all the processes, the main concern is to find the critical value streams, to



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assure that value is added and waste is eliminated (Rother and Shook, 2003).

Manufacturers need to optimize operations, supply chains and capital assets (Pagatheodrou, 2005). 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 (Moore and Gibbons, 1997; Allway and Corbett, 2002; Pagatheodrou, 2005). Recently, achieving this goal has become increasingly complicated due to the fast moving global market, budget cuts and capacity downsizing (Pagatheodrou, 2005). Hence, lean manufacturing has become a key approach to manage this complexity (Liker, 1998). Toyota Production System has become the basis for much of the optimization that has dominated manufacturers in their developments since the last decade (Liker, 1998; Hall, 2004). The objectives vary, overlap and differ in their emphasis on different firms e.g., on lean production versus lean behavior (Emiliani, 2000). Several studies have defined a portfolio of tools or techniques to implement lean manufacturing (Rother, 1998; Hines and Taylor, 2000; Emiliani, 2000; Sullivan, 2002).

The basic lean manufacturing elements include production flow, organizing, process control, measurement and supporting. 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 (Hayes et al. 1988).

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 "International 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 (Biazzo and Panizzolo, 2000). 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 (Lockamy, 1995).

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 & 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 (Horacio and Merida, 2002).

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 (Machado and Pereira, 2009). 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



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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 (Wilson and Roy, 2010).

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 (Bayou and Korvin, 2008).

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 (Amerald Group, 2004). 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 (Murray, 2003). Also another research work conducted by Warwick University and Massachusetts Institute Technology (Massachusetts institutes of technology and university of Warwick, 2001) 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 Eq. (1):

$$^{1}\,DA = \prod_{i=1}^{n}\left(\frac{x_i}{y_i}\right)^{w_i} \qquad (1)$$

Where $W_i$ is the weight of each factor, $X_i$ is performance criterion score of supplier No. 1, $Y_i$ indicates performance criterion score of 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 Eq. (2) as follows:

$$DA = \sqrt[\Sigma w_i]{\prod_{i=1}^{n}\left(\frac{X_i}{Y_i}\right)^{w_i}} \qquad (2)$$

[1]-Degree of Adaptability



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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 No. 3 is presented as follows:

$$DA_{Lean} = \left(\frac{DOA_1}{DOA_{1s}}\right)^{w_1} \times \left(\frac{DOA_2}{DOA_{2s}}\right)^{w_2} \times \left(\frac{DOA_3}{DOA_{3s}}\right)^{w_3} \times \left(\frac{DOA_4}{DOA_{4s}}\right)^{w_4} \times \left(\frac{DOA_5}{DOA_{5s}}\right)^{w_5} \times \left(\frac{DOA_6}{DOA_{6s}}\right)^{w_6} \quad (3)$$

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 & logistics system, organization and leadership, marketing & 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 |



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**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 & scoring are developed to determine weight and also the score of main & 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 & efficient managers and average score of sub factors is presented by all experts & 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.

**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 | | | | |



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**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 |
| | | 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 | | | | |

In the final step, the degree of adaptability of main factors to lean manufacturing characteristics has been calculated based on the Eq. (2), using Tables (7, 9) as follows:

$$DA_{(\text{Information Technology})} = 0.700 \qquad DA_{(\text{Procurement Management})} = 0.735$$

$$DA_{(\text{SupplyChain Management})} = 0.733 \qquad DA_{(\text{Quality Management})} = 0.746$$

$$DA_{(\text{Organize \& Leadership})} = 0.749 \qquad DA_{(\text{Marketing\& Sales})} = .764$$



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Also, the degree of adaptability of entire system to lean manufacturing characteristics has been calculated based on the Eq. (3), using Table (8) as follows:

$$DA_{Total} = .744$$

It should be noted that in Eq. (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. 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. 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. 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. 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. 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 and future researches**

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. 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.

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