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Virtual Roulette Spreadsheet: A Teaching Tool

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The quest for novel teaching and delivery methods is never ending. As professors we are continually challenged to find new or different approaches to present materials to stimulate students' interest by having exciting examples or interesting applications that accomplish the associated pedagogical goals. This is the motivation behind the approach presented here. In our OR/MS classes we use a model familiar to most or all students—the game of roulette—for teaching simulation techniques as well as teaching basic probability concepts using spreadsheets.

The Basic Strategy

The model considers a single player playing roulette against the house in a simplified roulette game where the only allowed betting scenarios consist of the following:

- Bet on an individual number (which pays back 35:1);
- Bet on an even number (which pays back 1:1);
- Bet on an odd number (which pays back 1:1);
- Bet on the numbers 1-6 (which pays back 1:5); and
- Bet on the numbers 13-24 (which pays back 1:2).

In all cases the amount of the bet is returned to the player.

We have found that most students are familiar with the game of roulette. Occasionally, for a student who may not have been exposed to roulette, we have a picture of a roulette wheel and table, showing how and where the bets are made. We also noticed that this is an instance where students familiar with the game readily and spontaneously offer their explanations and insights to their less experienced peers! We explain in class that the course is not "Gambling 101" (which usually raises a laugh), but that the purpose is to understand simulation better.

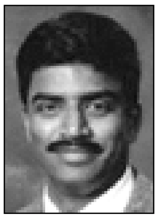
To keep the model simple we choose just a few representative betting scenarios. Other scenarios could be implemented as well, but many of them are equivalent to those we chose (e.g., betting on 7-12 is equivalent to betting on 1-6) and others can be incorporated as easy extensions to the model.

The model can be used to investigate various betting strategies. The player can choose from the following bets:

1. Dollar amount on the same number each play.
2. Dollar amount on even each play.
3. Dollar amount on the numbers 1-6 each play.
4. Dollar amount on the numbers 13-24 each play.
5. Dollar amount on even *and* odd each play.
6. Dollar amount on even *and* odd each play *and* an individual number.
7. Double the previous bet amount on even if the previous play was a loss.

The Basic Model

An abbreviated version of the model is presented in Figure 1. (A copy of the Excel file can be obtained by e-mail from either of the authors.) The figure shows an input section and the main model for 200 plays of the roulette wheel. For the purpose of illustration, 200 plays were chosen to approximate "a day's" history of plays—if one play is assumed to take 6 minutes, 10



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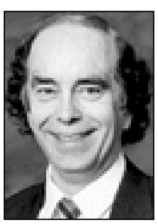

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plays take an hour, and so 200 plays represent 20 hours of play, which could be argued to be an "average" day, since some of the night-time hours may be slow. The point of the "day's play" is to let the students calculate the day's winnings or losses (which is graphed) and appreciate the power of probability, which is creating wealth for the house. Clearly, one can extend the spreadsheet to any number of plays by simply copying the rows.

The roulette ball is "rolled" by generating a random number in column B and illustrates Monte Carlo simulation. The first play is graphed using a pie chart to show the number bet and the outcome of the roulette wheel. Columns C through G record the amounts paid to the player for the corresponding bets, which are then totaled in columns H and I. Figure 2 provides the main formulas. A comprehensive paper with full details of all formulas is being prepared by the authors and will be available on request. Formulas are entered once in row 12 and then copied down for the number of roulette plays to be simulated.

For compactness of display in Figure 1, only one of the strategies that returns 5:1 (i.e., bet on a value in the ranges 1-6, 7-12, 13-18, etc.) is included. Similarly, only one of the strategies that returns 2:1 (i.e., bet on a value in the ranges 1-12) is included. A full implementation would simply have the extra columns, with corresponding formulas. At this point we can discuss why there should be no difference in which set of numbers is chosen. Similarly, for reasons of compactness of the displayed model, the red-black strategy is omitted. The underlying logic (i.e., Excel formulas) is the same as for the odd-even strategies. In fact, it has been found that given the model shown in Figure 1, implementing fully the kinds of strategies described in this paragraph is a useful (and realistic) exercise for students to hone their spreadsheet skills.

