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Time- and Capacity-Based Measurement of Restaurant Revenue

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In this article, the authors examine how a common metric of revenue performance—RevPASH, or revenue per available seat-hour—is calculated. In a simple example, a real restaurant, and an extensive simulation study, the authors find inaccuracies in the existing approaches to calculating RevPASH. However, the extent of the inaccuracy is much greater when RevPASH is calculated based on check-open times rather than on the time interval from check open to check close. Since accurate RevPASH values are important in guiding managers' revenue-enhancing decisions, the article's findings have importance for practice. Furthermore, as RevPASH has been a commonly used metric for academic research, the article's findings are important for those performing research on restaurant revenue management.

Keywords: restaurant revenue management; revenue per available seat-hour; RevPASH

The aim of restaurant revenue management is to improve restaurant profitability by managing both capacity and demand. Demand management actions include pricing decisions, while capacity management actions include identifying top-performing table mixes and managing dining durations.

A key analysis metric for restaurant revenue management is RevPASH, the revenue per available seat-hour. This metric, first introduced in 1998 (Kimes et al. 1998), captures the effects of revenue, time, and capacity. RevPASH is useful for comparisons both across and within restaurants (Kimes 1999). It has been suggested that management can tailor its revenue-enhancing efforts based on RevPASH. Those revenue-enhancing efforts can include raising prices or reducing meal durations during periods of higher RevPASH and attracting more customers or implementing up-selling during periods of lower RevPASH (Kimes 1999). RevPASH can be calculated for any length of time, whether entire meal periods or periods as short as fifteen minutes (Kimes 1999). We refer to the length of time in question as an *analysis time interval*. The advantage of using analysis time intervals that are shorter than the duration of the meal period is that information gleaned from the shorter analysis periods can serve to tailor the revenue-enhancing decisions to the within-meal-period conditions. For example, a manager might decide to have wait staff up-sell patrons during the shoulder periods when RevPASH is lower.

The calculation of RevPASH should not include tips, service charges, or any taxes. RevPASH should focus on the amount of money that the restaurant is earning that will help offset its fixed costs, of which tips, service charges, or taxes offset nothing. Another advantage of removing these items from a RevPASH calculation is that they can make comparisons across restaurants cleaner, since taxes often vary across locations.

For similar reasons, takeout and curbside service should be excluded from the RevPASH calculation. Since RevPASH is capturing revenue on the basis of capacity measured in seats, including the revenue from takeout or curbside would reduce the utility of using RevPASH as a performance metric. The best way to handle this additional revenue is to track it separately from the in-house RevPASH, using a similar time-based measure.

Two approaches have been applied to calculate RevPASH. The first approach is to count the revenue based on the time at which the check is opened for a party (Kimes, Barrash, and Alexander 1999; Kimes 2004b), which we call RevPASH-Opn. In a report we wrote for the Cornell Center for Hospitality Research (Thompson and Sohn 2008), we advocated calculating RevPASH using the entire period from check open to check close, which we refer to as RevPASH-Ent. We argued that RevPASH-Ent is more accurate than RevPASH-Opn. As we show later in this article, both approaches to calculating RevPASH are only approximations to the true RevPASH, and our goal in this article is to evaluate the accuracy of these two approximations. Based on the results of a simulation study of more than twelve thousand restaurant scenarios, we find that the extent of the inaccuracy in RevPASH-Opn is at least an order of magnitude higher than the inaccuracy of RevPASH-Ent.

In the remainder of this article, we first review relevant literature on restaurant revenue management. We then present a means of calculating the true RevPASH value and show, with a simple example, how both RevPASH-Opn and RevPASH-Ent measure RevPASH inaccurately. Using data from a real restaurant, we next compare the inaccuracy in RevPASH-Opn and RevPASH-Ent. We then describe and present the results of an extensive simulation study that we conducted to develop more general findings. We close with implications of our findings.

Literature Review

Sheryl Kimes and her coauthors extended revenue management concepts to restaurants in 1998 to incorporate issues of capacity and demand management (Kimes et al. 1998). This study built on Brian Sill's earlier work on restaurant capacity (Sill 1991; Sill and Decker 1999). Since its introduction, a significant amount has been written on restaurant revenue management, much of it originating at Cornell University and published in this journal.

Several overviews of restaurant revenue management exist, beginning with the seminal article by Kimes and her coauthors (1998). Papers and reports published in 1999 and 2004 further developed those initial ideas (Kimes 1999; Kimes, Barrash, and Alexander 1999; Kimes 2004a, 2004b). A particularly useful overview of the topic appears in Kimes's 2004 report published by Cornell University's Center for Hospitality Research (Kimes 2004a).

Dining-duration management and table-mix management are two areas in the restaurant revenue management literature that have received considerable attention. In an international study of restaurant patrons, Kimes, Wirtz, and Noone (2002) examined the preferred dining durations of customers at casual restaurant across international locations. They found that Europeans prefer to spend more time at restaurants than do North Americans and Asians. In a study of the duration of components of restaurant meals, Noone and Kimes (2005) found that customers like some parts of the process to proceed expeditiously (e.g., ordering, check delivery, and payment processing) and other parts to proceed at a leisurely pace (e.g., when they are actually consuming their meal or lingering over coffee and dessert).

With respect to restaurant table mixes, coauthor Thompson (2002) found that for most restaurants with walk-in business, it is better to have a mix of dedicated table sizes than it is to have relatively small tables that can be combined to seat larger parties. He also examined how combinable tables should be deployed, for those restaurants using such tables (Thompson 2003). Kimes and Thompson investigated the best table mix for a specific restaurant (Kimes and Thompson 2004) and later compared, under a wide variety of simulated restaurants, approaches for finding table mixes (Kimes and Thompson 2005). All of these table-mix studies judge performance using RevPASH or an equivalent measure.

Calculating the True RevPASH

In an ideal world, RevPASH would be calculated by apportioning a party's revenue during the entire time related to the party's "usage" of a table. That time would include the time from when the table was committed to them (by a host or hostess, for example) through when the table had been bussed and reset for the next party—or one entire service cycle. Other things equal, the more times this cycle is repeated during a given meal period, the more money the restaurant makes. We call this calculation RevPASH-True, although making this calculation is impractical because the full service cycle extends beyond the interval recorded by the point-of-sale (POS) system from check open to check close. POS systems may omit the time between when the table is committed to a party and when the check is opened—for example, the time required for a host or hostess to take the party to their table—or the time after the check is settled but the party lingers at the table and the table is cleared and reset. Other sources of POS inaccuracy include data errors, such as recording the number of people in a party or neglecting to close a check in timely fashion.

