IMPROVEMENT OF OPERATIONS OF PICKING AND DISPATCH FOR A BUSINESS IN THE MATTRESS INDUSTRY, SUPPORTED BY DISCRETE SIMULATION

MEJORA DE LAS OPERACIONES DE PREPARACIÓN DE PEDIDOS Y DESPACHO DE UNA EMPRESA DEL SECTOR COLCHONERO APOYADO EN SIMULACIÓN DISCRETA

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ABSTRACT: Warehouse management and operations of picking and dispatch in the supply chain and logistics are key factors for operational efficiency and client satisfaction. For this reason, the present article aims to develop a discrete simulation model that supports the analysis and evaluation of improvement alternatives for these operations. This model is for a medium size business in the mattress business in the city of Medellin. The business could reduce the permanency time of a mattress in the system from 4.12 h to 3.7 h and the number of mattresses attended would rise from 102 to 110 units with a confidence level of 95%. This is done via the implementation and analysis of the results of a discrete simulation model of the operations under consideration. The model allowed the mattress company to evaluate different alternatives that not only allowed analysis to improve efficiency, but also to focus on client satisfaction in warehouse management.

KEYWORDS: discrete simulation, warehouse management, picking and dispatch, algorithms.

RESUMEN: En la cadena de suministro y en la logística, la gestión de almacenes y en especial las operaciones de preparación de pedidos y despacho, son determinantes en la eficiencia operacional y en la satisfacción del cliente; por estos motivos, el presente artículo tiene como objetivo desarrollar un modelo de simulación discreta que apoye el análisis y evaluación de alternativas de mejora de estas operaciones en una empresa mediana del sector colchonero de la ciudad de Medellín. A través de la implementación y análisis de los resultados del modelo de simulación discreta de las operaciones en estudio, la empresa podría disminuir el tiempo de permanencia de un colchón en el sistema de 4.12 h a 3.7 h y el número de colchones atendidos aumentaría de 102 a 110 unidades con una confianza estadística del 95%. El modelo permitió que la empresa de colchones evaluara diferentes alternativas que no sólo le permitiera analizar la mejora de su eficiencia, sino también enfocarse a la satisfacción del cliente en la gestión de almacenes.

PALABRAS CLAVE: simulación discreta, gestión de almacenes, preparación de pedidos y despacho, algoritmos.

1. INTRODUCTION

In the last decade, businesses in the mattress industry in the department of Antioquia (Colombia) have needed to improve their efficiency and the efficiency of their processes. They have also needed to improve relationships with providers and their clients, seeking to gain a competitive advantage. In this scenario, the concept of logistics has gained importance in the coordination of processes, as has adequate use of resources and a focus on the satisfaction of client needs. In business logistics, warehouse management has been converted into a critical process given that operations and resources can be planned, implemented, and controlled to respond to client orders. With this comes the importance of adequate design and improvements, to operate in an efficient and effective manner.

The present article aims to develop a discrete simulation model to support the analysis and evaluation of alternative improvements to picking and dispatch operations for a medium size business in the mattress industry in the city of Medellin. This is especially important given that the picking and dispatch operations are important factors in the operational efficiency of storage and therefore of client satisfaction. Furthermore, the model can be adapted by businesses of the same industry. Regarding the audience, this article is aimed at professors, students, researchers, and business people who are interested in learning about or deepening their knowledge of discrete simulation as applied to warehouse management.

The article is divided into two parts. The first part is the theoretic contextualization of warehouse management and discrete simulation. In the second part, the simulation model is developed to support improvements to picking and dispatch operations for the mattress business located in the city of Medellin.

2. THEORETIC CONTEXTUALIZATION

In this chapter, a theoretic review is conducted, based on general concepts such as warehouse management and its relation to logistics. Later, picking and dispatch operations, and discrete simulation are gone into in more depth.

