SUPERMARKET SIMULATION USING SIMSCRIPT II. 5

Vahap TECIM (*)

ÖZET

Simülasyon programlama dili SIMSCRIPT 11.5 ile büyük bir süpermarketin işleyişinin ortaya konması amaçlanmaktadır. Ele alınan örnek modelde kasada ve departmanlarda bulunması gereken eleman sayıları belirlenmeye çalışılmaktadır. Süpermarkette altı departman bulunmakta ve yalnızca günlük departmanında kuyruk oluşmaktadır.

Model aşağıda belirtilen varsayımları içermektedir:

- (1) müşterilerin gelişi birbirnden bağımsızdır ve dakikada beş müşteri gelmektedir,
 - (2) kuyruk kapasitesi sınırsızdır,
 - (3) müsteri kaynağı sınırsızdır.

Simülasyon modeli müşterilerin ortalama bekleme süresinin kasada yaklaşık bir dakika ve günlük (taze dilim et ve peynir) departmanında yaklaşık 30 saniye olması gerektiğini ortaya koymuştür:

- (1) Günlük deparımanında 3 eleman çalışmalı,
- (2) Diğer departmanlarda 1 eleman gerekli,
- (3) Kasada 11 elemana gereksinim duyulmaktadır.

1. (i()AL

The purpose of this simulation study is to understand how a supermarket works by analyzing the characteristics of queues and the other working utilities of the system. In particular this study attempts to find out what resources could be added or omitted to help the customers doing their shopping and to satisfy supermarket policy. We should try to reduce the length of queues and waiting time at the cashier and at the ordering desk' and also to obtain a general idea of the shopping preferences of customers.

The simulation study is undertaken to determine the following:

^(*) Arş. Gör. D. E. Ü. I. I. B. F. Ekonometri Bölümü.

- a) The maximum and mean waiting tune in queuing for each department,
- b) The maximum and average number of customers in the queue for each department,
 - c) The work of clerk(s) in utilization for each deparment,
 - d) The maximum and mean queing time for each cashier,
 - e) The maximum and average number of customers queuing for each cashier,
 - f) Cashier utilization (multiple queue, multiple server).

2. ASSUMPTIONS

The assumptions behind the model simulation were justified by actual observations of a large supermarket in downtown Ottowa during the period November to December 1991.

At 8:00 am the supermarket opens its doors at 9:00 pm, but clerks and cashiers, continue working until all the customers have been served. Simulation time is 13 hours a day (13*60=780 minutes a day). This program was first run only for one day, and then for one week; however users can run this program for as long as they wish, provided there is sufficient computer memory space and disk space.

The supermarket has 6 departments: grocery, vegetable, deli, meat, cheese and bakery. The user of the program has the option of changing the following parameters to reach the best combination to suit his needs:

- (1) Mean interarrival time,
- (2) Duration of time to run the simulation,
- -(3) The number of grocery department clerk(s),
 - (4) The number of vegetable department clerk(s),
 - (5) The number of deli department clerk(s),
- (6) The number of meat department clerk(s),
- (7) The number of cheese department clerk(s),

- (8) The number of bakery department clerk(s),
- (9) The number of cashiers.

When a customer arrives at the supermarket he may go to one or two or all departments. The grocery, vegetable, meat, cheese and bakery departments are self-service: customers do not have to line up in those departments. Only the deli department has a queue and its service area is a single queue, multiple server system. On arrival at the deli department the customer has to go to the ordering counter, if clerk(s) are busy then the customer has to line up and wait for service. After being served, the customer has to go to the cashier and he has to line up if there is a queue, after paying he may leave the supermarket. This simulation is based upon the following assumptions: unlimited queue length (both of them, deli department and cashier check), arrival from an infinite source and finally customer arrival is exponential interarrival.

3. CONCEPTUAL MODEL

Generating abinary number for each department. First the customer is assigned a number for grocery department, if the number is 1 then he will go to this department, if the number is 0 then he does not want to go this department. And in the grocery department, if he has a problem (for example may be he can not find a particular item, etc.) he will ask a grocery clerk and then he will continue his shopping. If he does not have any problem he helps himself. After the grocery department he may go to the vegetable department and his choice again is expressed by a binary number. If vegetable department binary number is 1 then he will go to this department and same procedure operates in the grocery department. So in total every customer has 6 shopping choices matching the six departments.

Naturally, after a customer has been served at the deli department at the ordering counter the clerk(s) becomes idle unless another customer is waiting, if so the clerk will continue serving customers as long as there are customers in the queue. The same procedure operates for each cashier.

