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Marriott International Increases Revenue by Implementing a Group Pricing Optimizer

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Marriott International's Group Pricing Optimizer (GPO), a decision support system, provides guidance to Marriott personnel on pricing hotel rooms for group customers. GPO uses demand segmentation, price-elasticity modeling, and optimization techniques to recommend an optimal rate. In operation since late 2006, the system has improved Marriott's hotel profitability and enhanced the sales process for both sales managers and customers.

Key words: pricing; optimization; revenue management; lodging/hotel industry; segmentation; group business.

Marriott International implemented its Group Pricing Optimizer (GPO), a group pricing system that helps its sales force price hotel rooms for group customers. The system uses price-elasticity models for each statistically derived market segment to recommend an optimal rate and negotiating range. To assist the sales manager during the negotiations, GPO also displays additional data, including availability of sleeping-room inventory, potential displacement of more valuable business, probability of the customer accepting the rate, and evaluation of alternate dates. In its first two years of operation, GPO has met its objectives to drive profitable revenue and improve the sales process for both the customer and the sales manager.

Marriott International

Marriott International, Inc., a leading hospitality company with more than 3,300 hotels in nearly 70 countries and territories, operates and franchises hotels under the Marriott, JW Marriott, The Ritz-Carlton, Renaissance, Residence Inn, Courtyard, TownePlace Suites, Fairfield Inn, SpringHill Suites, and Bulgari brand names. It also develops and operates vacation ownership resorts, operates Marriott Executive Apartments, provides furnished corporate housing through its Marriott ExecuStay division, and operates conference centers. Headquartered in Bethesda, Maryland, the company has more than 140,000 employees worldwide.

Marriott's heritage can be traced to a root beer stand that J. Willard and Alice S. Marriott opened in Washington, DC in 1927 (Marriott and Brown 1997). Today, *Fortune* magazine ranks Marriott as the lodging industry's most admired company and one of the best companies for which to work.

Revenue Management

Revenue management has long been recognized as a critical business practice that contributes increased revenues across various industries (Talluri and van Ryzin 2004, Ingold et al. 2001, Cross 1997). The birth of revenue management is largely attributed to the airline industry; its first application was optimizing revenue associated with individual passengers on a single flight leg (Belobaba 1987). The scope of the

revenue-management discipline has expanded greatly over the last two decades, as have the underlying models and technology. The models, which initially provided inventory-allocation recommendations, now also generate inventory and pricing controls. We recognize that the models and technology have evolved significantly over these last two decades; however, the user's interaction with the system still remains an important consideration.

Marriott International was a pioneer in implementing a revenue-management system for the hospitality industry. For more than 20 years, it has applied automation to performing revenue management for individual bookings. Today, 97 percent of Marriott's hotels use its One Yield (Overby 2005), a revenue-management system developed for individual bookings, to provide detailed demand forecasts, optimal inventory allocations, and a seamless interface to the reservation system that executes these control policies. Marriott's reservation system handles more than 75 million transactions per year, making it a rich source of information about individual transactions.

A typical revenue-management system uses a statistical model to forecast unconstrained demand, an optimization model to generate optimal control policies based upon optimal inventory allocation, and a reservation system to execute these policies (see Figure 1). One Yield helps Marriott manage millions of bookings a year. It is primarily a batch system that produces a demand forecast for each rate category and length of stay for each arrival day up to 90 days in advance and establishes inventory allocations that are published to the reservation system. Subsequently, various channels sell the controlled inventory of hotel rooms; these include Marriott.com, Marriott's 800-reservations telephone number, the specific hotel, and global distribution systems to which airlines, car rental companies, and travel agents have access.

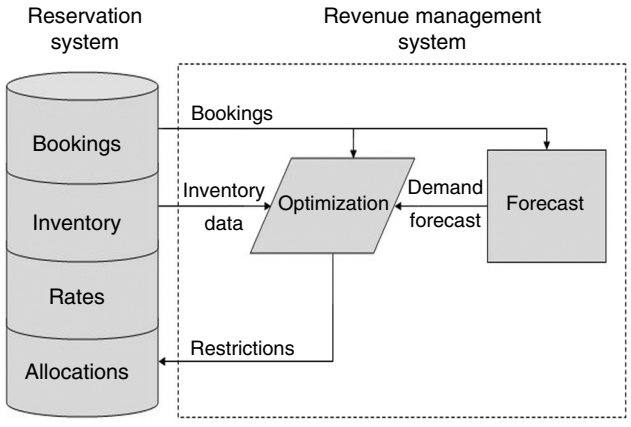

Figure 1: The diagram illustrates the relationship between a reservation system and a revenue-management system.

