Modelling Social Preferences of Ride-sharing

by

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Abstract

Ride-sharing also known as carpooling is sharing of journeys from one place to another so that more than one person can travel together and obviate others from driving to the locations themselves. By having more than one people sharing a vehicle, ride sharing avails to reduce personal expenses such as fuel, driving stress and tolls. The objective of this paper is to model the social preferences of people ride-sharing together i.e. to identify challenges and barriers people face to adopt ride-sharing and model their social preferences to obtain the final prediction for probabilities. First from the literature problems and challenges were identified which people face to adopt ride-sharing. Then a questionnaire was created as a survey which was conducted among the citizens of the United States to know the preferences and attributes of the ride-sharers. Further, using the data collected from the survey, a discrete mode choice analysis was performed. There were 13 main latent variables used for modeling. These 13 variables were grouped into four factors using factor analysis. Finally, four models were created using ordinal logistic regression to predict the probabilities of a person enjoying his/her shared rides in social aspects from his attributes and preferences. After the estimation of 4 final models we estimated a matching index using preference probabilities from the models that give a compatibility ratio between riders.

Keywords: ride-sharing behavior; survey; social preferences; ordinal logistic regression; factor analysis; latent variables.
Dedicated to my family and friends . . .
Chapter 1

Introduction

Ride-sharing also called as carpooling is sharing of journeys from one place to another so that more than one person can travel together and obviate others from driving to the locations themselves. By having more than one people sharing a vehicle, ride sharing avails to reduce personal expenses such as fuel, driving stress and tolls. It additionally avails reducing pollution, gaseous emissions like carbon, traffic on roads and desideratum of parking spaces. Ride-sharing additionally has potentials to increment social capital as it lets different people meet and know each other. Ride-sharing is thereby considered as environment-friendly and sustainable way of traveling.

As mentioned in most of the previous studies ride sharing is considered an efficient way to reduce road traffic, pollution, etc. for any country, business, or an individual. However, ride-sharing can struggle to be flexible to accommodate changes in times and working patterns. According to one of the survey, flexibility was the most common reason for not ride-sharing (19). As stated by (1) in their paper there are three main issues people face to adopt ride sharing – trust, awareness, inconvenience, and availability. They conducted a survey to understand the issues people face to
adopt ridesharing. Based on the results and analysis of their survey they proposed to design a system for dynamic ride-sharing which will incorporate all these issues.

Ride-sharing has not been adopted very commonly. There are many systems in the form of bulletin board-like websites that facilitate the match between drivers and passengers. The driver announces the number of empty sets in his vehicle many days before he is going to travel. Then the passengers and the driver’s coordinate with each other through the website, private messages or email. This is a static way of ride-sharing. In this case, there can be many social barriers or problems between the passenger and the driver as there is no way to get the social compatibility between them. Also, very few ride-sharing platforms have taken into account travelers’ social attributes and ride discomfort with strangers for their matching algorithms. Accordingly, knowing the social barriers and trying to match driver and passenger as per their preferences will lead to an increase in adoption of ride-sharing. This was the main motivation of the study to social barriers that restrict people to adopt ride-sharing.

The main objective of this study is to identify the challenges and social barriers people actually face to adopt ride sharing. It also aims to identify significant factors that lead people to not adopt ride sharing and to identify one’s social preference in choosing ride-sharer.

The objective is achieved by conducting a survey among the citizens of US asking them about the challenges they face to adopt ride sharing. Using the result of the survey a model was created to identify significant factors and to predict the probability of compatibility between people ride sharing together.
Following are the steps undertaken in this study:

- Identifying major problems and challenges people face to adopt ride sharing from the literature.
- Creating a questionnaire for the survey to be taken using the problems and challenges identified.
- Conducting the survey among citizens of US and getting the responses for further analysis.
- Factor analysis of the responses to group down all 13 latent variable responses into four different factors.
- Using the survey results to create discrete choice models to identify significant factors. Then four different models were created using logistic regression with latent variables.
- Then using the preference probabilities from the model a matching index was calculated which gives the compatibility ratio between riders.
Chapter 2

Literature Review

We classify the literature in ride-sharing behavior into two categories: Non-survey-based approach and Survey based approach which are as follows:

2.1 Non-survey-based approach

There are many methods that were used to improve adoption of ride sharing. One of them is through combining ride sharing with social network. Wessel, R. proposed a web system that combines with social network which will tend to improve trust and security (3). The factors considered are friendliness, safety, and reliability. The results showed such that about 23% of people are willing to lose more time to pick up a friend rather than a stranger which is 6%.

The paper (7) by Gidofalvi, G. et al. considered maximization of social connections to improve adoption of ride sharing. The author tried to reduce the social discomfort and safety risks which
are associated with ride sharing. Users are connected to each other by a social network data source. The number of short paths between two users tells us about the strength of the connection between them. But the issues of the adoption of ride-sharing were not taken into account.

Another study (8) proposed a system which divides passenger route into different small segments which are part of other trips, called as dynamic multi-hop system. This paper also considered the social aspects, like matching drivers and passengers by linking the application with social networks such as Facebook etc. and matching the user profiles.

The paper (5) reported on the HOV (High Occupancy Vehicles) lane and suggested no fees for HOV’s on bridges. The author also suggested giving priority to female passengers by not leaving them alone for a longer duration waiting for a ride considering safety. There were some suggestions provided by the author for future research which includes safety and reputation system design i.e. authenticating users before matching.

2.2 Survey-based approach

Survey is an unbiased approach to take decisions in any research. As said by Wyse in (11) that the four reasons why businesses and researchers should conduct surveys are that surveys help uncover answers about any research, give your survey respondents an opportunity to discuss important key topics, base decision on objective information and help provide information like thoughts, comments and opinions about the target audience of the survey. Survey for ride-sharing research is also conducted to know what difficulties people face to adopt ride sharing.
As given in paper (12) by Ayele and Byun, to understand personal, social psychological and other factors affecting ridesharing programs, they designed a “Ride-sharer survey”. They analyzed this survey considering two different aspects of which one involved general statistics and other was a cooperative statistical analysis in which they grouped ride-sharers in different groups (by income, age, sex, and race etc.). The results from this research were compared to identify how these variables affect ride sharing.

