Using Service Level Approach to Achieve Lean Production

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Abstract: In the present article, based on the postulates of Customer Service Level, an approach is presented for deciding on “Service Level of Workstations” that will enable the process of defining such a costly beneficial level of Work-In-Process Inventory through the entire operations which, in turn, would enable an easy adoption of Lean Principles in a low-size batch production environment – the domain of Theory Of Constraints.

Key words: Lean Production, Service Level, Work-in-process, Safety Stock, Theory of Constraints.

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Използване подхода на „ниво на обслужване“ за постигане на Lean-производство

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Резюме: В настоящата статия, на основата на постановките за Ниво на обслужване при взаимоотношенията с клиента, е представен един подход за определяне „Нивото на обслужване на работните места“, който ще подпомогне пресмятането на такива икономически изгодни равнища на незавършено производство (задели/запаси) по протежение на целия операционен процес, които от своя страна ще позволят по-лесното въвеждане на Lean-принципите и в условията на малкосериен производството – „територията“ на Теория на ограниченията.

Ключови думи: Lean-производство, ниво на обслужване, незавършено производство, гаранционен запас/задел, теория на ограниченията.

I. Introduction

In the conditions of an intensive competition and difficult market environment the organisations are forced to function in, the ones with the highest degree of customer satisfaction in respect to product diversity, quick and efficient delivery, appropriate quality, and price of the product/service will have a leading position.

I. Въведение

При интензивната конкуренция и трудните пазарни условия, в които са при нуждени да функционират организациите, водещо място ще заемат тези, които в най-висока степен удовлетворяват очакванията на клиентите по отношение на продуктово разнообразие, бърза и ефективна доставка, качество и цена на желания продукт и/или услуга.
That is why the main requirements to the producers are: achieving a high level of flexibility, reducing production costs, and assuring quick fulfillment of customer orders, without any problems.

One approach to doing this is to provide the appropriate Service Level (SL) needed for separate workstations – the one that will guarantee the timely execution of the operations, as well as the achievement of steady and maximally “thin” (i.e. Lean) material flow throughout the entire operational process (Andreev, 2000; Andreev, 2009; Wincel, 2004; Womack & Jones, 2003).

To achieve this, a safety stock should be kept at certain points, in order to eliminate accidentally appearing breakdowns.

The aim of the present article is to offer an approach to defining such cost beneficial levels of safety stock throughout the operations that would form a favorable SL for workstations, and as a result – the highest possible continuity of the process up to the end item fabrication.

II. Presentation

The Service Level is defined as 
\[(1-k)\]
where “\(k\)” is the probability of failing to deliver the quantity ordered by a customer, before this quantity, manufactured by the supplier, has become available (Andreev, 2000; Andreev, 2005; Andreev, 2009; Krajewski et al., 2009; Owens, 1983).

Therefore, the numerical value of SL shows the probability of immediately (from stock) delivering a random quantity of end items at any certain point of time. That is why, in order a given SL to be provided, it is necessary a corresponding quantity of safety stock of end items to be kept on hand.
A way for quantitative defining the economically favorable value of safety stock, as well as calculating its corresponding SL, is presented in (Andreev, 2000; Andreev, 2009; Owens, 1983). Its basic idea lies in keeping the level of maintaining costs, associated with the required SL, not bigger than the benefits expected with a sufficient degree of certainty (probability).

The above-mentioned approach is associated with the relationship between the firm and its clients, but it could also be applied to the job coordination among workstations inside the production units.

However, at this level it is important to stress that the safety stock of Work-In-Process (WIP) is concerned, instead of the one of end items.

1. The traditional approach

In the Bulgarian literature, a necessity for a safety stock of WIP inventory is considered only in the production units, where the operations are synchronized, as well as only after the most unreliable workstations inside them (BDS 30.183, 1985; Dakov & Enimanev, 2006; Tsvetkov, 2006). In this way, the logic of using safety stock of WIP inventory is constrained to planning and managing production units/ departments that are product focused – those with mass production and flow lines.