The current generation of revenue-management systems in the lodging industry performs demand forecasting and optimization for the individual customer segment of the hotel business. The next generation, referred to as total hotel revenue-management systems, will span the entire hotel, including both meeting space and guest rooms, and will optimize both individual and group demand segments (Cross et al. 2009). Marriott is currently developing Total Yield, the next generation of its hotel revenue-management systems to improve profitability for all the major revenue streams of a hotel: guest rooms sold to individuals, guest rooms sold to groups, meeting space sold to groups, and meeting space sold for local use without associated guest rooms (see Figure 2).

Performance Measurement

To establish the size of the total hotel revenue-management opportunity and to define the specific functionality needed to address this opportunity, we enhanced an existing performance metric, the revenue-opportunity model. The concept behind this effectiveness metric is to compare the actual decisions made with those of an optimal model with perfect knowledge. The optimization model maximizes profitability given all available information about demand and supply for a period in the past. The demand

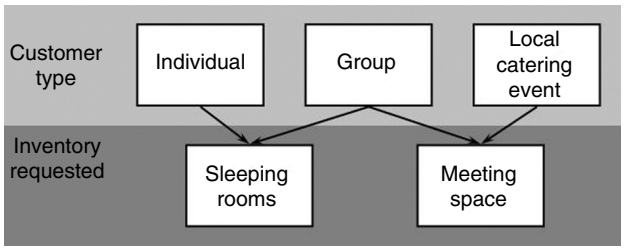

Figure 2: Multiple customer segments compete for rooms and space.

provided to the model includes booked individual and group business, the statistically unconstrained individual demand beyond that which was booked, and the lost or turndown information about groups (i.e., the customer or the hotel declined the booking). Because the optimal policy has the advantage of perfect hindsight and the ability to remake all decisions about which business to take or turn down, it produces a theoretically optimal solution. The ratio of actual revenue to optimal revenue measures the effectiveness of the revenue-management controls, as implemented by Marriott staff, processes, and systems. An advantage of using this metric is that it isolates the effects of revenue-management controls from those of exogenous factors, such as local, regional, national, and global macroeconomic variables, which can influence lodging demand, supply, and costs. The gap between actual and optimal revenue should lessen as better revenue-management decisions are made.

A final enhancement to this revenue-opportunity model includes the effect of using price controls for the group segment. We used a Monte Carlo-based simulation technique, which we refer to as the Pricing and Inventory Revenue Opportunity Model (PROM), to obtain a distribution of the enhanced metric. The PROM findings established the magnitude of the business case and enabled us to prioritize the functionality needed for a total hotel revenue-management system.

Group Business

Group business contributes significant revenue to Marriott International. For full-service brands (i.e., Marriott, JW Marriott, Renaissance, and The Ritz-Carlton), it can represent more than half the hotel's revenue.

Group business contains characteristics that make modeling it difficult. The longer booking windows associated with groups (compared with individuals) lead to greater statistical uncertainty because decisions taken far in the future are more often subject to change. Groups demand blocks of rooms, introducing a combinatorial aspect to the optimization problem. In addition, transaction data, especially for the largest groups and smallest hotels, are sparse.

To forecast accurately, we need information about both actual demand and demand that might have been booked under different control policies. For the individual customer, we can use statistical methods to infer unconstrained demand (Orkin 1998, Zeni 2001); however, we rely on sales managers to record lost and turndown data for the group segment. In some cases, certain group inquiries with a short booking window and small number of rooms simply are not logged, resulting in incomplete information. In cases for which we do have turndown information, it is also often incomplete. For example, group attrition—the difference between the number of actual (stayed and paid) rooms and the number contracted—is sometimes significant. This information is available only for groups that have materialized and is lacking for lost or turndown groups.

Group business is highly negotiated; therefore, contracted group room rates differ from retail rates and frequently differ from target, budget, or forecasted rates. The other source of variation in group rates relates to the group's requirements. For example, the rates of groups that need only guest rooms differ from those of groups that also need meeting space.

Group Sales Processes

The sales process for groups begins when a hotel's leadership team, which comprises the general manager and personnel from revenue management, sales, and marketing, agrees upon a group sales strategy. The process includes establishing group target rates, goals, and ceilings (maximum rooms to be allocated for groups) by season. The revenue manager conducts a historical review of past group data to understand patterns that can be expected to repeat.

Although the team conducts considerable analysis as part of the historical review, it sets rate and volume targets manually. Because the manual process cannot manage the complexity of daily updates and rapid changes in demand over a very long booking horizon, the target rates are largely static and independent of group size.

This manual approach has two serious deficits: (1) target rates do not reflect individual customers' willingness to pay, and (2) target rates do not reflect the potential for displacement or the trade-off between one type of booking and another that might have higher value.

