B.9 Ninth Annual Contest: SM Electronics

SM Electronics is a small manufacturer that produces electronic parts used by a variety of other manufacturers. Recently, we noticed problems in a department that produces three different parts. The demand mix for these three products has changed slowly over time. The department is almost fully automated and consists of four lines. Each of the first three lines produces a single product and they have all been modified over time to meet the current demand mix. When the almost-finished parts (Parts A, B, and C) exit these three lines, they all enter the fourth line where the final operations are performed for all product types. The new product mix has caused the fourth line to become a bottleneck.

SM Electronics employed several consultants to collect data and recommend modifications to this line. Although we’ve received sufficient information to proceed with the modifications, the actual performance after the modifications are implemented is in question. Two different approaches were suggested. At this time, it’s not clear which approach would provide the best results. It’s also possible that both suggested modifications may be required in order to achieve the desired performance. In light of this uncertainty, we are initiating this request for recommendations.

You are asked to evaluate the current design and propose the configuration(s) that will result in approximately minimizing operating cost while still achieving the desired performance levels. With this in mind, this document describes the current system and presents the two different modifications that have been proposed, as well as including data where they are available.

Your analysis should concentrate on the fourth line, and a schematic of it is shown. We do not anticipate a need to change the first three lines, so we will give you only limited information on them.

Parts A, B, and C enter the fourth line on the left. Since the lines that produce these parts are fully automated, their arrival rates are very predictable. The normal arrivals for the three parts are: Part A, every 2.8 minutes; Part B, every 1.4 minutes; and Part C, every 2.0 minutes. There are occasional jams on these lines, which can cause slight delays in part arrivals. The collected data show that delays occur 2%, 1.75%, and 0.5% of the time on Lines A, B, and C, respectively. The data for these delays have been analyzed and triangular distributions have been fitted to the data. The parameters for these distributions are (5,15,60), (5,20,55), and (5,20,65) for Lines A, B, and C, respectively. Note that the time units for these parameters are in seconds.
The arriving parts are merged (in the order in which they arrive) onto a single input conveyor, which feeds the fourth and final system. The input conveyor from the merge point to where the parts enter the fourth system has room for 40 parts. If this input conveyor becomes full and a new part attempts to merge onto the conveyor, then the line producing that part temporarily shuts down until space becomes available. Currently, there are numerous shutdowns during each day. For analysis purposes, you can assume that if a part arrives and the input conveyor is full, that part is considered to be lost production. The cost for a lost part is $0.89, $0.63, and $0.72 for Parts A, B, and C, respectively.

The fourth system consists of eight work cells connected by a power-and-free conveyor. The distance between each work cell is 18 feet. When a new part enters the system from the input conveyor at Work Cell 8, it must wait for a special pallet that will hold the part as it travels through the system. Presently, there are 40 pallets in the system, each requiring 2 feet of space. Thus, there is room for eight pallets between each pair of successive work cells (16 feet of buffer space and 2 feet for the work cell). The travel time between work cells (18 feet) is 15 seconds.

When both a pallet and a new part are available at Work Cell 8, the finished part is first removed from the pallet, and then the new part is loaded. This unload/load process is fully automated and takes 25 seconds. A jam occurs approximately 1% of the time, requiring additional time. The time to respond to a jam follows a triangular distribution with parameters (5,15,75). These parameters are expressed in seconds. Once the unload/load process is complete, the pallet moves to the buffer area in front of Work Cell 1. If there is no room in the buffer area, the pallet remains at the unload/load work cell until room becomes available. In effect, the waiting loaded pallet blocks the unload/load work cell.

The new part moves through the system where an operation is performed at each of the remaining seven work cells. Work Cells 1, 3, 4, 5, and 6 are automated operations. Work Cells 2 and 7 are manual operations.

When a pallet enters an automated work cell, a scanner reads the part type on that pallet. If the part type is different from the last part type at that work cell, the work cell must undergo a setup. The required setup time is dependent only on the new part type. These setup times (in seconds) are given in the table below.
For example, if a Part B arrives at Work Cell 1 and the previous part at that work cell was either an A or C, then a 20-second setup is required. If the previous part was a B, then no setup is required.

