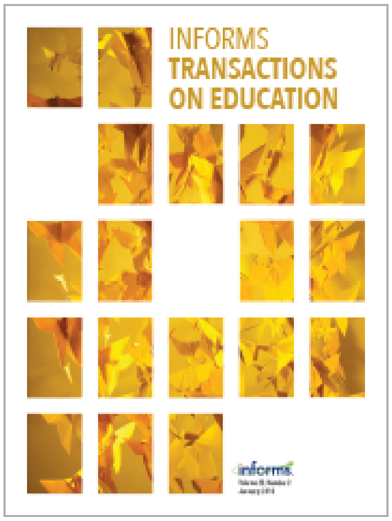

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Teaching Note

Spreadsheet Modeling to Determine the Optimum Hotel Room Rate for a Short High-Demand Period

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In this article, we describe a business modeling exercise that helps students understand the complex relationship between demand and price. The exercise seeks to determine the optimum pricing, in view of anticipated occupancy response that maximises profit for a hotel. Through the exercise, students are introduced to advanced Excel operations such as Goal Seek and Solver. This exercise goes through a systematic series of basic modeling steps, starting from identifying input variables and performance measures, and building from a basic model to a final model with sufficient complexity to represent reality. A problem commonly encountered when modeling real-world problems is the lack of complete information; often, information has to be inferred from what little is available from the past. This is demonstrated in developing the hotel occupancy and rate relationship. To ensure the model is robust, we show how trade-off and sensitivity analyses can be conducted.

Key words: spreadsheet modeling; demand management
History: Received: January 2010; accepted: June 2010.

1. The F1 Night City Race

The scenario for this business spreadsheet modeling exercise is based on the inaugural Formula One Grand Prix ("F1") night city race, which was going to be held in Singapore. This would not only help to boost tourism in the short term but also to increase the city's global presence. The small country won the 5-year contract to host one of the F1 annual races in the downtown business district. This would be the first time ever that a city race would be conducted at night. There was a palpable sense of novelty, excitement, and high tension. New lighting and improvement ideas would have to be tried out to ensure that the unprecedented race event would take place successfully.

Clearly, massive costs would be incurred in setting up the infrastructure for the race. The tourism authority had decided to impose a 30% levy on hotel room charges for a limited time period to hotels located near the race venue. They believed that, given the popularity of the event, hotels could charge up to three times their usual rates and still achieve full occupancy.

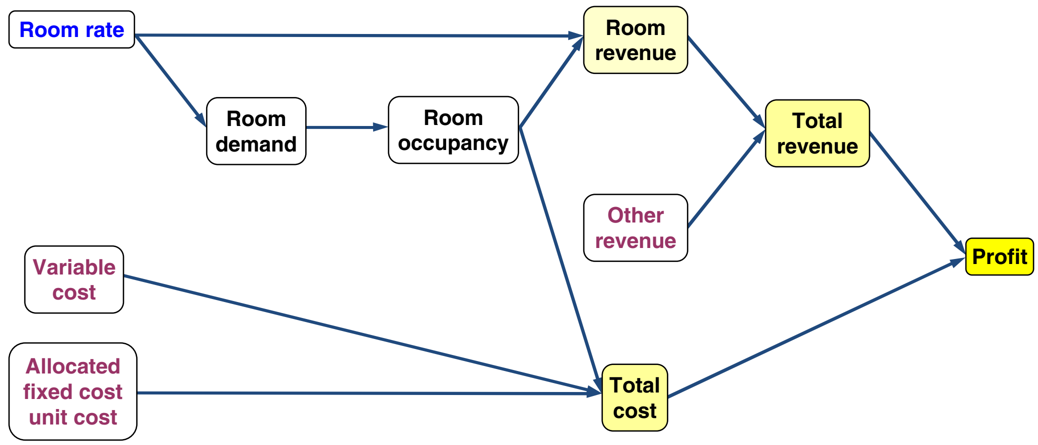
The hotel managers affected were, however, rather sceptical about full occupancy at such high room rates and wanted to understand the situation better before deciding on the final room pricing. Some managers were considering throwing in extras, such as wine, cheese, fruits, and possibly tickets to popular tourist attractions, to make the steep increase in room rates more palatable.