Assumptions or conventions in building the model include the following:

- In order to facilitate comparison of strategies, it is assumed that the same strategy will be followed by the player for all plays (200 in the illustrative example).
- 0 and 00 are represented by the random numbers 37 and 38 by using the **RANDBETWEEN**(1,38) Excel function. This is purely to make the resulting formulas simpler to read and to test for values >36 with one test to represent the generated 0 or 00. Students must have the Data Analysis tool loaded to use the **RANDBETWEEN** Excel function.

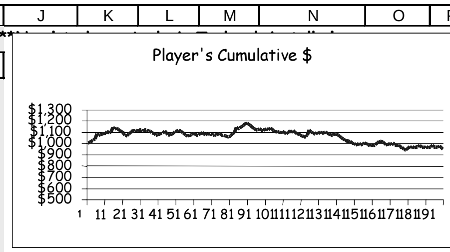
The basic model is given to students so that it can be used to demonstrate the simulation method. The process starts with identification of appropriate measures of performance or outputs, usually by class discussion. Relatively simple, yet useful measures of performance are the long-term payoffs for the player, the maximum bet, and so on, after a certain number of plays (**I2:I5** in Figure 1).

Discussion

Once the outputs are identified, it is important to discuss the need for repeating the runs a large number of times to demonstrate the steady state or the long-term average behavior of the system. There are various ways this can be done. The simplest way is to use an add-in package such as *Crystal Ball* (Decisioneering Inc.) or *@Risk* (Pallisades Corporation). Alternatively, one can also manually execute the runs by simply using the calculate button **<F9>** and keeping track of the outputs systematically, usually in some form of an Excel Data Table for eventual calculation of the long-term averages. We used *Crystal Ball*, which is now available with many current Operations Management/Management Science textbooks (e.g., Eppen et. al, 1998; Ragsdale, 2000). That way the students can avoid the tediousness of the runs, get the statistics instantly, and see the behavior of the system in multiple formats.

The software is easy to use with a point-and-click interface and works seamlessly with spreadsheets. However, even if the simulation add-ins are not available, the students can get a good feel for the process of simulation manually. Our experience in class suggests that the students should be exposed to the manual way

	A	B	C	D	E	F	G	H	I
1	**BASIC MODEL**						Player's initial amount:		$1,000
2				**Initial**	**Conditions**		Player's final amount:		$952
3	Lucky number chosen to bet on:				17	Odds	Payoff	Exp final:	$842
4	Amount to bet on this number:				$1	2.6%	$36	**Max**	**$1,181**
5	Amount to bet on even:				$2	47.4%	$4	**Min**	**$943**
6	Amount to bet on odd:				$3	47.4%	$6		
7	Amount to bet on 1-6:				$4	15.8%	$24		
8	Amount to bet on 13-24:				$5	31.6%	$15		
9	Player's Total Bet:				$15	Exp Win	$14.21	Exp Winnings	
10			Amount paid to player						Player's
11	Play Number	**Ball**	if number comes up	if even comes up	if odd comes up	if 1-6 comes up	if 13-24 comes up	Total paid to player	cumulative $
12	1	**13**			$6		$15	**$21**	$1,006
13	2	**18**		$4			$15	**$19**	$1,010
14	3	**6**		$4		$24		**$28**	$1,023
15	4	**23**			$6		$15	**$21**	$1,029
16	5	**6**		$4		$24		**$28**	$1,042
17	6	**17**	$36		$6		$15	**$57**	$1,084



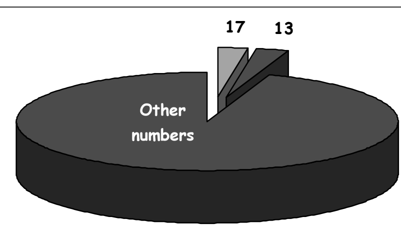


Figure 1: The basic spreadsheet model.

