A Traffic Simulation for a Drive-Thru Pharmacy

THIS FEATURE PRESENTS A TRAFFIC STUDY FOR DRIVE-THRU LANES AT A PHARMACY STORE. THE PRIMARY OBJECTIVE WAS TO COMPARE TRAFFIC CONDITIONS BEFORE THE ADDITION OF A SECOND DRIVE-THRU LANE TO CONDITIONS EXPERIENCED AFTER THE SECOND LANE BECAME OPERATIONAL. A SIMULATION MODEL WAS DEVELOPED TO DISCOVER THE BEST LANE CONFIGURATION THAT WOULD SIGNIFICANTLY REDUCE QUEUES AND WAITING TIMES.

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INTRODUCTION

The success of operating a drive-thru facility depends on queues and waiting times experienced by customers. Drive-thru facilities are required to provide queuing areas that can hold the expected maximum queue length. Rates of arrivals and service times affect the required queuing areas for drive-thru facilities.

Gattis recommended queuing areas for drive-thru facilities located at businesses such as fast food restaurants, banks, day care facilities, dry cleaners and car washes.[1] However, the study did not discuss queue lengths for drive-thru lanes at a pharmacy store.

This feature presents a traffic study for drive-thru lanes at a pharmacy store. Traffic counts were collected before and after the addition of a second lane at two drive-thru pharmacy stores in Indiana. Per the pharmacy's decision-makers, the two-lane configuration adopted at both stores included a full-service window lane and a lane for drop-offs only.

To further extend the investigation of the benefits of adding a second drive-thru lane, a simulation model was developed to compare three different double-lane configurations against the single lane. Three drive-thru lane configurations were examined and simulated:

- The window lane is full service (drop-off and pick-up) and the second lane is for use only to customers intending to drop off a prescription.
- Both lanes are full service.
- The window lane is for pick-up only and the second lane is for drop-off only.

Using the same traffic patterns (average arrival and departure rates) to study before and after conditions eliminated the effect of the randomness of service times as well as daily variation in drive-thru traffic. Therefore, the differences in the simulation model results can be attributed only to the changes in the drive-thru lane configuration.

DATA COLLECTION

Traffic counts were collected at two locations (Site A and Site B) in Indiana to compare the traffic conditions before and after the construction of the second lane. Continuous traffic counts (using programmable counters) were performed at one of the two pharmacy stores (Site B) for four days (from Friday, November 26, 2004 at 10:00 a.m. to Monday, November 29, 2004 at 10:00 a.m.) to determine traffic volumes for the existing single drive-thru lane.

From these traffic counts, peak-hour volumes for weekdays (p.m. peak-hour) and weekends (midday peak-hour) were determined. Drive-thru traffic was found to peak between 3:00 p.m. and 6:00 p.m. for both weekdays and weekends. No significant difference in observed traffic counts was found between weekends and weekdays. This peak period was verified with pharmacists at the two pharmacy stores considered in this study.

Drive-thru traffic for before and after conditions then was monitored by conducting hand-counts during the peak period for a typical weekday before and after the addition of the second lane. Traffic counts for the two drive-thru lanes were conducted a minimum of four weeks after the completion of construction of the second lane to allow customers to familiarize themselves with the new lane before traffic data collection.

Manual traffic counts included the collection of vehicle arrival time, service-start time, departure time, number of vehicles waiting to be serviced at arrival and type of service (drop-off or pick-up). Each day (a typical weekday) chosen for traffic collection had good weather conditions to assure that drive-thru traffic conditions were normal.

RESULTS OF DATA COLLECTION

Table 1 summarizes the general statistics of the data collected for single-lane drive-thru conditions during a typical weekday from 3:00 p.m. to 6:00 p.m. The maximum observed queue was four, which included one customer in service and three waiting customers. A queue, in this context, is a set of customers waiting for service.

The standard deviation for observed queues was found to equal 0.92. This means that the maximum queue can reach seven vehicles (the majority of measurements will lie within three standard deviations of the mean).

The two-lane configuration adopted (per the pharmacy decision-makers) at Sites A and B was a window lane for full service and a second lane for drop-off only. Drive-thru traffic for the two lanes then was monitored after completion of construction of the second lane.

