Evaluation and Optimization of Inventory Policies and Production Layouts in Production Systems

-A Case Study

Emelie Järlid and Jenny Karlsson
Division of Production Management, LTH

Building a production facility from scratch is a demanding task that involves several complexities. To assure that the plant will be efficient when it comes to material handling it is important that the flows within the plant are analysed so the best material handling equipment and storage solutions are chosen and that the layout is supporting the greatest flows during the year. It is also important to know how large the inventories and the production areas need to be to assure that there is enough space while still the transportation distances are kept short. Forecasting methods and inventory policies can be used to get values of how many pallets the inventories need to be able to store, a layout algorithm gives optimal placements for the different units within the plant, and a simulation model helps the understanding of what material handling equipment that is required.

Background
This study takes place at a company that are facing the task of building an entirely new plant. This is because they suffered from fire accident that completely destroyed the plant a while ago.

The layout of the previous plant was not optimal since the equipment had not been reallocated when new equipment was added. The fire was a setback, but the company wants to turn what happened into developing something better.

The company has been working on its market for a long time and are known for its low prices, on-time deliveries and high quality. These are performance index that the company wants to remain.

Objective
The objective is to analyse the company’s material flows as a basis for decision making about the layout of the inventories. The purpose is also to look at what and how many handling equipment to use.

The objective is also to analyse the previous inventory levels and finding ways to improve the forecasts if needed, to be able to recommend the dimensions of the new inventories.

The company wants to have low prices compared to competitors, but also achieve a good flexibility to become more competitive, which is affecting the final recommendations.

Method for Optimizing the Plant Layout
There are several different algorithms that can be used for optimizing a layout. In this project an algorithm called CRAFT, Computerized Relative Allocation of Facilities Technique, is used. This algorithm is built upon initial layouts where pairwise exchanges are made to find the layout that gives the lowest value of the objective function. The exchanges follow a kind of a Greedy Algorithm where the exchanges continue until the value of the objective
function does not improve anymore. However, in this project the exchanges continue further since it was found that the Greedy Algorithm did not always give the best result. In this project a modified greedy algorithm is therefore used because it works better in this case where the objective function has several minima.

The objective function and its parameters are presented below.

\[ \min z = \sum_{i=1}^{m} \sum_{j=1}^{m} f_{ij}c_{ij}d_{ij} \]

where \( m \) = number of departments
\( f_{ij} \) = flow from department \( i \) to department \( j \) (unit loads/unit time)
\( c_{ij} \) = cost of moving a unit load one distance unit from department \( i \) to \( j \)
\( d_{ij} \) = distance from department \( i \) to \( j \)

(Tompkins et al. 2003)

The achieved effect by using this algorithm is that units within a plant that have a great flow of material in between are placed adjacent, to get an objective function with a low value.

**Method for Simulating a Production Facility**

Simulation is a tool that can be used by companies when scenarios and changes in a production system need to be tested. By applying simulation technology the company can avoid making poor investments or rebuilding because they are able to test different ideas beforehand (Kelton, Law 2000). In this case the structure of the facility has been regarded as rather complex and the model is therefore built in a simulation software, ExtendSim8, instead of using a mathematical model.

**Method for Deciding Inventory Levels**

There are two different methods for deciding inventory levels to use depending on if the demand seems to have seasonal variation or not. These are Winter’s Trend Seasonal model and Exponential Smoothing. The products in question are analysed and the products are grouped together according to its features. Sales data are used in lack of demand data and an analysis of this data is used to decide if the demand behaviour is seasonal or not.

The forecasted demand forms the basis for the recommended inventory levels that are calculated using the \((R, Q)\) inventory policy, with its maximum level that is equal to the order quantity plus the reorder point. The optimal reorder point is the minimum value of \( R \) such that the prescribed fill rate is attained. The definition of Serv2, also called the fillrate, is the fraction of demand that can be satisfied immediately from stock on hand. The order quantity, \( Q \), is attained from regarding historical data.

**Result and Analysis**

The CRAFT algorithm resulted in a couple of different possible layouts. The algorithm is run with different flow matrix, \( f_{ij} \), because the flow of products looks different depending on if it is summer, winter or the whole year, resulting in three different layouts. Some modifications are made to some of the layouts since there are restrictions that some units need to be adjacent even though there is not a large flow of products between them.

The chosen layout is the one for the winter season and this layout presented below. The numbers represents different units within the building. The difference between the layouts for the winter season and the whole year is just the placement of area 6 and 7 and these two areas are merged in the final layout, Layout 1. All areas are equally large, which is a simplification that makes it possible to exchange all areas without limitations.
The simulation model gives a hint of how many wheel loaders, double-reach trucks and ports to the building that are needed. The simulation model does not give one optimal solution but makes it possible to compare solutions and finding the relatively best solution. The performance of a setup of material handling equipment is evaluated on how well the customers are served and how high the utilization rate of the equipment is. Different scenarios have been tested where the initial inventory level varies and a different number of loading ports is used. Simulations are run ten times for each scenario tested and confidence intervals are calculated that are used to validate if the improvement is significant.

Below is an example of how different scenarios are compared in the aspect of how the material handling equipment is utilized. Both the double-reach truck and the wheel loader are harder utilized in scenario 2 than in 1. This increase in utilization is significant since the confidence intervals do not intersect.

<table>
<thead>
<tr>
<th></th>
<th>Utilization Scenario 1</th>
<th>Utilization Scenario 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Double-Reach Truck</td>
<td>0.7932±0.02984</td>
<td>0.8441±0.02354</td>
</tr>
<tr>
<td>Wheel Loader</td>
<td>0.3251±0.01737</td>
<td>0.3472±0.03111</td>
</tr>
</tbody>
</table>

For the inventory analysis the products are divided into product groups with similar properties. Depending on the seasonality in the product group different forecasting methods are used and with the usage of the (R, Q) policy a total number of pallet positions is calculated for all product groups. The result from the inventory analysis is that there needs to be three different mayor inventories for product groups with different demands. To get the total number of the pallet positions needed in all these inventories the values from all product groups included in the inventory are summed for each month in a year. The inventories are then dimensioned based on the number of pallet positions needed for the month with the highest level.

The products that are to be stored in an inventory affect the choice of storage method: floor storage or any kind of rack storage. The lane depths are given from an optimization formula, which take the storage height, the number of different products, the aisles width and the number of pallets of each product into consideration. The result is that the lane depth should be 2 lanes deep in one of the inventories, 7 in another, which both have rack storage, and 16 in the third inventory, where floor storage is recommended.

**Conclusions**

With the result from the CRAFT analysis and the inventory analysis it is possible to recommend final layouts for the two most complex buildings in the plant. The first layout is built upon the suggested layout from CRAFT, however it has been modified to the correct dimension of the different units and to make it work in reality.
The second layout has not been designed by the help from CRAFT since it is not that complex. This layout has instead been suggested by analysing flows manually.

![Diagram showing the layout of one of the larger buildings needed.]

All lift trucks working in the plant will be double-reach trucks since they are required for loading the trucks in the building in Layout 1. It will also be beneficial in Layout 2 to have double-reach trucks because it makes it possible to reach all pallet positions even though the depth of the pallet racks is two pallet positions. The result from the simulations is that there is a need for one wheel loader and one double-reach truck in the building in Layout 1 and two double-reach trucks in Layout 2.

The sizes and the dimensions of the pallet racks in the two layouts are decided from the result of the forecasted inventory levels.

It could be concluded that the CRAFT method is suitable for recommending a layout for a facility plant. Also, the simulation software is a great tool to use for systems that are complex in reality.

References
