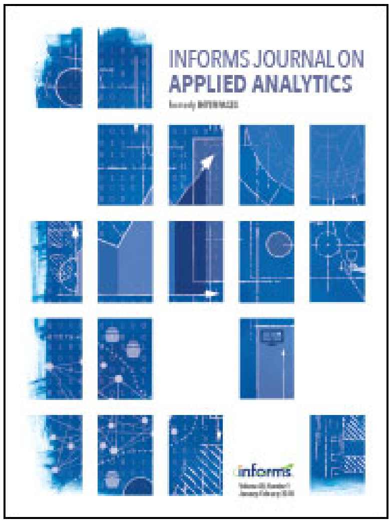

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The "Killer Application" of Revenue Management: Harrah's Cherokee Casino & Hotel

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Harrah's Cherokee Casino & Hotel is an unusual example of the use of revenue-management (RM) techniques. Typical RM installations yield revenue improvements of between 3 and 7 percent. The Harrah chain has seen 15-percent improvements, with Harrah's Cherokee Casino & Hotel as the largest beneficiary—although it does not serve alcohol or have traditional table games. In addition, the RM techniques that the Cherokee uses, such as its pricing decisions and customer-segmentation rules, are different from those used in RM applications in other industries.

Key words: linear programming applications; hotel/motel industry; perishable inventory; gambling.
History: This paper was refereed.

It's a typical Thursday summer night at the reservations office of Harrah's Cherokee Casino & Hotel (the Cherokee): 183 of its 576 rooms are still unreserved for tomorrow night. A returning customer calls.

Customer: "I'd like to reserve a room for tomorrow night."

Operator: "May I have your Total Rewards number?"

Customer: "10701319246."

This number identifies the customer as Joe Smith. Historically, Joe Smith bets an average of $2,000 per night. Probabilistically, this means that the Cherokee will net $140 profit on Mr. Smith's gambling alone.

Operator: "Sorry, Mr. Smith, all the rooms at the Cherokee are booked. Would you like me to make you a reservation at the Ramada? The room will be complimentary, of course."

For those who have studied revenue management (RM), Mr. Smith's reservation request has several unusual aspects. The Cherokee denied his room request, although it has 183 unreserved rooms for that night, and gave Mr. Smith a free room at another hotel. The Cherokee's management believes that the hotel's RM system, which makes such decisions, contributes to the hotel's profitability.

In other industries, RM systems have increased revenue by 3–7 percent (Cross 1997). Harrah's system has increased revenue per room across the hotel chain by 15 percent (Underwood 2003). Because the Cherokee opened with an RM system in place, there is no percentage improvement available. However, it is clearly financially successful; it returns a 60 percent profit margin on gross revenue—double the industry norm (Smith 2006).

RM applications in the gaming industry have received some attention in the academic literature. Talluri and van Ryzin (2004) briefly mention RM; Hendler and Hendler (2004) and Kuyumcu (2002) explain the theory of how it should be accomplished and the difficulties of implementation. While the Cherokee has a state-of-the-art RM system, our purpose in this paper is not to describe innovative RM algorithms. Rather, our goal is to showcase the success and value of a significant application of RM. Indeed, the Cherokee application represents the "killer application" of RM.

Revenue Management in Casino Hotels

RM systems in casinos differ from RM systems in other industries. Gambling requires different pricing and customer-segmentation approaches. Additionally, the tremendous difference in customers' willingness-to-pay in this industry compared to other industries is the engine that drives the extra profitability.

Pricing

Smith et al. (1992) have defined the purpose of RM as selling the right capacity to the right customer at the right price. For now, let us accentuate price.

The top graph in Figure 1 depicts traditional price setting as Economics 101 explains it: A market clearing price P_0 occurs where the supply and demand curves meet. The shaded region above the price point and below the demand curve represents *consumer surplus*, or the difference between the price that a consumer would pay and the price that a consumer must pay. A major RM concept is setting differential prices for homogenous capacity. That is, for capacity, such as coach-class seats on an airplane or standard hotel rooms, which appears the same to an outside observer; a goal is to get those who would pay more to do so. The middle graph depicts the typical RM approach. Several prices are set; however, only the shaded regions above each price point P_0, P_1, and P_2 are consumer surplus. Consumers who are willing to pay more than P_1 for the service are no longer paying just P_0. Setting appropriate prices is a difficult and crucial aspect of traditional RM.

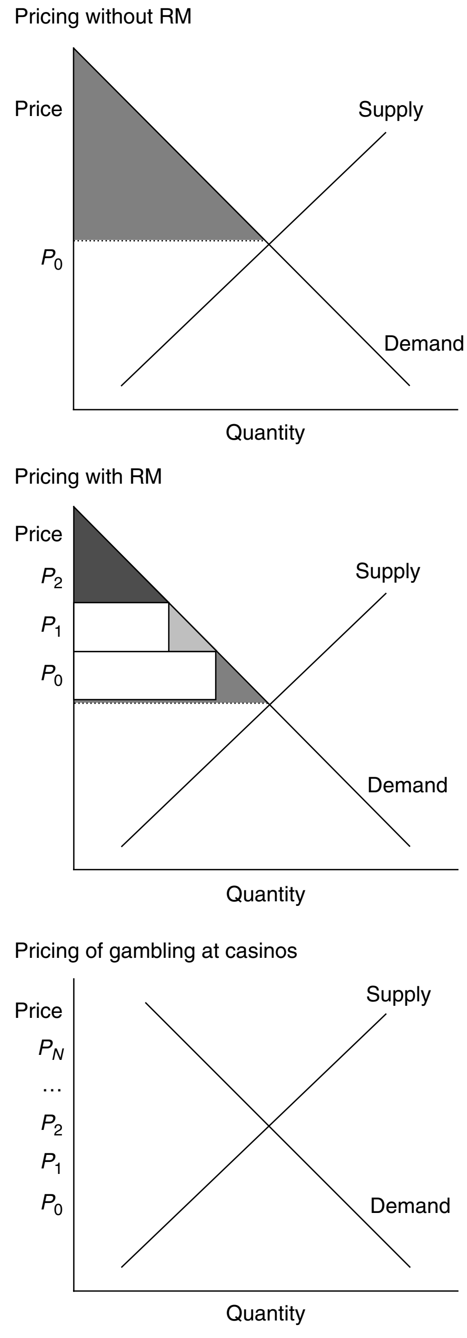

Figure 1: Casino pricing differs from traditional RM pricing.