Although the existing individual revenue-management system performed all of its calculations during

an overnight batch process, we determined that the deficits of a batch approach were too limiting. Managing group blocks and calculating displacement using real-time pricing would be a better approach.

Group Pricing Analytics

The group reservation request requires a response to two questions: Does the hotel have sufficient rooms to house the group? What rate is recommended for the rooms?

One traditional method for calculating an optimal price to offer to a customer is to combine the probability to win a particular piece of business as a function of price and the corresponding profit (Phillips 2005). We describe one such model in the appendix.

To implement this model in a system, we must have a way of computing the profit function while simultaneously evaluating a particular group request, a method of computing displacement cost, a technique for estimating pricing curves, and a one-dimension (1-D) optimization algorithm that maximizes expected profit. Although a 1-D optimization approach might appear trivial, it is necessary if the solution is to run in real time and provide subsecond response to the user. In GPO, we implemented the standard pricing model described above; however, for successful application to the hotel group pricing problem, we needed to find creative solutions to several parts of the model.

When pricing a block of hotel rooms, we generally know the direct costs of selling one room in a hotel (e.g., the cost of room cleaning, supplies, etc.). We also know the sales cost, which usually incorporates commissions or rebates, for each group request.

Our challenge in the profit function is estimating the displacement cost. A hotel has limited capacity; to calculate displacement we need to determine the value of the business that we will have to turn away if we give the inventory to a candidate group. We developed a displacement model that uses the following input to calculate displacement cost:

- Forecast of remaining unconstrained individual-customer guest-room demand (the demand we would have seen between today and the arrival date if we had an unlimited supply of rooms) and associated rates for individual customers. These forecasts must be very detailed and incorporate customers' anticipated lengths of stay. Our revenue-management system already had a model that provided forecasts 90 days in advance; as part of the GPO project, we extended that period to two years.
- Forecast of cancellations for bookings already received.
- Forecast of guest-room demand and associated rates for additional group customers. Ideally, we want these forecasts to be unconstrained and very detailed. Our revenue-management system already included constrained group room projections that revenue managers in the field were maintaining in the system for other purposes. The role of a field revenue manager includes oversight of forecasts for individual customers (these are automated), analysis and input of forecasts for group business, pricing for all customer segments, and review of sleeping-room inventory levels in the reservation system as recommended by the revenue-management system. For the initial implementation, we used the revenue-manager inputs of constrained group projections as a proxy for the "ideal" unconstrained forecasts. In later phases, we replaced them with unconstrained group room forecasts and built the displacement model to accommodate the detailed group forecasts when they became available.
- A count of guest rooms that have been sold to other guests and of any rooms that are not available for each stay date (e.g., rooms under renovation).
- A count of guest rooms the candidate group needs for each stay date.

Using the data above, we apply the following methodology to calculate the displacement cost:

- We compute the forecasted maximum profit *without* the current group for that hotel by solving an optimization model for a window long enough to cover the group's stay plus surrounding days.
- Next, we solve the same optimization model for the same period—after we have removed the candidate group's rooms from inventory. In practice, we set the revenue contribution of the group to zero and force it in.
- We compute the difference between maximum profit *without* the current group and maximum profit *with* the current group; this gives us the estimate for the displacement cost, which we include in the contribution function.

We augmented the model to account for cases in which we do not initially have enough available inventory to accommodate the entire group. In such a situation, we apply a much higher penalty to any room that will be overbooked; this feature is very useful because it allows GPO to return a price for groups when only a small portion of the rooms will need to be overbooked. GPO quickly pulls correct values for the direct costs and marginal cost of sales and then runs the displacement model to obtain the displaced profit. With these values, GPO then computes the contribution function and its derivative for any price.

Estimating Pricing Curves

The estimation of the pricing curves was at the heart of the GPO effort. We hypothesized that customer price sensitivity varies based on many variables, including occasion, group size, and season. Because we did not know a priori the factors that influenced customer price sensitivity, we needed to segment our customers and transactions by price sensitivity before estimating the curves. The traditional approach to this problem involves the following steps:

- Create a database that houses requests for group business with an indicator of whether it is actual (won) business or lost business, the price quoted (or paid), and any other variables that might impact price sensitivity.
- Clean the data.
- Perform univariate and regression analysis to see which variables correlate most highly with win rate.
- Use CART (classification and regression trees), CHAID (chi-squared automatic interaction detector), or similar tree algorithms to segment the data, using win rate as a target variable (Hill and Lewicki 2005).
- Fit pricing curves by segment using some standard functional form of the curve (e.g., logistic curve).

Marriott is a data-rich company, and we were able to create a database containing 180 descriptors for 800,000 group requests relatively quickly. However, when we attempted to implement other steps of the traditional approach, we faced several challenges for which we needed to find innovative solutions.

