SIMULATION TOOL FOR MANAGING A NON-AUTOMATED DISTRIBUTION WAREHOUSE

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ABSTRACT

In this paper, a simulation study is carried out to identify potential improvements in the management of a non-automated distribution warehouse which is located between manufacturers and small retailers. The simulation model has been used to obtain valuable knowledge of the operational characteristics of the warehouse. We aim at understanding the effect of an automatic storage upon the occupied space of the warehouse. Different scenarios are taken into account by using an experimental design technique. The analysis of the simulation results lead up to find out the value of the parameters causing the strongest effect on the performance measures previously defined, allow to assess the value of introducing changes provided the current storage procedure and give important insights about the behaviour of the whole system.

INTRODUCTION

Nowadays, the warehouse management has been asked to increase customer service, reduce inventories, handle a large number of stock keeping units, and improve space utilization. Warehouse management has realized that these conflicting objectives require a much more professional approach (Smith 1992). Distribution warehouses serve as products handling stations in the logistics system. More space is allocated to temporary storage and most of the attention is given to speed and ease the product flow. The modern warehouse must play the role not only of storing parts and end products, but also of a dynamic inventory control. Regarding to this task, it is established a information system to update kinds and quantities of stored items.
The primary purpose of a warehouse management system is to control the movement and storage of materials within an operation. The basic logic use a combination of item, location, quantity, unit of measure, and order information to determine where to stock, where to pick, and in what sequence to perform these operations. When we think of optimizing warehouse operations, we usually think of automated material handling systems. However, there are non-automated distribution warehouses which face the fact of an old management system. In this study, the company is interested in assessing the impact on the storage space if a new management system is adopted.
Storage and warehousing consist of many discrete operations that occur randomly. Simulation modeling in the form of discrete-event simulation has evolved to become one of the most popular and cost-effective means of analyzing complex systems. In non-automated distribution warehouses the simulation models are much more difficult to build because materials handling is much more complicated. Regarding to modeling non-automated distribution warehouses, (Takakuwa et al. 2000) developed a simulation program for a real distribution warehouse.
In this paper, we propose a simulation-based planning tool to evaluate the effects on the size as the management system changes and so, help with decisions concerning the needs of storage space. The paper is organized as follows. In Section 2 the real system is described. After making a set of assumptions about how the system works, a model is built in section 3. Finally, in section 4 the experimentation and the results are considered.

CASE STUDY. DESCRIPTION OF THE DISTRIBUTION WAREHOUSE

Firstly, there has to be an initial understanding of the physical layout and the processes in the system as it existed. A schematic layout of the distribution warehouse is shown in Fig. 1. There are two major areas inside the distribution warehouse.

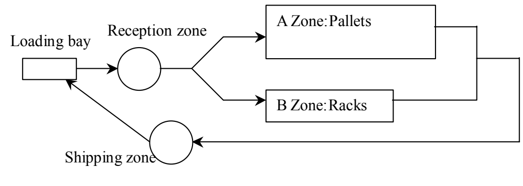

Figure 1: Layout of the Distribution Warehouse

At the major area or A zone, pallets are put directly on the floor because of the volume or weight of the corresponding items. In B zone, small items are putting on the racks. Although this second area use less physical space than A zone, approximately the two thirds of the products are

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located on the racks. Moreover, B zone had been identified by the company, as an area requiring improvements on the management system. The fundamental reasons behind the study of B zone are two. Firstly, the lack of an automated location and the possibility of different products on the same storage location, require an employee training to avoid making mistakes in preparing orders. Secondly, the accessibility to material in the current method of storing is extremely poor, time is wasted by employees wandering around the warehouse searching for a product.

Physical Characteristics Of B Zone

A plant view of B Zone is shown in Fig. 2. It consists of 13 modules of racks, placed in 7 corridors.

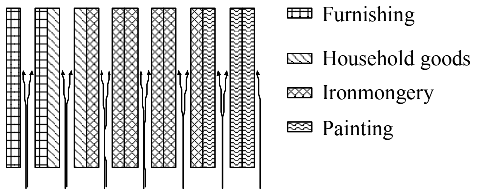

Figure 2: Plant View of B Zone

Each module contains 17 racks with 15 shelves each one. Fig. 3 shows an elevation view of a module. There are two types of shelves depending on its height, single and double, with 42.5 cm and 78 cm., respectively.

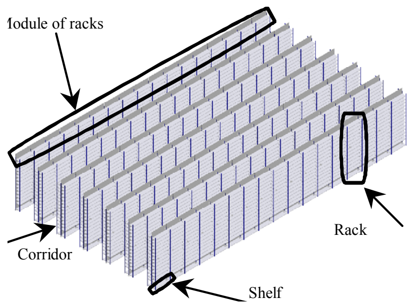

Figure 3: Elevation View of a Module and a Rack

The products are classified into four families: furnishing, household goods, ironmongery and painting. The number of modules and shelves assigned to each family is shown in Table 1. At the present time, each shelf is divided into six storage locations or positions, which are all coded.

