- ♦ Modeling Uncertainty: From Scenarios to Continuous Distributions
- Example: Designing a New Apartment Building
- Connecting Random Inputs and Random Outputs in a Simulation
- Setting up and Running a Simulation in Excel
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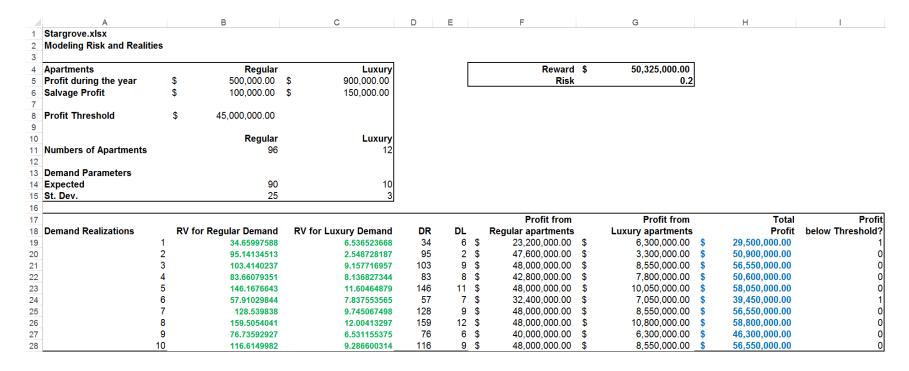
Session 3

Evaluating Alternative Decisions using Simulation Results

◆ The profit (in \$):

 $\Pi = 500,000*\min(D_R,R) + 900,000*\min(D_L,L) + 100,000*(R-\min(D_R,R)) + 150,000*(L-\min(D_L,L))$

♦ Stargrove.xlsx



 Sample of random variables from the normal distribution with mean 90 and standard deviation of 25 and its descriptive statistics

Demand Realizations	RV for Regular Demand		RV for Regular	RV for Regular Demand	
	1	34.65997588			
	2	95.14134513	Mean Standard Error	100.235027 12.31380659	
	3	103.4140237	Median	99.2776844	
	4	83.66079351	Mode	#N/A	
			Standard Deviation	38.9396755	
	5	146.1676643	Sample Variance	1516.298328	
	6	57.91029844	Kurtosis	-0.581372514	
	7	128.539838	Skewness	-0.101693197	
	^		Range	124.8454282	
	8	159.5054041	Minimum	34.65997588	
	9	76.73592927	Maximum	159.5054041	
	10 116.6149982	Sum	1002.35027		
	10 110.0143302		Count	10	
			Confidence Level(95.0%)	27.85576579	

◆ Sample mean is based on a small sample of n=10 instances of the underlying random variable. It is just an approximation to the true expected value of the random variable being simulated

 Sample of random variables from the normal distribution with mean 90 and standard deviation of 25 and its descriptive statistics

Demand Realizations	RV fo	r Regular Demand	RV for Regular	Demand
	1 2 3 4 5	34.65997588 95.14134513 103.4140237 83.66079351 146.1676643 57.91029844	Mean Standard Error Median Mode Standard Deviation Sample Variance Kurtosis	100.235027 2.31380659 99.2776844 #N 38.9396755 516.298328 581372514
	7 8 9 10	128.539838 159.5054041 76.73592927 116.6149982	Skewness Range Minimum Maximum Sum Count	.101693197 24.8454282 4.65997588 59.5054041 1002.35027
			Confidence Level(95.0%)	7.85576579

◆ 95% confidence level identifies the "95% confidence interval" for the expected value of the simulated random variable: based on the results of this simulation, we are 95% confident that the true expected value is in the interval = sample mean +/- 95% confidence level ≈ 100.24 +/- 27.86 = [72.38, 128.10]

 With a simulation that samples the random input variables only 10 times, the reliability of the estimates for the mean and the standard deviation for any random quantity involved may be limited