After being served (all departments depend on the customer's choicebinary number) the customer has to go to the cashier. The cashier service is a multiple queue, multiple server system. The customer first looks at all the lineups; if one cashier is free he will go there directly. Otherwise he will go to the cashier who has the shortest queue. But after he will look again abd at that time he pays attention to the customers' items in their shopping carts for each cashier. After he will choose the cashier which has least total items in that queu

Table 1.Initial Values Of The Model Simullation
(All Times Are In Minutes)

Department	Probability Of Asking Clerk	Clerk's Work Time (Uniformly dist.)		Cust.Spend Time (Per Item-Unif.)
Grocery	0.15	1.00±0.50	7 ± 6	0.35±0.15
Vegetable	0.10	0.75±0.25	4 ± 3	0.50+0.25
Deli	1.00	1.00±0.50	3 ± 2	
Meat	0.15	0.75 ± 0.25	3 ± 2	0.35±0.15
Cheese	0.10	0.50±0.25	2 ± 1	0.50±0.25
Bakery	0.15	0.75±0.50	2 ± 1	0.20±0.10

In Table 1, the second column gives the probability of customer's asking the clerk(s) for something for each department. For example first row customer has a 15% probability of asking something from the grocery clerk(s). The third column gives the clerk's work time for each department: they are uniformly distributed. The fourth column gives the number of items which a customer may buy in each department. They are integer random numbers. The last column shows the customer's time spent for each item in each department. They are uniformly distributed too.

We assume that the interarrival times of customers are independent exponential random variables with a mean of 0.2 minutes. That is, mean interarrival rate=5 customers/per minute. All the data and customer's processes are confirmed by the manager of the supermarket. For each customer every item which the customer buys at different department is recorded. For example, the customer will buy at least one or at most 13 items in the grocery department. Per-

haps this department has 120 or 150 items, but the customer will buy at most 13 items on each shopping trip. The number of items to be purchased influences the length of time the customer spends in a given department.

4.ORGANIZATION OF THE SIMULATION MODEL

The customers arrive at the supermarket independently. After arriving, the customer has to know which department he will go to. All customers go through the same process when they arrive at the supermarket. The customers follow this direction: Vegetable dep. \rightarrow Deli dep. \rightarrow Grocery dep. \rightarrow Meat dep. \rightarrow Cheese dep. \rightarrow Bakery dep.

There are 3 processes.

- (a) Process ARRIVAL. GENERATOR, generates customers' arrivals. The customers can arrive until time is less than simulation time (SIM. TIME) which in our model is 780 minutes. And mean interarrival time is 0.20
- (b) Process CUSTOMERexpresses the customer's total behaviour, except for eashier check at the supermarket. The customer's total shopping trip is only one process because this way it is very easy to follow the customer. At the beginning we assign zero to some local variables. VEG, DELI, GROC, MEAT, CHEESE and BAK express customer's shopping choices for each department, then the customer knows where he will go to variables VEG. ITEMS, ..., BAK. ITEMS express the customer's items which he will buy at different departments.

When the customer arrives at the supermarket he will go first to the grocery department. If the binary number (GROC) is 1 then the customer will make a purchase in this department, otherwise he doesn't want to go to this department. After arriving at the grocery dpatment he has a 15% probability of asking something from the grocery clerk. If the number is less than 15, then he will ask something from the clerk, but if the clerk is busy, he will wait until the clerk is free. And we are measuring the customer's waiting time to gether some statistical information. After the customer buys some items; in the grocery department he can buy at least 1 and at most 13 items, and he will spend uniformly 0.35 ± 0.15 minutes in purchasing each item.

If the customer decided to go to the grocery department, then the simulation time should wait until he finishes his purchases in the grocery department. For that reason we decided to model most of the customer's behaviour as only one process for each customer when the customer completes his shopping trip in the six departments he leaves the process and goes to the cashier check out. Sometimes one customer's shopping takes a long time and at the same time other customers in the supermarket can pass that customer. This process covers all the possibilities for different kinds of customer, the other 5 departments have the same procedures 9except for some changes of the deli dpartment; in the deli department the customer has to go to the counter desk and he has to wait for the clerk's service).

(c) Finally after being served in all the departments the customer has to go to the cashier with his items. For that reason process CASHIER. CHECK acepts the customer with his items. The customer goes to the cashier, if one is free, otherwise he will go to the cashier which has the shortest queue, but later he decided to choose the cashier who has the least total items in that queue. And the cashier works uniformly 0.20 ± 0.10 minutes for each item. After paying for his items the customer may leave the supermarket. And we gather additional statistical information from the cashier check- out.

Our RESOURCES are CLERKS for each department and CASHIER clerks have checkout delay and total items which we are calculated from the number of items per customer. Cashiers are multiple queue multiple server, for that reason we should keep important data on each cashier. We use this information for customer's choice of line up for the cashier check -out. If the customer knows how many total items waiting for each cashier, then he can choose the cashier who has fewest items.

We defined the variables for statistical information in the PREAMBLE section. We use TALLY command o get statistical information from the time-independent variable and ACCUMULATE command for the time-dependent variables.

ROUTINE READ. DATA, read some data from the terminal and report writes simulation results to the file or terminal. With routine INITIALIZE we create all our resources. Further the number of clerks of in each department is set in this section. All remarks were placed in this program. Table 2 gives us

global va. ables a..d their meaning. Definition of local variables is given in the SIMSCRIPT program.

