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Design of Warehouse for Material, Which Is Non-uniform and Difficult to Handle

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Abstract

Main goal of this paper is warehouse layout optimization with emphasis on maximum space utilization. It is about rack system design, which leads to capacity maximization of warehouse for non-uniform material with heavy weight. The warehouse system has to enable at least partial automation (the possibility to use AS/RS system), minimization of service time and minimization of man effort. Initial constraining conditions for warehouse design in our case are warehouse area, maximum load of racks or shelves, maximum allowed floor load and existing location of arrival road for material loading and unloading.

1 Introduction

Warehouse design and planning is very important part of company strategic planning. Tompkins [1] presents five basic optimization criterions for effective operation of warehouse. Rushton et al. [2] distinguishes thirteen basic steps for warehouse design. Baker [3] presents, that there isn't comprehensive systematic method for warehouse design today and he proposes eleven steps for warehouse design including used tools. These steps are based on literature compare and review and on practical approach of warehouse design companies.

In ideal case we can design new warehouse and at the same time we can also choose the location for new warehouse. However, in practice there may exist many constraining conditions such as limited amount of financial resources or fixed location for warehouse. Very specific is the solution for cases, when the existing warehouse is unsatisfactory and it is necessary to make its reconstruction or modernization. The primary effort is to decrease costs due to unsatisfactory capacity, obsolete facilities or work inefficiency. The main constraining condition in this case is given area of warehouse, layout of warehouse (leading ramp, inner and outer ways) and eventual requirement to keep some parts or areas in the warehouse.

The installation of new technologies, which enables automation of storage processes in the general practice, changed the requirements on storage and also on warehouse design. Automated storage and retrieval systems (AS/RS) are wide spread especially there, where the unified units (such as pallets) are stored. However, there are some commodities which it isn´t possible to store or transport in unified way. Also in this case it is possible to establish the partial or full automation, but general procedures for warehouse design is necessary to adjust for concrete commodity. The metallurgic and construction materials (sheet metal, sectional bars, rods, reinforcing steel bars, parts from concrete) belong to these commodities.

2 Input conditions

In business with metallurgic and construction materials it is necessary to operate a large number of warehouses due to big size and variety of material. It is possible to store some types of these materials (sheet metal, sectional bars, and parts from concrete) in open space. Increasing requirements of customers on quality of material force makers and suppliers to store these materials in indoor warehouses. Development of new storage capacities isn´t always possible, so the sellers try to increase capacity of existing warehouses through the change of inside equipment and work organization.

Subject of our solution is the warehouse for metallurgic material, whose part with area 1242 m^2 and size 60 x 22 x 8 m has to be modernized (see Figure 1). The material is stored only in one layer today. Due to this situation the capacity of warehouse is decreased and storing isn´t effective due to unused space.

Assortment of metallurgic material is very exacting on storage area. It is necessary to take into account the floor loading and loading limits of handling facilities. Lighter material is traded in packets. Wire is used for binding the packets. Heavier material (sheet metal, profiles) is handled separately. However, the material is controlled and traded in tons. This is important requirement for solution of warehouse capacity and choosing of handling facilities. Capacity of rack shelves is declared in tons, but material is handled separately (in pieces).

