New warehouse design methodology at strategic and operational level

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Abstract: - The picking process is a critical supply chain component for many companies to satisfy customer orders. A proper warehouse configuration, storage policies, trays replenishment policies, and other factors are also important to reduce not only the delivery time, but also increase productivity while maintaining quality factors at competitively cost. This paper presents a warehouse design under several space constraints due to the increasing volume and the warehouse new location. The proposed design methodology integrates warehouse layout configuration, storage policy design, replenishment policy design, picking policy design, routing policy and also trays and shelves sizes design. This work minimizes also the number of operators and the required special equipment to support all warehouse operations.

Key-Words: - Picking, storage, warehouse, simulation, distribution, strategic, operational, colored petri nets

1 Introduction

New information technologies have irrupted drastically in some logistic processes supporting a better coordination of transport systems with the production systems. Thus, new production planning policies integrated with routing policies can be adopted to minimize production costs while improving customer quality factors. Although a critical chain link between production and transport subsystems is the picking process, relatively little changes in its warehousing operations have been properly justified during the last years.

In the literature it is found research regarding warehouse systems and its management presenting models supporting decision making at distribution system or warehouse design, or at storage allocation and others [8]. There are other works regarding travel time analysis and estimation to improve the cost of the picking process [9,10]. There is also research on clustering techniques to optimize the picking process [11]. On the other hand, several papers regarding the use of simulation as a tool in warehouse design have been written: models of order picking systems, cost models for inventory and inventory sizing models, models for warehouse capacity expansion [1,3,4,5,7]. And it is also possible to find some work comparing and mixing different picking, storage and routing policies in a manual warehouse [12].

It is important to note that unlike popular belief, every warehouse is not the same: critical aspects that should be properly understood are the effect of product mix, stock keeping units (SKUs), batch sizing, order sizing, etc. on the layout and tray storage type of a warehouse to obtain an efficient picking productivity factor.

Some warehouses has been designed to serve as processing or materials handling stations in the logistics system, other warehouses are designed as distribution centres located between manufacturers and customers. When a warehouse is used to store raw material for an automated production system and, at the same time, it is used as distribution centre, highly complex material flows appear.

In this paper a non-automated warehouse of an optical company is analysed using a simulation model to optimize picking productivity considering space layout constraints and its functionalities: Storage of raw material for a production system and capillarity distribution center. An expected increment of 72% in the number of costumers together with high space constraints and productivity factors subjected to random perturbations have forced new warehouse elements design, new layout configuration and the development of an innovative method with new picking, storage, routing and replenishment policies.

In Section 2 the initial system and its special characteristics are described; then Section 3 shows the evolution of this work. Section 4 presents the general results of this study. Concluding remarks and acknowledgments are given in Section 5 and Section 6 respectively.

2 System descriptions

The warehouse was allocated to storage frames which were picked and introduced into bins to send them to costumers. The warehouse consists in several picking shelves with trays in its center part. The shelves under the trays and the top shelf were allocated to pile up master boxes.

The picking policy was operator-to-product, which means that the operator moves through the aisles to collect the picking lines of a certain customer order (see Fig. 1).

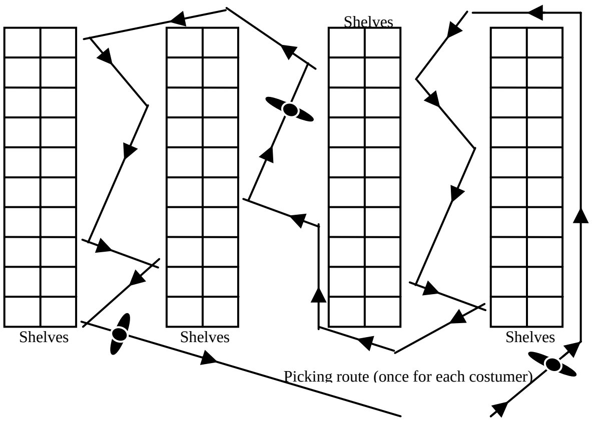


Figure 1: Operator-to-Product

The storage policy was very conservatives; it consist in to place the over-stock of each SKU near the tray where the SKU was located for picking purposes: overstock product could be placed only in master boxes at the same column of the tray in area below or over the picking shelves. In case no free space could be found in the column, the master boxes were placed in a random storage area nearby of the picking area.