Horowitz (13) gave significant importance to study of the role of psychological attitude in ridesharing. He came up with a framework in which attitudes, beliefs affecting behavioral intention, can affect ridesharing. He hypothesized that everyone has a set of positive and negative evaluation about ridesharing. Also, he developed a mathematical model of ridesharing to explore how advantages and disadvantages of ridesharing determine behavioral tendency.

As mentioned by Burkhardt and Millard-Ball in (16), innovativeness and pro-environmental attitudes are recognized as the common characteristic among the ridesharing users. Schaefers in his research (18) also identified social innovativeness and pro-environmental considerations with two other motivational patterns which are thriftiness and convenience as the underlining patterns for ride-sharing use. Kopp et al. in his research (17) suggested that ridesharing users are more likely to exhibit multi-modal travel patterns which were also corroborated by Schaefers (18) in his work.

Krueger, Rashidi, and Rose (14) studied the travel behavior impacts, by identifying willingness and characteristics of users who are more likely to adopt Sports activity vehicle (SAV). A survey was conducted and analyzed using a logit model. The results of the research in (14) convey that
the service attribute can be critical determinants of SAV and ridesharing acceptance. The uptake of ridesharing and SAV will differ across different population groups, and the set modes may be considered as an important determinant of subgroup membership.

As stated in (15), shared vehicles are the vehicles that serve several people throughout a day. There are more than 25 ride-sharing companies that already exist but people still face issues to adopt ride sharing.

From the literature, it can be seen that the major problems and challenges people face to adopt ride sharing are psychological factors like trust, compatibility etc. Although a number of studies have been conducted to identify these factors and tries to improve the adaptability of ride sharing. Our study aims to improve the adaptability by identifying factors as well as checking the compatibility between people who want to ride share together. Having the compatibility ratio before even ride sharing with someone will help to improve the adaptability. In this study, a survey-based approach is devised and the methodology used for model creation and predicting the probability is similar to the choice model from the study of Bierlaire (22).
Chapter 3

Survey Design and Analysis

3.1 Data Preparation

A survey was designed and distributed among national residents of USA through the paid service provided by Survey Monkey. This survey was intended to know the influence of the social, psychological and other personal factors on ridesharing. The main objective of this survey was:

- to determine challenges that people face to adopt ride-sharing;
- to obtain attitudinal data indicating social preference in ride-sharing;
- to determine impacts of personal demographics to prospective riders.

3.2 Survey Methodology

The survey questionnaires contained 9 different questions which include personal demographics and also questions to determine challenges that people face to adopt ride-sharing.
The main questions asked in the survey included questions about demographics, personal characteristics, and what kind of people one would like to ride share with. First five questions were about demographics and personal questions like age group, gender, race, income, etc. The sixth question asked people to tell about themselves. The seventh question was about the major or expertise. Eight question was to know if a person smokes, drinks, likes shopping, like to be on social media, etc. The ninth question contained 13 different sub-questions asking the preferences of people about the ones they would like to ride share with. For example, “who as similar income as I do?”, “who has the same gender as I do?”, etc. The response to the ninth question was as a latent response with seven levels from “strongly disagree” to “strongly agree”. In this manner, 273 responses to the survey were collected for further analysis.

3.3 Analysis of the survey

The analysis of this survey focused on the analysis of general characteristics and a comparative and statistical analysis in which people were grouped by income, age, race, gender, education level, major or expertise.

Statistical analysis of survey responses is explained as follows:
3.3.1 Demographics:

As seen in Figure 1, there were 53.68% of male responders, 45.59% of the female responders and the rest 0.74% were who preferred not to disclose their gender.

As seen in Figure 2, the responders for the survey were all distributed in different age groups. The highest number of responders was from age group “21-29 years” (31.62% of the total responders) and the lowest number of responders were from the age group “18-20 years” (5.68% of total).
From Figure 3, it can be seen that the highest number of responders for our survey were “White”, i.e. 73.53% of the total responders and least were “American Indian or Alaskan Native” and “Native Hawaiian or other Pacific Islander” i.e. 0.74% of the total responders for the both.

### 3.3.2 Education and Income:

From Figure 4, it can be seen that more than 50% of the responders had a bachelor degree or higher, and more than 70% of the responders pursued degree higher than high school or equivalent.
Figure 5: Distribution of household income of the individual responders in percentage.

From Figure 5, it can be seen that the responders were mostly evenly distributed among all income groups from less than $20,000 to $150,000 and more. However, the highest number of responders (20.22% of total responders) had income in the range of $50,000 to $74,999.

From Figure 1 to Figure 5, one can see that the demographic distribution of responders roughly followed the demographic distribution of the entire population of U.S. Therefore, this survey collected (and reflected) public values of ride-sharing in the U.S.
3.3.3 Personality and personal preferences:

Table 1: The personality of responders in percentage of total responders.

