LAYOUT OF RACK SYSTEM UNDER DEFINED CONDITIONS

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Abstract

The paper deals with design layout of rack system for specific conditions. The paper presents concrete proposals of rack systems layout. For each layout are designed way tracing of picking (routing of trucks). The suitable layout of rack system is recommended on the basis of selected parameters.

Keywords: Rack system, layout, routing

1. INTRODUCTION

In global logistics systems, warehousing plays a critical role. Warehouse, which is one of the supply chain elements, plays a vital role in the success or failure of the company [1]. Warehousing is one of the key factors in the supply chain management [2]. Warehouse is the important link between producer and costumer. A warehouse is a location from where raw material, semi-product and finished products are received, transferred or put away, picked, sorted and accumulated, cross-docked and shipped in [3]. Warehouse layout plan includes storage area plan, aisle plan, shelf types and sizes. Generally, warehouse layout design models attempt to optimize different objectives such as the orientation of storage racks. In traditional warehouses, forklift drivers travel among aisles, to reach a storage location, resp. place of picking. Aisle dimensions and arrangement are determined on the basis of several factors, e.g., a warehousing method, rack dimensions, dimensions of a used truck, rack arrangement, etc. Conventional warehouses comprise parallel as well as transversal aisles, arranged perpendicularly. Rack system arrangement and aisle types influence the speed of performed operations, transfer of storage units into racks, and transfer (routing) in order picking. Several authors discuss in their technical articles the issues of two diagonal aisles in the “V” shape or they describe them as non-orthogonal aisles and non-traditional aisles - the Flying-V and Fishbone. Non-orthogonal aisles were first mentioned in years 1965-1972 [4]. The issues related to the selection and arrangement of racks, arrangement of storage units, working technology type, orientation and parameters of working and traffic aisles, and routing in order picking influence the logistics performance [5, 6, 7, 8] and safety of the operation [9].

2. PROBLEM FORMULATION

A rack system layout is the arrangement of individual racks on the warehousing area. Rack layout design is a process influenced by several factors and it must be planned in advance.

The objective of this paper is a layout design for a warehousing area in a distribution warehouse according to the general layout creation algorithm.

3. THEORY AND CALCULATION

A planning process typically consists of individual steps displayed in **Figure 1** in the following sequence: defining objectives, warehousing area analysis, input parameters determination, rack layout plan designing, calculation of characteristics, optimal layout selection.