Table 2. Model- specific variables for the supermarket system.

Variables	Definition			
	Time average number of customers in the cashier queue. Time avarage number of customer in the grocery (vege			
AVG. GROC. QUEUE.LENGTH	table, deli, etc.) queue.			
CASHIER UTILIZATION	Utilization of the particular cashier.			
CUS. GROC. ITEMS	Number of itema which the customers buy from the grocery (veg., deli, etc.) depatment.			
DELAY. IN QUEUE. GROC	Delay in queue of a particular customer in the grocery			
	(veg, deli, etc.) department.			
GROC. UTILIZATION	Utilization of the grocery (veg.,etc.) clerks.			
MAX. CASH. QUEUE. LENGTH	Maximum number of cust, in the particular cashier queue.			
MAX. CHECKOUT. DELAY	Maximum checkout delay of customer in the particular cashier queue.			
MAX.DELAY IN .QUEUE.GROC	Maximum delay in queue of a customer in the particu lar cashier queue.			
MAX.SHOPPING. TIME	Maximum shopping time of a customer.			
MAX.GROC. QUEUE. LENGTH	Maximum number of customers in the grocery (vegeta ble, deli, etc.) queu.			
MEAN. CHECKOUT. DELAY	Mean checkout delay of customer in the particular cash ier queue.			
MEAN. DELAY.IN.QUEUE.GROC	Mean delay in queue of a customer in the grocery (veg, deli, etc.) department.			
MEAN. GROC. ITEM	Mean grocery items sold during the simulation time.			
MEAN INT. TIME	Mean interarrival time.			
MEAN. SHOPPING. TIME	Mean shopping time of a customer.			
NUM. CASHIER	Number of cashiers.			
NUM. GROG. CLERKS	Number of grocery (veg., deli,etc.) c;erks.			

SHOPPING. TIME

SIM. TIME

Shopping time of a particular customer.

Amount of simulation time.