The objective of this classroom exercise is to demonstrate how to systematically build a spreadsheet model to analyse the interactions between revenue, cost, and profit while taking into account the price-demand relationship. The model seeks to determine the optimum hotel room rate.

A large body of work has supported the notion that room demand (room occupancy rate) tends to be price insensitive in the long term. Enz et al. (2009) and Canina and Enz (2008) in their studies have concluded that pricing room rates below those of their competitors resulted in an increased room occupancy rate but suffer in terms of revenue per room. On the contrary, pricing room rates above the competitions results in increasing the revenue per room performance despite a drop in room occupancy. This finding has been found to be consistent during both good and bad times and across all market segments from luxury to economy.

Before building any business spreadsheet model, it is important to understand the variables involved.

Figure 1 **Influence Diagram**



This can be done through a brainstorming session, diagrammatically representing them as boxes. The relationships between the variables in turn can be displayed using arrows (or connectors) as shown in Figure 1, as an Influence Diagram. The input decision variable is the Room Rate, and the parameter inputs are *Variable Cost*, *Allocated Fixed Cost*, and *Other Revenue*. The output performance measure is the *Profit* and consequence variables are *Total Revenue*, *Room Revenue*, and *Total Cost*.

To provide an alternative view, the *Influence Diagram* can be summarized into a Black Box diagram as shown in Figure 2.

Decision variables are controllable by the model-user while parameters are externally determined. In our exercise, the room rate is the only decision variable, and "uncontrollable" parameters are fixed cost, variable cost, and other revenue. The performance measures are outputs of key interest to the decision maker, and intermediate outputs are results that are computed leading to the performance measures. The latter are useful for "drill-downs" when the business decision makers need further understanding as to why the performance measure values are what they are.

2. Basic Price-Profit Model

Following the diagram's construction, the second activity for the class exercise is to create a simple spreadsheet model to compute room profit and profit margin given the following data:

Room rate	\$200,
Allocated fixed cost	\$100,
Variable cost	\$10,
Occupancy	70%.

Students would have to derive the following formulas on their own:

$$\text{Room revenue} = \text{room rate} \times \text{occupancy},$$

$$\text{Total room cost} = \text{allocated fixed cost} + \text{variable cost} \times \text{occupancy},$$

$$\text{Room profit} = \text{room revenue} - \text{total room cost},$$

$$\text{profit margin} = \text{room profit}/\text{room revenue}.$$

Figure 2 **Black Box Diagram**

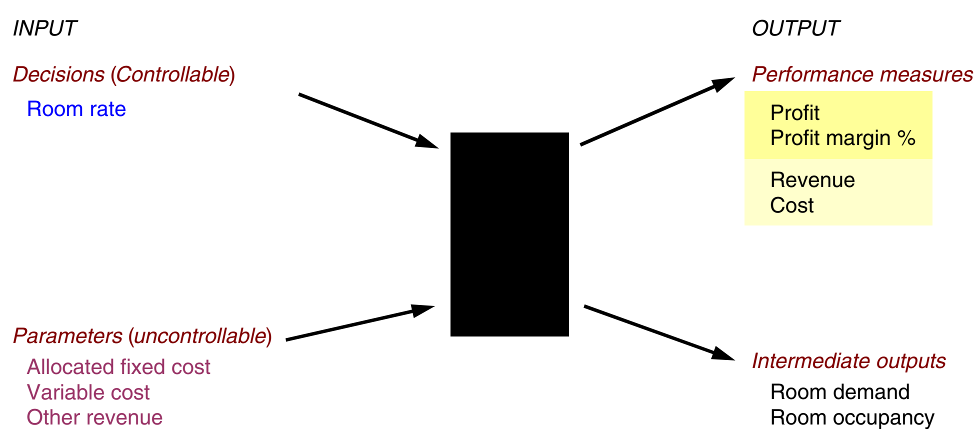
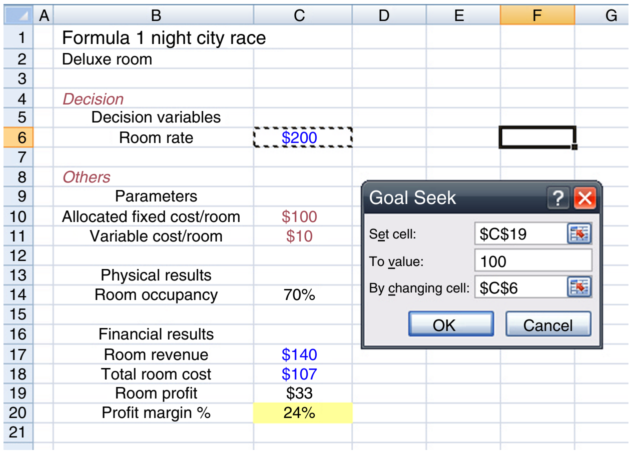


