DESIGN OF A STORAGE SYSTEM FOR A PART OF THE DISTRIBUTION WAREHOUSE BY APPLYING THE LOGISTICS PRINCIPLES

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Abstract

The paper presents an example of a storage system that was designed applying the logistics principles. The process of designing a storage system includes the application of design logistics systems. This process consists of several phases: project identification, design process paradigm selection, system analysis, synthesis, and project evaluation. The main focus is on the synthesis of two alternatives of the rack assembly.

Keywords: Design, storage system, pallet rack, layout

1. INTRODUCTION

The storage process, as one of the logistics processes, currently holds an irreplaceable position in logistics systems in companies and in the supply chain. The proper function of storage operations depends on, inter alia, the type of the used technology (storage systems) and their utilisation.

The analysis of the warehouses designing processes described in the literature [1] clearly indicates that designing a warehouse comprises a large number of interrelated decisions that are made while applying various methods and procedures. The source [2] describes five areas to be addressed when designing a warehouse: the determination of a general structure, selection of an operating strategy, the determination of the warehouse capacity and layout, and selecting the warehouse technology. The present article deals with one of the above listed areas, that is, the selection of warehouse technology, in particular a storage system. Obviously, designing a storage system is also related to the remaining four areas. Such designing process is carried out while considering the principles of logistics: the systematic approach, coordination, planning, algorithmic thinking, and global optimisation [3].

The systematic approach means that we view the processes and objects we manage as a system. Within the systematic approach, storage may be characterised as a process but also as a part of the logistics system - the storage subsystem.

Within the systematic approach, the process is generally characterised with five components [4]. With regard to the storage process, they may be characterised as follows:

A. Process Inputs and Outputs (stored inventory, groups of inventory, storage units, etc.);
B. Flow Units within the Process (kilograms, tonnes, numbers of pallets, containers, etc.);
C. Activities (receiving, placing, picking, shipping, etc.);
D. Sources (warehouse technology, handling equipment, staff, etc.);
E. Information Structure (information system, bar codes, etc.).

The above listed components represent the parts of a company's internal or external warehouses that may, obviously, exist in various forms.

2. METHODOLOGY

The process of designing a storage system represents the application of the process of designing logistic systems that is carried out in several consecutive phases described by authors Malindžák and Takala in the paper titled Designing Logistic Systems: project identification, selection of the designing process paradigm, system analysis, synthesis of the logistics system, and project evaluation [5]. This process was applied to the desig process of raw material transportation as well [6].

The basic steps within the process of designing a logistic system, adjusted to the requirements of the storage system design, are listed in **Figure 1**.

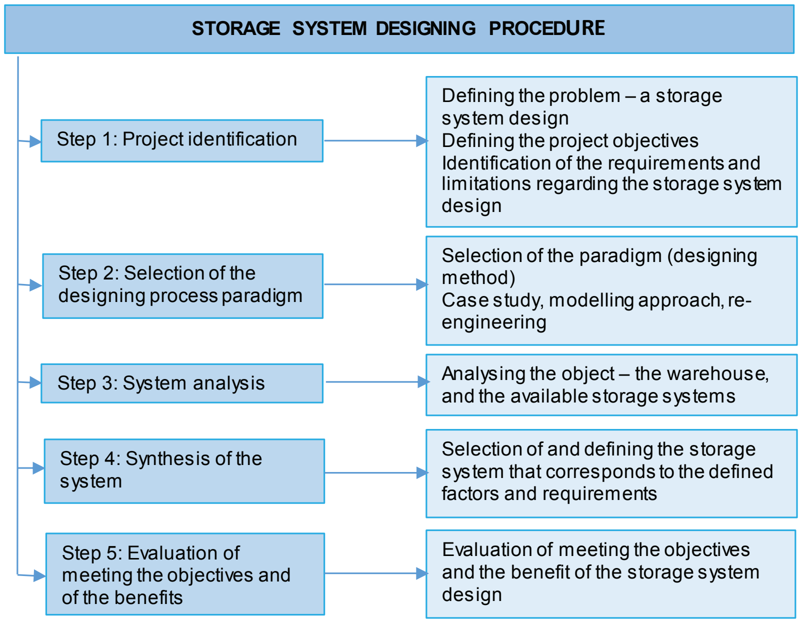

Figure 1 Modification - designing a storage system.