According to (BDS 30.183, 1985; Dakov & Enimanev, 2006; Makedonska & Panayotova, 2008; Tsvetkov, 2006), the safety stock ($z_{gap}$) is calculated by the formula:

$$z_{gap} = \frac{T_{gap} \cdot \delta}{m_{j+1}}$$

where:
- $T_{gap}$ is the duration of the accidental workstation's work (min.);
- $t_{on_{j+1}}$ - the cycle time of (j+1)-st workstation operation (min.);
- $m_{j+1}$ - the number of machines performing the (j+1)-st operation;
- $\delta$ - a coefficient characterising the authenticity of $T_{gap}$.

В (Andreev, 2000; Andreev, 2009; Owens, 1983) е предложен начин за количественото определяне на икономически изгодния размер на гаранционния запас и съответстващото му НО, основната идея на който е разходите за поддръжка на желаното НО да бъдат не по-големи от очакваните с достатъчна степен на сигурност (вероятност) ползи.

Горният подход, отнасящ се за взаимоотношенията на предприятието с клиентите, може да бъде приложен и при съгласуването на работата между работните места и производствено-операционните звена.

Както беше посочено, на това равнище терминът „гаранционен запас“, е „гаранционен задел“.

1. Традиционният подход

В нашата литература за необходимост от гаранционен задел се говори само при производствени звена, в които операциите са синхронизирани и то – само след най-ненадеждните работни места (BDS 30.183, 1985; Dakov & Enimanev, 2006; Tsvetkov, 2006). Така логиката за неговото използване се ограничава до проектиране и управление работата на предметно специализирани звена, преобладаващо с поточна форма на организация.

Съгласно (BDS 30.183, 1985; Dakov & Enimanev, 2006; Makedonska & Panayotova, 2008; Tsvetkov, 2006), гаранционният задел ($z_{gap}$) се определя по зависимостта:
It is important to note that $T_{3arj}$ should include all additional consumptions of time caused by the breakdowns themselves (Dakov & Enimanev, 2006; Makedonska & Panayotova, 2008; Panayotova, 2008) – for instance: the time period with reduced productivity of the workstation under consideration, taking also into account the degree of the productivity reduced, as well as the time spent for additional “waste producing” due to the breakdowns etc.

Finally, it is assumed by default that an expert assessment for the breakdown duration is to be made and to be used for the calculations.

2. Approach for safety stock defining according to the SL of workstations required

Having in mind the above goal, the task of this paper is a model to be elaborated for using safety stocks of WIP inventory inside the production departments that are working in a batch and/or small-batch environment (following the contemporary trends), with a final target – satisfying the customer SL needed.

Following the logic for customer SL calculation described in (Andreev, 2000; Andreev, 2009; Owens, 1983), the pairs of “feeding-receiving” workstations are considered as "producer-consumer" ones. So when the quantity of safety stock of WIP inventory proper for a given situation is to be defined, the following values have to be calculated:

- Mean value of interruptions’ duration of the feeding workstation pair;
- Amplitude of the deviations from the value of mean duration;
- SL desired for the receiving workstation.

Важно е тук да се подчертае, че $T_{3arj}$ трябва да включва и всички допълнителни разходи на време, породени от самите прекъсвания (Dakov & Enimanev, 2006; Makedonska & Panayotova, 2008; Panayotova, 2008) – например: времето с намалена производителност на работното място, като се вземе пред вид до каква степен тя е намалена, както и времето, загубено за „производство” на допълнителен брак, причинен от прекъсването и т.н. В крайна сметка обаче тук по подразбиране се приема една „ ekspertна” преценка за вероятната продължителност на самото случайно прекъсване, която е определяща за пресмятанията.

2. Подход за определяне на гаранционния задел в зависимост от необходимото НО на работните места

Имайки пред вид поставената по-горе цел, задачата на настоящата публикация е да бъде разработен модел за използването на гаранционни задели и при звена, работещи в условията на малка сериеност (каквито са съвременните тенденции), с оглед получаването в крайна сметка на необходимото НО за клиента.