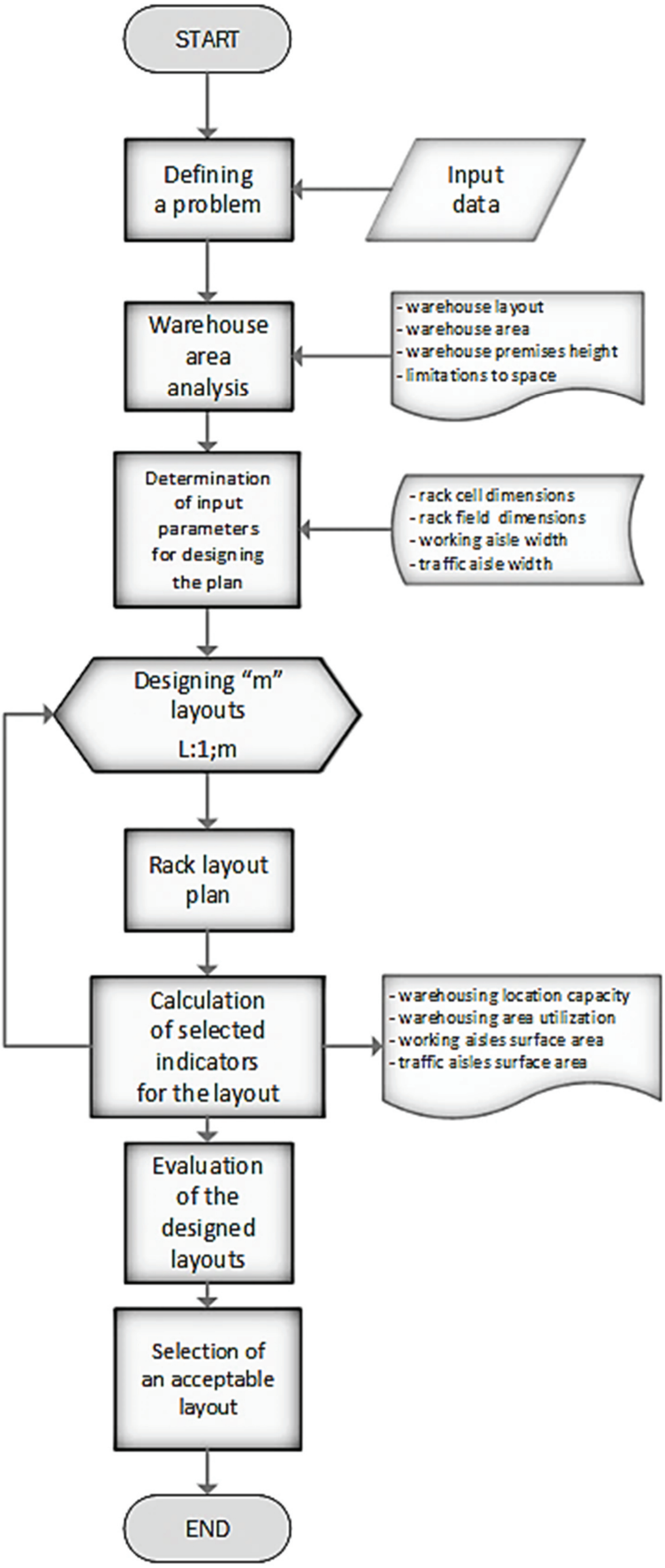


Figure 1 Layout designing steps

Defining objectives - in this case it is necessary to define specific objectives compliant with the warehousing strategy, e.g., the maximisation of the quantity of warehousing positions, efficient utilisation of the warehousing area, increasing the speed of placement and the speed of picking, etc.

Warehousing area analysis - the information should include the warehousing premises specifications (locations of doors, pillars, etc.) and the specification of the dimensions of the warehousing area where the racks are to be placed.

Determination of input parameters for designing the plan - determination of the rack cell dimensions on the basis of the number of placed storage units, determination of the number of the rack field levels, calculation of the working aisle width and the traffic aisle width.

Rack layout plan designing - based on the input parameters, a rack and aisle layout plan is designed for a given warehousing area. For this particular warehousing area it is necessary to design several plans, differing in rack orientation and aisle arrangement.

Number of selected plan characteristics - for these plans it is necessary to calculate selected parameters and make a comparison thereof.

Optimal plan (layout) selection - on the basis of selected criteria [10].

In addition to the above listed steps, it is also necessary to plan the execution thereof directly in the operation.

For the purpose of the rack system layout designing it is necessary to determine or calculate the following parameters:

1) rack field dimensions, length "*l*" and width (depth) "*w*", depending on the type and number of pallets placed in a rack field.

2) the working aisle width "w_h", the minimum width of the working aisle for a truck is calculated using the formula (1) [11]:

$$w_h = 2R + X + 2S \quad (1)$$

where *R* is the external turning radius (specified by the manufacturer) in mm,

X - a load's (pallet's) length exceeding the truck fork's length in mm

S - safety clearance (B= ~200 mm).

3) the traffic aisle width "w_t", a traffic aisle width for one-way traffic is calculated using the formula (2) [11]:

$$w_t = w + 2S \quad (2)$$

where *w* is the width of a truck or of a transferred load (depending on which of the dimensions is larger) in mm,

S - safety clearance (B= ~200 mm).

The width of a two-way aisle is determined as the double the width of a one-way aisle.

To compare individual alternatives, it is necessary to calculate the following parameters:

4) Rack system area "A_R" is calculated using the formula (3):

$$A_R = \sum_{i=1}^{k} \left[m \cdot \left(A_f + n \cdot A_a \right) \right] \quad (3)$$

where A_f is the basic rack field area in m^2,

A_a - additional rack field area in m^2,

n - number of additional rack fields,

m - number of racks

k - number of rack types (depending on the number of rack fields).

A_f and A_a areas are calculated as the product of length "*l*" and width "*w*" of rack fields, dimensions of which depend on the type and the number of storage units (pallets) placed in a rack field, **Figure 3**.

5) Percentage of the warehousing area utilization, calculated as the quotient of the rack system area "A_R" to the warehousing area "A_w".

4. RESULT AND DISCUSSION

Layout design was carried out applying the above described procedure for the warehousing area in the distribution warehouse.