The process of designing a storage system for a part of the distribution warehouse is divided into six phases that comprise the modification of the process of designing logistic systems, as show in **Table 1**.

Table 1 Process of designing a storage system

1	Defining the design and selection of the paradigm	Step 1, Step 2
2	System analysis - analysis of the object and of potential theoretical solutions	Step 3
3	Defining a storage unit	
4	Designing two alternatives of the storage system (selection of the rack assembly, designing the rack field and the rack cell, selection of the operating technology, layout alternatives and evaluation thereof)	Step 4
5	Evaluation of the alternatives by applying the selected methods of the multi-criteria evaluation, and selection of an acceptable alternative	
6	Evaluation of meeting the objectives and of the benefits	Step 5

3. RESULTS - A DESIGN OF THE STORAGE SYSTEM FOR A PART OF THE DISTRIBUTION WAREHOUSE

3.1 Defining the design and selection of the paradigm

Designing a storage system for the new walk-in cooler with the temperature of 8 - 12 °C to be used for the storage of pallets carrying several types of inventory in the racks. The cooler is a part of the distribution warehouse. The purpose is to design a storage system that would consist of a rack assembly and the handling equipment that would facilitate the use of the maximum possible warehouse area at minimum costs.

On the basis of the available information, a paradigm - the modelling approach was selected to be applied in the following phase of the designing process because the present design is a design of a new storage system. The company is extending its business activities with storage services to be provided to its long-standing partner.

3.2 Object analysis

The storage system area was determined as the area with the dimensions of 20 m and 30 m, and with the height of 5.5 m. Therefore, the maximum height of the storage system is 5.4 m. On the basis of defining the design inside the walk-in cooler it was proposed to consider the technology of storing pallets in racks. Only two operations will be carried out in this particular warehouse, i.e., racking and picking the pallets. Receiving and shipping operations will not be carried out there. The storage area is 600 m2.

For the design purposes, the analysis of racks and handling equipment available on our market, as well as relevant suppliers, was carried out.

3.3 Defining the storage unit

The rack assembly will be used for the storage of storage units placed on EPAL pallets with the dimensions of 1,200 mm, 800 mm, and 144 mm, and with the loading area of 0.96 m2. The maximum height of the inventory to be placed on the pallet is 1,500 mm; the weight of the storage unit is approximately 800 kg.

3.4 Storage system design

On the basis of the analysis of the available and typically used rack assemblies, two alternatives of the rack assembly were chosen, as shown in **Figure 2**:

Alternative 1: Standard pallet rack with wide aisles.

Alternative 2: Dynamic flow racks.

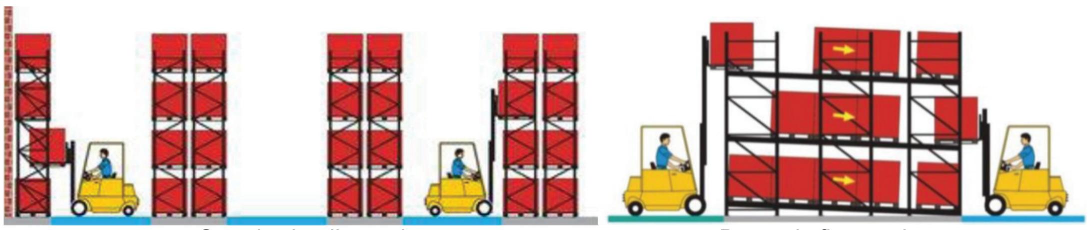

Figure 2 Storage rack alternatives [7]

The dimensions of the rack cell depend on the dimensions of the storage unit and the number of storage units in a rack cell.