G9	=SUMPRODUCT(G4:G8,F4:F8)	Expected Payoff this play
B12	=RANDBETWEEN(1,38)	Simulation of the final value of the ball on this play, i.e., a random number in the range 1-38, where 37 and 38 represent 0 and 00 respectively.
C12	=IF(B12>36,0,IF(E3'=B12,36*E4,0))	If the ball comes up >36 (i.e., 0 or 00) the amount paid to the player is zero. If the ball comes up with the lucky number the amount paid to the player is 36 times the bet.
D12	=IF(B12>36,0,IF(ISEVEN(B12)'=TRUE,E5*2,0))	If the ball comes up >36 (i.e., 0 or 00) the amount paid to the player is zero. If the ball comes up with an even value the amount paid to the player is twice the bet made.
E12	=IF(B12>36,0,IF(ISODD(B12)'=TRUE,E6*2,0))	If the ball comes up >36 (i.e., 0 or 00) the amount paid to the player is zero. If the ball comes up with an odd value the amount paid to the player is twice the bet made.
F12	=IF(B12>36,0,IF(B12>6,0,E7*6))	If the ball comes up >36 (i.e., 0 or 00) the amount paid to the player is zero. If the ball comes up with a value >6 the player is paid zero, otherwise the player is paid 6 times the bet.
G12	=IF(B12>36,0,IF(B12<13,0,IF(B12>24,0,E8*3)))	If the ball comes up >36 (i.e., 0 or 00) the amount paid to the player is zero. If the ball comes up with a value <13 or >24 the player is paid zero, otherwise the player is paid 3 times the bet.

Figure 2: Main formulas for the basic model presented in Figure 1.

	A	B	C	D	E	F	G	H	I	J
1	DOUBLING MODEL							Player's initial amount:		$1,000
2					Initial Conditions			Player's final amount:		$0
3	Lucky number chosen to bet on:						Odds	Payoff	Exp final:	$870
4	Amount to bet on this number:						2.6%		Max	$1,039
5	Amount to bet on even:					$1	47.4%	$2	Min	$0
6	Amount to bet on odd:						47.4%		Multiplying factor if	
7	Amount to bet on 1-6:						15.8%		lost previous bet:	2
8	Amount to bet on 13-24:						31.6%		Max Bet	$512
9	Player's Average Bet:					$12.39	Exp Win	$11.74		
10				Amount paid to player						Player's
11	Play Number	Bet	Ball	if number comes up	if even comes up	if odd comes up	if 1-6 comes up	if 13-24 comes up	Total paid to player	cumulative $
12	1	$1	15						$0	$999
13	2	$2	17						$0	$997
14	3	$4	21						$0	$993
15	4	$8	9						$0	$985
16	5	$16	30		$32				$32	$1,001
17	6	$1	1						$0	$1,000
18	7	$2	24		$4				$4	$1,002
19	8	$1	24		$2				$2	$1,003
20	9	$1	38						$0	$1,002

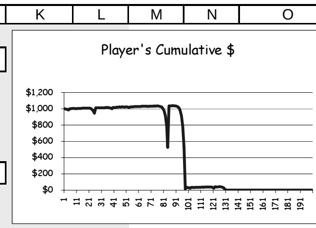


Figure 3: Variation of the basic model of Figure 1, to illustrate the bet doubling strategy (on even).

of conducting a simulation before being introduced to the add-in software as this provides a good way for students to experience the mechanics of simulation convergence, as well as the cost/results tradeoff. In advanced undergraduate electives or graduate courses the need for writing macros could be investigated or illustrated to accomplish this. Figure 4 shows the frequency distributions produced by Crystal Ball for the player's total purse using the strategy of "bet the same amount ($1) on odd and even," after 50 and 200 plays.

