Proceedings of the 1996 Winter Simulation Conference
ed. J. M. Charnes, D. J. Morrice, D. T. Brunner, and J. J. Swain

SIMULATION AND ANIMATION OF THE OPERATION OF A FAST FOOD RESTAURANT

Kambiz Farahmand

Texas A&M University-Kingsville
Department of Mechanical & Industrial Engineering
Campus Box 191
Kingsville, Texas 78363

Alejandro Francisco Garza Martinez

Componentes Mecanicos
De Matamoros, S.A. De C.V.
P.O. Box 4447
Brownsville, Texas 78523

ABSTRACT

A model was developed for the Simulation and Animation of the Drive-Thru (DT) and the lobby sections of a fast food restaurant. A discrete, non-continuous, parallel simulation of the operation using animation in the Witness environment has made it possible to utilize real time data or forecasted data to optimize scheduling and maximize operation efficiency. Performance measures such as the number of customers balking from the system, the average time each customer spends in the system, the average waiting time for the customers, the average queue length before and after placing an order, the average time to fill an order and even the average utilization of each employee could be determined.

The results could serve as basis to provide recommendations on how to improve efficiency and throughput for the fastest growing industry and the largest employer in the US. The modeling methodology and the tracking mechanism could also prove useful for the manufacturing or other service industries employing similar queuing techniques.

1 INTRODUCTION

In its broadest sense, computer simulation is the process of designing a mathematical-logical model of a real system and experimenting with this model on a computer. Thus simulation encompasses a model building process as well as the design and implementation of an appropriate experiment involving that model. These experiments, or simulations, permit inferences to be drawn about systems and their operation without actual construction of the system. Decisions regarding the capacity requirements are difficult, since it is often impossible to accurately predict when units will arrive to seek service and/or how much time will be required for the service provided. Allocating more resources than necessary would involve excessive costs. On the other hand not providing enough resources would increase queue size. Therefore our goal is to achieve an economic balance between the cost of service and the cost associated with waiting for that service.

In the DT operation, customers (cars) arrive at the station, pull up to the DT sign, place an order, form a queue before and after placing an order if there are any customers seeking service, pay and receive the order and leave the system. In the lobby section, customers go to the lobby, walk to the cashiers area, form a queue to order if there are any other customers seeking service, place an order, pay, wait to receive the order, go to tables area, eat and leave the system. This paper presents the modeling of the above scenario in a realistic but simplified animation network. Operation recommendations have been made to optimize operation, labor and resource utilization, improve quality and customer service, and increase efficiency.

2 MODEL BUILDING

WITNESS was selected as the simulation software to be used for the simulation and animation of the operation of a fast food restaurant due to its applications strengths such as manufacturing, service and process environments, hardware requirements such as a personal computer running the Microsoft Windows and relatively low cost. WITNESS provides facilities for building models of great complexity, but the principles of building a WITNESS model are simple. Using three commands from the Model menu, you can start building useful models.

After defining, displaying and detailing the elements of the model (see Figure 1), it can run immediately and modified by adding, changing or deleting elements.

This ability to build a model incrementally, testing each section as you go, is a powerful aid to productivity, and generates confidence in the validity of the model. The model could be run in a variety of modes, from step-by-step with full screen display to a "batched" time in the future, with no screen display.

