

# Class 18: Design of Experiments / Multivariate Testing

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MKTG 482: Customer Analytics  
Kellogg School of Management

## Customer Analytics Course Structure

### Customer Centric Marketing

- Customer Analytics and AI Overview (Class 1)  
AI and Analytics,  
Why Customer Analytics and AI Needs Customer Centricity

### Getting Ready for Analytics

- Using R for Customer Analytics and AI (Class 2)
- Statistics Review (Class 3)

### Targeting Customers for Acquisition and Development

- Predicting Response with RFM analysis (Class 4)
- Case Analysis: "Tuango: RFM Analysis for Mobile App Push Messaging" (Class 5)  
Lift and Gains
- Predicting Response with Logistic Regression (Class 6)
- Predicting Response with Neural Networks (Class 7)
- Using Neural Networks for Customer Analytics and AI (Class 8)  
Training Machine Learning Models
- Case Analysis: Intuit QuickBooks Upgrade: Moving to the Cloud (Class 9)
- Predicting Response with Tree Methods (Class 10)

### Targeting based on Incrementality

- From Propensity to Uplift (Class 11)
- The Causality Checklist (Class 12)
- Case Analysis: Creative Gaming Uplift Modeling (Class 13)
- Hyper-Personalization: Next-Product-to-Buy Models (Class 14)

### Retaining Customers

- Predicting Attrition (Class 15)
- Linking Analytics with a Business Outcomes Model (Class 16)
- Case Analysis: "S-Mobile: Churn Management" (Class 17)  
From Prediction to Action

### Selecting the Right Offers

- Design of Experiments / Multivariate Testing (Class 18)
- Case Analysis: "Capital One: Information-Based Credit Card Design" (Class 19)

### Scaling Analytics

- Scaling Analytics in Practice (Class 20)  
Course Wrap-up

# The simplest experimental design is a two group random assignment

## TWO GROUP RANDOM ASSIGNMENT

- Assign units (e.g. customers) randomly to receive or not receive treatment
- Treatment and control groups are not identical, because they consist of different individuals, but they are “probabilistically equivalent” meaning that there are no systematic differences between the groups in their characteristics or how they would respond to the program

R      O1  
R   X   O2

- The difference in outcomes between treatment and control is the estimated effect of the program, O2-O1

## Consider testing a change in the free shipping threshold for a website

### EXAMPLE: FREE SHIPPING THRESHOLD

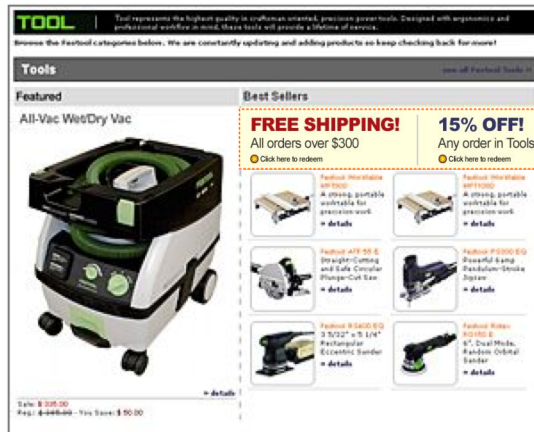
- Tools website, so far \$300 threshold for free shipping

The screenshot shows the TOOLS website interface. At the top, a banner reads: "Tool represents the highest quality in craftsman oriented, precision power tools. Designed with ergonomics and professional standards in mind, these tools will provide a lifetime of service." Below this, the "Tools" category is highlighted. The main content area is divided into "Featured" and "Best Sellers" sections. The "Featured" section displays a large image of an "All-Vac Wet/Dry Vac" with a price tag of \$399.00. The "Best Sellers" section features a grid of smaller product images, including various power tools like drills, saws, and sanders. Overlaid on the right side of the website are two promotional banners. The first banner, titled "FREE SHIPPING!", states "All orders over \$300" and includes a "Click here to redeem" link. The second banner, titled "15% OFF!", states "Any order in Tools" and also includes a "Click here to redeem" link. Arrows point from these banners to the "Best Sellers" section, indicating the application of the offers.