Figure 3 **Preliminary Model**

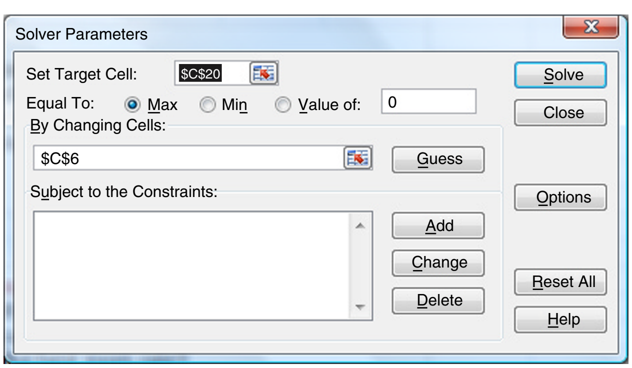


With the preliminary model completed, as shown in Figure 3, the modeler could apply any room rate value to compute the room profit. Students could be asked to use this model to determine the best room rate to achieve the highest profit. It would soon be evident that the higher the room rate, the higher the profit would be. Before exploring this further, students could be lead to determine the room rates for any target profit value. This could be done manually by trial and error. Alternatively, the Goal Seek operation (in Excel 2007, click on the *Data* tab, and in the *Data Tools* group, select *What-If-Analysis*) can be used as shown in Figure 3 below.

There is a flaw in the model, because the room profit increases indefinitely with increasing room rate. To illustrate this point, a student can run *Solver* (in Excel 2007, click on the *Data* tab, and in the *Analysis* group, click *Solver*) to maximize the profit margin by setting target cell as C20 and by changing cell C6 (see Figure 4). (*Solver* is an Excel add-in that has to be set up for use if this is not already done so.) The solution *Solver* proposes will be a very high room rate value.

Students would be asked at this juncture to think about the missing link in this preliminary model.

Figure 4 ***Solver*** **Settings**



They will soon recognise that occupancy is not a decision variable and that a price-demand relationship (i.e., room rate impact on room occupancy) is missing in the model, which renders its results meaningless. It is reasonable to assume that an increase in price will result in a drop in demand and vice-versa. Even though the demand in this F1 night race scenario can be assumed to be higher than usual, any significant increase in room rate beyond the rate that just achieves full occupancy should reduce the occupancy.

3. Price-Demand Relationship

For simplicity, we will initially assume a linear price-demand relationship. We create a table for *Room Rates*, *Room Occupancy* (*Current*), and *Room Occupancy* (*F1 Season*) as shown in Figure 5. We assume that *Deluxe* rooms are currently priced at $200 per room per night and that current room occupancy is at 70%. We further assume that room occupancy is expected to increase by 0.5% for every 1% drop in room rate and decrease by 0.45% for every 1% increase in room rate. Of course in actual application of the model, the managers are expected from their experience to provide such information.

For the F1 race season, the hotel manager is doubtful (so says the exercise scenario) of achieving 100% occupancy with the anticipated high room rates (three times the current room rate) as suggested by the tourism authority. From his experience, the manager is inclined to believe that full occupancy is possible if the room rates are kept to below two times the current level during the F1 season. He feels that increasing the room rates to three times the current level may result in decreasing room occupancy to 65%. While achieving 100% occupancy is desirable, the manager thinks that it need not be the goal for the hotel.

