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RETRIEVING PROCESS ANALYSIS IN A PARTS DISTRIBUTION CENTER: A CASE STUDY OF MANUAL TROLLEY FLEET SUBSTITUTION

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ABSTRACT

This paper summarizes the results of a simulation study for a Parts Distribution Center (PDC), which contains approximately 30000 items, modeling its retrieving process in simulation software ARENA® 5.0. The collection of the parts is carried out manually by five employees, being supported by manual trolleys. The current problem of PDC is to decide if that manual trolley fleet should be substituted, since the existent ones are unbalanced in comparison with the same market competitors, considering the retrieving process total time effectiveness. The Input data to the model about the fleet is the decision factor. Those data are statistically organized in two levels, according to the design of experiments 2^k and the results of each test are obtained from two replications. With these results, managers will be able to evaluate possibilities, compare to the current situation and conclude how viable it is to change the fleet.

1 INTRODUCTION

The competition among companies for market share has been forcing several areas of the companies to search for solutions to reduce their costs. In fact, companies are dynamic and constantly suffer internal modifications to attend competition.

In a Supply Chain, there are several activities which are responsible for receiving orders and dispatching products to the customers. Those activities are carried out in the warehousing systems (Petersen and Aase 2003). As part of a company, these systems also suffer competitiveness for customer's support. Therefore, constant improvement is fundamental in those systems (Gunasekaran et al. 1999).

According to Coyle et al. (1996), the retrieving process cost demands around 50 to 70% of the total warehousing process cost. Computational tools have been applied successfully to warehousing processes aiming at supporting managers on their decisions. Vaughan and Petersen (1999) comment that computational software are able to convert picking lists into collecting lists (CL), and they are also able to organize CL in a sequence of employees route. With these information, managers can improve the management of the company.

In fact, those software are efficient, but the information can be obtained from them just when the company receives an order. Managers are not able to predict or prepared for unexpected situations, such as the way in which the number of employees can affect the time order consolidation, among others.

There are also other kinds of computational software, called simulation tools. Kelton et al. (1998) affirm the importance of creating and executing the simulation models to provide information before taking any kind of mistaken decision that can result in excessive costs. Some examples of applications of such simulation models are presented in several papers, such as shown in (Alfieri and Brandimarti 1997). Both authors presented the importance of using simulation models in supply chains, and so on.

This paper presents a case study of the Parts Distribution Center (PDC), located in São Paulo (Brazil). The current problem of the retrieving process is to decide if the manual trolley fleet should be altered, since the existent ones are unbalanced in terms of retrieving process total time. However, it implies a considerable short term investment. The motivation for the use of simulation in this paper is that managers are intimidated on taking decisions due to the fact that they are not absolutely sure whether the changes will result any short term benefits.

Therefore, this paper aims at using simulation tools, including statistic methods, to analyze the effectiveness obtained with the changes of the manual trolley factor on retrieving time.

2 BIBLIOGRAPHY REVIEW

In published warehousing papers, cases studies focused on certain factors of the process, aiming at route minimization, are commonly found. This also means cost reduction due to the routing time minimization.

Some techniques related to the factors, such as batching orders in Gademann et al. (2001), Gibson and Sharp (1992) and Rosenwein (1996), routing policies for collecting items in Hall (1993), Lin and Lu (1999), Goetschalckx and Ratliff (1988) and Caron et al. (1998), problems in allocating items in Malmborg and Al Tassan (2000), Kallina and Lynn (1976) and Liu (1999) and also related to the shelves layout described in Roodbergen and De koster (2001a) and Roodbergen and De koster (2001b) aim at employees routing reduction. Those papers rarely mention two or more factors acting simultaneously, due to complexity. Moreover, managers have difficulties on applying the proposed methods to obtain solutions which may permit quick decisions.

The computer simulation presents the construction of the models which represent real systems. Banks et al. (1984) comment that simulation tools permit internal interactions of the models. Carrying out those interactions makes the whole system possible to be understood. In simulation, the input data organization is important to visualize and comprehend what is intended to be obtained with the model. The data organization is one of the steps of the study and it is named design of experiments.

Simulation seems to present itself as one of the most important tools to be explored in papers due to its capacity of dealing with several factors simultaneously (Marín et al. 1998).

3 PDC DESCRIPTION

3.1 Layout and Dimensions

The construction machinery parts company, located in Piracicaba City, has one PDC with layout and measures similar to the one illustrated in Figure 1.

