Final Project: Simple Restaurant Case

DS 632 System Simulation

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Introduction

The Simple Restaurant is a problem where customers enter the restaurant with a varying arrival rate for each hour interval. The customers get in the cashier queue to place their orders. Once they place their order, the kitchen staff start work on preparing the meal. Once the meal is ready, the customer receives their meal and sits at an empty seat at the dining area or leaves if the order is to-go. With this model, we want to analyze if the workflow or use of resources can be improved to maximize profit while maintaining high customer satisfaction.

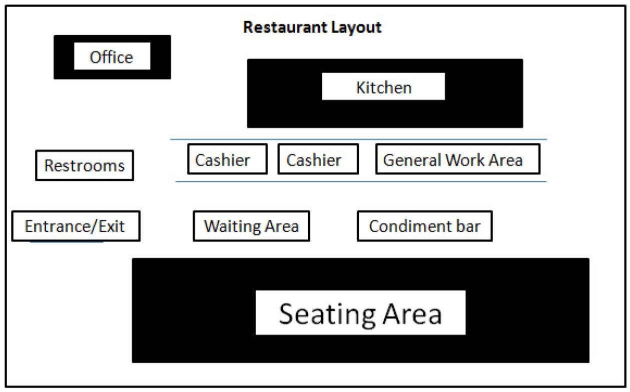

Figure A.16: Restaurant Layout

Description of the enterprise

The Simple Restaurant has the layout shown in Figure A16. They are open for 12 hours, from 8:00 am to 8:00 pm. They offer dine-in or to-go food. A waiting area is provided for customers to wait after placing their order at the cashier. To-go orders are prioritized in the kitchen over dine-in orders. Once an order is made, it is distributed to the customer who ordered it in the waiting area. Customers who wait over 30 minutes for their food become unsatisfied. If they are a to-go customer, they leave the restaurant; if the customer orders dine-in, they seat themselves (or wait in a line until seating is available). The restaurant staff is made of two Managers, five General Workers, and eight Kitchen workers.

Description of the system to be simulated

The restaurant depicted in Figure A.16 has many areas within the layout. Only the Entrance (source), Exit (sink), Cashiers (server), Kitchen (server), Waiting Area (combiner), and Seating Area (server) are utilized within Simio. Additionally, there are workers for each type of worker: Managers, KitchenWorkers, and GeneralWorkers. Lastly, entities were made to represent groups of customers (Customer), food items ordered (Food), and messes left at dine-in tables (Mess).

Customers arrive at the entrance and follow the path to the Cashier to place their order (to-go or dine-in). Based on the case description, 90% of customers dine-in and 10% order to-go. Alternatively, Customers can leave the system and balk (Exit_Balk) if the Seating Area has over five Customers waiting for a table. After a Customer places their order at the Cashier, they go to the Waiting Area to wait for their food to be made and delivered to them. One Food entity is created for each member of a Customer group. Food is produced within the Kitchen once the order is placed at the Cashier. Once the Food is completed, it is distributed by a worker to the associated Customer in the Waiting Area. After combining Food and Customers, the Customer exits the restaurant (Exit_ToGo) if they have a to-go order, or proceeds to the Seating Area if they have a dine-in order. After eating, dine-in Customers leave the Seating Area, leaving a Mess on the table, and leave the restaurant (Exit_DineIn). If there is a Mess at a table, a worker must clean it before another Customer can utilize it.

There are three types of workers within the restaurant: Managers, Kitchen Workers, and General Workers. Managers prioritize helping make orders in the Kitchen, but can also distribute orders to Customers in the Waiting Area. General Workers take orders, distribute orders, and clean the Mess off tables. Kitchen Workers' only job is to make Food in the Kitchen. When workers are idle, they return to their home nodes until they are needed to complete a task.

