Abstract
The added value has become a true measurement to evaluate the company's performance. This added value has been approached to different fields within the business management. In this paper, we use a procedure to calculate the added value in each process of a power meter supply chain. This added value is very close to economic value added (EVA) concept, and is calculated by the weight and the added costs to the product in each process. This weight depends on three fundamental aspects to identify the bottleneck process. The procedure application allows identifying the highest added value process matching with the bottleneck process (calibration process).

1 Introduction
Companies now invest heavily in research to improve their performance. The researchers use metrics or indicators to achieve this goal. One of those ways is the calculation of EVA in each one of the supply chain processes.

EVA index was rapidly promoted when it was put forward in USA, and was introduced for performance evaluation in many enterprises such as COCA-COLA, SIEMENS and so on. The introduction of EVA has further promoted with the development of the financial engineering management concept, and has been gradually and widely recognized as the core of the financial engineering management strategy. EVA, a registered trademark of Stern Stewart & Company, has been implemented in numerous large companies to motivate managers to create shareholder value [1].

The value added is defined as the difference between the output value and input value of a product after going through an operation or process [2-4].
However, the most used variants is the equation 1, although authors such as [5] use others notations.

\[ \text{EVA} = \text{NOPAT} - (\text{NOPAT} \times C) \quad (1) \]

The previous formula shows how to calculate the added value in a company. However, this approach, haven't into account the added value in each one of the processes, just a global added value.

Moreover, there are other methodologies in the literature review with similar approach (difference of input and output value) but using different ways, such as [2], [10], [11], [4] and other. [2] calculates the added value by the expression 2.

\[ V_{AP} = (V_{PP} + V_{MBP} + V_{EBP}) - (V_{PI} + V_{OI} + V_{EI}) \quad (2) \]

Where:
- \( V_{AP} \) is the total value added by the operation;
- \( V_{PP} \) is the value of the primary product produced by the operation;
- \( V_{MBP} \) is the value of the material by-products produced by the operation;
- \( V_{EBP} \) is the value of the energy by-products (fuels and electricity) produced by the operation;
- \( V_{PI} \) is the value of the biomass inputs to the operation;
- \( V_{OI} \) is the value of the other material inputs to the operation;
- \( V_{EI} \) is the value of the energy supply inputs (fuels and electricity) to the operation.

On the other hand, [10] and [11] use the classic expression (expression 1) to determinates the EVA. And [4], use the expression 3 to calculates the added value.

\[ X_{ik}(CA, Xn) = CA_{ik} + Xn_{ik} \quad (3) \]

Where
- \( X_{ik} \) is the value added to product \( k \) in operation \( i \);
- \( CA_{ik} \) represents the added costs to product \( k \) in operation \( i \);
- \( Xn_{ik} \) is the net value added to product \( k \) in operation \( i \).

After we analyze the previous tools we will use the last because we can calculate the added value in each process, and this added value is approached to the supply chain performance by bottleneck detection.

3 Procedure to calculate the added value

The procedure to calculating the added value is composed by five step like the figure 1 shows.

![Figure 1: Procedure to calculating the added value](image)

**Step 1. Definition of the product’s selling price.**
Price fixing is the conspiracy by several manufacturers to set prices for goods or services above the normal market rate [12]. To 
fix the product’s selling price is necessary take into account the production costs and the price competitors. The cost is a firm’s variable, and depends on the required resource to manufacture a product [13]. By other hand, the competitors price is a start point to fix the product selling price able to cover the production costs and, at the same time, to be competitive in the market.

Step 2. Identification of process operations.
According to [14], the process can be defined like a coordinated system of operations through which the product gets value added. At same time, the processes requires an enormous effort and it still needs to be adapted to satisfy the specific characteristics of different project situations [15]. In this step every process must be identified according to its production capacity. We will use the equation 4 to calculate the operation capacity.

Where:
- $C_k$: capacity of operation $i$ in product $k$.
- $r_k$: specific weight of product $k$ in the total production volume.
- $T_{ik}$: Time of operation $i$ in product $k$.
- $F_i$: available time for operation $i$.
- $n$: number of products to be manufactured in operation $i$.

Step 3. Identification of operational requirements.
According to Marrero-Delgado [16], at this stage the limit conditions and requirements of each operation must be established, taking into account the list of materials, components and other required resources for the process.

Step 4. Calculation of the value added coefficient.
The added value is determined by equation 3, where depends of $CA_{ik}$ and $Xn_{ik}$. The $Xn_{ik}$ is calculated by expression 5, depending of the relative importance of operation $i$ en product $k$ ($W_{ik}$), the final value of product $k$ ($C_{ik}$) and the production cost of product $k$ ($C_{pk}$).