These inputs are now gathered into the table (in columns B–D) in Figure 5. Formulations are created to compute additional data points (in bold) for *Room Occupancy* (*Current*) at cell C15 and C21 to permit a linear function to be fitted between room occupancy and rate.

The formulations for modeling room occupancy to increase by 0.5% for every 1% drop in room rate and decrease by 0.45% for every 1% increase in room rate are

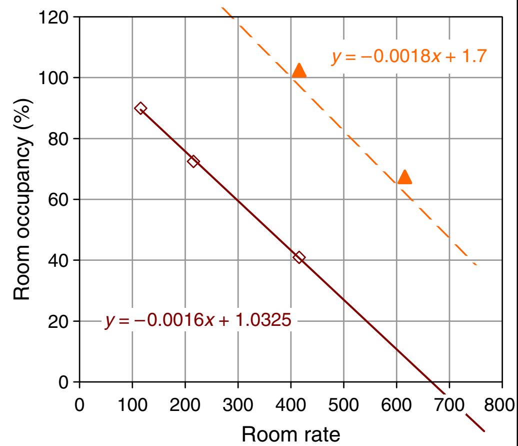
$$\text{Cell C15} = (1 + 0.5 * (\text{B17} - \text{B15})/\text{B17}) * \text{C17},$$

$$\text{Cell C21} = (1 - 0.45 * (\text{B21} - \text{B17})/\text{B17}) * \text{C17}.$$

Because the *Room Occupancy* (*F1 season*) column already has two data points, it is not necessary to generate additional points to derive a linear function.

Figure 5 **Price-Demand Relationship**

Row	Room rates	Room occupancy (current)	Room occupancy (F1 season)
15	$100	88%	
16	$150		
17	$200	70%	
18	$250		
19	$300		
20	$350		
21	$400	39%	100%
22	$450		
23	$500		
24	$550		
25	$600		65%
26	$650		
27	$700		
28	$750		



A plot of the straight line equation depicting the relationship between room occupancy and rate is shown in Figure 5. The two equations are

$$\text{Current season: } y = -0.0016x + 1.0325,$$

$$\text{F1 season: } y = -0.0018x + 1.7.$$

With these straight line functions, it is possible to compute room occupancy for any given room rate. Note that the slope, which is based on certain assumptions made earlier, could potentially influence the outcome of the analysis. This will be discussed using sensitivity analysis later in this article. The price-demand relationship should be approximately linear over a limited range of prices. If needed, the range can be shifted to where it is more relevant, and the slope and intercept of the linear function recomputed to make the approximation more accurate. The price range should contain the optimal price determined in the subsequent steps.

4. Model with Price-Demand Elasticity

After recognizing that the price-demand relationship can be approximated by a linear function, the next step is to use this function to revise the preliminary profit model. To adjust the model to closer represent reality, a government levy ("Govt Levy") on room revenue is also added. The revised profit model is shown in Figure 6. The *Govt Levy* as a tax on revenue is added to the *Cost* component. The formulation for *Cost* is thus given by

$$\begin{aligned}\text{Cell H5} &= \text{C5} + \text{F5} * \text{D5} + \text{E5} * \text{G5}\\ &= (\textit{Fixed Cost} + \textit{Occupancy} * \textit{VarCost}\\ &\qquad + \textit{Govt Levy} * \textit{Revenue}).\end{aligned}$$

Test cases for different room rate values with the assumed *Govt Levy* of 30% and *Occupancy* of 100% are presented in rows 10 to 12. However, this part of the model still assumes price-inelastic demand.

To make it easier to include the price-demand relationship into the model, the values for y-intercept (cell B16) and slope (cell C16) should be computed and not read off a chart (see scenario 1 in Figure 6). The value for the y-intercept is computed using the *Intercept* function using existing data point y-coordinates (C19:C20) and x-coordinates (B19:B20). The formulation is given by

$$\text{Cell B16} = \text{INTERCEPT(C19:C20, B19:B20)}.$$

Similarly, the slope value is computed using

$$\text{Cell C16} = \text{SLOPE(C19:C20, B19:B20)}.$$

Scenario 2 has a different pair of y-intercept and slope values (Cell G16 and H16). It is created using the same method, based on a different set of occupancy rates (H19:H20).