Description of the input and how it was obtained

Our team's Simple Restaurant simulation was obtained from our class's textbook, "Simio and Simulation: Modeling, Analysis, Application 5th Edition by Smith, Sturrock, and Kelton". We are given the data for staffing, operation, and customers. Under other circumstances, our team would have collected data of an actual restaurant for the input parameter. The quantitative data, like the arrival-rate schedule, would have been cleaned with the help of a statistical analysis tool. A distribution fit or a schedule table would be outputted and incorporated in the model. The qualitative data, such as a worker's movement layout, would have assisted with the model's creation and logic. Due to the textbook's problem description, all inputs are located within the book.

The workers are paid the following hourly rates: Managers ($10/hr), Kitchen Workers ($7.50/hr), and General Workers ($6/hr). The Seating Area has 25 tables that can accommodate 25 Customer groups. They also have a maximum of two cash registers to receive all orders. The time for workers to complete tasks/serve Customers is in the table below, along with the number of workers allotted to each task.

Table A.14: Service-time (in minutes) and Worker Information (in minutes)

Service	Service-time distribution	Number of workers
Taking orders	exponential(mean 0.5)	1-2
Making orders	tria(2, 5, 9)	5-10
Cleaning tables	exponential(mean 0.5)	1-2
Distributing	—	1-3

The hours of operation within this establishment are from 8:00 am until 8:00 pm (12 hours), but guests can stay in the restaurant until they finish eating their meals. Additionally, the restaurant offers to-go orders, which 10% of Customers choose, and are a priority for the Kitchen Workers over dine-in orders. Table A.13 was given in the textbook to demonstrate the average arrival rate schedule of customers on a busy day. These Customers arrive in group sizes one (10%), two (30%), three (40%), or four (20%) with a given probability that represents a non-stationary Poisson process. The Customer entity represents one group arriving with Customer Group Size being determined by in the previous sentence's distribution. This group size affects the Food preparation time, as in the Food for a group of four takes four times the time to make than Food for a group of one. Thus, the Customer orders one Food per group member, and each Food takes two minutes to nine minutes to make, with an average of five minutes (triangular(2,5,9)). Once all Foods are completed, they are brought as one order to the Customer group in the Waiting Area. All Customers take 25 minutes to 60 minutes to eat, with an average of 45 minutes (triangular(25,45,60)), regardless of the group size. If Customers have to wait more than 30 minutes to receive their Food after ordering, they become dissatisfied.

Table A.13: Restaurant arrival-rate schedule for an average busy day

Time interval	Groups per hour
8:00 am - 9:00 am	39
9:00 am - 10:00 am	35
10:00 am - 11:00 am	48
11:00 am - 12:00 pm	44
12:00 pm - 1:00 pm	49
1:00 pm - 2:00 pm	39
2:00 pm - 3:00 pm	26
3:00 pm - 4:00 pm	20
4:00 pm - 5:00 pm	39
5:00 pm - 6:00 pm	48
6:00 pm - 7:00 pm	37
7:00 pm - 8:00 pm	31

After a dine-in Customer finishes their food in the seating area, a Mess is created and needs to be cleaned before the table is available for another Customer to use it. General Workers come to clean the Mess (at a rate of exponential(.5)) so that the dine-in customers in the Seating Area queue can sit down at a clean table.

Approach to building the Simio model and description

Based on the description above, the layout of the model is shown in Figure 1 and the object type is in Table 1. Paths connect objects. Managers, Kitchen Workers, and General Workers have their respective home nodes and travel networks, giving them a place to go when idle and paths to travel to perform their associated tasks.