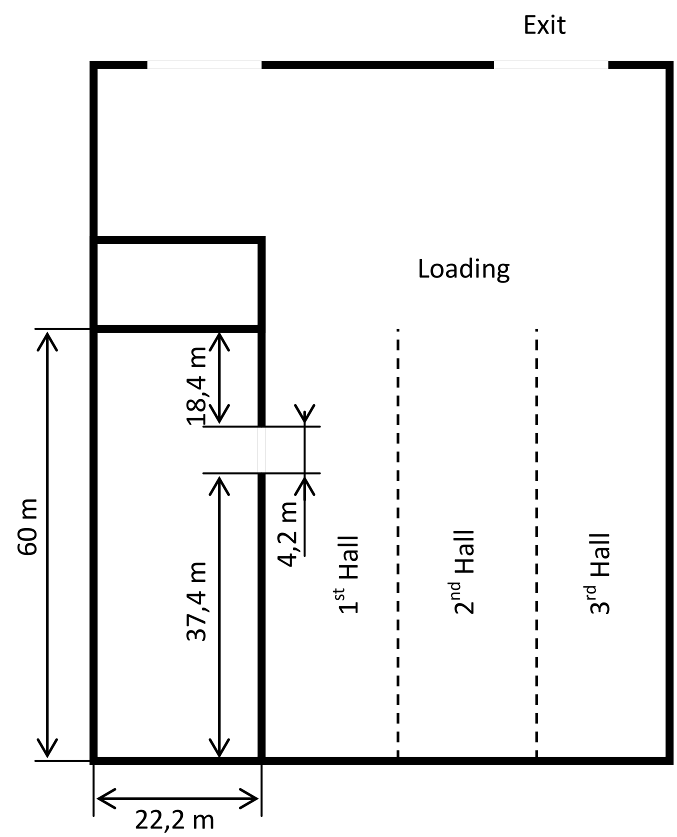

Figure 1: Today´s situation in warehouse

3 Data analysis

3.1 Warehouse requirements

Company, which operates the warehouse, establishes the requirements on warehouse design. Especially very important is the company's subject of concentration. Another requirements on warehouse has the production company and another the trade company. For the production company is specific, that the warehouse stock depends on production requirements and the basic stock composes of stock-in-trade and safety stock for case of failure. Stocks can be very well forecasted in conditions of steady production. For trade company is specific, that the warehouse stock depends on customer requirements. A part of stock is stored due to long-term contracts (can be forecasted very well) another part is stored due to actual market requirements (can be prognosticated worse). The trade companies also can store the speculative stocks.

In our case it is about company which sells a wide variety of metallurgical material. The company expects the triple increase of stock turn in next few years in modernized warehouse. The goal of warehouse design and possible contribution is mentioned in table 1.

Table 1: Warehouse requirements.

Requirement:	**Supposed contribution**
• maximization of load area in vertical and horizontal way	• warehouse capacity increasing
• maximum load of cell 2,5 tons	• better usage of space, the flexibility of stocking, greater possibilities of sorting
• racking of material in direction of handling	• saving of technologic time when turning
• at least partial automation of system	• accelerating of warehouse operation, improvement of safety, minimization of risk of stock records errors, shortening of operations related to material control
• minimal service time	• accelerating of warehouse operation
• minimization of number of workers	• safety improvement
• integrated scale for material control	• necessary part – material is filed and trade in tons • in case of integrated scale, there isn’t technologic process of weighting

Above mentioned goals are in harmony with common requirements on warehouse design, which are mentioned in literature [1, 2, 3].

3.2 Stored material

Product line includes logs of different diameter, tubes of different diameter and flat steel. Parameters of material are in table 2.

Table 2: Parameters of stored material.

Material	**Length of packet** l_i *[m]*	**Diametr of packet** d_i *[m]*	**Max. weight of packet** m_i *[t]*	**Max. specific weight of packet** ρ_i *[t.m^{-3}]*	**Percentage share of material [%]**
Round logs	6	0,3	2,2	5,18	60
	3	0,3	1,2	5,65	
Tubes	6	0,6	1,2	0,71	30
	3	0,6	0,8	0.94	
Flat bars	6	0,3	2	4,72	10
	3	0,3	1,2	5,66	

From table it stands to reason, that in the warehouse are stored six parametrical different materials. For design of racks' size is critical length and weight of packet. Today stock turnover is about 800 tons per month.

3.3 Material handling and storage racks

Today the bridge crane with maximal load six tons is used for material handling. The crane is operating through the remote control. The crane is invested with automatic scale, which is used for material invoicing and files. The device for gripping of load is used the girder with hooks. Material is stored in cantilever racks. System of racks is organized in three rows, six meters wide with two aisles for warehouse servicing. Length of these rows is 35 meters. This system of cantilever racks creates 75 cells for material stocking (see figure 2).

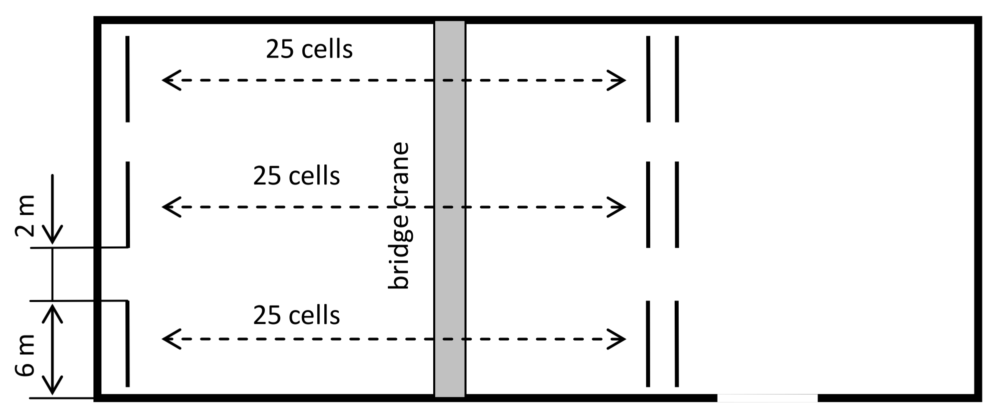

Figure 2: Current stocking system

From above mentioned follows that the warehouse is used non-effectively. Bridge crane indeed enables to minimize the width of aisles, but on the other hand the material can be stored only in one layer, so that the capacity is unsatisfactory even if the number of rack is relatively high.