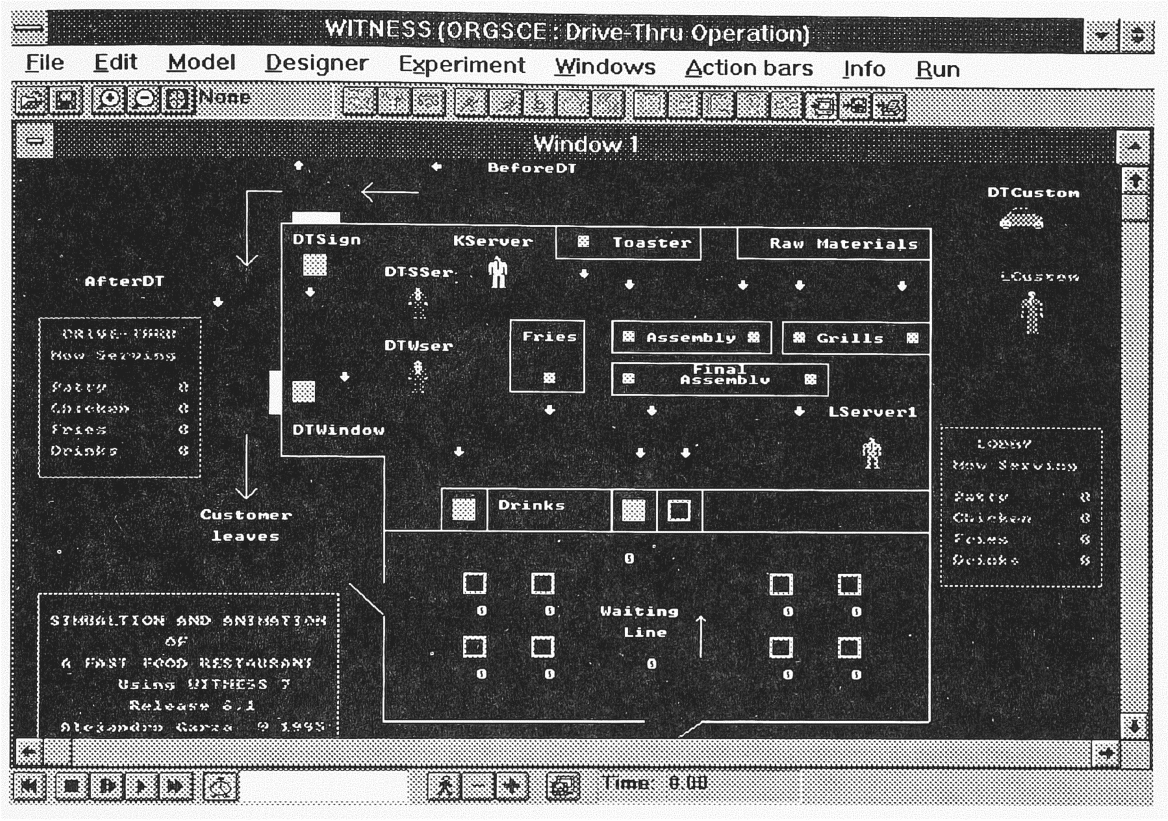

Figure 1: Main Screen

2.1 Model Structure and Details

2.1.1 Parts

DTCustom (Drive-Thru customers)
Part defined to identify Drive-Thru customers.
LCustom (Lobby customers)
Part defined to identify Lobby customers.
Patty (Patty burger)
Part defined to identify Patty burgers.
Chicken (Chicken burger)
Part defined to identify Chicken burgers.
Drinks (Soft drinks)
Part defined to identify soft drinks.
Fries (French fries)
Part defined to identify French fries.
Buns (Buns)
Part defined to identify Buns

2.1.2 Machines or Stations

PMac (Patty machine)
Machine or station where the Patties are cooked or grilled.
CMac (Chicken machine)
Machine or station where the Chicken is cooked or grilled.
AMac (Assembly machine)
Machine or station where initial assembly is made of bun sets and patties
AMac2 (Assembly machine 2)
Machine or station where initial assembly is made of bun sets and Chicken
FAMac (Final assembly machine)
Machine or station where the final assembly of Patty burgers is made.
FAMac2 (Final assembly machine 2)
Machine or station where the final assembly of Chicken burgers is made.
FMac (Fries machine)
Machine or station where French fries are cooked or fried.

TMac (Toaster machine)
Machine or station where the buns are cooked preparing them for burgers assembly.
DTSign (Drive-Thru sign)
Machine or station where Drive-Thru customers place their orders.
DTWindow (Drive-Thru window)
Machine or station where Drive-Thru customers pay and pick up orders.
LCash (Lobby cashier)
Machine or station where Lobby customers place and pay their orders.
LDel (Lobby delivery)
Machine or station where Lobby customers receive the orders placed after paying.
Lobby (Lobby)
Machine or station where Lobby customers eat after paying and receiving their orders.
DMac (Drinks machine)
Machine or station where soft drinks are served or dispensed.

