Storage Location Assignment Problem: implementation in a warehouse design optimization tool

Fumi A., Battista C., Giordano F., Schiraldi M.M.

Department of Enterprise Engineering
“Tor Vergata” University of Rome, Italy

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Storage Location Assignment Problems

- S.L.A.P. concern the assignment of stock to storage locations:
  - Minimize the overall required space
  - Increase the easiness in retrieving allocated items
  - Reduce material handling times

- A critical issue in Operations Management and Research since ‘70 (see Hausman, Schwarz and Graves, 1976):

  - Dedicated Storage:
    \[ M_{ded} = \sum_{p} \max_{t} \left\{ M_{pt} \right\} \]

  - Randomized Storage:
    \[ M_{ran} = \max_{t} \sum_{p} M_{pt} \]

  - Class-Based Storage:
    \[ M_{ded} = \sum_{j} \max_{t} \left\{ \sum_{p} M_{pt} \right\} \]
Warehouse Management Systems

• Storage areas are critical to a wide range of customer service activities and are also significant from a cost perspective:
  • More than 22% of logistics costs in the US (Davis, 2005)
  • More than 25% in Europe (ELA/AT Kearney, 2004)

• W.M.S. should provide a set of computerized procedures to:
  • Handle the receipt of stock into a warehouse facility
  • Model the logical representation of the physical storage facilities
  • Manage the stock within the facility enabling a link to order processing and logistics management aiming to pick, pack and ship products out of the facility

• ERP W.M. modules often do not favor:
  • Competitiveness increase
  • Cost decrease (Malhotraa and Temponi, 2010)
S.L.A.P. issues and W.M.S. limits

“None of the existing tools has yet succeeded in effectively combining all these aspects and features” (Renaud 2007; Pessotto 2009).

- Data analysis
- Decision support
- Inventory management
- Storage area layout design
- Ease of use
- Tangible results guarantee
- Reduced cost of implementation

Tangible results guarantee
Aim of the research

• From an organizational point of view, performances of a storage area are fundamentally based on two variables:
  • The space reserved for material allocation
  • The time required for internal material handling operations

• The time variable, often not properly taken into account but crucial from a cost point of view, is strictly related to:
  • The number of warehouse operators to employ
  • The number of material handling vehicles (forklifts, etc.) to buy
  • The management cost of warehouses

• Need to integrate an appropriate storage policy with an accurate material handling time-saving approach

Warehouse design and management support tool
Tool’s desired features - Layout Design

- The tool should embed a customizable warehouse map to help users with *as-is* and *what-if* analysis on alternative layouts.
- Users should be able to easily represent their current warehouse’s layout locating shelves, aisles and IN/OUT point.

As-is analysis to evaluate existing warehouse performance
What-if analysis through virtual re-layout of the warehouse
Tool’s desired features - Data Analysis

- Starting from input data, the tool should analyze items movements occurred during the considered period providing:
  - The upper and lower bound on the number of required slots to allocate all products basing on a Dedicated and Randomized Storage Policy
  - The overall number of input and output movements per each product identifying “fast mover” items and “slow mover” items

- Basing on the created map and considering warehouse’s slots and forklifts height, the tool should provide in output:
  - The number of ground slots
  - The number of total required shelves levels
  - The overall available volume

- Pointed out warehouse input and output positions and considering forklifts speeds the tool should calculate:
  - Horizontal and vertical metric distances from each slot to the IN/OUT point
  - The average loading and picking time required for each available slot
Tool’s desired features - Inventory Mgmt

- The tool should calculate and visually represent a specific partition of slots "weight" according to the time needed to reach them. Weights can be computed using:
  - Metric distances from the input/output points and time to reach the slots
  - Enter/exit probability of products
  - Appropriate thresholds to split slots in classes (i.e. ABC analysis)

![Snapshot of slots weight visual representation]
The Decision Support System

- Pre-ordered list of products based on their decreasing M.R.
- Pre-ordered list of slots based on their increasing weight
- Matching between the product list and the slot list
- Optimum slot-code allocation assigns “hot” slots to fast movers items
- Efficient material handling times minimization
- Products specific volumes and weights
- Products movements in terms of handling frequency
- Performance characteristics of forklifts on the market
- Overall distance to cover basing on the slot-code assignment
- Most suitable model and number of forklifts to purchase

THE STORAGE OPTIMIZATION TOOL
Validation of the prototype - case 1

- Medium enterprise, one plant, one warehouse
- 3,487 items analysed on a period of one year
- Oversized and heavy weighted products -> single-stacking procedure
- Unique input-output point

![Graph showing material handlings](graph1.png)

The 80% of material handlings were related to the 25% of products.
Validation of the prototype - case 1

Evidences:
- The majority of codes was almost permanently stored in the warehouse.
- Absence of an effective warehouse information system.
- Inappropriate slot-code assignment.

