DOI: 10.1177/0010880406297072
Volume 48, Issue 1 88-100

A Simulation-Based Optimization Approach for Investment Decisions

A Case Study of Pure Allergy-Friendly Rooms

by DAVID A. DITTMAN and JAMES W. HESFORD

In this article, the authors demonstrate how to use optimization combined with Monte Carlo simulation to model an investment decision by means of a case study of a hotel considering the converting a portion of its inventory to allergy-friendly rooms (by applying a proprietary method). Using survey data on consumer demand and hotel occupancy data, the model considers the random nature of occupancy to determine the optimal number of rooms to convert and the corresponding price to charge. In setting up the model, the authors demonstrate the limitations of traditional approaches using average occupancy data.

Keywords: simulation; optimization; investment; Monte Carlo; net present value; project choice; risk

In 2004, Brian Brault, CEO of Advanced Facilities Services International, Inc. (AFSII), was approached by Goran Anderson, a Swedish inventor, to distribute and service his latest invention, Pure Allergy Friendly Rooms. After evaluating the product, Brault secured the rights to be the U.S. distributor of the Pure Allergy Friendly Room process, materials, and supplies. A new company, Pure Solutions N.A., LLC, was formed to distribute the concept. Brault now faced the task of convincing hotel executives that they should convert some portion of their room inventory to Pure Allergy Friendly Rooms. This case looks at the investment decision faced by a hotel executive who is considering the feasibility of converting rooms to become allergy friendly. As part of that decision the executive must consider how many allergy-friendly rooms should be converted and what premium the hotel might charge for these rooms.

The Pure Solutions Process and Its Costs per Room

The seven-step process used to convert a hotel room to a Pure Allergy Friendly Room consists of the following:

1. purification of the air-handling unit: installation of a tea-tree-oil cartridge and filters to kill and suppress bacteria, mold, and fungi in the unit and, consequently, room air;
2. cleaning of all soft surfaces (e.g., carpet and furniture) with Pure Clean, a solution designed to extract mold, mildew, and other allergens;
3. fogging the room with Pure Shield, a solution designed to create a bacteria-static barrier to prevent mold and mildew spore growth for up to two years;
4. initial treatment of the room with a high concentration of ozone to kill living organisms in the room;
5. mattress and pillow encapsulation with coated, high-fiber-count covers designed to trap accumulated dust mites, skin fragments, and other allergens;
6. installation of a special shower head to remove chlorine from the water; and
7. installation of a high-quality, state-of-the-art air purifier with charcoal and High Efficiency Pariculate Air (HEPA) filters.

The quality of the Pure Allergy Friendly Rooms is guaranteed provided the prescribed maintenance schedule is followed. The cost per room is $1,500 for the conversion process and $75 per quarter, starting at the end of the first quarter. For two years after conversion, the air-handling unit is cleaned, and the tea-tree-oil cartridge and filters are replaced quarterly. After two years, rooms need a reinitiation process costing $750, followed by quarterly maintenance again costing $75 (Bouich 2005, 60).

Determining Demand for Allergy-Friendly Rooms

To assess the demand for allergy-friendly rooms, Brault engaged the Survey Research Institute (SRI) at Cornell University. AFSII provided a draft of a survey instrument with SRI providing input regarding wording of questions and response options. SRI then conducted a telephone survey, obtaining 329 useable responses. Survey respondents, who were partitioned into business and pleasure travelers, were asked if they were willing to pay extra to stay in an allergy-friendly room. Panel A of Exhibit 1 gives the results of these responses. Panel B provides the responses of those who are willing to pay extra, in $5 increments above a $100 room rate.

Based on the responses in Exhibit 1, we constructed conditional probability tables for business and pleasure customers regarding the amount above a $100 room rate that each group would be willing to pay. As one can see in Exhibit 2, the conditional probability distributions for business customers and pleasure customers are practically

Exhibit 1:
Survey Results

	Panel A: Willingness to Pay Extra		
Type of Guest	*No*	*Yes*	*Total*
Business	26 41.3%	37 58.7%	63
Pleasure	105 41.5%	148 58.5%	253
Total	131	185	316

	Panel B: Premium the Hotel Should Charge for an Allergy-Friendly Room					
Type of Guest	*$5*	*$10*	*$15*	*$20*	*Over $20*	*Total*
Business	11 31.4%	14 40.0%	3 8.6%	4 11.4%	3 8.6%	35
Pleasure	53 36.3%	55 37.7%	14 9.6%	14 9.6%	10 6.8%	146
Total	64	69	17	18	13	181

Note: Four respondents indicated a willingness to pay but did not specify an amount.

identical, enabling us to combine these into one distribution. From the figures in the second-to-last column, we see that 41 percent of all guests are unwilling to pay extra for an allergy-friendly room, whereas 4 percent are willing to pay a $25 premium.[1]

From the combined probability density figures, we built a cumulative probability distribution. For example, 10 percent of the customers would be willing to pay a $20 premium for an allergy-friendly room. (This combines those willing to pay more than $20 with those willing to pay the $20 premium.) Continuing, 16 percent of the guests would be willing to pay at least $15 more for an allergy-friendly room, and so on. The cumulative probability distribution for the premium that a hotel guest would be willing to pay is given in the last column of Exhibit 2.