<table>
<thead>
<tr>
<th>Answer Choices</th>
<th>Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>I see myself as: Extraverted, enthusiastic.</td>
<td>28.68%</td>
</tr>
<tr>
<td>I see myself as: Critical, quarrelsome.</td>
<td>11.76%</td>
</tr>
<tr>
<td>I see myself as: Dependable, self-disciplined.</td>
<td>51.47%</td>
</tr>
<tr>
<td>I see myself as: Anxious, easily-upset.</td>
<td>14.71%</td>
</tr>
<tr>
<td>I see myself as: Open to new experiences, complex.</td>
<td>45.26%</td>
</tr>
<tr>
<td>I see myself as: Reserved, quiet.</td>
<td>37.13%</td>
</tr>
<tr>
<td>I see myself as: Sympathetic, warm.</td>
<td>44.12%</td>
</tr>
<tr>
<td>I see myself as: Disorganized, careless.</td>
<td>8.46%</td>
</tr>
<tr>
<td>I see myself as: Calm, emotionally stable.</td>
<td>38.60%</td>
</tr>
<tr>
<td>I see myself as: Conventional, unreactive.</td>
<td>9.56%</td>
</tr>
</tbody>
</table>

Total respondents: 272

From Table 1, it can be seen that most responders have described themselves to be “Dependable, self-disciplined”, “Open to new experiences, complex”, “Sympathetic, warm”, “Reserved, quiet”, etc. The least number of responders have described themselves as “Disorganized, careless”, “Conventional, unreactive”, etc.
Table 2: Self-Identified personal characteristics of respondents

<table>
<thead>
<tr>
<th>Answer Choices</th>
<th>Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smokes sometimes</td>
<td>15.81%</td>
</tr>
<tr>
<td>Drink Sometimes</td>
<td>60.29%</td>
</tr>
<tr>
<td>Like to go shopping</td>
<td>41.18%</td>
</tr>
<tr>
<td>Play a musical instrument</td>
<td>25.00%</td>
</tr>
<tr>
<td>Like going out for eating sometimes</td>
<td>83.82%</td>
</tr>
<tr>
<td>Like watching movies</td>
<td>76.47%</td>
</tr>
<tr>
<td>Like to be on social media</td>
<td>42.65%</td>
</tr>
<tr>
<td>Go out for parties, get-together, outings etc. sometimes</td>
<td>47.06%</td>
</tr>
<tr>
<td>Go on a vacation trip sometimes</td>
<td>76.84%</td>
</tr>
<tr>
<td>Play sports sometimes</td>
<td>36.40%</td>
</tr>
<tr>
<td>Like outdoor activities like trekking, hiking etc.</td>
<td>56.25%</td>
</tr>
</tbody>
</table>

Total Respondents: 272

From Table 2, it can be seen that most responders are interested in going out for eating, watching movies, vacation and are cool with drinking occasionally. There were very fewer responders who responded that they were okay with smoking sometimes. The average percentage of responders, about 30% to 50%, responded that they would like to be on social media, go out to parties, play sports sometimes, like to go shopping, etc.
Table 3 Preferences regarding rideshare passengers. % (# of obs.)

<table>
<thead>
<tr>
<th></th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Slightly Disagree</th>
<th>Unsure</th>
<th>Slightly Agree</th>
<th>Agree</th>
<th>Strongly Agree</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>who has similar income as I do.</td>
<td>13.65%</td>
<td>15.13%</td>
<td>6.64%</td>
<td>33.58%</td>
<td>15.50%</td>
<td>13.65%</td>
<td>1.85%</td>
<td>271</td>
</tr>
<tr>
<td>who has similar education level as I do.</td>
<td>12.55%</td>
<td>10.33%</td>
<td>7.75%</td>
<td>26.20%</td>
<td>16.97%</td>
<td>22.14%</td>
<td>4.06%</td>
<td>271</td>
</tr>
<tr>
<td>who has similar major/ expertise/job type as I do.</td>
<td>12.18%</td>
<td>14.39%</td>
<td>8.12%</td>
<td>24.35%</td>
<td>19.93%</td>
<td>17.71%</td>
<td>3.32%</td>
<td>271</td>
</tr>
<tr>
<td>who has same race as I do.</td>
<td>26.84%</td>
<td>18.75%</td>
<td>7.72%</td>
<td>28.68%</td>
<td>7.72%</td>
<td>6.99%</td>
<td>3.31%</td>
<td>272</td>
</tr>
<tr>
<td>who has the same gender as I do.</td>
<td>21.85%</td>
<td>16.67%</td>
<td>8.52%</td>
<td>29.26%</td>
<td>9.26%</td>
<td>10.74%</td>
<td>3.70%</td>
<td>270</td>
</tr>
<tr>
<td>who has similar preferences (sport, movie, etc) as I do.</td>
<td>11.07%</td>
<td>9.96%</td>
<td>9.59%</td>
<td>25.46%</td>
<td>20.66%</td>
<td>18.08%</td>
<td>5.17%</td>
<td>271</td>
</tr>
<tr>
<td>who has similar smoking preferences as I do.</td>
<td>11.90%</td>
<td>5.20%</td>
<td>1.86%</td>
<td>20.45%</td>
<td>8.18%</td>
<td>16.36%</td>
<td>36.06%</td>
<td>269</td>
</tr>
<tr>
<td>who has similar drinking preferences as I do.</td>
<td>12.50%</td>
<td>9.19%</td>
<td>4.41%</td>
<td>26.84%</td>
<td>16.18%</td>
<td>16.54%</td>
<td>14.34%</td>
<td>272</td>
</tr>
<tr>
<td>who has similar social attributes as I do.</td>
<td>10.00%</td>
<td>8.52%</td>
<td>8.15%</td>
<td>29.26%</td>
<td>20.00%</td>
<td>18.89%</td>
<td>5.19%</td>
<td>270</td>
</tr>
<tr>
<td>who belongs to similar age group as I do.</td>
<td>12.18%</td>
<td>14.02%</td>
<td>11.81%</td>
<td>24.72%</td>
<td>18.08%</td>
<td>15.87%</td>
<td>3.32%</td>
<td>271</td>
</tr>
<tr>
<td>who participates in group activities as often as I do.</td>
<td>11.76%</td>
<td>11.40%</td>
<td>6.62%</td>
<td>33.46%</td>
<td>18.01%</td>
<td>15.81%</td>
<td>2.94%</td>
<td>272</td>
</tr>
<tr>
<td>who uses social media as often as I do.</td>
<td>15.44%</td>
<td>16.18%</td>
<td>8.09%</td>
<td>36.40%</td>
<td>9.19%</td>
<td>11.03%</td>
<td>3.68%</td>
<td>272</td>
</tr>
<tr>
<td>who participates in outdoor activities as I do.</td>
<td>11.40%</td>
<td>13.24%</td>
<td>6.99%</td>
<td>33.09%</td>
<td>15.81%</td>
<td>14.34%</td>
<td>5.15%</td>
<td>272</td>
</tr>
</tbody>
</table>

This was the main question asked to responders about their preferences about the person they would like to ride-share with. It includes 13 different questions which were linked to the other question asked before in the survey. The response to this question was in the form of Likert scale with 7 levels:
1. strongly disagree,
2. disagree,
3. slightly disagree,
4. unsure,
5. slightly agree,
6. agree, and
7. strongly agree.