1. Defining the objective - a primary objective is to design a layout of standard pallet racks in order to obtain the maximum number of warehousing positions on the given warehousing area. The secondary objective is to ensure efficient and cost-effective order picking, i.e. minimising the routes when the goods are being picked up. The goods will be picked up upon a pick-list, manually, from the lowest position in the rack system (floor), by collecting the necessary number of boxes from the stored pallets. Having received a pick-list, a picker will move to the required location and collect the necessary number of boxes and then move to the following position, until the entire order is picked up.

2. Warehousing area analysis - the warehousing area is a part of the distribution warehouse with the layout shown in **Figure 2**. The area for placing the rack system is sized 70x50 m, i.e. 3,500 m^2.

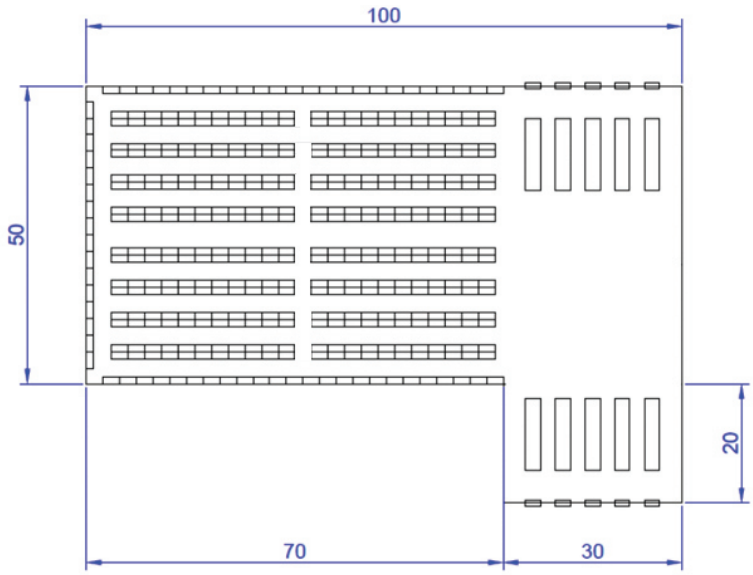
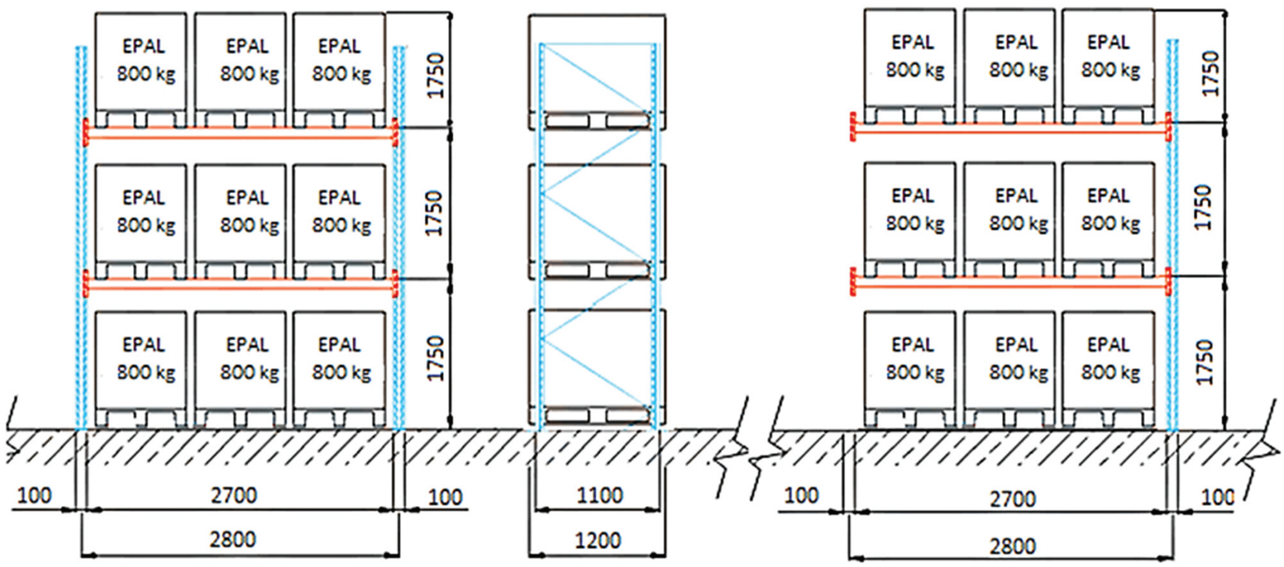


Figure 2 Ground plan of the warehouse

3. Determination of input parameters for the plan designing:

Storage unit - an EPAL pallet sized 1200x800x14.4 cm, the maximum weight of a storage unit is 800 kg.