The Usual Approach to Determining Conversion and Price Premium

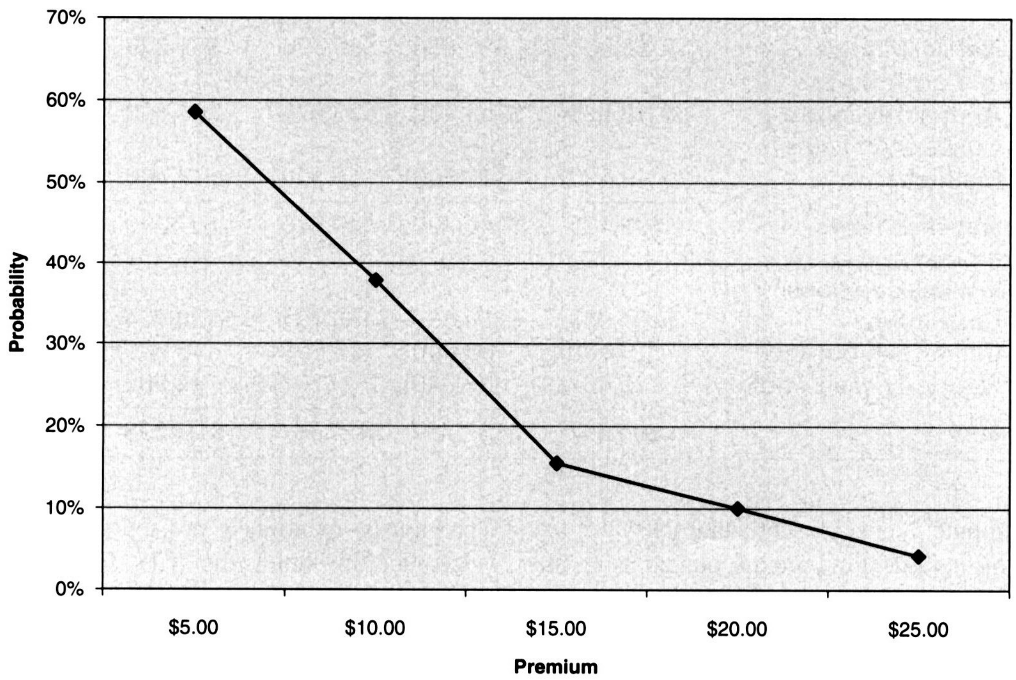
Building a model to determine the optimal number of rooms to convert and the corresponding price to charge requires assumptions about room demand. In building an average model, analysts will be tempted to use the hotel's average occupancy. The approach usually taken for room build-out is to compute the expected cash flows using average daily occupancy, price, cost, and expected demand. As we saw above, demand is a function of price. With a

1. Actually, the interview survey asked respondents if they were willing to pay in excess of a $20 premium. We artificially set this at $25, the next $5 increment.

Exhibit 2:
Customer Demand for Allergy-Friendly Rooms

	Business		*Pleasure*		*Combined*		
Willingness to Pay ($)	*Number*	*%*	*Number*	*%*	*Number*	*%*	*Cumulative %*
0	27	44	101	41	128	41	100
5	11	18	53	21	64	21	59
10	14	23	55	22	69	22	38
15	3	5	14	6	17	6	16
20	4	6	14	6	18	6	10
25	3	5	10	4	13	4	4
Total	62	100	248	100	310	100	

Exhibit 3:
Allergy-Friendly Room Demand



downward-sloping demand curve, allergy-friendly rooms are a normal good (see Exhibit 3). Equation (1) shows the usual approach to modeling this problem:

$$\text{Annual Cash Flow}_t = \text{Total Rooms} \times \text{Avg. Daily Occupancy} \times \text{Prob. Demand} \times (\text{Per-Room Daily Price} \times 365 \text{ Nights} - \text{Per-Room Cost}_t). \quad (1)$$

