INCREASING EFFICIENCY OF LARGE UNIVERSITY DINING HALL USAGE

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ABSTRACT

Simulation historically was applied first to productivity and queuing problems in the manufacturing sector of the economy. More recently, simulation has been aggressively applied to such problems in other sectors of the economy, such as health care, warehousing, transportation, harbor operations, and service industries. We here describe the application of simulation to a heavily trafficked cafeteria.

Bursley Dining Hall is one of many large and busy cafeterias provided by the University of Michigan Housing Department. During peak hours (typically driven by class schedules), long queues develop at some buffet stations. For this project, the analysts simulated the current cafeteria operations and analyzed various improvement plans. The result was recommendations which significantly reduced queuing times and increased fiscal soundness of cafeteria operations.

Keywords: Service industry, food service, capacity planning, discrete-event simulation, bottleneck analysis.

1. INTRODUCTION AND SYSTEM DESCRIPTION

Discrete-event process simulation, historically, was first typically used in the manufacturing sector of the economy. More recently, its use has expanded into other sectors such as health care delivery, warehousing, transportation, maritime and harbor operations, and service industries. For example, in the transportation sector, (Nanthavanij et al. 1996) undertook performance analyses of car park systems. In the service-delivery sector, (Otamendi et al. 2008) used simulation to manage resources at an international airport. In the health care delivery sector, (Lote, Williams, and Ülgen 2009) used simulation to optimize resource allocation in a medical testing laboratory. Likewise, (Williams, Karaki, and Lammers 2002) used simulation to establish cost-effective cashier staffing policy in a large retail store.

Bursley Dining Hall is one of several cafeterias run by the University of Michigan Housing Department. This cafeteria provides the university community with full-service dining and many options suitable for the various preferences of an international clientele of faculty, students, and approved (invited) visitors. Its function and operation are rather like those of a *mensa* at a German university. Tourist guidebooks often recommend a *mensa*, touting its prices, selection, and quality, to "those who can produce a student ID." Hence the cafeteria has many food stations (e.g., Harvest Bar, Pizza, Ice Cream), each with its own server queue. Stations serving the daily entrees are staffed individually; drink stations and other food bars are periodically replenished by Bursley staff throughout a shift also.

2. PROBLEM FORMULATION AND OPERATIONS OVERVIEW

The simulation analysis undertaken was formulated with the objective of recommending changes to operational policy and equipment availability to decrease queue lengths and waiting time, thereby improving service and increasing incoming revenue. Surveys of cafeteria customers indicated that decreased queuing times would increase income both by serving more customers (balking at the queues being frequent) and increasing the average purchase per customer. Cafeteria managers explained to the simulation team that the environment is highly dynamic, with many food choices available, including different "daily specials" during each week. The dining hall is open ten hours each day, seven days per week, during each semester (three per academic or calendar year) that the University is in session.

Diners entering the cafeteria first have their entry card (student, instructor, or approved visitor) approved and then go to the main buffet queue. Diners then obtain a beverage and visit one of the Salad, Pizza, or Harvest stations. Then the diner goes either to a table to eat, or visits the Ice Cream station. After eating the main meal, some diners who did not visit the Ice Cream station previously will do so ("I didn't want the ice cream to melt right away"). The various food stations are staffed individually and independently; that is, workers do not, due to operational constraints, move from a station temporarily idle to a different station with a long queue.

3. DATA COLLECTION

Data concerning cafeteria operations were collected partly by surveys and partly by direct observation during the most busy times during the 10-hour shifts. These observations supported the following assumptions built into the simulation model:

1. If entrees run out at the main buffet queue, customers will wait until more entrees are provided.
2. Diners arrive in groups of one. Even if, as is common, friends come in a group, they will typically travel through the service areas autonomously before rejoining at a table. This customer behavior is in sharp contrast to the "size of group" consideration typical of, and requiring modeling attention, at restaurants where customers are seated at a table or booth and then order (Godward and Swart 1994).
3. Each student selects exactly one beverage.
4. No diner ever has to wait for a table to sit down and eat.
5. All queues have a first-in-first-out (FIFO) discipline.

Even very casual and immediate observation revealed that the most persistent, longest, and most notorious queues form at the main buffet and the ice cream stations. Queues often form, but are less conspicuous, at the Harvest Bar or Salad stations. Random selection of customers (sample size 63) indicated that 20% prefer to buy ice cream along with the rest of the meal, 70% prefer to eat the meal and then return for ice cream, and 10% do not buy ice cream at all. Of the diners who wish to buy ice cream before eating the main meal, 35% will not balk, but 65% will balk if the queue is eight or longer. Of the diners who intend to purchase ice cream after eating the main meal, 80% will not balk; the other 20% will balk if the queue is eight or longer. By contrast, no diner will balk at the main buffet queue – that is where the diner obtains the principal entrée of his or her choice.