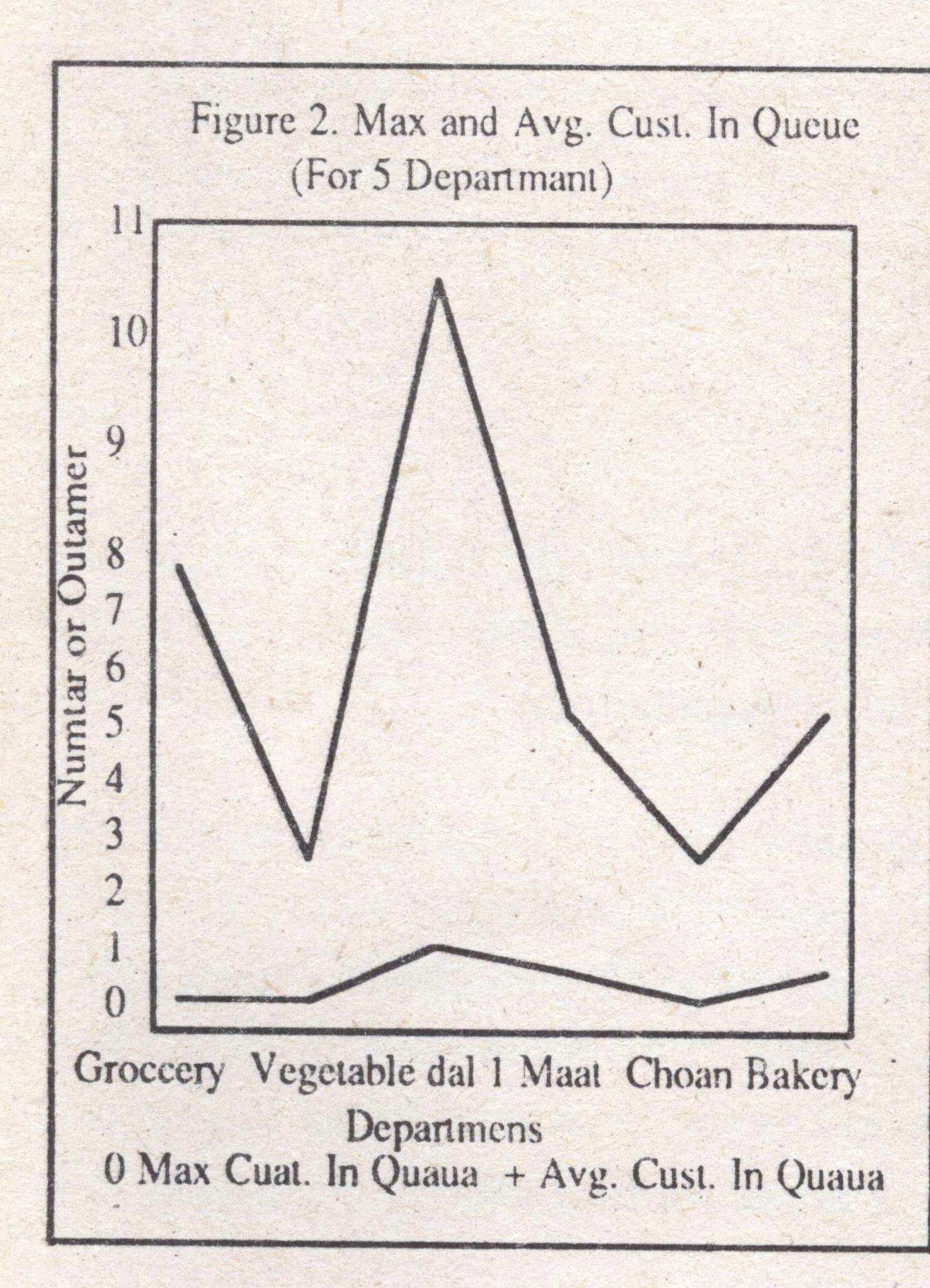
GENERAL ASSESSMENT OF THE MODEL

The simulation program may not be complicated enough to cover everythig, but it is sufficiently complex to solve our basic conceptual model. And the solution is acceptable for this supermarket.

We VERIFY this model seaeral times to get an acceptable solution. Especially we tried to obtain real data. And we tied different combination of clerk(s) for each department and cashier. Finally we obtained a satisfactory solution not an optimal solution; and almost the same as the system working in the real supermarket where we collected our observed data.

RESULTS

After several runs of this program we decided that grocery, vegetable, meat, cheese and bakery departments should have 3 clerks, because when look at the results in the Appendix, there is a mean delay in queue about 10 seconds for first 5 department and one minute for the deli department. These are acceptable. Eleven cashiers are needed; the cashier mean delay in queue is about one minute.