Следвайки логиката за определяне на НО за клиентите, описана в (Andreev, 2000; Andreev, 2009; Owens, 1983), двойките „подаващо-потребявящо” работни места се разглеждат като двойка „производител-клиент”. При определяне количеството на гаранционния задел, което е подходящо за дадената ситуация, трябва бъдат пресметнати следните величини:

- Средната стойност за продължителността на прекъсване на подаващото от разглежданата двойка работни места/звена;
- Амплитудата на отклоненията от средната продължителност;
- Желаното НО за потребяващото от разглежданата двойка работни места/звена.
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For this purpose, an analysis of the feeding workstation’s history of breakdowns – their nature and durations should be performed. Usually, the normal distribution law is assumed to be in action. Therefore, the following values could be used in the present case:

- Mean duration of breakdowns expected for the j-th (feeding) workstation

\[ T_j = \sum_{i=1}^{n} T_{ij} \cdot f(T_{ij}) \]  

where:

- \( T_j \) is the mean duration of breakdowns of the j-th workstation (min.);
- \( T_{ij} \) – the duration of i-th breakdown of j-th workstation (i = 1 ÷ n);
- \( n \) – the number of breakdowns in consideration / in the representative extract of their values;
- \( f(T_{ij}) \) – relative quota of breakdowns with duration \( T_{ij} \) min.:

\[ f(T_{ij}) = \frac{k_{T_{ij}}}{n} \]  

where:

- \( k_{T_{ij}} \) is the number of breakdowns with duration of \( T_{ij} \) min.

- Standard Deviation

\[ \sigma_j = \sqrt{\sum_{i=1}^{n} (T_{ij} - T_j)^2 \cdot f(T_{ij})} \]  

In the present case, the normal distribution law postulates could be presented in the way it is made on Figure 1.

Depending on the decision made for the quantity of safety stock, it will be possible the corresponding duration of workstations’ breakdowns to be covered. The amount of the surface “covered” under the normal distribution curve that corresponds to this duration, is in turn the SL for the receiving/consuming workstation.

В случаите графика на кривата на закона за нормалното разпределение ще изглежда по начина, показан на фиг. 1. В зависимост от решението за големината на гаранционния задел ще бъде възможно да бъде покрита съответна по големина продължителност на произволно нeregламентирано прекъсване, на което съответства определена стойност на „покритата” под кривата площ, а тя от своя страна по дефиниция представлява само НО на потребяващото работно място.
According to the approach presented here, the above decision could be made while solving the reverse problem:

- Define SL desired for the particular item in production and for \((j+1)\)-st workstation/production unit under consideration;
- Calculate \(T_j\) and \(\sigma_j\) through equations (2) ÷ (4);
- Define the (unforeseen) breakdown’s duration to be covered according to the SL chosen;
- Calculate the safety stock required to cover this duration.

3. Defining the desired SL for the workstations

Obviously, after the analysis of breakdowns history, and the calculation of their parameters according to section 2, the most important phase of the procedure is the one that enables decision making for the SL value through the workstations.

In Table 1, data are cited for the values of the most common types of costs associated with inventory handling, given in terms of shares of the end item price (Andreev, 2005).

Naturally, they are approximate values depending on, and reflecting the firm’s inventory policy.

3. Определяне на желаното НО на работните места

Очевидно, след анализа на характера на нерегламентираните прекъсвания и пресмятането на техните характеристики от раздел 2, най-важната част от горната процедура е вземането на решение за големината на НО по работните места.

В табл. 1 са цитирани данни за най-често срещаните видове разходи, свързани с издръжката на материалните запаси, изразени като дял от цената на крайното изделие (Andreev, 2005).

Разбира се техните стойности са ориентировъчни, зависят от и са отражение на конкретната политика на предприятието по заделите/запасите.
Table 1. Basic types of costs associated with inventory handling

<table>
<thead>
<tr>
<th>Type of expenditure/cost</th>
<th>Percentage of product price % от цената на изделието</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost of working capital (interests)</td>
<td>10÷20</td>
</tr>
<tr>
<td>Warehouse usage</td>
<td>2÷5</td>
</tr>
<tr>
<td>Ullage allowances</td>
<td>4÷6</td>
</tr>
<tr>
<td>Storage conditioning</td>
<td>1÷2</td>
</tr>
<tr>
<td>Administration</td>
<td>1÷2</td>
</tr>
<tr>
<td>Insurance, security etc.</td>
<td>1÷5</td>
</tr>
<tr>
<td><strong>Total/Общо</strong></td>
<td><strong>19÷40</strong></td>
</tr>
</tbody>
</table>

However, these data can serve as a reference point during the workstations’ SL decision making process. It is clear that, while raising SL these costs would rise too, and therefore – the total costs of the firm would rise as well. Apart from this, due to the nature of the normal distribution curve, the “SL price” will rise dramatically when SL approaches 100% (Figure 2).

