Completation Of Items In High Storage Warehouse with the Expert System

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Improvement of logistics processes, searching for new solutions, access to fast and complete information, flexible reaction to changes – these are some of the reasons for making companies more competitive in contemporary market. Following the reasons given above the authors of the hereby paper strive for finding new solution to shorten lead time of completation process for items allocated in high storage warehouses. The goal of the paper is to introduce the most important aspects of high storage warehouses management, expert system used to allocate items in a warehouse and potential benefits emerging from application of artificial intelligence methodology in this area.
Keywords: completation, high storage warehouse, storing, expert systems

1. IT SUPPORT FOR LOGISTICS PROCESSES

Most companies are now aware that time is a strategic variable which has a substantial influence on success in competition on a market [Coyle et al., 2002, p. 41]. Dynamics of a market forces companies to striving for continuously increasing efficiency and flexibility to enable faster and effective reaction to changes appearing in their market environment. Development of manufacturing technologies and IT, as well as of theories in management and organization area enables meeting the requirements of contemporary market pre-mentioned by implementation – choice, implementation and exploitation – of suitable IT systems [Klonowski, 2004, p. 145]. In logistics area, there are numerous logistics processes identified, including: purchasing planning process, suppliers choice process, warehousing process, material flow management process etc. All these processes, including listed above, are within three major fields of logistics, namely: purchasing logistics, manufacturing logistics and distribution logistics. Hence, logistics process can be defined as a sequence of actions integrated by time, connected with material, information and financial flows, which leads to a predefined goal. The most important components of logistics process are the following [Skowronek, Sariusz-Wolski, 2003]:

- flow of physical goods;
- information flow and decision-making process;
- stock keeping;
- infrastructure of logistics processes;
- logistics costs.

The amount of data requiring process and number and diversity of decisions that need to be taken make IT support really necessary for efficient performance of accompany and fast realization of its goals.

Nowadays, there are many software packages and systems supporting employees at all the levels of organization of functioning of a company. What is more, the lack of IT support makes functioning of an enterprise almost impossible. Analysis of all the areas of logistics proves that thesis with the well known and commonly use systems including: MRP [Sarjusz-Wolski, Skowronek, 2000], [Pasternak, 2005], MRP II [Dwiliński, 2002], [Kisielnicki, Sroka, 1999], ERP [Długosz, 2009], [Ciesielski, 2009], ERP II [Klonowski, 2004], [Lech, 2003]. These systems are to improve functioning of an organization by better control of processes, both inside and outside of a company, with tools supporting proper performance of activities and processes. They are IT systems of modular structure, and they support all the areas of company's activity, including marketing and planning, as well as purchasing, technological production support and control, distribution, sales and human resources management [Florek, Klimasara, 2002, s. 74]. In production process there are some dedicated solutions supporting design process, construction and manufacturing, i.e. CAD, CAE, CAM [Dwiliński, 2006], [Durlik, 1993], [Kawecka-Endler, 2004]. They enable databases management, computerized visualization of construction of items, simulation.

In distribution logistics planning the size and rhythm of demand to final foods supports DRP planning system, which is especially important in situation in which company's distribution net includes numerous local warehouses which are supplied by one distribution center [Nowosielski, 2008], [Coyle et al., 2002].

When discussing systems and software, spreadsheets should be mentioned as they can be used in all the areas of logistics mentioned. They support activities connected with MRP [Pawłyszyn, Jurga, 2010], supplies organziation, optimization of completation process [Szymczak, 2011] etc.

Solutions representing the next stage of IT tools development is artificial intelligence, represented by numerous techniques and tools among which experts systems [Knosala et al, 2002], [Zieliński, 2000], genetic algorithms [Goldberg, Grygiel, 2003], [Man et al, 1999], neural networks [Tadeusiewicz, 1998], [Kosiński, 2007], fuzzy systems [Łachwa, 2001], [Verbruggen, Babuska, 1999] are the most common. They support making various decisions concerning logistics processes including manufacturing scheduling, purchasing optimization, technological processes optimization etc.