2.1.3 Buffers or Queues

BeforeDT (Before Drive-Thru)
Waiting line or buffer before placing an order at the Drive-Thru sign.
AfterDT (After Drive-Thru)
Waiting line or buffer after placing an order at the Drive-Thru sign.
LCBuf (Lobby)
Waiting line or buffer formed by the Lobby customers before placing an order at the Lobby cashier.

2.1.4 Labor or Employees

LServer1 (Lobby server 1)
Server or employee dedicated to operate or attend the Lobby cashier, Fries machine, Drinks machine, Final Assembly of Patty and Chicken burgers and delivery of orders to Lobby customers.
KServer (Kitchen server)
Server or employee dedicated to operate or attend the Patty machine or grill, Chicken machine or grill, Toaster machine, initial assembly Patty machine and initial assembly Chicken machine.
DTSSer (Drive-Thru sign server)
Server or employee dedicated to operate or attend the Drive-Thru sign, Fries machine and Toaster machine.
DTWser (Drive-Thru window server)
Server or employee dedicated to attend the Drive-Thru window, Fries machine, Toaster machine and final assembly of Patty burgers.

2.2 Measuring Performance

2.2.1 Drive-Thru

- Drive-Thru customers leaving because of full queues
- Average time Drive-Thru customer spent in the system
- Average waiting time for the Drive-Thru customer before ordering
- Average waiting time for the Drive-Thru customer after ordering
- Average queue length before placing an order at the Drive-Thru
- Average queue length after placing an order at the Drive-Thru
- Average time to fill an order at the Drive-Thru

2.2.2 Lobby

- Lobby customers leaving because of full queues
- Average time Lobby customers spent in the system
- Average waiting time for the Lobby customer before ordering
- Average queue length before placing an order at the Lobby
- Average time to fill an order at the Lobby

2.2.3 Labor

- Average utilization of Lobby employee
- Average utilization of Kitchen employee
- Average utilization of Drive-Thru window employee
- Average utilization of Drive-Thru sign employee

3 SENSITIVITY ANALYSIS

This sensitivity analysis contains the original scenario and seven alternate scenarios where modifications to the original assumptions were made. The file name is the name under which each scenario was saved. The conditions presented are only the outstanding conditions that have been changed from the original scenario. Table 1, sensitivity analysis summary, does not specify units for the input data. The model is valid as long as all units are presented consistently. The following fields in this summary contain the evaluated factors and their outputs under each scenario provided by the corresponding simulation reports.

- Drive-Thru customers leaving because of full queues
- Lobby customers leaving because of full queues

- Average time Drive-Thru customer spent in the system
- Average time Lobby customers spent in the system
- Average waiting time for the Drive-Thru customer before ordering
- Average waiting time for the Drive-Thru customer after ordering
- Average waiting time for the Lobby customer before ordering
- Average queue length before placing an order at the Drive-Thru
- Average queue length after placing an order at the Drive-Thru
- Average queue length before placing an order at the Lobby
- Average time to fill an order at the Drive-Thru
- Average time to fill an order at the Lobby
- Average utilization of Lobby employee
- Average utilization of Kitchen employee
- Average utilization of Drive-Thru window employee
- Average utilization of Drive-Thru sign employee

Table 1: Sensitivity Analysis Summary

Simulated Scenario	**Original**	**Case 1**	**Case 2**	**Case 3**	**Case 4**	**Case 5**	**Case 6**	**Case 7**
File Name	ORGSCE	CASE1	CASE2	CASE3	CASE4	CASE5	CASE6	CASE7
Conditions		No Balking	No Balking 2 DT Window Servers 2 DT Windows	Balking 2 Lobby Servers 2 DT Window Servers	Balking LBuf=14 BeforeDT = 14	Balking 2 DT Window Servers 2 DT Windows	Under capacity	Over capacity
Drive-Thru customers leaving because of full queues	166	309	269	134	161	155	449	0
Lobby customers leaving because of full queues	233	84	79	218	220	221	2412	0
Average time Drive-Thru customer spent in the system	53.41	165.24	106.64	46.27	78.85	51.06	72.84	10.10
Average time Lobby customers spent in the system	63	56.01	54.8	54.94	86.4	65.26	62.98	59.11
Average waiting time for the Drive-Thru customer before ordering	112.69	114.24	71.05	98.06	178	84.71	114.00	0
Average waiting time for the Drive-Thru customer after orderin	33.06	33.62	19.5	28.34	31.99	23.89	33.06	0.21
Average waiting time for the Lobby customer before ordering	39	28.02	25.78	31.79	66.17	41.55	47.44	0