The formula for *Occupancy* under scenario 1 is given by

$$\text{Cell F24} = \text{B16} + \text{C16} * \text{B24}.$$

Figure 6 Model with Price-Demand Relationship

F24 ▼ f_x = B16 + C16∗B24

F1 Night city race

Intercept	*Current*				Per room			
Room rate	Fixed cost	VarCost	Govt levy	Occupany	Revenue	Cost	Profit	Profit %
$200	$100	$10		70%	$140	$107	$33	24%

Price-inelastic demand — Per room

Room rate	Fixed cost	VarCost	Govt Levy	Occupany	Revenue	Cost	Profit	Profit %
$400	$100	$10	30%	100%	$400	$230	$170	43%
$500	$100	$10	30%	100%	$500	$260	$240	48%
$600	$100	$10	30%	100%	$600	$290	$310	52%

Scenario 1

Intercept	Slope
1.70	0.00175

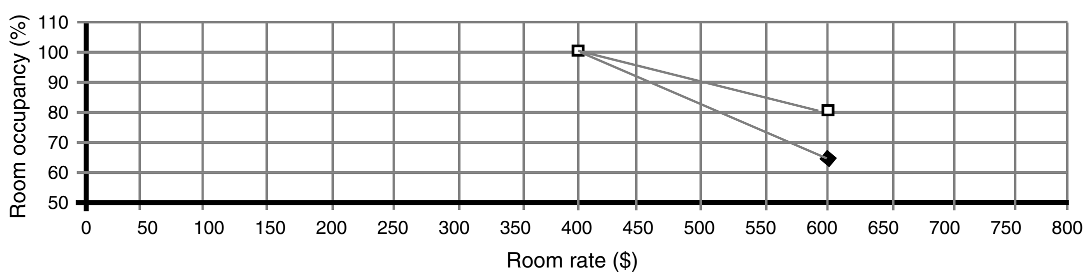
Room rate	Occupancy
$400	100%
$600	65%

Scenario 2

Intercept	Slope
1.40	−0.00100

Room rate	Occupancy
$400	100%
$600	80%

Room rate	Fixed cost	VarCost	Govt Levy	Occupany	Revenue	Cost	Profit	Profit %	
$493	$100	$10	30%	84%	$413	$232	$181	44%	1
$714	$100	$20	30%	69%	$490	$261	$229	47%	2



The formula for *Occupancy* under scenario 2 is given by

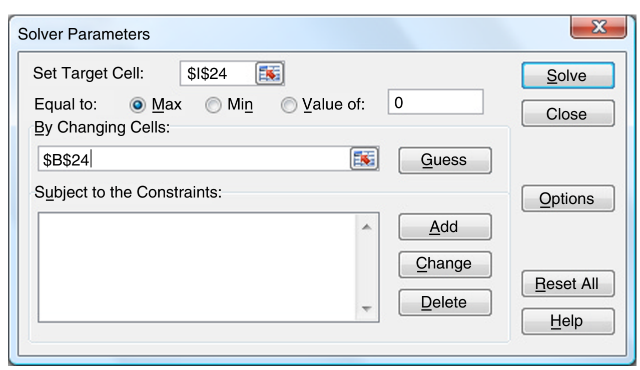
$$\text{Cell F25} = \text{G16} + \text{H16} * \text{B25}.$$

With an elastic price-demand function, an increase in room rate does not necessarily increase profit, unlike the outcome of the earlier model in §2. Students would be encouraged at this point to determine the room rate that maximises profit. Some students still adopt the trial-and-error approach, while most use *Solver*.

To run *Solver* for scenario 1, enter *Set Target Cell* as I24 and *By Changing Cells* as B24 (see Figure 7 below). The same can be applied to scenario 2 by entering *Set Target Cell* as I25 and *By Changing Cells* as B25.

In reality, other considerations beside room rate affect the occupancy rate. Many of the variable occupancy costs are tangible: the cost of the housekeeping, utilities, and amenities like soap, coffee, and tea.