2.1. Warehouse management

According to Frazelle [1] warehouse management is "a set of operations such as the receipt, placement, storage, and picking and dispatch, that serve to store raw material, work in progress or finished product that allow the offset of gaps between demand and production; allowing attention to client orders."Inclusive in warehouse management, information administration, inventory, orders, and coordination with distribution are considered in order to adequately satisfy client needs [2,3].

2.2. Warehouse management operations

For Frazelle and Rojo [4], the most common operations in warehouse management are receipt, placement, storage, picking, and dispatch. For his part, Urzelai [5] indicates that there are administrative activities and assistants that support the planning and execution of the operations described.

The operations of picking and dispatch are described in greater detail below, given that they are directly related to the article's objective. If you require more information on other operations, please look at Frazelle and Rojo [4] and Mauleon [6].

2.2.1. Picking operation

Preparation of orders or *picking* represents between 45 and 75% of the total cost of warehouse management, and is therefore highly important [6,7]. Regarding the definition, Mauleón [6] stated that it consists of "collecting products from the stored position whilst fulfilling the conditions established in the order (type of packaging, special marking, quantities, etc)." Furthermore, Errasti and Bilbao [8] complemented this definition indicating that this operation consists of the recovery of articles from the storage zone in response to the client request.

Adequate management of the picking requires an appropriate selection method, shelves, machinery for handling materials, competent human resources, and information and communication technology (ICT) [6,9].

According to Pau and Navascués [7], picking operation consists of the activities of processing of orders, collecting the products, moving them to the dispatch area, and the verification of orders. Adequate management of the picking requires an appropriate method selection, shelves, machinery for handling materials, competent human resources, and information and communication technology (ICT) [6,9]. Finally, adequate planning, execution, and control of the preparation of the order contribute to the reduction of mistakes and an increase in satisfying client needs [7,10].

2.2.2. Dispatch operation

The dispatch operation is defined by Hadman [11] as: "the verification of quantity, identification of damage to products, revision of invoices and associated documentation, and loading of vehicles." Due to the relation to client satisfaction, this operation is thought of as a critical aspect of exiting logistics, and must be properly planned and controlled. In the design or

improvement of dispatch, the method for the operation and control of machinery to handle materials, staff, ITC, and other factors, need to be chosen [12].

The need to design or improve picking and dispatch operations using different qualitative and quantitative tools is due to their importance in warehouse management and logistics. To aid in decision-making, quantitative tools such as lineal programming, system dynamics, discrete simulation, experiment design, among others are used [13–15].

Of these methods, discrete simulation allows an imitation of warehouse management processes via a computational model with the aim of supporting the evaluation of design or improvement scenarios. In this type of simulation, changes are presented in certain discrete points in time; that is to say, with the start, end, change of order, and machinery to handle materials, used in picking and dispatch operations [16,17].

2.2.3. Discrete simulation as a tool to improve picking and dispatch

Discrete simulation is used as a quantitative tool to carry out the proposed improvements for picking and dispatch operations in the mattress business. Such a tool allows for a representation of activities and resources while considering uncertain conditions, and therefore supports design and improvement decisions [18,19]. Furthermore, this allows experimentation and evaluation of alternatives with a quantitative focus, and without incurring high costs or affecting productivity [20]. On the other hand, simulation can be used to study different alternatives or strategies for picking and dispatch, while evaluating conditions of time and efficiency [21].

Scientific literature has identified several articles that use discrete simulation in warehouse management. For this reason, we present the results below that are related to operations picking, storage, and dispatch (see Table 1). From all reviewed articles (see Table 1), can see that discrete simulation is used to computationally represent warehouse management, and quantitatively support decisions. Furthermore, it should be highlighted that in the articles , very few proposals for its application in picking and dispatch were found, which is considered by the authors as an opportunity to contribute to

research and business application; thereby justifying the development of the current article.