Total	
Profit	
\$ 29,500,000.00	
\$ 50,900,000.00	
\$ 56,550,000.00	
\$ 50,600,000.00	
\$ 58,050,000.00	
\$ 39,450,000.00	
\$ 56,550,000.00	
\$ 58,800,000.00	
\$ 46,300,000.00	
\$ 56,550,000.00	

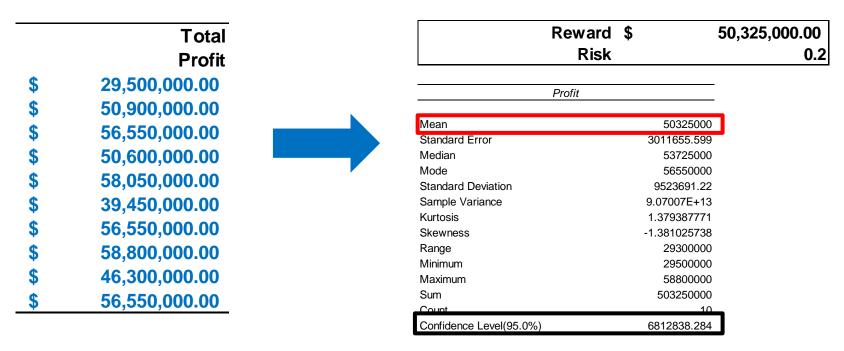
Reward	\$ 50,325,000.00
Risk	0.2

 With a simulation that samples the random input variables only 10 times, the reliability of the estimates for the mean and the standard deviation for any random quantity involved may be limited

Total	
Profit	
\$ 29,500,000.00	
\$ 50,900,000.00	
\$ 56,550,000.00	
\$ 50,600,000.00	
\$ 58,050,000.00	
\$ 39,450,000.00	
\$ 56,550,000.00	
\$ 58,800,000.00	
\$ 46,300,000.00	
\$ 56,550,000.00	

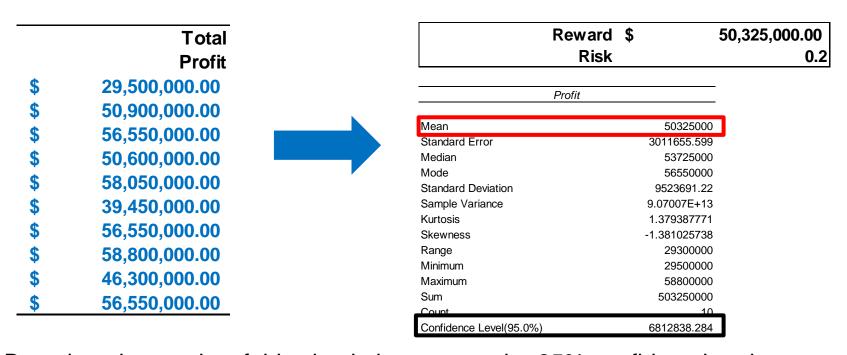
	Reward	\$	50,325,000.00
	Risk		0.2
	Profit		
Mean		50325000	
Standard Error		3011655.599	
Median		53725000	
Mode		56550000	
Standard Deviation		9523691.22	
Sample Variance		9.07007E+13	
Kurtosis		1.379387771	
Skewness		-1.381025738	
Range		29300000	
Minimum		29500000	
Maximum		58800000	
Sum		503250000	
Count		10	
Confidence Level(95.0%)		6812838.284	

 With a simulation that samples the random input variables only 10 times, the reliability of the estimates for the mean and the standard deviation for any random quantity involved may be limited