# Consider testing a change in the free shipping threshold for a website

## EXAMPLE: FREE SHIPPING THRESHOLD

- Tools website, so far \$300 threshold for free shipping



**FREE SHIPPING!**  
All orders over \$300  
[Click here to redeem](#)

**15% OFF!**  
Any order in Tools  
[Click here to redeem](#)

**FREE SHIPPING!**  
All orders over \$200  
[Click here to redeem](#)

**15% OFF!**  
Any order in Tools  
[Click here to redeem](#)

## We can now measure the effect of a lower shipping threshold

### TWO GROUP RANDOM ASSIGNMENT

- Assign customers randomly to be exposed to
  - \$300 (no treatment -- regular)
  - \$200 (treatment)

**R      O1** --> \$300 condition

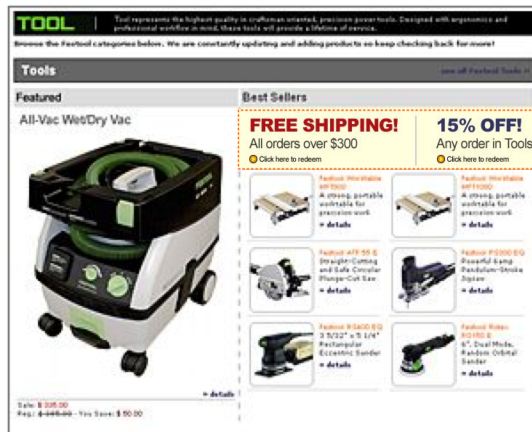
**R   X   O2** --> \$200 condition

- The difference in outcomes between treatment and control is the estimated effect of the program, **O2-O1**
- Assume:
  - O1 is 500 sales for 10,000 exposures
  - O2 is 580 sales for 10,000 exposures--> Effect of a lower free shipping threshold is 80 sales

## Often, we want to test more than one marketing idea

### EXAMPLE: FREE SHIPPING THRESHOLD

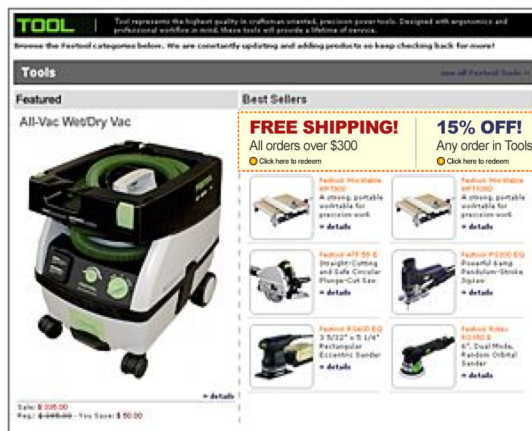
- Tools website, so far \$300 threshold for free shipping



## Often, we want to test more than one marketing idea

### EXAMPLE: FREE SHIPPING THRESHOLD

- Tools website, so far \$300 threshold for free shipping



## We can run two separate experiments with a common control group

### THREE GROUP RANDOM ASSIGNMENT

- Assign customers randomly to be exposed to
  - \$300, 15% (no treatment -- regular)
  - \$200, 15% (treatment 1)
  - \$300, 20% (treatment 2)

R      O1      --> \$300, 15% condition  
R   X1 O2      --> \$200, 15% condition  
R   X2 O3      --> \$300, 20% condition

- The difference in outcomes between treatments and control is the estimated effect of the program, O2-O1 for treatment 1 and O3-O1 for treatment 2
- Assume:
  - O1 is 500 sales for 10,000 exposures
  - O2 is 580 sales for 10,000 exposures
  - O3 is 560 sales for 10,000 exposures



Effect of a lower free shipping threshold is **80 more sales**  
Effect of a higher discount is **60 more sales**