In Alternative 1, the capacity of the designed rack cell was three pallets placed next to each other in the rack depth of 1,200 mm. With this type of racking, the cell width was 2,700 mm. The height of the rack cell was calculated as the value of 1,750 mm (including the allowance and the height of the beam). The loading capacity of the rack cell was 2,400 kg. The rack cell comprised three levels (storeys). The first level represented the warehouse floor. The height of the rack cell represented the height of three storage levels loaded with pallets. The height of the rack cell was determined as 5,250 mm; this meets the requirement defined in the beginning of the article, i.e., the maximum height of the storage system of 5.4 m.

In Alternative 2, the rack cell width was 2,700 mm again, and for the given storage unit (within the pallet width of 800 mm) three segments of a roller conveyor will be placed next to each other. The height of the cell (flow tunnel) was 1,750 mm. It was assumed that the rack field will also consist of 3 vertically arranged tunnels. The length of the tunnel was determined on the basis of the layout.

For the design purposes, the use of the STILL ESM 1 electric fork-lift with the loading capacity of 1,000 kg was considered as the handling equipment. The width of the aisle was to be determined by the manufacturer.

The layout of A1 of the storage system is shown in **Figure 3**. As can be seen in the Figure, in this case there are 7 racks with the length of 27,100 mm. In each rack there are 10 rack cells. The first rack is located by the wall on the right side of the door, in the distance of 100 mm from the warehouse wall, in order to eliminate the contact with the storage unit. Then there are 3 double rows of racks with the spacing of 100 mm that corresponds to the space between two adjacent pallets in adjacent rows. The total depth of the double rack, including the stored pallets, is 2,500 mm. The width of the handling aisle is 2,800 mm > 2,711 mm (determined by the manufacturer). The width of the two-directional transport aisle is 2,900 mm.

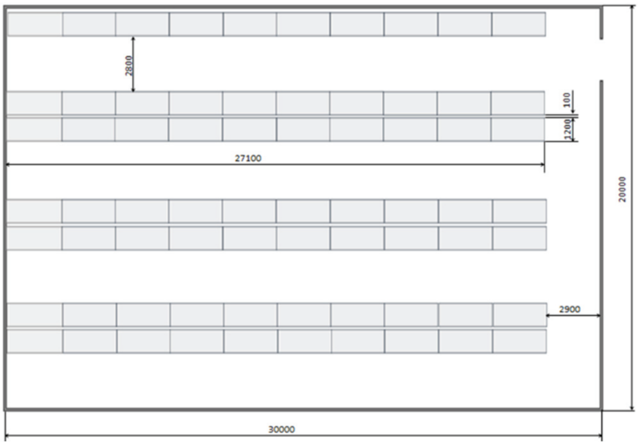

Figure 3 Layout of A1

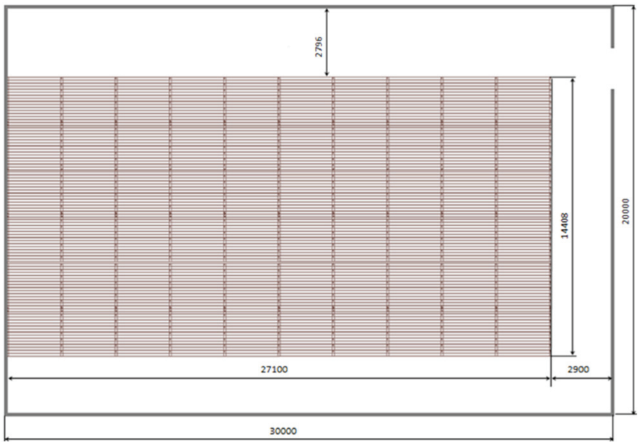

Figure 4 Layout of A2

The layout of A2 of the storage system is shown in **Figure 4**. The rack assembly consists of 10 flow racks with the tunnel depth of 14,416 mm. The dimensions of the rack assembly are 27,100 mm and 14,408 mm; the superelevation of the tunnel between the entry and the exit is 2° (503 mm). In the tunnel there are 12 storage units (pallets). The height of the rack assembly at the entry into the tunnel is 5,753 mm > 5,400 mm. How can we reduce this height? By reducing the number of vertically arranged tunnels or reducing the depth of the tunnel? **Table 2** contains the results of calculations for both of these methods. **Table 2** indicates that two of the concepts meet the requirement regarding the maximum height of the storage system, i.e.,

Table 2 Concepts of reducing the height of the rack assembly at the entry into the tunnel below 5,400 mm.