By other hand, $W_{ik}$ is calculated by the equation 6 where $CD_{ik}$ and $CI_{ik}$ are, respectively, the direct and indirect cost of product $k$ in operation $i$; $CD_{ik}$ and $CI_{ik}$ represent the direct and indirect cost of the entire process; $\gamma_{ik}$ is the processing time of product $k$ in operation $i$; $T_{ik}$ is the total processing time of product $k$; $Inv_{ik}$ is the inventory level in operation $i$ and $Inv_k$ is the total work in process of product $k$.

In the case of $C_{pk}$, is determined by the equation 7, depending of initial raw material ($Cmp_k$) cost and the number of operation in the process ($n$).

Step 5. Calculation of the value for each product at each operation
With the relative importance calculated, we will determinate the added value for each product at each operation. This added value will be calculated by equation 8 having into account that the final value of any process is equal to the initial value of the next process. This equation depends on the final added value ($F_{ik}$) and the added value calculated in the equation 3.

Step 6. Calculation of the required money for raw materials purchasing
To calculation the required money for raw material purchasing depends of the initial value of the first process because both value are equals. In case that the initial value of the first process ($W_{i1}$) be less than the raw material cost, then the difference between this values represent a loss. By other hand, if $W_{i1}$ is greater than the raw material costs is considered a saving to the company. In both case this difference (losses or saving) decrease or increase the profits, changing directly the added value per process.

4 Results
The procedure was applied in the 127V’s electric power meter (EPM) process. This process belongs to the electromechanical products company, located in Villa Clara (Cuba).

Step 1. Definition of the product’s selling price.
In the selected process to apply the procedure are produced two types of electric power meter. This two types are differenced according to his voltage (127V and 220V). The price of 127V’s EPM is $13.60. This prices was established by the Government being a 20% of the production cost.

Step 2. Identification of process operations.
In the selected process, some operations are semiautomatic and other manual. The production line and the manufacturing time of both product is shown in the table 1. This supply chain is composed by six processes. There are:
supplying, preparation, calibrating, assembly and sealing, packing and storage.

Some materials, components and other resources are required to produce this product. The table 2 shows the list of these.

### Step 3. Identification of operational requirements.

<table>
<thead>
<tr>
<th>Process</th>
<th>Manufacturing time (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Supplying</td>
<td>5.76</td>
</tr>
<tr>
<td>2. Preparation</td>
<td>7.20</td>
</tr>
<tr>
<td>3. Calibrating</td>
<td>16.00</td>
</tr>
<tr>
<td>4. Assembly and sealing</td>
<td>7.20</td>
</tr>
<tr>
<td>5. Packing</td>
<td>5.76</td>
</tr>
<tr>
<td>6. Storage</td>
<td>5.00</td>
</tr>
</tbody>
</table>

**Table 1. Processes and manufacturing time**

<table>
<thead>
<tr>
<th>Resources</th>
<th>Resources</th>
<th>Resources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uncalibrated EPM</td>
<td>Refined tin</td>
<td>Nicron wire</td>
</tr>
<tr>
<td>Electric power</td>
<td>Paper tube extinguisher</td>
<td>Drill</td>
</tr>
<tr>
<td>Human resources</td>
<td>Oil</td>
<td>Blade to roller</td>
</tr>
<tr>
<td>Stamps</td>
<td>sulfuric aced</td>
<td>Carbon’s electrodes</td>
</tr>
<tr>
<td>Stickers</td>
<td>Extra flexible wire</td>
<td>Other</td>
</tr>
<tr>
<td>Required information</td>
<td>Copper sheet</td>
<td></td>
</tr>
</tbody>
</table>

**Table 2. Required materials, resources and components**

### Step 4. Calculation of the value added coefficient.

The table 3 shows the inventory and cost in each process. The manufacturing times are the same showed in the table 1. The data to calculate the added value to 127v’s EPM are shown in the table 3. As we see in this table, the added cost in the supply chain corresponds to a value of $1.52, matching with the direct cost of the supply chain. The profits are $2.59 and the remaining represents the raw material cost ($9.72). On hand, the bottleneck is the calibrating process with the highest net added value while the process of highest added value is the assembly and sealing process.

### Step 5. Calculation of value for each product at each operation.

The obtained value added at each operation is shown in the figure 2. As it is shown, the final value of the product at any operation is equal to the initial value in the following operation. For example, 11.76 is the final value at calibrating operation and thus initial value at operation of assembly and selling.