Extensions

The model lends itself to more challenging extensions and improvements. A reasonably routine extension would be the strategy of betting on 1-18, 19-36, or on four values. We illustrate a slightly more advanced extension by a so-called doubling-strategy, that is, continuously betting on even, for example, but the player doubles the bet whenever the previous bet is a losing bet. The spreadsheet model for this is shown in Figure 3, which is essentially the same as the basic model except for the extra column B. The model is set up with a bet-multiplying factor parameter (cell **J7**) so that variants of the doubling strategy, such as multiplying the previous losing bet by 1.5 or 3, can also easily be investigated. The graph dramatically shows when the player goes bust (the house always has deeper pockets).

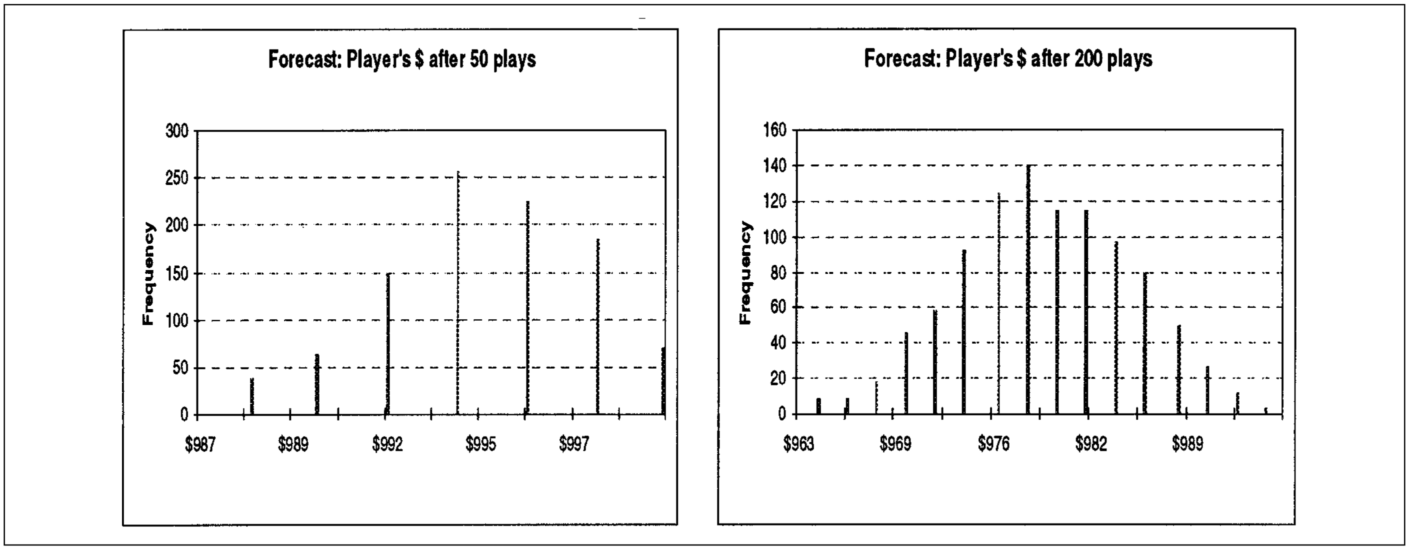


Figure 4: *Sample results from Crystal Ball.*

Final Comments

The approach is extremely flexible and adaptable to various levels of complexity, sophistication, and focus. Consequently, we believe that the example can also be used in a statistics course with minor changes, mainly in emphasis during delivery. In a statistics course, there would be less emphasis placed on the model implementation aspects by having a full template or pre-built model provided to the students. Students can be asked to calculate the long-term average of different betting strategies using probability theory and then can verify their theoretical results against the simulation outputs. Thus they can gain a deeper understanding of the nature of probabilities and expected values through experiential learning with the model as opposed to (or in addition to) the traditional abstract formulas.

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