Although traffic counts for after conditions were conducted nearly two months after the completion of construction of the second lane, observed traffic counts showed that no customer used the second lane at Site A and only three customers used the second lane at Site B.

Therefore, the observed results did not change significantly between before and after conditions. The addition of the second drive-thru lane (assigned only for drop-off customers) had no effect on the length of the maximum observed queue. The observed queue at the two locations for before and after conditions was as large as four vehicles.

Observed waiting times were slightly higher for Site A for the after conditions in comparison with the before condition and were lower for Site B for the after conditions. However, because very few customers used the second lane, changes in waiting times cannot be related to the addition of the second lane. Differences in observed waiting times could be attributed to the differences in service times and traffic patterns observed before and after adding the second lane.

For example, the observed service times were 148 and 131 seconds per customer for before and after conditions at Site B, respectively. Service time variations were attributed only to characteristics dealing with window attendant personnel, method of payment and other similar items.

Table 1. General statistics for single drive-thru lane during a typical weekday from 3:00 p.m. to 6:00 p.m.

	Site A	Site B
Number of customers	55	58
Average inter-arrival time between vehicles (seconds)	198	201
Drive-thru lane utilization* (percent)	59	73
Customer type (percent)		
Drop-off customers	25	25
Pick-up customers	75	68
Drop-off/pick-up customers	—	7
Overall average service time (seconds per vehicle)	116	148
Drop-off customers	54	72
Pick-up customers	137	163
Drop-off/pick-up customers	—	284
Average waiting time (seconds per vehicle)	70	158
Traffic mix distribution (percent)		
Passenger cars	58	64
Pick-up trucks	20	17
SUVs	15	14
Vans	7	5
Customer gender (percent)		
Male	35	34
Female	65	66

*Note: Lane utilization refers to the proportion of time that the drive-thru lane is busy handling customers.

Also, the observed inter-arrival time for the double-lane configuration at Site B was 177 seconds versus 201 seconds for the single-lane configuration. Shorter inter-arrival times indicate more customers per hour. This may put more pressure on the window attendant to work hard to keep the drive-thru customer satisfied.

Therefore, the observed reduction in waiting time before and after adding the second lane at Site B was a result of improved service and should not be attributed to the addition of the second lane. During the counting days for the double lanes, pharmacy employees were asked at both locations about their experience with the new second drop-off lane. They agreed that very few customers used the new lane and that the benefits of the second lane were minimal.

To further extend the investigation of the benefits of adding a second drive-thru lane, a simulation model was developed to compare traffic conditions of two different double-lane configurations in addition to the as-built (at Sites A and B) against the single lane.

The simulation model can more completely analyze the benefits of operating the second lane for drop-off only or full service. Also, the expected ultimate reduction in queues and waiting times due to the addition of a second lane can be estimated.

BEFORE/AFTER COMPARISON USING SIMULATION MODEL

A simulation refers to any analytical method meant to imitate a real-life system, especially when other analyses are too mathematically complex or too difficult to reproduce. Without the aid of simulation, a deterministic model (which means that the inputs are fixed) will reveal only a single outcome, generally the most likely or average scenario. To view alternative results for a different scenario, additional data collection is required to manually change the inputs in the model.

By building a simulation model, the effect of varying inputs can be automatically analyzed on outputs of the modeled system. For each uncertain variable (one that has a range of possible values), the possible values are defined with a probability distribution. The type of selected distribution is based on the conditions surrounding that variable.

A simulation model can consist of as many trials (or scenarios) as desired. During a single trial, the simulation model randomly selects a value from the defined possibilities (the range and shape of the distribution) for each uncertain variable. Therefore, simulation is a way to quickly generate and analyze many possible results.

To carry out a simulation using random inputs such as inter-arrival times and service times, probability distributions must be specified. In this simulation model, sequences of random points in time for arrivals and service times must be generated. Standard techniques of statistical inference are used to fit a theoretical distribution form (exponential) to the data and perform hypothesis testing to determine the goodness of fit.