Finally, discrete simulation is a quantitative tool that can be used in picking and dispatch operations to simulate behavior and experiment with better alternatives, without incurring high costs or affecting the normal functioning of warehouse management, aiming to satisfy the client's needs and obtain greater efficiency (see Table.1)

Table 1. Application of discrete simulation in the picking and dispatch

| Takakuwa et al. [22]	Cho and Hwang [23]
Developed a discrete simulation model that supports the design of warehouse management for finished products, including picking and dispatch operations. Furthermore, he made a design proposal for simulation models for non-automatic distribution centers.	Constructed and presented a model for the evaluation of performance of a system for picking in a warehouse with finished products, from which decisions can be made.
Chin, Pontes, and Porto [24]	Potter, Yang, and Lalwani [20]
Proposed a model to evaluate and take decisions on the design of the picking process, supported in a 2^k experimental design. The contribution of this article is to support decision making using technical statistics, which allow the improvement of order picking in the search for efficiency.	Developed a discrete simulation model in Arena® to support decision making and the evaluation of alternative activities. This study aimed to seek better performance of warehouse management for dispatch operations in the metallurgy business industry.

3. CASE STUDY: USE OF DISCRETE SIMULATION AS A TOOL TO SUPPORT ANALYSIS AND IMPROVE OF THE PICKING AND DISPATCH OPERATIONS

Due to the importance of being competitive in Antioquia mattress industry, in the last decade product innovation, operation efficiency, and adequate warehouse management have become critical factors for businesses to be able to properly satisfy the needs of their clients. To improve picking and dispatch operations contribute to an adequate use of resources, inventory administration and relationships with providers and clients.

For these reasons, and with a methodology of improving picking and dispatch operations based on discrete simulation, this report contributes to the development of research as well as applications that promote the use of quantitative methods in warehouse management.

3.1. Methodology to improve picking and dispatch operations

The following stages have been established to analyze and support decision improvement in warehouse management, picking and dispatch operations in the mattress industry using discrete simulation (See Fig.1).
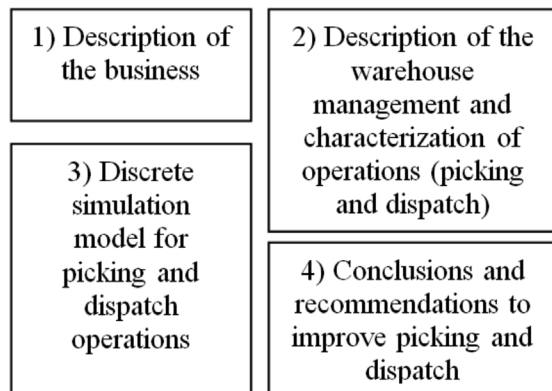
Figure 1. Methodology to improve the preparation of orders and dispatch

Each stage of the methodology is developed below. This methodology is to support decisions for improving picking and dispatch operations in mattress businesses.

3.1.1. Stage 1: Description of the business under study

This is a medium-sized business of the mattress industry located in the city of Medellin. It is dedicated to the manufacture and commercialization of articles for client's rest. Their average sale is 3000 mattresses per month and they cover the national market. The supply chain of this business is made up of a storage processes, production, storage, transport, distribution, and commercialization.

3.1.2. Stage 2: Description of warehouse management for finished product, including picking and dispatch operations

The general points of storage and the characterizations of picking and dispatch operations are described below. Primary information (interviews and direct observation) and secondary information (current documentation and reports on warehouse management) is used.

• General points for storing finished product to be modeled

The general points for storing finished product are:

  • The receipt, placement, storage, picking, and dispatch are planned, executed, and controlled.

  • The storage area is 990 m^2.

  • To move products, a ladder and manual pallet jack will be used.

  • The warehouse staff includes the business administrator, the head of dispatch, and two storage operator assistants.

• Description of the picking operation

  • This starts when an order is made with references and quantities of products that must be collected to meet the client's needs.

  • The *order picking* method is used to recover stored products.

  • Once the order is prepared, the order is marked as collected and is moved to a temporary storage gondola before being dispatched and loaded onto a truck.

- Description of the dispatch operation

  - Starts with the identification and classification of orders in the dispatch gondola.

  - Loading of cargo onto the trucks.

  - Making and delivery of documentation.

  - The dispatch information is registered in a format that states the reference, the quantity of the mattresses, the truck information, and the invoice number.