A rack cell is designed for placing 3 storage units (pallets) and for 3 rack field levels (floor 2 levels). The rack field layout, including the dimensions, is shown in **Figure 3**, **Table 1**.



a) Basic rack field

b) Additional rack field

Figure 3 Rack field scheme

Table 1 Parameters of rack field

	d [mm]	w [mm]
Basic rack field	2900	2800
additional rack field	1200	1200

A pallet will be placed into a rack using a forklift trolley, for which the manufacturer specifies the turning radius of 1,293 mm. The working aisle width was calculated, using the formulas (1) and (2), as 2,836 mm; the one-way traffic aisle width as 1,390 mm.

Order picking will be carried out using a picking forklift truck; its turning radius specified by the manufacturer is 1,395 mm; the aisle width specified by the manufacturer is 2,960 mm. The working aisle width was calculated, using the formulas (1) and (2), as 2,990 mm and the traffic aisle width as 1,010 mm.

When designing a layout, it is necessary to respect the minimum working aisle width of 2,990 mm and the minimum traffic aisle width of 1,190 mm, based on the calculations for both trucks.

4. Rack layout plan designing - for the selection of an optimal layout, three layouts were designed; 2 with conventional aisles and 1 layout with a V-shaped aisle.

Layout 1 (**Figure 2**) consists of racks of three different lengths. Rack parameters are listed in **Table 2**. The rack system layout is based on the longitudinal rack arrangement - 16 two-row racks and racks along the walls. The width of working aisles between the racks is 3 metres; the width of the longitudinal central aisle is 4.4 meters; and the width of the central transversal two-lane traffic aisle is 2.8 meters. This rack system layout option provides 416 rack fields with the total capacity of 3,744 pallet locations (the capacity on one storey is 1,248 pallets).

Layout 2 (**Figure 4**) consists of racks of three different lengths listed in **Table 2**. The rack system layout is based on transversal rack arrangement in a rack field - 24 two-row racks and racks along the walls, similar to Layout 1. Width of working aisles between the racks is 3 meters, whereas the central two-way traffic aisle, leading along the whole width of the rack field, is 2.4 meters. This rack system layout option provides 400 rack fields for the storage of 3,600 pallets (the capacity on one storey is 1,200 pallets)

Layout 3 (**Figure 4**) consists of racks of several different lengths listed in **Table 2**, with a dominant V-shaped aisle. The rack system layout provides in total 384 rack fields capable of storing 3,456 pallets (the capacity on one storey is 1,152 pallets). This layout design is similar to Layout 1, with the difference being the orientation of a V-shaped traffic aisle, instead of the central transversal traffic aisle.

5. Optimal plan (layout) selection. The layout comparison based on parameters: number of rack fields, number of pallets in a rack system, rack system area A_R [m^2] calculated using the formula (3) and the percentage of the warehousing area utilisation are shown in **Table 3**. Considering the data contained in **Table 2**, we can state that the primary objective is met by the Layout 1, providing the largest number of warehousing positions, i.e. 3,744, using 40.05% of the area.

However, which of the layouts meets the secondary objective?

Another step within the optimal layout type selection was the picking route modelling. The routes were examined for the route length parameter, whereas the route starting points and final points were identical in all the cases. The layouts and routes were designed in the AutoCAD software. Lengths of individual routes were read directly from the technical drawing created in the AutoCAD software.

