Week 3: Risk and Evaluation of Alternatives

- Making Decisions in Low-Uncertainty vs. High-Uncertainty Settings
- Example: Evaluating a Wireless Data Plan
- Reward and Risk
- Connecting Random Inputs and Random Outputs
- Simulating Uncertain Outcomes in Excel
- Interpreting Simulation Results: “Short” vs. “Long” Simulations
- Using Histograms to Visualize Simulation Results

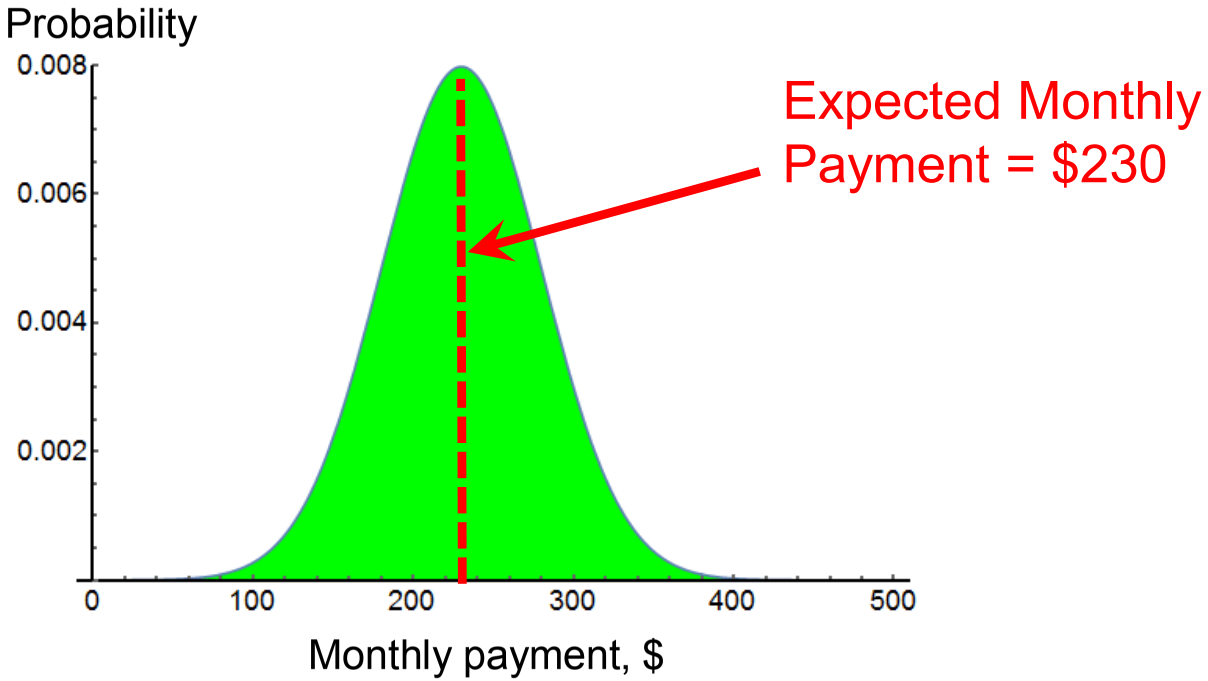
Example: Evaluating a Wireless Data Plan

- A business analytics consultant based in Philadelphia is considering changing her wireless data plan to accommodate her family's growing use of video streaming services
- Under her current data plan called "Family Share" she pays $10 for each GB of data her family uses
- After doing research on data plans offered by her wireless carrier, the consultant has decided to select the plan her carrier calls "Superior Share"
- Under the Superior Share plan, the consultant will pay a flat fee of $160 for up to 20GB of data per month. This data allowance may be shared among the members of her family

Example: Evaluating a Wireless Data Plan

- If her family's actual monthly data usage exceeds 20GB, she will then have to pay for any data usage above this threshold at the rate of $15 per GB
  - For example, if her family's monthly data usage is 22GB, her monthly payment will be $160+(22-20)*$15 = $190
- If her family's actual monthly data usage does not exceed 20GB, she will still have to pay the full $160 amount, and the amount of unused data under 20GB will not "roll over" to the next month
  - For example, if her family's monthly data usage is 17GB, her monthly payment will be $160

We Have a Complete Description of the Random Future Monthly Payments Under the Old Plan



- Consultant estimates that her monthly data usage is distributed as a normal random variable with the mean 23 GB and the standard deviation 5 GB
- So, the expected value of monthly payments under the old plan is **$230**
- The standard deviation of monthly payments under the old plan is **$50**

What About the Distribution of Monthly Payments Under the New Data Plan?