To illustrate how RevPASH-True could be calculated, and to show the inaccuracies in RevPASH that can occur with both approaches examined in the literature, we will present a simple example. Consider a restaurant open for lunch from 11:30 to 13:30, which has five 4-tops. Assume that there are five reservations slots: 11:30, 11:45, 12:00, 12:15, and 12:30. Assume also the following: a party of four is scheduled to arrive at each reservation time; there is a five-minute delay from when a table is committed to a party and when the check is opened; each party has an average

Exhibit 1:
Calculation of True Revenue per Available Seat-Hour (RevPASH-True)

Party	*1*	*2*	*3*	*4*	*5*	*Total Revenue*	*RevPASH-True*
Table committed	11:30	11:45	12:00	12:15	12:30		
Check opened	11:35	11:50	12:05	12:20	12:35		
Check closed	12:35	12:50	1:05	1:20	1:35		
Table reset	12:45	1:00	1:15	1:30	1:45		
Revenue from party	$60.00	$60.00	$60.00	$60.00	$60.00		
True revenue per minute[a]	$0.80	$0.80	$0.80	$0.80	$0.80		
Revenue in 11:30-12:00[b]	$24.00	$12.00				$36.00	$3.60
Revenue in 12:00-12:30[b]	$24.00	$24.00	$24.00	$12.00		$84.00	$8.40
Revenue in 12:30-13:00[b]	$12.00	$24.00	$24.00	$24.00	$24.00	$108.00	$10.80
Revenue in 13:00-13:30[b]			$12.00	$24.00	$24.00	$60.00	$6.00
Revenue in 13:30-14:00[b]					$12.00	$12.00	$1.20
Total apportioned revenue	$60.00	$60.00	$60.00	$60.00	$60.00		

a. True revenue per minute = total revenue divided by service cycle time (table reset time minus table committed time).
b. Revenue in an analysis interval is calculated by multiplying the true revenue per minute times the number of minutes of the service cycle that falls in the interval.

check per person of $15; the check is open for sixty minutes for each party; and there is ten-minute lag between the check being closed and the table being ready for the next party. Finally, assume that RevPASH is tracked using thirty-minute periods.

The RevPASH-True values for this example are shown in Exhibit 1. The values range from $10.80 per seat-hour in the third analysis interval to $1.20 per seat-hour in the final half-hour analysis interval. These values are calculated by first dividing the total revenue from the party by the length of the service cycle for the party (i.e., the table reset time minus the table committed time) to yield the true revenue per minute. Then, the numbers of minutes of the service cycle falling in each analysis interval are multiplied by the true revenue per minute, to give the revenue in each analysis period for each party. For example, party 2 has a true revenue per minute of $0.80 (= $60.00 / 75 minutes). The table is committed for this party at 11:45, meaning that 15 minutes of the service cycle falls in the 11:30 to 12:00 analysis period. This 15 minutes, multiplied by the $0.80 per minute, yields the $12.00 of party 2's total revenue that is apportioned in the 11:30 to 12:00 interval.

In terms of calculation effort, RevPASH-Opn is much simpler than RevPASH-True

Exhibit 2:
RevPASH Calculation Using the Traditional Approach of Check-Open Time (RevPASH-Opn)

Party	*1*	*2*	*3*	*4*	*5*	*Total Revenue*	*RevPASH-Opn*
Table committed	11:30	11:45	12:00	12:15	12:30		
Check opened	11:35	11:50	12:05	12:20	12:35		
Check closed	12:35	12:50	1:05	1:20	1:35		
Table reset	12:45	1:00	1:15	1:30	1:45		
Revenue	$60.00	$60.00	$60.00	$60.00	$60.00		
Revenue in 11:30-12:00	$60.00	$60.00				$120.00	$12.00
Revenue in 12:00-12:30			$60.00	$60.00		$120.00	$12.00
Revenue in 12:30-13:00					$60.00	$60.00	$6.00
Revenue in 13:00-13:30						$0.00	$0.00
Revenue in 13:30-14:00						$0.00	$0.00
Total apportioned revenue	$60.00	$60.00	$60.00	$60.00	$60.00		

(or RevPASH-Ent), since the entire revenue is captured when the party "comes on the books," in this case, when the check is opened. Thus, as shown in Exhibit 2, all of the revenue for parties 1 and 2 is apportioned to the 11:30 to 12:00 analysis interval, all the revenue from parties 3 and 4 is apportioned to the 12:00 to 12:30 analysis interval, and all of party 5's revenue is captured in the 12:30 to 1:00 analysis interval. Summing the apportioned revenue by period and converting it to an hourly revenue per seats yield RevPASH values of $12.00 in each of the first two analysis intervals, $6.00 per hour in the third, and $0.00 in each of the last two intervals.

RevPASH-Ent calculations are presented in Exhibit 3. In form, the calculations are similar to those for RevPASH-True, except that the check-open time is used instead of the service cycle time. The revenue per minute is calculated for each party, then the total revenue apportioned based on the number of minutes of the check open time that falls in each analysis interval. For example, party 1 has a revenue per minute of $1.00 (= $60.00 / 60 minutes). Since 25 minutes of the time the check is opened falls in the 11:30 to 12:00 analysis interval, $25.00 of the party's revenue is apportioned to that interval and the remainder to the next two intervals. Repeating this calculation across all parties and analysis intervals, then summing the apportioned revenue by period, and converting those revenues to dollars per seat per hour, yields a RevPASH of $3.50 in the first interval, increasing to $11.00 in the third interval, and falling to $0.50 in the last interval.

Exhibit 3:
Revenue per Available Seat-Hour (RevPASH) Calculation Using the Approach of the Entire Time the Check Is Open (RevPASH-Ent)

Party	*1*	*2*	*3*	*4*	*5*	*Total Revenue*	*RevPASH-Ent*
Table committed	11:30	11:45	12:00	12:15	12:30		
Check opened	11:35	11:50	12:05	12:20	12:35		
Check closed	12:35	12:50	1:05	1:20	1:35		
Table reset	12:45	1:00	1:15	1:30	1:45		
Revenue	$60.00	$60.00	$60.00	$60.00	$60.00		
Revenue per minute[a]	$1.00	$1.00	$1.00	$1.00	$1.00		
Revenue in 11:30-12:00[b]	$25.00	$10.00				$35.00	$3.50
Revenue in 12:00-12:30[b]	$30.00	$30.00	$25.00	$10.00		$95.00	$9.50
Revenue in 12:30-13:00[b]	$5.00	$20.00	$30.00	$30.00	$25.00	$110.00	$11.00
Revenue in 13:00-13:30[b]			$5.00	$20.00	$30.00	$55.00	$5.50
Revenue in 13:30-14:00[b]					$5.00	$5.00	$0.50
Total apportioned revenue	$60.00	$60.00	$60.00	$60.00	$60.00		

a. Revenue per minute = total revenue divided by check-open time (check-close time minus check-open time).
b. Revenue in an analysis interval is calculated by multiplying the revenue per minute times the number of minutes of the check-open time that falls in the interval.