However, price setting in gambling does not really occur. Each customer sets his or her own price—the amount he or she wishes to gamble. Given N standard hotel rooms, there are N different amounts of revenue that the casino derives from customers using undifferentiated capacity, as the bottom graph of Figure 1 depicts. Consumer surplus is entirely ceded to the producer.

Segmentation by Restriction

The middle graph in Figure 1 depicts an ideal RM situation. All who are willing to pay above price P_2 pay P_2; all who are willing to pay above price P_1 pay at least P_1. In reality, many who are willing to pay a high price find a way to pay a lower price. A basic RM problem is how to enforce differential prices for the same service. Typically, prices are enforced by restrictions. For the airlines, typical restrictions are how far in advance a customer books a flight and whether the trip includes a Saturday stay-over. Business travelers are less concerned about price; they tend to book reservations very close to their day of departure and tend not to want to stay over a Saturday. Leisure travelers are more price-conscious; they tend to book well in advance and stay the weekend.

However, segmenting by restriction has many downsides. Some restrictions are illegal. "Ethnic pricing" of airfares—charging different prices based on nationality—is illegal in the United States, but is a common practice elsewhere (Mitchener 1997). Segment accuracy is a more common problem. Business travelers who plan in advance or are willing to stay over on a Saturday receive cheaper airfares, even if they would been willing to pay more. Some customers avoid paying higher prices by finding ways, some creative, some too creative, to circumvent the rules (Metters et al. 2006, p. 251). Negative customer perception and loss of goodwill are also problems with segmenting restrictions. Casinos, however, have no need to create such restrictions because customers segment themselves. This lack of artificial segmentation is an advantage for RM operations.

Willingness-to-Pay

Because of the large differential in customer willingness-to-pay, RM decisions have a greater impact in casinos than in other industries. Among those who receive standard hotel rooms, the top casino gamblers may lose several thousand dollars per day, while other customers may lose $50 per day. Thus, the highest-paying customers are willing to pay 20 to 50 times more than the lowest-paying customers. Conversely, the highest-paying airline coach-class customers might only be willing to pay three to five times more than the discount customers, and the highest-paying customer in a standard hotel room in a non-casino hotel might pay merely double the discount rate. Consequently, the opportunity cost of filling a room with a low-paying customer rather than a high-paying customer is much greater for casinos, and the differential in willingness-to-pay makes improving RM decisions very profitable. We now discuss the Cherokee in particular.

Cherokee Property Description and Background

The 13,000-member Eastern Band of Cherokee Indians owns and operates Harrah's Cherokee Casino & Hotel. Harrah's and the Eastern Band operate the hotel jointly, with Harrah's sharing less in daily operations and profit over time.

The Cherokee casino differs from a typical casino because of its goals and competition. Unlike other casinos, it uses its profits to better the life of the immediate Cherokee Indian community. Instead of returning profits to stockholders, it returns profits to Cherokee tribe community funds. These funds support all tribe members; they specifically aim to support better health care, education, and other initiatives to increase the tribal standard of living. Because of this community-centered goal, Cherokee management makes some uncommon casino decisions.

The casino does not serve alcohol and prohibits entry to patrons who notify the Cherokee that they have a gambling problem. Because of negotiations between the tribe and the state of North Carolina, the Cherokee has no table games, such as roulette, craps, and poker. It has no dice or physical playing cards. The blackjack and baccarat games are electronic—the dealer pushes a button and a card image appears on the players' screen.

The Cherokee, which is in the town of Cherokee in rural western North Carolina, has a location challenge. It draws many of its customers from the Atlanta, Georgia metro area, a three-hour drive away, and from other metro areas throughout South Carolina, North Carolina, and Tennessee. It has no direct competitors for hundreds of miles, giving it a natural monopoly. However, the Cherokee recognizes that its customers can easily fly to Las Vegas or other gambling locations that serve alcohol and provide poker, roulette, and craps tables.

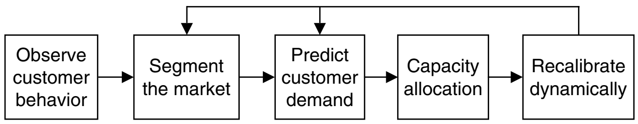

Figure 2: A flowchart of the typical RM process illustrates key tasks.

The Cherokee contracted with Harrah's to manage its casino. Harrah's, the world's largest gaming company, has a history of bringing advanced mathematical analysis to the gaming industry. A former Harvard Business School professor, CEO Gary Loveman, has published articles about the pioneering use of analytic techniques at Harrah's (Loveman 2003) and at other organizations (Loveman 1998). Many articles in the popular press have extolled the virtues of Harrah's analytic approach to the industry (McGinn 2005, Schlosser 2004, Underwood 2003). As Chang and Pfeffer (2003, p. 7) note in a Stanford Business School case written about Loveman and Harrah's, "Loveman believed that there was an opportunity to apply science to the gambling business." This analytic approach has been instrumental in the Cherokee's profitability.

The Cherokee, which opened in November 1997, expanded to 252 rooms in 2002 and to 576 rooms in 2005. It now has 88,000 square feet of gaming space, 3,400 gaming devices, and several restaurants and meeting spaces. However, its 576 rooms are insufficient. Its occupancy rate averages 98.6 percent during January through November, weekdays and weekends. It extends hotel stays only to its very best customers. However, the Cherokee has so many good second-tier customers that it purchases blocks of rooms at neighboring hotels for them. Let us restate some pertinent facts: The Cherokee is a three-hour drive from its target market, offers no alcohol or physical, tangible table games, yet has a 98.6 percent occupancy rate. It returns a 60 percent margin on revenue to the Cherokee tribe. Truly, it is an unusual property.

Figure 2 shows the key tasks involved in most hotel RM systems. In the following sections, we provide more details on each of these tasks and on what makes the RM practice at the Cherokee so unusual.

Observing Customer Behavior

The middle graph in Figure 1 illustrates an idealized version of assigning customers to segments in a typical RM situation. The bottom graph in Figure 1 depicts a Utopian version of RM at a casino. If N rooms are available, how can a system be devised to say "yes" to the N most profitable customers who wish to book a room for that evening, while declining the bookings of all other customers?

For Harrah's the answer starts with its customer-tracking program. The system is based on the "Total Rewards" card program, which tracks customers' wagers. Before playing an electronic game, customers enter their card into the gambling device; the system tracks the plays electronically, recording the amount each customer bets. For the electronic table games, the customer presents the card to a casino employee, who notes the average wager and duration of play.