Figure 7 Using ***Solver*** for Scenario 1



However, there are other intangible occupancy costs, such as the potential cost of dissatisfying customers if service suffers when occupancy is high (for example, slower service at restaurant, longer waits at the front desk, and slower room service).

In scenario 2, the manager considers adding extras, such as wine, cheese, and fruits, to make their hotel rooms more attractive to potential guests. In the model, this would increase the variable cost per room. Here, we assumed that it was doubled from $10 to $20 (cell D25 in Figure 6). This move may influence room occupancy for each possible room rate, or it may not, if competitors also do the same. Ignoring competitive response, we factor in the impact as improving occupancy to 80% at a room rate of $600. We can further evaluate the impact of adding even more extras by adding a multiplier on the occupancy.

5. Trade-Off Analysis

Though *Solver* can help us find the optimal room rate, it would be good at this point to understand how the profit would change if the optimal room rate is not applied. Let us continue this analysis with the price-demand function defined in scenario 1.

The following steps will lead to the model constructed in Figure 8.

1. Input room rate starting from $300 to $1,000 in steps of $100, as shown in cell range C12:J12.
2. Input *Fixed Cost* as $120 in cell C13.
3. Input *Variable Cost* as $10 in cell C14.
4. Input *Government Levy* as 30% in cell C15.
5. Formulate *Occupancy* in cell C16 = MIN(1,MAX (0, B4 + C4 * C12)). The MIN function is used here to ensure that occupancy rate does not exceed 100%, as reality demands.
6. Formulate *Revenue* in cell C17 = C12 * C16 and apply the same function to cell range D17:J17.
7. Formulate *Cost* in cell C18 = $C13 + $C14 * C16 + $C15 * C17 and apply the same function to cell range D18:J18.
8. Formulate *Profit* in cell C19 = C17 − C18 and apply the same function to cell range D19:J19.
9. Formulate *Profit %* in cell C20 = IFERROR (C19/C17, "") and apply the same function to cell range D20:J20.

The trade-off analysis plot in Figure 9 shows how revenue, cost, and profit vary with room rate. It is apparent from the plot that revenue, cost, and profit peak when room rate is around $500. The breakeven point (where profit is zero) occurs when room rate is around $850. Any further increase in room rate beyond this point will result in making a loss. The plot also shows that the profit does not change very much from the optimal profit for room rates between $400 and $600. This gives the hotel manager a lot of room to play without sacrificing profit. He can choose to set the room rate closer to $600, which will make occupancy lower and thereby not overly stress his staff to compromise service performance. Alternatively, he can choose to set room rate closer to $400, attracting more guests to give more visibility to his hotel and help spread the good word-of-mouth message to attract future potential guests.

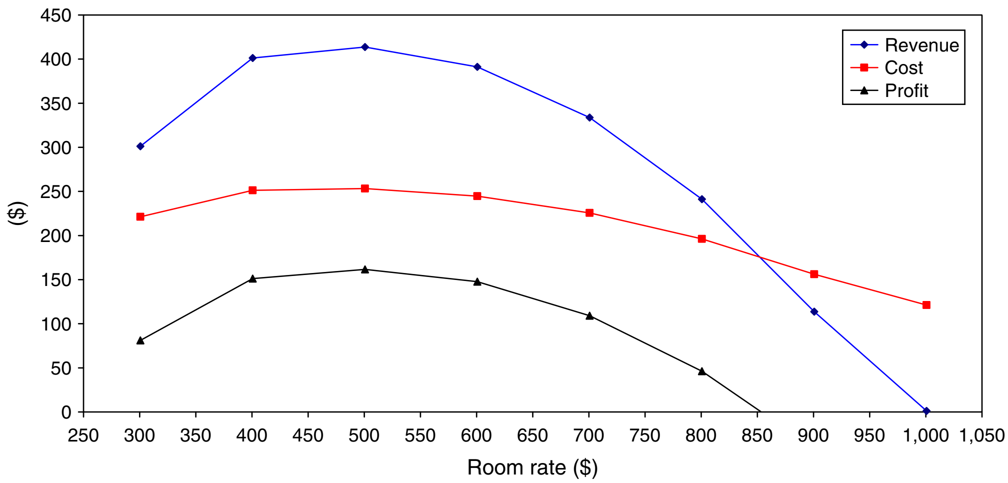
6. Sensitivity Analysis

In any model, it is inevitable that some variables are beyond the control of the model-user. This includes external factors like interest rates and the government levy. To ensure that the decisions supported by the model are robust, it is a good practice to perform