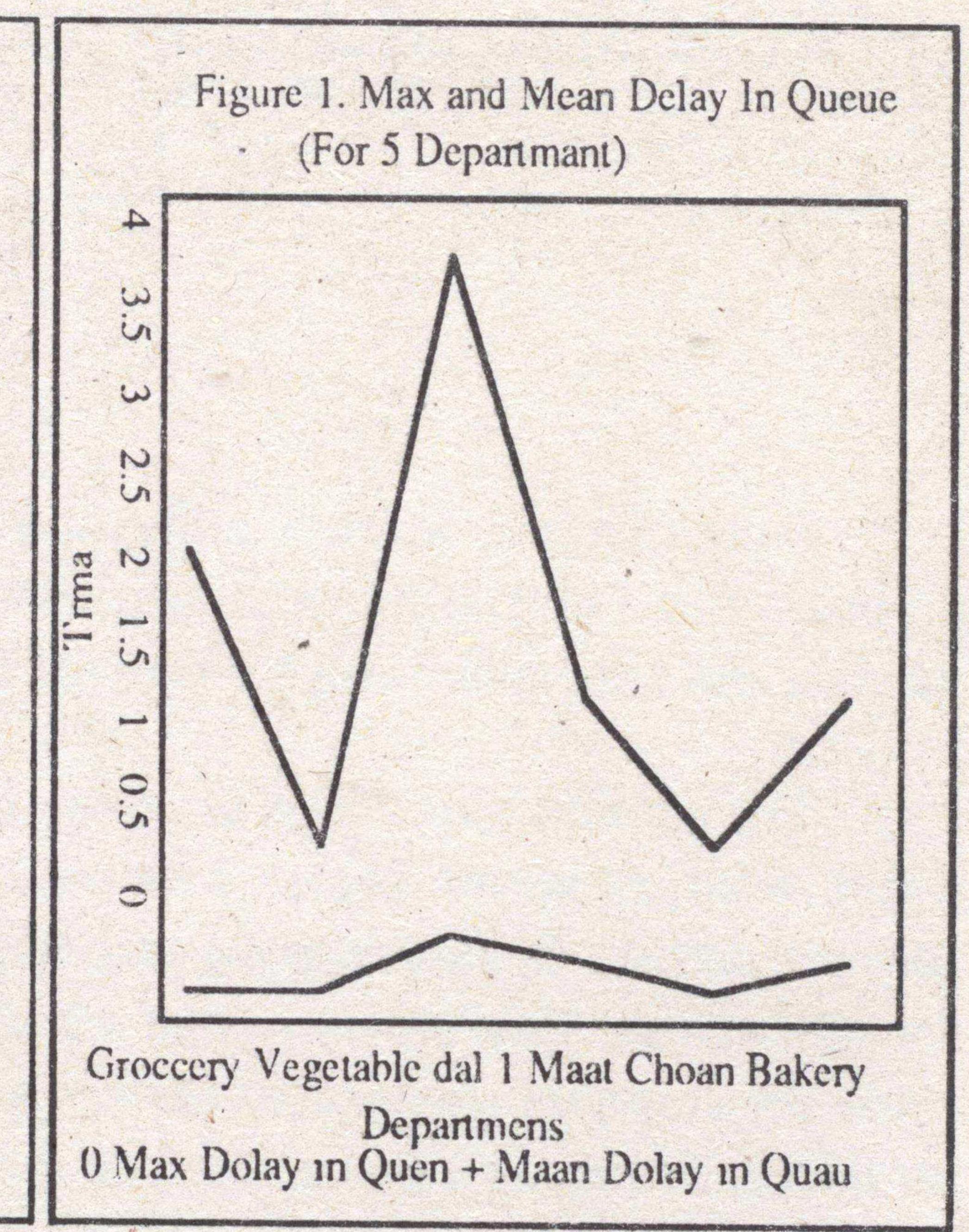


Figure 1 shows us mean delay in queue and maximum delay in queue for each department. Only deli department maximum waiting time is higher than the others, because every customer has to line up and wait for clerks services.

Figure 2 shows us the average and maximum number of customers in queue for each department. Almost the same solution