From Table 3, it can be seen that responders cared more about the smoking, drinking and social attributes with and the least they cared about was the demographic characteristics about the people they want to ride-share with.
Chapter 4

Methodology and Experimental Results

In order to characterize the relationship between responses to ride-sharing preferences (i.e. “I prefer to rideshare with someone who has similar drinking habits.”) and other rider attributes a model of latent variables that inform multiple observed ordinal choices (attitudinal Likert scale statements) was estimated with the survey data. This section presents the model formulation and estimation results, including discussion and interpretation results. The next section discusses the data cleaning and preparation, followed by the model formulation.

4.1 Data Cleaning and Preparation

Before using the survey response for model estimation, the original Likert scale responses were collapsed to a 3-item scale (1-disagree, 2-unsure, 3-agree). The motivation for this was to provide item levels with a reasonable number of observations each. Other variables used as covariates to explain the response to Likert scale items include (i) personal socio-demographics; (ii) general preferences and hobbies (i.e. like shopping, playing musical instruments, etc.); and (iii) self-identified personality traits (i.e. quarrelsome, extroverted, anxious, etc.). Additionally, respondents
indicated preferences for ride-sharing passengers through a series of attitudinal Likert scale statements. These variables and items are listed and described next. The personal attributes of respondents from the survey are listed and described in Table 4.

Table 4: Survey data variables - personal attributes

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AGE</td>
<td>Age group range: 1 = 18 to 20 years, 2 = 21 to 29 years, 3 = 30 to 39 years,</td>
</tr>
<tr>
<td></td>
<td>4 = 40 to 49 years, 5 = 50 to 59 years, and 6 = 60 years+.</td>
</tr>
<tr>
<td>GENDER</td>
<td>Gender: 1 = Male, 2 = Female, 3 = N/A</td>
</tr>
<tr>
<td>RACE</td>
<td>Ethnicity origin (or Race): 1 = White, 2 = Black/African-American, 3 =</td>
</tr>
<tr>
<td></td>
<td>American Indian/Alaskan native, 4 = Asian, 5 = Native Hawaiian/other</td>
</tr>
<tr>
<td></td>
<td>Pacific Islander, 6 = From multiple races, and 7 = Other</td>
</tr>
<tr>
<td>EDUCATION</td>
<td>Highest level of Education: 1 = Less than high school degree, 2 = High degree or equivalent, 3 = Some college but no degree, 4 = Associate degree, 5 = Bachelor degree, 6 = Graduate degree, and 7 = PhD</td>
</tr>
<tr>
<td>INCOME</td>
<td>Household Income Range for 2016: 1 = Less than $20,000, 2 = $20,000 to $34,999, 3 = $35,000 to $49,000, 4 = $50,500 to $74,999, 5 = $75,000 to $99,999, 6 = $100,000 to $149,999, and 7 = $150,000 or more.</td>
</tr>
<tr>
<td>SMOKES</td>
<td>1 = Smokes; 0 = Does not Smoke</td>
</tr>
<tr>
<td>DRINKS</td>
<td>1 = Drinks Alcohol; 0 = Does not Drink Alcohol</td>
</tr>
</tbody>
</table>
**Self-Identified Descriptors**: Additionally, binary responses were collected from respondents indicating if the following statements properly characterized or described themselves; variable names are in parentheses:

- Likes Shopping (SHOP)
- Plays a Musical Instrument (MUSIC)
- Likes Watching Movies (MOVIES)
- Likes using Social Media (SMEDIA)
- Likes Parties (PARTY)
- Likes Vacations (VACATION)
- Plays Sports (SPORTS)
- Extroverted/Enthusiastic (EXTROVERT)
- Critical/Quarrelsome (CRITICAL)
- Dependable/Self-Disciplined (DEPENDABLE)
- Anxious/Easily Upset (ANXIOUS)
- Open to new Experiences/Complex (OPEN)
- Reserved/Quiet (QUIET)
- Sympathetic/Warm (WARM)
- Disorganized/Careless (CARELESS)
- Calm/Emotionally Stable (CALM)
- Conventional/Uncreative (UNCREATIVE)

**Passenger Preference Responses**: Finally, respondents were asked to respond to 3-item Likert Scale attitudinal statements regarding the type of passengers with whom they prefer to ride-share
with. These statements are listed below with variable names in parentheses. The three levels are: 1 = disagree; 2 = unsure and 3 = agree. For example, if the respondent answered "1" to "Income Level," they disagree that they would like to ride with similar income level passengers.

- Income Level (S_INCOME)
- Education Level (S_EDU)
- College Major (S_MAJOR)
- Race (S_RACE)
- Gender (S_GENDER)
- Preferences (sports teams, watching movies, etc.) (S_PREF)
- Smoking Habits (S_SMOKE)
- Drinking Habits (S_DRINK)
- Social Habits/Attributes (S_SOCIAL)
- Age (S_AGE)
- Participation in Group Activities (parties, etc.) (S_GROUP)
- Use of Social Media (S_SOCIALMEDIA)
- Outdoor Activities (i.e. trekking, hiking, etc.) (S_OUTDOOR)

4.2 Factor Analysis

The survey dataset contained 13 multi-item Likert scale questions regarding preferences for ride-share passengers described above. In order to distill these responses into latent variables that characterize the response to these 13 questions, a factor analysis was conducted to reveal the
number of latent variables needed to explain the majority of variation in responses. An ordinal logit joint among groups of statements was estimated for each of the resulting latent factors. A factor analysis for M= 3, 4, 5, 6 factors was completed to identify the appropriate number of latent factors. Based on the chi-square statistic for the model with two and three factors (M=2, 3), the factor analysis model with M=3 had a lower test-statistic and higher p-value, indicating preference over the M=2 factor model. Based on chi-square test statistic for the model with 4 factors (M=4), at, was preferred. We accept the hypothesis that four factors sufficiently explain the variance.