The product of the first three terms represents the number of rooms converted to allergy-friendly rooms. As noted above, per-room costs consist of the following two components: quarterly maintenance costs and, in year one, an initial cash outlay for room conversion. In subsequent odd-numbered years, there is a renewal cost. To

Exhibit 4:
Case Data: Traditional Approach

	Panel A: Hotel and Project Characteristics
Rooms	150
Average occupancy	74%
Discount rate (cost of capital)	15%
Room conversion cost	$1,500
Quarterly maintenance cost	$75
Project life (years)	2

Panel B: Financial Calculations

	$5.00	*$10.00*	*$15.00*	*$20.00*	*$25.00*
Rooms converted	65	42	17	11	5
Year 1 cash flows					
Annual revenues	$118,625	$153,300	$93,075	$80,300	$45,625
Conversion costs	(97,500)	(63,000)	(25,500)	(16,500)	(7,500)
Maintenance	(14,625)	(9,450)	(3,825)	(2,475)	(1,125)
Net cash flows	$6,500	$80,850	$63,750	$61,325	$37,000
Year 2 cash flows					
Annual revenues	$118,625	$153,300	$93,075	$80,300	$45,625
Conversion costs	—	—	—	—	—
Maintenance	(19,500)	(12,600)	(5,100)	(3,300)	(1,500)
Net cash flows	$99,125	$140,700	$87,975	$77,000	$44,125
Net present value (NPV) calculations					
Cash inflow	$204,933	$264,837	$160,794	$138,724	$78,821
Initial cash outflow	(97,500)	(63,000)	(25,500)	(16,500)	(7,500)
Quarterly cash outflow	(29,467)	(19,040)	(7,707)	(4,987)	(2,267)
NPV	$77,967	$182,797	$127,587	$117,238	$69,054

compute the net present value (NPV) of the project, cash flows are discounted using the firm's weighted average cost of capital over the life of the project. Since treatments are required every two years, we decided to model the project life at two years.

For this case study, we used data from a hotel in central New York. The hotel size, average occupancy, and discount rate are given in panel A of Exhibit 4 along with the previously mentioned project characteristics. For this hotel, the NPV for the five prices surveyed is shown in panel B of Exhibit 4.[2] For each of the five price points, the number of rooms converted comes from the first three terms in equation (1). We see that NPV is maximized at $182,797 by setting the price of an allergy-friendly room at $10 per room-night with a conversion of forty-two rooms.

2. The revenues are incurred daily and therefore are discounted over 730 days (two years). The maintenance cost are incurred starting at the end of the each quarter and therefore are discounted quarterly for seven quarters. At the end of the eighth quarter, the hotel general manager has to make the decision to renew the treatment for the rooms at a cost of $750 and therefore maintenance cost for the end of the eighth quarter is subsumed into this renewal investment.

This approach, however, is flawed. In fact, with forty-two rooms converted, the hotel will be unable to achieve the expected NPV. A simple example will demonstrate our assertion. Imagine two, one-hundred-room hotels. One hotel has seventy guests arrive every day. The other hotel is a seasonal property fully occupied 256 nights a year but is closed 109 days a year. Thus, both have an average occupancy of 70 percent. If the full-time hotel were to build out rooms based on the traditional model, it would convert twenty-seven rooms, and all allergy-friendly rooms would be occupied every night at a $10 premium.[3] Over a two-year period, profits from this investment would be $142,425. Profits, however, for the seasonal hotel would be much smaller. Being sold out each night of operation, the seasonal hotel will have a demand for thirty-eight allergy-friendly rooms. However, with only twenty-seven rooms converted (having used the traditional model), this hotel would be unable to satisfy demand. The profits for the seasonal hotel would be $83,565. The unsatisfied demand (eleven rooms per night) resulting from an inadequate supply of rooms represents an opportunity cost. (Recall that opportunity cost is defined as contribution to income forgone by not using a resource in its next-best alternative use.)

The seasonal hotel could improve its profit by converting thirty-eight rooms instead of twenty-seven. At an up-charge of $10 per night, the hotel could sell all thirty-eight of those allergy-friendly rooms per night. Profits with this conversion would be $117,610.[4] But is this optimal? In this case, yes. But with demand fluctuating and uncertainty in other aspects of the model (e.g., customer demand), the answer is not so simple. The manager's question, then, becomes, "Given uncertainty in demand, what is the optimal number of rooms to convert, and what is the resulting profit?" We now demonstrate how to address these questions.

Daily Versus Annual Occupancy

Unused capacity represents a real cost that must be balanced against the (unrecorded) opportunity cost of unfulfilled demand during periods of high occupancy. By using daily occupancy figures, we can create a model that captures these tensions. We next describe how we estimated the investment choice using real-world data from the hotel in central New York.