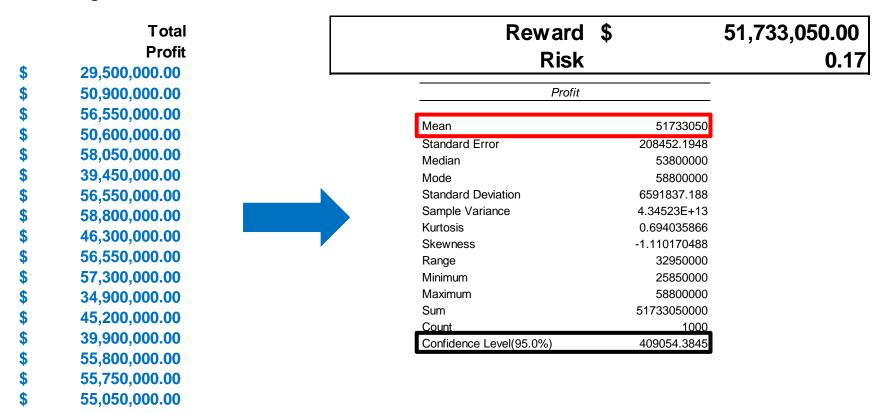
◆ Our estimate for the reward measure, ≈ \$50,325,000 may also be quite removed from the true expected profit value associated with the decision we consider

 With a simulation that samples the random input variables only 10 times, the reliability of the estimates for the mean and the standard deviation for any random quantity involved may be limited



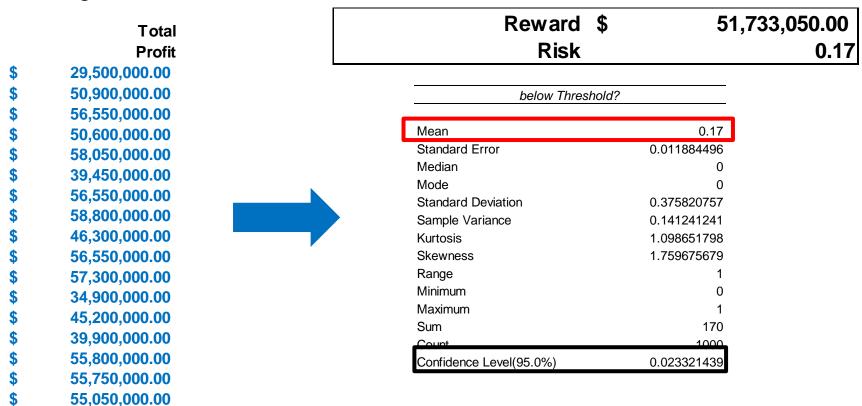
◆ Based on the results of this simulation, we can be 95% confident that the true expected profit under the decision we consider lies in the interval ≈ \$50,325,000 +/- \$6,812,838 = [\$43,512,162, \$57,137,838]

◆ Stargrove_1000.xlsx, seed 123 for the B column and seed 1234 for the C column



◆ Based on the results of this longer simulation, we can now be 95% confident that the true expected profit under the decision we consider lies in the interval ≈ \$51,733,050 +/- \$409,054 = [\$51,323,996, \$52,142,104]

◆ Stargrove_1000.xlsx



◆ Based on the results of this longer simulation, we can be 95% confident that the true value of the risk measure under the decision we consider lies in the interval ≈ 0.17+/- 0.023 = [0.147, 0.193]

- ◆ Suppose that Stargrove would like to compare the decision of building 12 regular floors and 3 luxury floors (R=96 and L=12) with the decision of building 11 regular floors and 4 luxury floors (R=88 and L=16)
- ♦ We can use 1000 random values we have already generated for the demand for regular apartments and 1000 random values we have already generated for the demand for luxury apartments to estimate the reward and the risk associated with the decision of R=88 and L=16
- ◆ We can then compare reward and risk estimates for the two decisions

◆ Stargrove_1000_TwoDecisions.xlsx

Profit for R=96, L=12		Profit for R=96, L=12 below Th	reshold?
Mean	51733050	Mean	0.17
Standard Error	208452.1948	Standard Error	0.011884496
Median	53800000	Median	0
Mode	58800000	Mode	0
Standard Deviation	6591837.188	Standard Deviation	0.375820757
Sample Variance	4.34523E+13	Sample Variance	0.141241241
Kurtosis	0.694035866	Kurtosis	1.098651798
Skewness	-1.110170488	Skewness	1.759675679
Range	32950000	Range	1
Minimum	25850000	Minimum	0
Maximum	58800000	Maximum	1
Sum	51733050000	Sum	170
Count	1000	Count	1000
Confidence Level(95.0%)	409054.3845	Confidence Level(95.0%)	0.023321439