- What is the expected monthly payment under the new data plan?
- What is the standard deviation of the monthly payments under the new data plan?

An Algebraic Formula: Monthly Payment for Any Value of Data Usage

- We can calculate the monthly payment value *P* (in $) for any value of data usage *U* (in GB)
- If *U* is below or at 20, then the monthly payment *P* is 160
- If *U* is above 20, then the monthly payment is 160 + 15*(*U*-20)
- We can combine these two cases into a single EXCEL formula:

=IF(Condition, Choice1, Choice2)

$P = 160 + IF(U>20,15*(U-20),0)$

- The IF function looks at the **Condition:** if the **Condition** is true, then the value of IF is equal to **Choice1**; if the **Condition** is false, then the value of IF is equal to **Choice2**

An Algebraic Formula: Monthly Payment for Any Value of Data Usage

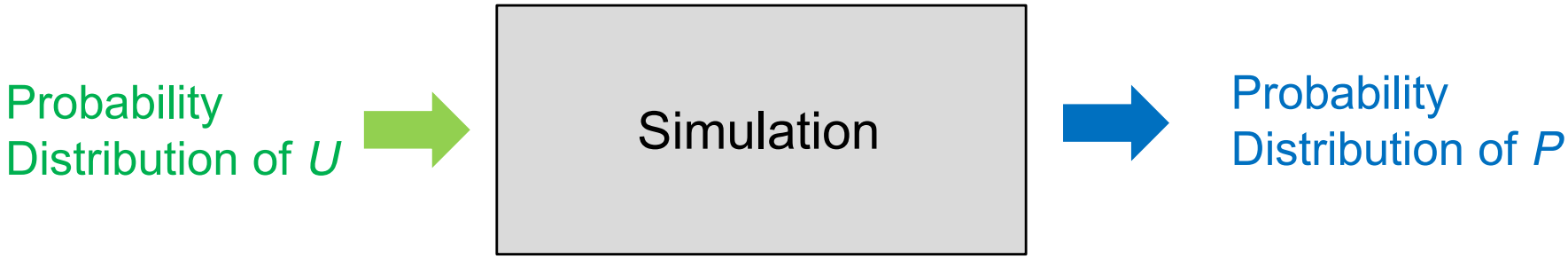
- $P = 160 + \text{IF}(U>20, 15*(U-20), 0)$
- U is distributed as a normal random variable with a mean of 23, and a standard deviation of 5
- What is the distribution of P?
- What is the expected value of P?
- What is the standard deviation of P?

Expected Value of Monthly Payment Under the New Plan?

- $P = 160 + \text{IF}(U>20, 15*(U-20), 0)$
- Expected value of U is 23
- So, shouldn't the expected value of P be $160 + 15*(23-20) =$ **205**?
- In general, we do not get the correct value for the expected monthly payment that way
- Example: suppose that U takes only 2 values, 18 with probability 50% and 28 with probability 50% (so that the expected data usage value of U is still 23)
  - If U=18, then P=160
  - If U=28, then P=160+15*(28-20) = 280
  - The expected value of P is 0.5*160+0.5*280 = **220**
  - This value is very different from 205, the value one gets after plugging in the expected data usage value into the monthly payment formula