We collected two years of daily occupancy data from this hotel. These daily occupancies were then broken down into occupancies at 5 percent intervals. By dividing the occupancy at each 5 percent interval by the total annual occupancy, we were able to construct a relative frequency for these occupancy levels. Notice that the probabilities in the right-hand column of Exhibit 5 add up to one and, therefore, form a probability-density function for daily demand or occupancy. Exhibit 5 gives the relative frequencies for these percentage occupancies.[5]

The average occupancy is 74 percent, but those familiar with the hospitality industry will realize that this is not a typical

3. 100 rooms × 70 percent average occupancy × 0.38 probability demanded (at $10.00/room-night).
4. An anonymous reviewer pointed out that the extent of the difference is a function of the variability in demand. That is, a property with steady occupancy rates will obtain similar results for both models, whereas a property whose demand is fluctuating (but not necessarily closed) will obtain significantly different results, as demonstrated above. The difference in models arises because of the committed, fixed nature of costs.
5. Reclassifying occupancy data into twenty categories was an arbitrary choice for expositional purposes. Using too few categories in the model has the potential to distort the optimization, but one can maintain the original distribution (the fineness being a function of the number of rooms). With our data, this reclassification did not change our results.

Exhibit 5:
Daily Demand

Daily Occupancy	*Relative Frequency or Probability of Occurrence*
0%	.0630
15%	.0027
20%	.0082
25%	.0082
30%	.0110
35%	.0137
40%	.0329
45%	.0082
50%	.0438
55%	.0438
60%	.0630
65%	.0301
70%	.0384
75%	.0521
80%	.0685
85%	.0850
90%	.0849
95%	.0877
100%	.2548

occupancy distribution. It is unusual because, on one hand, the hotel is closed 6.3 percent of the time while, on the other, it is fully occupied 25.5 percent of the time. If we used the average annual occupancy to build out forty-two allergy-friendly rooms at a $10 daily premium, we would have no occupancy on 6.3 percent of the nights. On the other hand, for 25.5 percent of the time, we could have filled fifty-seven rooms at the $10 premium. Knowledge of the daily occupancy can be used to develop a simulation model that will optimize the NPV of the investment's two-year cash flow. The decision variables in such a model are the number of rooms to convert and the corresponding price. Our model is described in the next section.

Simulating Average Daily Occupancy and Maximizing Net Present Value

The traditional model does not take into account that demand is a random variable. When the realized demand is high (e.g., on sold-out nights), the demand for allergy-friendly rooms will exceed capacity. The lost revenues from the unmet demand are opportunity costs because, in this model, all costs are fixed costs. (Despite their importance, opportunity costs frequently go unnoticed because they are not recorded transactions in the accounting system.) Conversely, when demand is low, allergy-friendly rooms may go unsold. The excess capacity in allergy-friendly rooms has a real, measurable cost. The optimal number of rooms to convert to allergy-friendly rooms, then, requires a balancing of the opportunity costs of lost revenues against the costs of excess capacity. Solving this problem requires the use of simulation-based optimization techniques, since a closed-form solution is not possible.

Optimization tools such as Microsoft Excel Solver enable one to optimize a specific objective (e.g., to maximize the value in a spreadsheet cell), but such tools do not model uncertainty. Spreadsheet models are deterministic, providing a solution for only one realization and multiple scenarios require a table of choice variables (this is illustrated in Exhibit 4, panel B). To model uncertainty, Monte Carlo (MC) simulations are used. MC models generate random values for uncertain variables, drawing from specified distributions. These random draws are conducted many times over, and spreadsheet calculations are stored for each round, providing a distribution of results. MC methods, however, do not provide for changing decision variables that optimize an objective (in our case, the

Exhibit 6:
Cash Flows—Two Years

Incremental Price[a]		$10.00
Rooms converted to allergy-friendly (AF)[a]		54
Average daily demand for AF rooms		42
Cash flows		
Total two-year revenues		$301,220
Total costs		
Total conversion costs	($81,000)	
Total maintenance	(28,350)	($109,350)
Net cash flows		$191,870
Present value		
Cash inflow		$260,189
Cash outflows		
Quarterly maintenance		($24,480)
Conversion ($t = 0$)	(81,000)	($105,480)
Net present value		$154,709

a. Indicates decision variables that are determined when the net present value is maximized.