The goal of the following paper is to improve one of the purchasing logistics' processes, namely completation of items stored in high storage warehouses. The IT support for the goal identified is one of the AI tools. More details can be found in [Pawłyszyn et al., 2010], [Pawłyszyn et al., 2011].

2. STORING IN HIG STORAGE WAREHOUSES – NEW APPROACH

According to Heragu [Heragu, 2006] for the product allocation problem, there are some publications dealing with design of forward and reserve areas. The literature presents both mathematical and heuristic procedures. Bozer (1985) considers the problem of splitting a pallet rack into an upper reserve and lower forward area. Hackman and Rosenblatt (1990) present a model for forward/reserve problem that considers both assignment (which product) and allocation (what amounts). They provide a heuristic that attempts to minimize the total costs for picking and replenishment. Frazelle et al. (1994) provide a framework for determining the size of forward area together with the allocation of products to that area. Hackman and Platzman (1990) present a mathematical programming procedure that solves more general instances of the assignment and allocation problems in a warehouse. Van den Berg et al. (1998) consider a warehouse with a busy and idle period where reserve picking is possible. The papers listed above do not cover the literature on the subject, though they are often referred to as methods they provide are general enough to be applied in various logistics systems. The method which is to be presented in the following in the paper is developed to solve a specific problem in a company, however the solution is universal and authors believe that it can be widely applied.

Completation of items necessary to complete production from shelves in high storage warehouse is a time-consuming and quite exhausting process. To find solution facilitating the process and making completing more efficient the following solution was developed.

The solution is developed for items used in a company of specific production profile, with the following characteristics:

- there are several thousands of purchasing items stored;
- some of the details are common for most of the orders realized in the company;
- departments in the company are divided with respect to customers making orders;
- completation of items is initiated by an order of a customer;
- purchasing warehouse is a high storage warehouse.

The solution developed can be used for manufacturing workstation if production is of similar character.

The main idea of the solution developed is segregation of items on the shelves in high storage warehouse according to companies ordering/ launching production. Whereas the main goal is fast finding and completation of items necessary to realize production and simultaneously ergonomic optimization of working conditions of warehouse staff. Hence, the optimization function is the following:

Maximize the following:

Z= f(Σnumber of free shelves, Σnumber of free racks, Σused storage capacity)

Considering the following constraints:

Number of operation for each MPK>=90%
Number of shelves used for each rack<=10
Percentage of space of each shelf used>=50%
Number of operation during last year>=24

The tool used to realize the solution developer is the expert system benefiting from knowledge and concluding procedures (Rutkowski, 2009) necessary to realized the predefined goal. Implementation scheme was developed as well and includes the following stages (Pawłyszyn et al., 2010, s. 43):

1. Grouping the items with destination department criterion;
2. Ranking items within groups identified (ranking criterion is frequency of handling);
3. Identification of space required and the way it should be filled in.

According to the stages defined, the first action to be taken is definition of items to be analyzed and allocation of the items in the department they are to be used in. The condition to be met to allocate the item to the department is 90% or more handling operations realized for the item-department pair (fig. 1). Each detail is represented by a code in which department is represented, as well as handling frequency and container to be stored in type. The next step is decreasing ranking for each department for which details are qualified. The goal of the ranking is grouping the details the most often handled to facilitate access to these items by allocating them on the shelves the easiest accessible.

The next information important for items allocation is knowledge on containers type as items are to be stored in containers. In the case analyzed, there are two types of containers, called A and B, which take respectively (fig. 2):

- A – full palette and full shelf in the case;
- B – half of palette (shelf).