Exhibit 4 presents a summary of the RevPASH values for this simple example. To reiterate, RevPASH-True provides the benchmark with which to judge the two RevPASH approximations. It is apparent that there are notable differences in the RevPASH values from the two approximations. In each of the five analysis periods, though, RevPASH-Ent better approximates the true RevPASH. RevPASH-Opn overestimates true RevPASH in early analysis intervals and underestimates true RevPASH in late analysis intervals.

Exhibit 4 also shows the percentage by which RevPASH is underestimated or overestimated and the weighted average absolute percentage inaccuracy (WAAPI) for each of the two approximations. In calculating WAAPI, the absolute percentage inaccuracy in each analysis interval is weighted by the interval's true RevPASH. This ensures that periods where RevPASH is low (typically, the shoulder periods) do not unduly influence the inaccuracy metric. RevPASH-Ent's better performance is reflected in its WAAPI of 10.3 percent compared to RevPASH-Opn's WAAPI of 80.0 percent.

Based on the results of the simple example presented here, it appears that the more commonly used approximation for RevPASH—RevPASH-Opn—has serious

Exhibit 4:
A Comparison of RevPASH Values and Inaccuracy with RevPASH-Opn and RevPASH-Ent

Analysis Interval	*RevPASH-True*	*RevPASH-Opn*	*RevPASH-Ent*
11:30-12:00	$3.60	$12.00 (233.3%)	$3.50 (-2.8%)
12:00-12:30	$8.40	$12.00 (42.9%)	$9.50 (13.1%)
12:30-13:00	$10.80	$6.00 (-44.4%)	$11.50 (6.5%)
13:00-13:30	$6.00	$0.00 (-100.0%)	$5.50 (-8.3%)
13:30-14:00	$1.20	$0.00 (-100.0%)	$0.50 (-58.3%)
Average (WAAPI)	$6.00	$6.00 (80.0%)	$6.00 (10.3%)

Note: RevPASH = revenue per available seat-hour; RevPASH-Opn = RevPASH calculation using the traditional approach of check-open time; RevPASH-Ent = RevPASH calculation using the approach of the entire time the check is open; WAAPI = Weighted average absolute percentage inaccuracy (= average of absolute values of the percentage overestimation or underestimaton of RevPASH, weighted by the true RevPASH). Values in parentheses are the percentage overestimation or underestimation of RevPASH.

inaccuracy problems. Moreover, while the newer approach of RevPASH-Ent is not perfectly accurate, it performed much better than RevPASH-Opn. Our desire to see whether these findings would hold more broadly motivated our examination of the accuracy of the RevPASH approximations in a real restaurant and in realistic, but simulated, restaurant situations. We consider the real restaurant next. Throughout our investigations, we will use WAAPI to judge the performance of the RevPASH approximations. As we will we show, RevPASH-Opn has significant problems in the vast majority of situations.

Results in a Real Restaurant

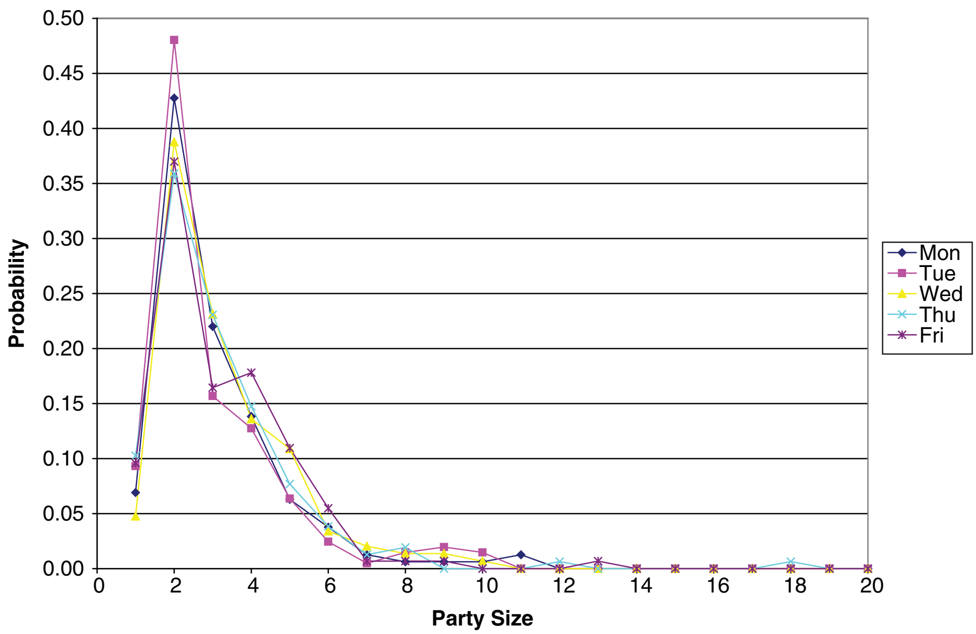
We analyzed weekday lunch data collected from the POS system from a restaurant with 45 tables and 118 seats. Weekday lunch, which runs from 11:30 to approximately 15:30, is the peak occupancy meal period for the restaurant in question. Its clientele during lunch on weekdays is primarily businesspeople, and 74.5 percent of parties make reservations. Though we analyzed data for eight months of operation, we will report the results only for October 2007, the last month for which we collected data, because the results are similar for the other months and because focusing on only one month makes it easier to report the findings. POS data typically require "cleansing" to remove invalid entries. For the data we obtained, we removed duplicate transactions, transactions with no revenue, transactions with zero covers, transactions where the average spending per person exceeded $100, and transactions with durations less than ten minutes. All the information we report is post data cleansing.

Exhibit 5 illustrates the distribution of party sizes by day of week. Parties of two are the most common every day, followed by parties of three (on four of the five days). On every day, parties of more than six people represent less than 6 percent of the total parties.

Exhibit 6 illustrates the party arrival rate by day of week, using fifteen-minute analysis periods. The arrival pattern is quite consistent across the days; arrivals increase evenly for the first hour, and then decline at a fairly stable rate for the next two hours. All days exhibit a peak arrival rate in the range of twenty to thirty parties per hour.