During the picking process no empty tray was found; however, the replenishment policy was conservative: if the picker found tray with a small number of frames, he had to find a master box for that SKU and he had to replenish the tray and take back the master box to the location if necessary.

The shelves and the aisles occupied 470 m2; however, a study of the occupation of this space determined that the real occupation of shelves was around 42% because of the following points:

- Free space into every tray due to the replenishment policy. There was free space into trays most of the time (See Fig. 2)
- Trays without a SKU assignation: due to the lack information about the period during which a reference can be bought and delivered, there were always some empty trays for new references (SKUs)
- Free space into some master boxes: when it was not possible to locate all the frames from a master box into a tray, the master box remained on a shelf with empty space in it (See Fig 2)
- Free space on the shelves due to the storage policy presented above

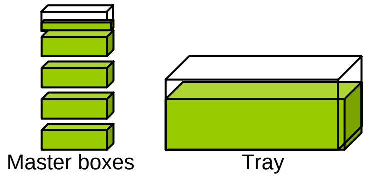


Figure 2: Free space in trays and boxes

According to certain characteristics there are some aspects that should be considered in the configuration of the warehouse and they are presented in the following paragraph.

Firstly, the optical company was placed inside an urban area of a city that has been growing in number of habitants during the last years. The new strategic market orientation of the company increasing the number of customers implied a material volume increment around 25% into the warehouse; unfortunately, there was no possibility to increase the floor area of the warehouse.

Secondly, due to historical cultural evolution of the company and the manual assembly process, the operative management and manipulation of frames lack of support of new information technologies (IT), like RFID. This lack of IT forced to a non efficient assignation of SKUs to tray locations, non efficient tray replenishment operations to avoid tray stockout during picking process, and a non efficient use of the space on the shelves of the warehouse.

Thirdly, optical market is ruled by a reduced amount of powerful glass and frame manufacturers, so they are allowed to provide the distribution centres with the amount and at a time more convenient to them. For example, Asiatic manufacturers allow a low number of transports with an important amount of frames or glasses.

Fourthly, unfortunately, it was not possible to develop a classification model according to turnover reference. It is possible to have really low demand for some frame models during several months and then have high demands for them during some weeks. Historic analysis of data confirm also very different and rare sales situations, such as for example, a certain glass frame can have a high demand in a certain area in Spain, while there is practically no interest in this frame in other areas of the country.

Finally, it is necessary to configure the warehouse to be able to absorb all the material flow due to the production line supply and the distribution to costumers. The picking process has to differentiate between the frames for the production line and the frames for distribution even they can be located in the same aisles.

Due to time constraints in the distribution quality factors and the time constraints in the production line supplying a tray storage rupture of a specific SKU with items in the random storage area could lead to important quality factor penalties; therefore, also the best replenishment policy to avoid an empty tray with items in the random storage area during picking operations have to be developed.

Due to the strategic and operational aspects to consider it is not possible to find an analytical technique to face this problem. Otherwise there is not clear objective because it is not possible, for example, to know if optimize space is better then optimize number of operators. Therefore, simulation is considered to confront this problem because, once the model is created, the possibility of experimentation permits changes in strategic and operational level.

3 Simulation Models

Simulation models were designed to be used as a tool to analyze different organization warehouse alternatives, as well as a method to experiment with different storage and process options. More specifically, simulation models were developed so that it could be used to answer the following concerns: production and distribution run size, shipping lead-time, replenishment tray policy, different rack/storage types, equipment/resource limitations, storage method efficiency, order picking method performance and layout efficiency.

Different submodels are described in this section, and for some of them, the simulation results are also presented because they are necessary for the following submodel.