If a particular theoretical distribution with certain values for its parameters is a good model for the service time data, a sample from this distribution is acquired when a service time is needed in the simulation. A theoretical distribution is a compact way of representing a set of data values. Law and Kelton provide a detailed discussion about simulation models.[2] The following steps briefly summarize the proposed simulation model:

- Fitting theoretical distribution form for inter-arrival and service times.
- At each customer's arrival time, the number of customers waiting in queue in all lanes is calculated. Theoretically, a customer tends to use the lane with the minimum number of waiting customers; however, some drivers may be skeptical about using the second drive-thru lane for reasons including less interaction with the attendant or fear that it offers slower service. Additionally, restricted sight distance upstream of the drive-thru lanes may not allow a driver to accurately ascertain the queue length in each lane and he/she may automatically choose the window lane in response. Therefore, the model incorporates the potential that some drivers will utilize only the first lane no matter the queuing in the lanes. In case of an equal number of waiting cars in the two lanes, the model assumes the driver will select the window lane.
- Start-service time can be calculated based on whether the previous customer still is in service. This can be done by taking the maximum of the current customer's arrival time and previous departure time.
- Departure time can be calculated by adding the service time to the start-service time.
- Service time depends only on the requested service (drop-off or pick-up). This means that service time for both drop-off and pick-up was entirely unaffected by the opening of a second drive-thru lane. These findings agree with rational thinking; the addition of a lane will not decrease the amount of time that certain services require. The effects of the second drive-thru lane are expected to be seen in the queue lengths and wait times. The addition of the second lane is

