EFFICIENT MATERIALS HANDLING
OF COMPONENT PARTS

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Managing the internal material flow of a complex assembly system is a difficult task involving the temporary stocking and transportation of an abundance of component items which arrive at different receiving points in the production plant and need to be transported to their respective production sections at the assembly line.

General Motors Continental located at Antwerp, Belgium, consisted of two car assembly plants, Plant I and II, each producing different car types until August 1988. Since then, the entire production of Plant I has been transferred to Plant II, together with the release of a brand new model. This resulted in a 43% production capacity increase of Plant II and a total change in model mix of two substantially different model types. As a consequence, the necessary parts supply increased as well, causing heavier traffic loads for receiving and internal distribution.

The stockroom for a particular item (see Figure 1) was determined by the location of the work center where it would be used, which may not be the most efficient way in terms of total internal transport. In particular, transport from the receiving point to the selected stockroom is not taken into account. The main objective was minimizing the distance for transporting components from a given receiving point to an appropriate stockroom, and subsequently from that stockroom to the relevant work center (see Figure 1).

The above problem could be modeled as a transshipment problem [4], resulting in a formulation of enormous dimensions for the situation at hand—in fact, modeling the situation for 13 receiving points, 7 stockrooms, and 50 work centers in transshipping 3000 items would result in over ten billion shipping possibilities. Alternative approaches in the material handling literature deal with much more simplified problem situations [1, 2, 3]. A more recent methodology of “simulated annealing,” which could be used for assigning possible product groups to stockrooms, described by Wilhelm and Ward [5], cannot take into account the stockroom capacities.

In minimizing distance, the available stockroom capacities must be taken into consideration. Then homogeneous item groups are formed based on function, type of subassembly or type of packing. These keep the total materials function transparent and manageable. Otherwise, components subject to similar types of subassembly might be dispersed over the production plant and would be harder to keep track of and locate (attempting to manage each component individually would make the problem prohibitively difficult).

THE METHOD

The algorithm can be divided into two steps. First, calculate for each stockroom a weighted average distance, defined as the total internal distance (in meters) driven to distribute the average daily requirement of an item group from the various receiving points to the stockroom and subsequently from that stockroom to the different work centers at the assembly line in need of that item (see Figure 1). Second, assign each item group to a single stockroom such that the total distance driven for distribution is minimized.

Step 1. Distance and capacity computations

For each item the optimal stockroom is computed in terms of minimal weighted average distance driven. In computing this distance, the average daily produc-
tion requirements and deliveries (because of a JIT-like supply chain) are initially translated into the amount of packings to be distributed pertaining to that item. Next, the most frequently used means of internal transport is determined, from which the number of times the transport vehicle has to drive back and forth is calculated. The relative frequencies of the receiving pattern over the different receiving stations are determined for that particular item.

Two important issues were taken into consideration when developing this distance measure: (1) the issue of ‘dead-end’ production streets at the assembly line, as illustrated in Figure 2. This caused the distance from a particular stockroom to a work center at the assembly line to depend on which side of the work center the item is delivered. (One could easily verify from Figure 2 that the distance from stockroom A to the left-hand side of the production section or work center is much smaller than the distance to the right-hand side of the same work center.) In order to incorporate this issue into the algorithm, the original work-center numbering system was modified by adding L or R, left or right side delivery at the line. (2) The transport vehicles have to return after delivery, hence a multiplication factor of 2 is inserted into the distance formula.

Example

Given the following data: two work centers, three stockrooms, and four receiving points, for item xyz with daily requirement of 1000, 50 items per packing, 4 packings per transport unit, and the distances in Tables 1 and 2, the distance pertaining to stockroom 2 is computed as:

\[
D_{xyz}\text{, }2 = 2[0.1(150) + 0.2(200) + 0.2(10) + 0.5(100) + 0.15(70) + 0.15(30) + 0.35(70) + 0.35(50)][1000]/50(4)
\]

\[
= 1,640.
\]

<table>
<thead>
<tr>
<th>Stockroom</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>W1 Left</td>
<td>80</td>
<td>70</td>
<td>20</td>
</tr>
<tr>
<td>W1 Right</td>
<td>120</td>
<td>30</td>
<td>40</td>
</tr>
<tr>
<td>W2 Left</td>
<td>10</td>
<td>70</td>
<td>40</td>
</tr>
<tr>
<td>W2 Right</td>
<td>50</td>
<td>50</td>
<td>20</td>
</tr>
</tbody>
</table>
For each group, the choice of stockroom in which to store relevant items is ranked in descending order as follows:
For a particular group under consideration, the stockroom that results in the minimal total distance needed for internal distribution, is listed as 'closest stockroom'. The stockroom that results in the second smallest total distance is denoted as second closest stockroom, etc.

Have all groups been allocated

Yes

Stop

No

Consider the group, not yet allocated, requiring the most capacity. Allocate this group to its closest available stockroom. Compute the total required stockroom capacity.