Harrah's customers have a strong incentive to use their Total Rewards cards. The Cherokee gives complimentary or reduced-price rooms, meals, casino chips, valet service, and other perks and amenities based on tracked play. The more a customer spends gambling, the more amenities the hotel gives. There is a potential weakness because some potentially high-profit customers do not have Total Rewards cards; however, 83 percent of the money wagered at Cherokee is "tracked" play. Thus, Harrah's is able to leverage its size. It is the largest gaming company in the world; its Total Rewards system tracks 27 million people and it tracks 76 percent of gambling revenue to specific customers (Binkley 2004).

At the Cherokee, free rooms are standard, not an exception. From January to November, 98.6 percent of the rooms are complimentary; nearly 100 percent are complimentary on most weekends. Thus, the average room rate is approximately \$6 per night. This seems unusual in the hotel industry, where traditional hotels try to increase their per-room revenue, not decrease it. The difference at Harrah's is that "revenue" means the total amount that a customer spends—including food, gambling, and hotel room. Although their rooms may be free of charge, Cherokee guests "pay" \$565 per night on average.

This tracking system has benefits beyond room-reservation decisions. Many Cherokee gamblers stay at another hotel in town or just visit for the day. Those not staying at the Cherokee also receive incentives for using their Total Rewards cards. The Cherokee monitors gambling in real time; if customers lose a lot of money, employees give them free \$5 or \$10 vouchers to help them "change their luck." In addition, customers who gamble during a given period are automatically entered in random drawings for prizes or cash while in the casino. These and other incentives give patrons an incentive to use their reward cards everywhere in the casino. This customer compliance aids the casino in understanding how people gamble. It can track the effect that marketing initiatives have on gambling patterns, giving the Cherokee the information it needs to improve each initiative.

The Cherokee also tracks each machine's total customer spending by the time of day. The casino can place the most popular machines farther into the casino, knowing that patrons will seek them out and spend money at other machines along the way. The casino constantly tracks the overall casino layout, and compares machine spend at one layout versus another to refine and optimize traffic flow. It also uses this information to encourage guests to stay a little longer (and spend more). For example, if the Cherokee sees that patrons start to leave about 2 PM on a Sunday, it may announce a random drawing for 3 PM to encourage them to stay an extra hour.

This tracking differs significantly from traditional casino practice. The casino staff has always pampered its big spenders. However, a knowledgeable employee tracked each big spender on a personal level; the tracking was done on an informal basis so that the precise customer spend was unknown. In addition, the designation of a customer suited for special treatment could be because an employee singled out a large tipper or a personal friend, rather than a true revenue producer for the Cherokee. This illustrates the difference between the Cherokee system and systems used at other casinos. The Cherokee's is far more accurate; thus, it is useful for RM purposes. The informal tracking previously done would be impossible on a scale large enough to serve as a basis for management decisions. Traditionally, casinos have only tracked the truly big spenders. Harrah's pioneered the concept of tracking "mid-tier" customers and found them to be very profitable, to the surprise of many experienced casino managers. While other casinos also have similar customer-loyalty programs, Harrah's is innovative in that it actually uses the Total Rewards data in its RM system.

Customer Segmentation

The Total Rewards program assigns a specific value to each customer. It is unnecessary to segment customers into "business," "leisure," or other designations for pricing purposes; the customers self-price by gambling. However, to visualize the data and to ease forecasting, it is useful to segment customers into discrete groups (Table 1).

Table 1 shows the customer-segmentation scheme. This visual display creates an environment that is easier to manage. Mathematically, it might be optimal to close rooms to customers whose expected profit is under \$379.25, and hold open 10 extra rooms for customers whose expected profit is between \$627.39 and \$745.67. However, administratively, it is more effective to visualize the data in a customer-segment format. The Cherokee uses 10 customer segments based on expected gaming losses, which it calculates by multiplying historical "coin-in"—the amount of money wagered—by the house percentage. For purposes of segmentation, whether a customer wins or loses money does not matter—only the amount that the customer gambles. CS0 is the highest gambling segment that the Cherokee uses. Patrons in this segment have an expected gambling loss of over \$1,000 per night. Correspondingly, CS1 patrons have expected gambling losses ranging from \$800 to \$999 per night. The lowest-level gamblers are in segment CS8. Segment CS9 is for potential customers who are not in the database.

Segment	Expected wagering profit (\$)	Unconstrained room demand	Demand override	Rooms allocated	Current sold	Bid price
CS0	≥1,000	119	119	120	84	RFB1*
CS1	800–999	128	128	122	75	RFB2*
CS2	600–799	126	126	124	69	ROC*
CS3	400–599	122	**150**	138	79	ROC*
CS4	300–399	155	155	43	43	\$125
CS5	200–299	168	168	0	0	\$225
CS6	100–199	144	144	0	0	\$325
CS7	50–99	103	103	0	0	\$375
CS8	0–50	92	92	0	0	\$425
CS9	Unknown	45	45	0	0	\$450

Table 1: The table data (approximate) illustrate the customer-segmentation scheme; they show Thursday data for a Friday event. *RFB1 refers to complimentary room, food, and beverage at level 1, the best rooms and restaurants available. RFB2 refers to a lesser level of complimentary meals. ROC indicates the "room only" is complimentary.

System operators see a more complex version of Table 1 for customer segmentation, forecasting, and bid prices. Figure 3 shows the main recommendation screen that operators view.

For confidentiality, Figure 3 shows a screen shot of an unnamed hotel that uses the same software. The main portion of the screen shows the same information as in Table 1. The left banner of the screen shows the status of each day in an eight-month horizon. If an operator clicks on a particular day, the system presents the data pertaining to that day. While the demand forecasts are refreshed daily, the operator can recalculate bid prices and computer-generated recommendations at any time. The software also has modules to address group sales.

The customer does not see this segmentation. Typically, a business hides its segmentation scheme from customers to avoid their taking advantage of the system. For example, consider a hotel customer who is willing to pay the "rack" rate—the undiscounted, highest rate paid at the hotel for that room. If the customer learns that a customer in a different segment can purchase the same room for a lower price, one of two events might occur: the customer will try to convince the hotel staff that he or she is in the preferred segment, or the customer will become angry and the hotel will lose goodwill.

