Chapter 12
Decision of Planning Input for Make-to-Order System

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Abstract Decision of planning input for make-to-order system based on learning rate is researched in the paper, affect of employee learning rate on the qualified rate in the manual operating system is analyzed and characteristics of the qualified rate' s random fluctuation under the changing production condition are studied. We propose that the random fluctuation of qualified rate is determined by different requirements in specifications, technical difficulties, materials of make-to-order and the random uncertainty characteristics of the production system itself. Considering of affects of learning rate and random factors on the qualified rate, a model of decision-making of planning input is established with the objective to minimize the total expected expenses composed of the costs about excess output, output gaps and scrap losses. By simulating with MathCAD, it is proved that there is an optimal input as customers' orders are certain.

Keywords Learning rate • Planning input • The qualified rate • Make-to-order

Researches Status Review

In the fierce market competition, it has become very important for enterprises to win customers' orders whether enterprises can completely meet customers' demand by delivering accurately their orders on time. In the traditional production plan management people pay more attention to delivery date and product quality, but there are few researches about how to determinate rational planning input in order to ensure accurate delivery with low cost and high benefit according to customers' demand. It is necessary for enterprises to make a reasonable decision of planning

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input according to the features of production systems and the characteristics of customers' orders considering of customer requirements and enterprise cost.

In 1936, Wright T. proposed the first learning curve when he studied that the tact time gradually decreased with the increasing of production number in the plane production (Wright 1936). Then learning curve is widely used in workers choose, quality control, plan, cost control and so on (Zhou zhantao and Li li 2006; Tian yungang 2003; Chen zhixiang 2007). Pan et al. (2008) established two models of the customer demand for the normal distribution and average distribution with the objective of the total cost minimization and studied the relation between learning curve and order batches, insurance inventory, lead time. Anzanello and Fogliatto (2007) put forward to categorize by product similarity and determine the learning curve of each group according to the customization features. Jaber and Guiffrida (2008) researched the production system which can be disrupted when there existed produced rework, and constructed several new quality learning curve to guide the production process quality control. There are many researches of learning curve and their extended field (Liu and Qi 2006), but its application in make-to-order produce system is not yet discovered. In the research of planning input Zhang bixi and Songjing (2008) has studied the planning input of make-to-order produce system and constructed the corresponding decision model (Zhang bixi and Songjing 2008). Michael A. Lapre based on the organization learning literature, derive a quality learning curve that links different types of learning in quality improvement projects to the evolution of the factory's waste rate (Lapre et al. 2000).

This paper studies the decision of planning input for make-to-order system based on learning rate and the random fluctuation of the qualified rate.

The Model of Decision of Planning Input Regardless of Learning Rate

The production cost decided the benefit of enterprises when customers' orders are certain. Therefore, the decision-making model of planning input is built with the objective to minimize the production cost as follows:

Define: D = the demand of customers; F = unit fee of input setup; C_q = unit rearrangement cost of shortage; C_g = unit disposal cost of excess; C_r = unit disposal cost of the unqualified products; P = planning input; r = the qualified rate of products (Assuming it is normally distributed);

$R(r) = \frac{1}{\sigma\sqrt{2\pi}} e^{\frac{(r-\mu)^2}{2\sigma^2}}$, R(r) is the probability density function of r

u = the median of the qualified rate of the product

Respectively the loss of excess and shortage are calculated as follows:

1. the expected loss of excess:

$$\begin{cases} W(P) = \int_{\frac{D}{P}}^{1} \left[C_g(rP - D) + C_r(1 - r)P\right] R(r)dr \\ st.\ rP \geq D \end{cases} \tag{12.1}$$

2. the expected loss of shortage:

$$\begin{cases} S(P) = \int_{0}^{\frac{D}{P}} \left[C_q(D - rP) + C_r(1 - r)P + F\right]R(r)dr \\ st.\ rP \leq D \end{cases} \tag{12.2}$$

3. Object to minimize the total excepted loss, the model of planning input is as follows:

$$\begin{cases} Min\ E(P) = \min \ (W(P) + S(P)) \\ st.\ P \geq 0, \quad \mathrm{r} \geq 0 \end{cases} \tag{12.3}$$

Case: There is one enterprise which got one order: $D = 600$ T; $C_g = 120$ yuan/t; $C_q = 180$ yuan/t; $C_r = 100$ yuan/t; $F = 2{,}000$ yuan/unit; $r = 0.6 \sim 1$; $\mu = 0.8$; $\sigma = 0.2$.