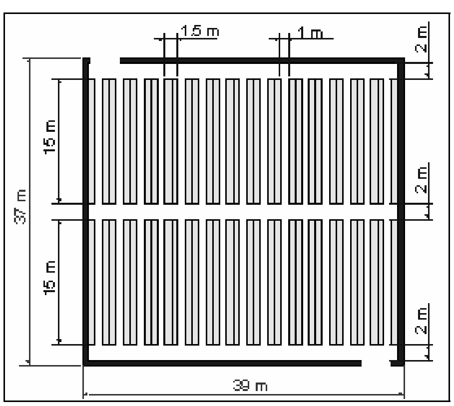

Figure 1: Layout and Measures of the PDC

On Figure 1, note that there are three horizontal aisles, also called cross-aisles. There are also 15 vertical aisles, and each one is composed by two shelves totalizing 30 shelves. The vertical aisle of each shelf is called subaisle. The measures of the shelves (length x width), cross-aisle and the width of the subaisle are (15 x 1.5m), 2m and 1m, respectively.

3.2 Sections (Picking areas) and Subsections

Each shelf is divided into ten picking areas (sections), in which employees go through, from one picking area to the other, according to the items described in the picking list. There are drawers in each section, where parts are stored. Each section has 1.5m of length owing to the 15m of subaisle length. It is also important to notice that employees can collect parts in both sides of the same shelf.

3.3 ABC Classification of Items in the Shelves

There are 30055 items distributed in 30 shelves, based on the ABC criteria. Table 1 contains current item's information by each classification. Slack et al. (1999) affirm that, in a PDC, some parts are much more required than others. They are classified as type A (more important) until type C (less important). In addition to this, Petersen (1999) comments that more important items must be stored closer to the gate.

There are two gates. In the upper side of PDC, see Figure 1, there is a gate where employees can reach the packing area (where products are unpacked). In the lower side of PDC, employees can reach the receiving area (where products arrive to PDC).

Table 1: Current Number of Items

	Information of Items	
Item Type	**Number of Items**	**Percentage**
A	1522	5.06%
B	3120	10.38%
C	25413	84.56%
Total	**30055**	100.00%

It is important to emphasize that the number of items is different from the parts quantity. Therefore, a customer may require two items with the quantity of 20 and 50 parts each one.

4 ACTIVITIES SCHEDULING

During the morning shift, the computational system of the PDC, located in the packing area, receives orders. Firstly, the system identifies the code and quantity of the items and consecutively creates a picking list.

As soon as new orders arrive to the system, new codes are added to the picking list. The codes are also automatically rearranged in crescent order.

The item's codes vary from one to 30055. The total number of items has a high variation, spanning from 1000 until 1850 items per day.

In the evening shift (maximum period of four hours of work), the picking list is sequentially separated by the system in small ones, called collecting lists (CL), distributed to five employees. Each employee receives some CL and then starts routing (from one section to the other) in aisles for the collection of the parts.

Several manual trolleys are available in the packing area to support employees in the collecting process. The route starts from the packing area to the shelves and when the capacity of trolleys is reached, the employee returns to the same area to unload the parts. All of the collected parts are dispatched to the customers in the afternoon shift.

5 CURRENT PROBLEM

The company is capable of collecting parts in approximately 3:30h. This fact is considered efficient since the maximum period is four hours (evening). Even increasing the collecting efficiency, the company can only dispatch parts in the afternoon. The issue consists in that competitors can collect parts in less than 3:30h. So, it is important to search for other ways to minimize costs.

Managers are analyzing the possibilities of an alteration of manual trolley fleet by another. This approach aims at increasing effectiveness on the retrieving process total time, and deciding or not to change the fleet technology. Basically, the main trolley characteristics are velocity and weight capacity.

The company previews the possibility of using electric vehicles, such as AVG (Automated Vehicle Guided), but the internal policy concerning insurance issues, has established that no vehicle can exceed 1.5m/s. In relation to the vehicle maximum load, there is the constraint from the supplier that it can only provide vehicles with 200kg of maximum capacity.

6 MODELING IN SIMULATION SOFTWARE ARENA® 5.0

The simulation software ARENA® 5.0 is one of the software available in the laboratory of discrete simulation, located at Nucleous of Advanced Manufacturing (University of São Paulo/Brazil). Shih (2005) applied successfully this software to model the same PDC on his dissertation. This work is, in summary, a extension of this dissertation.