A unique aspect of RM in the gaming industry is that the customers' motives are aligned with the segmentation scheme. The customer does see a segmentation scheme at the Cherokee; however, it is not the scheme that Table 1 shows. The Total Rewards cards have three levels: gold, platinum, and diamond. Customers earn larger perks and discounts, including preferred seating at restaurants and exclusive promotions, at each successively higher level. They attain higher reward levels by gambling more money; the hotel earns higher profits when customers gamble more money. Hence, the customer and the firm have aligned incentives within the RM system.

Forecasting Demand

The room-allocation process starts with forecasting "unconstrained demand" for each of the market segments. "Unconstrained" refers to a forecast of *true* customer demand for a service. Like other RM applications, the forecast for today's demand is based on comparable historical data. For example, the forecast for a particular Friday would be based on what happened on the previous few Fridays and on a similar date last year. In many RM applications, the true demand for prior events is unknown—only the number of people given reservations is known. To get a clearer picture of true demand, the Cherokee also tracks, by customer segment, customers who were denied reservations. It is able to do so because customers provide their Harrah's Total Rewards number when requesting a reservation. Most Cherokee reservations are booked through its call centers and Web pages; however, a small percentage is booked using third-party channels such as Travelocity, Expedia, and Orbitz.

Although the Cherokee can capture customer denials when the customers book through its own channels, it is unable to capture third-party channel data. Therefore, it must unconstrain the demand data from third parties. It does so by using a simple method. Assume that for a given customer segment, the Cherokee allows 20 bookings through its own channels, but observes a total of 25 booking requests (i.e., five customers were denied bookings). Thus, total demand for this segment was 125 percent of the booked demand. Assume also that four reservations were made using third parties for the same night, but no denied requests were recorded. To unconstrain the demand data from the third-party sites, the RM system will multiply the four recorded bookings by 125 percent, resulting in a total of five booking requests. Thus, the total unconstrained demand recorded for this segment on this night will be 30 $(25+5)$.

Note that we do not recommend this unconstraining method for properties that do not book a large percentage of their reservations using their own channels because extrapolating the percentage of denied bookings to a much larger sample could lead to significant errors. Most other hotel chains and airlines are in this second category; other unconstraining methods are more suitable for these firms (Queenan et al. 2007). After unconstraining historical demand, the Cherokee applies a forecasting algorithm that is similar to a Holt-Winters smoothing model. The forecast includes smoothed values for base demand, demand trends, annual and day-of–the-week seasonality, and special-event factors. A forecast is created for every customer segment and every day in the booking

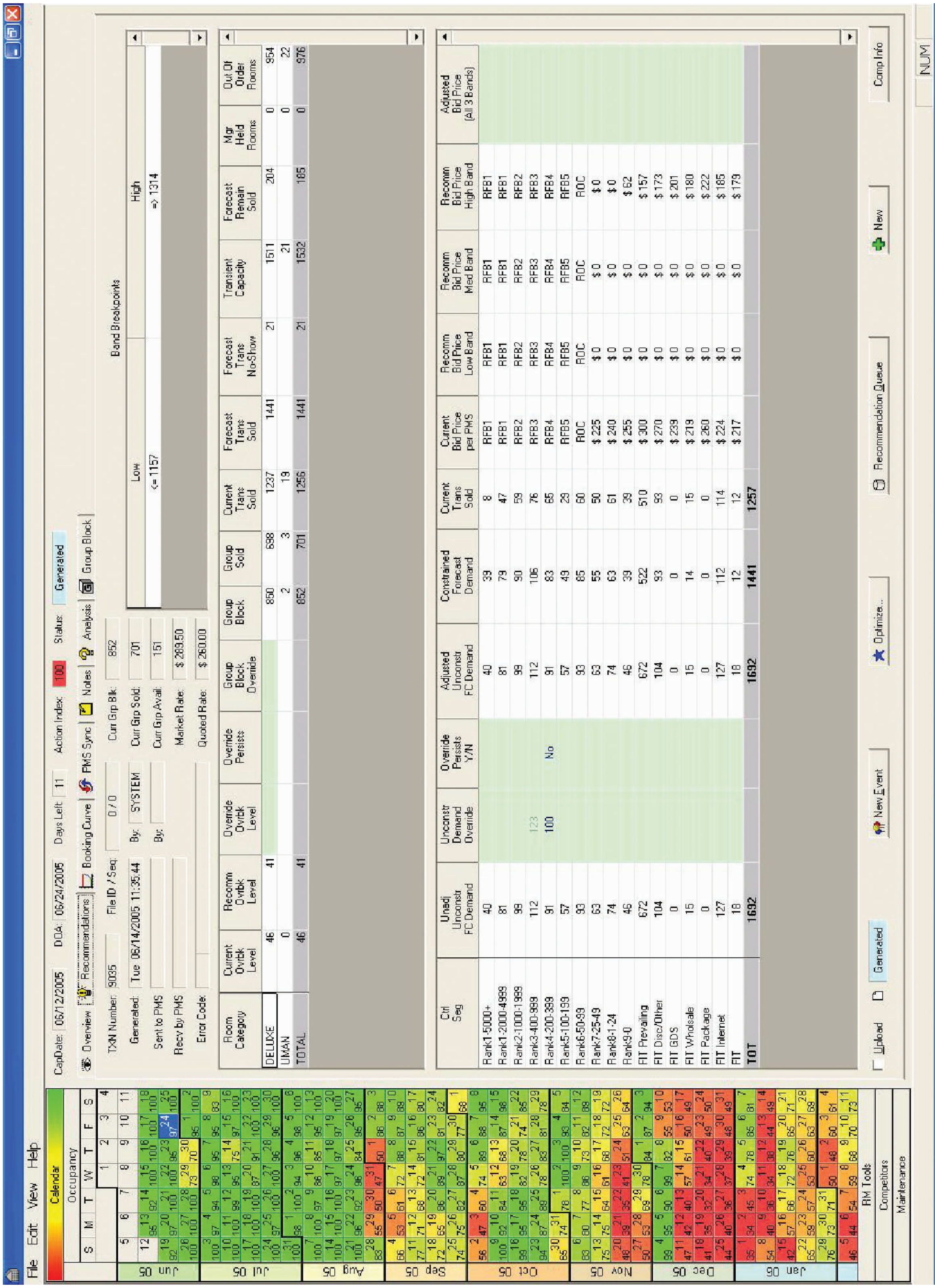

Figure 3: This screen capture shows the customer-segmentation schemes available.

