Personalized substitution suggestions in online grocery retailing

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Ajanay Barnes and her roommate, craving ice cream on a recent night, used the grocery-shopping app Instacart to load up a basket at Walmart.

They asked for strawberry shortcake ice cream. They received sausage, egg and cheese breakfast rolls. After delivery, Instacart issued a refund.

Roses swapped for bell pepper. A thermometer switched for mac and cheese. A rapid Covid test traded for Halls lozenges.

[“Raspberries for Cauliflower? The Bizarre World of Online Grocery Store Substitutions,” WSJ, 2/3/22]
Ajanay Barnes and her roommate, craving ice cream on a recent night, used the grocery-shopping app Instacart to load up a basket at Walmart.

They asked for straw and cheese breakfast

Whole Foods Market shopper A

One of the items in your Whole Foods Market order is out of stock, please review substitution option(s).

OUT OF STOCK 365 by Whole Foods Market, Organic Cauliflower Florets, 10 Ounce $3.59

SUBST Berry R Red Co 8 Ounce

3.49 A

Decline

Raspberries for Cauliflower? The Bizarre World of Online Grocery Store Substitutions

The pandemic stoked an explosion in grocery delivery. Supply chain issues are causing some off-the-wall substitutions

Ajanay Barnes, 22, bought strawberry shortcake ice cream. She got sausage, egg and cheese breakfast rolls. AJANAY BARNES
Online grocery shopping is rapidly growing

286 billion USD, 2021

2.2 trillion USD, 2030

7-14 %

Market size of the global online grocery retail industry

(GrandViewResearch Inc., 2021)

Global average percentage of out-of-stock products per category

(Gruen & Corsten, 2022; Cavallo & Kryvstov, 2023)
Out-of-stocks (OOS) result in lost sales

- Stock outs result in lost sales or substitutions

- Decide what to buy
- Pick from the shelf
- Carry it home

Increasing on-shelf availability

Lost sales
Customer satisfaction

Traditional offline store purchase behavior

How retailers deal with the problem
Out-of-stocks (OOS) result in lost sales and reduced labor productivity

Lag between order & pick stages → OOS not known when ordering

Ordering stage
- Online

Picking stage
- Physical store

Substitution costs
- Labor productivity

Lost sales

Substitution costs
- Reimbursements

Customer satisfaction

Picker decides
- Picker calls the customer
- Retailer presents the picker with recommendations
- Picker picks the customer's pre-selected substitute

Focus of our research

How retailers deal with the problem

Temporarily removing an item of the assortment when it is OOS
- Providing customers with a low inventory hint

Increasing on-shelf availability
- Substituting the OOS item

Save downstream costs by asking customers to choose subs

Lost sales

Online grocery purchase behavior

Focus of our research

Online grocery purchase behavior
Which of these would be acceptable subs for the customer?

out-of-stock

Interpan The Wellness Breads Wholegrain Bread
(109)

Mulino Bianco Sandwich Loaf Hard Grain Ideal for Sandwiches
(99)

Mulino Bianco Pullman Loaf Ideal for Toast 16 Loaves
(100)

Interpan The Tradition Breads Terni Wholegrain Bread
(112)

Mulino Bianco Sandwich Loaf Wholegrain Ideal for Sandwiches
(161)

Mulino Bianco Large Sandwich Loaf Rustic Bread
(170)

Interpan The Tradition Breads Homemade Bread
(110)

Dailybread Rye Rustic Bread
(151)

Mulino Bianco Sandwich Loaf White Ideal for Sandwiches
(101)

Mulino Bianco Pullman Loaf Ideal for Toast 24 Loaves
(169)

plus 50 other alternatives!
Wholegrain?

Mulino Bianco Sandwich Loaf Wholegrain Ideal for Sandwiches (161)
Mulino Bianco Large Sandwich Loaf Rustic Bread (170)
Interpan The Tradition Breads Homemade Bread (110)
Dailybread Rye Rustic Bread (151)
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plus 50 other alternatives!
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Same brand?

Mulino Bianco Sandwich Loaf Hard Grain Ideal for Sandwiches (99)
Mulino Bianco Pullman Loaf Ideal for Toast 16 Loaves (100)
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out-of-stock
Interpan The Wellness Breads Wholegrain Bread (109)

Same # of slices?

Mulino Bianco Sandwich Loaf Hard Grain Ideal for Sandwiches (99)
Mulino Bianco Pullman Loaf Ideal for Toast 16 Loaves (100)
Interpan The Tradition Breads Terni Wholegrain Bread (112)

plus 50 other alternatives!
If sorted by frequency of selection as a substitute

Items previously chosen as subs by customers in the past

Mulino Bianco Sandwich Loaf Wholegrain Ideal for Sandwiches (161)
Mulino Bianco Large Sandwich Loaf Rustic Bread (170)
Interpan The Tradition Breads Homemade Bread (110)
Interpan The Tradition Breads Terni Wholegrain Bread (112)

Dailybread Rye Rustic Bread (151)

Sorting customized to individual customer preferences

High-powered ML algos

These suggestions miss the item the customer wants as a sub

This list is NOT PERSONALIZED!