The average check per person by party size and day of week is shown in Exhibit 7. Because of the small number of parties

Exhibit 5:
Distribution of Party Sizes by Day of Week



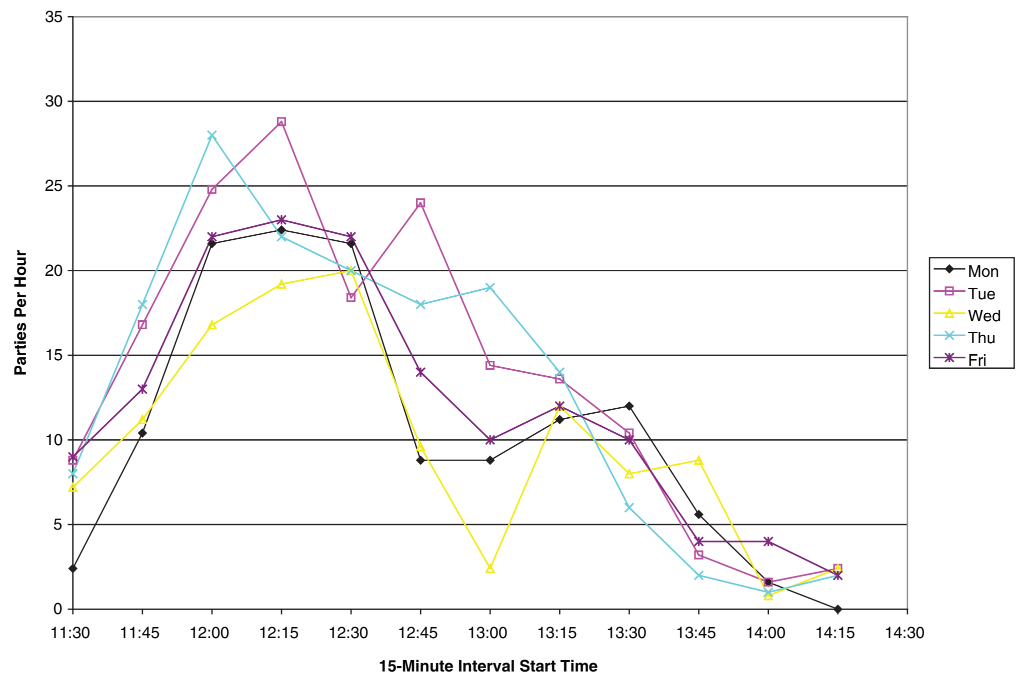
with more than eight people, we have removed them from the chart. Overall, the average check per person is quite stable, around $16.50.

The mean dining duration by party size and day of week is given in Exhibit 8. Again, we show the results only for parties of eight or fewer people, because of the small number of parties with more than eight people. For Monday through Thursday, dining durations generally grow with party size, while the reverse is true on Friday. Friday also has a notably longer mean dining duration, at more than seventy-seven minutes, compared to other days, which average less than sixty minutes. Given the nature of the clientele, longer lunches on Friday are not surprising.

Because the POS data from the restaurant included only information on when the check was open for a party, we simulated the time before and after check opening. We assumed a uniform distribution for the time interval from the table being committed to the check being opened, with integer values from zero to three minutes. For the check-close-to-table-reset time, we selected random integers from a negative exponential distribution with a mean of five minutes. We selected the exponential distribution for the check-close-to-table-reset time because most restaurants do not control the customer portion of this time (that is, customers choose when to leave). For this estimate, small times would typically have a greater probability than long times (i.e., customers will generally leave sooner, rather than later, after the check is closed).

Exhibit 9 summarizes the inaccuracy (WAAPI values) of the RevPASH approximations for the restaurant lunch period, by length of the analysis time interval, by day and overall. In general, both approximations are less accurate with shorter analysis time intervals. Only with analysis intervals of

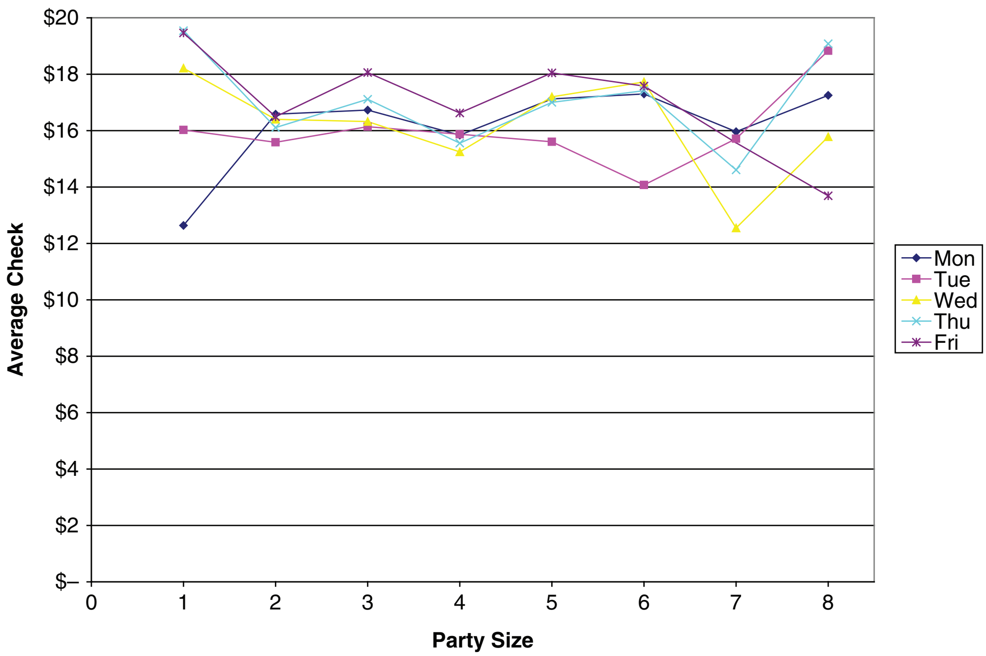
Exhibit 6:
Party Arrival Rate, by Day of Week



four hours or longer—essentially the entire meal period—do the RevPASH approximations correctly represent the time-based revenue. The degree of the inaccuracy in RevPASH-Opn is considerable—more than 40 percent for any analysis periods shorter than 150 minutes. Indeed, on the 15- or 30-minute intervals that a manager would typically use to gain insight into the appropriate revenue-enhancing actions, RevPASH-Opn inaccuracy exceeds 60 percent. By contrast, RevPASH-Ent is a much more accurate approximation of the true revenue—at worst its inaccuracy is less than 6 percent, and it is 5 percent or less for 15- and 30-minute analysis intervals.

To yield insight into the sources of RevPASH-Opn inaccuracy, Exhibit 10 displays the RevPASH values, by fifteen-minute analysis time periods, for the weekdays with the lowest (Monday) and highest (Thursday) RevPASH. Several patterns emerge from comparing the RevPASH-Opn values, which are indicated by the dashed lines, to the true RevPASH values, which are indicated with the solid lines. First, as we saw with the simple example presented earlier, RevPASH-Opn overestimates revenue early in the meal period and underestimates revenue later in the meal period. Second, RevPASH-Opn shows revenue as peaking higher than its true peak. Third, RevPASH-Opn shows shorter-duration revenue peaks than really occur. Finally, RevPASH-Opn shows more variation from period-to-period than actually exists (i.e., the true revenue values rise and fall more smoothly). In contrast to RevPASH-Opn, RevPASH-Ent exhibits none of these problems, instead tracking the true RevPASH much more closely across all analysis intervals. To determine whether the inaccuracies we observed in this restaurant

Exhibit 7:
Average Check per Person, by Party Size and Day of Week



occur more broadly, we conducted a simulation study, as we next describe.