Focus:
- Reducing distances travelled and handling times rather than the overall space.
- Dedicated Storage Policy selection.
- Gain the desired negative correlation between slot proximity to the IN/OUT point and products M.R. through a more efficient slot-code allocation without changing the original warehouse layout.
In the as-is storage allocation the average distance travelled to reach each slot resulted to be 38,9 meters and the overall distance travelled to handle all the products through the whole year resulted to be 3’389’621 meters.

The new travelling average value was 24,2 meters granting a 37,8% reduction of material handling inefficiency;

The overall travelled distances through the whole year fell to 2’107’673 meters;

Alternatively, the optimization could lead to the possibility of managing the same material handling volumes using only the 62,2% of existing resources.
Validation of the prototype - case 2

- Storage area: 2’569 products handled
- Receiving area: 1’195 products handled
- Delivery area: 6’447 products handled

- Slots and shelves selection basing on products weight and size
Validation of the prototype - case 2

- Planning of storage area’s position, size, shape and stock capacity basing on slots/shelves selection and items quantity

**Performance parameters**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Static capacity</td>
<td>7488 slot</td>
</tr>
<tr>
<td>Net static capacity (pallet mm 1200 x 800 x 1100)</td>
<td>7907.33 mc</td>
</tr>
<tr>
<td>Aisles number (2.8 m)</td>
<td>15</td>
</tr>
<tr>
<td>Area width</td>
<td>74 m</td>
</tr>
<tr>
<td>Number of slot per shelf unit</td>
<td>39</td>
</tr>
<tr>
<td>Shelf width</td>
<td>36.5 m</td>
</tr>
<tr>
<td>Number of ground slots</td>
<td>1248</td>
</tr>
<tr>
<td>Mean distance per ground slot</td>
<td>46.3 m</td>
</tr>
<tr>
<td>Max distance per ground slot</td>
<td>85.9 m</td>
</tr>
<tr>
<td>Mean overall distance per slot</td>
<td>67.3 m equivalent</td>
</tr>
</tbody>
</table>
Validation of the prototype - case 2

- Layout selection: multiple alternative computation
- Cross aisle granted a 36,5 meters saving per handling in different vertical “one-way” aisles:
  - A 17 seconds saving using forklifts (2,77 m/s horizontal speed and 80% efficiency);
  - A 21 seconds saving using electric transpallet (2,1 m/s horizontal speed and 80% efficiency);

<table>
<thead>
<tr>
<th>Performance parameters</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Static capacity</td>
<td>6480 slot (6 levels/3 levels)</td>
</tr>
<tr>
<td>Net static capacity</td>
<td>7672.32 mc</td>
</tr>
<tr>
<td>Number of ground slots</td>
<td>1368</td>
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</tbody>
</table>
Validation of the prototype - case 2

- Forklifts choice based on planned layout and slot access probability

<table>
<thead>
<tr>
<th>Storage level</th>
<th>Probability</th>
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</thead>
<tbody>
<tr>
<td>Level 1 (ground floor)</td>
<td>46,2%</td>
</tr>
<tr>
<td>Level 2</td>
<td>23,9%</td>
</tr>
<tr>
<td>Level 3</td>
<td>13,9%</td>
</tr>
<tr>
<td>Level 4</td>
<td>8,2%</td>
</tr>
<tr>
<td>Level 5</td>
<td>4,8%</td>
</tr>
<tr>
<td>Level 6</td>
<td>2,9%</td>
</tr>
</tbody>
</table>

Jungheireich ETV-214 770DZ – Performance kpi

<table>
<thead>
<tr>
<th>Performance kpi</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fork lift height</td>
<td>7,7 m</td>
</tr>
<tr>
<td>Fork lift speed (up)</td>
<td>0,44 - 0,70 m/s</td>
</tr>
<tr>
<td>Fork lift speed (down)</td>
<td>0,5 – 0,5 m/s</td>
</tr>
<tr>
<td>Horizontal speed</td>
<td>3,88 m/s</td>
</tr>
<tr>
<td>Minimum aisle width</td>
<td>2757 mm</td>
</tr>
</tbody>
</table>

- Selection of preferencial zones for forklifts missions assignment

![Diagram](image)
THANKS FOR YOUR ATTENTION

Andrea Fumi, Eng, PhD Candidate
Operations Management Research Group
Department of Enterprise Engineering
“Tor Vergata” University of Rome
Via del Politecnico 1 - 00133 Rome (Italy)
andrea.fumi@uniroma2.it