Figure 8 Trade-Off Analysis

	A	B	C	D	E	F	G	H	I	J
1		F1 Night city race								
2										
3		Intercept	Slope							
4		1.7	−0.00175							
5										
6		Room rate	Occupancy							
7		$400	100%							
8		$600	65%							
9										
10		*Model*								
11			Room rate							
12			$300	$400	$500	$600	$700	$800	$900	$1,000
13		Fixed cost	$120							
14		VarCost	$10							
15		Govt levy	30%							
16		Occupancy	100%	100%	83%	65%	48%	30%	13%	0%
17		Revenue	$300	$400	$413	$390	$333	$240	$113	$0
18		Cost	$220	$250	$252	$244	$225	$195	$155	$120
19		Profit	$80	$150	$161	$147	$108	$45	−$43	−$120
20		Profit %	27%	38%	39%	38%	32%	19%	−38%	
21										

Figure 9 **Trade-Off Analysis Plot**



sensitivity analysis. The term *Sensitivity Analysis* is used here when uncontrollable input variable values are changed to examine how sensitive the performance measures are to their changes. In this exercise, a sensitivity analysis was performed to evaluate the impact of varying the occupancy-to-rate slope on profit per room.

The table in Figure 10 is created using the *DataTable* operation (in Excel 2007, click on the *Data* tab, and in the *Data Tools* group, select *What-If-Analysis*). The resulting DataTable is a range of cells in Excel that shows the results of a given model for different values used as inputs to that model.

The following steps show how the data table is constructed in Figure 10.

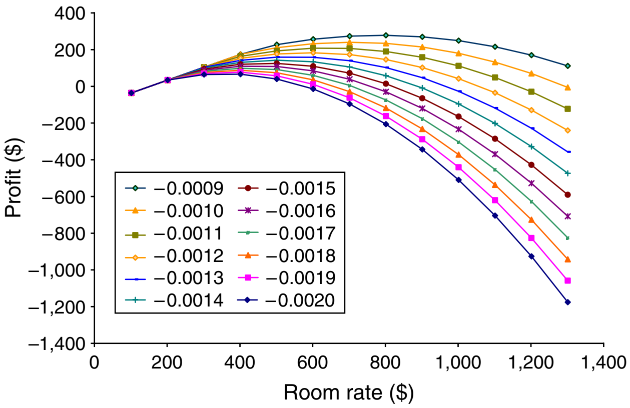
1. Create the profit model for computing profit in row 5, as shown in Figure 10.
2. Create a row header for occupancy-rate slope values, ranging from −0.0020 to −0.0009 in steps of 0.0001, in cell range D8:O8.
3. Create a column header for room rate values, ranging from 100 to 1,300 in steps of 100, in cell range C9:C21.
4. Link the cell that computes profit to the top-left corner cell in the DataTable. That is, set cell $C8 = N5$.
5. Select the cell range C8:O21 and activate the *DataTable* operation (in Excel 2007, click on the *Data* tab, and in the *Data Tools* group, select *What-If Analysis*).
6. The row input cell is cell E5, and the column input cell is cell G5.

In Figure 10, negative profits are given in "(parentheses)," and the maximum profit is highlighted in bold. This highlighting is done using the *Conditional Formatting* operation in Excel. The table here shows