The operation or process time at the automated work cells is also part dependent. These operation times (in seconds) are given in the following table. For example, a Part B at Work Cell 4 requires a 38-second operation time.

<table>
<thead>
<tr>
<th>Part Type</th>
<th>Work Cell 1</th>
<th>Work Cell 3</th>
<th>Work Cell 4</th>
<th>Work Cell 5</th>
<th>Work Cell 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Part A</td>
<td>25</td>
<td>52</td>
<td>35</td>
<td>29</td>
<td>11</td>
</tr>
<tr>
<td>Part B</td>
<td>20</td>
<td>21</td>
<td>22</td>
<td>14</td>
<td>19</td>
</tr>
<tr>
<td>Part C</td>
<td>17</td>
<td>34</td>
<td>24</td>
<td>37</td>
<td>17</td>
</tr>
</tbody>
</table>

The operation or process times at the two manual work cells follow triangular distributions with the parameters given, in seconds. No setup is required at the manual work cells.

<table>
<thead>
<tr>
<th>Part Type</th>
<th>Work Cell 2</th>
<th>Work Cell 7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Part A</td>
<td>36,45,52</td>
<td>27,35,41</td>
</tr>
<tr>
<td>Part B</td>
<td>21,32,39</td>
<td>31,39,43</td>
</tr>
<tr>
<td>Part C</td>
<td>32,36,42</td>
<td>22,27,38</td>
</tr>
</tbody>
</table>

Based on our observations, we feel that you can safely assume that no jams or failures occur at Work Cells 1 through 7.

The factory is currently working two shifts, a 16-hour production day, five days a week. The lines are shut down at the end of each day, leaving the incomplete parts in the system, and they are restarted at the beginning of the next working day.

Although casual observations by the consultants and our production engineers indicate that our lost production cost is high, we are not able to place a dollar value on that loss. Thus, the first question we would like you to address is: What is the cost of lost production for our current system? Please provide this as a weekly cost.

We would then like you to evaluate the two proposed modifications to see if they make economic sense. The first proposed modification requires that we add pallets to the existing fourth system. Since the current control logic for that system was developed specifically for 40 pallets, that logic must be modified. The fixed cost for this modification is $17,000. This cost is incurred even if only one pallet is added. In addition, there is an incremental cost of $3,000 for each pallet added.
The second proposed modification requires that we insert additional space for incoming parts by adding three new buffer conveyors. The amount of additional storage is limited, based on available space. The current available space would allow three buffer conveyors to be added at the incoming merge point, one conveyor for each part type. Each of these conveyors would have space for an additional ten parts. The concept is that each of the first three lines would insert their parts into their own buffer conveyor (limited to ten parts on each conveyor). Logic would then be developed that would allow these parts to be released in batches to the existing buffer conveyor (limited to 40 parts). For example, you might release in batches of five. When these batches of five (all the same part) are processed by the final system, there would be only one setup at each of the automated operations at the start of the batch. We have already priced this option with a conveyor manufacturer. The cost to implement this modification is $56,000. This cost includes the equipment cost, installation cost, and the development of whatever release logic is required.

SM Electronics requests that during your analysis you evaluate and answer the following questions:

1. What is the cost of lost production for our current system?
2. What is the cost savings, if any, resulting from the implementation of the first proposed modification?
   - How many additional pallets should be added?
3. What is the cost savings, if any, resulting from the implementation of the second proposed modification?
   - Include a detailed description of your proposed release logic.
4. Should we implement both of the proposed modifications?

Please provide all cost comparisons in dollars per week. Your report should include a recommendation for the most cost-effective system. Your analysis may reveal that neither of the two options should be considered.

We are currently occupied by other activities and will not require a solution until early April. Since there are several groups competing for this contract, we have decided that we will not provide additional information during the analysis period. However, you are encouraged to make additional reasonable, documented assumptions. We look forward to receiving your report in April and reviewing your proposed solution.