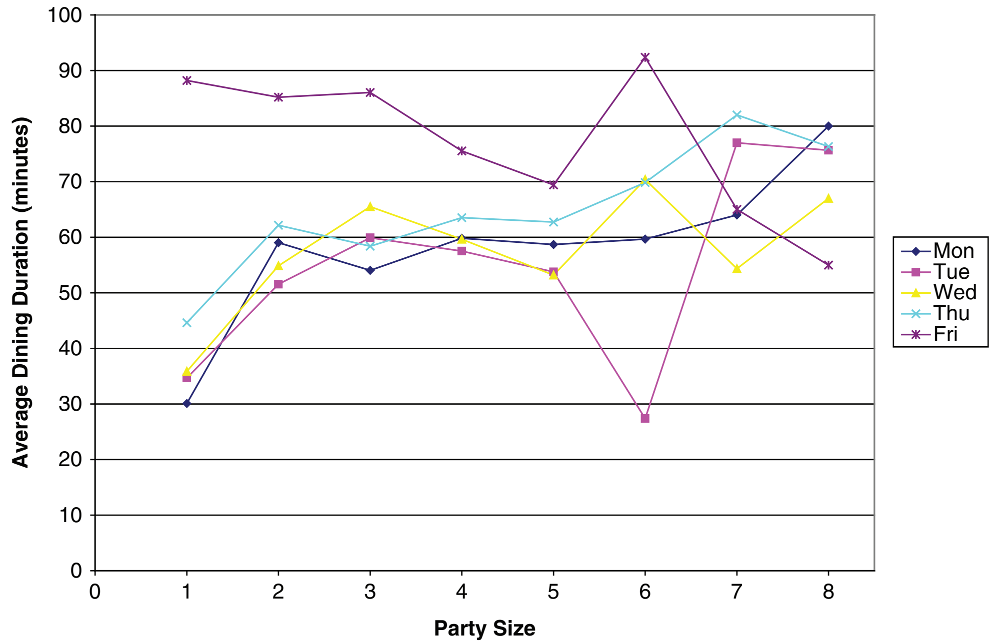
Simulation Study

In this section, we examine the simulation study we performed to investigate the inaccuracy of the RevPASH approximations. Below we describe the study design, study assumptions, our efforts to ensure the validity of the study, and our results.

Study design. Thirteen factors constituted study 2, as shown in Exhibit 11. We selected the factors, and factor levels, for two reasons: we either believed that the factor would affect the inaccuracy of the RevPASH approximations, or we believed that the factor would be important in ensuring the applicability of our results to a wide range of restaurants. The first twelve factors served to specify a restaurant scenario, and the thirteenth considered the length of the analysis time interval. The combinations of the levels of the first twelve factors resulted in a total of 12,288 restaurant scenarios.

We used two factors to represent information inaccuracy in the POS, to mimic the discrepancy of the check open-close time interval compared to the service cycle time. The first of these factors represents the amount of time from when a table is committed to a party to when the check is opened. The two levels of the factor had mean times of one and three minutes, both normally distributed with a coefficient of variation of .30. The second information uncertainty factor represented the time from when a check is closed to the time when the table is reset and ready for the next party.[1] This factor also had two levels, with mean times of two and ten minutes. We assumed negative exponential distributions for this factor, to reflect the fact that some parties may linger.

Exhibit 8:
Mean Dining Duration, by Party Size and Day of Week



The four demand-related factors were as follows. The maximum party arrival rate had three levels, to capture restaurants of different demand or size; four levels captured the length of the peak demand period, using durations of zero, one, two, and three hours; and two levels of mean party size, 2.5 and 3.5 people, represented the two observed modes (see party size probabilities in Exhibit 12). Though the smaller mean party size is more similar to the one reported instance in the literature (approximately 2.6 customers per party; Kimes and Robson 2004), we included the higher level for robustness. Finally, the arrival-process factor employed one level to represents evenly spaced times between party arrivals, much like what would be seen in a restaurant using a large proportion of reservations, and a second level with randomly spaced arrivals, much like what would be seen in a restaurant with a high proportion of walk-in parties.

Three factors specifically related to dining duration. We used two levels of mean dining duration: forty-five and ninety minutes, one corresponding to restaurants where people dine quickly and the other to restaurants where they dine more leisurely. It has been observed that larger parties commonly take longer to dine (Bell and Pliner 2003; Kimes and Robson 2004; Kimes and Thompson 2005). To capture this, we used two levels for the dining duration variation across party sizes, where the ratio of the average dining duration for parties of ten people was 1.5 and 2.0 times the average dining duration for parties of

1. The authors wish to thank Professor Sheryl Kimes of Cornell University for suggesting the inclusion of this factor.

Exhibit 9:
Inaccuracy (WAAPI) of RevPASH-Opn and RevPASH-Ent, by Length of the Analysis Time Interval (in percentages)

Analysis Period Length	*RevPASH-Opn*						*RevPASH-Ent*					
(Minutes)	*Mon*	*Tue*	*Wed*	*Thu*	*Fri*	*Overall*	*Mon*	*Tue*	*Wed*	*Thu*	*Fri*	*Overall*
5	81.9	62.3	85.1	75.0	86.2	77.6	5.9	4.9	5.3	4.8	7.7	5.7
10	76.1	58.7	73.8	74.6	74.3	71.3	5.1	4.4	4.5	4.7	6.8	5.1
15	80.3	56.2	76.4	66.4	76.0	70.4	5.2	3.9	4.7	4.5	6.6	5.0
30	63.2	56.2	59.2	66.1	74.3	64.0	4.2	3.6	4.0	3.5	6.6	4.4
60	57.3	56.2	59.2	61.9	60.2	59.0	3.7	3.5	3.7	3.3	6.5	4.2
90	63.2	53.2	58.6	66.1	74.3	63.2	3.9	2.3	2.5	3.2	2.7	2.9
120	36.6	37.0	41.7	41.0	60.0	43.5	3.7	3.5	3.7	3.3	6.5	4.2
150	26.6	15.6	27.8	16.3	36.9	24.3	2.8	2.3	3.2	2.7	4.7	3.1
180	5.1	3.3	8.4	3.3	16.8	7.3	1.7	0.7	1.6	0.8	1.6	1.2
210	0.0	0.1	0.5	0.1	4.4	1.1	0.0	0.1	0.5	0.1	1.0	0.3
240	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
270	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
300	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Note: RevPASH = revenue per available seat-hour; RevPASH-Opn = RevPASH calculation using the traditional approach of check-open time; RevPASH-Ent = RevPASH calculation using the approach of the entire time the check is open; WAAPI = Weighted average absolute percentage inaccuracy (= average of absolute values of the percentage overestimation or underestimaton of RevPASH, weighted by the true RevPASH).

one person. We assumed a linear relationship between party size and mean dining duration in both instances. The factor representing variation in the within-party dining duration had two levels: coefficients of variation of .25 and .50, which is within the range of .16 to .50 that has been previously observed (Bell and Pliner 2003; Kimes and Robson 2004).