4 Choosing of handling device and rack system

Choice of handling device is necessary make together with rack system design, because each handling device has other space requirements. From this the width of aisles is designated (see figure 3).

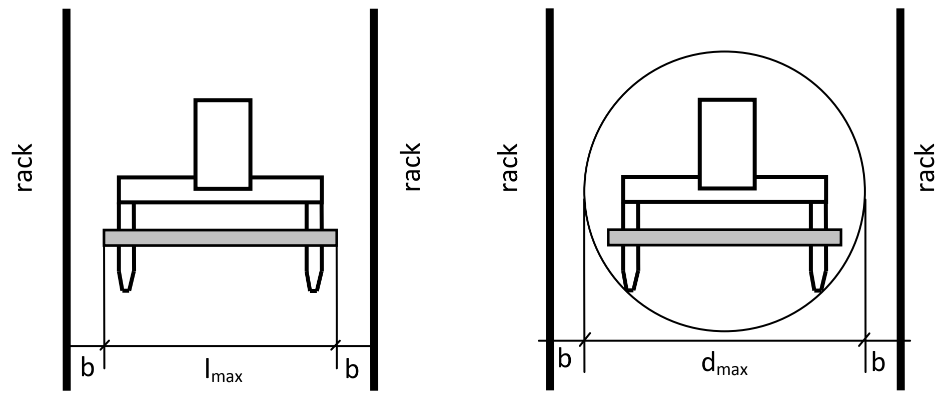

Figure 3: Width of aisles (top view)

Length of rack is count from length of handled parts. When only one type of rack with given length and width is used, it is possible to determine number of racks (with crosswise ordering) as:

$$n_r = \frac{B_w - [n_{tr}(l_{\max} + 2b) + n_{man}(d_{\max} + 2b)]}{L_r} \cdot \frac{L_w - [n_{tr}(l_{\max} + 2b) + n_{man}(d_{\max} + 2b)]}{B_r}$$

where:

n_r – number of racks in warehouse,
B_w – width of warehouse,
L_w – length of warehouse,
N_{tr} – number of transport aisles,
n_{man} – number of handling aisles,
l_{max} – maximal length of handled part,
d_{max} – maximal turn diameter of handling device,
b – safety distance of handling device from rack,
B_r – width of rack,
L_r – length of rack.

Based on defined requirements (chapter 3.1) is possible to choose for this warehouse two basic variants:

- industrial truck
- crane stacker.

The main advantage of industrial truck is flexibility, low purchase price and low operation costs. Disadvantage is need of large width of transport and handling aisles. This system provides partial automation. Crane stacker needs relatively small width of transport aisles and provides full automation. Disadvantage of this equipment is high costs of investments. In both cases is possible to use the cantilever racks, which provide the stocking of long and heavy parts in more layers.

5 Warehouse capacity

Capacity of warehouse in our case is determined in tons, even if the material is handled separately. The reason is the file and trade of material in tons. The capacity is given as:

$$Q_w = n_r . n_{c\cdot} \cdot Q_c$$

where:

Q_w – maximal capacity of warehouse [tons],
n_c – number of cells in one rack [pieces],
Q_c – capacity of one cell [tons].

Due to big floor load by stocking of material with big specific weight must be fulfilled following condition:

$$\frac{Q_c \cdot n_c + m_r}{F_r} \le q$$

where:

F_r – area of rack on floor of warehouse [m^2]
q – allowed floor load [tons/m^2]

Required capacity of one cell is 2.5 tons. Possible height of rack is about 5 m. With view to maximal weight of handled parts (also in case of storing of more than one packet in one cell), the real maximal amount of stored material will not achieve maximal warehouse capacity.

The inner configuration of warehouse is possible to design in several versions by using of industrial trucks and crane stacker (see figure 4). Final parameters of each version are in table 3. All four versions are improvement of current state. Reduction of workers is the same in all cases. The best minimization of service time is in version with industrial trucks. It is very interesting, that the best capacity results was achieved with lengthwise ordering of racks and in version number 3 was achieved the minimal service time too. The initial requirement on crosswise ordering of racks because of handling time shortening (turning) was needless.

