The Determination of the Average WIP Inventory and Buffer Size for a Two-stage Manufacturing System

Khalid A. Aldakhilallah

Department of Quantitative Methods, College of Business and Economics
King Saud University, Qassim Branch, PO Box 6033, Al-Molaida, Al-Qassim, Saudi Arabia

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Abstract. An analysis of work-in-process (WIP) inventory for a two-stage manufacturing system is provided with the following objectives: (1) the determination of the maximum buffer size and (2) the determination of the average WIP inventory. This analysis consists of three conditions and each condition is investigated for two cases which are based on the batch size. The conditions are as follow: Condition A1 states that the processing time of the first work station is greater than that of the second work station, Condition A2 states that the processing time of the first work station is less than that of the second work station, and Condition A3 states that the processing time of the first work station is equal to the processing time of the second work station. Examples are provided throughout the paper to drive the maximum WIP inventory and the average WIP inventory.

Keywords: Work-in-process, Buffer size, Maximum inventory, Average inventory.

1. Introduction

Manufacturing systems consist of work stations that carry out specific operations to create a predesigned product. There are many types of manufacturing systems that have been studied from different points of view. These systems are classified into a job shop, flow-line, continuous production systems, etc. A job shop manufacturing system is a facility that produces a wide range of products. These products require different processing sequences
on a set of machines (work stations). In these systems, scheduling and routing represent an enormous problem facing production control. On the other hand, a flow line manufacturing system is a facility that produces a few discrete products. All products in this system are required to go through all machines in the same sequence which allows the production of large quantities. Finally, a continuous process manufacturing system utilizes highly specialized equipments to produce products such as petroleum petrochemicals, etc. However, each manufacturing system has its own characteristics and requirements in terms of production and inventory control.

Overall, the objective of a production system is to transform raw materials or sub-components into a final product which is delivered to customers. Therefore, the production process of a product consists of several stages such as raw material inventory, machining (processing), buffer inventory (WIP), and final product inventory. These stages of a production process are shown in Fig. 1.

Fig. 1. A production process in a manufacturing system.
Inventory is an essential component of a production system environment. It exists in these systems in three forms as follows: raw material, work-in-process (WIP), and finished goods inventories. Raw material inventory includes items that require some type of processing to manufacture a final product. Some final products of production systems are considered as raw materials or sub-components to other production systems. Work-in-process (WIP) inventory exists in production systems where different types of raw materials are processed into finished products. Also, it exists as buffer between two work stations if the output of a work station is transferred in batches to the next work station. Finished product inventory represents items that are held at the manufacturing storage facility waiting to be shipped to the customers. Hence, inventories are used to balance variability and uncertainty in supply and demand. However, as the size of inventory increases the cost of managing and holding inventory increases as well. The costs that associate with holding inventory are as follow: storage space, handling, insurance, taxes, etc. Therefore, production systems aim at reducing the size of inventory in all three forms of inventory to reduce the total cost of production.

In this paper, a work-in-process (WIP) inventory in a production system that consists of two work stations is studied. The objective of work-in-process (WIP) inventory is to smooth and balance the work flow of operations (decouple operations) in a production system which results in systems performance enhancement. However, increasing the buffer size would result in more space requirement and more inventory holding costs. The objectives of this paper are to determine the maximum buffer size and average work-in-process (WIP) inventory under three manufacturing conditions and each condition is analyzed for two cases.

The organization of this paper is as follows. Section 2.0 describes the production system that is considered in this study. Section 3.0 analyzes the production system when the processing time of the first work station is greater than that of the second work station. Section 4 investigates the production system when the processing time of the first work station is less than that of the second work station. Section 5 studies the production system
when the processing time of the first work station is equal to the processing time of the second work station. Section 6 presents conclusions and direction for future research.

2. The Production System

The Production system considered in this paper consists of two work stations (a two-stage production system) and a buffer between these two stations. Figure 2 depicts the production system under consideration. In this system, it is assumed that there is a single product to be produced. First work station (WS₁) processes a batch size of Q units. The batch is then transferred to the buffer space between the two work stations as WIP inventory.