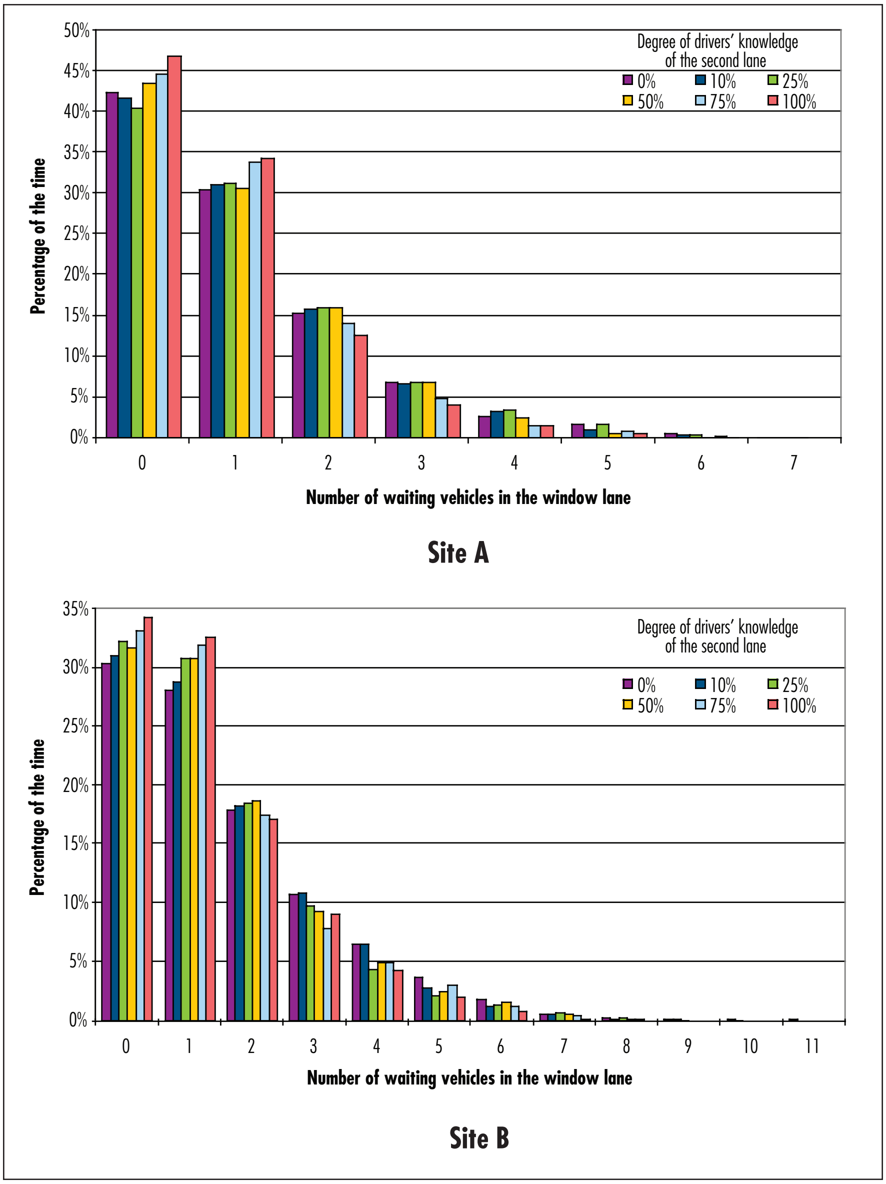

Figure 1. Queue results based on simulation model: "The window lane is full service and the second lane is for drop-off only."

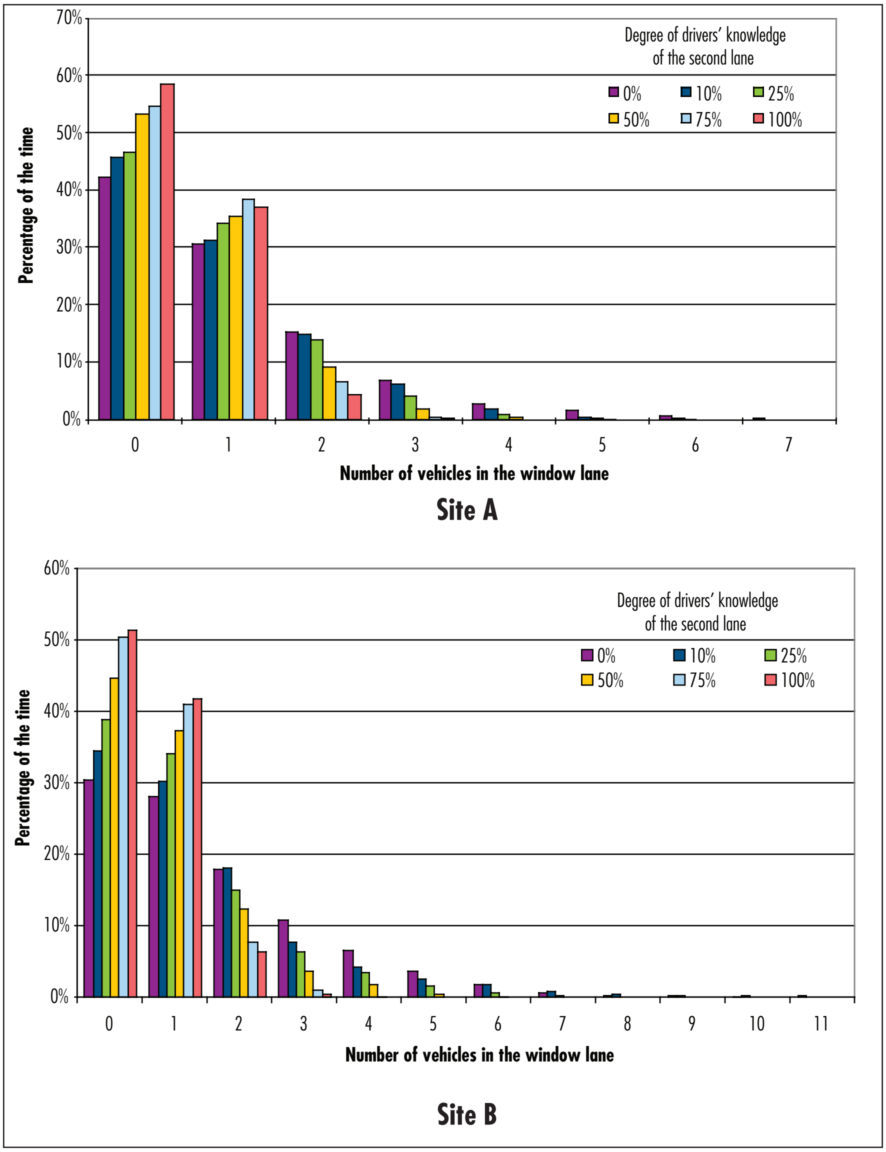

Figure 2. Queue results based on simulation model: "Two-lane with full service."

expected to decrease the encountered queues for customers and decrease the wait time that the average customer would experience to begin service. The reduction of queue length and wait time will depend on how willing drivers are to utilize the second lane when available.