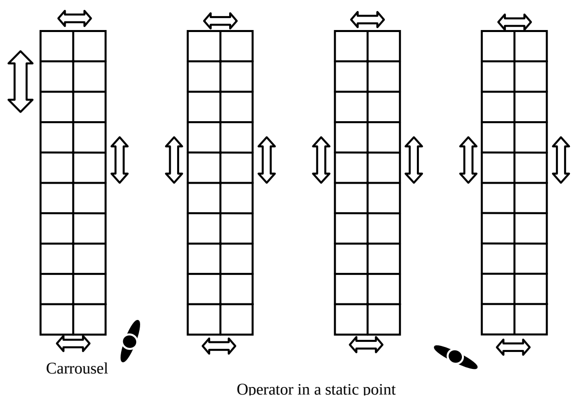


Figure 3: Product-to-Operator

3.1 Initial basic simulation

Initially, a very simple model was performed to help the study of the initial characteristics for the new warehouse. Since it is not possible to increase the warehouse floor area even though the material to be located presents an increment of 25%, it is necessary to design a new storage method.

At the very beginning, the occupation of the actual warehouse was calculated and just the 42% of the space was used, therefore the first idea was redesign the warehouse to be able to use around 80-85% of the space. The first simulation compared the use of automatic warehouse and the manual system used by the company.

Regarding the use of automatic warehouse infrastructure to optimize the picking area, this option was rejected due to the following facts:

- The volume that the carrousels were going to occupy was so large for the frames could be located
- High investment for the carrousels and accessories
- No possible interaction between the picking process and the replenishment operations

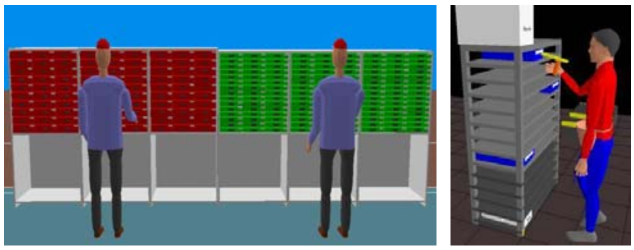


Figure 4: Multi-Tray concept and ergonomic simulation image

The simulation contributed positively to the design of the warehouse because it was noted that the warehouse had to be designed as a manual warehouse but with some characteristics of automatic warehouse because the picking policy operator-to-product used too much pickers due to the travel time of each one. Thus, a new picking policy was introduced, product-to-operator, which place the operator in a fix position and the trays with the product moves automatically till this position (See Fig. 3). Since automatic warehouse was rejected, the new design should consider a manual system where the picker should work in front of as much references as possible to minimize its travel time (See Fig. 4 left).

Experimenting with this submodel it was studied the use of conveyors to transport the frames from the warehouse to the production line; however it was also refused due to the following facts:

- Decrease of the picking productivity due to traceability operations (picking-to-conveyor and conveyor-to-production)
- High investment for the conveyors and the accessories

- Poor performance of conveyors: just one conveyor could be used at the same time
- Conveyors use square meters that are needed for shelves to be able to store all the frames
- A public corridor between the warehouse and the production area impeded the connection between them using conveyors

In that case, it should be necessary the implementation of a transport policy to move the frames from the warehouse to the production line over the public corridor, and also to the distribution point which it was not clear its situation in that point of the work.

3.2 Spreadsheet model for sizes and capacities

As mentioned in section 3.1, trays and shelves were designed to fit as much SKUs as possible into as less lineal shelves as possible. This kind of compacting is also useful since there was a new room to accommodate the storage area and other warehouse sections measuring just 650 m^2. At the same time, the size of the trays had to be large enough to avoid empty trays during one day of picking operations. Using a spreadsheet model it was determined the maximum number of pickings of the same SKU during a day and it conditioned the trays design.

Two types of frames were considered for the new design, one for glasses and one for sunglasses (See Fig. 5 left). Once the trays were designed, it was necessary to study the shelves where the trays would be located. Since two types of trays were designed, two different shelves were also designed. Fig. 5 right shows that there are some shelves in the middle to allocate the trays, and the top shelf and shelves bellow the trays are used to store frames within the master boxes. An ergonomic study was made to determine if all the points were accessible.

And finally, notice that this shelves design should not be useful if the picking process policy was not changed because there will be more different SKUs in less space and the pickers would disturb each other. And it should not be also useful if radio frequency was not introduced because the idea is to use 80-85% of the shelves and trays space, so due to the trays capacity there will be more master boxes to locate than in the actual warehouse.