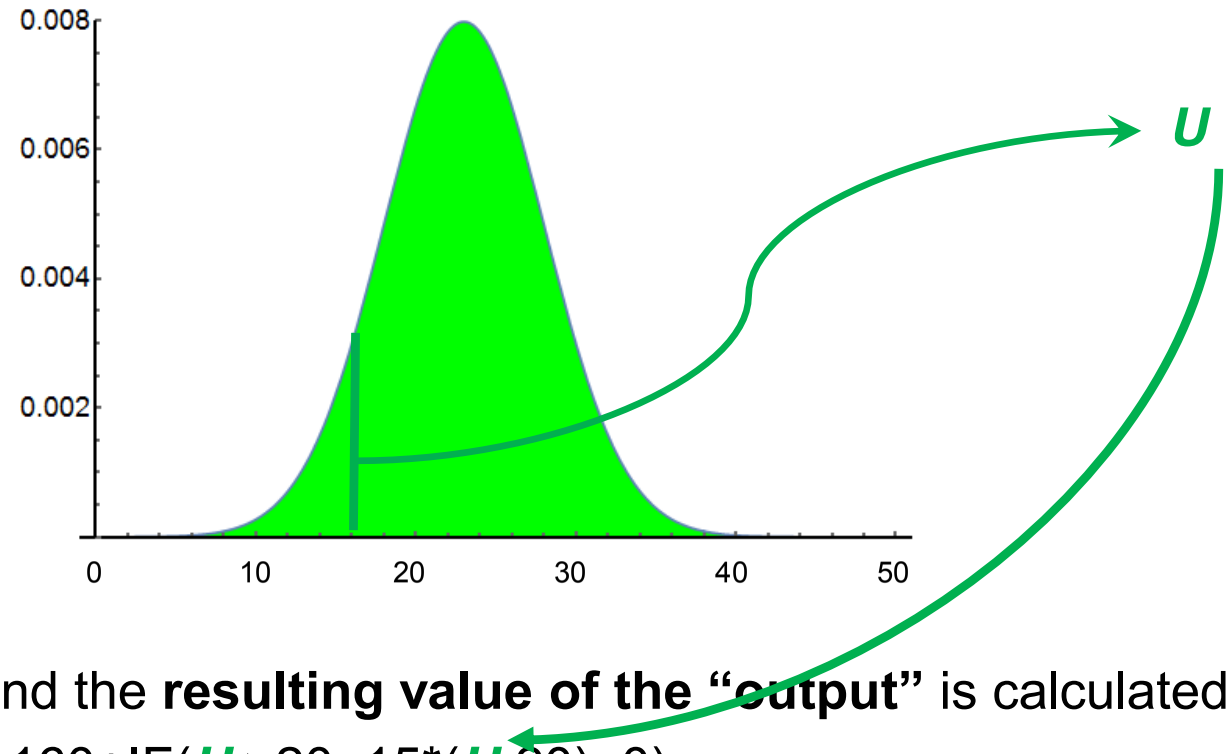
Simulation as an Analytics Tool

- Simulation is a tool that uses a probability distribution of the “input” random variable (such as data usage *U*) to create a distribution of the “output” random variable (such as monthly payment *P*)



Simulation as an Analytics Tool

- In each step of a simulation, a **random instance of the "input" variable is generated…**



- … and the **resulting value of the "output"** is calculated:

  P = 160+IF(***U*** >20, 15*(***U***-20), 0)

Simulation as an Analytics Tool

- These simulation steps (called "**simulation runs**") can be repeated as many times as necessary to generate the "**sample distribution**" of "output" values
- Once this "sample distribution" of output is generated, it can be analyzed to determine estimates for the expected value, standard deviation, etc. – and any other reward and risk measures we choose
- Excel can be used for both running the simulation and for the follow-up analysis