4. DATA ANALYSIS

Data concerning station service times and downtimes, collected by stopwatch, were entered into Microsoft Excel® workbooks and subsequently analyzed using the Stat::Fit® (Grove and Coddington 2005) distribution-fitting software tool. To minimize or avoid the Hawthorne effect (Martinich 1997), these observations were collected as quietly and unobtrusively as possible. These analyses produced the following recommendations for distributions to use in the simulation model:

Table 1. Service and Downtime by Location

Location	Service	DT Freq.	DT Length
Door	0.09 min	Never	None
Buffet	W(1.1,0.3)	15 minutes	0.18 min
Drink	0.3 min	100 people	1 min
Salad	U(1.0,0.2)	30 minutes	1 min
Harvest	T(0.4,0.6,0.8)	30 minutes	1 minute
Pizza	0.4 min	15 minutes	0.1 min
Ice Cream	0.4 min	60 minutes	5 minutes

In this table, "W" signifies Weibull; "U," uniform; and "T," triangular. All times are in minutes except the interval between downtimes for the Drink station. Interarrival time at the door was exponential – as expected for independent arrivals (Scheaffer 2009) – with mean, at peak times, of 0.6 minutes. The highly predictable intervals between station downtimes and the downtime durations (to restock a station with food or drink) were treated as constants, since all their coefficients of variation were very low.

5. MODEL CONSTRUCTION, VERIFICATION, AND VALIDATION

The modeling team chose the ProModel® simulation software tool (Harrell and Price 2003) to construct a model of the dining hall; this software provides convenient constructions such as Locations, Entities, Resources (either static or mobile), Attributes, etc., the ability to write and reuse macros, plus powerful modeling logic which permits modeling balking and reneging in queues. For example, the model used Attributes to specify which stations (Salad, Pizza, etc.) diners would visit, Variables to access the number of diners in a queue, and Resources to provide service at stations and/or to restock the stations during their downtimes for that purpose.

Verification and validation of the model were performed using standard techniques such as structured walkthroughs of model logic among the simulation team, examination of the animation (which ProModel® conveniently provided) at slow speed, sending single entities through the system, removing all randomness temporarily to facilitate arithmetic checks, and comparing queue statistics observed in the dining hall with queue statistics produced by the model (Sargent 2004). After correction of garden-variety errors and oversights, the model queue performance metrics (average queue length, maximum queue length, average waiting time, and maximum waiting time) matched observational data within 5%, earning the model high credibility among the cafeteria managers.

6. RESULTS OF ANALYSIS

After verification and validation of the base model, eight scenarios were explored, as summarized in Table 2. These scenarios were run with ten replications of five hours each, with a warm-up time of one hour used to “burden” the model with high-traffic rates characteristic of the busiest times.

Table 2. 95% Confidence Intervals of Time (Minutes) in Main Buffet and Ice Cream Station Queues

Buffet Stations	Ice Cream Stations	Buffet Queue Time	Ice Cream Queue Time
1	1	[2.10,9.33]	[2.39,2.75]
2	1	[0.12,0.16]	[2.96,3.91]
1	2	[3.36,6.13]	[1.10,1.20]
2	2	[0.10,0.16]	[1.20,1.54]
2	3	[0.11,0.18]	[0.85,1.07]
2	4	[0.13,0.18]	[0.83,0.99]
2	5	[0.10,0.14]	[0.83,0.97]
2	6	[0.10,0.14]	[0.80,0.96]

The first row of this table represents the base case of one buffet station and one ice cream station. As expected, these results indicated negligible correlation (confirmed by hypothesis test) between queue statistics at the buffet station and queue statistics at the ice cream station. Furthermore, the results made it very clear that any ice cream stations above three would be of well-nigh zero incremental value; even a third station has minor incremental value. This sudden “plateauing” of improvement associated with additional servers is well-known and commonly observed in operations research queuing situations (Hillier and Lieberman 2009). On the other hand, having two main buffet stations instead of only one produces an average queue waiting time reduction of slightly more than five minutes.

7. CONCLUSIONS AND RECOMMENDATIONS

Marketing and financial analyses already undertaken by cafeteria management, plus surveys of frequent customers of the cafeteria (primarily students) indicated that for each average wait time reduction in queue of ten seconds, one more repeat customer will visit the cafeteria frequently during a semester, and the incremental revenue from this customer will then be $600 per semester. This high sensitivity of diners’ willingness to patronize the dining hall to queue waiting times is readily understandable in view of students’ and professors’ class schedules. A student considering eating at the dining hall often must attend classes both immediately before and immediately after eating, and must allow for significant walking time (often up to fifteen minutes) across campus to reach the dining hall from the prior class and/or to reach the next class from the dining hall. Likewise, a professor may need to teach and/or hold office hours both before and after eating.

Balancing these potential increases in patronage are the various costs associated with plausible investments in increased service capacity. Prevailing server wages are $9 per hour. An additional ice cream machine costs $2000 per semester (attributable to depreciation, maintenance, and operating costs). Therefore, cost-benefit analysis of the main buffet queue indicated that addition of one station (for a total of two) would increase revenue by slightly more than $18,000 per semester at a cost of slightly less than $9000 per semester, producing an incremental improvement of more than $9000 per semester. However, adding a third buffet station would make the “bottom line” worse. Similarly, adding one ice cream station (for a total of two) would produce an incremental improvement of about $4000 per semester, but a third station would actually make the financial outlook marginally worse.

Therefore, the simulation team recommended adding one main buffet station and one ice cream station. Standard engineering economic analyses, from the viewpoints of both cost-to-benefit ratio and rate of return (Sullivan, Wicks, and Koellling 2011), easily justified both of these capital investments. These recommendations were accepted and have resulted in the predicted revenue improvement and noticeable reductions in queue lengths and waiting times at those two stations (hence reducing time-in-system overall and accommodating more customers at busy times). Further analyses of “back-office” operations such as cooking, dishwashing, and others are planned.

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