The inventory size in the buffer increases by one unit as soon as the first work station processes a unit. The second work station processes one unit of the batch per given time units. In other words, the number of units in the buffer fluctuates up and down. Also, it is assumed that the total demand (D) for the item is constant and the item is produced in equal batches (Q). The processing time (Pₖ, j=1, 2) of operations is known and constant. Finally, set up time (S) is assumed to be negligible. Moreover, it is assumed that WS₂ does not start production of a batch until the entire batch is processed by WS₁.

![Fig. 2. A production system with two-stages.](image)

This production system is evaluated under three conditions and each condition is considered and analyzed for two cases. Figure 3 shows the branches of the analysis and the notations that will be used to define each case. The three conditions are P₁>P₂ (A1), P₁<P₂ (A2), and P₁=P₂ (A3). Each condition involves two cases as follows: n=1 (Case Ay.1) and n>1 (Case Ay.2) (where y=1, 2, and 3). As a result, six instances will be analyzed in this paper.
3. Condition A1 \( \{P_1 > P_2\} \)

Condition A1 considers a production system where the processing time \( P_1 \) of WS\(_1\) is greater than the processing time \( P_2 \) of WS\(_2\) (i.e., \( P_1 > P_2 \)). Therefore, the manufacturing system will be analyzed for two cases which are dependent on the number of batches that are produced. In Case A1.1, it is assumed that the number of batches that need to be produced is one \( (n=1) \). On the other hand, Case A1.2 assumes that the number of batches that need to be produced is greater than one \( (n>1) \). These cases will be described in the following discussion.

3.1 Case A1.1: One batch \( (n=1) \)

The determination of average WIP when the number of batches is one \( (n=1) \) will be discussed using the following example:

Example. Assume that the total demand \( (D) \) is 1000 units and there is one batch \( (n=1) \) to be produced, hence the batch size \( (Q) \) is 1000 units. Also, assume that \( P_1=6 \) (production time of WS\(_1\)) and \( P_2=5 \) (production time of WS\(_2\)). Therefore, the WIP inventory behaves...
as shown in Fig. 4 and Table 1. It can be seen from Fig. 4 that during the production phase of WS$_1$, WIP inventory builds up at a rate equal to one unit per 6 time units. Hence, WIP inventory reaches its maximum (Q) level at the time when WS$_1$ completes the production of the batch (i.e., 6x1000=6000 time units). Also, it can be seen from Fig. 4 that WIP inventory decreases until it is exhausted during the production time of WS$_2$. Therefore, by evaluating the area under the triangle in Fig. 4, we found that the average WIP is as given in Equation (1).

![Fig. 4. WIP inventory level when P$_1$>P$_2$ and n=1.](image)

### Table 1. An example for P$_1$>P$_2$ and n=1

<table>
<thead>
<tr>
<th>Time</th>
<th>Units processed by WS$_1$</th>
<th>Buffer inventory</th>
<th>Units processed by WS$_2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>6000</td>
<td>1000</td>
<td>1000</td>
<td>0</td>
</tr>
<tr>
<td>11000</td>
<td>0</td>
<td>0</td>
<td>1000</td>
</tr>
</tbody>
</table>

\[
\overline{\text{WIP}} = \frac{Q}{2}
\]  

(1)

### 3.2 Case A1.2: Multiple batches (n>1)

The determination of average WIP when the number of batches is greater than 1 (n>1) will be discussed using the following examples:

**Example.** Assume that D=1000 units and n=2, hence, the batch size is 500 units. Also,
assume that $P_1=6$ and $P_2=5$. Therefore, WIP inventory behaves as shown in Figure 5 and Table 2. It can be seen from Figure 5 that during the production phase of the first batch by $WS_1$, WIP builds up at a rate of one unit every $XP_1$ time unit ($X$: is the number of units produced from the first batch by $WS_1$) until it reaches its maximum ($Q=500$). Then, WIP inventory decreases until it reaches a level that is given by the following equation: $[(P_2Q)/P_1]$. This reduction occurs because of the difference between the production rates of the two work stations. $WS_2$ starts processing the first batch at time=3000 (the time in which $WS_1$ completed the first batch) and ceases production at time=5500, then waits for the completion of the second batch by $WS_1$. Thus, $WS_2$ becomes idle until $WS_1$ completes the production of the second batch at time=6000 in which WIP inventory begins to decrease.