<table>
<thead>
<tr>
<th>Processes</th>
<th>$CD_{ik}+C_{ik}$ ($)</th>
<th>$t_{ik}$ (s)</th>
<th>$Inv_{ik}$ (art)</th>
<th>$W_{ik}$</th>
<th>Profit ($)</th>
<th>$X_{ik}$ ($)</th>
<th>$CA_{ik}$ ($)</th>
<th>$X_{ik}$ ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supplying</td>
<td>0.17</td>
<td>5.76</td>
<td>0.00</td>
<td>0.08</td>
<td>0.21</td>
<td>0.15</td>
<td>0.36</td>
<td></td>
</tr>
<tr>
<td>Preparation</td>
<td>0.25</td>
<td>7.20</td>
<td>164.00</td>
<td>0.20</td>
<td>0.52</td>
<td>0.26</td>
<td>0.78</td>
<td></td>
</tr>
<tr>
<td>Calibrating</td>
<td>0.18</td>
<td>15.00</td>
<td>216.00</td>
<td>0.38</td>
<td>0.98</td>
<td>0.21</td>
<td>1.19</td>
<td></td>
</tr>
<tr>
<td>Assembly and sealing</td>
<td>0.67</td>
<td>7.20</td>
<td>0.00</td>
<td>0.19</td>
<td>0.49</td>
<td>0.59</td>
<td>1.08</td>
<td></td>
</tr>
<tr>
<td>Packing</td>
<td>0.18</td>
<td>5.76</td>
<td>0.00</td>
<td>0.08</td>
<td>0.20</td>
<td>0.17</td>
<td>0.37</td>
<td></td>
</tr>
<tr>
<td>Storage</td>
<td>0.17</td>
<td>5.00</td>
<td>0.00</td>
<td>0.07</td>
<td>0.18</td>
<td>0.15</td>
<td>0.33</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1.61</strong></td>
<td><strong>45.92</strong></td>
<td><strong>380.00</strong></td>
<td><strong>1.00</strong></td>
<td><strong>2.59</strong></td>
<td><strong>2.59</strong></td>
<td><strong>1.52</strong></td>
<td><strong>4.11</strong></td>
</tr>
</tbody>
</table>

**Table 3. Added value per process of the 127v’s EPM**
Step 6. Calculation of the required money for raw materials purchasing

In this step we’ll analyze if there are losses or saving in the 127V’s EPM. The initial and final added value per process is shown in the figure 2, where the initial value of first process is $ 9.49 and the raw material cost is $ 9.72.

According of the initial value of first process and the raw material cost there is a loss of $ 0.23 (difference between 9.72 and 9.49). This loss decreases the profits, affecting at same time the added value per process in this EPM. Supposing the company buys the raw material anyway, the new added value in each process will be as table 5 shows.

![Figure 2. Initial and final added value per process to 127v’s EPM](image)

<table>
<thead>
<tr>
<th>Process</th>
<th>Supplying</th>
<th>Preparation</th>
<th>Calibrating</th>
<th>Assembly and sealing</th>
<th>Packing</th>
<th>Storage</th>
</tr>
</thead>
<tbody>
<tr>
<td>$W_k$</td>
<td>0.08</td>
<td>0.20</td>
<td>0.38</td>
<td>0.19</td>
<td>0.08</td>
<td>0.07</td>
</tr>
<tr>
<td>Profit ($)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$X_{nk}$ ($)</td>
<td>0.18</td>
<td>0.47</td>
<td>0.89</td>
<td>0.45</td>
<td>0.19</td>
<td>0.17</td>
</tr>
<tr>
<td>$CA_{nk}$ ($)</td>
<td>0.15</td>
<td>0.26</td>
<td>0.21</td>
<td>0.59</td>
<td>0.17</td>
<td>0.15</td>
</tr>
<tr>
<td>New $X_{nk}$ ($)</td>
<td>0.33</td>
<td>0.73</td>
<td>1.10</td>
<td>1.04</td>
<td>0.36</td>
<td>0.32</td>
</tr>
</tbody>
</table>

Table 5. New added value per process to 127v’s EPM

Conclusion

The main contribution of this tool is the added value calculating. This added value is calculated independently of the initial raw material cost and product profit. At same time this procedure is very important because allows detect the bottleneck process. Moreover, the calculated initial value allows comparisons with the purchasing budget, providing additional decision criteria (purchasing capacity) to supplier’s selection.

In this supply chain we could see how the added value per product change, varying only the profits and his added value per process. In the case of a machine or process dedicated to various products, the only one difference will be the inventories, costs and manufacturing time. On the other hand the process of highest net added value is the calibrating process and the assembly and selling process is the highest added value process.

This procedure can’t be applied to services supply chain because the service processes have different characteristics to the production process. One of these main characteristics is the elements of the customer services.

4. Vinajera, A., F. Marrero, and W. Sarache, *Procedure for calculating added value: application in the medium-