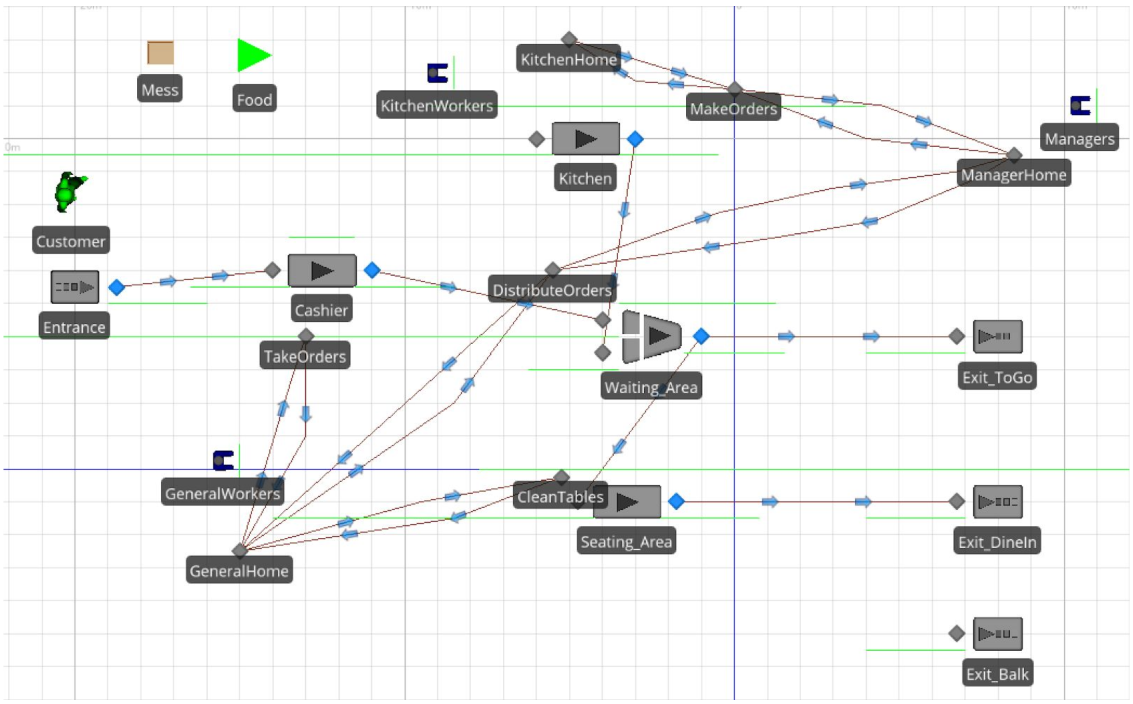

Figure 1: Entities and Objects Layout in Simio (Not Draw to Scale)

Table 1: Simio Model Objects

Simio Object Type	Names in the Model
ModelEntity	Customer, Mess, Food
Source	Entrance
Server	Cashier, Kitchen, Seating_Area
Worker	GeneralWorkers, KitchenWorkers, Managers
Combiner	Waiting_Area
BasicNode	GeneralHome, KitchenHome, ManagerHome, TakeOrders, MakeOrders, DistributeOrders, CleanTables
Sink	Exit_ToGo, Exit_DineIn, Exit_Balk

At the Entrance, the Customer type and group size is determined, with green representing dine-in customers and red representing carry out customers. The maximum time is 12 hours so there are no customers coming after 8:00 pm.

At the Cashier, GeneralWorkers are seized/released based on server status. When a customer has placed an order, the Customer entity is sent to Waiting_Area. Meanwhile a Food entity is created and sent to Kitchen. Food for to-go orders are given higher priority. The Customer and Food entities are both assigned the same order number so that they can be matched at Waiting_Area. The time when the customer places the order is recorded as *ModelEntity.tmp*.

At the Kitchen, resources who make orders are seized from a list consisting of KitchenWorkers and Managers, and KitchenWorkers has higher priority to be seized when both workers are available. The worker is released after the service.

At the Waiting_Area, resources who distribute orders are seized and released in the same fashion as in the Kitchen, except GeneralWorkers replaces KitchenWorkers. At this point, the Customer entity and the Food entity with the same order number are combined. The model substracts *ModelEntity.tmp* from the current time in the system to get WaitingTime for the food, and this value is tallied for each Customer. If WaitingTime is over 30 minutes, the customer gets unsatisfied, otherwise satisfied. Customers who ordered food to go exit the system through Exit_ToGo, while dine-in customers proceed to Seating_Area.

At the Seating_Area, A Mess entity is created after a customer is seated and finished eating, representing a dirty table that needs to be cleaned. The Mess entity is then sent back to the input of Seating_Area. A decision now has to be made whether the incoming object is Customer or Mess. If it’s a Mess, GeneralWorkers is seized to clean the table. If it's a Customer, Mess is created and GeneralWorkers is released and so forth. Customer leaves through Exit_DineIn after finishing their meal.

