# Prediction of Shopping Behavior Using a Huff Model Within a GIS Framework

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# Background

- A common retail marketing question is “How can I estimate consumer demand for individual retail locations?”
- Reilly (1931) applied the gravity concept to retail trade analysis:
  - Determine the retailing pulling power of two competing cities on an intervening area
  - Drawing power of a facility is directly proportional to the size of the facility and inversely proportional to distance
  - Focused on stores rather than consumers

# Huff Model

- The Huff Model (1963) is a probabilistic retail gravity model used to predict consumer behavior among competing retail shopping locations.

$$P_{ij} = \frac{\frac{S_j}{T_{ij}^{\lambda}}}{\sum_j^n \frac{S_j}{T_{ij}^{\lambda}}}$$

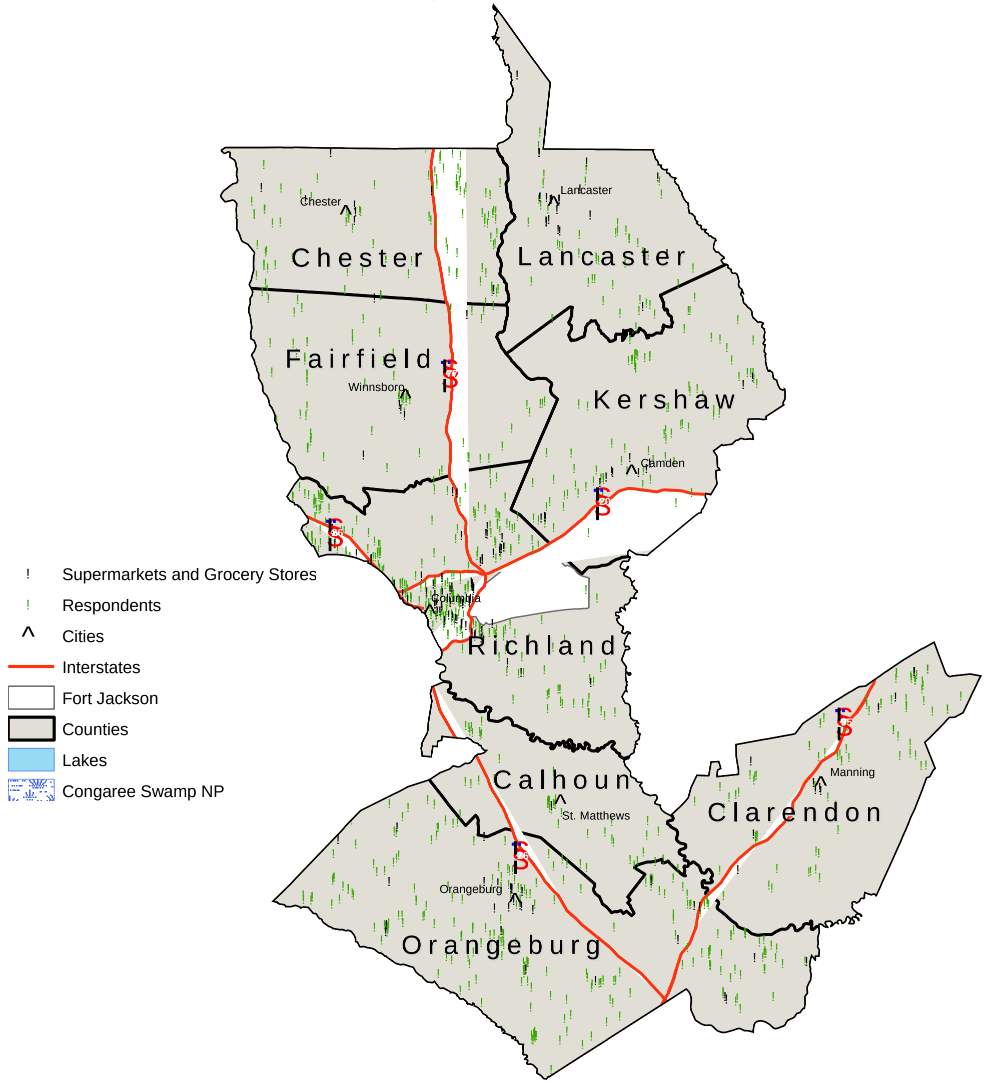
| | |
|---|---|
| $P_{ij}$ | The probability of a consumer at point *i* travelling to retail location *j* |
| $S_j$ | Size of retail location *j* |
| $T_{ij}$ | Travel time (or distance) from consumer at point *i* to travel to location *j* |
| $\lambda$ | Estimated parameter to reflect effect of travel on shopping trips (1-2) |