One challenge was that data collected at different points in the group's life cycle had characteristics whose value was unavailable: if the group request was turned away at the initial call, we had limited information available about it; however, we had very detailed data for stayed-and-paid groups. For example, when we naively looked at our data, we found that audiovisual revenue was one of the most important drivers of group win rates. The irony with this finding was that we were winning 99.9 percent of groups with audiovisual revenue greater than \$1, revealing that this field was not filled in for any lost or turndown business. This is not surprising; a group generally determines its audiovisual needs only when it knows and has agreed to most other booking details, including the room rate.

After we began working on the segmentation, we quickly realized that the most "statistically significant" segmentation did not make intuitive sense and would be hard to communicate to field personnel. Because user acceptance hinged on the field's ability to understand the segmentation, this was a critical juncture; however, the new system disrupted long-held assumptions about the segmentation, which we found that the data did not support. Reviewing and test-pressuring all the tree splits by a joint statistical-business team helped us to develop segmentation that nontechnical personnel would consider to be business reasonable and sufficiently statistically significant.

The most challenging activity was fitting the pricing curves. We decided to use the logistic model for the shape of the curve (Talluri and van Ryzin 2004, Phillips 2005). However, we needed a way to aggregate pricing data for different hotels by establishing a reference price. Additionally, we needed the pricing curves, in combination with the profit function, to yield business-reasonable rates.

To address the challenge of fitting the pricing curves, we defined a proprietary reference price. Unlike in other industries that use a combination of a retail or manufacturer suggested retail price for a product and its competition, in the hospitality industry the same room has different values for different days of week, seasons, and specific arrival dates; in addition, a competitive price differential exists among hotels. To ensure that the forecasts would be accurate, we needed to find a reference price that we could compute historically and forecast into the future, and that would be fairly stable. Before settling on the most desirable metric, the team evaluated at least 11 different candidates.

The second challenge of making the rates realistic led to the development of the dependent pricing-curve model. When we attempted to fit curves to

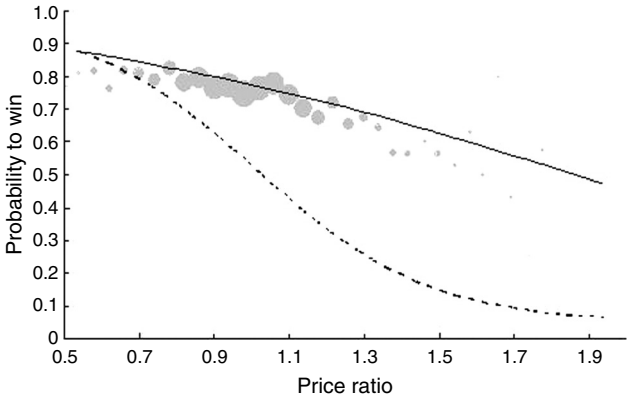

Figure 3: This graph illustrates the challenge of making pricing curves sharp enough. The bubbles on the chart represent the win rate of observed data (the size of the bubble corresponds to the number of observations). The solid line represents the logistic regression curve for this data—it results in optimal rates two to three times greater than the average rates historically offered by the hotel; the broken line illustrates the pricing curve that would produce optimal rates within range of the rates the hotel is selling today.

the existing data, using standard logistic regression, the resulting pricing curves were not sharp enough—they implied price-insensitive demand. Implementing these curves into the 1-D optimization model returned optimal prices that were too high to be business reasonable when compared with other prices on the market. Figure 3 illustrates this problem.

This problem of pricing curves not being sufficiently sharp happens often when analyzing pricing data, especially in the presence of active supply and demand management. This can be addressed by considering endogenous processes that have a strong effect on price elasticities and curve estimation (Bijmolt et al. 2005).

Another way to address the problem is to assume that an endogenous process exists that influences quoted prices, so that the price that the salesperson quotes to the customer is correlated with some other variable Y that we have in our database (the value we ultimately used for the variable Y is proprietary). For our group pricing, we developed a new "model with dependence" that addresses our curve-sharpness issue.

Price-Optimization-Model Summary

In GPO we implemented, in one system, the profit function (including the displacement model), pricing curves by segment, and a 1-D optimization model that computes the optimal price. The pricing segmentation and the curves are validated and refreshed regularly as a separate process and then loaded into GPO.

Field Collaboration and Acceptance

After our pricing research was complete, the technical team built a basic Java Web-based prototype for 28 hotels. In developing the prototype, our objective was to gather feedback from revenue and sales managers at these hotels on the quality of the rates being returned and the features they would like to see incorporated into a production system. The revenue managers would input sample group leads and the prototype would return a price and a negotiating range. The result of this prototype phase was that the users deemed the rates were reasonable; however, in the system we implemented, the revenue managers needed more controls around the rate and the sales managers wanted more supporting details displayed on the pricing response screen.