## A factorial design is a randomized experiment on multiple program features

### FULL FACTORIAL DESIGN

- Frequently you want to know not only
  - **whether** a program has an effect or not or **how big** the effect is,
  - but what **combination of features** will make the program most effective

#### Experimental design:

- Factor 1: Free shipping threshold, (Xi)
- Factor 2: Tools discount (Xj)  
=> "2x2 factorial design"
- Send one offer for each combination of factors to a sample of potential new customers
- Measure sales from first 10,000 exposures

R   X11   O11  
R   X12   O12  
R   X21   O21  
R   X22   O22

<b>FREE SHIPPING!</b> All orders over \$300 <a href="#">Click here to redeem</a>	<b>15% OFF!</b> Any order in Tools <a href="#">Click here to redeem</a>
<b>FREE SHIPPING!</b> All orders over \$200 <a href="#">Click here to redeem</a>	<b>15% OFF!</b> Any order in Tools <a href="#">Click here to redeem</a>
<b>FREE SHIPPING!</b> All orders over \$300 <a href="#">Click here to redeem</a>	<b>20% OFF!</b> Any order in Tools <a href="#">Click here to redeem</a>
<b>FREE SHIPPING!</b> All orders over \$200 <a href="#">Click here to redeem</a>	<b>20% OFF!</b> Any order in Tools <a href="#">Click here to redeem</a>

## The factorial design first simply replicates the two independent experiments

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SALES (FOR 10,000 EXPOSURES) BY EXPERIMENTAL CONDITION

		Discount	
		15%	20%
Shipping threshold	\$300	500	560
	\$200	580	



- Decrease the **shipping threshold** increase sales by **80**
- Increasing the **tools discount** increases sales **60**

## The factorial design adds to simple experiments by also estimating whether there is an interaction effect

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SALES (FOR 10,000 EXPOSURES) BY EXPERIMENTAL CONDITION

		Discount	
		15%	20%
Shipping threshold	\$300	500	560
	\$200	580	680

## The factorial design adds to simple experiments by also estimating whether there is an interaction effect

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SALES (FOR 10,000 EXPOSURES) BY EXPERIMENTAL CONDITION

		Discount	
		15%	20%
Shipping threshold	\$300	500	560
	\$200	580	680



- Decrease the **shipping threshold** increase sales by **80**
- Increasing the **tools discount** increases sales **60**
- Decreasing the **shipping threshold AND** increasing the **tools discount** increases sales by an additional **40** units

## Full factorial designs can lead to too many “experimental conditions”

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### EXAMPLE OF MORE COMPLEX FACTORIAL DESIGN

Test an offer to attract Harrah's customer to the Las Vegas Property

#### Variations in the offer

- Factor 1: Number of free nights (1,2, or 3)
- Factor 2: Free chips (0, \$50, \$100)
- Factor 3: Free show (no, yes)
- Factor 4: Expiration date (3 months, 6 months, 12 months)
- Factor 5: Follow-up phone call (no, yes)
- Factor 6: Follow-up e-mail (no, yes)

#### Objectives

- Maximize customer profitability over next year

3x3x2x3x2x2 full factorial design => 216 different offers

## Consider the following example to illustrate how to deal with too many experimental conditions

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### EXAMPLE: TOOLS WEBSITE CONTINUED

- Factor 1: Free shipping threshold (\$200, \$300)
- Factor 2: Discount (15%, 20%)
- Factor 3: Coupon code  
(Manual, automatic)



## What is the sales effect of a lower shipping threshold?

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### FULL FACTORIAL DESIGN

Free Shipping	Discount	Coupon Entry	Sales
\$ 300.00	15%	Manual	500
\$ 300.00	15%	Automatic	520
\$ 300.00	20%	Manual	560
\$ 300.00	20%	Automatic	580
\$ 200.00	15%	Manual	580
\$ 200.00	15%	Automatic	600
\$ 200.00	20%	Manual	640
\$ 200.00	20%	Automatic	660



