A Portfolio Theory of Route Choice (TRB 12-3941)

David Levinson and Shanjiang Zhu

Abstract: This study introduces an individual route choice model where choosing a portfolio of routes instead of a single route is the best strategy for a rational traveler who cares about both journey time and lateness when facing stochastic network conditions. It differs from previous individual route choice models which may have incorporated travel time variability as a decision factor, but are typically still deterministic in the sense that the optimal strategy requires choosing one particular route that maximizes utility. The proposed model is then tested with GPS data collected in metropolitan Minneapolis-St. Paul, Minnesota. Our data suggest strong correlation among link speed when analyzing morning commute trips. There is no single dominant route (defined here as a route with the shortest travel time for a 15 day period) in 18% of cases when links travel times are correlated. This paper demonstrates that choosing a portfolio of routes could be the rational choice of a traveler who wants to optimize route decisions under variability.

Model:
Objective: \( \text{Min } U = E(p't) \)
\[ \text{s.t. } \text{Var}(p't) \leq \sigma_c \]
\[ \sum_i p_i = 1 \]
\( p_i \in [0,1] \forall i \in N \)

where: \( p' = (p_1, p_2, \ldots, p_n) \) is the vector of route choice probabilities.
\( t' = (t_1, t_2, \ldots, t_n) \) is the vector of link travel time, where each member is a stochastic variable.

Figure 1: The morning commute route diversity among 95 subject during 3 weeks. Percentage indicates share of distance which may differ without routes still being considered “different”. Data were collected by in-vehicle GPS devices during September, 2008 for a study focusing on route choice behavior before and after the reopening of I-35W Mississippi River Bridge in Minneapolis.

Figure 2: Optimal strategy under different travel time reliability criteria in the case of one OD pair linked by two parallel routes.

1. Any \( p_1 \) is feasible and optimal is achieved at \( p_1 = 1 \).
2. There is no feasible \( p_1 \) that satisfy \( \text{Var}(p't) < \sigma_c \).
3. \( p_1 \) is feasible in \([0, p_c]\) and optimal is achieved at \( p_1 = p_c \).
4. \( p_1 \) is feasible in \([p_c, p_2]\), and optimal is achieved at \( p_1 = p_2 \).

Figure 3: Normal probability plot of home-to-work travel time observations for one subject during 13 weeks.

Statistical test shows that travel time for the majority (77%) of all 95 subjects follow normal distribution.

Figure 4: Comparison between observed mean route travel time and predicted mean route travel time under two assumptions:
1) Link travel time of all links along a route is IID;
2) Link travel time of all links along a route is perfectly correlated. Under either assumption, for a significant number of travelers, no single route dominates in both travel time and travel time variability. In those cases, the portfolio theory could predict a mixed strategy for daily route choices.

The authors would like to acknowledge Michael Paul, Minnesota. Our data suggest strong correlation among link speed when analyzing morning commute trips. There is no single dominant route (defined here as a route with the shortest travel time for a 15 day period) in 18% of cases when links travel times are correlated. This paper demonstrates that choosing a portfolio of routes could be the rational choice of a traveler who wants to optimize route decisions under variability.