Based on the positive feedback from our prototype users, the team decided to deploy a system pilot; we built the pilot as we would have built an operational production system (in a much more robust form than the prototype), put it in the hands of sales and revenue-management users, and used it to gather additional feedback. Assuming that the pilot did not have any critical deficiencies, we planned on transferring it to a production system and rolling it out to the entire user base. At the end of the pilot phase, the pilot hotels had experienced successful use of GPO by their group sales managers located at the hotels and in regional sales offices. Their sales and revenue-management users provided excellent feedback on enhancements that would need to be included in the operational, fully deployed production version.

During the pilot phase, several obstacles to a successful rollout became evident. Some required technical enhancements; some required business process changes. To receive a pricing response from GPO, the business process required that sales managers enter the group request information into the sales system in real time as they talked on the telephone with the customer.

To ensure adequate data with integrity, the team decided to build a real-time link to pull group

requests from the sales-CRM system. This approach required sales managers to capture complete information on group business, both won and lost, ensuring quality data for individual pricing requests and for maintaining the pricing models. Although this seemed to be a small change to the business process, the sales organization expressed great concern that it not negatively impact the customer's experience. This was addressed by ensuring that the system linkage was fast through performance tuning and by teaching the sales managers to log the details while conversing with their customers. The sales managers were able to ultimately accommodate this change with no interruption to the sales process.

The Total Yield team learned a lot about the information needed to speedily conclude a group sale and augmented the basic information coming from the pricing engine to support that end. Because GPO only solves the room-rate problem, we included additional information to communicate the strategy for meeting space when it is requested in conjunction with group sleeping rooms. To do this, we gave the revenue manager controls for two key statistics to use as thresholds—the rooms-to-space ratio and catering revenue per group room night. For each of these thresholds, GPO calculates whether the group under evaluation is within bounds. If not, the sales manager receives an alert message that the group does not meet the desired threshold. We also created special control levers to allow revenue managers to stop the automated pricing for very large groups or special situations. These situations required a thorough review of proposed pricing and contractual terms by the sales-strategy team. The Total Yield team also created controls for special events and group-pattern controls. These allow a revenue manager to indicate, by day, if no additional group business is desirable or if it must meet minimum length-of-stay requirements to be considered. Controls are then communicated to the sales managers to help them understand why rates are not provided or why the recommended rates are high.

By integrating GPO with Marriott's reservation system, GPO is able to provide real-time information on guest-room inventory. The information is more robust than a simple yes or no, as Figure 4 illustrates. Using this real-time inventory information and additional group information that is available in the