Average queue length before placing an order at the Drive-Thru sign	7.78	7.77	7.67	7.75	13.53	7.71	7.87	0
Average queue length after placing an order at the Drive-Thru sign	1.98	1.98	1.95	1.98	1.98	1.96	1.98	0.01
Average queue length before placing an order at the Lobby	7.02	4.88	4.69	6.93	12.44	7.06	7.78	0
Average time to fill an order at the Drive-Thr	42.18	42.77	28.78	37.62	41.13	32.94	156.21	9.37
verage time to fill an order at the Lobby	13.08	13.34	13.2	13.42	13.47	13.4	60.69	13.42
Average utilization of Lobby employee	100	100	99.98	59.35	100	100	99.93	75.77
Average utilization of Kitchen employee	14.94	14.61	20.47	19.07	14.72	19.2	15.59	11.14
Average utilization of Drive-Thru window employee	100	99.98	88.69	62.87	99.95	74.03	100	67.26
Average utilization of Drive-Thru sign employee	38.34	38.12	50.71	40.6	37.12	44.24	36.66	26.47

4 ORIGINAL SENARIO

Scenario Description: This project consists of the Simulation and Animation of the Drive-Thru (DT) and the lobby sections of a fast food restaurant. In the DT operation, customers (cars) arrive at the station, pull up to the DT sign, place an order, form a queue before and after placing an order if there are any customers seeking service, pay and receive the order and leave the system. In the lobby section, customers go to the lobby, walk to the cashiers area, form a queue to order if there are any other customers seeking service, place an order, pay, wait to receive the order, go to tables area, eat and leave the system.

This operation is served by four employees or servers which are assigned to the following main areas of responsibility: Drive-Thru sign, Drive-Thru window, Kitchen and Lobby. However, there are shared responsibilities for each station or machine in the restaurant based on pre-assigned priorities. There are also other stations with a dedicated server.

Results: Simulation results show that the amount of Lobby customers rejected is larger than Drive-Thru customers. Average time in the system is larger for Lobby customers than Drive-Thru customers. All queues lengths are almost always at full capacity. The Lobby is by far the station which is idle the larger amount of percentage of time. The kitchen and Drive-Thru sign employees are idle the largest amount of percentage of time. The Lobby and Drive-Thru window employees are always busy.

4.1 Case 1

Scenario Description: This scenario presents the case where the Drive-Thru customers do not balk to the Lobby if the queue in the Lobby is full. This condition is to be maintained even if the queue is not full to the capacity.

Results: Simulation results show that the amount of Drive-Thru customers rejected is larger than Lobby customers. The average time in the system is larger for the Drive-Thru customers than Lobby customers. The queue lengths for the Drive-Thru section are almost always full but the queue at the Lobby is not full all the time. The Lobby is by far the station which is idle most of the time. The kitchen and Drive-Thru sign employees are idle the largest amount of percentage of time. The Lobby and Drive-Thru window employees are always busy.

4.2 Case 2

Scenario Description: This case presents a scenario where Drive-Thru customers are not allowed to go to the Lobby if the queue for ordering is full. There are two Drive-Thru windows and two employees to serve them. These conditions are to be maintained even if the queue at the Lobby can accept more customers.

Results: Simulation results show that the amount of Drive-Thru customers rejected is larger than Lobby customers. The average time in the system is larger for the Drive-Thru customers than Lobby customers. The queue lengths for the Drive-Thru section are almost always full but the Lobby queue is not full all the time. The Lobby is the station with the largest percentage of idle time followed by the Lobby delivery station and Drive-Thru windows. The kitchen employee utilization is very low followed by the Drive-Thru sign employee. The Lobby server is busy almost all the time.