Figure 10 **Sensitivity Analysis**

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	Sensitivity analysis														
2															
3															
4				Intercept	Slope		Room rate	Fixed cost	VarCost	Govt Levy	Occupany	Revenue	Cost	Profit	Profit %
5	Occupancy function			1.4	−0.0015		$600	$100	$10	30%	50%	$300	$195	$105	35%
6															
7			Profit	Occupancy Slope											
8			105	−0.0020	−0.0019	−0.0018	−0.0017	−0.0016	−0.0015	−0.0014	−0.0013	−0.0012	−0.0011	−0.0010	−0.0009
9		Room rate	100	($40)	($40)	($40)	($40)	($40)	($40)	($40)	($40)	($40)	($40)	($40)	($40)
10			200	$30	$30	$30	$30	$30	$30	$30	$30	$30	$30	$30	$30
11			300	$60	$66	$72	$78	$84	$90	$96	$100	$100	$100	$100	$100
12			400	$62	$73	$84	$94	$105	$116	$127	$138	$148	$159	$170	$170
13			500	$36	$53	$70	$87	$104	$121	$138	$155	$172	$189	$206	$223
14			600	($18)	$7	$31	$56	$80	$105	$130	$154	$179	$203	$228	$253
15			700	($100)	($66)	($33)	$1	$34	$68	$102	$135	$169	$202	$236	$270
16			800	($210)	($166)	($122)	($78)	($34)	$10	$54	$98	$142	$186	$230	$274
17			900	($348)	($292)	($236)	($181)	($125)	($69)	($13)	$43	$98	$154	$210	$266
18			1000	($514)	($445)	($376)	($307)	($238)	($169)	($100)	($31)	$38	$107	$176	$245
19			1100	($708)	($624)	($541)	($457)	($374)	($290)	($206)	($123)	($39)	$44	$128	$212
20			1200	($930)	($830)	($731)	($631)	($532)	($432)	($332)	($233)	($133)	($34)	$66	$166
21			1300	($1,180)	($1,063)	($946)	($829)	($712)	($595)	($478)	($361)	($244)	($127)	($10)	$107
22															

Figure 11 Sensitivity Analysis Plot



that the optimum profit increases with increasing room rate and increasing occupancy-rate slope. With increasing occupancy-rate slope, the range of positive profit also gradually widens. To understand why, note that a gentler occupancy slope implies that a large increase in room rate leads to a small reduction in the occupancy rate. This is a situation in which the demand is strong.

The outcome of the sensitivity analysis is given in Figure 11. For a given room rate, when the value of occupancy-rate slope decreases (i.e., steeper slope), profit decreases as well. At one extreme, an occupancy slope of −0.0020 is characterised by an early peak in profit at $62 with a room rate of $400, followed by a rapid drop in profit with increasing room rate. At the other extreme, an occupancy slope of −0.0009 gives a maximum profit at a much higher value of $274 with a corresponding higher room rate of $800. Beyond the maximum this point, profit drops at a slower rate. However, if the difference in occupancy slope is small, the result is not significant. It implies that if the initial assumption of the occupancy slope is taken accurately, the model will be relatively robust to small changes in the assumed uncontrollable inputs.

We can also observe that the *Occupancy-Rate Slope* (an uncontrollable input) can have high impact on profitability, particularly at higher room rates. *Profit* can vary more than fourfold at the extremes, as demonstrated in this exercise. This suggests that setting a lower rate is better; at higher rates, wrong assumptions of the price-demand relationship can have disastrous outcomes.

7. Conclusions

Further observations can be made from the results computed if students have a keen eye and entrepreneurial aptitude. Students should realize that the goal of developing the model and doing the analysis is to better understand the issue on hand and discover what the challenge poses and draw insights from the modeling, as well as from the analysis. It is not about numbers-in and numbers-out calculations. The use of the spreadsheet should not be just a computation tool, but rather an exploratory discovery tool. In the process, the underlying problem becomes clearer. At that point, the modeller can proceed to start looking at what the solution should be or attempt to change the problem to his favour.

Given the right tools to do this, the modeling and analysis would be fun. This spreadsheet exercise demonstrates that this can be done. The afternote to the exercise is that the actual responses of hotel managers were indeed as expected. They did not raise the room rates by three times in magnitude but kept them at around two times their prevailing rate. An observation not evident during the before-race modeling was that while a large number of hotel rooms were sold, the actual occupancy turned out to be much lower than expected. Many organizations bought tickets and paid for confirmed rooms for their high-worth customers who did not show up for the race. This may be a valuable input to hotel managers for the next race.

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