  - The trucks are sent to the loading zone and drivers start distributing the orders.

  - The company currently has three trucks to perform order distribution.

3.1.3. Stage 3: Discrete simulation model for the picking and dispatch operations

The development of the discrete simulation model for picking and dispatch operations conforms to stages such as: defining the problem, the description of simulation variables, model assumptions, the conceptual model, the computational simulation model, the verification of the model, analysis of the current behavior and performance picking and dispatch operations, and sensitivity analysis. Each stage is developed below.

- *Stating the problem.* When high volumes of orders need to be dispatched, large queues may occur which generate an increase in dispatch times, errors in loading cargo and sending documentation (billing) associated with the order, delays in distribution, and possible client dissatisfaction. These situations lead warehouse management in the mattress industry to reduce their efficiency and the level of client service.

- *Model assumptions.* The assumptions for the simulation are:

  - The picking server (P) assumes that it has an infinite queue, given that the mattresses are found to be available in the inventory.

  - The FIFO method is used in the system, given that the prepared articles (*picking*) are being organized in a sort of queue in order of arrival, to be dispatched later.

- The first orders to be dispatched during the day have been prepared the day before.

- The maximum capacity of each truck is used.

- The capacity of trucks 1 and 2 is double the capacity of truck 3.

- Each order has 3 mattresses, approximately.

- *Definition of simulation variables.* The variables for the simulation model for the preparation of orders and dispatch are presented in Table 2.

Table 2. Exogenous, state, and endogenous variables

ExogenousVariable	
TFIN: Simulation Time	
StateVariables	
• **NCAP:** Clients attended by P	• **NCAC2:** Clients attended by C2
• **NCAC:** Clients attended by C	• **NCAC3:** Clients attended by C3
• **NCAC1:** Clients attended by C1	• **NCCP:** Number of clients queue P
EndogenousVariables	
• **TPLL:** Time of next mattress arrival	• **TC3:** Time to take mattresses to clients in Truck 3
• **TP:** Picking Time	• **TPP:** Time for next departure from P
• **TM1:** Time to load truck 1	
• **TM2:** Time to load truck 2	• **TPM1:** Time for next departure of M1
• **TM3:** Time to load truck 3	• **TPM2:** Time for next departure of M2
• **TC1:** Time to take mattresses to clients in Truck 1	• **TPM3:** Time for next departure ofM3
• **TC2:** Time to take mattresses to clients in Truck 2	• **TPC1:** Time for next departure of C1
	• **TPC2:** Time for next departure of C2
	• **TPC3:** Time for next departure ofC3

- *Collection of data:* To collect data, a sample was taken and the time was recorded with a

chronometer for the preparation operation variables for orders and dispatch.

Two samples were taken, one on Saturday April 4, 2009, between 7:30 a.m. and 12:00 p.m., and the other on Monday April 6, 2009, between 7 a.m. and 1 p.m. Fifty-four pieces of data were obtained for the preparation time of orders TP. Fifteen, 16, and 25 pieces of data were obtained for loading times to different trucks TM1, TM2, and TM3, respectively. To validate these sample sizes, the following formula was used:

$$n = \left(\frac{\sigma\, Z_{1-\frac{\alpha}{2}}}{d} \right)^2$$

The sample size is vital to guarantee the validity of the simulation model.

Where $Z_{\alpha/2}$ is the value in Table Z for a 0.05 alpha (1.96), d is the standard error of maximum predetermined error (1 s), and σ is the standard deviation. Subsequently, an analysis of averages and standard deviation was carried out which showed that the selected sample size for the variables was sufficient and valid. The detailed results of this analysis are not shown due to the scope of the article.

Statistical tests to determine the probability distribution of the variables are the following: A goodness-of-fit statistical test was used with the support of statistical software Statgraphics® 5.1 to determine the probability distribution of the following variables: time of next mattress arrival (TPLL), time to load cargo to Truck 1 (TM1), Truck 2 (TM2), Truck 3 (TM3), and picking time (TP).

