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SIMULATION AND EXPERIMENTAL DESIGN APPLIED TO SIZING SUPERMARKET CASHIERS IN COLOMBIA

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ABSTRACT

A framework for Colombian supermarkets challenges in order to find an adequate number of cashiers and baggers was developed, translated to a simulation model using Promodel® and proved through an experiment varying register item time, number of cashiers and number of baggers for eight real Colombian supermarkets. The framework proved to be successful in finding a cashier-bagger combination for average waiting and system times, but not powerful enough for service promises involving all of the most part of the clients due to variability of maximum times. An interaction among cashiers and baggers combination was found that makes valuable to increase the number of baggers only for some specific number of cashiers working.

1 INTRODUCTION

Finding an adequate number of cashiers for a supermarket could be a hard-to-solve problem for a retailer involved in this business. As Dick Larson stated, (Parker 2003) , "In supermarkets, the real state is too valuable. If anyone can solve the supermarket queuing problem- the way banks and airlines have done- that person will become rich and famous".

Although the great efforts supermarket chains probably have done, there are few public literature available addressing that specific problem. Melachrinodius y Olafsson (Melachrinodius and Olafsson 1992) proposed a cashier scheduling taking into consideration only hourly labor demand constraints and availability of labor constraints for each day of the week, in order to minimize the number of cashiers. Recently, (Melachrinodius and Min 2008) that model was improved adding into consideration order sizes and customers check-out station selection method, fixing an acceptable level of customer service to be met, and refining the objective function. Other attempts to model and simulate services have addressed different problems, such as banks and call centers (Saltzman and Mehrotra 2001); (Deutsch and Mabert 1980), but didn´t attack the specific supermarket problem with their particular difficulties.

The research objective was to create a general framework for Colombian supermarkets in order to face the decision about the minimum number of cashiers and baggers needed given a service level, put the model in a simulation environment and prove the effect of the main factors defined and their second level interactions through experimental design based in real data.

The rest of the paper is ordered as follows: The second section shows the challenges and specific factors to be taken into account in the supermarket environment and in the Colombian context; the third part explains the data collection process and explains the experimental design performed; the fourth heading discuss the results obtained; and the fifth part has the conclusions, remarks and prospective of the research work.

2 THE MODEL

After reviewing the literature available and interviewing three cashiers supervisors in different supermarket chains, three factors were chosen to be simulated: day-of-the-month scenario, supermarket size and item register time. Two supermarket supervisor decisions were evaluated: number of cashiers and number of baggers. In addition, a new cashier selection method (by the customer) was developed. All the supermarkets have regular cashiers and a fast cash for customers who has less than eleven items to pay. The service promise was to serve 98% of the customers in less than 7 minutes.

2.1 Cashier selection method

A customer doesn´t select a line in a supermarket at random. For instance, researchers have found that the appearance of the line does matter in customer perception (Hornik 1984) Usually, a customer evaluates the queue length in his decision. But in a supermarket, not only the

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queue length counts: it´s important how many items people in the line have, also. In order to get a better simulation, a weighted decision index was created. 60% of the index is based in the queue length and 40% in the total amount of items on line. The customer chooses the line with the lowest index among the available cashiers. If the customer has less than eleven items to pay, he tries to get the fast cash; but if the fast cash is occupied, he evaluates the weighted index and makes a decision in consequence. This way, we have reached a more realistic way to give customers out among lines.

Customers doesn´t join the line (balking behavior) if its length exceeds a fixed number established for each supermarket size (see 2.3)

2.2 Day-of-the-month scenario

In Colombian context, there are four different kind of days that configure different scenarios of demand behavior, including variable number of items bought per client. Those are: regular working days, Saturdays, holidays and bi-weekly payment days. Not only averages are different, but probability densities are. Saturdays are the most demanded days, followed by bi-weekly payments; holidays are less demanded but the open hours are shorter; regular working days are in the last place.

2.3 Supermarket size

Different supermarket sizes- referring to the real state floor surface and the number of cashiers available- leads to different amounts of customers. The simulation evaluates eight different supermarket sizes, ranging from five to forty cashiers available, and from 1210 m^2 to 9696 m^2.

2.4 Item register time method

As methods of item registration can vary, it´s important to taking them in account. Two different item register time methods were evaluated: a fast register time method, and a slow register time method. It´s important to notice that in the Colombian context there are not self-services cashiers that could lead to a different and more variable item register time.

2.5 Cashiers and baggers

The number of cashiers was referred to the supermarket size, and the number of baggers was embedded in the number of cashiers. Number of cashiers was set as a percentage of available capacity ranging from 20% to 100% in steps of 20%. Number of baggers was set as a percentage of the number of cashiers working, being 50%, 75% or 100% of the cashiers in operation. Baggers are assigned at the cashier with a fixed rule.