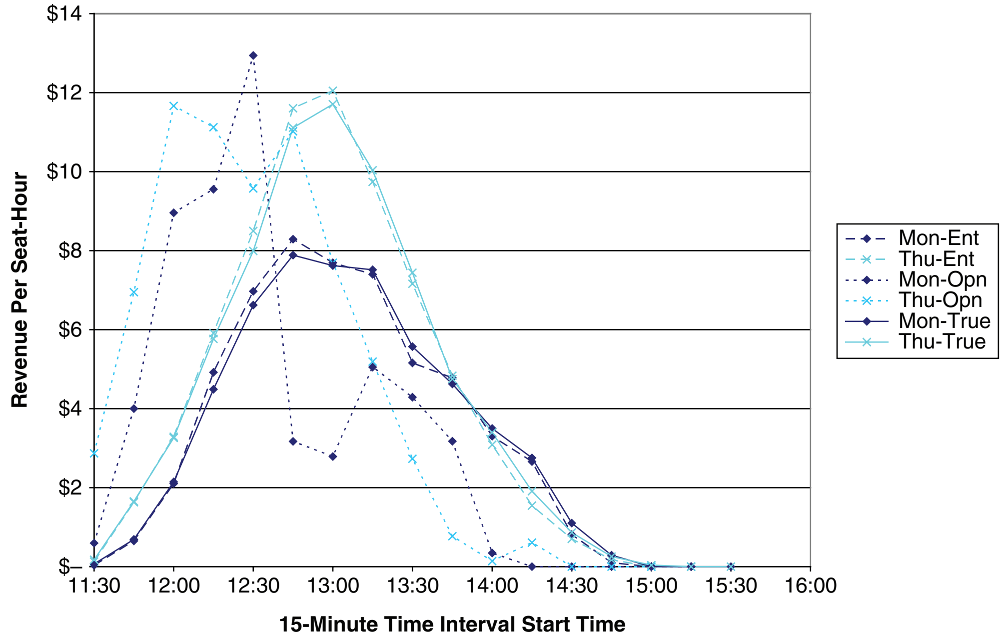
Two factors related to the check size: the difference in average check per person across party sizes and variation in per-person checks for same-size parties. Restaurants typically see spending per person decrease as the party size increases. To capture this, we assumed a $15.00 average check for parties of one in both levels, with one level decreasing $0.10 for every extra person in a party, and the other decreasing by $0.20. For per-person check differences in same-size parties, we used coefficients of variation of .15 and .30.

Finally, two factors were related to analysis issues. The first was the number of days from which data would be collected to be analyzed. We used two levels—four and thirteen days—which thereby gave us one month of observations from the same day of the week a quarter-year's worth of same-day observations. Finally, we applied thirteen different lengths for the analysis time periods. The levels ranged from five to three hundred minutes (essentially the entire meal period).

Study assumptions. The study proceeded under the following four assumptions: party sizes from one to ten people, dining durations following a lognormal distribution (because of the parties that linger over their meals), customer arrivals increasing at a constant rate over an hour-long period prior to the peak demand window and decreasing at a constant rate over an hour-long period following the peak demand

Exhibit 10:

Revenue per Available Seat-Hour (RevPASH) Values for the Weekdays with the Highest (Thursday) and Lowest (Monday) RevPASH Values



window, and check amounts for the price of the meal only (excluding taxes, tips, and service charges).

Study hypotheses. We believed that most of the factors included in the study would affect the accuracy of the RevPASH approximations, and for reasons explained above, we also expected that neither RevPASH-Ent nor RevPASH-Opn would be as accurate as RevPASH-True.

Inaccuracy in the POS data—the mismatch between check-open time and service cycle time—will affect both measures, as we saw in the real restaurant:

> *Hypothesis 1:* Larger time discrepancies between when a table is committed to a party and when the party's check is opened will yield greater inaccuracy in RevPASH-Opn and RevPASH-Ent.
>
> *Hypothesis 2:* Larger time discrepancies between when a party's check is closed and when the party's table has been reset for the next party will yield greater inaccuracy in RevPASH-Opn and RevPASH-Ent.

We note that hypotheses 1 and 2 apply to both RevPASH calculations, while the remainder of the hypotheses are specifically targeted at RevPASH-Opn.

With smaller restaurants (or other restaurants with lower peak party arrival rates), there is likely to be more variation in the time between parties, simply because of lower numbers of arrivals. Thus,

> *Hypothesis 3:* Lower maximum party arrival rates will result in greater inaccuracy in RevPASH-Opn.

If demand is stable, then the problems of capturing revenue at check open should be diminished. The reason for this is that

Exhibit 11:
Factors, and Factor Levels, for the Simulation Study

	# Levels	Levels
Information-related factors		
Mean time between table committed and check open (minutes)	2	**1**, 3
Mean time between check close and table reset (minutes)	2	**2**, 10
Demand factors		
Maximum party arrival rate (# parties/hour)	3	**20**, 60, 180 (50, 150, 450 seats)
Length of peak demand period (hrs)	4	**0**, 1, 2, 3
Mean party size (# covers)	2	2.5, **3.5**
Arrival process	2	Evenly spaced, Poisson
Duration factors		
Mean dining duration (minutes)	2	45, **90**
Variation in dining duration across party sizes, measured as the ratio of dining duration for parties of 10 people to the dining duration for parties of one person	2	**1.5**, 2.0
Variation in dining duration within party sizes, measured as a coefficient of variation	2	0.25, **0.50**
Check-related factors		
Check variation across party sizes	2	**Low**, high ($15.10-$0.10x and $15.20-$0.20x, respectively, where x = party size)
Check variation within party sizes (cv)	2	0.15, **0.30**
Analysis-related factors		
# days of data	2	**4**, 13 (corresponding to a specific day being analyzed for one month and one quarter, respectively)
Analysis period length (minutes)	13	5, 10, 15, 30, 60, 90, 120, 150, 180, 210, 240, 270, 300

Note: Factor levels in bold most closely correspond to those in the real restaurant we examined.

Exhibit 12:
Party Size Probabilities in the Simulation Study

Party Size	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
Mean = 2.5	.290	.430	.080	.070	.050	.030	.020	.015	.010	.005
Mean = 3.5	.100	.300	.210	.140	.090	.060	.040	.030	.020	.010

when demand is increasing, RevPASH-Opn overstates the revenue being captured; while if demand is decreasing, RevPASH-Opn understates the revenue being captured.