In addition, it can be seen that at the end of each production phase (the production of each batch) of $WS_1$, WIP inventory builds up to its maximum ($Q=500$). Hence, by evaluating the area shown in Fig. 5 which can be divided to four separate areas, we found that the average WIP inventory is as follow:

$$\text{WIP} = \frac{1}{4} \left[ \frac{Q_1}{2} + \frac{P_2Q_1}{2P_1} + \frac{P_2Q_1}{2P_1} + \frac{Q_2}{2} \right]$$  \hspace{1cm} (2)$$

$Q = 500$, $P1 = 6$, $P2 = 5$

**Fig. 5.** WIP inventory level when $P_1>P_2$ and $n = 2$. 
Table 2. An example for $P_1>P_2$ and $n=2$

<table>
<thead>
<tr>
<th>Time</th>
<th>Units processed by $W_{S_1}$</th>
<th>Buffer inventory</th>
<th>Units processed by $W_{S_2}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>3000</td>
<td>500</td>
<td>500</td>
<td>0</td>
</tr>
<tr>
<td>5500</td>
<td>417</td>
<td>417</td>
<td>500</td>
</tr>
<tr>
<td>6000</td>
<td>83</td>
<td>500</td>
<td>0</td>
</tr>
<tr>
<td>8500</td>
<td>0</td>
<td>0</td>
<td>500</td>
</tr>
</tbody>
</table>

Since $Q_1=Q_2$ and $n=2$, then:

$$WIP = \frac{1}{4} \left[ 2Q + \frac{P_2Q}{P_1} \right] = \frac{1}{4} \left[ nQ + (n-1) \frac{P_2Q}{P_1} \right]$$

(3)

Now, let us assume that $n=5$ which implies that the batch size is 200 (1000/5) units. WIP inventory level behaves as shown in Figure 6 and Table 3. It can be seen from Figure 6 that at the end of each production phase of $W_{S_1}$, WIP inventory level reaches its maximum ($Q=200$). Also, at the end of each production phase of $W_{S_2}$, WIP inventory level is given by the following equation: $[(P_2Q)/P_1]$. Hence, WIP inventory level fluctuates up and down in the same pattern. These patterns occur at the time $W_{S_2}$ starts the production of the first batch and it ends at the time $W_{S_2}$ starts the production of the last batch. Therefore, by dividing the area that is shown in Figure 6 to 10 separate areas which are defined by the marks on the line describing the WIP inventory level we obtain the following:

$$WIP = \frac{1}{10} \left( \frac{Q_1}{2} + \frac{Q_1 + \frac{P_2Q_1}{P_1}}{2} + \frac{P_2Q_1 + Q_2}{2} + \frac{Q_2 + \frac{P_2Q_2}{P_1}}{2} + \frac{P_2Q_2 + Q_3}{2} + \frac{Q_3 + \frac{P_2Q_3}{P_1}}{2} + \frac{P_2Q_3 + Q_4}{2} + \frac{Q_4 + \frac{P_2Q_4}{P_1}}{2} + \frac{P_2Q_4 + Q_5}{2} \right)$$

(4)
Equation (4) determines the average WIP inventory for $n=5$. Solving Equation (4), we obtain:

$$\overline{\text{WIP}} = \frac{1}{10} \left( (Q_1 + Q_2 + Q_3 + Q_4 + Q_5) + \frac{P_2 Q_1}{P_1} + \frac{P_2 Q_2}{P_1} + \frac{P_2 Q_3}{P_1} + \frac{P_2 Q_4}{P_1} \right) \tag{5}$$

Since $Q_i = Q_k$, for $k=1, \ldots, n$ and $j=1, \ldots, n$, then Equation (5) becomes:

$$\overline{\text{WIP}} = \frac{1}{10} \left( \sum_{i=1}^{n} Q_i + \frac{P_2}{P_1} \sum_{i=1}^{n-1} Q_i \right) = \frac{1}{10} (nQ + (n-1) \frac{P_2 Q}{P_1}) \tag{6}$$
Therefore, from Equations (3) and (6) we obtain the following:

\[
\overline{WIP} = \frac{Q}{2n} \left[ n + (n - 1) \left( \frac{P_2}{P_1} \right) \right]
\]

where \( n = D/Q \). Equation (7) applies to any batch size \( n \geq 1 \) as long as the two assumptions \( (P_1 > P_2 \text{ and } S=0) \) hold. Thus, if \( P_1 > P_2 \), then the maximum WIP inventory (buffer size) for the two-stage manufacturing system is equal to the batch size \( Q \) and the average WIP inventory is as given in Equation (7).