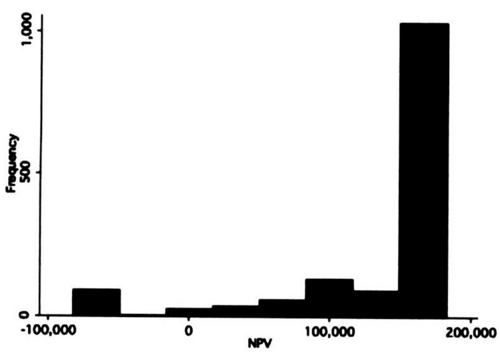
NPV of a project). Moreover, manually iterating hundreds—or thousands—of combinations is slow, tedious, and error-prone. What is needed is a combination of optimization and MC techniques to solve the build-out and pricing problem. To demonstrate our solution, we used the software package RiskOptimizer, by Palisade Software, although other software vendors offer similar products.

Our model optimizes NPV by manipulating price and room conversion, subject to constraints, given consumer demand and the uncertainty in daily occupancy (see Exhibit 6). The simulation-optimization software begins by selecting initial values for the management-decision variables (i.e., the parameters selected by management that will maximize NPV of the future cash flows). As noted above, our model's decision variables are how many rooms to convert to allergy-friendly rooms and the premium (up-charge) above normal price that management can charge for an allergy-friendly room.

With the initial selection of the two decision variables, the MC simulation is then run. For each of many iterations, a new value for the random variable (occupancy) is drawn from the probability distribution given in Exhibit 5, simulating variation in daily occupancy. A typical simulation will involve thousands of iterations, generating a distribution for daily occupancy and, consequently, NPV. An example of one such distribution is shown in Exhibit 7. When the simulation has finished, the optimization software records the results of the trial and selects new choices for the decision variables. The entire process is then repeated.

Rather than try all possible combinations or randomly select combinations, the optimization software uses one of several algorithms to iterate toward an optimal solution. The optimization process is completed when one of several stopping conditions are met (typically convergence, or a set number of trials). With a modern computer, the simulation process takes just minutes, and quantitative

Exhibit 7:
Example Distribution of Net Present Value (NPV)



and graphical results are produced. Exhibit 8 diagrams the simulation optimization process.

To run the simulation, the analyst needs to select a number of parameters. (The steps involved are summarized in greater detail in the accompanying sidebar.) For the decision variables—room build-out and price—we selected the recipe-solving method. This method allows both variables to be selected independently. We constrain the room build-out to be in the range from 0 to 150 rooms, and the price is constrained to be in $5 increments between $5 and $25. For the random number generator we selected a seed of 1, enabling us to reproduce our results. Each simulation is run for 730 iterations, equivalent to two years' worth of arrivals. Finally, the optimization was run over 3,000 trials.

Simulation Results

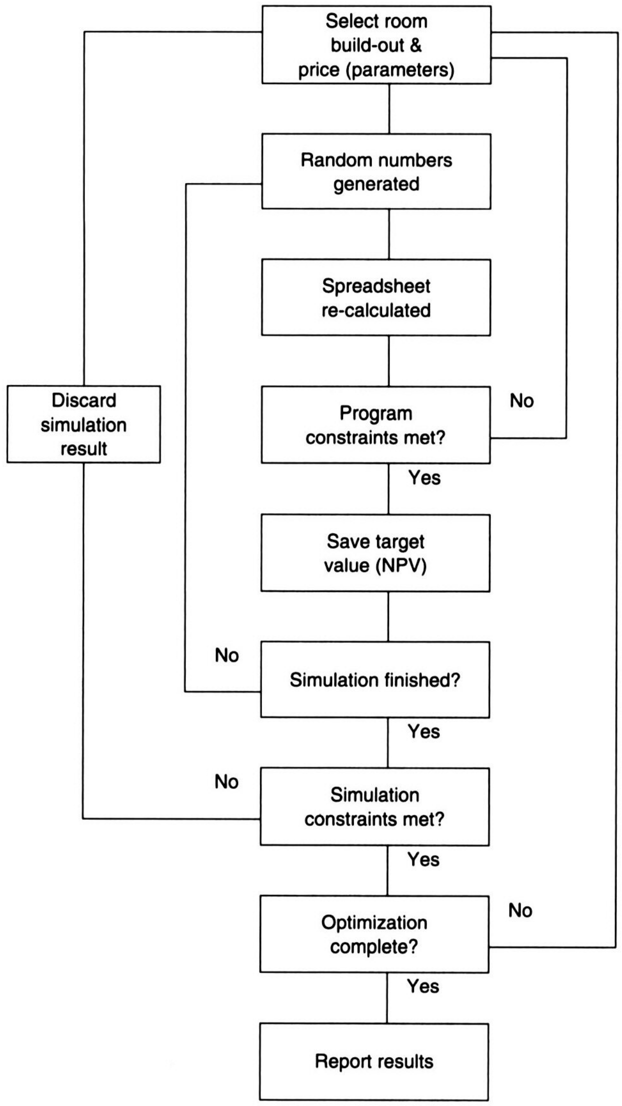
In our simulation, the optimization software selected 499 combinations out of a possible 750 combinations of room build-out and price. Exhibit 9 illustrates the frequency of combinations over 3,000 trials. The results are summarized in Exhibit 6. We see that it is optimal for the hotel general manager to convert fifty-four rooms and charge a $10 premium per room. With fifty-four rooms converted, the expected NPV is $154,709. Because arrivals are random, actual results for a given year will vary, depending on the specific realization of hotel occupancy and demand for allergy-friendly rooms. We are, therefore, most interested in the mean of the NPV, but analysts will also want to examine other data output from the simulation. These include the minimum NPV, maximum NPV, and standard deviation of the mean NPV for the various combinations of decision variables. Some managers, for example, may prefer to trade off a higher expected mean NPV with a room-price combination providing a lower return and lower risk.