as we got in the previous graph. Only deli department has a big queue, but the average is acceptable for the customer.

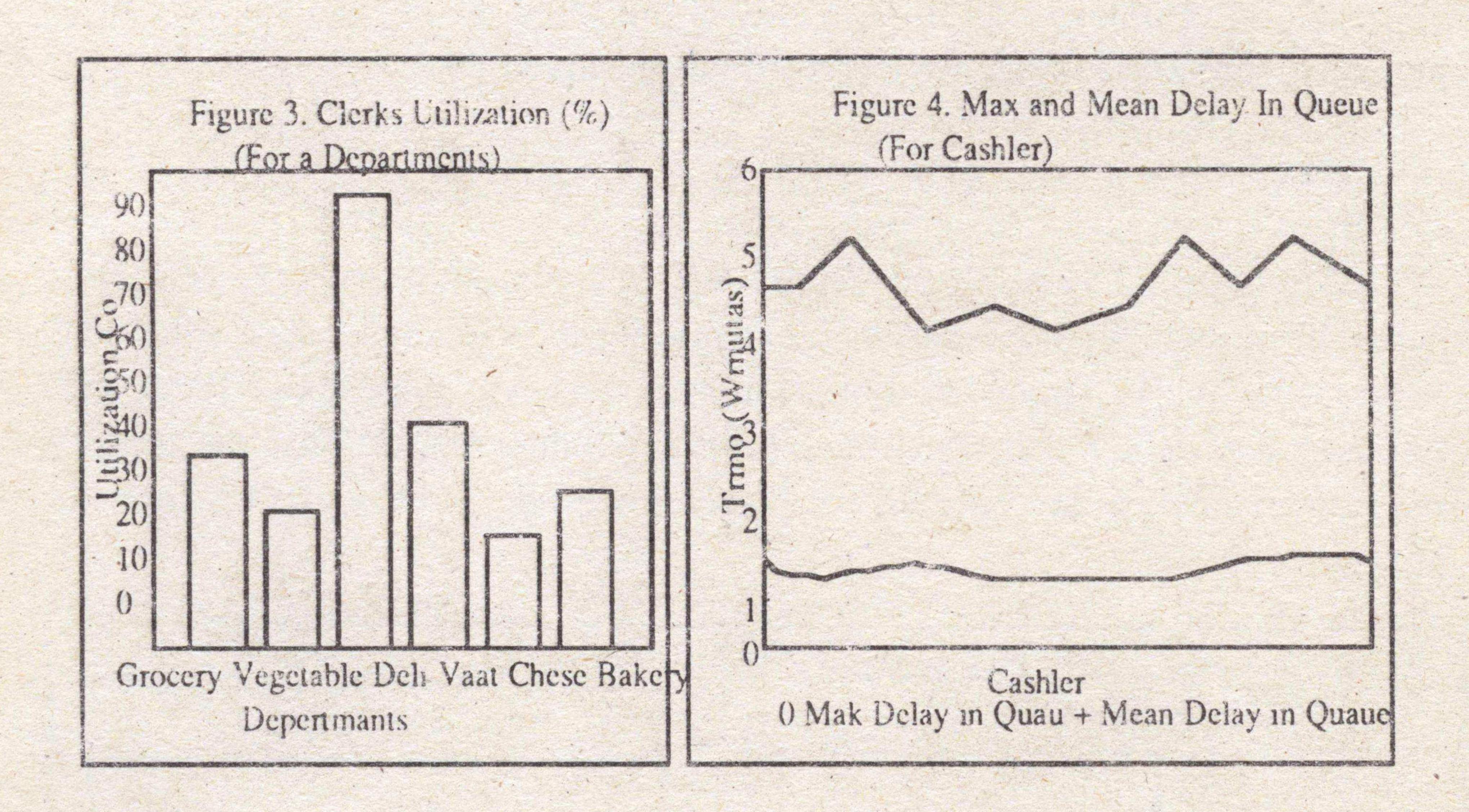


Figure 3 shows us clerk utilization for each department. Only the deli department has 3 clerks; the other departments have one clerk. And deli department's clerk utilization is higher than the other departments.