To accept or reject the hypothesis that the variable follows a probability distribution, Kolmogorov-Smirnov tests were run using p value of 0.05.

Once the goodness-of-fit statistical analysis is carried out for the variables, the service times for the TP picking can be concluded. They are adjusted to a lognormal distribution (value p>0.10), while the other service times are adjusted to normal distributions (p>0.05). Given this, it can be concluded that the data is appropriate to be used within the simulation model for the preparation of orders and dispatch.

- *Computational simulation model.* The objective of this model is the preparation operations for orders

and dispatch in the simulation software SIMUL 8. The conceptual model is represented with the program functionalities, where servers are used to symbolize operations, queues for the expected entities, and some routers to simulate classification in the gondolas and the loading of the trucks. Additionally, the entrance and exit from the system is represented. A screenshot of the designed model from the simulation package SIMUL 8 is shown in Fig. 2.
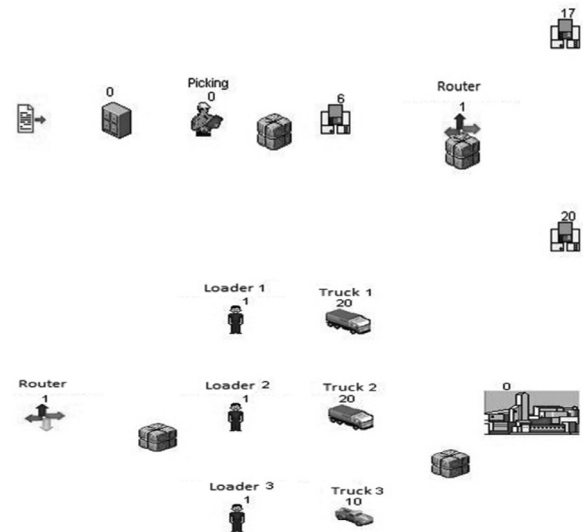
Figure 2. Computational model of preparation operations for orders and dispatch

From the computation model in the simulation software (Fig.2), we can see how the arrangement of orders entering the system (entry), are transformed by the *picking* server for products which are later classified in the gondolas and then loaded to the truck to attend to client orders (exit).

- *Model Verification.* Once the model has been developed, the model compares the results with those of the current preparation operations and dispatch of the company. Verification takes place via interviews with those responsible for warehouse management, and a comparison with the characteristics of the preparation operations for orders and dispatch is carried out.

- *Analysis of behavior and current performance of operations of picking and dispatch.* We select the

duration of each run of the simulation for one day, with the equivalent system functioning of 28800 seconds (8 h). The times between arrivals and service are expressed in seconds.

The average time that a mattress is in the warehouse is 14823.41 seconds (4.12 h) and approximately 102.00 mattresses were prepared and dispatched.

Ninety-five percent of trips were between 96.45 and 107.55 mattresses, which indicates that the deviation in the number of mattresses attended to is reasonable when compared to the current dispatch of the business.

In general, the trucks show high levels of use in relation to the available time in the warehouse. Specifically, truck 3 is used 95.99% of the time, which demonstrates efficient use.

The service time of the loaders seems to be affected by the service time of the trucks, meaning that their leisure time is high, equaling the leisure time in order preparation.

Regarding the gondolas, it can be noted that, on average only half of their maximum capacity is used, while the queues to locate mattresses in these are low for the available storage capacity.

- *Sensitivity analysis.* The impact on service time for operations of picking and dispatch is analyzed due to the change of time between arrivals. This type of analysis allows for identification of opportunities to improve. The sensitivity analysis that is planned and implemented consists of increasing the service average for trucks by 10% and decreasing the time between arrivals by the same percentage.

Increasing the service average by 10%, the number of mattresses attended went from an average of 102 to 104; that is to say, an increase of less than 2% at the end of the day. The trucks and gondolas registered a maximum usage of the available capacity. The average time for mattresses in the system was 14,964 s (4.16 h) compared to 14,823.41 s (4.12 h) on the current state, representing an increase of less than 1%. Therefore, the increases seen are not very significant, given that they generate a very small variation in results.