Table 1: Space Assigned to each Family

Family	Furnishing	Chemist	Ironmongery	Painting	**Total**
Modules	2	2	6	3	**13**
Single shelves	442	442	1326	663	**2873**
Double shelves	68	68	204	102	**442**
Total	**510**	**510**	**1530**	**765**	**3315**

Operations At The Warehouse

Operations at the warehouse comprised purchasing, receiving, storing, picking and shipping the items. When a truck carrying items arrives at the warehouse, the incoming items are unloaded and place into storage in A Zone or B Zone. Regarding to B Zone, items are put on its family shelves. If it is not possible, items may be assigned to any available storage location. In addition, items are put on the racks according to an ABC inventory classification.

The management system depends on the philosophy followed in assigning material to storage space. The current system keeps track of the present location of every item in storage, but let mix different products in the same position. The storing operation is suspected of causing problems and is considered by the company as the essential point. It was not known how changes to this operation would affect the space requirements.

A fixed location storage trades efficiency in use of space for easy accessibility to material, and random location trades material handling efficiency in use of space. We consider the current system as a “pseudo”-random location storage with a poor accessibility to items at the picking operation. In this study, we consider a combination location storage for middle-of-the road efficiency in use of space and accessibility to material.

SYSTEM MODELLING

The analysis of a new management system in a warehouse is ideally suited to simulation modelling, and benefits from using simulation are well known (Law and Kelton 2000). Firstly, the simulation model involves, understanding warehouse problems, data collection within the company and communication with management and shop floor workers.

In the first stage, we consider a suitable sample of products stored in B zone in order to obtain a system less complex. This simplification allows us to build a simpler simulation model with a quick and easy alterations of specific modelling parameters. The sample should be sufficiently representative to permit valid conclusions to be drawn about the whole zone and, which is more important, establish the guidelines on a future study for the whole B zone.

Selection Of Products

The selection of products to be considered in the simulation model, was made with the company. After gathering information from interviewing employees of the company, we identified those items that deserve its most attention, namely the A items. Next, the products were chosen paying attention to the percentage of each family of items at the B zone and being heterogeneous in shape and size. Thus, we modelled a system with 34 products from ironmongery, 17 from furnishing, 13 from household goods and 4 from painting. Each product is described by the physical dimensions (height, width and length) of the smallest storage unit. Moreover, some products are special because of its weight or volume.

Because of the selection of a subset of products, we had to estimated the number of racks we should assign to each family, bearing in mind the real warehouse. For this purpose, we collected data about the inputs and outputs from July 1, 1999 to June 30, 2001 and the stock in June 25, 2001. These data allowed us to calculate the initial stock and the number of shelves associated with each family, which are shown in Table 2.

Table 2: Number of Shelves for each Family

Family	Furnishing	Chemist	Ironmongery	Painting
Single shelves	10	5	14	2
Double shelves	1	1	2	0
Total	**11**	**6**	**16**	**2**

Management Warehouse System

The decision as to which parameters and structural assumptions are considered fixed aspects of a model and which are experimental factors depends on the goals of the study rather than on the inherent form of the model. Discussion with the company revealed a number of factors that were suitable for change and the output performance measures.

The different management warehouse systems, analysed in this study, keeps three rules of the current one: classification of storage space by families, FIFO control and treatment of special products. In addition to these rules, we introduce another ones which suppose an important change in storage procedure. Bearing in mind that clear identification of the products and positions will make order picking and putway faster and more accurate, in each position is only allowed items of the same product. Moreover, if a product, because of its size, takes more than one position, all of them are automatically blocked.

There are a range of ways the system could be changed:

Position size: In the real system a shelf is divided into six positions.

Number of days using the same position: In order to improve the use of space, the system allows to assign a non-empty position to incoming items of the same product. This factor indicates the period of permission.

Location of products: Each product have two different ways of putting on the rack.

Initial space: In order to consider the mixture of products from different families, we define the initial number of shelves corresponding to each family of products. We allow to create new ones when all of the initial shelves are full.

The alternatives to these factors and the effect of changes have to be measured to determine how they help to achieve the company's objectives. The most important measurement was the space requirement. This is easily accountable, by computing the maximum of shelves needed to allocated all items over the same time horizon. Other measurement criteria are: the percentages of non-empty space at each day and for each product and the percentage of mixture of each family and each corridor.

