Creation of Warehouse Models for Different Layout Designs

Preliminary Communication

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Abstract – *Warehouse is one of the most important components in logistics of the supply chain network. Efficiency of warehouse operations is influenced by many different factors. One of the key factors is the racks layout configuration. A warehouse with good racks layout may significantly reduce the cost of warehouse servicing. The objective of this paper is to give a scheme for building warehouses models with one-block and two-block layout for future research in warehouse optimization. An algorithm for creating a model database of a warehouse is introduced.*

Keywords – *efficiency, optimization, warehouse layout, warehouse model*

1. INTRODUCTION

The success of today's business is affected by the supply chain network. Warehouses are parts of that supply chain network. They connect suppliers, manufactures, distributors and customers with each other. Efficiency of the supply chain network depends on warehouse operations, and warehouse efficiency is influenced by many different factors. One of the highly significant factors affecting efficiency of warehouse operations is the warehouse layout configuration. Therefore, this paper attempts to help with optimization of warehouse layout by presenting algorithms for creating a warehouse model database. The presented models use the pallet racks as a way of storing goods. Pallet racks are used in most warehouses and they are the most widely used storage equipment in the world.

In this paper, warehouse logistics is discussed. Section 2. gives warehouse definition and activities and highlights some goals. Rack layout configurations are examined and model requirements are given in Section 3. Furthermore, input parameters are explained and proposed algorithms for warehouse models are given in the same section.

2. LOGISTIC OF WAREHOUSE

In a broader sense, a warehouse is fenced or unfenced area, covered or uncovered space used for storing different goods such as raw materials, semi-finished or finished products [1]. Warehouses are one of the most important parts of a logistic chain. From a logistics point of view, a warehouse is a point in the logistics network in which the goods are accepted, stored and forwarded in a different direction within the network. Logistics is the process of planning, implementing, controlling the efficient flow and storage of materials. Logistics is also a list of services and related information from sources to the point of consumption in order to meet customer requirements [2].

Warehouses have four main activities: receiving and storing goods, order picking and shipping [3]. Storage is the process of assigning goods to warehouse storage locations. Order picking is the process of selecting and retrieving specified goods from a warehouse, in customer specified quantities, to satisfy an order [4]. These two activities can be tested and simulated to develop new operational strategies in warehouse models.

Some goals of storage are to accelerate the flow of goods in order to shorten the business process and thus accelerate the turnover ratio of funds related to stock. Through these improvements of business operations, storage contributes to the growth and competitive ability of the organization. It is evident from these objectives that for storage, but also the entire procurement process, efficiency, i.e., the shortest possible delivery time of goods, is one of the main priorities. In order to meet these objectives, it is necessary to improve the efficiency of the warehouse. One way of improving business operations of a warehouse is to perform simulations on the model of the warehouse for the purpose of introducing new solutions and observing their impact on the overall operation of a warehouse.

Therefore, it is very important to have means to make good models for testing everyday operations in a warehouse.

2.1. RACK LAYOUT CONFIGURATION

Many factors influence the efficiency of warehouse business operations, but one of the main factors is a stock layout. A warehouse with a good layout can significantly reduce the cost of operations. Warehouses are mostly rectangular in shape and the arrangement of goods is usually divided into three types [5]. The first type consists of two blocks with stocking aisle running parallel with the main passageway that leads to the main warehouse input/output (I/O) point, as shown in Fig 1. The second and the third type have only one block with stocking aisle running perpendicular to the main passageway with warehouse I/O point. The I/O point can be located at the center, as shown in Fig 2 (a) or in the lower left corner, as shown in Fig 2 (b).

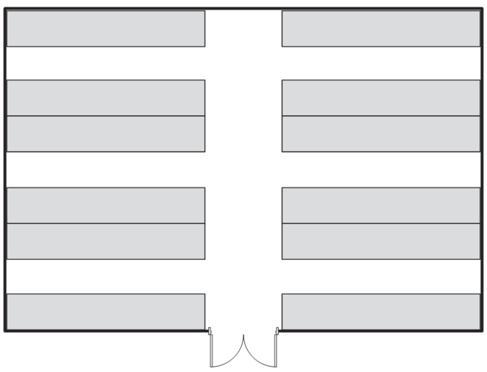

Fig. 1. Two-block warehouse layout

2.2. MODEL REQUIREMENTS

In order to make a warehouse model, it is necessary to determine the type of goods stored in racks. According to the type of goods, a warehouse can be divided into storage for raw materials, semi-finished products, finished products, storage for tools and spare parts storage.