4.3 Case 3

Scenario Description: This case presents a scenario similar to the original problem but there are two employees at the Lobby and two employees at the Drive-Thru window. Balking from the Drive-Thru sections to the Lobby is allowed again.

Results: Simulation results show that the amount of Lobby customers rejected is larger than Drive-Thru customers. The average time in the system is slightly larger for Lobby customers than Drive-Thru customers. All queue lengths are almost full all the time. The Lobby station is idle about half the time. All employees utilization are very poor.

4.4 Case 4

Scenario Description: This case presents a scenario where the queues before ordering at the Drive-Thru and the Lobby have capacity for 14 customers. Balking from the Drive-Thru sections to the Lobby is allowed again.

Results: Simulation results show that the amount of Lobby customers rejected is larger than Drive-Thru customers. The average time in the system is slightly larger for Lobby customers than Drive-Thru customers. All queue lengths are almost full all the time. The Lobby station is idle about half the time. The Lobby and Drive-Thru window employees are always busy. The Kitchen and Drive-Thru sign employees are very poorly utilized. See Appendix E for more detailed simulation results.

4.5 Case 5

Scenario Description: This case presents a scenario where Drive-Thru customers are allowed to go to the Lobby if the ordering queue is full. There are two windows at the Drive-Thru and two employees to serve them. The remaining details of the original scenario are maintained.

Results: Simulation results show that the amount of Lobby customers rejected is larger than Drive-Thru customers. The average time in the system is slightly larger for Lobby customers than Drive-Thru customers. All queue lengths are almost full all the time. The Lobby and Drive-Thru window stations are idle a very significant amount of time. The Lobby employee is always busy. The Kitchen and Drive-Thru sign employees are very poorly utilized.

4.6 Case 6

Scenario Description: This case presents a scenario where Drive-Thru customers and Lobby customers arrive in such high frequency rate that the operation becomes insufficient due to under capacity in relation to the demand. The remaining details of the original scenario are maintained.

Results: Simulation results show that the amount of Lobby customers rejected is larger than Drive-Thru customers. However average time in the system is larger for Drive-Thru customers than Lobby customers. All queue lengths are almost at maximum capacity. The Lobby station has the highest percentage of idle time from all stations. The Kitchen and Drive-Thru sign employees are idle most of the time and Lobby and Drive-Thru window employees are almost always busy..

4.7 Case 7

Scenario Description: This case presents a scenario where Drive-Thru customers and Lobby customers arrive in such low frequency rate that the operation becomes oversized due to over capacity in relation to the demand. The remaining details of the original scenario are maintained.

Results: Simulation results show that there are not customers rejected because of full queues. The average

time in the system is larger for Lobby customers than Drive-Thru customers. All queues are normally empty. The Drive-Thru sign, Lobby cashier and Lobby station have the highest percentage of idle time. The Kitchen and Drive-Thru sign employees have the highest percentage of idle time.

5 CONCLUSIONS

5.1 Lobby Section

The number of Lobby customers leaving the system because of full queues or waiting lines is larger when the Drive-Thru customers are allowed to balk to the Lobby. The original scenario, Case 3, Case 4 , Case 5 and Case 6 represent this condition. The scenario introduced in Case 7 is an exception of this behavior due to the over capacity.

The average time Lobby customers spent in the system is not significantly affected unless the queues or waiting lines are made larger such as in Case 4. Scenarios represented in Case 2 and Case 3 generate the smallest times in the system.

The average waiting time for the Lobby customers before ordering is smaller if Drive-Thru customers are not allowed to balk to the Lobby. Scenarios represented in Case 1 and Case 2 generate the smallest times in the system.

The average time to fill an order at the Lobby does not change significantly under all simulated scenarios at the given conditions. Other factors need to be modified and analyzed in order to reduce the average time.

5.2 Drive-Thru Section

The number of Drive-Thru customers leaving the system because of full queues or waiting lines is larger when balking to the Lobby is not allowed such as in Case 1 and Case 2 and when the under capacity scenario is presented such as in Case 6. This means that the Drive-Thru section of the restaurant is not able to satisfy the demand for the Drive-Thru arrival rate.