Simulation Model

The simulation model was built using WITNESS, the visual interactive simulation software (The Lanner Group 1998). Regarding to the input data about incoming and outputs items, we have historical data collected during two years. These data display a usual behaviour of the warehouse. Thus, we consider as the simulation horizon two years and use the historical data as input data for simulation. The two years considered provide 487 working days. The experimental set-up for all simulation experiments will be the initial stock estimated.

Elements Of The Simulation Model

Products and shelves are modelled by using elements. A product is defined as an element type Part and named Refer and have various attributes that let us distinguish it among each others. The incoming and outgoing of items are implemented in the model through elements type File. The value of the attributes of each product and the initial stock are also introduced by an element type Partfile. A shelf is defined as an element type Buffer and they are put into groups according to its family and its type (single or double). The management system is defined by a set of rules which are implemented in the model through elements type machine, function, buffer and variable.

The Logic Of The Simulation Model

The logic of the simulation program comprises three major process. The logic for put out/shipping operations, that removes items from the shelves and the warehouse, the logic for arrivals of items and the logic for storing operation of items on the shelves. The unit of time in the model is one day. The operations are carried out in a sequence each day: put out/shipping, arrivals and storing.

User Options

The model has to incorporate the parameters which could be changed to build different scenarios, hence different management warehouse systems. At the beginning of each experiment, the model incorporates a friendly interface for the introduction of all the values associated with the different parameters. The implemented function is executed at the same time that User Actions.

Recorded Values

The results of the simulation have to provide a complete statistic summary of the system performance. For this purpose, the simulation model defines some given indicators and records their values in output text files. Each indicator is evaluated everyday twice, after the put out/shipping operation and after the storing operation.

Simulation Experiments

In a previous section we identified the factors that could be changed to generate different scenarios. As the first step of the simulation experiment, user options should be introduced to perform the model. The ranges of variation allowed for each factor are:

A: Position size: an integer number in [1,35].

D: Number of days using the same location: an integer greater than 0.

B: Location of products: L (length) or W (width).

C: Initial space: cm (allowing mixtures) or sm (without mixtures).

Secondly, we also identified the responses or output performance measures. Although the simulation model provides the value of many indicators, we only consider in this study as the response of interest the maximum of necessary shelves over the time horizon. Thus, we like to know how each factor affects the response, as well as to determine whether the factors interact with each other and what are the combinations of factor levels that minimize the response.

Research Methodology

A 2^4 factorial design provides the alternative system configurations which are evaluated afterwards by the simulation model (Montgomery 2001). This procedure let us obtain the desired information with the least amount of simulating. This strategy requires the choice of two levels for each factor. These values were identified from information gathered from the company. The model takes into account some limitations of the real system, for instance, about the size of position, the company imposed that the most of the selected products should occupy only one position.

Regarding the levels of each factor, thirty-six alternatives are examined by means of simulation experiments. Such experiments allow to carry out nine 2^4 factorial designs. A primary goal when screening designs is to identify the "key" factors that influence on the response. The qualitative factors, B and C, are fixed at two levels, (L,W) and (cm,sm), respectively all over the designs.

Results

In this section we shall present some of the results obtained. The significant factors for each design are shown in Table 3. The first column contains the levels of the numeric factors, A and D, associated with the corresponding design. First, we notice that, in general, the significative effects are due to the main effects rather than the interactions.

Table 3: Factors Influence

	Influence of an effect						
Design	+ influence					- influence	
A(3,6) D(0,30)	B	D	A	C	AD	ABD	AB
A(3,6) D(0,90)	B	D	A	C	AD		
A(3,6) D(30,90)	B	A	C	D	CD		
A(3,8) D(0,30)	A	D	B	C	AD	AB	
A(3,8) D(0,90)	A	D	B	C	AD	AB	
A(3,8) D(30,90)	A	B	AB	C			
A(6,8) D(0,30)	B	A	D	C	AB	CD	
A(6,8) D(0,90)	B	D	A	C	AB	BD	
A(6,8) D(30,90)	B	A	AB	C	D		

The inspection of Table 3 also reveals that changes in both factors, position size(A) and Location of products(B), cause the major effects on the number of shelves required. In the Figure 4, the interaction plots provided by Minitab (Minitab 1999) are shown.