Running Simulation in Excel: Analysis ToolPak

- Likely to be a part of standard Excel installation on Windows

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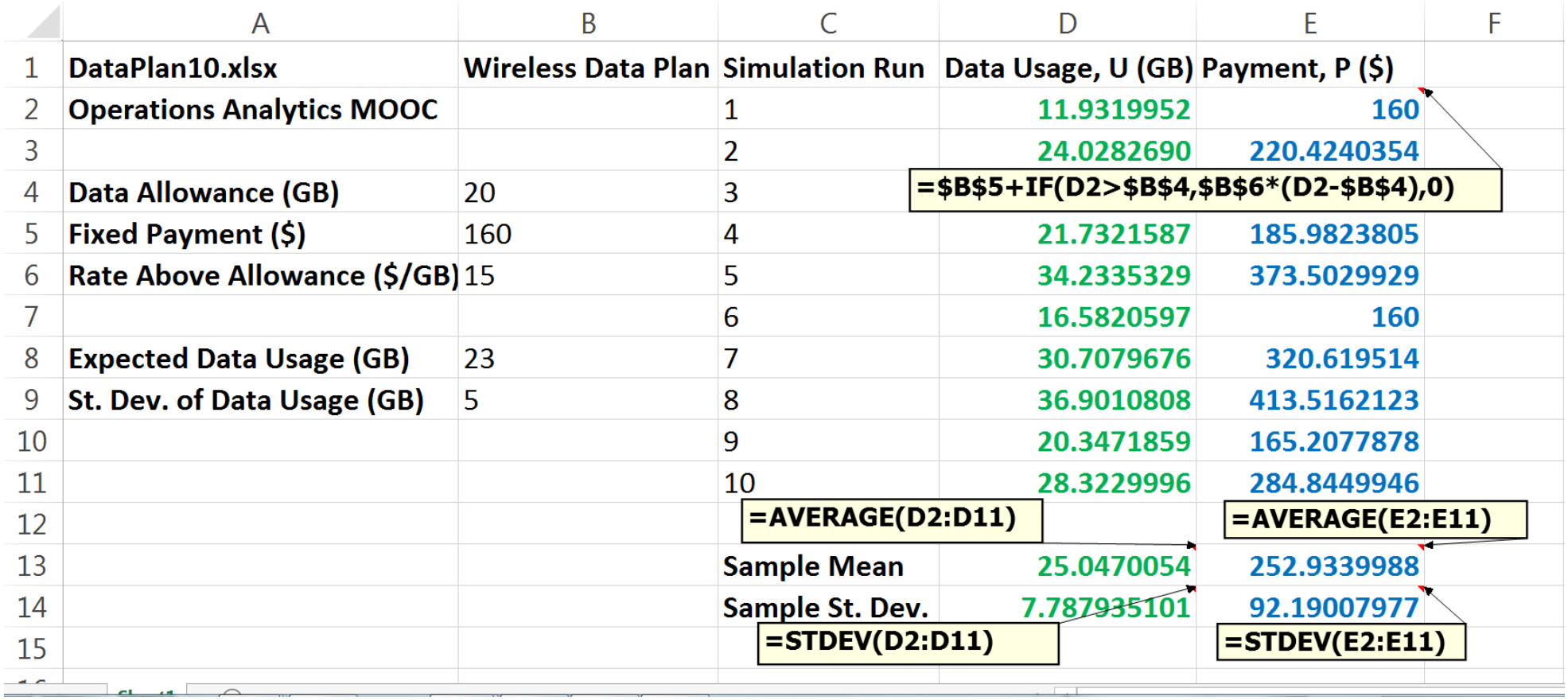
- Likely to be a part of standard Excel installation on Windows
- On Mac (see https://support.microsoft.com/en-us/kb/2431349)
  - Included on Excel 2016 for Mac
  - Not included on earlier versions of Excel, but you can use a similar free software called StatPlus:mac LE, available here: http://www.analystsoft.com/en/products/statplusmacle/
- On Google Sheets: an equivalent add-on called XLMiner Analysis ToolPak is available

Simulated Data Usage Values and Corresponding Monthly Payment Values: Excel Implementation



	A	B	C	D	E	F
1	DataPlan10.xlsx	Wireless Data Plan	Simulation Run	Data Usage, U (GB)	Payment, P ($)	
2	Operations Analytics MOOC		1	11.9319952	160	
3			2	24.0282690	220.4240354	
4	Data Allowance (GB)	20	3	=B5+IF(D2>B4,B6*(D2-B4),0)		
5	Fixed Payment ($)	160	4	21.7321587	185.9823805	
6	Rate Above Allowance ($/GB)	15	5	34.2335329	373.5029929	
7			6	16.5820597	160	
8	Expected Data Usage (GB)	23	7	30.7079676	320.619514	
9	St. Dev. of Data Usage (GB)	5	8	36.9010808	413.5162123	
10			9	20.3471859	165.2077878	
11			10	28.3229996	284.8449946	
12			=AVERAGE(D2:D11)		=AVERAGE(E2:E11)	
13			Sample Mean	25.0470054	252.9339988	
14			Sample St. Dev.	7.787935101	92.19007977	
15			=STDEV(D2:D11)		=STDEV(E2:E11)	

- See DataPlan10.xlsx