- There is no "customer loss" at the drive-thru regardless of the existing queue when a driver approaches the facility. Realistically, when a driver enters the facility, if the queue is at a level that a particular driver considers unreasonable, the driver will bypass the drive-thru. According to the model, no matter what length of queue exists, each driver approaching the drive-thru will remain until being serviced. However, the model can be easily generalized to include a factor to account for this. Based on observed traffic conditions for the two drive-thru lanes at both locations, all customers waited until service was completed.
- Once a drive-thru customer selects a lane, the driver will remain in the chosen lane. The model requires the vehicle to remain in the initially selected lane, regardless of the condition (queue length or number of vehicles) of the other lane.

SIMULATION RESULTS

The logic of the proposed simulation model was examined against the queuing theory equations by using assumed exponential inter-arrival and service-time rates.[3] After 30 runs, results of the model were similar to that of the queuing theory. Note that the queuing theory closed-form equations were limited to exponential inter-arrival and service-time rates, which was not the case for the proposed simulation model. The proposed simulation model can handle any combination of distributions for inter-arrival and service time.

Results of the simulation model for a single-lane operation were validated with the collected data. Average service time, average waiting time, percentages of drop-off and pick-up customers and average queue length all were used to verify model results against the collected data. Model results were the average of 30 simulation runs (equivalent to 30 working days); each run analyzed 60 customers.

Model results showed that simulated data closely resembled the actual collected data. Based on the model, the maximum occurring queues were seven and 10 customers for the studied stores at Site A and Site B, respectively.

Model results for maximum queue length seemed to be higher than the collected data (observed maximum queue was four cars at the two locations). This is because the collected data were for a single day only; however, the model reported the maximum queue that could occur within a 30-day time period. This shows that the model can account for the temporal randomness of traffic patterns.

Based on the model results, the 98th-percentile queues for the two stores of interest were four cars and six cars, for Site A and Site B, respectively. The 98th-percentile queue length is the length at which there is a rare chance of only 2 percent that actual queue length will exceed this value. These results agreed with the traffic counts.

Therefore, the simulation model was able to replicate the trends observed in the field. For each pharmacy site, three different scenarios were simulated and evaluated:

- The window lane is full service (drop-off and pick-up) and the second lane is for use only to customers intending to drop off a prescription.
- Both lanes are full service.

- The window lane is for pick-up only and the second lane is for drop-off only.

For the first and second simulation scenarios, drivers' knowledge of the second lane was integral in calculating the expected reduction in queue length and wait time. Six different levels (between 0 and 100 percent) of driver willingness to use the second lane when feasible (such as shorter queue length than the window lane) were simulated.

For example, 25 percent means that one in four customers were willing to use the second lane when feasible; 0 percent means that no one was willing to use the second lane; and 100 percent means that all customers would use the lane with the minimum number of waiting vehicles.

During the development of the simulation models, the following practical assumptions were made: With a two-lane drive-thru configuration, two customers can be serviced at the same time. This assumption states that the driver utilizing the second lane does not have to wait for a gap in customers in the first lane before receiving service. This is a reasonable assumption based on field observations because there was never a time while on-site that fewer than two pharmacists were present.

Figures 1–4 show simulation results for queue length and wait time in the window lane for three different lane configurations. The following sections discuss results from both sites. Results are presented in terms of reduction in queue lengths and wait times for the window lane as compared to the single lane conditions.

Site A

The window lane is full service and the second lane is for drop-off only: The maximum numbers of waiting vehicles are 7, 7, 7, 7, 6 and 6 cars for drivers' familiarity levels of 0, 10, 25, 50, 75 and 100 percent, respectively. If at least 75 percent of drivers are familiar with the second lane, the mean time percentages are 45, 33, 14, 5, 2, 0.9 and 0.1 percent of having zero, one, two, three, four, five and six cars waiting in the window lane, respectively. Note that the chance of having more than four waiting cars is only 1 percent. Also, the average wait time is