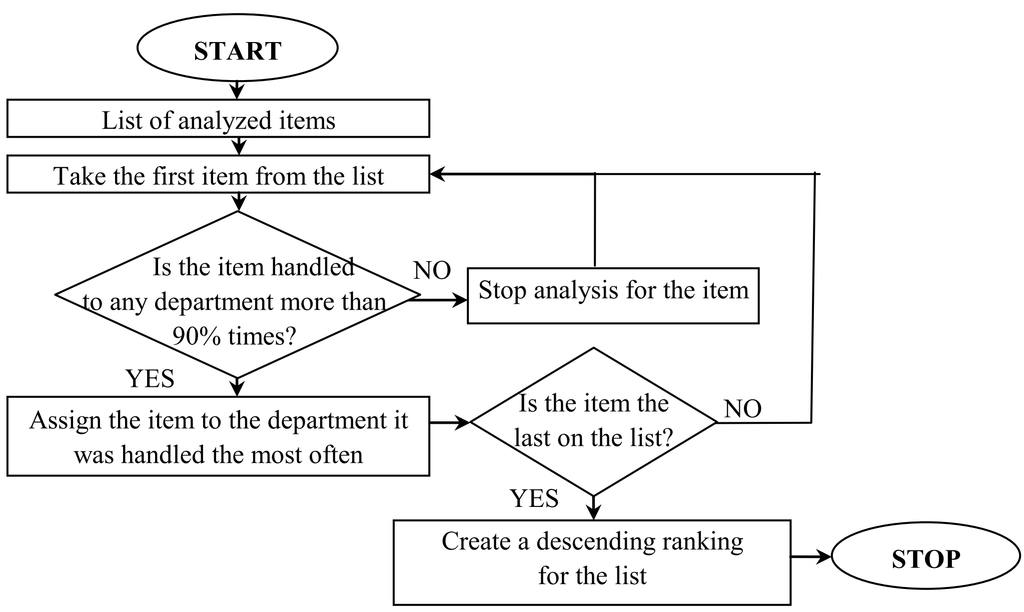

Figure 1. Items classification procedure

Source: (Pawłyszyn et al., 2011, p. 3)

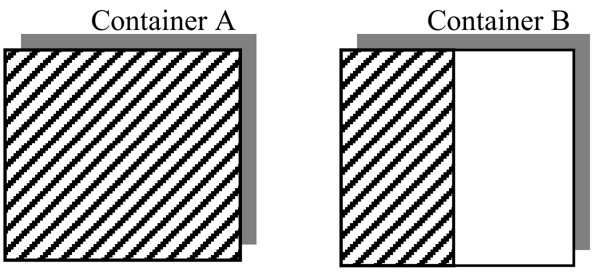

Figure 2. Types of containers and their allocation on a pallet

Source: Own work

Containers with items inside are to be placed on a palette (to facilitate access with fork lift) on the shelves respectively to their size.

Hence, there are the following options of containers allocations on a shelf:

1. One A-type container;
2. Two B-type containers;
3. One B-type container.

The scheme of containers allocation on the shelves is presented in the figure 3.

The most efficient are 1. and 2. options as they provide 100% shelf space use, while 3. option does not take the full space accessible. That is why before B-type container is allocated on an empty palette, system should check if there is any palette half-taken by B-type container. Thanks to this B-type containers will not be located separately and space available will be efficiently used.

Shelves in the case are replenished according to the following order: 3, 2, 1, 4, 5, 6, 7, 8, 9, 10. The reason is easy access to shelves 3, 2, 1, which can be reached without fork-lifts commonly used for