Using MathCAD to calculate Eqs. (12.1), (12.2), and (12.3), we get the expected loss curve of excess and shortage in Fig. 12.1 and the total expected loss curve in Fig. 12.2. At the same time we find the optimal planning input is 780 t and the minimum expected loss is 12,070 yuan.

The Model of Decision of Planning Input Considering of Learning Rate

In manual operation system, workers proficiency has a direct impact on the qualified rate of unit product, in other words, the qualified rate will raise if production repetitions increases. In manual operation system the unit qualified rate is affected by systemic growth trend and fluctuations caused by random factors of system. According to learning curve, we suppose the unqualified rate of the product x is: $S_1 x^{\frac{\log b}{\log a}}$, The qualified probability is:

$$h_x = 1 - S_1 x^{\frac{\log b}{\log a}} \tag{12.4}$$

h_x = the qualified probability of the product x; S_1 = the qualified probability of the first product; b = Learning coefficient (The smaller the value of b the better the learning); a = constant; x = Output (production repetitions);

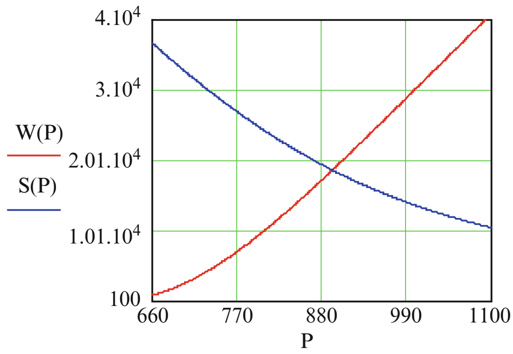


Fig. 12.1 The expected loss curve of excess and shortage

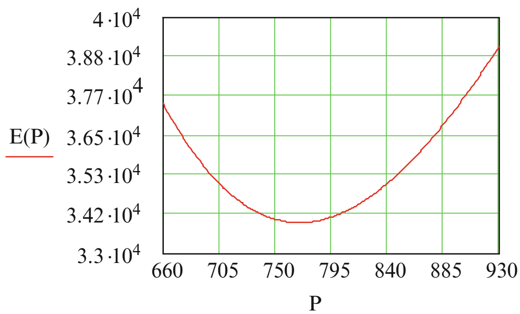


Fig. 12.2 The total expected loss curve

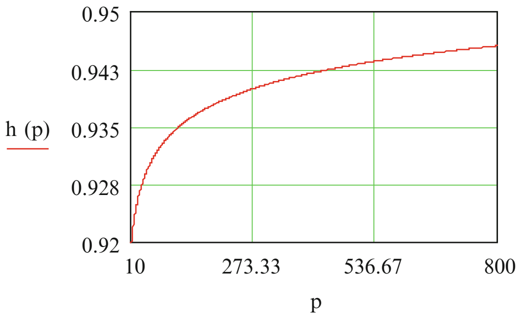


Fig. 12.3 The curve of the qualified probability

If $b = 0.92$, $a = 2.5$, $S_1 = 0.1$, with the output increasing the curve of the qualified probability is as shown in Fig. 12.3:

Supposed P is the planning input b, a and S_1 are given we get the equation of Q_x regardless of random factors:

$$Q_x = \int_0^P \left(1 - S_1 x^{\frac{\log b}{\log a}}\right) dx \tag{12.5}$$

Given P = 10,000 units, from Eq. (12.5) we get the actual output as follows:

$$Q_x = \int_0^{10000} \left(1 - 0.1x^{\frac{\log 0.92}{\log 2.5}}\right) dx = 9524(\text{unit})$$

When the planning input is 10,000 units, the actual average qualified rate is 95.24 %.

We analyze the loss of planning input with the objective of minimize the expected loss as follows:

1. the expected loss of excess as Eq. (12.6):

$$\begin{cases} W(P) = \int_{\frac{D}{P}}^{1} \left(C_g\left(r\int_0^P \left(1 - S_1 \cdot x^{\frac{\log b}{\log a}}\right)dx - D\right) + \left(C_r(1-r)\cdot \int_0^P \left(1 - S_1 \cdot x^{\frac{\log b}{\log a}}\right)dx\right)\right)R(r)dr \\ st.\ rP \geq D \end{cases} \tag{12.6}$$

The definition of all parameters in Eq. (12.6) is the same to Eq. (12.1), the first part of Eq. (12.6) is the disposal cost of excess and the second part is the disposal cost of the unqualified products. $\int_0^P \left(1 - S_1 x^{\frac{\log b}{\log a}}\right)dx$ Indicate the influence of learning rate to the qualified rate, and r is the influence of random factors to the qualified rate.