1st

(1st 10th)

(1st 10th)

(1st 10th)

(1st 10th)
Previously chosen subs sorted by individual customer preferences

La Molisana Wholegrain Penne Rigate #20 (49)
Barilla Wholegrain Spaghetto #1 (77)
Rummo Bio Wholegrain Penne Rigate #66 (95)

56 products in the category “wellness pasta”

Top-3 products for customer in the category with NO filtering

La Molisana Wholegrain Farfalle Rigate #66 (89)

For large (& frequently changing) categories, previously chosen subs:
→ may not have good coverage, and
→ may be at the bottom of a customer’s pref list

PERSONALIZED LISTS WITH NO FILTERING MAY BE BETTER!

out-of-stock
De Cecco Wholegrain Large Fusilli #234 (64)
Top-3 products for customer in the category with NO filtering

- Actimel Citrus Fruits 6x100g (162)
- Actimel Strawberry 6x100g (301)
- Bontà Viva Bifidus Fiber 2 Cereal, 2 Oatmeal Nuts, 2 Kiwi Cereal, 2 Pear Cereal, 8x125g (339)

Previously chosen subs sorted by individual customer preferences

- Arborea Ayo Yogurt Rich in Protein Zero% Fat (107)
- Zymil High Digestibility Lactose-free Greek Yogurt Zero Fat White (140)
- Arborea Ayo Yogurt Rich in Protein (108)

Products within [50%, 150%] price range of focal product, sorted by cust. preferences

- Zymil High Digestibility Lactose-free Greek Yogurt 2% Fat Lactose-free (1)
- Meteora Greek Yogurt 2% Fat Lactose-free Honey and Vanilla (220)
- Consilia Low Fat Yogurt Lactose-free White 2x125g (37)

PRICE FILTER TO ELIMINATE PRODUCTS WITH OUTLIER PRICES

Popular value packs of yogurts, but probably not good subs for a single yogurt

114 products in the category “wellness yogurt”

out-of-stock

Arborea Ayo Yogurt Rich in Protein Lactose-free (114)
Our approach: Sort by preferences + filter by relevancy

**Personalization**
- Customer's personalized preferences rank
  - DAG-based choice models
  - w/ offline data (~10,000 hr compute)

**Intention**
- (First-choice/Focal Product)
  - Previously chosen subs filter
    - Past chosen substitutes for the focal product
  - Price range filter
    - 50% to 150% of the focal product’s price
  - Sub-category filter
    - Products in the same level-3 category of focal product

**Relevancy Filters**
- Availability filter
  - Products in the same level-3 category of focal product

**Operational Filters**
- Sorted previously chosen subs
- Sorted within price range products
- Sorted within sub-category products

**Diversified Recos**
- Relevant Recos
- Un-filtered Recos
We use DAG-based choice models to estimate customer preferences

Step 1: Customer’s past purchases:
  → first choice (initial selection)
  → second choice (sub selection, if any)
  → offered, but not selected

Control algorithm relies ONLY on this signal

Step 2: Fill in the missing preferences using purchases of “similar” customers
  Step 2a: Cluster customers with “similar” DAGs together
  Step 2b: Fit an MNL choice model separately for each cluster

Step 3: Use the cluster-level model + individual DAGs → individual-level pref weights
  Sort products in the decreasing order of the pref weights
We validated the DAG-based model by back-testing it against the standard LC-MNL model on predicting which sub will be picked

Hit rate metric

<table>
<thead>
<tr>
<th>Actual</th>
<th>Prediction</th>
<th>Hit</th>
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<tbody>
<tr>
<td>![Image]</td>
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<td>✗</td>
</tr>
<tr>
<td>![Image]</td>
<td>![Image]</td>
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</tr>
<tr>
<td>![Image]</td>
<td>![Image]</td>
<td>✓</td>
</tr>
<tr>
<td>![Image]</td>
<td>![Image]</td>
<td>✗</td>
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</tbody>
</table>

Hit rate = 60%

Hit rate improvement over the LC-MNL benchmark model (%)

<table>
<thead>
<tr>
<th>Category</th>
<th>Improvement</th>
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<tbody>
<tr>
<td>beer</td>
<td>13.4%</td>
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<tr>
<td>ice cream</td>
<td>7.9%</td>
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<tr>
<td>carb. beverages</td>
<td>6.6%</td>
</tr>
<tr>
<td>rice</td>
<td>2.5%</td>
</tr>
<tr>
<td>olive oil</td>
<td>-1.0%</td>
</tr>
<tr>
<td>coffee</td>
<td>-6.7%</td>
</tr>
<tr>
<td>overall</td>
<td>5.6%</td>
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</tbody>
</table>
We are currently running a *large-scale* field experiment in Italy to pit our proposed model against Everli’s current model.

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<td>50,500+</td>
<td>185</td>
<td>2</td>
</tr>
<tr>
<td>users</td>
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<td>largest chains</td>
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<tr>
<td>81</td>
<td>7,900+</td>
<td>4</td>
</tr>
<tr>
<td>L3 categories</td>
<td>SKUs</td>
<td>weeks</td>
</tr>
</tbody>
</table>
RESULTS FROM OUR EXPERIMENTS

**22%**

Success rate improvement over the control group

A TOUGH COMPARISON!

**CONTROL ALGO:**
- under development for a few years
- constantly updated
- uses feature info we don’t have
- already quite good!

Estimated impact for an online retailer with 1 billion USD in revenue:

- 3.25 million USD in annual revenue
- 3,570 fewer picker hours per year

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*a* Significant at 10% in a one-tail test of difference in proportions (p-value = 0.092).

a. Success rate is the percentage of the substitution opportunities in which the customer selected a substitute from those presented by the model.

1. Assuming the retailer has a 10% stock out rate
FUTURE OF ON-SHELF-AVAILABILITY (OSA)

USE DATA-SCIENCE/ML TO IMPROVE OSA

Signals: cameras, robots, sales, deliveries, replenishments, etc.

Detect Phantom-OOS

Auto-Correct Inventory Records

Better Replenishments $\rightarrow$ Better OSA

Subst. Suggestions

Minimize Lost-Sales

Can result in 1-2% sales lift from in addition to labor productivity gains
Thank you!

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