Nowadays, high rack warehouse are built with a height of up to 50 meters. Racks are made of steel, with shelves that can be adjusted according to the height of the goods. Racks are available in minimum three or more levels. Types of racks include: shelving racks, pallet selective racks, pushback racks, drive-in and drive-through racks, console racks, moveable racks, etc.

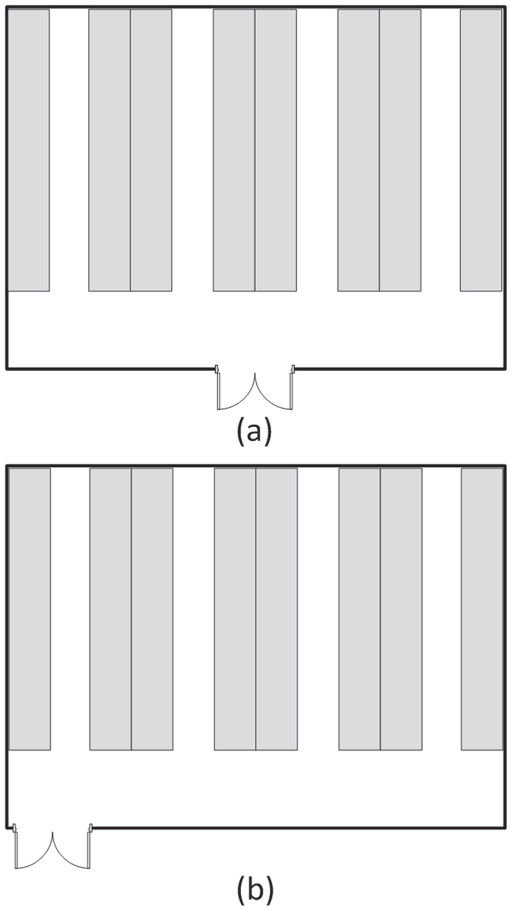

Fig. 2. Two types of one-block warehouse layout

The distance between racks depends on the type of goods in the warehouse. The majority of goods in Europe is delivered on the EUR-pallets or EPAL-pallets. These pallets are made mostly from wood, but they can be also plastic, metal or cardboard, with dimensions of 1200 × 800 × 144 mm, as shown in Fig 3. They provide the ability to easily transport products.

Pallets are stored on pallet racks, and the distance between two pallets on the rack should be at least 10 cm.

The International Organization for Standardization (ISO) sanctions five more pallet dimensions in its ISO 6780 standard [6]. All standards are presented in Table 1.

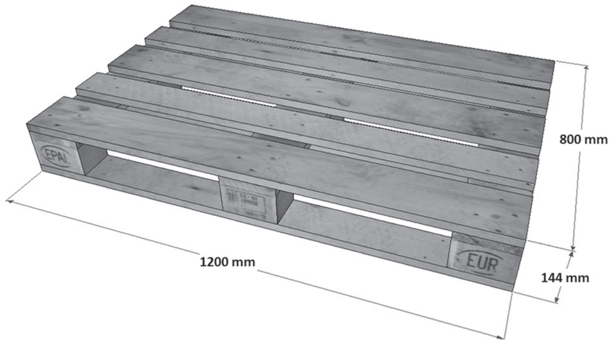

Fig. 3. The EUR-pallet

Table 1. Pallet dimension by the ISO 6780 standard.

Dimensions (WxL) mm	Region it is most used in
1016 × 1219	North America
1000 × 1200	Europe, Asia
1165 × 1165	Australia
1067 × 1067	North America, Europe, Asia
1100 × 1100	Asia
800 × 1200	Europe

While designing a warehouse building, it is important to follow the instructions. Internally, the distance of at least 50 cm should be left between racks and the walls to allow easy access in case of fire emergency. The aisle width should be adjusted to the method of handling the goods in the warehouse. All partition walls should be removable and beams should be made of steel, doors and windows should be protected for possible burglary. Apart from these design guidelines, it is very important to know, when planning storage space, how most of the goods will be packed in order to maximize the efficiency and productivity of the warehouse.

3. ALGORITHMS FOR WAREHOUSE MODELS

In this section, input parameters and restrictions will be explained and algorithms for creating warehouse models will be given.

3.1. INPUT PARAMETERS

In order to create a model for performing various simulations of warehouse operation, introducing new solutions and observing their impact on warehouse operation, it is necessary to determine what kind of warehouse it is, what kind of products these are, and what the dimensions of pallets and other various warehouse properties are.