Profit for R=88, L=16	Profit for R=88, L=16 below Threshold?			
Mean	50203250 Mean	0.168		
Standard Error	178926.0363 Standard Error	0.011829		
Median	51650000 Median	0		
Mode	53900000 Mode	0		
Standard Deviation	5658138.074 Standard Deviation	0.374053		
Sample Variance	3.20145E+13 Sample Variance	0.139916		
Kurtosis	1.657913101 Kurtosis	1.16612		
Skewness	-1.322835317 Skewness	1.778705		
Range	32750000 Range	1		
Minimum	25650000 Minimum	0		
Maximum	58400000 Maximum	1		
Sum	50203250000 Sum	168		
Count	1000 Count	1000		
Confidence Level(95.0%)	351113.9795 Confidence Level(95.0%)	0.023212		

Stargrove_1000_TwoDecisions.xlsx

Profit for R=96, L=12		Profit for R=96, L=12 below Three	eshold?
Mean	51733050	Mean	0.17
Standard Error		Standard Error	0.011884496
Median	53800000	Median	0
Mode	58800000	Mode	0
Standard Deviation	6591837.188	Standard Deviation	0.375820757
Sample Variance	4.34523E+13	Sample Variance	0.141241241
Kurtosis	0.694035866	Kurtosis	1.098651798
Skewness	-1.110170488	Skewness	1.759675679
Range	32950000	Range	1
Minimum	25850000	Minimum	0
Maximum	58800000	Maximum	1
Sum	51733050000	Sum	170
Count	1000	Count	1000
Confidence Level(95.0%)	409054.3845	Confidence Level(95.0%)	0.023321439

Reward and risk measures for two policies

Profit for R=88, L=16	Profit for R=	88, L=16 below Threshold?
Mean	50203250 Mean	0.168
Standard Error	178926.0363 Standard Erro	*****
Median	51650000 Median	0.011020
Mode	53900000 Mode	0
Standard Deviation	5658138.074 Standard Devi	ation 0.374053
Sample Variance	3.20145E+13 Sample Varian	ice 0.139916
Kurtosis	1.657913101 Kurtosis	1.16612
Skewness	-1.322835317 Skewness	1.778705
Range	32750000 Range	1
Minimum	25650000 Minimum	0
Maximum	58400000 Maximum	1
Sum	50203250000 Sum	168
Count	1000 Count	1000
Confidence Level(95.0%)	351113.9795 Confidence Le	vel(95.0%) 0.023212

Stargrove_1000_TwoDecisions.xlsx

Decision	R=96, L=12	R=88, L=16
95% Confidence Interval for Reward, in \$ millions	[51.3, 52.1]	[49.9, 50.6]
95% Confidence Interval for Risk	[0.147, 0.193]	[0.145, 0.191]

- ◆ Based on the results of the simulation with n=1000 runs, we are 95% confident that the expected profit under the decision R=96, L=12 is higher than the expected profit under the decision R=88, L=16
- ◆ The results of this simulation do not allow us to distinguish between the levels of risk associated with those two decisions at the same level of confidence

- ♦ We can add other reasonable decisions to our comparison set
- If two decisions cannot be distinguished on the basis of the results of a particular simulation, we can also run longer simulations to obtain more narrow confidence intervals for reward and risk measures

- ♦ We can add other reasonable decisions to our comparison set
- ◆ If two decisions cannot be distinguished on the basis of the results of a particular simulation, we can also run longer simulations to obtain more narrow confidence intervals for reward and risk measures
- Ultimately, the goals are to 1) limit the consideration set to decisions that result in risk measures limited by the tolerance level of a decision maker, and 2) among the decisions that satisfy constraint(s) on acceptable risk level(s), choose one that generates highest reward, at the selected confidence level
- Simulation provides "imperfect" estimates of reward and risk, but the notion of confidence intervals enables a decision maker to compare alternatives even using those imperfect estimates