## What is the sales effect of a lower shipping threshold?

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### FULL FACTORIAL DESIGN

Free Shipping	Discount	Coupon Entry	Sales
\$ 300.00	15%	Manual	500
\$ 300.00	15%	Automatic	520
\$ 300.00	20%	Manual	560
\$ 300.00	20%	Automatic	580
\$ 200.00	15%	Manual	580
\$ 200.00	15%	Automatic	600
\$ 200.00	20%	Manual	640
\$ 200.00	20%	Automatic	660

Sales effect of free shipping threshold

- With \$300, sales are

$$(500+520+560+580)/4 = 540$$

- With \$200, sales are

$$(580+600+640+660)/4 = 620$$

=>  $620-540 = 80$  incremental sales

## What is the sales effect of a higher discount?

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### FULL FACTORIAL DESIGN

Free Shipping	Discount	Coupon Entry	Sales
\$ 300.00	15%	Manual	500
\$ 300.00	15%	Automatic	520
\$ 300.00	20%	Manual	560
\$ 300.00	20%	Automatic	580
\$ 200.00	15%	Manual	580
\$ 200.00	15%	Automatic	600
\$ 200.00	20%	Manual	640
\$ 200.00	20%	Automatic	660

Sales effect of an increased discount

- With 15%, sales are

$$(500+520+580+600)/4 = 550$$

- With 20%, sales are

$$(560+580+640+660)/4 = 610$$

=>  $610-550 = 60$  incremental sales

## What is the sales effect of automated coupon entry?

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### FULL FACTORIAL DESIGN

Free Shipping	Discount	Coupon Entry	Sales
\$ 300.00	15%	Manual	500
\$ 300.00	15%	Automatic	520
\$ 300.00	20%	Manual	560
\$ 300.00	20%	Automatic	580
\$ 200.00	15%	Manual	580
\$ 200.00	15%	Automatic	600
\$ 200.00	20%	Manual	640
\$ 200.00	20%	Automatic	660

Sales effect of automated coupon entry

- With manual entry, sales are

$$(500+560+580+640)/4 = 570$$

- With automated entry, sales are

$$(520+580+600+660)/4 = 590$$

=>  $590-570 = 20$  incremental sales

## A partial factorial design uses fewer cells to calculate averages

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### FULL FACTORIAL DESIGN

Free Shipping	Discount	Coupon Entry	Sales
\$ 300.00	15%	Manual	500
\$ 300.00	15%	Automatic	520
\$ 300.00	20%	Manual	560
\$ 300.00	20%	Automatic	580
\$ 200.00	15%	Manual	580
\$ 200.00	15%	Automatic	600
\$ 200.00	20%	Manual	640
\$ 200.00	20%	Automatic	660

### PARTIAL FACTORIAL DESIGN

Free Shipping	Discount	Coupon Entry	Sales
\$ 300.00	15%	Manual	500
\$ 300.00	20%	Automatic	580
\$ 200.00	15%	Automatic	600
\$ 200.00	20%	Manual	640

Idea:

- Cuts down the the number of offers and groups of customers that must be compared to estimate main effects.

## We can still calculate the effect of a lower free shipping threshold

### FULL FACTORIAL DESIGN

Free Shipping	Discount	Coupon Entry	Sales
\$ 300.00	15%	Manual	500
\$ 300.00	15%	Automatic	520
\$ 300.00	20%	Manual	560
\$ 300.00	20%	Automatic	580
\$ 200.00	15%	Manual	580
\$ 200.00	15%	Automatic	600
\$ 200.00	20%	Manual	640
\$ 200.00	20%	Automatic	660

Sales effect of free shipping threshold

- With \$300, sales are  
 $(500+520+560+580)/4 = 540$

- With \$200, sales are  
 $(580+600+640+660)/4 = 620$

=>  $620-540 = 80$  incremental sales

### PARTIAL FACTORIAL DESIGN

Free Shipping	Discount	Coupon Entry	Sales
\$ 300.00	15%	Manual	500
\$ 300.00	20%	Automatic	580
\$ 200.00	15%	Automatic	600
\$ 200.00	20%	Manual	640