The model checks if the system is empty (no customers eating at Seating_Area) after 12 hours since the restaurant is open. If it is empty, close the restaurant (EndRun); if it’s not empty, the model keeps running until customers finish dining then close the restaurant. The majority of the steps mentioned above were done through add-on processes.

Since the restaurant owner wants to improve the service, reduce cost, and increase profit in the restaurant, we set the number of tables in the seating area and the number of each type of worker as model Properties. The changes in these controls influence the outputs and recommendations in the following sections.

Description of the Simio output

After one simulation run, it takes 772 minutes (about 12.8 hours) to clear all the customers in the restaurant. The pivot grid in the Result page of Simio gives us the results of the model. We also assigned several specific statistics that we are especially interested to know.

Customer, Balk:

Customer	[Population]	Throughput	NumberCreated	Total	459.0000
			NumberDestroyed	Total	459.0000
		FlowTime	TimeInSystem	Average (Minutes)	44.3958
				Maximum (Minutes)	91.9362
				Minimum (Minutes)	0.0238
				Observations	459.0000
		Costs	CostPerItem	Average (USD)	0.0451
				Maximum (USD)	0.2803
				Minimum (USD)	0.0000
				Observations	459.0000
		Content	NumberInSystem	Average	26.3877
				Maximum	51.0000

Figure 2: Output of Customer Object

Figure 2 is a summary of the groups of customers. Some other statistics we are interested in are shown in Table 3. Table 4 shows the average utilization rate of workers. We found that the current operation is not sufficient enough.

Table 2: Customer Statistics

	Group of customers	DineIn	ToGo	Balked	Total
	459	353	40	66	459
Satisfied		353	30		383
Unsatisfied			10		10

Table 3: Other Statistics

Total Number of Foods (= Number_Ordered)	1054
The average number of customers in a group	2.3
Customer's Average TimeInSystem	44.39 mins
Sales (User Specified)	$9,486
Profit (User Specified)	$8,070

Cashier:

Scheduled Utilization is about 13%, which means 13% of the time, the cashiers are busy. The average time to take an order is about 0.5 minute.

Kitchen:

Scheduled Utilization is about 73%, which means 73% of the time, the kitchen workers are busy. The average time to make an order in about 5.3 minutes.

Seating Area:

Scheduled Utilization is about 80%, which means 80% of the time, the tables are occupied. The average time the groups of customers spend sitting is about 21.8 minutes.

Waiting Area:

We tallied the waiting time as a user-specified result. The average time waiting in the waiting area is about 11 minutes.

RestaurantCaseSt...	RestaurantCaseStudy	[Object]	Costs	TotalCost	Total (USD)	1,415.7748
		Profit	UserSpecified	OutputValue	FinalValue (USD)	8,070.2252
		Sales	UserSpecified	OutputValue	FinalValue (USD)	9,486.0000
		SatisfactionRate	UserSpecified	OutputValue	FinalValue	0.9746
		TotalWaitingTime	UserSpecified	OutputValue	FinalValue (Minutes)	4,369.2769
		WaitingTimeTally	UserSpecified	TallyValue	Average (Minutes)	11.1178
					Maximum (Minutes)	35.0905
					Minimum (Minutes)	2.3971
					Observations	393.0000

Figure 3: Case Study Financial Output

As we expected, customers spend less time in the cashier than at the dining tables while spending more time waiting for food.

Workers:

Table 4: Worker Utilization Output

Worker	GeneralWorkers	[Population]	Capacity	ScheduledUtilization	Percent	10.28
Worker	KitchenWorkers	[Population]	Capacity	ScheduledUtilization	Percent	75.16
Worker	Managers	[Population]	Capacity	ScheduledUtilization	Percent	62.31

Cost, Profit, and Sales:

We assigned Costs of workers and Sales of food in the system. The total cost of workers working and being idle in the system is $1,415 for one day.