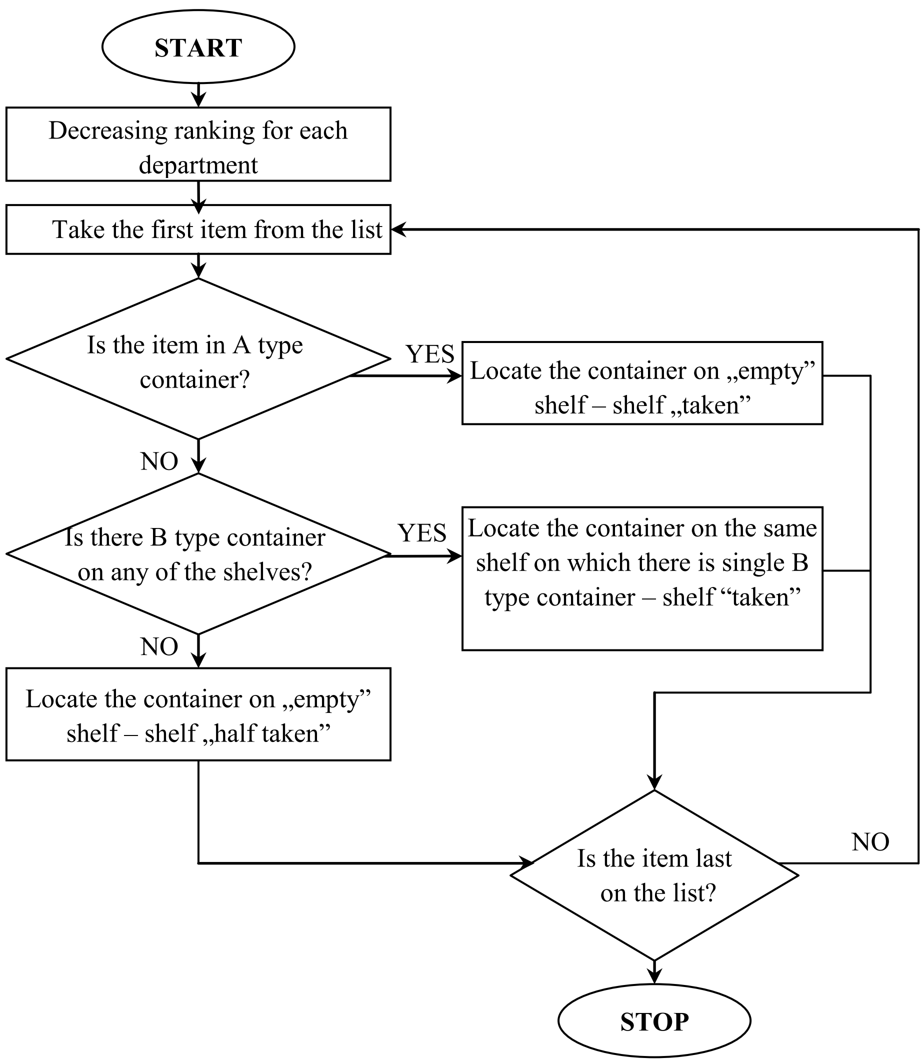

Figure 3. Containers grouping procedure

Source: Own work

operations concerning high storage warehouse. Shelf nr 4 can be reached without fork-lift but items can be taken out from a container only with some help, for example a ladder. The shelves 5, 6, 7, 8, 9 and 10 can be reached only with a fork-lift.

Types of containers used to segregate items are defined by users, who have access to knowledge on items allocated with the algorithm developed.

According to the scheme in figure 3, the expert system developed will group containers with items and allocate them on shelves, starting with the most often handled and finishing with the ones least often handled to provide the best allocation of containers on shelves. The assumption concerning cases size was taken, according to which each case has 10 shelves and there are no other limitations for items allocation was taken.

If there is an item in a container and its dedicated and allocated on a shelf, separately or with other items, to provide the most efficient layout, it will be removed from the ranking and not considered in further search. In such case, the ranking includes only parts not taken into consideration when defining the number of shelves required (Pawłyszyn et al., 2010, s. 45).

3. EXPERTS SYSTEM IN WAREHOUSING PROCESS

Taking all the reasons introduced above, the processes designed to be included in the experts system locating items on shelves are introduced, and defined as follows.

1. Communication with users:

1. Input data introduction (list of indexes with codes defining number of handling operations in the last year, container type and index number);
2. User decides whether all department should be considered in allocation procedure, if not, he should identify the ones to be included in the analysis;
3. System identifies and introduces number of shelves necessary to store items for all the departments in the company;
4. User gets a list of cases and their shelves presented as a table: rows are shelves numbers and columns are case number.

2. Experts system identifies items to be considered in the algorithm and these are the items typical for a given department, the following procedure is used to enable such identification:

1. Items which were handled >= 2*12=24 times (which means that only the items which were handled average two times per months are to be considered);
2. Items which were handled >= 90% to the given department.

Items which will not be qualified at this stage of the procedure are to be listed and their allocation is to be optimized by the algorithm developed but during the next stages. These items are assigned to MPK (department) = 0.