First, for algorithm input data it is necessary to select one of the three warehouse layouts, i.e., two-blocks or one-block rack layout. The following parameters that need to be entered are the width of the main passageway *MPW* and the length *SAL*, the width *SAW* and the number *SAN* of stocking aisles between racks. The number of stocking aisles determines the total number of racks in a warehouse. The number of racks is always four times (for a two-block layout) or two times (for a one-block layout) greater than the number of aisles [5].

The next step is to enter the size of the pallet (length *PL* and width *PW*) on which the product is delivered and will be stored in a warehouse. It is also necessary to specify the maximum number of pallets *PN* that needs to be stored in order to determine the number of levels *RLV*. The height of the racks in the end is determined by the maximum height of the product on the pallet *PW* and *RLV*.

The result of these initial parameters is a database that contains information about the location of individual racks and every single pallet thereon. The location is given in form of coordinates of the lower left corner of the pallet when viewed from the warehouse ground plan. Based on these data and other entered data, it is possible to calculate the other coordinates of that pallet. It is possible to calculate coordinates for each product on the pallet, considering the condition that the size of the product is known.

3.2. MODEL RESTRICTIONS

The model is limited for tree previously mentioned layouts [5] in a pallet selective warehouse. All racks are of the same height and design for just one dimension type of pallet. As the final result depends on the input data, there is a possibility that some of the parameters do not comply with the terms of warehouse design.

3.3. ALGORITHMS

Two algorithms for creating warehouse models are made. The first proposed algorithm is used for creating a two-block layout model and it is shown in Alg. 1. Input data for the algorithm are the main passageway width *MPW*, dimension of the stocking aisle such as length *SAL*, width *SAW* and the number of stocking aisles *SAN*. Other input data are pallet dimensions, length *PL*, width *PW*, height *PH* and the number of the pallets *PN*.

Algorithm 1. Two-block warehouse layout

```
Input:    the main passageway width MPW
              the length, width and number of stocking
              aisles SAL, SAW, SAN
              the length, width, height and number of
              pallets PL, PW, PH, PN
Calculate the number of pallets in one rack level NPL=SAL/ PL;
if (NPL+1)* 10cm > SAL
          NPL= NPL-1
end if
Calculate rack length RL=NPL*PL+(NPL+1)*10cm
Calculate rack width RW=PW+10cm
Calculate the number of rack levels RLV=ceil(PN/(SAN*4*NPL))
Calculate the main passageway length
MPL=RW*SAN*2+SAN*SAW+100cm
Calculate warehouse dimensions WD (WL,WW,WH)
WL= MPW+2*(RL+50); WW=MPL; WH=PH*RLV+100cm
```

for all racks

if *First two border rack*

Calculate rack position of first border rack

R_{ix}*=50cm; Riy=50cm*;
Increment *i=i+1*;
Calculate rack position of second border rack
R_{ix}*= 50cm+SAL+MPW;* R_{iy}*=50cm*;

else if Middle racks

Calculate rack position of first middle rack

R_{ix}*= 50cm;* R_{iy}*=* $R_{(i-1)y}$*';+SAW+PW*;
Calculate rack position of second middle rack
Increment *i=i+1*;
R_{ix}*= 50cm+SAL+MPW;* R_{iy}*=* $R_{(i-1)y}$*';*;
Calculate rack position of third middle rack
Increment i=i+1;
R_{ix}*= 50cm;* R_{iy}*=* $R_{(i-1)y}$*';+PW*;
Calculate rack position of fourth middle rack
Increment *i=i+1*;
R_{ix}*= 50cm+SAL+MPW;* R_{iy}*=* $R_{(i-1)y}$*';*;

else if Last two border racks

Calculate rack position of first border rack

R_{ix}= 50cm; R_{iy}= $R_{(i-1)y}$';+SAW+PW;
Calculate rack position of second border rack
Increment i=i+1;
R_{ix}= 50cm+SAL+MPW; R_{iy}= $R_{(i-1)y}$';;

end if

end for all

First, the number of pallets in one rack level *NPL* is calculated by using the length of stocking aisles *SAL* and pallet length *PL*. Rack length *RL* is calculated in the next step using *NPL* and *PL*. Rack width *RW* is 10 cm larger than pallet width to ensure enough space for pallet placement. Each rack consists of several vertical levels *RLV*. To ensure the correct level number, levels are calculated by using the number of pallets *PN* and the stocking aisle number *SAN* and the number of pallets in one rack level *NPL*. After the main passageway length is calculated, the algorithm is able to calculate warehouse dimensions such as warehouse length *WL*, warehouse width *WW* and warehouse height *WH*. After calculations of warehouse and main passageway dimensions, the algorithm is able to calculate rack positions.

