# The Study of Lean Production's Maturity and Improving Rating

**Jun Li, Meng-yi Qiu, Fu-xing Zhang, and Xiao-Li Wei**

**Abstract** Based on the concept of lean production, considered from the enterprise culture, people, production, environmental, we firstly proposed the concept of lean production maturity. Secondly, we adopt logic curve and distance synthesis rules, and come up with equations which can measure the maturity level of the enterprise lean production and promote the improving rating of the implementation of lean production mode. We apply this formula to make the enterprise not only understand their status of lean production, but also know the gap with goals and problems. Then we targeted improvement strategy.

**Keywords** Determination of the level • Improving strategy • Lean production • Maturity degree

## 1 Questions Suggested

Facing the intense market competition environment, the lean production, derived from Toyota, was hailed as the third mode of production after manual production and assembly line production. Many companies at home and abroad followed. It is still weak that how to measure implementation capabilities and effects to promote lean production continued to advance and how to establish a lean management system. According to the retrieval of literature, mostly studies were from production indicators and financial evaluation, they are emphasis on short-term results and ignore the developing laws of lean production and implementation training. Finally, it leaded most companies to push the lean production spectacularly for some time, and back to before, and then pushed over and over again, as an enterprise get out

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of the circle (Zhang Hongliang 2010; Yan Jun and Li Xinghuan 2001; Dymond 1995; Nightingalea and Mizeb 2002). Therefore, it became an important worthy study that how to measure the development of enterprise lean stage, find problem, suggest the direction for improvement, improve the company's lean production. On this issue, we combine logical curves and the law of lean development and describe the dynamic development and improvement process that the enterprise lean production is from disorder to order by maturity. It will format an upgrading maturity curve to lead the enterprises continually identify problems in implementing lean manufacturing. It guided the enterprises make appropriate improvements about the maturity in the different stages of carrying on lean production. The enterprise will eventually establish their own lean production management system through orderly circulation. The purpose is to explore the aims of Chinese enterprise promoting lean production mode and the coordination problems of tasks. We hope the discuss the problems with peers.

## 2 The Concepts of Lean Production Maturity and Level Determination

### *2.1 The Concepts of Lean Production Maturity*

Maturity is a quantitative concept which measures the gap between assessing object and the reference standard to determine their growth stages, and propose appropriate improving strategies. We defined lean production maturity which refers to the implementing capacity of enterprise lean and developing stage. It is a comprehensive indicator to assess the enterprise's entire implementation capabilities and management level. The study aims to fully and systematically reflect the effects and stages of lean implementation and helps the enterprise to find the problems and improving directions in lean production, which avoid blindness and conformity in the process of lean production promoting. It is because that the lean production is a systematic project, not just an application of lean manufacturing methods to get an immediate effect in the short term. It will need a long period of gradual and orderly progress. Therefore, we must implement and evaluate lean production from the entire height.

### *2.2 Determining the Maturity Level of Lean Manufacturing*

Deborah J. Nightingale and Joe H. Mize refer enterprise level Transition to Lean (TTL) (Liu Zeshuang et al. 2008; Bayou and Korin 2008; Yoshiki Matsui 2007) Roadmap in their works. We translated this figure as shown in Fig. 1, which reflects the characteristics of lean gradual and phased. And implementing lean production