In the Colombian context, if there´s not bagger, the cashier must pack the items for the customer after registering. When the bagger is available, cashier and bagger work simultaneously, so registering and packing processes finish at the same time . As long as cashiers are also trained to pack, there are not difference in the time of packing distribution between cashier and bagger. Due to Colombian law regulations, cashiers and baggers can´t be paid per hour and are scheduled for a six hours shift . Supermarkets are open twelve hours a day, except on holidays when they are open for 9 hours with no shift.

2.6 Ways of payment

There are four different ways of payment: cash, debit card, credit card and others(checks and vouchers). Proportions of use are established according to day-of-the-month scenario and supermarket size. Those proportions are specific for Colombian supermarket operations context, where cash is usually preferred. Each way of payment generate its own time of service added to the total service time.

3 COLLECTING THE DATA AND ANALYZING THE INPUT

3.1 Sample facts

Data was collected from seven supermarkets which size was according to defined in 2.3. The sample was collected during 69 consecutive calendar days which include all kind of day-of-the-month scenarios. For each supermarket size, number of arrivals, number of registered items and ways of payment proportions per hour were collected during those days. After that, 130 transactions for each way of payment were filmed in order to estimate way-of-payment time distributions and a overall bagging time average per item.

Additionally, this sample of transactions allowed to establish item register time distributions (final sample= 1340 items), number-of-items per client distribution and percentage of items that had to be registered manually because its bar code couldn´t be read by the scanner. (25%). Filming was intended to avoid the effect of being watched in cashiers and baggers and to allow a better accuracy in measures.

3.2 Experimental design

Each combination of supermarket size and day-of-the-month was treated as a different scenario when modeled. Inside each scenario, a three fixed full factorial design was used (Kenett and Zacks 2000) .The factors were item register time (two levels), number of cashiers as a percentage of the available capacity, (five levels), and number of packers as a percentage of the number of cashiers (three levels), resulting in a 2x3x5 design for each of the 8x4 scenarios. For each of the treatments, 100 days of operation were simulated. These number of runs was set based on the proposal of Kuehl for two factors, with 95% of power for a difference of 0.8 minutes among treatments and α=1%. (Kuehl 2001). The experiment was done using Promodel®.

4 RESULTS AND DISCUSSION

Table 1 shows the percentage distribution of arrivals during the day for the biggest supermarket analyzed in each scenario, which fed the Arrival cycles feature in Promodel®.

Table 1: Percentage distributions of arrivals in the biggest supermarket

Hour	Saturday	Bi-weekly	Regular	Holiday
8-9	4.2%	2.4%	3.0%	N.A.
9-10	6.7%	6.1%	7.3%	5.3%
10-11	10.3%	8.2%	9.8%	12.6%
11-12	9.0%	8.8%	8.6%	13.5%
12-13	8.3%	8.5%	7.1%	15.2%
13-14	8.7%	8.3%	6.2%	14.2%
14-15	9.8%	8.8%	7.9%	11.7%
15-16	10.5%	10.4%	10.2%	10.9%
16-17	11.1%	10.9%	11.1%	11.1%
17-18	10.5%	12.2%	12.0%	5.4%
18-19	9.9%	11.0%	12.3%	N.A.
19-20	1.0%	4.4%	4.4%	N.A.
TOTAL	100.0%	100.0%	100.0%	100.0%

As can be seen in Table 1, afternoon hours have a higher rate of customers than morning hours, except on holidays, which demand peak is around noon . That can suggest a more flexible schedule of shift in order to cover that demand.

Table 2 shows ways of payment proportions for the biggest supermarket. Cash is preferred in about 80% of the cases, a remarkable difference with more industrialized countries.

Table 2: Ways of payment proportions in the biggest supermarket

Way of Payment	Saturday	Bi-weekly	Regular	Holiday
Cash	79.7%	78.0%	86.4%	81.1%
Debit card	5.4%	6.1%	3.3%	7.5%
Credit card	4.5%	12.2%	2.7%	6.0%
Others	10.4%	9.8%	7.6%	5.4%

Table 3 shows way-of-payment time best-fitting distributions founded for each scenario. Cash is not only the preferred way of payment, but the fastest payment processed, probably due to a specialization of cashiers in the most demanded way of payment. Credit card Colombian regulations probably force this payment to be the lowest. Notice that three of the distributions are triangular, having a more probable time and two extreme values while cash density seems to follow a poison process. Item register times were 0.045 minutes(slow) and 0.151 minutes (fast).

Table 3: Way-of-payment time best-fitting distribution. Parameters are in minutes.

Cash	Exp (0.44)
Debit card	Triang (1.11; 1.63; 3.44)
Credit card	Triang (1.28; 1.76; 1.93)
Others	Triang (0.7; 1.25; 1.33)

Table 4 shows number-of-items per client best-fitting distribution. Although several distributions were found suitable for all the scenarios, geometric distribution was chosen for being a discrete variable and for having a possible interpretation: the number of items collected until reaching the “success” of finishing the shopping. It´s remarkable than Saturdays and holidays are the day-of-the-week scenarios with the higher number of expected articles per client.