Sales effect of free shipping threshold

- With \$300, sales are  
 $(500+580)/2 = 540$

- With \$200, sales are  
 $(600+640)/2 = 620$

=>  $620-540 = 80$  incremental sales

## The partial factorial approach generates the same result

### FULL FACTORIAL DESIGN

Free Shipping	Discount	Coupon Entry	Sales
\$ 300.00	15%	Manual	500
\$ 300.00	15%	Automatic	520
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\$ 200.00	15%	Manual	580
\$ 200.00	15%	Automatic	600
\$ 200.00	20%	Manual	640
\$ 200.00	20%	Automatic	660

Sales effect of an increased discount

- With 15%, sales are  
 $(500+520+580+600)/4 = 550$

- With 20%, sales are  
 $(560+580+640+660)/4 = 610$

=>  $610-550 = 60$  incremental sales

### PARTIAL FACTORIAL DESIGN

Free Shipping	Discount	Coupon Entry	Sales
\$ 300.00	15%	Manual	500
\$ 300.00	20%	Automatic	580
\$ 200.00	15%	Automatic	600
\$ 200.00	20%	Manual	640

Sales effect of an increased discount

- With 15%, sales are  
 $(500+600)/2 = 550$

- With 20%, sales are  
 $(580+640)/2 = 610$

=>  $610-550 = 60$  incremental sales

## The partial factorial approach generates the same result

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\$ 300.00	20%	Automatic	580
\$ 200.00	15%	Manual	580
\$ 200.00	15%	Automatic	600
\$ 200.00	20%	Manual	640
\$ 200.00	20%	Automatic	660

Sales effect of automated coupon entry

- With manual entry, sales are  
 $(500+560+580+640)/4 = 570$
  - With automated entry, sales are  
 $(520+580+600+660)/4 = 590$
- =>  $590-570 = 20$  incremental sales

### PARTIAL FACTORIAL DESIGN

Free Shipping	Discount	Coupon Entry	Sales
\$ 300.00	15%	Manual	500
\$ 300.00	20%	Automatic	580
\$ 200.00	15%	Automatic	600
\$ 200.00	20%	Manual	640

Sales effect of automated coupon entry

- With manual entry, sales are  
 $(500+640)/2 = 570$
  - With automated entry, sales are  
 $(580+600)/2 = 590$
- =>  $590-570 = 20$  incremental sales

## Consider the same effect but with slightly different sales results

### FULL FACTORIAL DESIGN

Free Shipping	Discount	Coupon Entry	Sales
\$ 300.00	15%	Manual	500
\$ 300.00	15%	Automatic	520
\$ 300.00	20%	Manual	560
\$ 300.00	20%	Automatic	620
\$ 200.00	15%	Manual	580
\$ 200.00	15%	Automatic	600
\$ 200.00	20%	Manual	640
\$ 200.00	20%	Automatic	700

Sales effect of free shipping threshold

- With \$300, sales are  
 $(500+520+560+620)/4 = 550$
  - With \$200, sales are  
 $(580+600+640+700)/4 = 630$
- =>  $630-550 = 80$  incremental sales

### PARTIAL FACTORIAL DESIGN

Free Shipping	Discount	Coupon Entry	Sales
\$ 300.00	15%	Manual	500
\$ 300.00	20%	Automatic	620
\$ 200.00	15%	Automatic	600
\$ 200.00	20%	Manual	640

## Consider the same effect but with slightly different sales results

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\$ 300.00	20%	Manual	560
\$ 300.00	20%	Automatic	620
\$ 200.00	15%	Manual	580
\$ 200.00	15%	Automatic	600
\$ 200.00	20%	Manual	640
\$ 200.00	20%	Automatic	700

Sales effect of free shipping threshold

- With \$300, sales are  
 $(500+520+560+620)/4 = 550$
  - With \$200, sales are  
 $(580+600+640+700)/4 = 630$
- =>  $630-550 = 80$  incremental sales