Reducing the times between arrivals by 10%, the number of mattresses attended went from 102 to 94 on average; that is to say, a decrease of 7.8% at the

end of the day. High usage of the truck and gondola capacity was noted. The average time for mattresses in the system was 16,286 s (4.52 h) compared with 14,823.41 s (4.12 h) in the current state, representing an 8.9% increase. A 10% increase in the service time of trucks does not generate a increase greater than 10%, which means that these increases are not significant. Furthermore, it can be noted that the model responds well to changes made in the average time between arrivals and service. This means that it is robust in supporting analysis decision and improvements in picking and dispatch.

3.1.4. Stage 4. Conclusions and results of the improvement proposal

Efficiency in picking and dispatch can be based on reducing the attention time given to trucks, given that this can be determined by factors outside the system such as distance between the factory and the destination, and road congestion, etc. This is why the acquisition of a small truck and an additional loader as an alternative to improve performance are proposed. With these, we can reduce service times and improve the agility of preparation operations for orders and dispatch.

A new simulation model for the preparation operation of orders and dispatch is shown in Fig. 3.
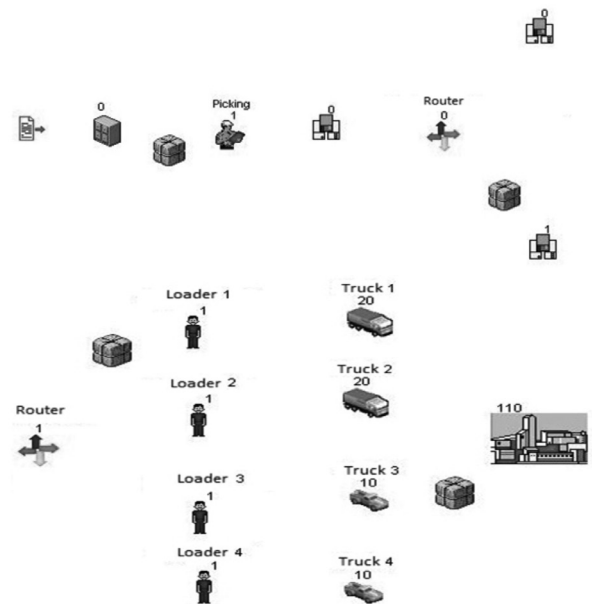
Figure3. Alternative simulation model for improvement

In the simulation model with the best proposal, the average time that a mattress is in the system passed from 14,823.41 s (4.12 h) to 13,467.52 s (3.7 h), and the number of mattresses attended rose from 102 to 110 in an interval between 92.44 and 127.256 at a 95% confidence level. The proposed solution allows for the establishment of an improvement to picking and dispatch, which may potentially positively impact the satisfaction of client's needs and efficiency in the finished products warehouse.

4. CONCLUSIONS

- Management of warehouses is a logistical process that impacts the efficiency of operations and customer satisfaction, and hence the importance of adequate design and continual improvement.

- Picking and dispatch are two operations of warehouse management that allow for one to fulfill client's requirements so that orders are delivered according to the demanded references, quantities, and qualities. For design and improvement, different quantitative tools were identified such as: investigation of operations, system dynamism, and discrete simulation, among others.

- From the results presented in the article, it can be noted that the simulation improves the capacity for picking and dispatch, due to our allowing for computational analysis and the evaluation of alternative improvements.

- The company could improve the permanency time of the mattress in the system from 4.12 h to 3.7 h, and the number of mattresses attended to could rise from 102 to 110 units with a confidence level of 95%. This can be done via the implementation and analysis of results from the discrete simulation model on current operations. Furthermore, the importance of a robust simulation model for operations of picking and dispatch was demonstrated. This should allow for the evaluation of improvement alternatives.

As a future project, the capacity for analysis and improvement of picking and dispatch could be increased. This could be done by using design experiments that allow for the establishing of current operation factor levels which contribute to efficiency and client service.

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