A period of stable demand, when RevPASH-Opn should be less inaccurate, can mitigate the problems with RevPASH-Opn during the ramp-up and ramp-down periods, so we expect

> *Hypothesis 4:* Shorter peak demand windows will yield greater inaccuracy in RevPASH-Opn.

When party arrivals are evenly spaced, such as might be expected in restaurants that take reservations, there will be much less variability in the time between party arrivals than when the arrival process is random (i.e., follows a Poisson distribution). We thus propose,

> *Hypothesis 5:* Greater arrival rate variation (i.e., more random arrivals than evenly spaced arrivals) will result in more inaccuracy in RevPASH-Opn.

With longer mean dining durations, real revenue accrues over a longer period of time. This, then, would exacerbate the problem of capturing revenue at the check open time, yielding

> *Hypothesis 6:* Longer mean dining durations will yield more inaccuracy in RevPASH-Opn.

Greater variation in dining duration across party sizes has the effect of spreading the real revenue over a longer time span, thus making it less accurate to capturing revenue at the time of check open. This gives the following hypothesis:

> *Hypothesis 7:* Greater variation in dining durations across party size will result in more inaccuracy in RevPASH-Opn.

Greater variation in dining durations within party sizes increases the differences between parties. While the real revenue captures these differences, RevPASH-Opn will not, yielding this hypothesis:

> *Hypothesis 8:* Greater variation in dining duration variation within party sizes will yield more inaccuracy in RevPASH-Opn.

With greater check variation both across and within party sizes, we anticipate that RevPASH-Opn will have greater inaccuracy, due to its capturing revenue only at the time of check open:

> *Hypothesis 9:* Greater check variation across party sizes will increase inaccuracy in RevPASH-Opn.
>
> *Hypothesis 10:* Greater check variation within party sizes will increase inaccuracy in RevPASH-Opn.

With more days of data used in the analysis, the randomness that could exist in party arrival times would tend to wash out, yielding observed arrivals closer to the true means. Thus, we expect

> *Hypothesis 11:* Fewer days of analysis data will result in higher inaccuracy in RevPASH-Opn.

As we saw with the simple example presented in the introduction, RevPASH-Opn correctly calculated RevPASH when the entire meal period was being analyzed but performed poorly with thirty-minute analysis periods. In general, we expect shorter analysis periods to be more problematic for RevPASH-Opn, simply because there will be more arbitrariness in how it captures revenue. Thus,

> *Hypothesis 12:* Shorter analysis periods will yield greater inaccuracy in RevPASH-Opn.

Study validation. To validate the study, we selected the factor levels that were most similar to those in the real restaurant described earlier, and then compared the inaccuracy values from the simulation to those from the real restaurant. The real

Exhibit 13:
Inaccuracy of RevPASH-Opn, by Length of the Analysis Time Interval (in percentages)

Analysis Period Length (Minutes)	*Overall (Real Data)*	*Spaced Arrivals (Simulated Data)*	*Poisson Arrivals (Simulated Data)*
5	77.6	106.3	119.8
10	71.3	104.0	114.5
15	70.4	104.0	110.2
30	64.0	104.0	102.3
60	59.0	73.4	68.5
90	63.2	104.0	102.3
120	43.5	73.4	68.5
150	24.3	31.5	26.8
180	7.3	9.6	8.3
210	1.1	2.3	1.4
240	0.0	0.0	0.0
270	0.0	0.0	0.0
300	0.0	0.0	0.0

Note: RevPASH = revenue per available seat-hour; RevPASH-Opn = RevPASH calculation using the traditional approach of check-open time.

restaurant was most similar to: the maximum party arrival rate of twenty parties per hour; a mean party size of 3.5 customers; a coefficient of variation of .50 for within-party-size dining durations; the lower level of variation in dining durations across party sizes; zero peak hours (i.e., the demand increases to a peak, then immediately starts declining); a coefficient of variation of .30 in the average check per party, within party sizes; the lower level of variation in the average check per party, across party sizes; a mean of one minute between a table being committed and a check being opened; a mean of two minutes between a check being closed and the table being reset for the following party; and one month's worth of data (i.e., four days). Exhibit 13 reports the inaccuracies of RevPASH-Opn for the real restaurant and, for comparison, those from the simulation study for the selected factor levels. The table gives the inaccuracy for both spaced arrivals and Poisson (random) arrivals from the simulation study. While we do not expect the results to match perfectly because there is an element of randomness to the simulation and because the real restaurant does not perfectly match the study's factor levels, there appears to be good congruence between the results from the real restaurant and those from the simulation study, at least for evenly spaced arrivals. In this restaurant, given that almost three-quarters of parties make reservations, one would expect that the arrivals would be well spaced (assuming, of course, that the reservations staff spread out the reservation times). As such, we judge that the simulation study correctly represents the inaccuracy of the RevPASH approximations.

Study results. Exhibit 14 presents summary results for the RevPASH approximations by level of the experimental factors and overall. Across the entire study, the inaccuracy of RevPASH-Opn was 36.66 percent, or more than fourteen times that of RevPASH-Ent's inaccuracy of 2.63 percent. However, RevPASH-Opn's inaccuracy was much worse under certain experimental conditions. For example, with a ninety-minute mean dining duration, RevPASH-Opn was more than eighteen times less accurate than RevPASH-Ent.

To test the study hypotheses presented earlier, we developed two regression equations, with each RevPASH approximation's inaccuracy (WAAPI) as the dependent variable and the experimental factors as the independent variables. The regression equation information is presented in Exhibit 15. We consider each RevPASH approximation in turn. For RevPASH-Opn, the base inaccuracy (intercept) is 43.41 percent, and the regression equation has an adjusted *R*-squared of .707. All of the coefficients in the regression equation were statistically significant at the .001 level, with the exception of the two check-related coefficients (the variation in per-person check sizes across and within party sizes), which were not statistically significant. For RevPASH-Ent, the base inaccuracy (intercept) is 2.96 percent and the regression equation has an adjusted *R*-squared of .681. With two exceptions, the coefficients in the regression equation were statistically significant at the .01 level: the dining duration variation within party sizes and variation in per-person checks across party sizes were not statistically significant.

Comparing the results of the two regression equations shows that all but one of coefficients in the RevPASH-Ent model were much lower in absolute value than the coefficients in the RevPASH-Opn model. This result is consistent with the overall lower level of inaccuracy in RevPASH-Ent.

