

## Lesson 5. Replications in Excel

### 1 Overview

- Last time: the experiment
  - Run the simulation  $n$  times
  - Compute performance measure (e.g. average bank time) for each simulation run (obtaining  $n$  observations of the performance measure)
  - Use the  $n$  observations to estimate the mean of the performance measure
- How do we do this (easily) in Excel?

### 2 The IF function

- In the Excel workbook for today's lesson, we have a spreadsheet containing the simulation of the first 3 customers at the bank drive-in window, along with a few additions:
  - A space to record some performance measures
  - A parameter: the bank's closing time, named `endtime`
- Let's modify the spreadsheet so that we simulate one day's operation (8 hours = 480 minutes) of the bank drive-in window
  - Assume that the drive-in window serves any customer that arrives before 480 minutes elapses
- Note: minimum interarrival time is 1 minute
  - ⇒ Maximum possible number of customers in one day =
- Idea:
  - Generate interarrival times and service times for maximum possible number of customers
  - Use the IF function to have the spreadsheet calculate begin service time, departure time, total time at bank, and contribution to  $N(t)$  only for all customers that arrive before 480 minutes, and return "na" otherwise
  - The IF function: `IF(logical_test, value_if_true, value_if_false)`
- For this one-day simulation, let's compute:
  - Average waiting time  $W$
  - Time average number of customers  $L$  in time interval  $[0, 480]$
  - Note that the AVERAGE and SUM functions ignore non-numbers, such as "na"

### 3 Replications using What-If Analysis

- There is another spreadsheet (tab) in the today's workbook called experiment
- This spreadsheet contains a table to record  $W$  and  $L$  for  $n = 30$  simulation runs
- In the first row of this table, let's reference the cells containing  $W$  and  $L$  in the other sheet (bank)
- Highlight the entire table (30 rows and 3 columns) and click Data → What-If Analysis → Data Table
- Leave Row input cell blank, enter A3 (the first row/column of the table) for Column input cell, and press OK
- Voila! 30 simulation runs

### 4 Estimating the mean of the performance measures

- Compute the following for the  $n = 30$  simulation runs for  $W$  and  $L$ :
  - Observed sample mean  $\bar{x}$ : AVERAGE(range)
  - Observed sample standard deviation  $s$ : STDEV(range)
  - $t_{\alpha/2, n-1}$  with  $\alpha = 0.05$ : TINV(alpha, n-1)
  - Standard error  $se(\bar{x})$

$$se(\bar{x}) = \frac{s}{\sqrt{n}}$$

- $100(1 - \alpha)\%$  confidence interval

$$[\bar{x} - t_{\alpha/2, n-1} \cdot se(\bar{x}), \bar{x} + t_{\alpha/2, n-1} \cdot se(\bar{x})]$$