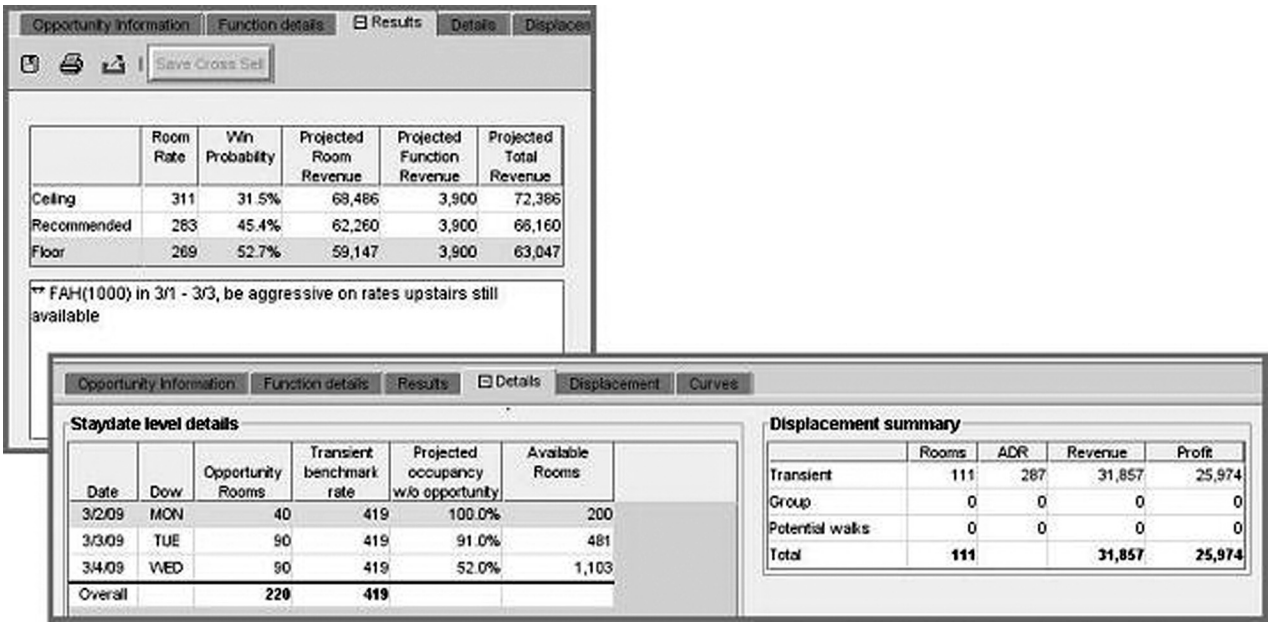

Figure 4: GPO provides a recommended rate, negotiating range, and additional information to support the group sales process.

revenue-management system, GPO is also able to display displacement details to the sales manager. This frequently answers the question, "Why is the rate so high?" Coupled with special-event comments, sales managers can be knowledgeable about market conditions. This helps them work with their customers. For example, a sales manager might say "The week you requested is a high-rate week because there is a citywide medical convention. May I suggest some alternate dates that will fit your budget?" They report that this added knowledge enables them to keep customers from contacting competitors and helps them to close sales during initial calls.

Early in the GPO design, the team designed critique tools that help revenue managers assess how well the system is being used. These views measure and compare contracted group rates and recommended rates. The tools also show divergence, by sales manager, allowing the sales-strategy team to decide if retraining is necessary and if the customer set is being served appropriately. We also developed additional analytical tools to track win rates against the theoretical win rate. This helped us to adjust to a rapid decline in group demand in 2008, as the recession began to have an impact. Usage tracking is an important indicator of sales force acceptance. The team tracks this in parallel with win rates to understand how well the sales team is complying with GPO recommendations. Because the team has been able to closely watch win rates, we have been able to keep sales usage and compliance high.

Implementation

Many distinct pieces of Marriott's infrastructure needed to be integrated to provide the real-time pricing response to the customer. These include sales, event-management, forecasting, and reservation systems.

Group request details for the set of GPO hotels are stored in two systems: the sales-CRM system and an event management system for managing the details of existing contracted customers. A real-time feed from the sales-CRM system, which was absolutely critical to the mechanics of the GPO system, was developed to price new sales leads immediately. A detailed overnight feed of the contracted group data already existed in the One Yield revenue-management application. In its final state, GPO seamlessly pulls data from all the data sources. The displacement model relies on forecasts of individual customer and group room demand for the entire two-year GPO pricing window. This function also exists in One Yield.

Another critical requirement of the GPO system is checking to ensure that the rooms requested by the group are indeed available to sell. This technical link to query Marriott's master sleeping-room reservation system was built prior to the system rollout. As a result, each time a sales manager prices a group request, the system performs a real-time availability check that references the same inventory database as Marriott's other sales channels.

GPO was designed to accommodate thousands of users selling rooms for hundreds of hotels. To maximize the system's accessibility, the GPO interface was built as a Java Web-based application, which is securely hosted behind the Marriott firewall. This allows sales managers to use GPO as a pricing tool from any computer (with an Internet connection) worldwide.

Rolling out GPO was challenging. As we mentioned in the previous section, we had many hurdles to overcome in the business processes to make the substantial changes to the revenue-management and sales processes to sell group business. The team felt it was critical to provide high-level training to senior managers in the sales, revenue-management, and event-management disciplines to enable them to assist with change management.

In June 2006, we conducted initial facilitated training. Attendees included 600 revenue-management, event-management, and sales managers from 150 hotels; an additional 1,000 sales managers used Web-based training, which is ongoing as new sales managers and hotels begin to use GPO. Revenue managers spent several months using the administrative setup and "test pricing" to become comfortable with the recommended rates. By September 2006, sales managers began using GPO in the sales process; by the end of 2006, we considered the system to be ramped up.

We undertook one additional integration effort. During the period in which we were implementing GPO, Marriott began its QuickGroup^{SM} initiative,

with the goal of selling small-group sleeping-room blocks online—"the way the customer wants to buy." In late 2007, we rolled out the initiative with a real-time link to the GPO pricing engine; customers are now able to book small groups (i.e., 10 to 25 rooms) using this self-service feature on Marriott.com and to reserve the rooms using a credit card.