The average time Drive-Thru customers spent in the system is larger when balking is not allowed to the Lobby. The average time in the system is reduced when balking is allowed because of the smaller times spent in the system by the Drive-Thru customers becoming Lobby customers. The average time is minimized when there are 2 Lobby servers and 2 Drive-Thru window servers such as in Case 3. Scenarios represented by Case 1 and Case 2 show these worst case scenarios.

The average waiting time for the Drive-Thru customer before ordering is not dependent on balking or not balking to the Lobby. This observation can be explained by the spread presented by cases with and without balking. If 2 Drive-Thru windows and 2 Drive-Thru window servers are available this time is reduced such as in Case 2. This time is directly proportional to the queue length. If the queue length is increased then this time also increases.

The average waiting time for the Drive-Thru customers after ordering is not dependent on balking or not balking to the Lobby. If 2 Drive-Thru windows and 2 Drive-Thru window servers are available this time is reduced. Scenario represented in Case 2 generates the smallest time in the system. The average queue lengths before and after placing an order at the Drive-Thru are full in all simulated scenarios at the given conditions. Other factors need to be modified and analyzed in order to reduce the queue lengths. The over capacity scenario presented by Case 7 is an exception to this condition.

The average queue length before placing an order at the Lobby is reduced if Drive-Thru customers are not allowed to balk to the Lobby. Otherwise, this queue length is almost full in all simulated scenarios. Other factors need to be modified and analyzed in order to reduce the queue length. The over capacity scenario presented by Case 7 is an exception to this condition.

The average time to fill an order at the Drive-Thru is independent of balking or not balking. The average time is reduced if 2 Drive-Thru windows and 2 Drive-Thru window servers are available. Scenario presented in Case 5 represents this condition.

5.3 Labor

The average utilization of the Lobby server is normally 100 %. If 2 Lobby servers are present, individual utilization is about 60 %. This means that 2 Lobby servers are needed to maintain the operation more effectively, unless work load is reassigned to somebody else.

The average utilization of the Kitchen server runs about 20 % in all simulated scenarios. The Kitchen server can carry additional workload easily. If additional workload is transfer from the Lobby server, overall utilization is higher and only one Lobby server may be needed.

The average utilization of the Drive-Thru window server is independent of balking or not balking since queues are normally full. Average utilization is about 100 % under the original scenario, Case 1and Case 4. Scenario represented in Case 3 generates the lowest server utilization.

The average utilization of the Drive-Thru sign server is independent of balking or not balking. Average

utilization is under 50 % under all simulated scenarios. The Drive-Thru server assigned to the sign can carry additional workload. Scenario represented in Case 2 generates the highest server utilization.

REFERENCES

AT&T ISTEL. 1995. Introduction to Witness.

AT&T ISTEL. 1995. Witness Training Manual.

COLLINS, M.J. 1995. Benchmarking with simulation: how it can help your production operations. Production Journal, 50-52.

LENZ, J. and NEITZEL, R. 1995. Cost modeling: An effective means to compare alternatives. Journal of Industrial Engineering, 18-19.

PRISTKER B. ALAN. 1986. Introduction to Simulation and SLAM II, John Wiley.

SMITH, D. J. 1994. Computer simulation applications in service operations. The Service Industries Journal, 395-408.

AUTHOR BIOGRAPHIES

KAMBIZ FARAHMAND is currently an Associate Professor of Industrial Engineering at Texas A&M University-Kingsville. His primary teaching and research activities are in the areas of design, implementation, and control of manufacturing systems, production and inventory control, and simulation. He earned a B.S. in Petroleum Engineering from University of Oklahoma. He completed his M.S. and Ph.D. in Industrial Engineering at University of Texas at Arlington. He is currently the president of the Coastal Bend Chapter of IIE, member of ORSA, HFES, ASEE, and APICS.

ALEJANDRO FRANCISCO GARZA MARTINEZ completed his M.S. in Industrial Engineering from Texas A&M University-Kingsville. He attended Institute Tecnologico de Matamoros where he obtained a Bachelor of Science degree in Electromechanical Engineering with minor in Production in 1983. He joined Delphi Interiors and Lighting Systems, former Inland Fisher Guide, a division of General Motors Corporation in 1985. He has worked in several Manufacturing Operations and Engineering Management positions.