Table 4: Item per user best-fitting distribution

Saturday	GEO(0.039)
Bi-weekly	GEO (0.042)
Regular	GEO(0.064)
Holiday	GEO(0.033)

Results trends of the experiment were similar among supermarkets. The following discussion will be centered in the biggest supermarket as a representative example of all the supermarket sizes.

The experiment yields significant main effects of the three factors (p value < 0.001) in all day-of-the-month scenario for average system time, average queue time, maximum system time and maximum queue time. The only significant interaction were between level of cashiers and level of baggers for average times (p value < 0.001). Maximum times didn´t show any significant interaction.

As expected, faster item register times lead to shorter waiting and system times, in average and for maximums in all scenarios (see Figure 1).

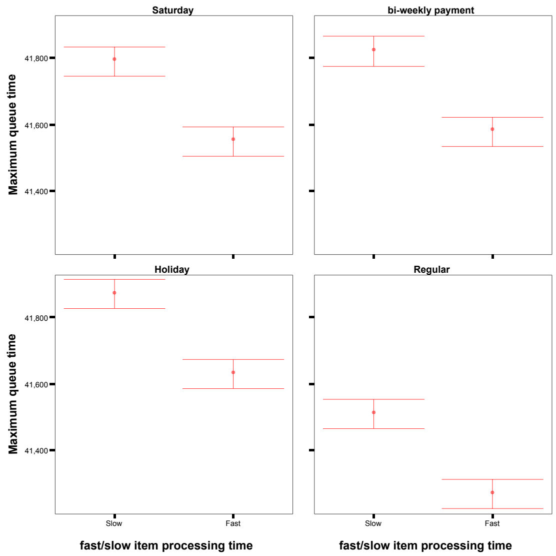

Figure 1: 95% confidence intervals for waiting maximums average times broken by item register times in four day-of-the-month scenarios

Also, as a main factor, a higher percentage of baggers yields in a shorter time for all performance measures, too. System average times are showed in Figure 2.

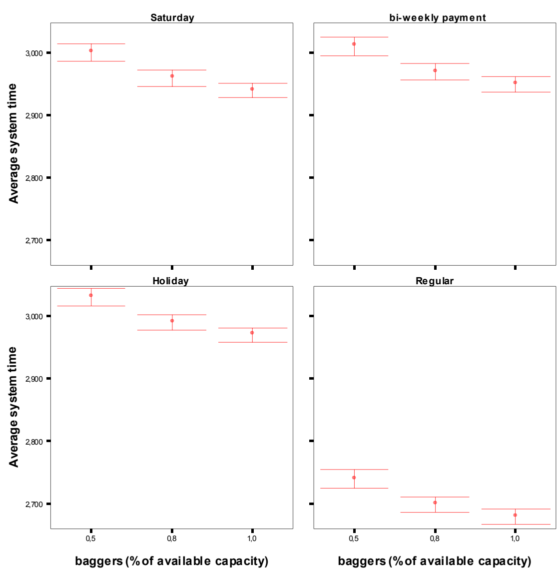

Figure 2: 95% confidence intervals for system average times broken by percentage of baggers in four day-of-the-month scenarios

Cashiers was a significant factor, but with different behaviors for average and maximum measures. For average measures, (see Figure 3) all five levels of cashiers were different, finding the lower average time -for system and waiting times- in 80% of the available capacity of cashiers and the higher average times in 20% of the capacity, as expected. A strange behavior came up for 100% of the capacity in average times, as can be seen in Figure 3, where the average time was upper than in 80% of the capacity. It can be due, in part, to a lower level of balking when there are more cashiers available (55 entities in average vs. 88 entities for the 80% capacity) , but it requires further confirmation.

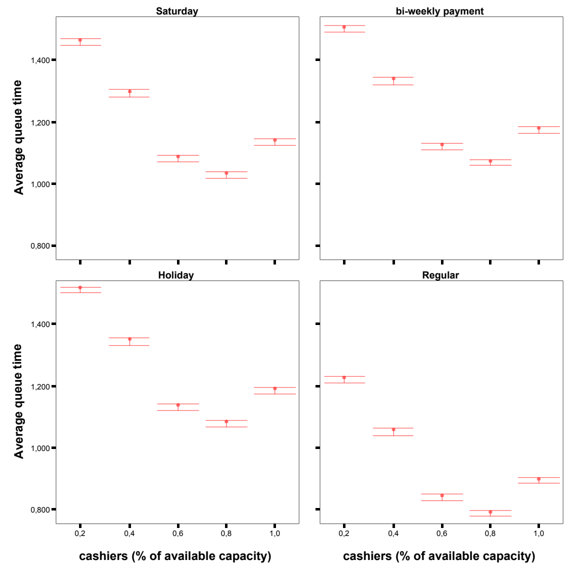

Figure 3: 95% confidence intervals for waiting average times broken by percentage of cashiers of available capacity in four day-of-the-month scenarios