4. Condition A2 \( \{P_1 < P_2\} \)

In this section, a two-stage production system will be analyzed in which the processing time of WS\(_1\) is less than that of WS\(_2\) \( (P_1 < P_2) \). It is assumed that setup time is negligible. As a result, the system will be investigated for two cases. Case A2.1 assumes that there is only one batch to be produced \( (n=1) \). Case A2.2 assumes that the number of batches is greater than one \( (n>1) \). These two cases will be investigated in the following discussion.

4.1 Case A2.1: One batch \( (n=1) \)

In this case, an example will be used to describe the behavior of the WIP inventory when the number of batches that need to be produced is one.

Example. Assume that \( D=1000 \) units that are produced as a one batch \( (Q=1000) \). Also, assume that \( P_1=5 \) (the processing time of WS\(_1\)) and \( P_2=6 \) (the processing time of WS\(_2\)). Thus, WS\(_1\) will produce the required quantity at time=5000 \( (1000 \times 5) \). Then, WS\(_2\) will start production of this quantity at time=5000 and end at time=11000 \( (5000+1000 \times 6) \). Table 4 and Fig. 7 show the behavior of the WIP inventory. Hence, it can be seen from Fig. 7 that WIP inventory builds up at a rate equal to one unit per 5 time units and it reaches its maximum \( (Q=1000) \) at time=5000. Then, WIP inventory decreases during the production phase of WS\(_2\). Therefore, as a result of evaluating the area in Fig. 7, the average WIP inventory is as given in Equation (8).

\[
\overline{WIP} = \frac{Q}{2}
\]

Table 4. An example for \( P_1<P_2 \) and \( n=1 \)
The Determination of the Average WIP Inventory …

4.2 Case A2.2: Multiple batches (n > 1)

The determination of average WIP inventory for n > 1 will be investigated in the following discussion.

Example. Let D=1000 and n=4, hence the batch size is 250 (Q=D/n). Also, assume that P₁=5 and P₂=6. As a result, the WIP inventory will behave as shown in Table 5 and Figure 8. It can be seen from Figure 8 that during the production phase of the first batch by WS₁, WIP inventory increases gradually by one up to Q=250. Then, as WS₂ starts production, the WIP inventory level increases at a rate equal to 0.167X units (X-X₁/P₂), where X represents the total number of units that are produced by WS₁ anytime after the completion of the first batch. For example, assume that WS₁ has produced 60 units of the second batch and WS₂ is producing the first batch, then WIP inventory level increases by 10 units (60-
Hence, WIP inventory level at this time is 260 units ($Q_1 + 60 - 60\times5/6$), where $Q_1 = 250$. Therefore, the maximum WIP inventory ($I_{\text{Max}}$) level is as given in Equation (9).

$$I_{\text{Max}} = (Q_1 + Q_2 + Q_3 + Q_4) - \left[\left(\frac{P_1}{P_2}\right) \sum_{i=1}^{n} Q_i \right] = \sum_{i=1}^{n} Q_i - \frac{P_1 \sum_{i=2}^{n} Q_i}{P_2}$$  (9)

Table 5. An example $P_1 < P_2$ and $n=4$

<table>
<thead>
<tr>
<th>Time</th>
<th>Units processed by WS$_1$</th>
<th>Buffer inventory</th>
<th>Units processed by WS$_2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1250</td>
<td>250</td>
<td>250</td>
<td>0</td>
</tr>
<tr>
<td>2500</td>
<td>250</td>
<td>292</td>
<td>208</td>
</tr>
<tr>
<td>3750</td>
<td>250</td>
<td>333</td>
<td>208</td>
</tr>
<tr>
<td>5000</td>
<td>250</td>
<td>375</td>
<td>208</td>
</tr>
<tr>
<td>7250</td>
<td>0</td>
<td>0</td>
<td>375</td>
</tr>
</tbody>
</table>

Fig. 8 WIP inventory level when $P_1 < P_2$ and $n = 4$.