Concept	Number of tunnel levels	Number of pallets in the tunnel	Depth of the tunnel [mm]	Superelevation [mm]	Height of the rack assembly at the entry into the tunnel [mm]	Capacity [number of pallets]
1	3	12	14,416	503	5,753	-
2	3	7	8,410	293	5,543	-
3	3	4	4,810	168	5,418	-
4	3	3	3,610	126	5,376	270
5	2	12	14,416	503	4,003	720

Concepts 4 and 5. With Concept 4, the rack assembly reaches the capacity of 270 pallets; if 2 such assemblies were installed (which is possible with regard to the warehouse area), the capacity would increase up to 540 pallets. However, the capacity of the system may be increased with Concept 5, that is, by reducing the rack assembly down to 2 levels; this corresponds to the capacity of 720 pallets. In such case, the width of the handling aisles would be 2,796 mm and the width of the two-directional transport aisle would be 2,900 mm.

3.5 Evaluation of storage system alternatives and selection of an acceptable storage system alternative

In the introductory part of the present article, the following definition was provided: "*The purpose is to design a storage system ... that would facilitate the use of the maximum possible warehouse area at minimum costs*".

In order to fulfil such objective, it was necessary to make a decision on which of the alternatives meets this requirement. The decision on the acceptable design was made on the basis of the results of the multi-criteria evaluation [8] and applying three selected methods: Ratio-Index Method, Saaty's Method and Method of Pairwise Comparisons [9].

The evaluation was carried out by applying the values on the basis of five evaluation criteria:

A - Capacity - the number of pallet places in the assembly, in pieces;
B - Percentage of the storage area out of the total warehouse area;
C - Percentage of the storage space out of the total warehouse space;
D - Access to individual pallets using a fork-lift;
E - Investment costs of 1 pallet place, in €.

Table 3 contains the parameters of the criteria that were applied in the determination of weights and partial utilities of the alternatives.

This task was defined as maximising; the alternative with the highest value of the total utility represents the best solution. The results of the multi-criteria evaluation are compared in **Table 4** [10].

Table 3 Parameters of evaluation criteria

Criterion	Alternative 1	Alternative 2
A	630	720
B	39.75	65
C	38.64	43.69
D	to all pallets	to pallets located at the entry and at the end of the tunnel
E	18	175

Table 4 Comparison of the results of the multi-criteria evaluation

Method	Alternative 1	Alternative 2
	U_1	U_2
Ratio-Index Method	**7.3300**	5.5300
Complete Method of Pairwise Comparisons	0.3333	**0.6667**
Saaty's Method	0.4807	**0.5150**

3.6 Evaluation of meeting the objectives and benefits

The purpose was to design a storage system so that the storage area is used to the maximum extent at minimum investment costs. Through the implementation of the proposed procedure, two alternatives of the storage system were designed. On the basis of the multi-criteria evaluation, Alternative 2 was chosen as the acceptable design of the storage system. This design represents a dynamic flow rack and considers the handling operations to be performed using fork-lifts.

The inventory in the dynamic flow rack is replenished applying the FIFO principle (first in, first out) which facilitates easier control of shelf lives, batches or series of products. Individual tunnels are filled with pallets on the racking side and the picking is carried on the other side. The advantage is that the receiving and picking operations are performed at different locations and, therefore, collisions of fork-lifts are prevented.

4. CONCLUSION

The article presents a design of the storage system adjusted to particular conditions in the real warehouse. The storage system was designed by applying the process of designing logistics systems while laying emphasis on the synthesis of the system - designing a rack assembly on the basis of its layout. The article presents two alternatives of the rack assembly intended for racking in rows or in blocks. The concluding part of the article contains the description of the multi-criteria evaluation upon which an acceptable, a better alternative was chosen. The chosen design may also be supplemented with the calculation of the required number of trolleys for handling the inventory in the warehouse, or other potential alternatives of the rack assembly arrangement in the warehouse may be designed and subsequently assessed.

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