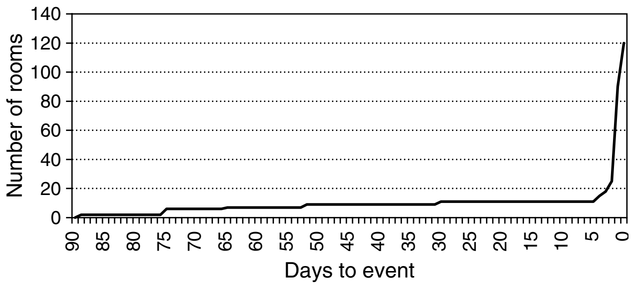

Figure 4: Booking curve of a typical weekend.

curve. For example, $F_{i,t}$ represents the forecast for customer segment i that is t days into the booking curve. If the booking curve is monitored for 90 days before arrival and there were no seasonal or special-event effects, then $t = 1, \ldots, 90$, and the forecasting model would just be a double exponential smoothing model, predicting a curve similar to the curve that Figure 4 shows.

However, seasonality and special-event effects are present; therefore, the forecast must be adjusted accordingly. Each of these effects is included in the forecast by multiplying its "smoothed" coefficient with the original base and trend component, similar to the Holt-Winters smoothing model. Thus, the forecasting model takes the general form:

$$F_{i,t} = (Base_{i,t} + Trend_{i,t})(Seasonal\ Month_{i,t}) \cdot (Seasonal\ Day_{i,t})(Event_{i,t}).$$

As an example of how the forecasting model works, suppose that we are forecasting demand for customer-segment 2 for a Thursday-night stay in April, and a new car will be given away at a special event scheduled for this night. The forecast of most interest is the total demand for customer-segment 2 throughout the booking horizon, i.e., $F_{2,90}$. If we are presently only 10 days into the booking curve, then we extrapolate the cumulative demand out to the entire 90-day booking horizon using double exponential smoothing. Thus, if the base component at $t = 10$ is 5 and the trend component is 1.5 customers per day, then the base + trend forecast for total demand will be 125 ($5 + 1.5(90 - 10)$). Suppose that demand in April is lower than average such that the monthly season coefficient is 0.87, the demand on Thursdays is higher than average such that the daily seasonal coefficient is 1.05, and the special-event coefficient is 1.12 (the car giveaway draws 12 percent more demand than normal). The final forecast for this day and this segment will then be $F_{2,90} = (125)(0.87)(1.05)(1.12) = 127.9$. All these factors are updated based on unconstrained demand data from previous booking curves. Management can override the forecast manually under special circumstances, such as a prediction of severe weather or a special event planned by the competition.

Capacity Allocation

The Total Rewards system provides information on the history of a customer who requests a reservation. The segmentation scheme helps by collecting these data into a manageable entity. However, the Cherokee system still must decide how many reservations to accept from each customer class.

The hotel staff makes day-to-day booking decisions; however Rainmaker manages the back-office aspects of Cherokee's RM system, as it manages RM systems for many gaming-industry properties. Talus (now called JDA) developed the system initially. Talus has also developed RM solutions for car-rental firms (Geraghty and Johnson 1997, Grimes and Carroll 1995) and other corporations; these include Ford, Hilton, Marriott, TUI, Omni Hotels, Continental Airlines, Sommerfield, and Limited Brands.

As is typical in RM hotel systems, the system controls all but the highest-value customers and suites. Casino staff directly books the extremely high-value, VIP customers and schedules all suite bookings. The RM system is used for booking the 547 standard rooms in the 576-room hotel.

Overbooking and optimization models use the forecasts as inputs to recommend inventory controls—the "constrained demand" in Table 1. The booking-recommendation system is, at its core, a linear program. The optimization model is a special case of the price-inventory management model of Kuyumcu and Popescu (2006). The bid-price model is updated (or reoptimized) each time one of the following events occurs: (1) 24 hours have passed since the last optimization, (2) five rooms have been booked since the last optimization, or (3) the RM analyst manually starts a new optimization (by clicking on the optimize button on the bottom of the screen that Figure 3 shows).

Bid-Price Construction

The basic task of any RM system is to determine, at the time of a customer request, whether it is more profitable to meet the customer's request, which will reduce the available capacity by one unit, or to deny the request in hopes that there will be an opportunity to sell the capacity to a higher-value customer before its expiration date. The key to this decision is the calculation of the "opportunity cost" from selling a unit of capacity to the wrong customer. Typically, this opportunity cost is calculated using the average revenues or profits of the higher-value customer segments multiplied by the probabilities that a higher-value customer will request that unit of capacity before its expiration date.

At the Cherokee, customers from a low-value segment are termed "nickel slotters" because their average spending is approximately \$30 per night, mostly from playing the nickel slot machines. In contrast, a customer from the "high-roller" segment might spend approximately \$500 per night. Obviously, the Cherokee prefers to sell a room to a high-roller customer. But, what if a room is available and a nickel slotter requests it first? The Cherokee uses a variation of a bid-price control system to determine whether to sell this customer a room. A bid-price system sets a threshold limit for the amount of expected revenue a customer will generate per night. If the customer is in a segment in which the average spend is less than this threshold, that customer is denied a room. If the customer is in a segment in which the average spend is higher, that customer is given a room.

To demonstrate how a bid-price control system works, assume for simplicity that a casino only rents rooms for one-night stays (this procedure can easily be modified to accommodate multiple-night stays, but the notation becomes more complex). Also assume that the casino segments its customers into K distinct segments. Let r_i represent the historical average revenue that a customer from segment i spends per night at the casino, where $i = 1, \ldots, K$. Let d_i represent the forecasted total demand for rooms from customers in segment i. The decision variable is X_i, the number of rooms to allocate to customers in segment i. The sum of the rooms allocated to each segment must be less than or equal to the casino's capacity. Using this notation, the bid-price control problem can be formulated as a linear program (LP) as follows:

$$
\begin{aligned}
\max \ \ & \text{Total Revenue} = \sum_{i=1}^{K} r_i X_i \\
\text{s.t.} \ \ & X_i \le d_i, \quad i = 1, \ldots, K, \\
& X_i \ge 0, \quad i = 1, \ldots, K, \\
& \sum_{i=1}^{K} X_i \le \text{Capacity}.
\end{aligned}
$$

The objective function in the above LP is the sum of the average revenues per segment times the number of rooms allocated to that segment. The first constraint ensures that the number of rooms allocated to a segment does not exceed the forecasted demand for that segment. The second constraint ensures against a negative allocation of rooms to a segment, and the third constraint ensures that total allocation does not exceed the casino's capacity.