Additionally, the Eigenvalues (SS loadings) indicate the amount of variance is accounted for each of four factors. Factors with high SS loadings reflect their significance for explaining variances in responses. A “rule of thumb” is an SS loadings value greater than 1, to indicate importance (25). All factors in the four-factor model have SS loadings greater than 1.

<table>
<thead>
<tr>
<th>Likert Scale Attitudinal Statement</th>
<th>Factor 1</th>
<th>Factor 2</th>
<th>Factor 3</th>
<th>Factor 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Similar Income (S_INCOME)</td>
<td>---</td>
<td>0.648</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Similar Education (S_EDU)</td>
<td>---</td>
<td>0.817</td>
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<td>Similar Major (S_MAJOR)</td>
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<td>0.600</td>
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<td>Similar Race (S_RACE)</td>
<td>---</td>
<td>---</td>
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<td>0.609</td>
</tr>
<tr>
<td>Similar Gender (S_GENDER)</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>0.741</td>
</tr>
<tr>
<td>Similar Preferences (S_PREF)</td>
<td>0.550</td>
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<td>---</td>
</tr>
<tr>
<td>Similar Smoking (S_SMOKE)</td>
<td>---</td>
<td>---</td>
<td>0.645</td>
<td>---</td>
</tr>
<tr>
<td>Similar Drinking (S_DRINK)</td>
<td>---</td>
<td>---</td>
<td>0.790</td>
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</tr>
<tr>
<td>Similar Social (S_SOCIAL)</td>
<td>0.555</td>
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<tr>
<td>Similar Age (S_AGE)</td>
<td>0.575</td>
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<tr>
<td>Similar Participation (S_GROUP)</td>
<td>0.854</td>
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<tr>
<td>Similar Social Media Use (S_SOCIALMEDIA)</td>
<td>0.605</td>
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<tr>
<td>Similar Outdoor Activities (S_OUTDOOR)</td>
<td>0.681</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Factor 1</th>
<th>Factor 2</th>
<th>Factor 3</th>
<th>Factor 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>SS loadings</td>
<td>2.901</td>
<td>2.016</td>
<td>1.511</td>
<td>1.351</td>
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<td>Proportion Variance</td>
<td>0.223</td>
<td>0.155</td>
<td>0.166</td>
<td>0.104</td>
</tr>
<tr>
<td>Cumulative Variance</td>
<td>0.223</td>
<td>0.378</td>
<td>0.494</td>
<td>0.598</td>
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</tbody>
</table>
Interestingly four factors (M=4) emerged that aligned with different groups of statements. The latent variables or factors from the factor analysis were interpreted as follows:

- **Factor 1 (Organizational):** Indicates preference for similar social or organizational engagement; this latent variable captures variance in responses to these statements: (i) Similar Preferences, (ii) Similar Social Habits, (iii) Similar Age, (iv) Similar Participation, (v) Similar use of Social Media; and (vi) Similar Outdoor activities.

- **Factor 2 (Socioeconomic):** Indicates preference for similar socioeconomic characteristics (i.e. education, household income); this latent variable captures variance in responses to these statements: (i) Similar Income; (ii) Similar Education; and (iii) Similar Major.

- **Factor 3 (Social Habits):** Indicates preference for similar drinking and smoking habits; this latent variable captures response variance to: (i) Similar Smoking Habits; and (ii) Similar Drinking Habits.

- **Factor 4 (Socio-Demographic):** Indicates preference for similar socio-demographics (i.e. gender, race, etc.); this latent variable captures response variance to: (i) Similar Race and (ii) Similar Gender.
4.3 Modeling Framework

Given the identified latent factors, we use an ordered response model representing each latent factor to investigate the relationship between survey responses and latent factors. Latent variables which are unobserved but measurable through responses to indicators arise frequently in the transportation and marketing literature. Our framework models the four types of preferences as latent variables. The data used for estimating these models were from an intercept survey that collected responses to attitudinal measurement indicators and other respondent information. The final model specification is a model of the latent constructs, with Likert scale responses as indicators. The entire model system is shown below in Figure 6. Latent variables and indicators all have measurement and other errors indicated as $e^s$ and $e^M$ respectively. The main components of the modeling framework in Figure 5 are as follows:

![Figure 6: Modeling Framework for ordered logit model.]

**Explanatory Variables** ($X$): These include observed attributes of the survey respondent. These are all collected through the survey developed.

**Latent Variables** ($X^*$): These are the four latent preferences towards ride-share passengers.
**Attitudinal and Perceptual Indicators (I):** These consist of respondent ratings towards statements regarding the dimensions of ride-share passengers that are latent and psychological. The marketing field has long developed scales that evaluate latent consumer perceptions (26). The list of indicators collected is given in Table 5.