Success to Date

Because of the challenges associated with measuring the impact of good revenue-management decisions, Marriott has invested in a set of tools we call revenue-opportunity models. As we discussed earlier in the *Performance Measurement* section, Marriott began using the revenue-opportunity model for individual bookings shortly after it originally implemented automated revenue management. Once we implemented GPO, we tracked the change in PROM's measures of revenue and profit. We were fortunate that the same demand levels existed in 2006 (our before-GPO data set) and in 2007 (our after-GPO data set). This allowed us a good before-and-after view without concerns that changes in group demand caused any changes in demand levels. The aggregate actual revenue/optimal revenue score for 2007, for those hotels that had implemented GPO, was 1.1 percent higher than for the same hotels in 2006. This equates to $46 million in revenue for 2007. As is the case with most revenue-management functions, these incremental revenues do not incur additional cost; therefore, they directly add to profit.

Completing this same estimate for 2008 is more difficult. If we took the native improvement from PROM, we would claim an even higher profit improvement because of implementing GPO. However, that figure is inflated by the lower demand we saw as the recession spread. We must restate demand relative to a baseline, so that we will always be able to consider one year's results against the baseline. An initial restatement of 2008 results from PROM indicates that GPO produced 1.8 percent incremental revenue and profit over the baseline 2007 adjusted for the different demand levels seen in these two years. Additionally, an increase in the number of hotels using GPO offset the decline in overall demand in 2008. Therefore, our estimate of the profit improvement from GPO in its first two years of use is over $120 million. By the end of 2008, Marriott had approximately 1,600 GPO users; they had used GPO to price more than 525,000 individual group opportunities and to book $1.3 billion of group business (already stayed and contracted for future arrival).

Supporting an Evolving Sales Organization

In 2005, Marriott's sales organization began to redefine a successful sales process from the customer's point of view. Customer feedback revealed that customers did not want individual sales managers representing unique hotels to call upon them. Therefore, we created Marriott's Sales Force One initiative to transform the sales process to focus around the customer rather than the hotel and to redeploy the company's sales managers to more effectively reach our thousands of customers. In summary, the company is evolving the sales force to sell the way our customers want to buy. To accomplish this goal, Marriott is investing in technology to make it possible for one sales manager to sell for multiple hotels to any customer.

Automation is critical because the sales managers are being removed from their hotels and placed in regional sales offices. They are no longer down the hall from their colleagues who establish the pricing and sales strategy. The information they need to close a sale must be at their fingertips and in much more detail than they required previously when their offices were in the hotels. GPO supports these regional sales offices by providing quick, rational pricing, thus allowing a sales manager to price and check availability at multiple hotels for the same group request. Because GPO provides much additional information beyond the recommended price, it enables these sales managers to feel in touch with each hotel they sell. With the assistance of GPO, Sales Force One has enabled the same size sales force to cover 10 times the number of accounts.

Other Indications of Success

GPO use continues to grow. Despite a declining economy and the need for exceptions to cover distressed inventory, the percentage of eligible opportunities

priced with GPO remains very high. From the start of 2007 to the end of 2009, the number of participating hotels increased 38 percent at their request. Revenue managers continue to rely on GPO to communicate the sales strategy despite, or rather because of, the challenging economy and sales managers continue to feel confident in the rates they quote using GPO. Finally, as our Sales Force One initiative is introduced to new markets, hotels in that market continue to request GPO. The sales team acknowledges that this technology is the key to enabling sales managers in the new organization to price and sell the way our customers want to buy.

Conclusion and Future Plans

Marriott International has successfully applied operations research techniques to a wide variety of problems. The group pricing functionality is a leading portion of a larger technology investment that Marriott is making to further empower our sales, revenue-management, and service associates. This systems effort includes GPO and adds to it the full meeting-space inventory and all the details needed for hotel staff to deliver group meeting space.

To complete Total Yield, the GPO team is building group forecasting functionality. This includes modules that forecast group room demand with all of its complexity, group room rates, and the future value of meeting space. The team will apply the total-hotel-optimization algorithm, which PROM uses, to solve for maximum profit by considering all the revenue categories for this problem: sleeping rooms, meeting space, food and beverage, audio visual, and others. Despite the economic downturn, Marriott International remains committed to these innovations, which reflect the wise application of operations research to challenging problems in the hospitality industry.