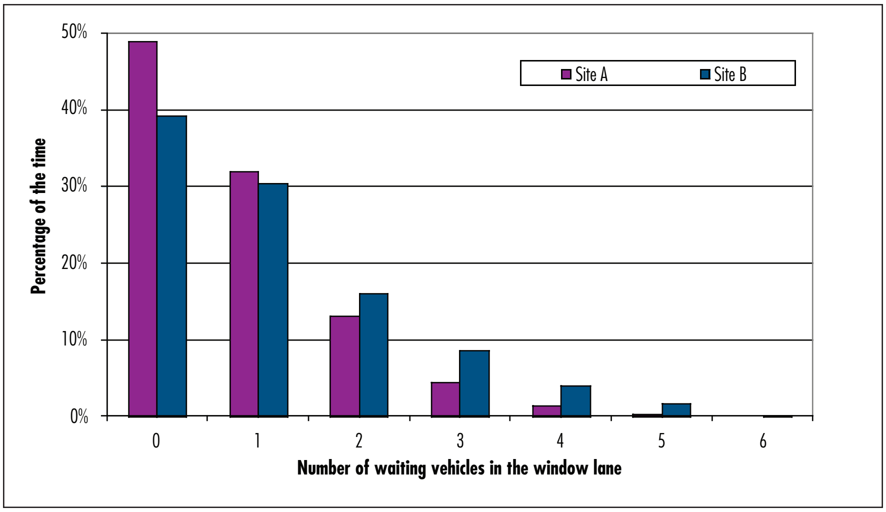

Figure 3. Queue results based on simulation model: "The window lane is for pick-up and the second lane is for drop-off only."