Update the total required stockroom capacity

No

Has the nominal stockroom capacity been surpassed?

Yes

Search for the group that results in the smallest total distance increase for the closest available stockroom. Compute the new capacity required for this stockroom if the group with the smallest distance increase were to be removed and reallocated to that group's 'next closest' available stockroom.

Reallocate the group to its 'next closest' available stockroom.

No

Has the capacity of the 'next closest' available stockroom been surpassed?

Yes

Do not reallocate this group. Consider the 'next closest' available stockroom as the current 'closest' available stockroom.

FIGURE 3: The allocation algorithm of Step 2
Similarly, distances to stockrooms 1 and 3 are calculated as 1660 m and 1800 m, respectively.

Next the effective storage capacity used is calculated, expressed in square meters for the average inventory level of a particular item. (Development of the equations for computing the distances and the effective capacity are available on written request from the fourth author.) As a rule, packings of different items are never stacked on one another.

After distance and capacity measures are computed for an individual item, the items are pooled into “homogeneous” groups. Homogeneity could be interpreted in different ways. A first grouping methodology could be according to “function,” e.g., bumpers that differ in color, dimension, and packing. Another way of grouping could be according to “type of subassembly,” e.g., the cockpit module. Finally, one could group items according to “type of packing,” which should preferably be limited to smaller standard parts that are to be stocked together. Management considered this grouping important to facilitate the location of an abundance of items over many stockrooms in order to make the physical location transparent and the retrieval process more straightforward.

In our example, grouping according to function was used. Groups of items are formed in such a way that individual items are assigned to one and only one group. For each resulting group, the total required capacity is computed as well as the total distance required when the group is allocated to a particular stockroom. All relevant computations of Step 1 are summarized in Table 3.

### Step 2. Allocation

In the second step, the distance and capacity information for each group is used to allocate the item groups over the different stockrooms, taking into account the respective capacity limits and maintaining homogeneity. Individual groups are not to be disaggregated over multiple stockrooms. The nominal stockroom capacities were calculated as the capacity minus an allowance for handling and maneuvering as well as a safety margin for “higher than average” stock levels.

The allocation algorithm of Step 2 is presented schematically in Figure 3.

### TEST STUDY

A test study was performed by allocating 69 randomly chosen A items (using ABC classification) over a subset of 7 stockrooms, 13 receiving points, and 50 work centers. Grouping according to function resulted in 37 homogeneous groups. The results of this test study are listed in Table 4.

### TABLE 4: Results of the Test Study

<table>
<thead>
<tr>
<th>Stockroom</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>N</th>
<th>P</th>
<th>V</th>
<th>SHED</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Groups Allocated</td>
<td>13</td>
<td>5</td>
<td>3</td>
<td>3</td>
<td>6</td>
<td>1</td>
<td>6</td>
<td>37</td>
</tr>
<tr>
<td>Current Distance Needed for Distr. (m/day)</td>
<td>131,240</td>
<td>53,271</td>
<td>13,500</td>
<td>21,492</td>
<td>43,119</td>
<td>7,776</td>
<td>241,434</td>
<td>511,832</td>
</tr>
<tr>
<td>Distance Needed with Allocation Procedure (m/day)</td>
<td>130,808</td>
<td>51,597</td>
<td>27,864</td>
<td>21,492</td>
<td>15,660</td>
<td>13,324</td>
<td>241,434</td>
<td>502,180</td>
</tr>
<tr>
<td>Difference (%)</td>
<td>0</td>
<td>3</td>
<td>−106</td>
<td>0</td>
<td>64</td>
<td>−71</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Required Capacity without Allocation (%)</td>
<td>80</td>
<td>11</td>
<td>89</td>
<td>40</td>
<td>80</td>
<td>90</td>
<td>79</td>
<td>79</td>
</tr>
<tr>
<td>Required Capacity with Allocation (%)</td>
<td>84</td>
<td>11</td>
<td>99</td>
<td>40</td>
<td>49</td>
<td>100</td>
<td>79</td>
<td>69</td>
</tr>
</tbody>
</table>
Extrapolating a 2% improvement, as indicated by the test study, to the realistic situation of approximately 3000 A and B items, results in a reduction of about 420,000 m of travel per day. At an average driving speed of 5 km/hr, this translates into potential savings of 12 material handlers, or $480,000 per year. The test study took 30 sec of computation time on a personal computer.

CONCLUSION

A method to improve the materials handling function of an automotive manufacturing plant was developed to minimize the distance components are transported from receiving points to relevant work centers at the assembly line, taking into consideration intermittent stockrooms. The procedure calls for similar groups of items to be stored in a selected stockroom so that scattering of individual items over multiple locations is avoided.

A test study demonstrated the computational feasibility of the procedure and its potential for substantial cost savings, as well as making it suitable for problems with large numbers of items, receiving points, stockroom locations, and work centers.

REFERENCES


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