These results in Exhibit 15 support seven of our twelve hypotheses for the simulation study (H2, H3, H4, H5, H6, H11, H12). Of the two hypotheses related to both RevPASH approximations, one was supported (H2) and one was not supported (H1). Both approximations were more accurate when there was a smaller time between check close and the table being reset but less accurate when there was a smaller time difference between a table being committed and the check being opened. Of the ten hypotheses specific only to RevPASH-Opn, six were supported (H3, H4, H5, H6, H11, H12), two were not confirmed (H7 and H8), and two did not have statistically significant results (H9 and H10). The counter results both related to the effects of dining duration variability on RevPASH-Opn, while the two check-related factors did not have significant effects, as we noted above.

To summarize the regression results, then, RevPASH-Opn's accuracy was compromised by a shorter time interval between a table being committed and the check being opened, a longer time interval between a check being closed and the table being reset for the next party, lower peak arrival rates, shorter peak demand windows, a bigger mean party size, random arrivals, longer dining durations, less variation in dining duration across party sizes, less variation in dining duration within party sizes, fewer days used to analyze performance, and shorter analysis time intervals. Similarly, the accuracy of RevPASH-Ent suffered, though not the to same extent as RevPASH-Opn, with a shorter time interval between a table being committed and the check being opened, a longer time interval being a check being closed and the table being ready for the next party, higher peak arrival rates, shorter peak demand windows, a smaller mean party size, random arrivals, shorter dining durations, less variation in dining duration across party sizes, more variation in per-person checks within party sizes, fewer days used to analyze performance, and shorter analysis time intervals.

Conclusions

In an examination of a real restaurant and in an extensive simulation study of 12,288 restaurant scenarios, we observed various levels of inaccuracy in both of the approaches that have been applied for

Exhibit 14:
Inaccuracy of the Revenue per Available Seat-Hour (RevPASH) Approximations in the Simulation Study

Factor	*Level*	*RevPASH-Opn[a] (%)*	*RevPASH-Ent[a] (%)*
Check-open time inaccuracy	1	37.21	2.76
(average inaccuracy, in minutes)	3	36.11	2.49
Check-close time inaccuracy	2	34.80	0.82
(average inaccuracy, in minutes)	10	38.52	4.43
Maximum party arrival rate (# parties/hour)	20	38.22	2.71
	60	36.20	2.70
	180	35.56	2.47
Length of peak demand period (hrs)	0	42.23	3.32
	1	39.06	2.70
	2	34.57	2.44
	3	30.78	2.04
Mean party size (# covers)	2.5	35.83	2.63
	3.5	37.49	2.62
Arrival process	0	36.35	2.59
	1	36.97	2.66
Mean dining duration (minutes)	45	25.86	2.62
	90	47.46	2.64
Variation in dining duration across party sizes,	1.5	37.12	2.64
measured as the ratio of dining duration for parties of 10 people to the dining duration for parties of one person	2	36.20	2.61
Variation in dining duration within party sizes,	0.25	37.98	2.63
measured as a coefficient of variation	0.5	35.34	2.63
Check variation across party sizes	0.1	36.72	2.63
	0.2	36.60	2.62
Check variation within party sizes	0.15	36.61	2.62
	0.3	36.71	2.63
# days of data	4	37.21	2.72
	13	36.11	2.53
Analysis period length (minutes)	5	58.77	4.17
	10	56.07	4.02
	15	54.89	3.91
	30	53.22	3.67
	60	48.62	3.34
	90	50.18	3.02
	120	45.47	3.02
	150	35.42	2.76
	180	27.68	2.15
	210	19.67	1.64
	240	13.86	1.15
	270	8.40	0.80
	300	4.33	0.47
Entire experiment		36.66	2.63

Note: RevPASH-Opn = RevPASH calculation using the traditional approach of check-open time; RevPASH-Ent = RevPASH calculation using the approach of the entire time the check is open.
a. Measured by the weighted average absolute percentage inaccuracy.

calculating RevPASH. The traditional approach, which captures revenue when the check is opened, tends to overstate revenue early in a meal period and understate revenue late in a meal period. The level of inaccuracy can be quite notable: on average, the

Exhibit 15:
Regression Results for the Two Revenue per Available Seat-Hour (RevPASH) approximations

Regression Model Variable	*RevPASH-Opn*	*RevPASH-Ent*
Intercept	43.41***	2.962***
Average number of minutes between a table being committed and a check being opened	–0.82***	–0.110***
Average number of minutes between a check being closed and the table being reset and made ready for the next party	0.46***	0.468***
Peak party arrival rate, in number per hour	–0.06***	0.010***
Length of the peak demand window, in hours	–3.60***	–0.342***
Average number of people per party	1.44***	–0.041**
Arrival process (= 0 for spaced arrivals, = 1 for random [Poisson] arrivals)	1.16***	0.130***
Average dining duration, in minutes	0.48***	–0.002***
Dining duration variation across party sizes (measured as the ratio of the dining duration for parties of ten to the dining duration for parties of one)	–1.93***	–0.085**
Dining duration variation within party sizes (measured as a coefficient of variation)	–10.63***	0.076
Per-person check variation across party sizes (measured as the revenue drop in the per-person check with a one-person increase in party size)	–1.40	–0.031
Per-person check variation within party sizes (measured as a coefficient of variation)	0.97	0.237**
Number of days of data used in calculating the RevPASH values	–0.23***	–0.041***
Analysis period length, in minutes	–0.22***	–0.015***
R-squared	.7074	.6812
Adjusted R-squared	.7073	.6812
Standard error	15.8483	1.6690

Note: RevPASH-Opn = RevPASH calculation using the traditional approach of check-open time; RevPASH-Ent = RevPASH calculation using the approach of the entire time the check is open.
$^*p < .05$. $^{**}p < .01$. $^{***}p < .001$.

level of inaccuracy was 36.6 percent across the whole simulation study. A new approach—calculating RevPASH based on apportioning revenue over the entire time a check is open—is much more accurate, having an average inaccuracy of 2.63 percent across the simulation study.

It has been advocated that managers tailor their revenue-enhancing decisions to the conditions, using different actions during periods of high RevPASH than in periods of low RevPASH. The inaccuracy of the traditional approach to calculating RevPASH, then, is problematic, in that calculating RevPASH in the traditional way could result in managers making the wrong decisions about appropriate methods to enhance revenue. Ideally, managers would calculate the true RevPASH. As we have noted, though, the limitations of existing POS systems make this impractical. An excellent alternative for managers, then, is to calculate RevPASH using parties' entire meal durations. As our extensive study showed, calculating RevPASH using the approximation based on the entire interval a check is open is about fourteen times more accurate than the traditional approximation of calculating it based on the instant a check is opened.

RevPASH has been used as a performance metric in a number of academic studies. While the traditional approach to calculating revenue is accurate when an entire meal period is being analyzed, it has significant inaccuracies when shorter analysis periods are used. We caution academic researchers, then, to ensure that their findings are not tainted by inaccurate RevPASH calculations. Our advice to managers also applies here: academic researchers should immediately begin calculating RevPASH using the entire meal duration for parties.

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