### PARTIAL FACTORIAL DESIGN

Free Shipping	Discount	Coupon Entry	Sales
\$ 300.00	15%	Manual	500
\$ 300.00	20%	Automatic	620
\$ 200.00	15%	Automatic	600
\$ 200.00	20%	Manual	640

Sales effect of free shipping threshold

- With \$300, sales are  $(500+620)/2 = 560$
  - With \$200, sales are  $(600+640)/2 = 620$
- =>  $620-560 = 60$  incremental sales

## Consider the same effect but with slightly different sales results

### FULL FACTORIAL DESIGN

Free Shipping	Discount	Coupon Entry	Sales
\$ 300.00	15%	Manual	500
\$ 300.00	15%	Automatic	520
\$ 300.00	20%	Manual	560
\$ 300.00	20%	Automatic	620
\$ 200.00	15%	Manual	580
\$ 200.00	15%	Automatic	600
\$ 200.00	20%	Manual	640
\$ 200.00	20%	Automatic	700

Sales effect of free shipping threshold

- With \$300, sales are  
 $(500+520+560+620)/4 = 550$
  - With \$200, sales are  
 $(580+600+640+700)/4 = 630$
- =>  $630-550 = 80$  incremental sales

### PARTIAL FACTORIAL DESIGN

Free Shipping	Discount	Coupon Entry	Sales
\$ 300.00	15%	Automatic	520
\$ 300.00	20%	Manual	560
\$ 200.00	15%	Manual	580
\$ 200.00	20%	Automatic	700

Sales effect of free shipping threshold

- With \$300, sales are  $(500+620)/2 = 560$
  - With \$200, sales are  $(600+640)/2 = 620$
- =>  $620-560 = 60$  incremental sales
- Sales effect of free shipping threshold
- With \$300, sales are  $(520+560)/2 = 540$
  - With \$200, sales are  $(580+700)/2 = 640$
- =>  $640-540 = 100$  incremental sales

**Problem?**

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Free Shipping	Discount	Coupon Entry	Sales	Free Shipping	Discount	Coupon Entry	Sales
\$ 300.00	15%	Manual	<b>500</b>	\$ 300.00	15%	Manual	<b>500</b>
\$ 300.00	15%	Automatic	<b>520</b>	\$ 300.00	15%	Automatic	<b>520</b>
\$ 300.00	20%	Manual	<b>560</b>	\$ 300.00	20%	Manual	<b>560</b>
\$ 300.00	20%	Automatic	<b>580</b>	\$ 300.00	20%	Automatic	<b>620</b>
\$ 200.00	15%	Manual	<b>580</b>	\$ 200.00	15%	Manual	<b>580</b>
\$ 200.00	15%	Automatic	<b>600</b>	\$ 200.00	15%	Automatic	<b>600</b>
\$ 200.00	20%	Manual	<b>640</b>	\$ 200.00	20%	Manual	<b>640</b>
\$ 200.00	20%	Automatic	<b>660</b>	\$ 200.00	20%	Automatic	<b>700</b>

**We have been measuring the effect of the shipping cost threshold assuming that there are no interaction effects**

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#### INTERACTION EFFECT PROBLEM

##### Problem for partial factorial approach

- The selection of which cases to consider will result in different estimates for the effect of a factor, depending on the values of the other variables that matter for interactions
- We cannot recover the size of the interaction effect because we do not observe the necessary combination of variables

#### TOOLS EXAMPLE

- Free shipping threshold effect (\$200 vs. \$300): **80 sales**
- Discount effect (20% vs. 15%): **60 sales**
- Coupon effect (Automatic vs. manual): **20 sales**
- Coupon with discount interaction effect (20% and automatic): **40 sales**

# R Demo

## Customer Analytics Course Structure

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### Getting Ready for Analytics

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### Targeting Customers for Acquisition and Development

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From Prediction to Action

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### Selecting the Right Offers

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- Scaling Analytics in Practice (Class 20)  
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