The cashiers' position is different, because they are independent multiple queue, multiple server. Figure 4 shows us maximum and mean delay in queue for each cashier. In particular the graphing of mean delay in queue almost same for all cashiers. This shows us that we seperated customers quite correctl. Because the customer chooses the cashier who has the least total items in particular queue, and mean waiting time and maximum waiting time is acceptable for the customer.

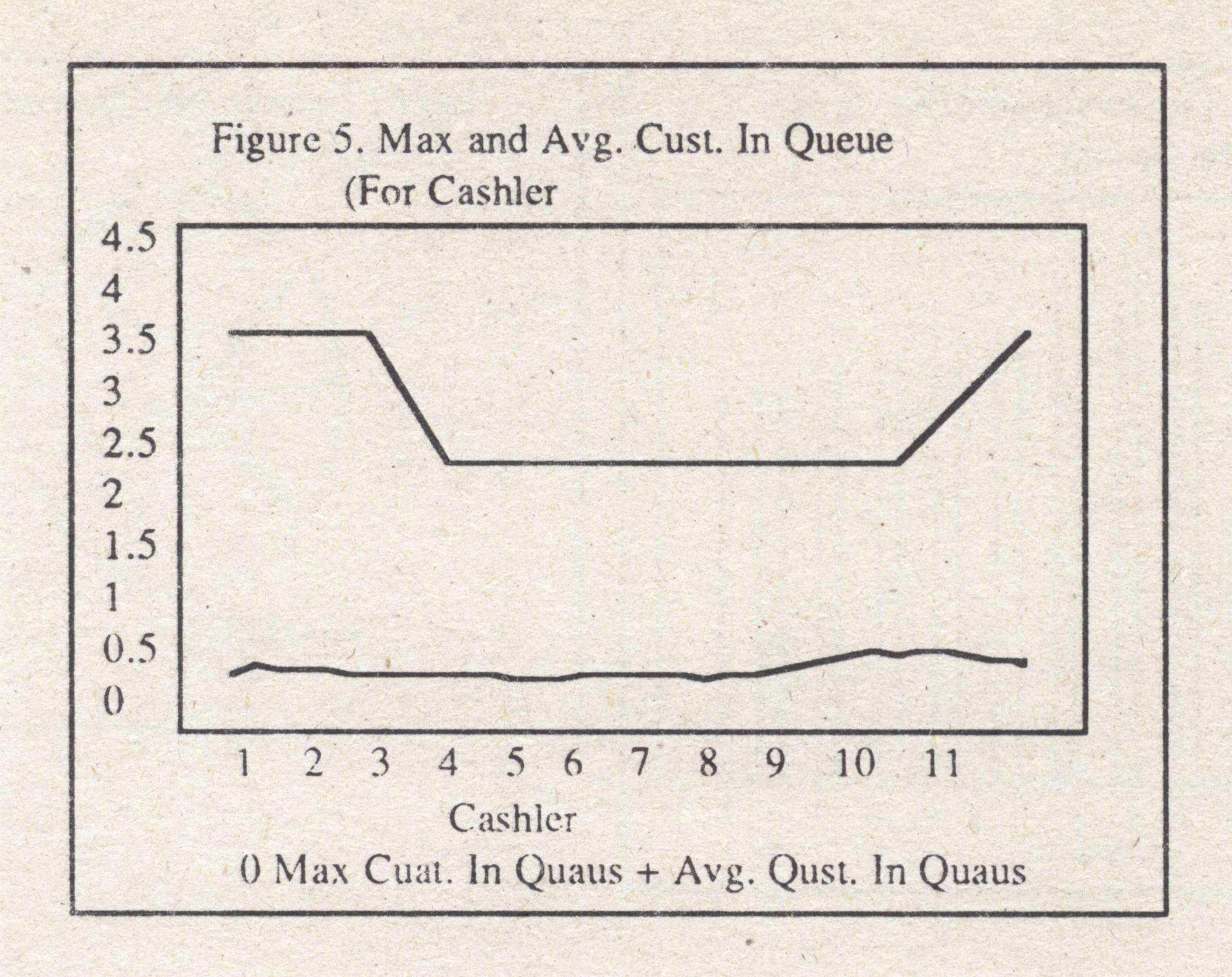
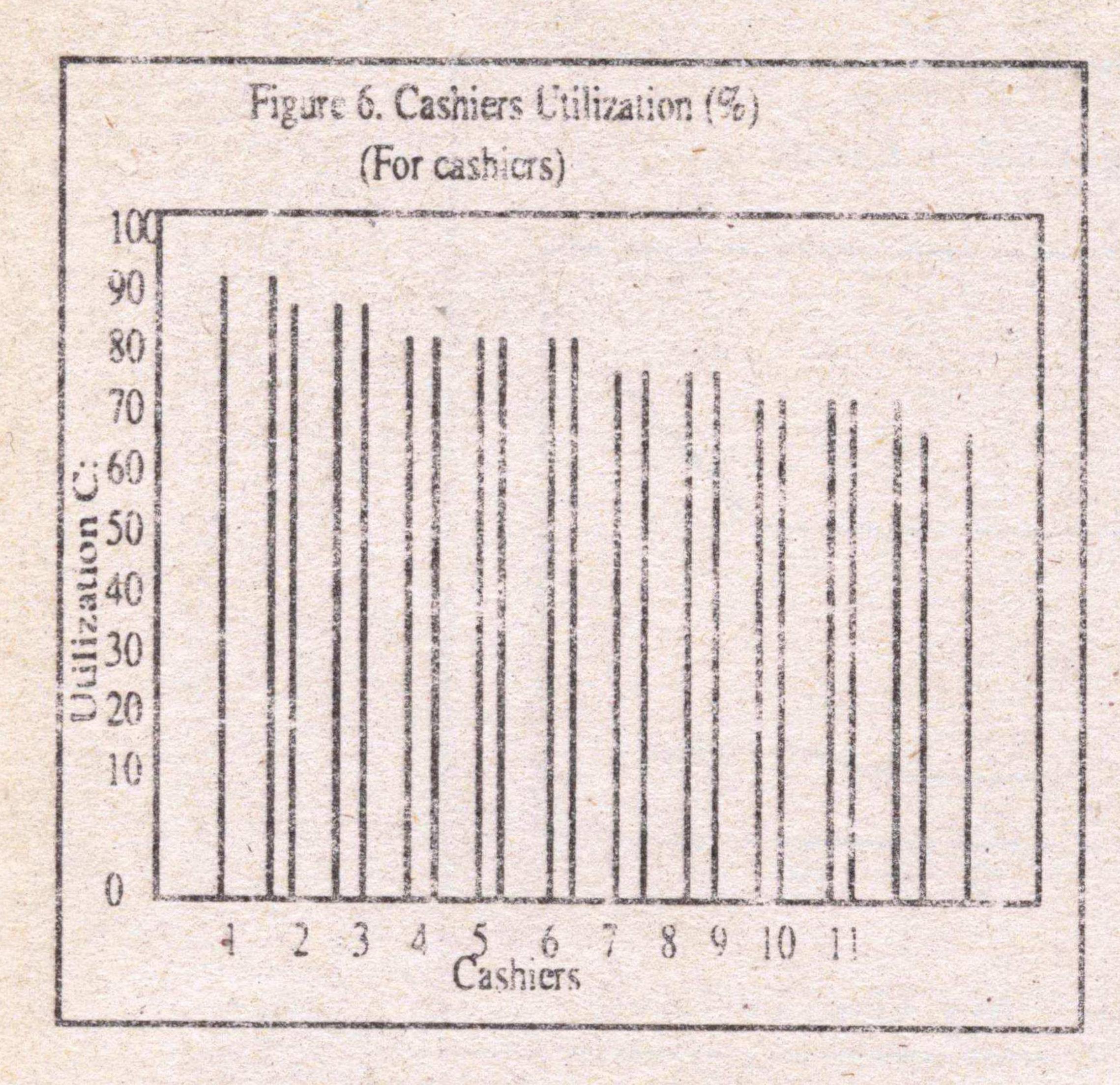