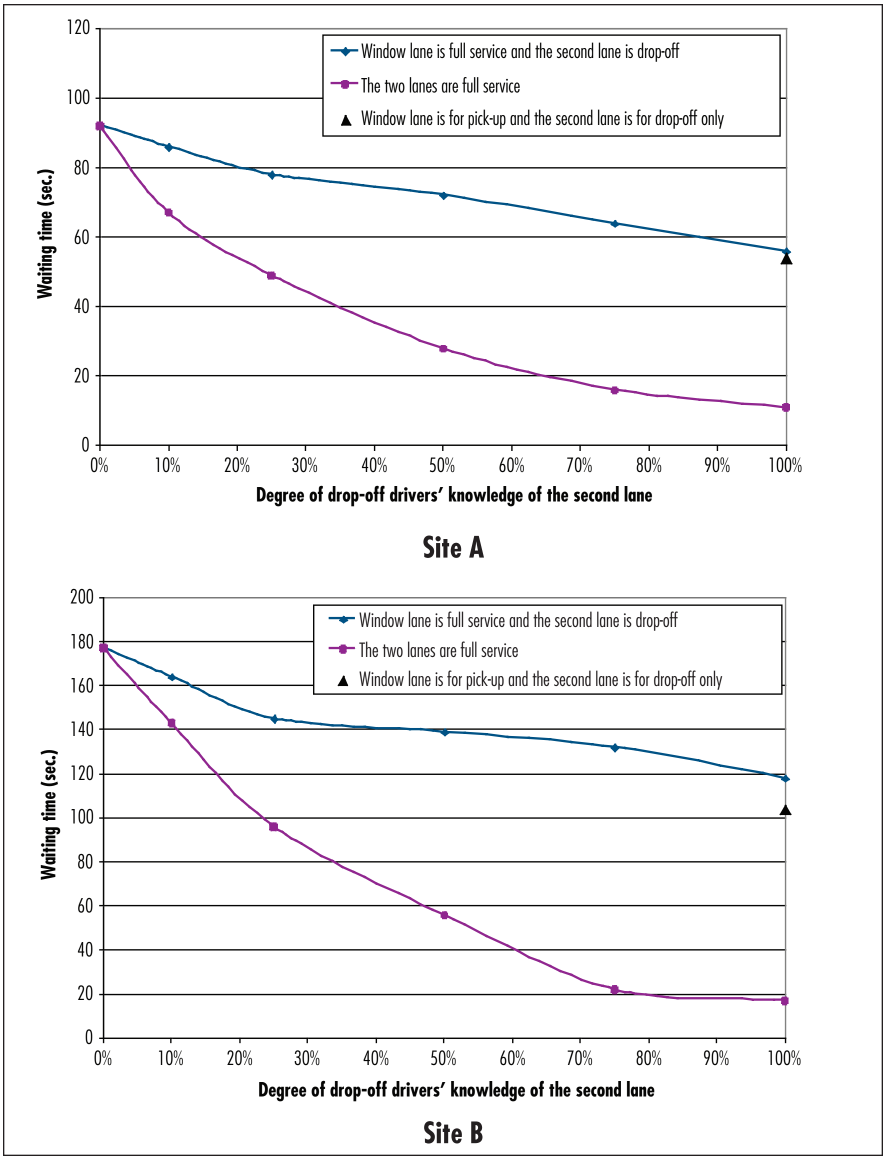

Figure 4. Wait time results based on simulation model.

expected to be reduced from 92 to 64 seconds (a reduction of 30 percent). The maximum reduction can reach 39 percent if all drivers desiring to drop off a prescription use the second lane when it is feasible (the window lane is busy or has a longer queue than the second lane).

Both the window lane and the second lane are full service: The maximum numbers of waiting vehicles are 7, 7, 6, 5, 3 and 3 cars for drivers' familiarity levels of 0, 10, 25, 50, 75 and 100 percent, respectively. If out of two drivers, one driver is familiar with the second lane, this could reduce the maximum number of waiting cars at the window from seven to five. If at least 75 percent of drivers are familiar with the second lane, the maximum number of waiting cars is three at the window. Also, the average wait time is expected to be reduced from 92 to 16 seconds (a reduction of 83 percent). The maximum reduction can reach 88 percent if all pick-up drivers use the second lane when it is feasible.

The window lane is for pick-up and the second lane is for drop-off only: The maximum number of waiting vehicles in the window lane is six cars. Also, the average wait time is expected to be reduced from 92 to 54 seconds (a reduction of 41 percent).

Site B

The window lane is full service and the second lane is for drop-off only: The maximum numbers of waiting vehicles are 11, 10, 9, 8, 8 and 7 cars for drivers' familiarity levels of 0, 10, 25, 50, 75 and 100 percent, respectively. If at least 75 percent of drivers are familiar with the second lane, the maximum number of waiting cars is eight at the window. Also, the average wait time is expected to be reduced from 177 to 132 seconds (a reduction of 25 percent). The maximum reduction can reach 33 percent if all drop-off drivers use the second lane when it is feasible.

Both the window lane and the second lane are full service: The maximum numbers of waiting vehicles are 11, 10, 8, 6, 4 and 3 cars for drivers' familiarity levels of 0, 10, 25, 50, 75 and 100 percent, respectively. If at least 75 percent of drivers are familiar with the second lane, the maximum number of waiting cars is four at the window. Also, the average wait time is expected to be reduced from 177 to 22 seconds (a reduction of 88 percent). The maximum reduction can reach 90 percent if all pick-up drivers use the second lane when it is feasible

The window lane is for pick-up and the second lane is for drop-off only: The maximum number of waiting vehicles in the window lane is six cars. Also, the average wait time is expected to be reduced from 172 to 104 seconds (a reduction of 40 percent).

CONCLUSIONS

This feature demonstrated the use of a simulation model to select the optimum lane configuration for a two-lane drive-thru at a pharmacy. Three possible configurations of the drive-thru were simulated and analyzed. The reduction in queues and waiting time with the second lane providing drop-off services only was found to be not substantial; the simulation model showed that no significant improvement would be achieved with such a configuration.

Based on the traffic counts at both locations, only 25 percent of customers are completing drop-offs. The queue reduction from a second lane providing a service that only one in four customers is seeking cannot be nearly as significant as a drive-thru design that provides two lanes offering full services. The improvements noted from the simulation of the two-lane drive-thru with both lanes offering full services were substantial.

The proposed methodology of this simulation model can be applied in other queuing systems such as fast food restaurants, car washes and banks. Slight modifications may be required to simulation inputs depending on the particular system; however, this model can be applied to a wide range of queue analysis applications. ■

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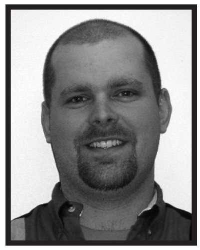

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