Figure 2. The price of SL

Ето защо е необходимо да се обърне внимание само на онези работни места, които със своя престой биха оказали директно влияние върху НО на клиента, а както е известно, това са т. нар. тесни места и тези, които са с производителност, близка до тяхната (т.нар. „ограниченя”) (Andreev, 2000; Andreev, 2009;
Makedonska & Panayotova, 2008; Panayotova, 2008; Tsvetkov, 2006; Goldratt, 1990; Goldratt & Cox, 1992). Hence, a high value of SL is only necessary to be kept for the bottlenecks and constraints. Regarding the rest of the workstations/departments, a safety stock should be build, according to their capacity, only to cover their expected breakdown duration.

Eventually, the economically favorable SL could be defined by comparing total costs needed for keeping the SL required through the whole operations route to the client with the benefits missed due to sales of end items that did not take place (Andreev, 2000; Andreev, 2009; Owens, 1983). The missed sales line has an opposite slope, equal to the profit of one piece of end item (Figure 3).

The cross-point of both lines (the ones of total costs and missed profit due to lost sales of end items) will define such a SL that equals them, and, therefore, raising SL above this value will be unreasonable – the certain costs will exceed the possible benefits.

\[
\begin{align*}
\text{Total Costs} & \quad \text{Missing profits through lost sales} \\
& \quad \text{through lost sales} \\
& \quad \text{SL / HO (\%)}
\end{align*}
\]

\[
\begin{align*}
& \text{€} \\
& \text{Missing profits through lost sales / Пропуснати печалби} \\
& \text{Total Costs / Сумарни разходи}
\end{align*}
\]

**Figure 3. “Break-Even Point” of missed profit and total costs**

Фиг. 3. Равновесна точка на пропуснатите печалби и общите разходи

4. Defining the duration of a possible breakdown that is desirable to be covered according to the SL chosen

In the present section, according to the decision made in the previous one concerning the SL for the consuming workstation/department (SL\(j+1\)), it is necessary to do the following:
- Calculating \(\text{SL}_{j+1\text{extra}}\).
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If the value of SL\(_{j+1}^{\text{extra}}\) is positive, than the safety stock should cover duration of breakdown, bigger than the mean value \(T_j\) and vice-versa (Figure 1 and Figure 4).

\[
SL_{j+1}^{\text{extra}} = SL_{j+1} - 0.5
\]  

(5)

При положително HO\(_{j+1}^{\text{extra}}\) следва, че гаранционният задел трябва да покрива прекъсване, съответно по-голямо от средната стойност \(T_j\) и обратно (фиг. 1 и фиг. 4).

![Figure 4. Area under the normal distribution curve in the interval [0 ÷ x]
Фиг. 4. Площ под кривата на Закона за нормално разпределение в интервала [0 ÷ x]

- Calculating \(x_j\). The value of \(x_j\) counts how many standard deviations \(\sigma_j\) are covered by \(SL_{j+1}^{\text{extra}}\) (Figure 4). It is defined by widely used tables presenting the area under the normal distribution curve (Andreev, 2009; Krajewski et al., 2009).

- Calculating the time interval \(T_{\text{gap}}\), that is going to provide the HO\(_{j+1}\) desired:

\[
T_{\text{gap}} = T_j + x_j \cdot \sigma_j
\]

(6)

5. Calculating the value of the safety stock providing the chosen SL

The value of the safety stock is calculated through the following equation:

\[
z_{\text{gap}} = \frac{T_{\text{gap}}}{t_{\text{on},j+1}}
\]

(7)

III. Conclusion

One of the basic characteristics and advantages of Lean Production is the steady and continuous operations performed throughout the entire process, as well as the fact that the material flow is at a maximum degree “thin” (i.e. – Lean).
One has to keep in mind that, according to the modern potential of industrial technologies, Lean is applicable mostly in the mass production and large-batch production environments, where the operations synchronization is economically effective.

In the small-batch production environments, this is not so preferable and the Theory of Constraints is "in power".

In the present publication, an approach is applied that supplements TOC basics offering a model of economically beneficial performing of the steps Two and Three of its procedure, namely: "Decide how to exploit the system’s constraints!” and "Subordinate everything else to the above decision!“

Thus, achieving the advantages of Lean principles becomes easy, even away from their traditional territory.

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