This fifty-four-room build-out is twelve more rooms than the prediction from the traditional model. Using the simulation, we find that had the general manager converted forty-two rooms, the hotel would realize a mean NPV of only $142,576. The difference of $12,133 is the average lost opportunity cost of not optimizing the room build-out.

Exhibit 10 provides an incremental income statement expected by converting fifty-four rooms and charging a premium of $10. This is based on an expected average daily increment in revenues of $412.63. The two-year expected incremental net income on the conversion of fifty-four rooms to allergy-friendly rooms is $191,870.

Exhibit 11 illustrates the mean and standard deviation of the NPV as a function of room build-out and price. Mean NPV, shown in panel A, provides a visual assessment of the sensitivity of the results to changes in the decision variables. Panel B can be thought of as providing a view of the risk, or volatility, of returns since this diagram depicts the standard deviation of the NPV as a function of the decision variables. From panel A, we see that a $5 price

Exhibit 8:
Flowchart of the Simulation Optimization Process



never provides much of a return. The $10 price provides the highest return and has a positive NPV for the broadest range of room conversions (ranging from 0 to approximately 130 rooms). Prices above $10 have a peak return in the range of 15 to 25 rooms and the negative return in the range of 60 to 80 rooms converted. Panel B reveals that the $10 price has the highest standard deviation in NPV. Two results here were not anticipated: (1) the lowest standard deviations of NPV correspond to the highest prices; and (2) the standard deviation is, for each price level, constant at the point of maximum return. The reason for the constant standard deviation is that build-outs beyond the maximum return point are, simply, excess capacity. These findings illustrate the importance of graphing results.

Steps in Creating the Decision Model

1. Create a spreadsheet with data on the investment: room conversion cost, quarterly maintenance fee, cost of capital, and modeling period. (Since the investment decision for this application is two years, we used two years.)

2. Next add property size and occupancy data. Occupancy data, used for the Monte Carlo simulation, must be of the form shown in Exhibit 5. Using the demand probabilities obtained from your occupancy data, the simulation software draws a random sample for each iteration. In the software we used, occupancy data was entered in the following form: RiskDiscrete({discrete values}, {corresponding probabilities}).

3. Add cells for price and demand. Price is one of our two decision variables. Demand can be discrete (obtained from a survey) or a continuous function estimated from survey data. To evaluate demand for a discrete distribution, one must use Excel's VLOOKUP function. For example, our formula is written as: =VLOOKUP(C24,A5:B9,2). The first argument, C24, contains the price variable. The range A5:B9 is a table containing price and demand data obtained from our marketing survey. The final argument, 2, is the column from which the answer is extracted. In other words, the lookup function provides the percentage of customers willing to pay for an allergy-friendly room for a given price. The percentage demand is multiplied by the daily occupancy (a random variable) and this is rounded off using Excel's ROUND() function (we cannot have partial rooms demanded).

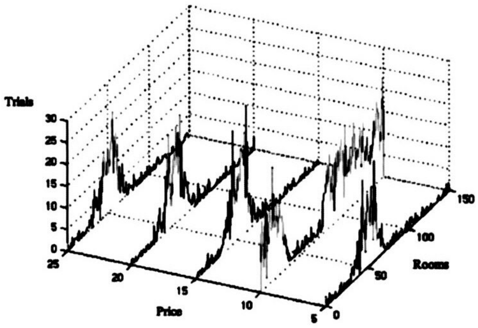
4. The next step is to determine the project's incremental revenues. Room demand (estimated in step 3) may exceed the number of rooms converted (our second decision variable). Because of this, we must use Excel's IF() function when computing revenue. This function has the following syntax: =IF (logical_test, value_if_true, value_if_false). Our logical test is whether demand exceeds the number of rooms built out. When it does, our formula computes daily revenues as the up-charge times rooms built out times 730 days. Otherwise, our formula computes daily revenues as the up-charge times demand times 730 days.