2. the expected loss of shortage as Eq. (12.7):

$$\begin{cases} S(P) = \int_0^{\frac{D}{P}} \left(C_q\left(D - r\int_0^P \left(1 - S_1 \cdot x^{\frac{\log b}{\log a}}\right)dx\right) + \left(C_r(1-r)\cdot \int_0^P \left(1 - S_1 \cdot x^{\frac{\log b}{\log a}}\right)dx + F\right)\right)R(r)dr \\ st. r \cdot P < D \end{cases} \tag{12.7}$$

The definition of all parameters in Eq. (12.7) is the same to Eq. (12.2), the first part of Eq. (12.7) is the rearrangement cost of shortage and the second part is the disposal cost of the unqualified products, the third part is the fee of input setup.

3. Object to minimize the total excepted loss, the model of planning input is as follows:

$$\begin{cases} min\ E(P) = min[W(P) + S(P)] \\ st.P \geq 0, \quad r \geq 0 \end{cases} \tag{12.8}$$

Assuming: $C_g = 180$, $C_q = 160$, $C_r = 120$, $D = 10000$, $E = 3000$, $\sigma = 0.12$, $u = 0.96$, $b = 0.92$, $a = 3$, $S_1 = 0.08$

Using MathCAD we get Fig. 12.4.

From Fig. 12.4 we find that when the planning input is 11282.5, the minimum expected loss is 93,070 yuan if we consider the learning rate.

Fig. 12.4 The total expected loss curve

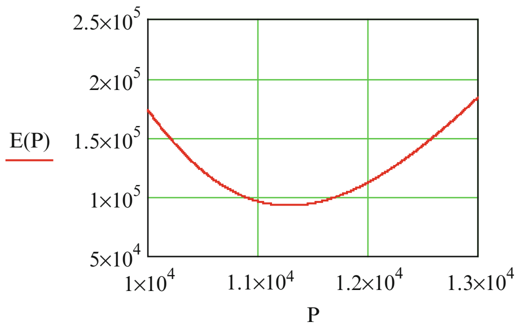
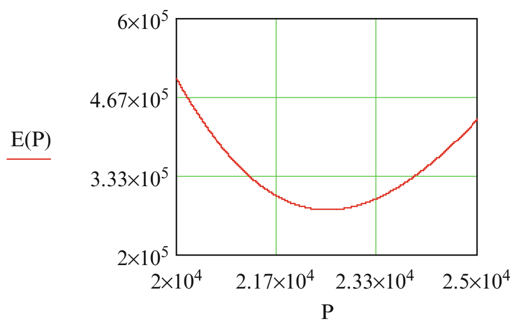


Fig. 12.5 The total expected loss curve considering of learning rate



Numerical Cases

An enterprise which professionally produces aluminum section uses the pattern of make-to-order. Because there are many random factors in its produce system, the situations of excess or shortage occur all the time. Now one customer ordered the product j, the demand quantity is 20,000 kg. According to the historical statistics: the excess will be melt as wastes and the cost of melt is 260 yuan/t; the rearrangement cost of shortage is 230 yuan/t; the disposal cost of the unqualified products is 180 yuan/t; unit fee of input setup is 3,000 yuan/unit. Now we need to determine the optimal planning input.

Because: $C_g = 260$, $C_q = 230$, $C_r = 180$, $D = 20000$, $F = 3000$, $\sigma = 0.12$, $b = 0.92$, $a = 2.5$, $S_1 = 0.1$, $u = 0.96$. Using MathCAD from Eq. (12.8) we get Fig. 12.5 as follows:

Considering of the learning rate, we find that when the optimal planning input is 22,298 kg, the minimum expected loss is 27,800 yuan.

Conclusions

Because of learning rate, the qualified rate will raise if production repetitions increases. This paper proposes a model of planning input with the objective to minimize the expected loss of excess and shortage considering of random fluctuation and learning rate. At last it is proved that this model can effectively deal with the problem of planning input of make-to-order enterprises to reduce the operation cost and increase the enterprise efficiency.

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