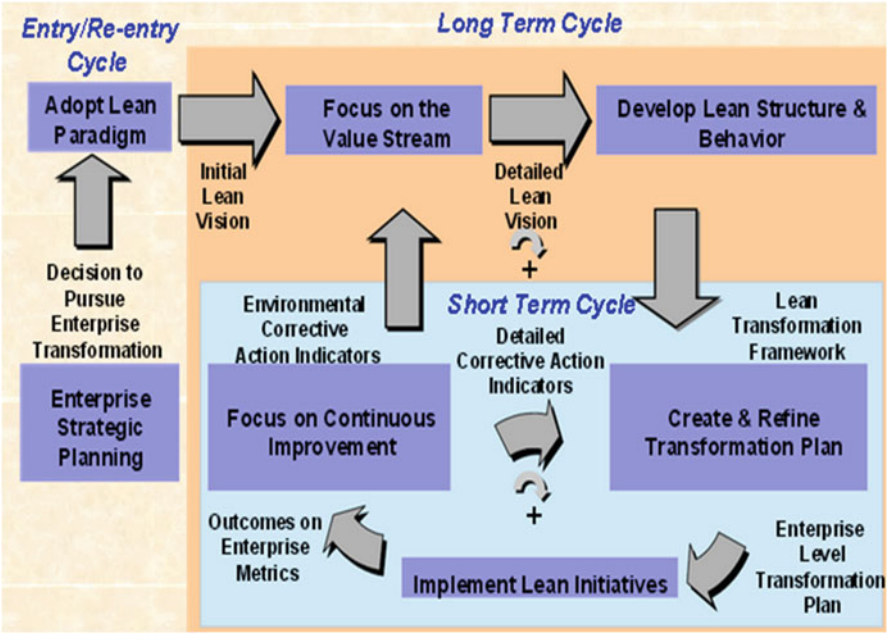



**Fig. 1** Enterprise level Transition to Lean (TTL) roadmap

**Table 1** Lean production maturity level definitions

| Lean production maturity level definitions | |
|---|---|
| Level 1 | Understanding lean; improving activities are sporadic, most fields are in infancy |
| Level 2 | Have a general sense of lean, some informal improving activities get certain effects and maintained |
| Level 3 | The enterprise applied systematical lean methods, have measurement standard, improving activities are well maintained |
| Level 4 | The enterprise developed continuous improving stage and got improving earnings |
| Level 5 | Lean has been a clear definition and was extended in the entire enterprise value flow (The enterprise value chain and supply chain). Lean activities are gotten well continued implementation |

can be divided into four stages: lean spot, lean factory, lean value and lean mode. Combining the feature of these stages, we divided the lean maturity process into five levels, showed in Table 1. Lean production maturity level used to measure the lean maturity and evaluation of enterprise capabilities, which provide guidance for the enterprise improvement process.

# 3 Lean Production Maturity Related Calculations

## *3.1 Maturity Curve Model*

In biological research, the law curve of things' development is firstly slow increasing, then fast growing and last becoming stable. Lean enterprise also fits this logistic curve. Lean production maturity is measured according to the maturity curve. Maturity curve is implementing ability function which is showed that the track of the lean production ripening period. The ideal of the maturity curve is a straight line, but in reality, S - shaped curve is better to describe its real growth. Lean production maturity defined [0, 1], which is quantified its extent by continuous value. "0" is completely immature, "1" means a fully grown.

### 3.1.1 Maturity Calculation of the Ideal Curve

The ideal Curve is a straight line, assume m lean time points, the capacity of implementation in i time point is $X_i$, The maturity of the $Y_i$ can be expressed as:

$$Y_i = aX_i + b, \quad i = 1, 2, \ldots, t \tag{1}$$

*Xmax = max{Xi}, Xmin = min{Xi}; When implementation of the capacity is Xmin, its maturity is Yo, Yo value in (0,1),When implementation of the capacity is Xmax, its maturity is 1,(Xmin,Yo), (Xmax,1) into equation (1) solutions:*

$$\begin{cases} a = \dfrac{1 - Y_0}{X - X_{\min}} \\ b = Y_0 - \dfrac{(1 - Y_0)\, X_{\min}}{X_{\max} - X_{\min}} \end{cases} \tag{2}$$

Type the formula (2) into the formula (1) obtained following maturity of formula:

$$Y_i = Y_0 + (1 - Y_0)\, \frac{X_i - X_{\min}}{X_{man} - X_{\min}}, \qquad i = 1, 2, \cdots, t \tag{3}$$

According to formula (3) drawn the lean production straight maturity curve shown in Fig. 2.

### 3.1.2 The Maturity of the S-Type Maturity Curve Calculation

The characteristics of the S-shaped curve is decreased at first and then increased, There are many functions can be expressed as such a shape, This paper introduces the demographer Pearl Ray of Model logic curve (Rachna and Ward 2007; Melton

**Fig. 2** Linear maturity curve

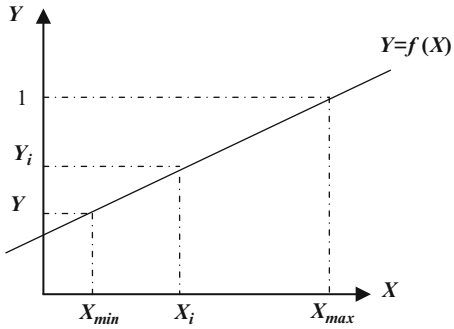
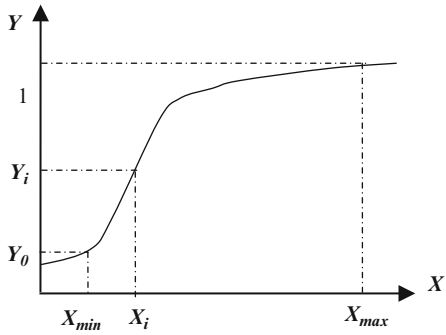