Since $Q_i = Q_k$, for all $j$ and $k$, then $I_{\text{Max}}$ is as follows:

$$I_{\text{Max}} = nQ - \frac{(n-1)P_1 Q}{P_2}$$  (10)

Therefore, the average WIP inventory is determined by dividing the area shown in Figure 8 to three separated areas and evaluating these areas. The average WIP inventory is given by the following equation.
The Determination of the Average WIP Inventory …

\[
\text{WIP} = \frac{1}{3} \left( \frac{Q}{2} + \frac{Q + I_{\text{Max}}}{2} + \frac{I_{\text{Max}}}{2} \right) 
\]

(11)

Therefore, from Equation (10) and Equation (11), the average WIP is as follows:

\[
\text{WIP} = \frac{1}{3} \left( \frac{Q}{2} + \frac{Q + nQ \cdot \frac{(n-1)P_{1}Q}{P_{2}}}{2} + \frac{nQ \cdot \frac{(n-1)P_{1}Q}{P_{2}}}{2} \right) 
\]

(12)

By solving Equation (12) the average WIP inventory becomes as given in the following Equation (13).

\[
\text{WIP} = \frac{Q}{3} \left[ (n + 1) - \frac{(n-1)P_{1}}{P_{2}} \right] 
\]

(13)

Equation (13) is applicable to any batch size that is greater than one \((n>1)\) as long as the following two assumptions \((P_{1}<P_{2}\) and \(S=0)\) hold. Thus, the maximum WIP inventory for this case is as given in Equation (10) and the average WIP inventory is as given in Equation (13).

5. Condition A3 \(\{P_{1}=P_{2}\}\)

Here, it is assumed that the processing times for both work stations are equal \((P_{1}=P_{2})\). Consequently, two cases will be analyzed. Case A3.1 will consider a system that produces only one batch \((n=1)\) and Case A3.2 will consider a system that produces more than one batch \((n>1)\). These cases will be discussed in the following.

5.1 Case A3.1: One batch \((n=1)\)

Assume that the total demand \((D)\) is 1000 units and \(n=1\). Also, assume that \(P_{1}=P_{2}=5\). Then, the WIP inventory behaves as shown in Table 6 and Fig. 9. The WIP inventory level increases by one unit until it reaches its maximum. The maximum WIP inventory level is equal to the batch size \((Q=1000)\). Then, WIP inventory decreases by one unit until it is
exhausted at time 10000. Therefore, by evaluating the area shown in Fig. 9 the average WIP inventory is obtained as follows:

\[ WIP = \frac{Q}{2} \]  

(14)

Table 6. An Example for \( P_1 = P_2 \) and \( n=1 \)

<table>
<thead>
<tr>
<th>Time</th>
<th>Units processed by WS_1</th>
<th>Buffer inventory</th>
<th>Units processed by WS_2</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>5000</td>
<td>1000</td>
<td>1000</td>
<td>0</td>
</tr>
<tr>
<td>10000</td>
<td>0</td>
<td>0</td>
<td>1000</td>
</tr>
</tbody>
</table>

\[ Q = 1000, \quad P_1 = 5, \quad P_2 = 5 \]

Fig. 9. WIP inventory level when \( P_1 = P_2 \) and \( n=1 \).

5.2 Case A3.2: Multiple batches (\( n>1 \))

The average WIP inventory for \( n>1 \) will be determined in the following discussion: Example. Let \( D=1000 \) units and assume that there are 4 batches need to be produced. Also, assume that \( P_1=5 \) and \( P_2=5 \) time units. WIP inventory behaves as shown in Table 7 and Fig. 10. The WIP inventory builds up at a rate of one unit until it reaches its maximum (\( Q=250 \)) at time 1250 time units. Then, the WIP inventory level stays at a constant level (\( Q \)) after the completion of the first batch by WS_1. This is because the number of units that is placed into the buffer is equal to the number of units that is drawing from the buffer inventory. Finally, at time 5000 time units, WIP inventory level decreases until it is exhausted. Therefore, by dividing the area that is shown in Fig. 10 to 5 areas we obtain the following:
The Determination of the Average WIP Inventory …

\[
\overline{\text{WIP}} = \frac{1}{5} \left( \frac{Q_1}{2} + \frac{Q_1 + Q_2}{2} + \frac{Q_2 + Q_3}{2} + \frac{Q_3 + Q_4}{2} + \frac{Q_4}{2} \right)
\]  