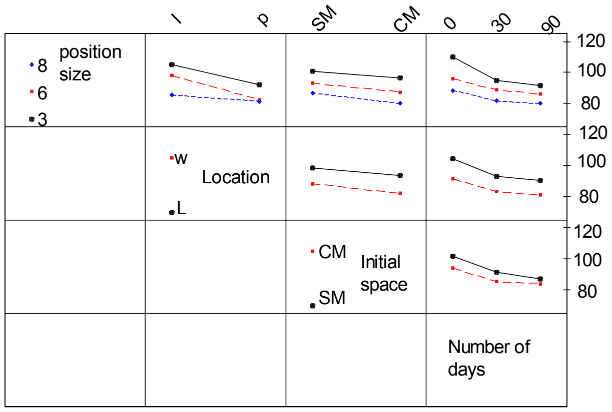

Figure 4: Interaction Plot-Data Means for maximo

In Table 4, the six configurations of the system requiring less space for a time span of two years are presented. In addition, the table contains the 0.8×100th and 0.9×100th percentiles of the shelves distribution. In Fig. 5, means of teh number of shelves are indicated by solid circles.

Table 4: Results for the Best Configurations of the System

Size Position	Location	Initial size	Number of days	Maximum of shelves	0.9×100th percentile	0.8×100th percentile
8	W	cm	90	76	73	65
8	W	cm	30	76	73	66
6	W	cm	90	76	74	68
8	L	cm	90	79	75	69
6	W	cm	30	79	77	69
8	L	cm	30	81	78	71

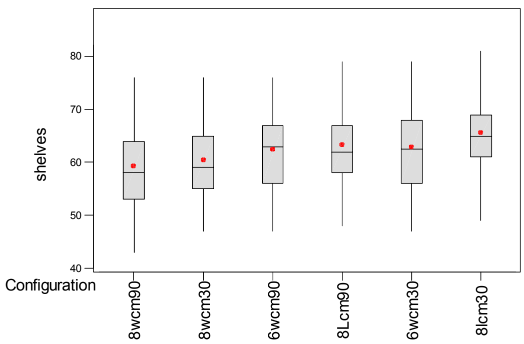

Figure 5: Boxplots of shelves by Configuration

Taking into account practical considerations and the main factors effects, we propose a management warehouse system with a position size of 6, a number of days using the same location of 30, a W location of products and the initial space cm. The current number of shelves in the warehouse is 28.6% lower than the best configuration obtained, and 37.5% lower than the proposed one. Hence, we consider that the increase in the number of shelves is low enough to use the proposed management system.

CONCLUSIONS

In this paper, we have built a simulation model to identify potential improvements in the management of a non-automated distribution warehouse. The proposed model provides a new and useful tool for the analysis of alternative management systems, at the lowest cost and with the least disruption to the storing operations. In particular, the simulation model let us know the behaviour of the real distribution warehouse under an automated movement to and from storage. The results obtained had been essential to assess the value of those changes, provided the current storage procedure. Moreover, the implemetation of the model let us change the products to be considered and the input data about incoming and outputs items.

The use of statistical experimental methodology and the simulation model allows to understand the effect of different factors upon the occupied space of the warehouse.

This preliminary study gives important insights about the behaviour of the whole system and a guide for further research. Firstly, we have found out that the when the position size is small, location of the products has to be “width”. Secondly, if the number of days using the same location is greater than 30, there is no significant changes in the space required. Thirdly, by increasing the position size, the number of shelves required is lower and finally, a mixture of products from different families always lead up to reduce the number of shelves required.

Regarding to the conclusions, in a future work we will analyze the whole warehouse by means of a cluster analysis in order to group the products. As the increasing of the position size is a way of reducing the number of shelves requiered and bearing in mind that a given storage location contains only one stock-keeping unit, we supposed that the size of these units will be an important cluster variable. Afterwards, the proposed simulation tool could determine the optimal position size for each group of products.

Moreover, we consider that the qualitative factor, initial space, deserve further analysis. So, eight new factors could be defined as the number of shelves (single and double) assigned to each family in the initial space.

Finally, we will introduced random incomings and outputs in order to check the robustness of the management system proposed.

REFERENCES

Law, A.M. and W.D. Kelton. 2000. *Simulation Modeling and Analysis, 3th Edition*. McGraw-Hill Higher Education.

Montgomery, D.C. 2001. *Design and analysis of experiments, 5th edition*. John Wiley and Sons, Inc.

Minitab Inc. 1999. *MINITAB Release 13 for Windows*.

Smith, J.D. 1992. “Storage and Warehousing”. In *Handbook of Industrial Engineering, 2th Edition*, Salvendy, G. (Ed.). Institute of Industrial Engineers, John Wiley and Sons, Inc, 1025-1048.

Takakuwa, S. and H. Takizawa, K. Ito, S. Hiraoka. 2000. “Simulation and Analysis of Non-automated Distribution Warehouses”. *In Proceedings of the 2000 Winter Simulation Conference*. J.A. Joines et al (Eds), 1177--1184.

The Lanner Group. 1998. *WITNESS Users Manual, Version 9.0*. Redite, UK.