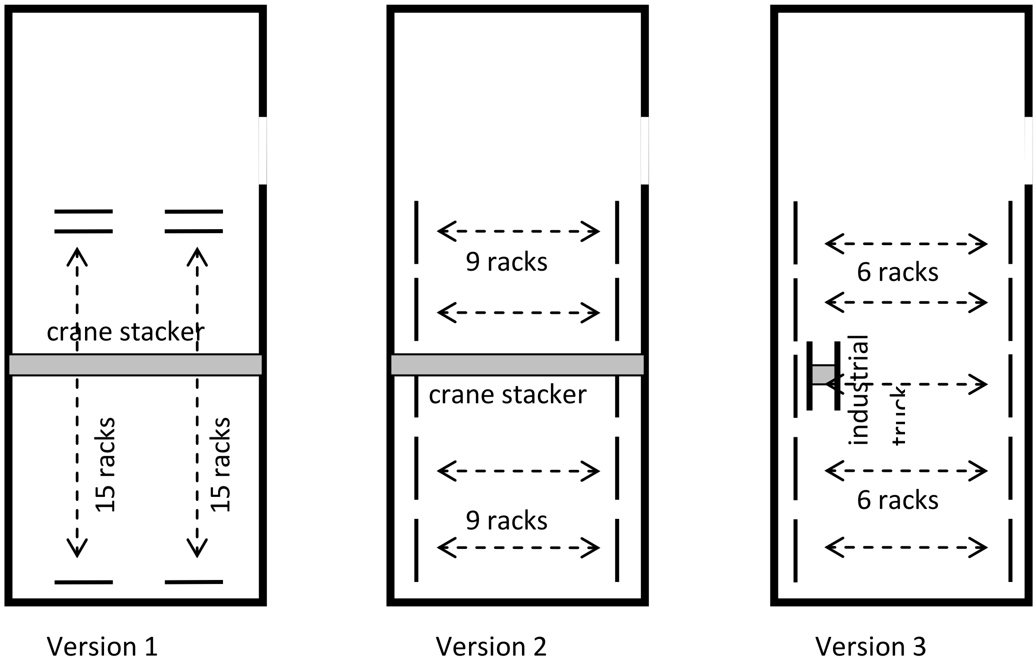

Figure 4: Versions of inner warehouse ordering

The comparison of resulting parameters of warehouse is in table 3.

Table 3: Comparison of results.

Parameters	**Original condition**	**Version 1**	**Version 2**	**Version 3**
Number of cells	75	504	720	480
Max. number of packets	300	504	720	480
Maximal capacity Q_w	660	1260	1800	1200
Speed of service	15 cycle/hour	30 cycle/hour	26 cycle/hour	42 cycle/hour
Min. number of workers	2	1	1	1

6 Generalization of methodological procedure of warehouse modernization

Mentioned case of warehouse modernization is characteristic with specific conditions, which are given by the character of stored material. The used procedure is possible to generalize:

1. Setting of warehouse requirement
   - Determination of goals of modernization (increasing of capacity, minimization of service time),
   - Warehouse operator has in most cases its own requirements, which must be fulfilled in design (requirement on method of stocking, preservation of part of equipment, preservation of reloading method, limited investments cost etc.).

2. Determination of modernization scope
   - Whole modernization procedure depends on scope of modernization (construction adjustments, exchange or preserving of stocking system, exchange or preserving of handling equipment etc.).

3. Analysis of input data
   - Information about current warehouse parameters (size of warehouse, capacities, stock turnover etc.).

4. Solution
   - Change of layout,
   - Change of handling equipment,
   - Change of stocking methods,
   - Change of work organization.

5. Evaluation
   - Fulfillment of input requirements, comparison with original state (capacity increasing).

7 Conclusions

In this case, we started from traditional procedures for warehouse design. Material had various character, but each type was enough defined by shape and size. This case was specific in that it wasn't about design of new warehouse, but modernization of current warehouse. In these cases there are more constrain conditions, which must be taken into account. The capacity of warehouse was increased because of height racks installation and implementation of partial or full automated system in our solution. Also the requirements on number of workers were lowered (we need only one worker) and the orientation in stored items was improved too.

In this case we resulted from traditional procedures for warehouse design. Material considered in this paper had various characters and each material type was sufficiently defined by shape and size.

Acknowledgement

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