We set up seven different scenarios in the experiment, shown in Figure 2. The model's output includes the overall Satisfaction Rate, the number of customers who balk, average wait time for food, total cost, profit, and sales. We sought to increase profit by reducing the number of balks and costs while maintaining a high Satisfaction Rate. We compared six other scenarios that we specified with the base scenario with 10 replications each, using different ranges for Controls, see Figure 3. Based on the current arrival, we found that at least 34 tables (i.e., nine extra tables) are needed to reduce the number of balks due to long waits to 0.

Figure 3: Simio Scenarios

Scenario		Repli...		Controls				Responses					
Name	...	...	C...	SeatingArea...	NumManagers	NumKitchenWo...	NumGeneralWor...	SatisfactionRate	NumBalk	AvgWaitTimeForFood (Min...	TotalCost	Profit	Sales
BaseScenario	...	10	of	25	2	8	5	0.977995	51.5	11.7481	1427.37	8215.23	9642.6
Half_KitchenWorker	...	10	of	25	2	4	5	0.0560082	0	204.002	1517.13	9505.17	11022.3
Increase_Kitchen&Half...	...	10	of	25	1	10	5	0.977995	51.5	11.7481	1492.25	8150.35	9642.6
Increase_SeatingArea	...	10	of	34	2	8	5	0.875392	0	16.0933	1427.6	9314.8	10742.4
Half_Manager	...	10	of	25	1	8	5	0.673926	32.4	23.7119	1313.74	8940.86	10254.6
Half_GeneralWorker	...	10	of	25	2	8	3	0.996585	49.9	10.7722	1269.77	8421.43	9691.2
OptimizedScenario	...	10	of	30	1	9	3	0.902868	9.9	15.0563	1234.08	9201.42	10435.5

The Optimal Scenario based on our experiment is to increase the tables in the Seating Area to 30, reduce one manager, meanwhile hire one more Kitchen Worker, and reduce 2 General Workers. Since there should be at least one manager on-shift all the time, and the manager should prioritize helping out in the kitchen. We think this is reasonable, since as shown in Table 4, the GeneralWorkers are idle in the system around 90% of the time, and Managers are idle in the system about 32% of the time. Given that there is a limit of kitchen space, which says only ten people can work in the kitchen at the same time, otherwise, it will be over-crowded, we think that another reason the Optimal Scenario works is that the sum of the total number of manager and kitchen workers in the Optimal Scenario will be precisely one so that we make sure manager workers are fully utilized.

Recommendations for improving the system

After analyzing the different scenarios, we find that increasing the seating area, reducing the number of managers, expanding the kitchen workers by one, and reducing general workers would be optimum.

In the last scenario, which we named "Optimized Scenario," we show the best conditions in which they can operate and maximize the profit while reducing cost. In this scenario, they would have 30 capacity in the sitting area (a reasonable increase of 5 tables), 1 Manager, 9 Kitchen workers, and three general workers. Since, in real life, it is likely that any random worker does not show up, we recommend hiring one more general worker just to be covered at all times and not risk lowering customer satisfaction. Based on our experiments, the last scenario, which is the Optimal Scenario yields a much lower number of balks (around 10), quite high satisfaction rate (around 90%) and high profit ($9,201).

Conclusion and recommendations for future work

After analyzing the current restaurants, there are a few changes our team is suggesting to improve his expectations to open a similar restaurant elsewhere. The owner should increase seating tables, the number of kitchen workers, and decrease the number of managers and general workers to improve his business. With these few changes and as long as the other input parameters are not altered, our team expects the owner to decrease his total cost while improving the sales. These adjustments increase his daily profit by about $1,000 daily. In terms of our model, a larger sampling size and an adequate warm-up time may help to make the model better in the future.

References

Simio, LLC. "An Introduction to Simio for Beginners." *Simio Production Scheduling and Simulation Software*, www.simio.com/resources/white-papers/Introduction-to-Simio/.

Smith, Jeffrey S., et al. *Simio and Simulation: Modeling, Analysis, Applications*. Simio LLC, 2018.

Models Referenced:

DiningTable.spfx

IceCreamStoreClosesNicely.spfx

Model_09_01.spfx

Model_9_2.spfx

Model_10_3Balking.spfx