# Study Region and Respondents

- For this study, a dataset of 968 respondents were geocoded and queried for their primary grocery shopping location
- These locations were then matched to a GPS-verified dataset of supermarkets, supercenters, warehouse clubs, and grocery stores in a 8 county region of South Carolina
- 18 could not be geocoded,  146 shopped at a location not accounted for in the verified data – 804 in the Huff model analysis

# Study Region and Respondents

- Respondents sampled by ZIP code to be in study area (~15 per ZIP code)
- 166 total supermarkets, large grocery stores, supercenters, and warehouse clubs identified in area
- All 166 served in model as potential destinations – 91 were actually utilized by respondents



# Methods

- Traditionally the model used planar distances to make it less computationally intensive to solve, however GIS allows for a more realistic approach using street distances and travel time

- Origin-Destination cost matrix
  - Calculates the shortest street distance from each respondent to each store.

- Employee number comes from InfoUSA retail outlet data
  - This was the most complete descriptive measure, and served as a proxy for attractiveness.

- Model accuracy was determined by percent agreement of store with largest probability to each respondents' self-reported primary food shopping outlet

# Methods

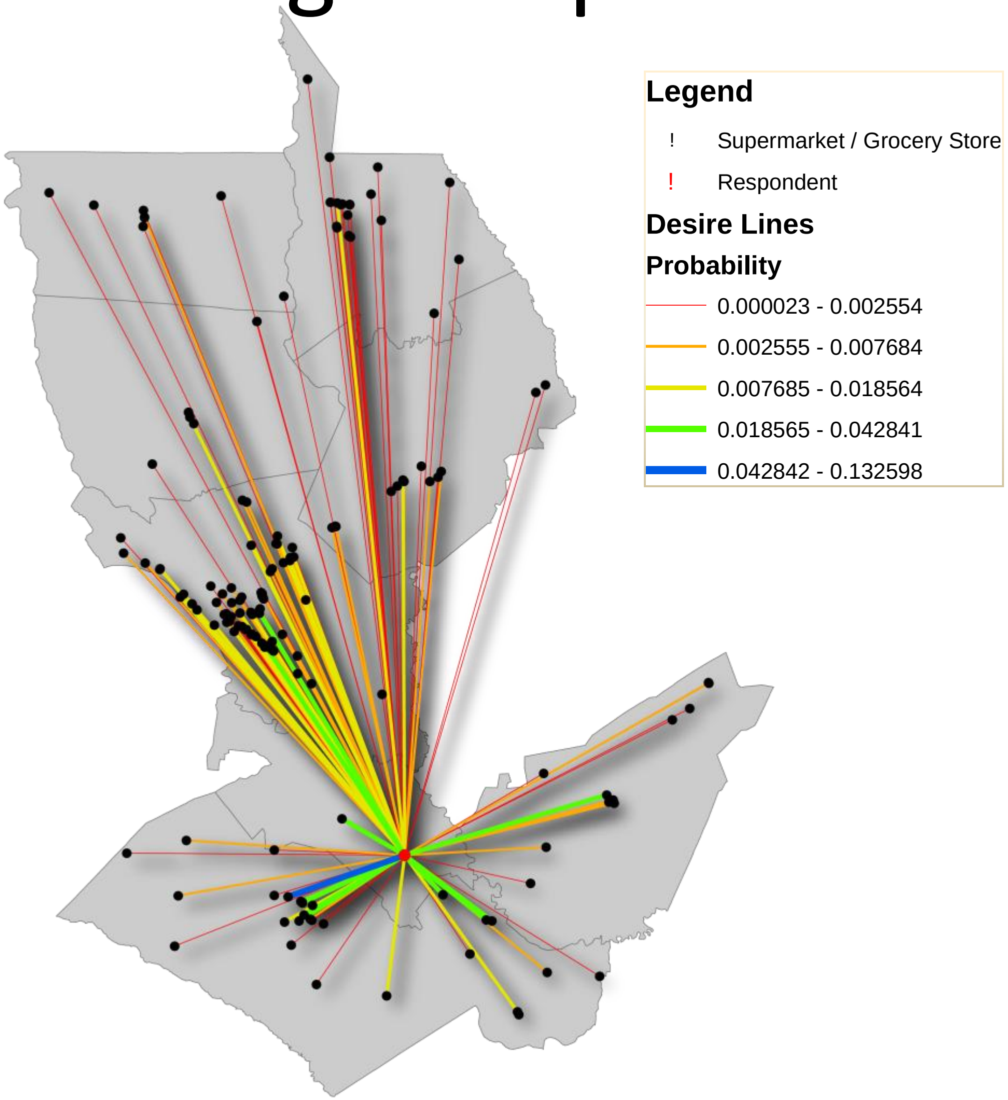
- Maximum probability as determined by the model is selected for each respondent