6.1 Homogeneous Distribution of Items in the Shelves

Each subsection is composed of 25 drawers and there are two areas to store two types of parts in each drawer. Therefore, 50 types of parts can be found in each subsection.

The number of items was rounded to permit equal distribution in the shelves, as illustrated on Table 2.

Table 2: Number of Items Rounded

Adopted	
Number of Items	**Percentage**
2000	6.67%
4000	13.33%
24000	80.00%
30000	100.00%

With the information exposed in Section 6.1, it is possible to store all of 30000 items. The items distribution, according to its classification, is shown in Figure 2.

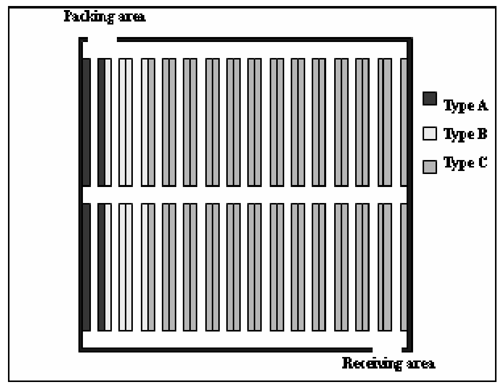

Figure 2: Shelves Distribution according to ABC Criteria

6.2 Composition of the Retrieving Process Total Time

According to Frazelle (1989), the time of retrieving process is composed basically by four components:

Identification of the section – This component is the time spent by the employee to identify the picking area. This time, for item, is a triangular distribution varying from 1.5, 2.5 and 4.0s.

Identification of the part – Depending on the shelves' layout, it is important for employees to know in which side of the subaisle and in which drawer the part is located. This time, given in seconds, is also a triangular distribution varying among 1.0, 1.5 and 3.0s.

Collecting time – It is the time spent by the employees to move their hands from the shelf to the trolley. Maynard (1970) affirms that the mass of the item can influence the collecting time, i. e. more weight implies more difficulty for employees and, consequently, the collecting time will be increased. This issue can be defined numerically by one factor, named Factor_M, as shown in expression (1).

$$Factor\_M = 0.5 + \frac{10 * Mass\_of\_Part\,[kg]}{20} \quad (1)$$

The time spent to move their hands (holding no parts) is a triangular distribution varying from 1.0, 3.0 and 4.0s. Therefore, the collecting time is this time multiplied by factor_M and multiplied by the quantity of collected parts.

Routing time – Time spent to route in aisles and alsoconsidered one of the components of the process time. As collecting time, the trolley velocity also suffers weight influence (Maynard 1970). As the manual trolley weight is increased, its velocity is reduced. The manual trolley's velocity (unloaded) is given by a triangular distribution, in meters per second, varying from 0.75, 1.00 and 1.20. therefore, the trolley velocity in the current situation is factor_V multiplied by the unloaded trolley velocity. The factor_V can be obtained by the equation (2).

$$Factor\_V = 0.75 + 0.25\left(\frac{120 - Weight\,[kg]}{120}\right) \quad (2)$$

6.3 Order Division

Table 3 contains average item's information of daily orders. These information were collected during a three-week period.

The distribution function will be used in each item type in the simulation model as shown in numbers (3) to (6) since the simulation software ARENA® 5.0 works with statistical distributions.

Table 3: Average Distribution, in Percentage, of Daily Order Items

Item Type	Percentage of the Order
A	From 30 to 40%
B	From 20 to 30%
C	From 30 to 50%

Number of Items (NI) = Integer(Triangular Distribution (1000, 1700, 1850)) (3)

A Items =
Integer (Uniform Distribution (0.3, 0.4)*NI) (4)

B Items =
Integer (Uniform Distribution (0.2, 0.3)*NI) (5)

C Items = NI – A Items - B Items (6)

Law and Kelton (1991) affirm that triangular distributions can be used in case of little available data. A sample less than 30 (i. e., three-week period), in term of statistics, can not evaluate the population adequately.

For items A, B and C, it is also necessary to choose one distribution function. Considering the item A, for example, the percentage varies from 30 to 40%. The uniform distribution is chosen because the use of other kind of distribution function would cause the model to provide a high concentrated value of percentage. Different from the real situation, the percentage of each item type is distributed equally.

With those information, it is possible to know which employees should run in specific parts of the shelves, since the collecting list is obtained from the division of percentage items distribution by the number of employees. In other words, it is similar to the employees distribution by the area A, B and C of PDC.