The EMSR-b algorithm (Talluri and van Ryzin 2004) is an alternative capacity-allocation algorithm that factors in demand uncertainty. Indeed, if the capacity allocations were not updated frequently over the booking horizon, the EMSR-b method would be preferable to the bid-price algorithm because the bid-price model uses expected values for its demand parameters. The use of expected values does not consider the possibility that having less capacity than demand might be more or less costly than having more capacity than demand (by factoring in demand uncertainty, the EMSR-b algorithm addresses this situation explicitly). However, the bid-price model compensates for ignoring demand uncertainty by constantly updating the forecast for each customer segment and reoptimizing the capacity allocations accordingly. Because of the frequent forecast updates, the negative impact of ignoring demand uncertainty is minimized in the same way that solving a deterministic production-planning model on a rolling horizon minimizes the negative impact of ignoring demand uncertainty in a production environment.

Although we could solve the LP above directly to determine the exact allocation of capacity for each customer segment, it is more practical to solve it and use the resulting "shadow price" from the capacity constraint. The shadow price provides an estimate for the opportunity cost of reducing capacity by one room. In other words, a customer who requests a room must bring in more revenue than the shadow price if it is to make economic sense for the casino to reduce its capacity by one room. RM systems refer to shadow prices as *bid prices*. Chen and Freimer (2004) provide a good introduction to hotel bid-price RM systems (including multiple-night stays); Talluri and van Ryzin (2004) provide some advantages and disadvantages of using bid-price controls rather than alternative RM capacity-allocation algorithms.

The bid prices that Table 1 shows are not only the outputs of an LP; they are administrative in nature. Table 1 includes the level of complimentary services accorded to each customer segment. As a practical matter, hotels do not charge more than their standard rate, even if the LP-generated bid prices indicate that they should, because they believe customer reaction would be negative to such a practice.

Table 1 illustrates a night when the Cherokee closed bookings to customers at the CS5 level and below. This level of closure is not unusual. For many weekend summer nights, the Cherokee closed reservations at level CS0 (>1,000), and excluded customers with a theoretical profit of $0–$1,000.

Booking Curves

A booking curve shows the cumulative demand for a product from a customer segment from the day the product is made available until its day of departure (airline) or arrival (hotel or casino). Cherokee booking curves differ substantially from those of other businesses that utilize RM systems. For a typical airline or hotel, demand from the less-desirable customer segments arrives early, while demand from the more-desirable customers arrives closer to the departure or arrival date. Airlines offer deeply discounted international-flight seats 21 days in advance only; these seats frequently sell out within days. Discounted hotel rooms associated with conferences are often blocked years in advance. Full-coach airfares and rack-rate hotel rooms are typically booked a week to a day in advance.

In contrast, the booking curves at the Cherokee resemble the curve that Figure 4 depicts. Figure 4 shows a disguised version of a typical weekend-night booking curve. For clarity, we show only one customer segment. The x-axis depicts the number of days prior to the date under consideration, with "0" as the day of the arrival. The y-axis shows the cumulative number of rooms reserved. The most striking aspect of the booking curve is the sharp spike as the arrival day approaches. For this 576-room hotel, which will be filled on Friday night, it is not unusual to have only 240 rooms reserved by the previous Wednesday. On Friday, approximately 100–120 customers without reservations will walk in and request a room. A Friday stay at the Cherokee is often an impulse, decided upon at work on a Friday afternoon. The Cherokee commonly receives reservation requests from guests calling on their cell phones while driving to the hotel.

This sharp spike in the booking curve speaks to an intense need for an RM system. Without a system that can accurately predict demand from more-desirable customer classes and reserve rooms for the predicted guests, the temptation would be overwhelming to grant reservation requests from less-desirable customer classes. Unlike typical hotels, there is no major difference in the shape of the demand curves between customer segments at the Cherokee. Most customers in all customer segments tend to wait until the day of an event to make their reservations.

The system operator observes a more complex version of Figure 4. Figure 5 shows a screen shot of actual booking curves (again, for confidentiality reasons, Figure 5 depicts a different hotel).

The color-coded lines in the lower-left portion of the screen show forecasts for the current day and the actual results from prior, similar days. The line starting at the upper-left portion of the screen represents the number of rooms that the system is allocating. This number changes over time because of overbooking considerations and decisions made about groups, such as conventions or meetings, which are outside the scope of the system.

As we noted earlier, the occupancy of the hotel is 98.6 percent. Typically, such a high occupancy rate indicates poor RM. The traditional way to achieve high occupancy is to accept all reservations as they come in; however, this shuts out the desirable customers when they try to book later. Best-practice RM saves a block of rooms for desirable customers. However, because of the stochastic nature of customer arrivals and the inability to accurately forecast, a significant portion of the saved rooms will remain unused. Indeed, Rainmaker reports that in a typical gaming application, occupancy will decrease by 4 percent, although revenue will increase by 17 percent.