Appendix

Let c denote the direct cost of providing this piece of business, which is usually not dependent on its sale price, to the customer; let D be any associated opportunity costs; and let α denote any sales or advertising costs as a fraction of the ultimate selling price. Then,

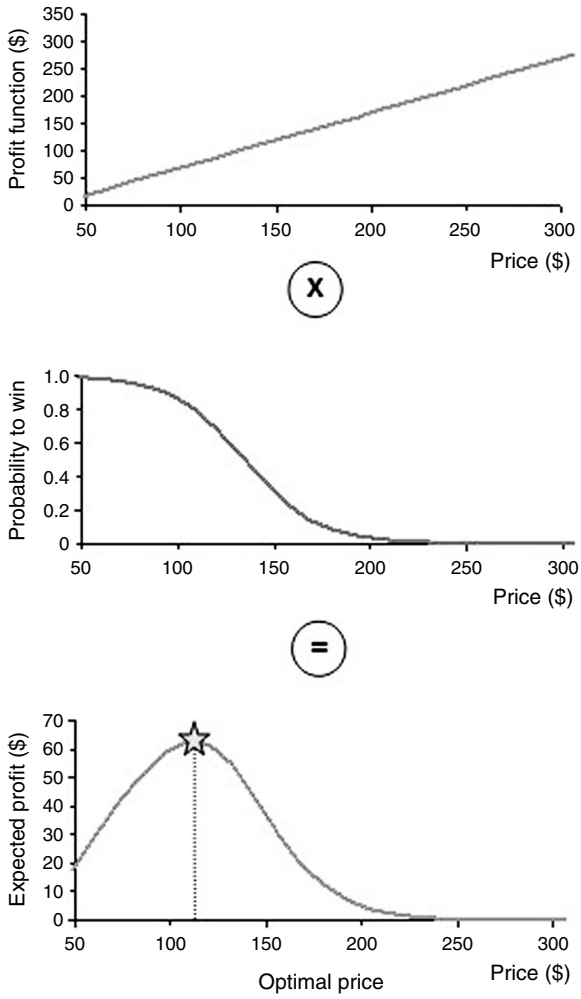

Figure A.1: This graph illustrates the pricing model: the optimal price is determined by combining the profit function and the probability to win.

the contribution to profit, as a function of price x, is given by

$$\text{Profit}(x) = (1-\alpha)x - c - D, \quad x > 0. \tag{1}$$

Let $\mathbb{P}\{\text{win at price } x\} = p(x)$, $x > 0$ denote the probability to win that customer's business at price x, usually referred to as the *pricing curve*; then the expected profit is given by

$$\begin{aligned}&\text{Expected\_Profit}(x)\\ &\quad = \mathbb{P}\{\text{win at price}x\} \times \text{Profit}(x)\\ &\quad = p(x)((1-\alpha)x - c - D), \quad x > 0.\end{aligned} \tag{2}$$

$p(x)$ is typically a decreasing function of x (i.e., the higher the price, the lower the chance that the customer will accept it). For most commonly used functional forms of $p(x)$ (i.e., linear, polynomial, logistic, power function), Expected_Profit(x) has a local maximum at x_o, which is a solution of the following 1-D optimization problem:

$$\begin{aligned} &\text{maximize} \quad \text{Expected\_Profit}(x), \\ &\text{subject to} \quad x > 0. \end{aligned} \tag{3}$$

The strategy of offering price x_o for each piece of business will maximize the expected profit in the long term (note that the optimal price could be different for each corresponding piece of business). Figure A.1 illustrates this model.

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References

Belobaba, P. P. 1987. Air travel demand and airline seat inventory management. Doctoral dissertation, Massachusetts Institute of Technology, Cambridge.

Bijmolt, T., H. Van Heerde, R. Pieters. 2005. New empirical generalizations on the determinants of price elasticity. *J. Marketing Res.* **42**(2) 141–156.

Cross, R. G. 1997. *Revenue Management: Hard-Core Tactics for Market Domination*. Broadway Books, New York.

Cross, R. G., J. A. Higbie, D. Q. Cross. 2009. Revenue management's renaissance. A rebirth of the art and science of profitable revenue generation. *Cornell Hospitality Quart.* **50**(1) 56–81.

Hill, T., P. Lewicki. 2005. *Statistics: Methods and Applications*. StatSoft, Tulsa, OK.

Ingold, A., I. Yeoman, U. McMahon. 2001. *Yield Management: Strategies for the Service Industries*, 2nd ed. Thomson Business Press, London.

Marriott, Jr., J. W., K. A. Brown. 1997. *The Spirit to Serve Marriott's Way*. HarperCollins Publishers, New York.

Orkin, E. B. 1998. Wishful thinking and rocket science: The essential matter of calculating unconstrained demand for revenue management. *Cornell Hotel Restaurant Admin. Quart.* **39**(4) 15–19.

Overby, S. 2005. The price is always right. *CIO Magazine* (February 15) 40.

Phillips, R. L. 2005. *Pricing and Revenue Optimization*. Stanford University Press, Stanford, CA.

Talluri, K. T., G. J. van Ryzin. 2004. *The Theory and Practice of Revenue Management*. Springer, New York.

Zeni, R. H. 2001. Improved forecast accuracy in airline revenue management by unconstraining demand estimates from censored data. Doctoral dissertation, Rutgers, The State University of New Jersey, New Brunswick.