At the beginning of the procedure, all the shelves are market as “empty”, hence:

for m=1 to 10 **do**
  for w=1 to 10 **do**
    w=w+1
    case [m,w,2]=”empty”
  next w
next m,

where **m** – case number, and **w** – shelf number.

3. Identification of number of shelves necessary to store the items available is performed with the following procedure:

1. Items for each MPK are ranked and the criterion is number of handling operations (the most often handles items are at the top of the list);
2. Identification of k[j] – which is a number of shelves required according to the principles defined for each department, and [k,1] shelf will pro ide information on items which are allocated on the shelf given, and [k,2] shelf –will provide information on items allocation.

- N[j]- number of items ranked for j department.
- J – number of department analyzed.

The principles are defined as follows:

For j=1 to J do
  For i=1 to N[j] do
    If part[i,j] is assigned to A-type container **Then**

```
            k[j]=k[j]+1  and part is eliminate
            from the ranking and shelf[k[j],
            1]=[A-type part[i,j],0] and
            shelf[k[j], 2]="taken"
        ElseIf   there is „half taken" shelf
        Then
            z=number of shelf found and
            eliminate the part from the ranking
            and shelf[z, 1]=[B-type part(part
            which already was allocated on the
            shelf);B-type part[i,j]]and shelf[z,
            2] ="taken"
        Else
            k[j]=k[j]+1 and eliminate the part
            from the ranking and
            shelf[k[j], 1]=[B-type part[i,j],0]
            and shelf[k[j], 2]="half taken"
        EndIf
      EndIf
    Next i
  Next j
```

4. Cases management:

1. Parts identified for each MPK (department) are allocated on separate cases; containers are assigned for department and allocated on predefined cases Orly. The exception is for parts not assigned for departments or rarely handled. These parts are allocated simply in empty cases on any case available;
2. In the first stage, the number of cases required is to be identified for each department, and then the shelves are to be filled in with the following order;
3. The following symbols are used:
   - d – number of cases required for each department;
   - case[m,w,1] defines set of items for m case for w shelf;
   - case[m,w,2] defines status of shelves for m case (shelf „empty", „taken" or „half taken");
   - m – case, m=1,..., 10;
   - J – number of department in the company (MPK).
4. Rules for allocation of items on shelves identified in 3) point: x=1. Principles presented below refer to all the department included in the algorithm (index j):

```
For j=1 to J do
    d=makeinteger(k[j]/10)
    m=0
    w=3
while w>0 do
    for z=0 to d-1 do
        case[m+z,w,1]=shelf[x[j],1]
        case[m+z,w,2]=shelf[x[j],2]
        x=x+1
        if x>k[j] then Go To 1
    next z
w=w-1
loop
w=4
while w<11 do
    for z=0 to d-1 do
        case[m+z,w,1]=shelf[x[j],1]
        case[m+z,w,2]=shelf[x[j],2]
        x=x+1
        if x>k[j] then Go To 1
    next z
w=w+1
loop
1:        x=1, m=m+d
Next j
```

5. Suggestion of allocation of items on empty shelves:

1. Sorting of items rejected according to number of handling operations (check 3a);
2. Identifying number of shelves required according to principles defined (check 3b) and with the assumption that j=0 department is considered;
3. Searching for "empty" shelves on cases (case[m,w,2]="empty");
4. Sorting "empty" shelves in the ranking which follows the following order: empty fourths, empty thirds, seconds, firsts and then fifths, sixths, ..., tenths.
5. Allocation of parts on the shelves according to their ranking position, which means that on the first empty fourth shelf (identified in 5d) the first item identified in 3b point will be allocated etc.

Each part considered in the algorithm is to be analyzed with reference to every department. Analysis is run to the moment when all the items are allocated on the shelves. All the information concerning items warehousing are "remembered" by the experts system and they are valuable source of information on items allocation in a warehouse and makes finding them really easy.

4. CASE STUDY

To demonstrate functioning of the experts system developed, the following case study is presented in the paper. Input data are introduced in the table below (table 1). Analysis was performed for one month.