6.4 Parts Quantity

Based on the same historical data of picking lists it is possible to notice that heavier parts (about 20kg) are not required in a high quantity. On the other hand, lighter parts can reach a quantity of 50. As commented before, the software ARENA® 5.0 works with distribution function, so the next step is to choose the best distribution for each part`s quantities. Due to this fact, four distributions are adopted to model these variations, according to the range of the mass. The mass of each part is shown in Table 4, varying from 0.1 to 20kg. The representation AINT, in ARENA, means integer.

Considering the 2nd line of the Table 4, for instance, the uniform distribution (UNIF) can represent adequately, because no matter which mass is chosen inside that range, the probability of a part to be the quantity 1, 2 until 8 is the same. The same idea can be applied to the other ranges. On the other hand, the range parts "until 1kg" presents a particular behavior. It can reach a quantity of 50. It is necessary to choose a distribution that can provide different concentration in a higher quantity. For this reason, the exponential distribution is preferred.

Table 4: Quantity of Parts Distribution in Relation to Mass

Mass of Each Part	Parts Quantity of Item
Until 1kg	AINT(EXPO(7))+1
From 1 to 5kg	AINT(UNIF(1;8))
From 5 to 10kg	AINT(UNIF(1;4))
From 10 to 20kg	AINT(UNIF(1;3))

6.5 Data Acquisition from the Model and Factorial Design 2^K

Due to the importance of analyzing the impact of two control factors on the retrieving process total time, ranges of values of velocity until 1.5m/s and maximum capacity of 200kg on vehicle are chosen. The results of those times, also including their level values, may be compared to current data situation if whether the process has improved statistically.

The importance of this paper is to emphasize that the main goal is not search for an "optimum" vehicle, since demand is extremely unstable and, as a consequence, the results would not be bruising to the reality. For these reasons, the impact of combining factor levels in the total time of the process is evaluated and, therefore, only two levels are chosen.

Factor of control x_1: Vehicle velocity: Levels 1.0 and 1.5m/s, (-1) and (+1);

Factor of control x_2: Load Capacity: Levels 150 and 200kg, (-1) and (+1).

Shih et al. (2005) comment that the retrieving process will be finished if all employees arrive in the packing area, where parts will be dispatched to customers with their collected items. Table 5 will register the time of the last employee. The time is measured in seconds.

Those results are obtained from two replications in each proposed alternative, considering the fact that equation (2) with the value 120 (or 120kg) will be changed according to the acceptable maximum weight of the vehicle.

Table 5: Factorial Design Experiments 2^2, with the Results of the Simulation Model (in seconds)

Proposal	**Main Effects**			**Average**
Alternatives (Tests)	**I**	$\mathbf{X_1}$	$\mathbf{X_2}$	$\mathbf{Y_{iaverage}}$
1	1	-1	-1	11388
2	1	1	-1	10410
3	1	-1	1	11023
4	1	1	1	10420

6.6 Hypothesis Testing

6.6.1 Student Statistic t

It is desired to test if the effects are significantly different from zero, so the hypothesis test is:

$$H_o: \mu_E=0$$
$$H_1: \mu_E\neq 0$$

I.e., the null hypothesis (H_o) is that the effect (average) is zero, opposing to the alternative hypothesis (H_1), in which the effect is different from zero. The Statistic "Student t" is used in the test, according to expression (7).

$$t=\frac{E_i-\mu_E}{S_E}=\frac{E_i}{S_E} \quad (7)$$

Where:
E_i represents the main or interaction effects;
S_E represents the standard deviation.

6.6.2 Main Effects and Interaction Calculus

Using the equations of Montgomery (1991) to calculate the main effects E_1, E_2 and the interaction E_{12}, with k as the number of control factors, it results in:
Value of E_1:

$$\frac{(-1)*(11388)+(+1)*(10410)+(-1)*(11023)+(+1)*(10420)}{\frac{2^k}{2}}$$

$= -790.5$

$$E_2=\frac{-355}{2}=-177.5\ ;\ E_{12}=\frac{375}{2}=187.5$$

The estimative of standard deviation, S_E, with $[2^k(n-1)]$ degrees of freedom can be obtained using expression (8).

$$S_E^2=\frac{4*S_p^2}{n*m} \quad (8)$$

Where:
S^2_p represents the common variance;
n represents the number of replications;
m is equal to 2^k.