In the other hand, maximum measures didn´t show different significant values for all five levels of cashiers. Three groups were formed: The highest maximum was found for 20% of the capacity; a medium group for 40% and 100% of the capacity; and a lower group including 60%, 80% y 100% of cashiers available capacity, as can be seen on the 95% confidence intervals of Figure 4. The variability in maximum times- higher than in average times (compare Figure 3 and Figure 4)- is probably the cause of making difficult to find distinctions among levels of cashiers and, of course, the cause of the supermarket difficulties for accomplish promise services for all or the most part of their clients every day.

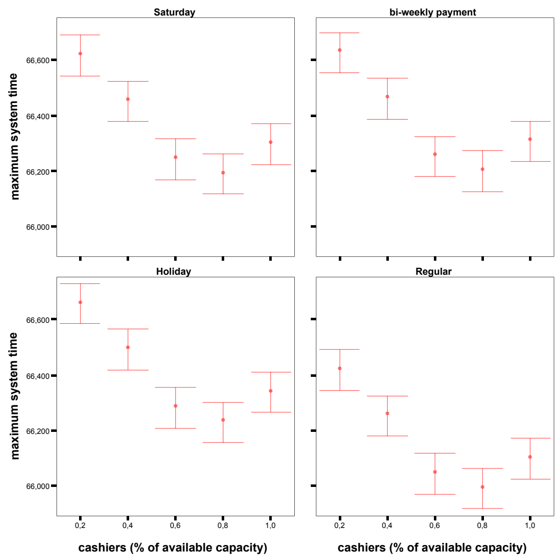

Figure 4: 95% confidence intervals for system maximum average times broken by percentage of cashiers of available capacity in four day-of-the-month scenarios

The interaction between cashiers and baggers is probably the most remarkable result of the experiment. It can´t be noticed in 95% confidence intervals of Figure 5.

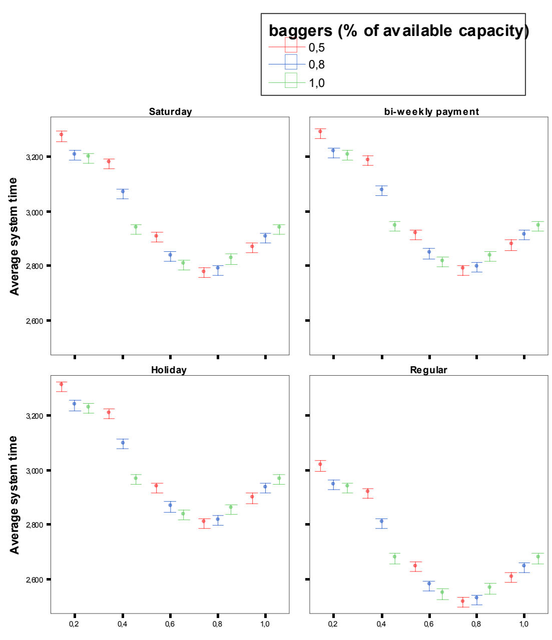

Figure 5: 95% confidence intervals for system average times broken by percentage of cashiers of available capacity and percentage of baggers in four day-of-the-month scenarios

It can be concluded than at 40% of the cashiers capacity level, increasing the percentage of baggers really make a difference in decreasing the expected time in system for a client. This difference is more subtle, but even significant for certain levels of baggers in 20% and 60%. In contrast, at 80% or 100% cashiers capacity level, increasing baggers doesn´t make a favorable difference for the average system time or average waiting time.

5 CONCLUSIONS

A general framework for Colombian supermarket challenge was successfully developed, and proved to be useful to find a cashier-bagger combination in order to meet an average service level and to suggest this combination for a promise service for all of the most part of the clients. Prospective research could try to integrate the model with real time data in order to make it sensitive to sudden changes in the customer behavior and look for a framework for promises services not-average based.

Simulation model included more refined ways of approaching the supermarket challenges, including customer rule decisions and different behaviors for both clients and number of items demand. In particular, it reflected specific matters related to Colombian supermarkets, as ways of payment and legal restrictions. It could be improved with a better modeling of balking and with a more sophisticated scheduling for approaching the variable demand among the day.

Finally, the experiment showed mostly the expected results but uncovered two strange behaviors to be investigated: A longer system average time for a full utilization of available capacity than expected, and an interesting interaction among cashiers and packers that could help managers to decide when could be really valuable to increase the number of baggers and when could be simply worthless.

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