Figure 5 shows us the maximum and average number of customers in queue. This gives us almost same information as the previous gparh in figure 4. Maximum 3 or 4 customers in the queue. This is more acceptable.

The cashiers utilization give us important information about how many cashiers we should hire. Of course this information should combine with the first two sets of data about the cashiers. But if we hire 30 cashiers we will probably see mean and maximum delay in queue is zero and average and maximum number of customers in queue is zero. But cashier utilization will probably be very low. For that reason utilization is very important, especially we will know how the customer's choice works for the cashier check. And the m, anager does not want very low utilization for his clerks.



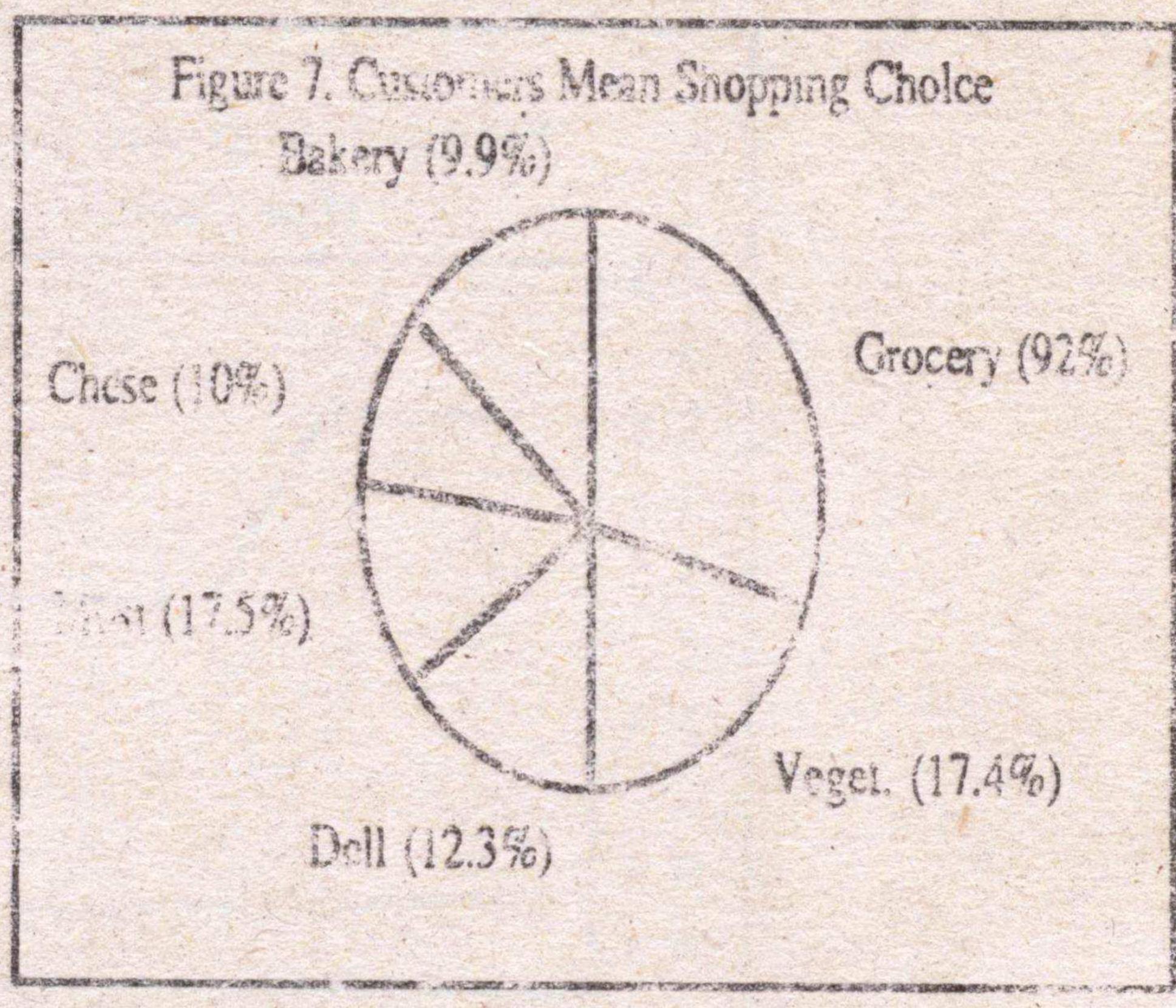


Figure 6 shows us utilization of cashiers. Cashier utilization is about 90%. And this satisfies the manager. As we see in figure 6, the first cashier utilization is higher than the second one and the second cashier utilization is higher than the third one etc.ie. utilization is decreasing, because each time customers choose the first cashier who has least total itmes in its queue. Each timea customer will look first at cashier 1, afterwards cashier 2,..., and so on up to cashier eleven.

In the appendix we enclose the SIMSCRIPT program and some outputs. The first output is a satisfactory solution; the other two outputs are presented to show why we choose the first set of results. We can compare their maximum and mean delay in queue, average and maximum number in queue, departments clerks and cashiers utilization.

Finally we found that maximum shopping time is 14.54 minutes and mean shopping time is 4.66 minutes. Figure 7 gives us (under our assumptions) how many items were sold during the simulation time. And the supermarket served 3914 customers in a day.

ABSTRACT

To understand how a large supermarket operates a simulation model was created using a simscript program. The model will help to determine the number of cashiers and clerks. The supermarket has 6 departments but only the delideprement has a queuing system.

Further it was assumed that:

- (1) customers arrive independently of each other and on average five customers arrive, each minute.
 - (2) there is no fixed limit to the length of a queue,
 - (3) there is no fixed limit to the number of customers.

The simulation model indicated that with average delay in cashier line up of about one minute for cashier and about 30 seconds in the deli department:

- (1) the deli department should have 3 clerks,
- (2) in each other department one clerk was sufficient,
- (3) eleven cashiers are needed.

REFERENCES

BRAUN, Jay E. (1983). Simscript II.5 Reference Handbook.C.A.C.I. Inc., Los Angeles.

JONES, Gilbert T.(1972). Simulation & Business Decisions. Penguin Books, Inc., Middlesex.

- LAW, A.M. and KELTON, W.D. (1987). Simulation Modelling and anlysis. McGraw-Hill, New York.
- LAW, A.M. and LARNEY, C.S. (1985). An Introduction to Simulation using SIM-SCRIPT II.5 C. A. C.I. Inc., La Jolla, CA 92037
- MacDOUGALL, M. H. (1987). Simulation Computer Systems: Tecniques and Tools.MIT press, Cambridge.

McNITT, Lawrance L. (1983). Basic Computer Simulation. Tab Books, Inc., Blue Ridge Summit.