**4.4 Model Specification**

Given the theoretical concepts, this section provides the model specifications for the four latent variables. This latent variable was modeled based on responses to 13 Likert scale indicator responses, of which only 11 were found to be statistically significant in the final four model specifications. The structural equation was specified as follows:

\[ X^* = \beta_0^S + \beta_1^SX_1 + \beta_2^SX_2 + \cdots + \beta_K^SX_K + \sigma^S\epsilon^S \]  
(Eq. 1)

- \(X^*\) a latent variable, in this case one of the four ride-share preferences
- \(X\) a vector of explanatory variables, observed and/or unobserved
- \(\beta^S\) a vector of parameters to be estimated from the data
- \(\epsilon^S\) a random error term, which is assumed to be Gumbel distributed
- \(\sigma^S\) scale parameter of \(\epsilon^S\)

The measurement equation \(Z\) that related the latent variable \(X^*\) to the observed responses to indicators \(I\) was specified as follows:
\[ I_i = f(x) = \begin{cases} 
  j_1, & X^* < k_1 \\
  j_2, & k_1 \leq X^* < k_2 \\
  j_3, & k_2 \leq X^* 
\end{cases} \quad (Eq. 2) \]

\( X^* \) a latent variable, in this case, one of the four ride-share preferences

\( I_i \) response to an indicator statement, such as an attitudinal statement i=1 to 13

This paper has three measurement levels M=3 in Eq. 6. For each Likert response, we define two parameters \( \tau_i \) and \( \delta_i \) that define the thresholds \( k_i \) as follows:

\[ k_1 = \tau_i \quad (Eq. 3) \]
\[ k_2 = \tau_i + \delta_i \quad (Eq. 4) \]

In the final model specification for the four latent variables, only 2-4 of the original i=1..13 Likert scale indicators were found statistically significant per factor. This was also indicated in the factor analysis in Table 5. The final specification for each latent model had the following equations:

a) 1 structural, for the single latent variable (Factor 1, Factor 2, Factor 3 or Factor 4) (Eq. 1)

b) 2-4 measurement equations, for each indicator retained (Eq. 2)

Given the Gumbel assumptions of the error term, probabilities of the particular ordinal choice of Likert scale level given a latent variable (Factors 1 to 4) is:

\[ Pr(agree) = \frac{1}{1+\exp(-(X^*+k_1))} \quad (Eq. 5) \]
\[ Pr(unsure) = \frac{1}{1+\exp(-(X^*+k_2))} - Pr(agree) \]  
(Eq. 6)

\[ Pr(disagree) = 1 - Pr(agree) - Pr(unsure) \]  
(Eq. 7)

The final likelihood function for the observed sample is:

\[ L_n(I|X; \beta^*, \tau, \delta, \Sigma) = \int_{\varepsilon} \prod_{r=1}^{R} Pr(I_r = j_{in} | \varepsilon^s) \cdot d\varepsilon \]  
(Eq. 8)

We estimate the final model using Full Information Maximum Likelihood (FIML) using the likelihood function in Eq. 12. The model was implemented and estimated in BIOGEME (21) an open-source freeware designed for the maximum likelihood estimation of parametric models in general, with a special emphasis on discrete choice models. The trust region method was used as the optimization algorithm to solve the maximum likelihood estimation problem. Next, we discuss the estimation results for the four models estimated.

4.4.1 Model 1: Organizational Latent Variable (Factor 1):

From Table 6, three person-level attributes were statistically significant in explaining the first latent variable characterizing organizational preferences (Factor 1). First, the variable ANXIOUS had a negative sign. If the respondent self-characterized him/herself as “anxious,” this had a negative impact on the thresholds for the ordinal logit model, indicating these individuals tend to disagree preference for passengers with similar social and other organizational activities. The
positive sign on UNCREATIVE indicates that individuals who were conventional or uncreative tend to agree with these statements, indicating a high preference for passengers with similar organizational attitudes. Finally, the respondent with household incomes less than $50,000 annually tends to prefer passengers with similar organizational attitudes. Second, the threshold parameter estimates (τ and δ) were similar for all four attitudinal statements (OUTDOOR, GROUP, PREF and SOCIAL). This indicates that controlling for all other factors, in general individuals responded to the 3-item Likert scales for these dimensions similarly.

4.4.2 Model 2: Socioeconomic Latent Variable (Factor 2):

For Model 2, Table 6 indicates the same three person-level attributes significant in explaining Model 1 were also significant for explaining the second latent variable characterizing socioeconomic preferences (Factor 2). Similarly, the variable ANXIOUS also had a negative sign indicating a negative impact on the thresholds for the ordinal logit model. Similar to Model 1, respondents who were self-described as “anxious” tend to disagree with the associated attitudinal statements. UNCREATIVE and INCOME both had similar effects to Model 1. Turning attention again to the threshold parameter estimates (τ and δ), these were similar for all THREE attitudinal statements (INCOME, EDU, and MAJOR). The thresholds for MAJOR were slightly more negative relative to the other two dimensions, indicating in general slightly more disagreement with that attitudinal statement.
### Table 6: Model estimation results

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>t-statistic</th>
<th>P-value</th>
<th>Value</th>
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<th>t-statistic</th>
<th>P-value</th>
<th>Value</th>
<th>t-statistic</th>
<th>P-value</th>
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<td><strong>Thresholds for Joint Ordinal Logit Model</strong></td>
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<tr>
<td>δ for S_OUTDOOR</td>
<td>1.420</td>
<td>10.690</td>
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<td>-</td>
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</tr>
<tr>
<td>τ for S_OUTDOOR</td>
<td>-0.595</td>
<td>-3.740</td>
<td>0.000</td>
<td>-</td>
<td></td>
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<td>-</td>
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<td>δ for S_GROUP</td>
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<td>-</td>
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<tr>
<td>τ for S_PREF</td>
<td>-0.627</td>
<td>-3.920</td>
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<td>δ for S_SOCIAL</td>
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<tr>
<td>δ for S_INCOME</td>
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<td>---</td>
<td>0.000</td>
<td>1.150</td>
<td>9.490</td>
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<td>τ for S_INCOME</td>
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<td>1.470</td>
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<td>-0.436</td>
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### Respondent Personal Attributes

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<th>P-value</th>
<th>Value</th>
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<th>Value</th>
<th>t-statistic</th>
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<tbody>
<tr>
<td>β for ANXIOUS = 1</td>
<td>-0.618</td>
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<td>-0.447</td>
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<td>β for UNCREATIVE = 1</td>
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<td>β for QUIET</td>
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### Summary Statistics