At that point, the minimum number of SKU positions was also fixed making and initial estimation and rounding up using the company knowledge and the shelves capacity. This minimum number of SKU positions determined the minimum number of shelves. Depending on the maximum possible volume of the warehouse (See section 3.4), other shelves configuration for master boxes could be needed.

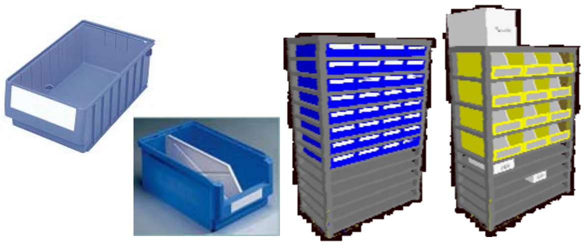


Figure 5: Trays and shelves design

3.3 Shelves ergonomics

All companies have to meet the ergonomic requirements to avoid possible penalties and to ensure the physical health of the operators. Fig. 4 (right) shows a static image of the ergonomic simulations.

3.4 Warehouse volume evolution

Before the implementation of the final model it was necessary to make an initial estimation of the possible frames volume to storage into the warehouse.

All this study of the volume was made using the historic data obtained from the company. Using this data and statistics, the day and month volumes were estimated by projecting the actual volume according to the estimated increase. Using the same boundary conditions for incomings and outgoings, it was noticed that there were two different types of months, high volume months and less volume months for both incomings and outgoings. Simulations were made combining the different types of incoming and outgoing months and using the maximum estimated volume at the end of a month as initial volume of the warehouse (See Fig 6). Note that the worst situation would be a high volume incoming month with a less volume outgoing month.

The result of this study determined the possible maximum volume of the warehouse, and a small increase of this value was used to ensure the warehouse capacity.

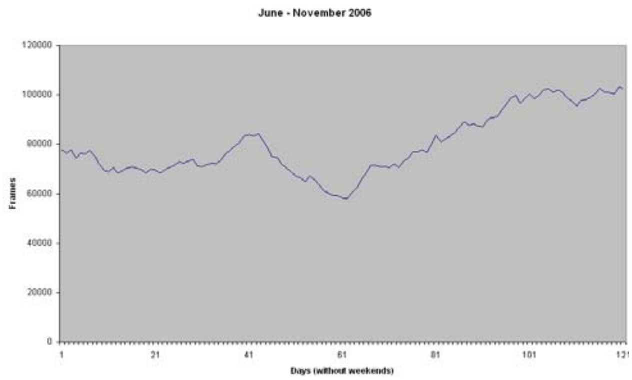


Figure 6: Warehouse volume evolution

3.5 Operational model
A Coloured Petri Net (CPN) [Jensen 1997, Piera 2004] model was developed to determine the number of operators for each process, the best operations policies and an acceptable layout distribution to deal with efficient operations to feed both: production demands at a particular rate and distribution demands to customers under a time window constraint.

Fig. 7 illustrates the main events considered in the simulation model specified under CPN formalism. The CPN model describes not only the main events that affect the warehouse, but also the reverse material flow from shops to the warehouse.

Different simulations permit the adjustment of the layout configuration as well as the number of operators and the different operations policies. The final results of these simulations are presented in the next section.

4 Results
The analysis was begun by simulating the quantities of operators and equipment suggested by the spreadsheet calculations. As mentioned in section 2.5, as a result of different experiments, the number of operators and the layout configuration for the warehouse were established, and the simulation confirmed that the new layout could support an increment of 25% frames to be stored and also can allocate other sections of the company due to the shelves area occupy 390m^2 of 650m^2 available. The exact distribution of these other sections is not treated in this paper, but it is considered because of they need enough space for pallet manipulation.

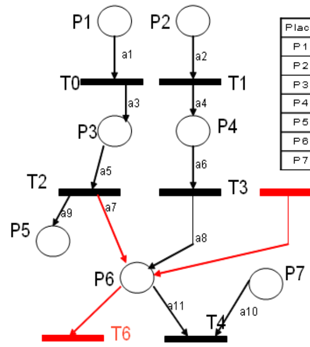
The experiments also permit the implementation of new storage policy, new combined picking policy, new tray replenishment policy and new transportation/routing policy.