In this model, there are eight types of rack positions. The first two are border racks, then at least four middle racks and two last border racks. For all types of racks there are two *x* coordinate values, as shown in Alg. 1. The first value is calculated by using formula R_{ix}*=50 cm*, to ensure 50 cm padding from walls and the second value is calculated by using formula R_{ix}*=SAL+MPW+50 cm*. For each rack type there are different y coordinate calculations using formulas shown in Alg. 1. Input data for the first *y* coordinate calculation are 50 cm padding from wall, *SAW* and *PW*.

The second proposed algorithm is used for creating a one-block layout model and it is shown in Alg. 2. Input data for algorithm are the main passageway width *MPV*, dimension of the stocking aisle such as length *SAL*, width *SAW* and the number of stocking aisles *SAN*. Other input data are pallet dimensions, length *PL*, width *PW*, height *PH* and the number of pallets *PN*. Input data are the same as in Alg. 1.

In the first step, the number of pallets in one rack level *NPL* is calculated by using length of stocking aisles *SAL* and pallet length *PL*. Rack length *RL* is calculated in the next step by using *NPL* and *PL*. Rack width *RW* is 10 cm larger than pallet width to ensure enough space for pallet placement. Each rack consists of several vertical levels *RLV*. To ensure the correct level number, levels are calculated by using the number of pallets *PN* and the stocking aisle number *SAN* and the number of pallets in one rack level *NPL*. Input data for calculations are the same as in the first algorithm; however, formulas are different, as shown in Alg. 2.

After the main passageway length is calculated, the algorithm is able to calculate warehouse dimensions and rack positions. In this model, there are three types of rack positions, i.e., first border rack, middle rack and border rack. For each rack type, there is different position calculation, as shown in Alg. 2. For the first border rack, an *x* coordinate is calculated by using formula R_{ix}*=50 cm*, to ensure 50cm of padding from walls. For the middle rack and the last border rack, an *x* coordinate is calculated by using an x coordinate of the previous neighbor rack, *SAW and RW*, as shown in Alg. 2. For all types of racks, a y coordinate is the same as shown in Alg. 2.

Algorithm 2. One-block warehouse layout

***Input**:* the main passageway width *MPW*
the length, width and number of stocking aisles *SAL, SAW, SAN*
the length, width, height and number of pallets *PL, PW, PH, PN*

Calculate the number of pallets in one rack level *NPL=SAL/ PL;*

if *(NPL+1)* 10cm > SAL*

NPL= NPL-1

end if

Calculate rack length *RL=NPL*PL+(NPL+1)*10cm*

Calculate rack width *RW=PW+10cm*

Calculate the number of rack levels *RLV=ceil(PN/(SAN*2*NPL))*

Calculate the main passageway length *MPL=RW*SAN*2+SAN*SAW+100cm*

Calculate warehouse dimensions *WD (WL,WW,WH)*

*WL=MPL; WW=MPW+RL+50; WH=PH*RLV+100cm*

for all *racks*

if *First border rack*

Calculate rack position

R_{ix}*=50cm;* R_{iy}*=MPV;*

else if *Middle racks*

Calculate rack position of first middle rack

R_{ix}*=* $R_{(i-1)x}$*';+SAW+RW;* R_{iy}*=MPV;*
Calculate rack position of second middle rack
Increment *i=i+1;*
R_{ix}*=* $R_{(i-1)x}$*'; +RW;* R_{iy}*=MPV;*

else if *Last border rack*

Calculate rack position

R_{ix}*=* $R_{(i-1)x}$*';+SAW+RW;* R_{iy}*=MPV;*

end if

end for all

These algorithms may be useful to create warehouse models and simulation in order to improve business operations. Algorithms can be used to introduce new solutions and then observe their impact on the overall logistic operations. Firstly, the presented algorithms are not tied to the existing software solutions and can be used for stand-alone simulations, which may be closely related to the problem of individual companies. Secondly, these solutions provide an insight into a step-by-step construction of models and the chance of presenting a real warehouse in the model ready for simulation.

4. CONCLUSION AND FUTURE WORK

The paper describes the need for simulation of warehouse operation in order to provide help with optimization of a warehouse layout. Warehouse logistics and its importance in the supply chain network is evident and explained. Three types of layouts are presented and model requirements are specified. A list of all input data and restrictions of the developed model are given. Two algorithms for creating warehouse models are given and explained in detail. By using these two algorithms, it is possible to create different database models and use them to optimize a warehouse layout.

For future work, it is planned to expand the model algorithm such that it will be able to combine different sizes of pallets as well as different sectors of the goods with different heights of racks. It is necessary to introduce scalability because warehouses are not homogenous groups of the same products on the same pallet size.

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