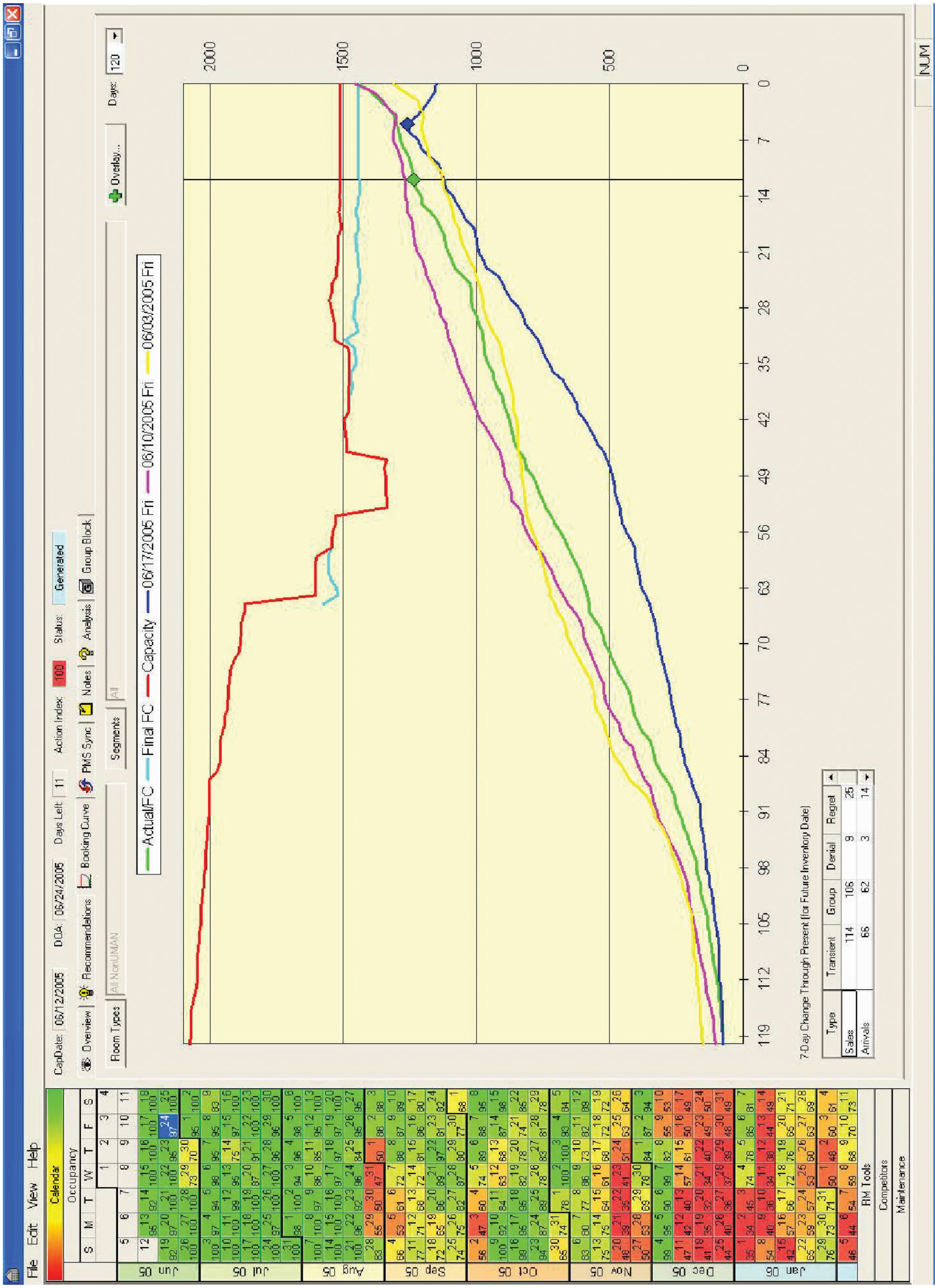

Figure 5: This screen capture shows the booking-curve information available.

The Cherokee avoids this because of the nature of its last-minute business and low no-show rate.

The nature of the last-minute reservations also helps to create a high occupancy rate; this increases profitability. For typical airlines and hotels, the discount business books well in advance; because of customer-segmentation rules, this segment is prohibited from booking at the last minute. Unfortunately, this process leaves these businesses with empty seats and rooms if the high-paying customers do not arrive as forecasted. For the Cherokee, however, this is not the case. If, at 8 PM on a Friday night, the predicted high-value customers have not arrived as forecasted, the Cherokee can give rooms to lower-value customers. It is important to note that the Cherokee's RM system is critical for predicting demand because the defined high-value customers vary from season to season. On a busy night (e.g., New Year's Eve), there may be enough demand from the two or three highest segments to fill the hotel. In a mid-week during a slow season, the hotel might need to book rooms from customers across all classes. The RM system allows the casino to turn away lower-value customers while knowing, with a reasonable probability, that higher-value customers will fill the rooms.

The no-show rate and resulting overbooking are essential elements of any hotel RM system. However, the no-show rate at the Cherokee is quite small and predictable, averaging only seven customers per night on Monday through Thursday, and 15 customers on the weekends. Largely, this is a function of the booking curve. No-shows are more likely to occur when a customer reserves a room far in advance, and intervening events cause plan changes. Because most rooms are reserved on only a few days notice—or while driving to the location—there are far fewer cancellations.

Figure 6 summarizes the decision process of the RM system each time a room request arrives (a customer in segment i in this example). Each room request updates the forecast whether or not the request is honored (assuming, as we discussed previously, that the request does not arrive from a third party). For each room request, the customer inputs his or her rewards number and the system pulls up the total expected nightly spend associated with this number. If this amount is greater than the current bid price, the customer receives a room; otherwise, the room request is denied. The forecast and bid prices are then periodically updated to reflect the new information about demand and capacity.

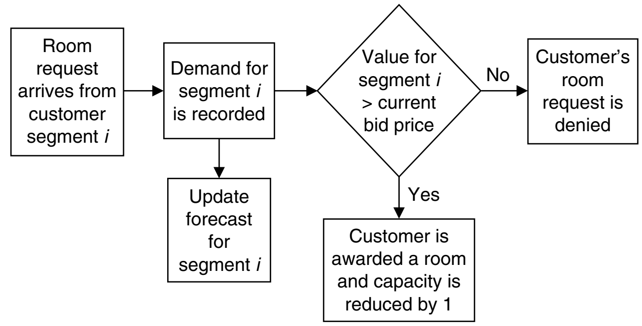

Figure 6: This flowchart shows the Cherokee RM decision process.

Measuring RM Effectiveness

A measure of system effectiveness, the *revenue-opportunity index* (ROI), demonstrates the need for an RM system:

$$\text{ROI} = (\text{actual revenue} - \text{optimal revenue}) \\ /(\text{revenue with no controls} - \text{optimal revenue}).$$

ROI is a hindsight measure. The optimal revenue is calculated based on the number of reservations denied from higher-segment groups, while reservations were accepted from lower-paying segments. Actual numbers are considered proprietary; however, the ROI calculation in Table 2 demonstrates the order of magnitude of using an RM system at the Cherokee.