4.1 Number of workers adjustment
Company estimation on the number of operators for the initial works were near 7 operators, but the experiments conclude that with 5 operators would be enough.

4.2 Final layout configuration
For the final layout configuration, the company forced the introduction of special shelves for master boxes as prevision in case the maximum fixed volume could be exceeded even though this value was already overestimated.

There are two types of areas, ones that need pallet manipulation and areas where it is not needed. The storage area do not need pallet manipulation and other sections needs, thus other sections were located as close as possible to a wide door in the warehouse.

The storage area configuration was designed to minimize movements of operators with a good connection with the production line even though there was a public corridor between both areas of the company. Shelves were distributed depending on the type of frames they allocated, grouping glasses and sunglasses, grouping graduate frames and non graduate frames for the sunglasses, and keeping a star-product area without shelves where the sunglasses in fashion for one season are located within the master boxes and picked directly from them.



Place	Place definition
P1	Supplier frames for replenishment according to a file
P2	Supplier frames for new collection according to a file
P3	New collection frames at the supplier reception area
P4	Replenishment frames at the supplier reception area
P5	New collection to be dispatched
P6	warehouse
P7	Frames to be dispatched according to a file

Transition	Transition definition
T0	Arrival of new collection frames at reception supplier area
T1	Arrival of replenishment frames at reception supplier area
T2	New collection frames carried to the dispatched area or to the warehouse
T3	Replenishment frames carried to the warehouse
T4	Warehouse frames carried to the dispatched area
T5	Frames from stores to be reallocated or to be returned to suppliers
T6	Old frames returned to suppliers

Figure 7: Warehouse CPN model

4.3 New Policies
As mentioned in section 4, the results of the experiments force the implementation of new policies.

Storage policy: The lack of space, the physical design of the shelves and some of master boxes sizes force the location of two columns of boxes lined up one behind the other on the shelves under the trays. And it is also possible to locate columns of master boxes at the top of the shelves. However, to locate boxes one behind the other or in columns could be chaotic, therefore radio frequency is introduced to know where is located a master box of some particular reference, how many master boxes are in the warehouse, how many frames are into each master box and into each tray.

Picking method: As mentioned in section 2.1 the picking policy should be similar to the product to operator method and it is possible thanks to the trays and shelves design. This policy will be use for the supplying of graduate glasses and sunglasses to the production line. However, the warehouse is also used for distribution of non graduated sunglasses to the costumers; therefore operator to product method must be used for this job. The locations of the different types of frames allow the pickers to work without interfering between them.

To improve even more the picking method, the picking lines should be ordered by SKU in just one list for all the costumers instead of an ordered list for each costumer. The order of the SKU's (frames) into this list will be as the order of the SKU's in the warehouse, minimizing the travel time of the pickers.

The last aspect to be considered to improve picking productivity is to avoid empty trays during the picking process with the item to be picked in master boxes wherever in the warehouse.

Tray replenishment policy: As mentioned before it is necessary to use a policy to guarantee no empty trays during the picking process. For that reason a new replenishment policy had to be used. Using the historic data and simulation it was possible to calculate the number of trays to be replenished every day. Also, due to the control on the volume of frames into the entire warehouse (trays and master boxes) it will be possible to identify the trays to replenish and the master boxes from which it has to be done.

The simulation model was used to validate the replenishment policy developed under different workloads.

Routing policy: Experiments results show that it is better to have dedicated operators for different operations; therefore it is considered that the picker just work in the picking process and somebody else has to transport the frames for the warehouse to the beginning of the production line.

Trolleys and new special trays were designed for the transportation of the frames. This design allows the transportation operator working without disturbing the picker.

5 Conclusions

Simulation has been used to confront a problem at strategic an operational level under high space and operational constraints developing a new method to be able to make decisions about the physic elements of the system and about the operational aspects.

Using this method it is possible to determine the equipment required to support warehouse operations, to fix the best layout configuration under layout surface constraints, and to develop the correct polices for the different processes (storage, picking, replenishment and routing). All the made decisions preserve certain customer quality factors as could be delivery time.

6 Acknowledgments

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