**Fig. 3** S-type maturity curve




2005; Jan Kosturiak and Milan Gregor 1999; Altinkilinc 2004). The logic curve is a commonly used form of the growth curve, It can also be applied to the maturity curve form, The mathematical model is:

$$N(t) = \frac{K}{1 + \left(\frac{K}{N_0} - 1\right) e^{-rt}} \tag{4}$$

$$\begin{cases} \dfrac{dN}{dt} = r\left(1 - \dfrac{N}{K}\right) N \\ N(0) = N_0 \end{cases} \tag{5}$$

In the formula (t) represents the number of population at time t, $N_0$ represents the population at t = 0, represents the net population relative growth rate, K represents the population growth of a stable equilibrium value.

$$N(t) = Y_i, \quad N_0 = Y_0, \quad r = (1 - Y_0) / (X_{\max} - X_{\min}), t = X_i - X_{\min} \tag{6}$$

The maturity of s-shaped curve under the condition of lean production maturity Yi point to formulas (7), Maturity curve of the S-type is represented graphically as Fig. 3.

$$Y_i = \frac{K}{1 + \left(\frac{K}{Y_0} - 1\right) e^{-\frac{(1-Y_0)(X_i - X_{\min})}{X_{\max} - X_{\min}}}}, \qquad i = 1, 2, \cdots, t \tag{7}$$

This formula is applied to each lean dimension synthesis overall lean enterprise maturity level, Respectively [0, 1] is divided into five levels. It's worth noting that If the enterprise maturity is lower than 0.4 in any dimension, The whole enterprise lean maturity rating level 1. Overall the lean maturity level is not the average, How it is assessed through lean manufacturing concepts continuously applied to all key dimensions for corporate ratings (CMMI-SE/SW 1999; Dymond 1995; Koufterors et al. 1998).

### *3.2 Determination of Dimensions of Lean Production Maturity*

J dimensions factors assuming the implementation capacity of lean production maturity, In order to determine the lean maturity, Need through some method and logical rules to the implementation of the j dimension synthesis capability maturity across the enterprise lean implementation capability maturity. Let Y (i) indicates the i point in time Lean maturity value, Yj (i) represents the value of the j dimension maturity.

Lean enterprise in this paper, divided into four dimensions to determine the ability to implement degree of maturity: lean culture, human factors, lean basis for protection, lean manufacturing process. Lean culture is divided into cultural awareness, continuous improvement. Lean basis for protection of the people is divided into site management, standardized operation, t corporate environmental adaptability; Lean manufacturing process is divided into flexible process, TPM, quality and the error correction, rapid change, billboards, balanced production, As shown in Fig. 4. Through the four dimensions to measure their implementation capacity, Can multiple perspectives to evaluate the implementation of enterprise lean, cost and production targets than before, and better reflects the concept and connotation of lean.

## 4 Lean Manufacturing Implementation Gaps and Measurement of Enhancing Rate

### *4.1 A Coefficient of Variation*

In order to arrive at lifting scheme, it need to calculate the coefficient of variation of the maturity of the enterprise. After calculate the lean maturity value by the

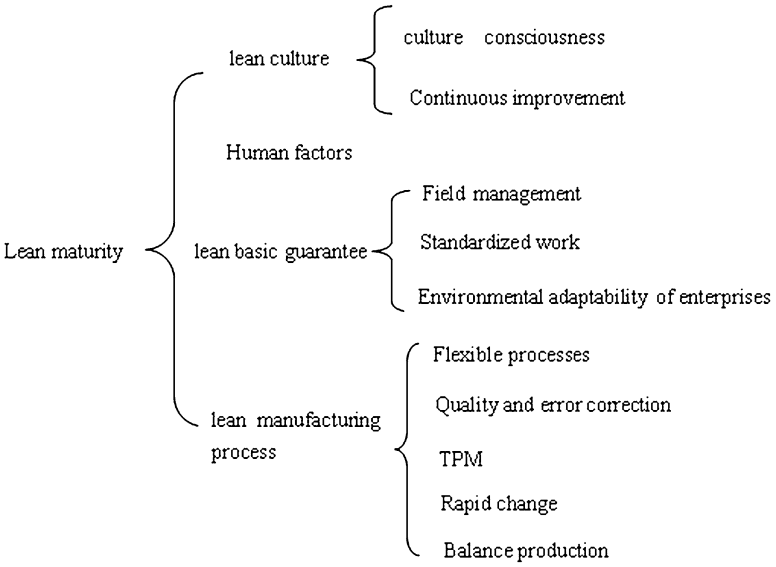



**Fig. 4** Maturity determination of dimensions

above formula, in accordance with the following formula to calculate their maturity coefficient of variation:

$$\alpha_j(i) = \frac{Y_j(i) - Y(j)}{Y(j)} \qquad j = 1, 2, 3, 4, \quad i = 1, 2, \ldots t \tag{8}$$

In formula (9), αj (i) is coefficient of variation of the i-th enterprise and j-th coefficient of variation of dimension.