| | Store 1 | Store 2 | Store 3 | Store 4 | Store 5 | Store Utilized | Store Predicted |
|---|---|---|---|---|---|---|---|
| Respondent 1 | .225 | .055 | .466 | .150 | .104 | Store 3 | Store 3 |
| Respondent 2 | .890 | .005 | .083 | .007 | .015 | Store 5 | Store 1 |
| Respondent 3 | .001 | .075 | .750 | .060 | .114 | Store 3 | Store 3 |

Output table: List of store preferences (percent of time expected to go to each store)

# Example output of a single respondent

- 160 probabilities calculated for each respondent
- Represented as "desire lines" – connecting respondents to their potential stores.
- Red represents stores of lower probability of use, blue and green of higher probability of use



# Results (Distance based)

| County | % Agreement | Population Density (persons / mile°) |
|---|---|---|
| Calhoun | 31.4 | 36.4 |
| Chester | 34.5 | 58.2 |
| Clarendon | 36.4 | 44.2 |
| Fairfield | 20.3 | 32.0 |
| Kershaw | 24.1 | 67.5 |
| Lancaster | 29.5 | 104.4 |
| Orangeburg | 39.7 | 81.9 |
| Richland | 35.2 | 409.6 |
| **Overall** | **33.5** | |

# Results (Time based)

| County | % Agreement | Population Density (persons / mile°) |
|---|---|---|
| Calhoun | 28.6 | 36.4 |
| Chester | 33.3 | 58.2 |
| Clarendon | 36.4 | 44.2 |
| Fairfield | 21.9 | 32.0 |
| Kershaw | 26.5 | 67.5 |
| Lancaster | 27.3 | 104.4 |
| Orangeburg | 38.7 | 81.9 |
| Richland | 33.8 | 409.6 |
| **Overall** | **33.0** | |

# Results Summary (Probability)

| | Rural (Distance) | Rural (Time) | Urban (Distance) | Urban (Time) |
|---|---|---|---|---|
| **Mean** | 0.22 | 0.19 | 0.24 | 0.22 |
| **Median** | 0.17 | 0.14 | 0.19 | 0.17 |
| **Mode** | 0.49 | 0.38 | 0.20 | 0.19 |
| **Standard Deviation** | 0.16 | 0.14 | 0.16 | 0.16 |
| **Sample Variance** | 0.03 | 0.02 | 0.03 | 0.02 |
| **Range** | 0.91 | 0.91 | 0.94 | 0.94 |
| **Minimum** | 0.05 | 0.05 | 0.06 | 0.06 |
| **Maximum** | 0.97 | 0.96 | 1.00 | 1.00 |
| **Sum** | 141.28 | 122.94 | 38.80 | 35.31 |
| **Count** | 641 | 641 | 163 | 163 |

# Discussion

- Overall, model predicted correctly for about 33% of respondents

- Results for distance and time as accessibility measures were similar (T and D highly correlated)

# Discussion

- Better accessibility data (Modifies ***T***)
  - Incorporate into the distance/time calculations enhanced travel times based on more realistic conditions (cost, and barriers)

$$P_{ij} = \frac{\frac{S_j}{T_{ij}^{\lambda}}}{\sum_j^n \frac{S_j}{T_{ij}^{\lambda}}}$$

- This study considered all stores in the study region – can be limited by neighborhood size (Modifies ***n***)

# Discussion

- Employee number was used as an "attractiveness" parameter since it was most complete – better parameters can be used such as sales volume, square footage, or consumer survey data (Modifies ***S***)

- Modify λ to reflect the sensitivity of the model with respect to distance

$$P_{ij} = \frac{\frac{S_j}{T_{ij}^{\lambda}}}{\sum_j^n \frac{S_j}{T_{ij}^{\lambda}}}$$

# Next Steps

- Parameterize the current Huff Model
- Actual market basket values used as attractiveness factor (attractiveness varies inverse to food costs)
- Exploration of other types of spatial interaction models

# Questions / Comments?