Table 2 Rack types and parameters

	Rack type	Number of fields in a rack [pc]		Rack length [m]	Number of racks [pc]	Number of pallet positions in a rack [pc]	Number of pallet positions in racks [pc]
		basic	additional				
Layout 1	1	1	10	30.9	32	99	3168
	2	1	23	67.3	2	216	432
	3	1	15	44.9	1	144	144
							3744
Layout 2	1	1	6	19.7	48	63	3024
	2	1	23	67.2	2	216	432
	3	1	15	44.9	1	144	144
							3600
Layout 3	1	1	16	47.7	2	153	306
	2	1	15	44.3	2	144	288
	3	1	13	39.3	4	126	504
	4	1	12	36.5	4	117	468
	5	1	10	29.8	2	99	198
	6	1	9	28.1	4	90	360
	7	1	8	25.3	2	81	162
	8	1	6	19.7	4	63	252
	9	1	5	16.9	4	54	216
	10	1	3	11.3	2	36	72
	11	1	2	8.5	2	27	54
	12	1	23	67.3	2	216	432
	13	1	15	44.9	1	144	144
							3456

Table 3 Layout parameter comparison

Parameter	**Layout 1**	**Layout 2**	**Layout 3**
Number of rack fields [pc]	416	400	384
Number of pallets in a rack system [pc]	3744	3600	3456
A_R[m^2]	1401.96	1349.88	1290.36
A_w[m^2]	3500	3500	3500
Warehousing area utilisation [%]	40.05	38.56	36.86

A model example shows the process of picking the boxes from 8 positions (locations). Positions of the boxes were chosen so that they are as identical as possible (minimum position variations) for all three layouts. Picking positions of boxes are presented as black fields, including the picking order. Picking routing is marked with a blue line and the routing direction is designated with an arrow, **Figure 4**. A route length for Layout 1 is 280.2 m. For Layout 2 it is 252.2 m and for Layout 3 it is 276.8 m.

5. CONCLUSION

The article describes an example of 3 different designs of a rack system layout for a selected warehousing area. In addition to the calculation of warehousing locations, we also presented a model example of picking the boxes from racks. The routing and selection of an optimal route direction depend in practice mainly on the number of items to be picked up, their location in a rack system, the speed of a picking truck, and, last but not least, a driver's skills. A different case is when the picking process is controlled by a control system which plans, controls and monitors the picking process, proposes a route for a truck so that it moves in a warehouse in a most efficient manner and in a sufficient speed.

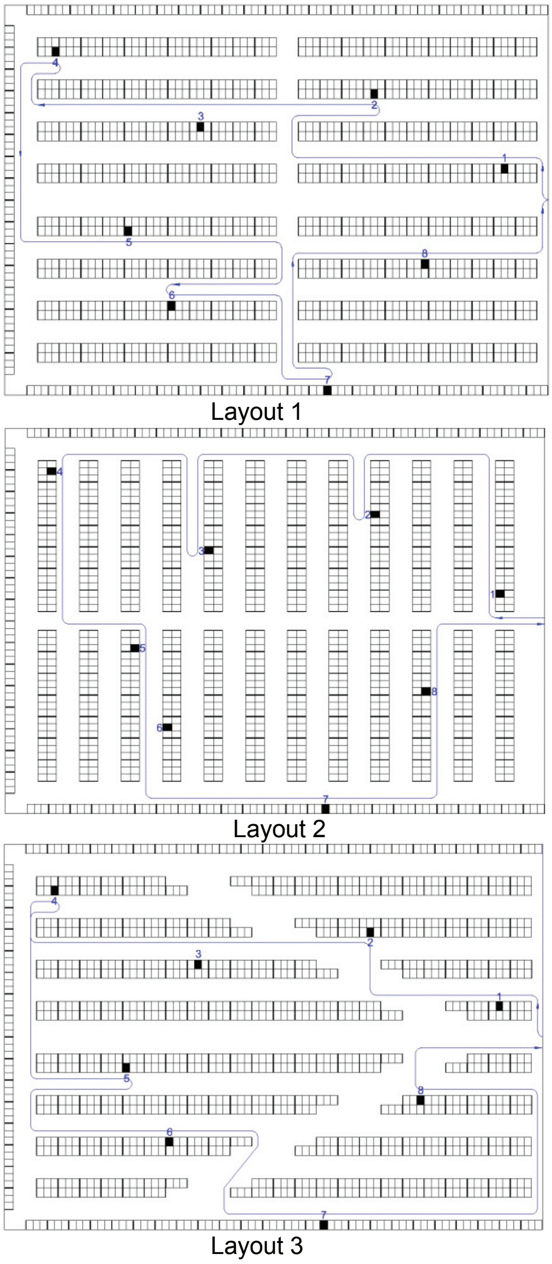


Figure 4 Truck routing

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