5. From revenue we need to subtract the costs of conversion (number of rooms built out times the unit conversion cost) and maintenance (rooms built out times the seven quarterly payments over the two-year period) to get cash flow.

6. To estimate the present value of the cash flows, we use Excel's present value function, PV(). The formula takes the cost

(continued)

Exhibit 9:
Optimization Trials: Number of Trials Versus Rooms and Price



Caveats, Extensions, and Conclusion

This article is a case study on how to use consumer-demand information to determine the optimal number of rooms to convert and the premium to be charged. Some may claim that given the nature of our sample occupancy (25.5 percent of the rooms being sold out and no occupancy 6.3 percent of the time), the incremental NPV of $12,133 gained by applying this more sophisticated model may not be worth the cost and effort, and the average occupancy model may indeed be a good approximation of the number of rooms to convert. We have two responses to this criticism. First, the relevant comparison is the $182,797 of the traditional model to the $154,709 to the sophisticated model. This difference is $28,088, representing an 18 percent error. Second, comparing the expected normal NPV ($142,576) to the traditional model's prediction, we would have a 28 percent error. These are not inconsequential errors, and when applied to larger (in a financial sense) problems, the dollar magnitude of the error is much larger. Second, the actual error is a function of the various distributions of the random variables and any covariance that might exist among these variables. Without properly considering these factors, management simply has no way of knowing whether the difference is managerially significant, and decisions then will be based on one's "gut" and intuition rather than on sound analysis. In our specific model, we assume that the difference between the traditional and simulation models will decrease as the variance in the occupancy decreases.

Two caveats deserve mention. First, the results—room build-out and price—may be sensitive to the input data. For example, we modeled a continuous demand function ($e^{-p/8.9}$) from the discrete measures taken from the survey. When using this function in our simulation model, the simulation yielded a solution of twenty-eight rooms with a $15 premium. That we get different results for different inputs is hardly surprising; it is important to keep in mind that the purpose of this study was to illustrate the application of a quantitative tool combining MC simulation and optimization.

Our second caveat is that we determined the demand function by combining business and pleasure guests. We did this for two reasons. First, the sample yielded only sixty-two useable observations for business travelers. Because of sampling variation, a larger sample would be needed to model business guests separately from pleasure guests (see Exhibit 2). Second, our point estimates for the demand curves of business and pleasure guests were similar. Using a combined or joint demand curve resulted in a simplified model. If the characteristics of leisure and business travelers were different (e.g., in length of stay), a more complicated model would be warranted. This second caveat, therefore, represents an obvious extension of this article. A related extension would be to model demand as a random variable.

This methodology can be applied to other hospitality management decisions. The daily demand and the simulation technique presented here can, for example, be extended to determining the optimal number of rooms in new construction (or room additions) and the optimal price structure of the build-out for new market entrants. As another example, it also can be used to determine the number of rooms a hotel chooses to hardwire with broadband internet connections and the price to charge for this service. A third application would be an airline considering installation of air-mobile telephones using the model to determine rates and routes on which to offer service. These examples are meant to be illustrative rather than exhaustive, and each application may require some modification of the model. Readers, no doubt, will conceive of many more applications.

Some readers may see this decision as similar to the problem of yield management. However, yield management seeks, for a given capacity, to maximize demand and, therefore, income. This decision model

(Sidebar continued)

of capital as its first argument, the number of periods as the second argument (we use 2 years times 365 days = 730), and the two-year revenues determined as described in step 4 for the third argument. The final two arguments, future value and type, are set to zero. An identical approach is used to model the present value of cash outflows for the maintenance costs.

7. The difference in the net present values of cash inflows and outflows gives us the project's net present value. This cell is selected an output cell using RiskOptimizer's RiskOutput() function. This function tells the optimization software to monitor and record the output of this cell as different values for the decision variable selected.