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<th>Value</th>
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<td></td>
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<tr>
<td>Log-likelihood at Convergence</td>
<td>-1163.164</td>
<td></td>
<td></td>
<td>-872.500</td>
<td></td>
<td></td>
<td>-523.888</td>
<td></td>
<td></td>
<td>-279.046</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
4.4.3 Model 3: Drinking/Smoking Habits Latent Variable (Factor 3):

In Model 3, the estimation results in Table 6 indicate different personal attributes that impact the latent variable characterizing riders who prefer passengers with similar drinking and making habits. For this model a total of four personal attributes were significant. In addition to respondents self-characterizing themselves as anxious (ANXIOUS) and conventional (UNCREATIVE), being open to new experiences (OPEN) and female (GENDER = 2) also had statistically significant impacts. Interestingly, being open to new experiences had a negative impact on the thresholds, indicating they tend to disagree more with respect to these two attitudinal statements, relative to other respondents. One possible explanation could be that respondents open to new experiences tend to have stronger opinions and more readily disagree. Self-identifying as a female led to higher threshold values, as indicated by the positive coefficient on GENDER=2. Both ANXIOUS and UNREACTIVE had similar signs to Models 1 and 2.

With respect to the thresholds, the τ for SMOKE was more negative than DRINK. This indicates that on average, respondents tend to agree with ridesharing with passengers with similar drinking habits more relative to smoking. This seems reasonable since smoking has a more direct consequence on passengers than drinking (you share the same space as smoke or its odors.).
4.4.4 Model 4: Socio-demographic Latent Variable (Factor 4):

Finally, looking at Model 4 the personal attributes impacting the thresholds for Model 4 were quite different from the other three models. In the case of the last model, RACE, being reserved (QUITE) and being male (GENDER=1) appear to significantly impact this latent factor. If the respondent identified as Asian or Native Hawaiian, the impact of the threshold increased, indicating a higher likelihood of individuals agreeing that they would prefer passengers with a similar race. Asian and Native Hawaiian respondents tend to prefer ridesharing with similar race passengers. The same holds true for individuals identifying as reserved (QUIET=1); these individuals prefer riding with other passengers with similar race. Interestingly, identifying as Asian has a much higher positive impact relative to others, indicating extreme preference for similar race passengers. Both being open to new experiences (OPEN=1) and male (GENDER=1) had negative impacts on threshold values. Respondents identifying as either do not prefer to rideshare with similar race passengers. Interestingly, observed responses to the statement of preferring passengers of similar gender (S_GENDER=1) had no significant impact on the model likelihood at convergence and was not included. The thresholds for Model 4 were similar to those for the other three models.

4.5 Matching Index

Using the preference probabilities calculated from equations 5, 6, and 7, a matching index for ranking riders with other riders with a high probability of matching preferences is calculated. The matching index gives a compatibility ratio between two riders.
Matching index can be calculated in three steps for any rider pair A and B respectively:

1. First calculate similarity between the riders you are considering for matching:

   Similarity between A and B can be given by:
   \[
   S_{i}^{AB} = \sum j \theta_{j} x_{j}^{AB} \tag{Eq.9}
   \]
   where, \( i = 1, 2, 3, 4 \) (all factors)

   \( \theta_{j} = \text{normalized values of original variable } j \text{ from factor analysis for factor } i \)

   \( \sum j \theta_{j} = 1 \)

   \( x_{j}^{AB} = 1 \text{ if } A \text{ and } B \text{ have similar } j \text{ and } 0 \text{ otherwise.} \)

   We need the similarity between riders to get a value that can be used in the further equation to calculate matching index. This will be used as a coefficient to be multiplied with the probability of agreement to get a value which lies between \([0, 1]\). It is a multiplication of normalized values \( \theta_{j} \) and \( x_{j}^{AB} \). As both the value lie between \([0, 1]\) the multiplication will result in values between \([0, 1]\).

2. Now we calculate the matching index as follows:

   \[
   M_{A/B}^{i} = Y_{3A}^{i} + (Y_{1A}^{i} \times S_{i}^{AB}) + (\gamma \times Y_{2A}^{i}) \tag{Eq.10}
   \]
   where, \( Y_{1A}^{i} = \text{probability of agree of person } A \text{ for factor } i \text{ from Eq.5} \)

   \( Y_{2A}^{i} = \text{probability of unsure of person } A \text{ for factor } i \text{ from Eq.6} \)

   \( Y_{3A}^{i} = \text{probability of disagree of person } A \text{ for factor } i \text{ from Eq.7} \)

   \( S_{i}^{AB} = \text{Similarity between } A \text{ and } B \text{ from Eq.9} \)

   \( \gamma = 0.6, \text{ factor considered for this thesis for a person being unsure} \)

   From Eq. 10, we can see that matching index was calculated by summation of three probabilities multiplied with their coefficients. To get a matching index which has a value
between $[0, 1]$ we made sure that all the three summation factors had values between $[0, 1]$. This equation was considered as it incorporated all three preference probabilities of the riders. $Y_{3A}^i$ is the preference probability of disagreement for factor $i$ of rider A. As this probability is for disagreement so it will directly affect matching index and there is no need of any coefficient for this. $Y_{2A}^i$ is the preference probability of a person being unsure about factor $i$. So it has to be multiplied by a coefficient $\gamma$, which is selected to be as 0.6 for this study. $Y_{1A}^i$ is the preference probability of agreement for factor $i$ of rider A. So, it is multiplied by a similarity index which is calculated in Eq. 9, So summation of all these preference probabilities multiplied with their coefficients gives us the matching index for a particular factor $i$. So the final value of the matching index for a particular factor $i$ lies between $[0, 1]$.