As all the tests' combinations are repeated the same number of times, the common unknown variance, S^2_p, is obtained by the expression (9).

$$S^2_p=\frac{S_1^2+S_2^2+S_3^2+...+S_m^2}{m} \quad (9)$$

There are 4 values of sample variance and, therefore, the value of m is 4. To obtain values from S^2_2 to S^2_4, equations similar to S^2_1 might be used.

$$S_1^2=\frac{(y_{11}-y_{1average})^2+(y_{12}-y_{1average})^2}{2-1}=(12376-11388)^2+(10400-11388)^2=1952288$$

$$S_2^2=861985\ ;\ S_3^2=896461\ ;\ S_4^2=191581$$

Therefore, the value of common variance is:

$$S^2_p=\frac{3902315}{16}=243894.68$$

The value of n is two because of the two replications, so the value of the standard error, S^2_E, will be 121947.34 or S_E = 349.21. The result of the statistic "Student t" is:

$$t=\frac{Ei}{349.21}$$

Table 6 contains data of effects´ estimates with their respective values of t.

Table 6: Statistic t Associated with its Effects

Effect	Effect Estimate	Value of Statistic t
E_1	-790.5	-2.26
E_2	-177.5	-0.51
E_{12}	187.5	0.54

6.6.3 Comparison of t from the Effects with the Statistic $t_{\alpha/2,v}$

The number of degrees of freedom is 2^2*(2-1) = 4. For α=0.05 (5% chance to commit the type I error), it results in:

$$t_{\alpha/2,v}= 2.776$$

Therefore, comparing the statistic t of the effects with $t_{0.05/2,4}$, all other effects have a t value associated in the interval [- $t_{0.05/2,4}$; $t_{0.05/2,4}$] where the Ho hypothesis is accepted. It means that the impact from the alternation of each control factor level is not significant in the retrieving process total time. Finally, the manager can choose any of the proposed alternatives. However, it is also important to evaluate if the chosen alternative is better than the current situation.

6.6.4 Comparison to the Real Situation and Comments

Table 7 presents the data of the real situation and the proposed alternatives to be compared. The difference of total time retrieving process (in minutes) of alternatives, related to the current situation, is presented in the last line. Moreover, it is possible to visualize the impact of level combination in the retrieving process total time.

It is important that the retrieving process total time be the least possible and in accordance with the data presented in Table 7, all alternatives permit minimizing the total time of the process related to the current situation. The proposed alternative 2 presents more reduction of time, even if it is not so significant, and, therefore, it would be the first option for managers.

Remaining the velocity in 1.0m/s and increasing the load capacity from 150kg to 200kg, causes a reduction of 6.08min of the total time. This reduction occur due to the fact that the increase of load on the vehicle can decrease the number of used electrical vehicles, even increasing the factor_V, Now remaining the velocity in 1.5m/s, the load increase makes the total time increase in only 0.17min or approximately 10s.

The alteration of manual trolley of variable velocity by the electrical one can be one of the alternatives, because it may result in 42.8min of total time reduction. However, it also needs very high short term investments to acquire new vehicles and battery chargers, maintenance (if it is not hired from another company) and manipulation training.

Table 7: Data Comparison: Current x Alternatives Situations

		Alternatives (proposals)			
	Current Situation	1	2	3	4
Velocity (m/s)	[Triangular (0.75, 1.00, 1.20)] * Factor_V	1.0	1.5	1.0	1.5
Trolley Capacity (kg)	120	150	150	200	200
Process Total Time (s)	12978	11388	10410	11023	10420
Difference (min.)	0	-26.5	-42.8	-32.58	-42.63

7 CONCLUSION

It is important to use simulation and statistic tools to evaluate and compare situations in manufacturing systems, especially in the PDC. This way, managers can visualize, from the information provided by the model, how the real system behavior will be avoiding taking any kind of mistaken decision.

In general, increasing the load of the vehicle may not reduce expressively the retrieving total time of the process. The reduction of the number of travels is neutralized by the weight factor. It is also possible to conclude that the main impact on the total time comes from the vehicle velocity, but it is not so significant.

Simulation tools are not used to get solutions, such as search for an “optimum” vehicle, but to provide information for managers as a support for decisions in dynamic systems. The simulation model permits to show hints, aims at improving the companies performance, but the real decision depends on the internal policy of the company, to keep or not the current manual trolley fleet.

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