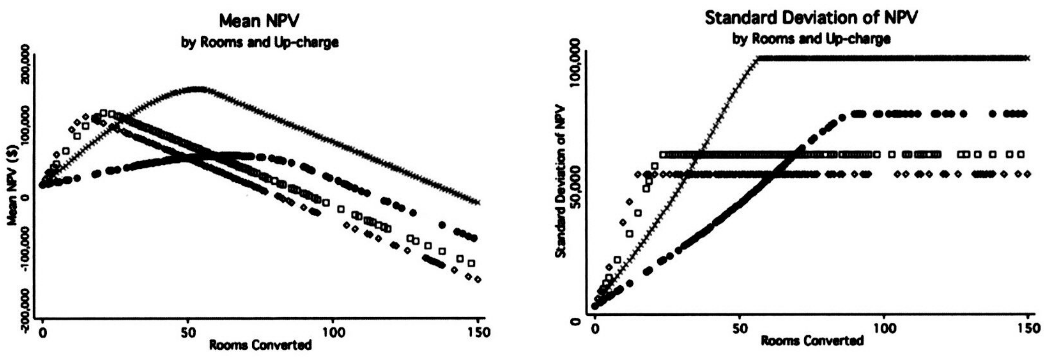
8. The next step is to select, within the simulation software, the cells that are used as the decision variables and the corresponding constraints on the range of those variables.

9. The final step is to set simulation options (number of simulations, simulation type, etc.). After starting the optimization, the software selects various combinations of the decision variables (subject to the constraints given), running a Monte Carlo simulation for each combination by drawing different occupancy figures from the distribution provided. After convergence or a set number of trials, the simulation stops and the results are obtained from the optimization software.

Exhibit 10:
Incremental Income Statement: Convert Fifty-Four Rooms to Allergy-Friendly Rooms, Charge a Premium of $10 per Room

	Year 1	*Year 2*	*Total*
Incremental revenues	$150,610	$150,610	$301,220
Less			
Quarterly maintenance expenses	12,150	16,200	28,350
Depreciation of initial cost	40,500	40,500	81,000
Incremental net income	$97,960	$93,910	$191,870

Exhibit 11:
Mean and Standard Deviation of Net Present Value (NPV) by Rooms and Up-Charge



Note: circle = $5; X = $10; square = $15; diamond = $20.

seeks to jointly determine the capacity and price that will maximize income for an uncertain demand. However, once capacity has been installed, yield management techniques can be used to maximize income.

On a broader level, then, this is a case study of quantitative methods for evaluating numerous types of investment decisions. Specifically, this article demonstrates the use of simulation and optimization to maximize, under uncertainty, the NPV of future cash flows by choosing the number of rooms to convert and a corresponding price premium for these conversions. We demonstrate that simulation with daily demand is superior to using average annual occupancies in selection the optimal conversion and up-charge.

Reference

Bouich, Lauren. 2005. Guests can breathe easier at Conrad Miami. *Hotel Business* 14 (21): 60.

David A. Dittman, Ph.D., is the Hubert E. Westfall Professor of Accounting at the Cornell University School of Hotel Administration (dad19@cornell.edu), where **James W. Hesford**, Ph.D., is an assistant professor of accounting (jh383@cornell.edu). The authors gratefully acknowledge support from the Rami Weisfisch Research Fund and the School of Hotel Administration's summer research fund.

***CQ* cases**

A Simulation-Based Optimization Approach for Investment Decisions: A Case Study of Pure Allergy-Friendly Rooms

by David A. Dittman and James W. Hesford

The complexities of modeling the financial outcomes of a hotel's development decisions are highlighted by a case study of the decision to convert regular rooms to allergy-friendly rooms. Among other factors, the analysis must capture the uncertainties of demand. That is, the simulation must capture and balance both the real expense of unsold premium rooms (when occupancy is low), while also accounting for the opportunity cost of unmet demand (when the hotel is sold out). Using an average occupancy figure will not satisfy these criteria, but a combination of Monte Carlo analysis and optimization will provide management with a solid indication of how many rooms to convert to the allergy-friendly premium. As compared to the average-occupancy analysis, the combined analysis suggested converting more rooms and would increase revenue by as much as 28 percent.

Tackling the Investment Decision as a "Newsvendor Problem"

by Gary M. Thompson

While the simulation analysis presented in the "Case Study of Pure Allergy-Friendly Rooms" offers a richness of data, the classic "newsvendor analysis" is a simpler approach to determining how many premium rooms to offer. The newsvendor inventory approach is based on the idea of creating additional inventory (ordering another newspaper to sell) as long as the expected marginal profit of selling the item exceeds the expected marginal cost of not selling it.

A Timely Product Innovation

by Brian Brault

The reason for converting rooms to the Pure Allergy Friendly concept is the same reason that the product was developed in the first place. That is, customers are demanding the product. Hotels that have taken the risk of converting an appropriate number of rooms have enjoyed strong return on that investment.