3. Aggregating 4 factor matching index to single matching index:

$$M_{A/B} = \sum_i \propto_i M_{A/B}^i$$  \hspace{1cm} (Eq.11)

where, $\propto_i =$ \textit{weightage of each factor $i$}

The weightage $\propto_i$ can be considered as same or different based upon the estimation. It can also be taken according to the number of statements grouped together by factor analysis. More the number of statements in a factor more will be the weightage. For this study we have considered all factors to have equal weightage so the Eq. 11 becomes as follows.

$$M_{A/B} = \propto \sum_i M_{A/B}^i$$  \hspace{1cm} (Eq.12)

where, $\propto = 0.25$ as \textit{all factors are cosidered with same weightage}
4.5.1 Numerical example:

Consider three people A, B and C with following attributes:

A: male, Asian, conventional unreactive, Income less than $50,000, open to new experiences, reserved/quiet, drinks sometimes but doesn’t smokes, have bachelor’s degree or equivalent.

B: male, Asian, anxious and easily upset, conventional/unreactive, Income in the range $50, 000 to $99,000, open to new experiences, reserved/quiet, drinks and smokes sometimes, have bachelor’s degree or equivalent.

C: female, Native Hawaiian, conventional unreactive, Income less than $50,000, open to new experiences, reserved/quiet, drinks and smokes sometimes, have bachelor’s degree or equivalent.

Therefore, using Eq. 9, the similarities are as follows:

Table 7: Calculated similarities between riders A, B and C for all factors.

<table>
<thead>
<tr>
<th></th>
<th>Organizational (Factor 1)</th>
<th>Socio-economic (Factor 2)</th>
<th>Social Habits (Factor 3)</th>
<th>Socio-demographic (Factor 4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$S_i^{AB}$</td>
<td>1</td>
<td>0.397</td>
<td>0.55</td>
<td>1</td>
</tr>
<tr>
<td>$S_i^{AC}$</td>
<td>1</td>
<td>0.721</td>
<td>0.55</td>
<td>0</td>
</tr>
</tbody>
</table>

Now the preference probabilities for A from Eq’s. 5, 6, and 7 is calculated as:

Table 8: Calculated preference probabilities for rider A for all factors.

<table>
<thead>
<tr>
<th></th>
<th>Organizational (Factor 1)</th>
<th>Socio-economic (Factor 2)</th>
<th>Social Habits (Factor 3)</th>
<th>Socio-demographic (Factor 4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$Y_i^{1A}$</td>
<td>0.673</td>
<td>0.732</td>
<td>0.513</td>
<td>0.99</td>
</tr>
<tr>
<td>$Y_i^{2A}$</td>
<td>0.209</td>
<td>0.169</td>
<td>0.227</td>
<td>0.009</td>
</tr>
<tr>
<td>$Y_i^{3A}$</td>
<td>0.118</td>
<td>0.099</td>
<td>0.088</td>
<td>0.001</td>
</tr>
</tbody>
</table>
Now using the values from Table 7 and Table 8, in Eq. 10 the matching index is calculated:

<table>
<thead>
<tr>
<th></th>
<th>Organizational (Factor 1)</th>
<th>Socio-economic (Factor 2)</th>
<th>Social Habits (Factor 3)</th>
<th>Socio-demographic (Factor 4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$M_{A/B}^i$</td>
<td>0.9164</td>
<td>0.491</td>
<td>0.678</td>
<td>0.996</td>
</tr>
<tr>
<td>$M_{A/B}^i$</td>
<td>0.9164</td>
<td>0.721</td>
<td>0.678</td>
<td>0.0096</td>
</tr>
</tbody>
</table>

Table 9: Matching index between A, B and C for all factors.

Therefore, overall matching index from Eq. 12 considering weightage of all factors as equal is calculated as:

$$M_{A/B} = 0.25 \sum_i M_{A/B}^i \text{ and } M_{A/C} = 0.25 \sum_i M_{A/C}^i$$

Using values from Table 9, in Eq. 11 we get,

$M_{A/B} = 0.771 \text{ and } M_{A/C} = 0.581$

Therefore, A will prefer a higher likelihood of matching with B over C for ride-sharing as

$M_{A/B} > M_{A/C}$. 

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Chapter 5

Conclusion and Future Research Directions

5.1 Conclusion

This study examines the social preferences of ride-sharing passengers for other passengers. A factor analysis of Likert scale attitudinal statements on these preferences uncovered four latent factors. We interpreted these factors as Organizational (Factor 1), Socioeconomic (Factor 2), Smoking/Drinking Habits (Factor 3), and Sociodemographic (Factor 4). For each of these four factors, a joint ordered logit model was estimated based on the responses to statements that grouped together from the factor analysis. The estimated models revealed interesting relationships between the respondent attributes and preferences for rideshare passengers.

First, individuals with anxiety tend to prefer riding with similar type passengers with respect to (i) organizational activities; (ii) socioeconomics and (iii) drinking/smoking habits. Anxious individuals who self-identify as quarrelsome with others intuitively would not prefer to ride with anyone in general, let alone passengers with similar characteristics. Conventional individuals who
do not experiment much not surprisingly prefer passengers with similar preferences. Conversely individuals who are open to new experiences do not prefer passengers with similar smoking/drinking habits or similar races. With respect to preference for similar race rideshare passengers, Model 4 indicated Asians have the highest preference for similar race passengers, followed by Native Hawaiians and those that self-identify as quiet and introspective. The model estimation did not reveal significant gender differences for preferring similar race and drinking/smoking habits. Both males and female responded negatively to these statements.

Further a matching index was computed using the preference probabilities from the estimated models. Matching index gave us the compatibility ratio between riders. Riders with high matching index will have a higher chance of ride-sharing together. A numerical example was taken into consideration with three riders A, B and C. As \( M_{A/B} > M_{A/C} \), A has higher chances of ride-sharing with B than he has with C.

\[ \text{5.2 Future Research Directions} \]

Future work includes incorporating more preferences and model estimates to give a good estimation. Data can be collected on larger scale for the analysis and estimation. Improvement in calculation of matching index can be done like getting different weights for different factors while calculating aggregated matching index and also we can have some way to validate matching index.
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