The following allocation of items on the shelves was the output of the experts system developed performance:

- department 1: *shelf[1]=*1; *shelf layout[1,3]=[IV];*
- department 2: *shelf[2]=*1; *shelf layout [2,3]=[VII];*
- department 4: *shelf[4]=*2; *shelf layout [4,3]=[XII, III], shelf layout [4,2]=[X];*
- department 5: *shelf[5]=*1; *shelf layout [5,3]=[V,VIII];*
- department 6: *shelf[6]=*3; *shelf layout [6,3]=[VI], shelf layout [6,2]=[II], shelf layout [6,1]=[XI].*

Analysis of all the departments leads to the conclusion that department 3 does not have any items which can be allocated with the system, because any of the items was handled for more than 90% comparing to other departments.

To make understanding of such allocation easier, part of reasoning process is introduced below, referring to ranking of 3a items for MPK 4 with the code of each item:

XII: 4_2640_B
X: 4_1563_A
III: 4_1230_B

These items were chosen as each of them met the criterion of more than 90% of handling operations to this department (that was the initial assumption for items selection). Assigning X item to department 4 is a result of the following: sum of all the handling operations for this item is 1716 pieces, and 1563*100%/1716=91%. Then, items were ordered according to hierarchy of handling operations and segregated on the shelves. The first item on the list (the most often handled for department 4) is XII which is allocated in B-type container and placed on shelf together with III item to meet requirements of efficient warehouse space management. According to this assumption, items are to be allocated on the third shelf of the high storage case so that warehousing staff had easy access to it, without necessity to use fork-lift. Thus in *shelf layout[4,3]=[XII, III]*, 4 is the department items are assigned to and 1 is a number of shelf. Items allocated on the case shelf are eliminated from the ranking, hence there is only X item left, and it is stored in A-type container. It will be allocated on the separate shelf (second shelf): *shelf layout[4,2]=[X]*. consequently, the number of shelves required for items storage in 4 department equals 2 (*shelf[4]=*2).

Table 1. Data set

Item nr	Container type	Handling operations number to:					
		MPK 1	MPK 2	MPK 3	MPK 4	MPK 5	MPK 6
I	B	480	-	520	832	-	210
II	B	-	13	-	-	64	998
III	B	20	86	7	1230	-	-
IV	A	350	-	-	-	5	-
V	B	-	37	11	-	480	5
VI	A	98	78	10	170	-	3214
VII	A	-	1320	2	-	55	86
VIII	B	-	-	8	-	81	-
IX	B	216	460	-	-	270	315
X	A	100	-	53	1563	-	-
XI	A	-	80	-	-	-	880
XII	B	92	-	96	2640	-	103
XIII	A	-	2157	-	450	170	-
XIV	B	930	-	12	-	-	42
XV	B	5	23	-	730	21	-

Source: Own work

In the case analyzed, two shelves are fully taken, while in department 6 two shelves are fully taken (items VI and XI) and one is half taken (item II). The order of allocation, according to handling frequency is the following: the first to be allocated, on the third shelf is item VI, then, on the second shelf item II and finally item XI is to be allocated on the first shelf.

Item I and IX are not assigned to any of the departments. Despite of that the items were quite often handled to various departments, but for any of the departments number of handling operations was not higher than 90%. According to assumptions taken, these items should be analyzed with procedure presented in point 5 and allocated in empty spaces available.

5. CONCLUSION

Purchasing logistics processes require taking numerous decisions substantially influencing financial condition of a company. Assessment of warehouse management condition requires focusing on waste hidden in logistics processes. It is coherent with the idea of Lean Management, contemporary approach to management, which puts a lot of stress on elimination of waste which is time, place and resources not providing any added value to final customers.

The solution presented was to eliminate time waste, often believed to be the main and the most important. Using expert system enables fast identification of purchasing items in warehouse and decreases completation time necessary to decrease lead time for customers. The next aspect, quite important from employees; point of view is reduction of workload connected with completation process. The goal was achieved by placing the most often handled items in low and easily accessible shelves, without necessity to use fork-lift every time when an item is needed.

Application of the solution presented, based on expert system methodology, is expected to increase efficiency of production process and improve financial efficiency of a company as a whole.

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