(15)

Since, \(Q_j = Q_k\) for all \(j\) and \(k\), and \(n=4\), then

\[
\overline{\text{WIP}} = \frac{1}{5} \left( \sum_{i=1}^{n} Q_i \right) = \frac{n}{(n+1)} Q
\]

(16)

Equation (16) applies to any batch size \((n1)\) as long as the assumption \((P_1 = P_2)\) holds.

Thus, the maximum WIP inventory level for Condition A3 is equal to the batch size \((Q)\) and the average WIP is as given by Equation (16).

Table 6. An example for \(P_1 = P_2\) and \(n=4\)

<table>
<thead>
<tr>
<th>Time</th>
<th>Units processed by WS1</th>
<th>Buffer inventory</th>
<th>Units processed by WS2</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1250</td>
<td>250</td>
<td>250</td>
<td>0</td>
</tr>
<tr>
<td>2500</td>
<td>250</td>
<td>250</td>
<td>250</td>
</tr>
<tr>
<td>3750</td>
<td>250</td>
<td>250</td>
<td>250</td>
</tr>
<tr>
<td>5000</td>
<td>250</td>
<td>250</td>
<td>250</td>
</tr>
<tr>
<td>6250</td>
<td>0</td>
<td>0</td>
<td>250</td>
</tr>
</tbody>
</table>

\[Q = 250, \ P_1 = P_2 = 5\]

Fig. 10. An example for \(P_1 = P_2\) and \(n > 1\).

6. Conclusion
An analysis of work-in-process (WIP) inventory for a two-stage manufacturing system is presented. The WIP inventory level is analyzed for three conditions and each condition is investigated for two cases as follows. First, Condition A1 states that the processing time of the first work station is greater than that of the second work station. Second, Condition A2 states that the processing time of the first work station is less than that of the second work station. Third, Condition A3 states that the processing times of both work stations are equal. These conditions are then analyzed based on the number of batches that are produced. It has been found that there are two cases of the batch size. The first case assumes that the number of batches is one and the second case assumes that the number of batches is greater than one.

We have concluded from this research that all three conditions give the same average WIP inventory when the number of batches is one (n=1). Also, they give the same maximum WIP inventory level for n=1. However, the average WIP inventories for these conditions are different if the number of batches is greater than one. Also, the maximum WIP inventory levels are unequal for all three conditions. This analysis can be extended to include material handling time and setup time into consideration. We are currently investigating these issues.

References

تحديد متوسط حجم المخزون تحت التصنيع

لظام تصنيع ذي مرحلتين

خالد بن عبد الله الدخيل
كلية الاقتصاد والإدارة، جامعة الملك سعود، قطع القصيمي

ملخص البحث. تم في هذا البحث تحليل المخزون تحت التصنيع في نظام تصنيع ذي مرحلتين.

و يهدف هذا التحليل إلى تحقيق التالي: 1) تحديد أقصى حجم مخزون تحت التصنيع و 2) تحديد متوسط المخزون تحت التصنيع. و يتكون هذا التحليل من ثلاثة شروط و كل شرط يحتوي على حالتين و تعتمد كل حاله على حجم الدفعة. و هذه الشروط هي كالتالي: الشروط الأول (A1) هو أن زمن التشغيل للاصلة الأولى أكبر من زمن التشغيل للاصلة الثانية، و الشروط الثاني (A2) هو أن زمن التشغيل للاصلة الأولى أقل من زمن التشغيل للاصلة الثانية، و الشروط الثالث (A3) هو أن زمن التشغيل للاصلة الأولى مساو لزمن التشغيل للاصلة الثانية. بالإضافة إلى هذا، لقد تم عرض أمثلة لتسهيل تحديد القيمة القصوى للمخزون تحت التصنيع و تحديد متوسط المخزون تحت التصنيع.