The RM system allocates rooms in the same manner as Table 1 illustrates, and generates $460,650 in gaming revenue that day. The "optimal" column indicates that a few guests who arrived at the last minute were not given rooms. If the system had perfect knowledge of all guests' intentions, then $471,100 could have been generated. However, consider the situation with no RM system. Because there would be no tracking of high- versus low-rollers, reservations would be accepted on a first-come-first-served basis. Given the booking curves of all segments, this would generate approximately uniform bookings among customer segments. Because no high-rollers would be tracked and no complimentary rooms provided, each patron would pay $125 per night per room. Including the additional room revenue, the first-come-first-served

Segment	Expected wagering profit ($)	Rooms sold: RM system	Gross revenue: RM system* ($)	Rooms sold: optimal	Gross revenue: optimal* ($)	Rooms sold: no system	Gross revenue: no system** ($)
CS0	≥1,000	120	180,000	125	187,500	55	89,375
CS1	800–999	122	109,800	130	117,000	55	56,375
CS2	600–799	124	86,800	124	86,800	55	45,375
CS3	400–599	138	69,000	140	70,000	55	34,375
CS4	300–399	43	15,050	28	9,800	55	26,125
CS5	200–299	0	0	0	0	55	20,625
CS6	100–199	0	0	0	0	55	15,125
CS7	50–99	0	0	0	0	54	10,800
CS8	0–50	0	0	0	0	54	8,100
CS9	unknown	0	0	0	0	54	12,150
Total		547	460,650	547	471,100	547	318,425

Table 2: The table data illustrate possible revenue streams: They show representative weekend-night data. *Gross revenue calculation assumes $15,000 per night for CS0 segment, and the midpoint of the expected wagering profit for other segments. **Gross revenue also assumes no complimentary rooms, a room rate of $125 per night, and $100 gaming revenue for segment CS9 (unknown customers).

solution would generate only $318,425. The RM system generates 45 percent more revenue than the first-come-first-served solution. While the ROI calculation indicates that the system could improve by 7 percent, it also shows the value of the RM system. It is more expensive to house 547 high-rollers than a mix of 547 high- and low-rollers; however, the results in Table 2 show that using an RM system generated an additional $142,000 in pure profit on this day alone.

Integrating Customer-Relationship Management and RM

The Cherokee integrates its marketing and RM functions so that its customer-relationship management (CRM) and RM systems enhance and support each other. For example, if booking data from the RM system suggests that hotel traffic will be light on a specific date, the marketing group uses the CRM system to select loyal customers who might want to stay at the Cherokee on that date. Marketing sends automated phone calls, e-mail blasts, or outgoing live calls to these targeted customers. These communications promise additional incentives to customers who come to the casino on the specific date. Because the communications are targeted to customers with reward numbers, the casino tracks which customers respond to the marketing initiatives. It tracks who responds, how quickly they respond, and which incentives work best, enabling the casino to continually improve its marketing methods for use the next time hotel booking curves are falling behind. Noone et al. (2003) and Hendler and Hendler (2004) provide details on integrating RM and CRM systems.

Implementation Difficulties and Challenges

When an RM system is introduced, employees might not trust its system-generated recommendations initially. When the Cherokee opened, its RM system was in place and had already been accepted throughout the many Harrah's properties; and the initial Harrah's management team had implementation experience. However, the gaming industry generally does not use RM systems such as the one we described. The RM implementation and usage challenges include both people and business-process issues.

The RM system impacts day-to-day activities of many people; some embrace the change; others resist it. For example, casino hosts and personnel who book wholesale and group business often feel that they are losing control over their inventory because an RM system might not make inventory available during high-season periods. Harrah's lost a quarter of its casino hosts when it converted its chain to this RM system. In addition, hotels or casinos that have been using locally set rates must often review the recommendations from a centralized RM department; this decreases their sense of autonomy. These changes can be threatening to employees.

RM system implementation typically requires changes to existing business processes, e.g., reservation or booking processes, wholesale or group-rate quotations, casino blocks, casino marketing and promotions, and events. Harrah's mitigated the challenge of business-process changes by attending Rainmaker's Revenue Management Best Practices (RMBP) workshop. Rainmaker asks key representatives of every area that the RM system will impact to attend a workshop. Most attendees will rarely, if ever, have direct interaction with the system; however, they will feel the impact of the RM decisions. RMBP workshops are tailored to the specific client; they are based on Rainmaker consultants' observations and interviews with staff across the organization, to learn how the organization conducted RM activities independently of an automated RM system. Those practices are compared and contrasted with industry best practices; the workshops highlight practices that are consistent and those that deviate from best practices. The consultants draft case study exercises for participants to work through in groups. The case studies are based on Rainmaker consultants' previous experiences in the gaming industry; they stress the particularly important aspects of the RM system. In addition, the workshops feature a full-system demonstration; all participants have the opportunity to see the types of information the system includes and how it produces its recommendations. Not surprisingly, when participants understand the RM processes, they accept the associated changes more readily. Skugge (2004) and Queenan et al. (2007) provide more information on the human side of RM.

Summary

The Cherokee generates high returns by applying RM to its business. It generates these returns partly because of the nature of the gambling industry and partly because of the tight integration between its CRM and RM systems.

Gaming-industry customers range widely in terms of their willingness-to-pay (or gamble). Some customers are willing to lose \$50; others are ready to lose \$2,000. This contrasts starkly with other RM applications, such as airlines or hotels, where the price differentials generated through RM are much smaller. This is the classic RM problem; when the differential is so large, each RM improvement returns more profit. Thus, researchers expect casinos to earn large payoffs from RM systems. However, the Cherokee also enhances its systems through tight integration of marketing and RM.

Because of the Cherokee's CRM system, the Cherokee knows exactly how much each customer plays. This allows it to segment customers precisely based on willingness-to-pay instead of creating customer segments by restriction as airlines and other industries do.

The Cherokee is able to forecast demand well. Because most of its customers book their rooms very close to their day of arrival, very few cancel or do not show, thus enhancing the Cherokee's ability to forecast. Its ability to record customers' reward-card numbers before a room request enhances its capability to capture demand that has been denied. This increased forecasting accuracy leads to more optimal decisions and higher profitability.

Because of accurate forecasting, the Cherokee revenue manager knows when hotel occupancy could be low. She informs marketing, which then selectively targets customers (identified by the CRM system) to encourage a trip to the casino on the underbooked days. Marketing staff carefully tracks these efforts to increasingly refine its efforts for optimum payoff.

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Steve Pinchuk, Director Revenue Management, Harrah's, One Harrah's Court, Las Vegas, Nevada 89119, writes: "I am writing on behalf of Harrah's Cherokee Hotel & Casino to confirm the highly successful application of revenue management techniques at our hotel. Our hotel is an extremely popular destination, and accurate forecasting of the amount of customer demand by market segment, combined with a revenue management system that correctly sets segment booking limits, is essential to our profitability. This article accurately reflects both our business situation and the value of revenue management to our hotel."