## *4.2 Degree of Deviation*

The lean production Maturity degree of deviation is a measure of the overall lean implementation, the average degree of deviation of each dimension of maturity, using the following formula:

$$\alpha(i) = \sqrt{\frac{1}{4}\sum_{j=1}^{4} \alpha_j^2(i)} \qquad i = 1, 2, \ldots \mathrm{t} \tag{9}$$

In the formula (9), alpha (i) indicates the degree of deviation of the maturity of i-th time points.

### 4.3 The Degree of Lean Coordination

Lean coordination refers consistent degree of maturity of the entire system dimension, represented by the β(i) is calculated as follows:

$$\beta(i) = 1 - \alpha(i) \qquad i = 1, 2, \ldots, \mathrm{t} \tag{10}$$

Assessed the short board of the system by degree of deviation and coordination, in order to determine the appropriate rate for improvement drawn to the program of enhance.

### 4.4 Rate of Enhance of Lean Maturity

Using the following formula to show the rate of enhance of Lean maturity:

$$\mu(i) = \frac{\Delta Y(i)}{Y(i)} \qquad i = 1, 2, \ldots \mathrm{t} \tag{11}$$

Wherein, μ (i) represents the i-th rate of enhance of Lean maturity, ΔY(i) represents the absolute value of i-th rate of enhance of Lean maturity.

### 4.5 Rate of Enhance of Dimensions Maturity

Using the following formula to show the rate of enhance of dimensions maturity:

$$v_j(i) = \frac{\Delta Y_j(i)}{Y_j(i)} \qquad i = 1, 2, \ldots \mathrm{t} \tag{12}$$

Wherein, $v_j(i)$ is the j-th dimension's maturity enhancing rate in the i-th enterprise. $\Delta \mathrm{Y_j}(i)$ is the elevated absolute value of the maturity of the i-th enterprise j dimension. νj(i),ν(i) s smaller, and therefore:

$$v(i) \approx \frac{1}{4} \sum_{i=1}^{4} v_j(i) \qquad i = 1, 2, \ldots t$$

### *4.6 The Synthesis of Lean Production Overall Maturity*

According to the addition rules, in the i-th enterprise lean production maturity synthetic function:

$$Y(i) = \sum_{j=1}^{4} \rho_j Y_j(i) \qquad i = 1, 2, \ldots, 30$$

Of which the weight coefficient $\rho_j$ is determined by the coefficient of variation, according to the following method to determine it.

1. Calculate the mean and standard deviation for each dimension of maturity:
   mean value:

$$\overline{y_j} = \frac{1}{n} \sum_{i=1}^{n} y_j(i)$$

$$\overline{S}_j = \frac{S_j}{\overline{Y}_j} \qquad j = 1, 2, 3, 4$$

   Standard Deviation: $s_j = \sqrt{\dfrac{\sum_{i=1}^{n} \left(y_j(i) - \overline{y_j}(i)\right)^2}{n-1}}$
2. Calculate the coefficient of variation:
3. Calculated weight coefficient:

$$\rho_j = \frac{\overline{S}_j}{\sum_{j=1}^{4} \overline{S}_j} \qquad j = 1, 2, 3, 4$$

According to the above data analysis, reflect the entire enterprise need to take appropriate measures to enhance lean maturity and strengthening items, formulate corresponding improvement measures, to ensure that the improvements implemented correctly, provide the basis for the smooth implementation of Lean.

## 5 Conclusion

The establishment of enterprise lean management model is a complex systems engineering, which cannot be achieved overnight, especially facing competition in the global market now, Small and medium-sized manufacturing industry of our

country must see opportunities and challenges. We must adopt the scientific method, design implementation plan according to the characteristics of the enterprise and improve the strategy. This paper proposed maturity of lean production, enhance the measurement and the calculation formula, which help the implementing lean manufacturing enterprises to continue to promote the improvement and establishment of lean management system. This research is an exploration, and the effectiveness of its application also needs to be further tested in practice.

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