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Time, Cost, and Reliability in Traffic Assignment

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Call for papers on Approaches to Modeling Traveler Response to Road Pricing

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Introduction

Anticipated travel time, cost, and reliability affect a traveler's decisions. In traditional four-step models, the link travel times determine route choice, and the inter-zonal times are fed back into trip distribution and mode choice. In models which have been enhanced for use in the analysis of pricing options, a "generalized cost" assignment procedure is used to convert tolls and other forms of road pricing into equivalent additional time, using the traveler's Value of Time. After the equilibrium assignment under the generalized cost conditions, the time and cost of travel can be separated for use in Mode Choice and Benefit Cost Analyses.

Until now there has been little data or analysis which could be used to model how the reliability of travel times can affect the traveler's decisions. In analyzing various pricing options, it is important to know what trade offs travelers will make between travel time, cost, and reliability. In future activity-based models, where trips are parts of longer tours, the reliability of travel times will become increasingly important.

Methodology

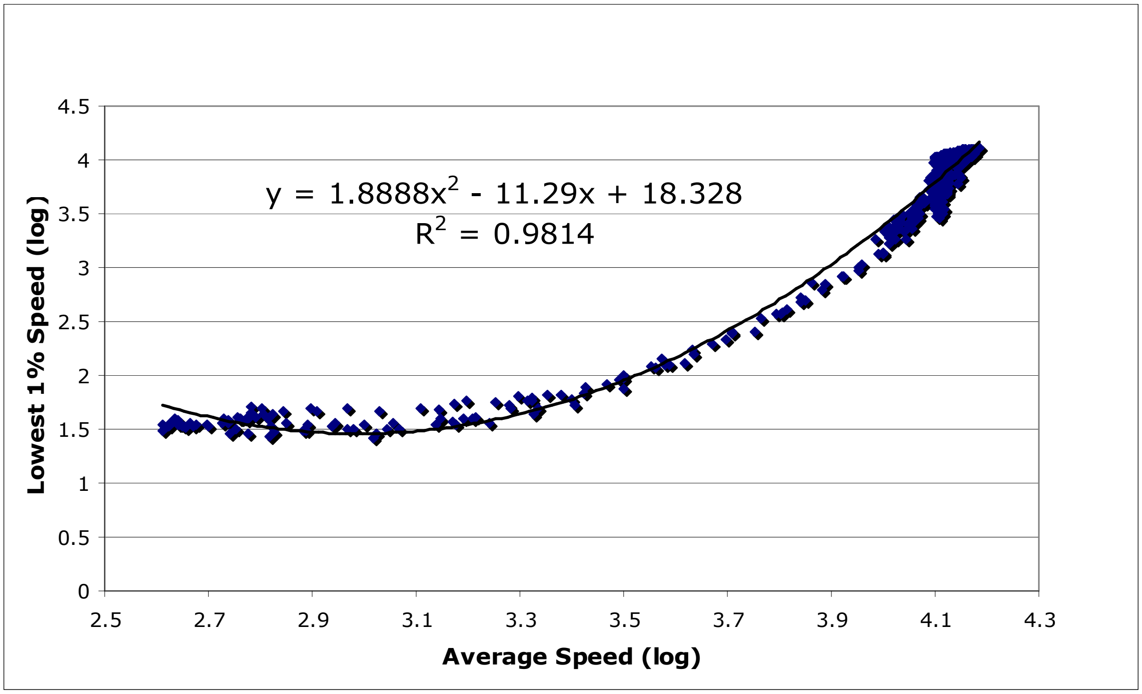
Utility maximization and discrete choice methods were applied in psychology and econometrics before they were adopted in modeling travel behavior. An approach to analyzing reliability can also be found in econometric studies. Over several decades dealers in stocks, commodities, and insurance have developed methods for translating variability about a mean into a "value of certainty." For example, what amount (called a "put option") would a buyer be willing to pay for the option to purchase, at a future time, a stock at its current price? This amount can be calculated from knowledge about the variability of the stock price around its mean.

As applied to travel on roads, this method of analysis calculates, for a given facility, an "absolute certainty" speed which is equivalent in the traveler's mind to traveling on that same facility at a higher speed with some positive risk of encountering a lower speed. For example, a traveler might be willing to trade travel on a congested freeway with an average speed of 45mph and a positive probability that the speed might drop much lower, for travel under different conditions with an absolute certainty of maintaining an average speed of 40mph. In just-in-time shipping, reliability of travel times can be more important than the times themselves.

Analysis

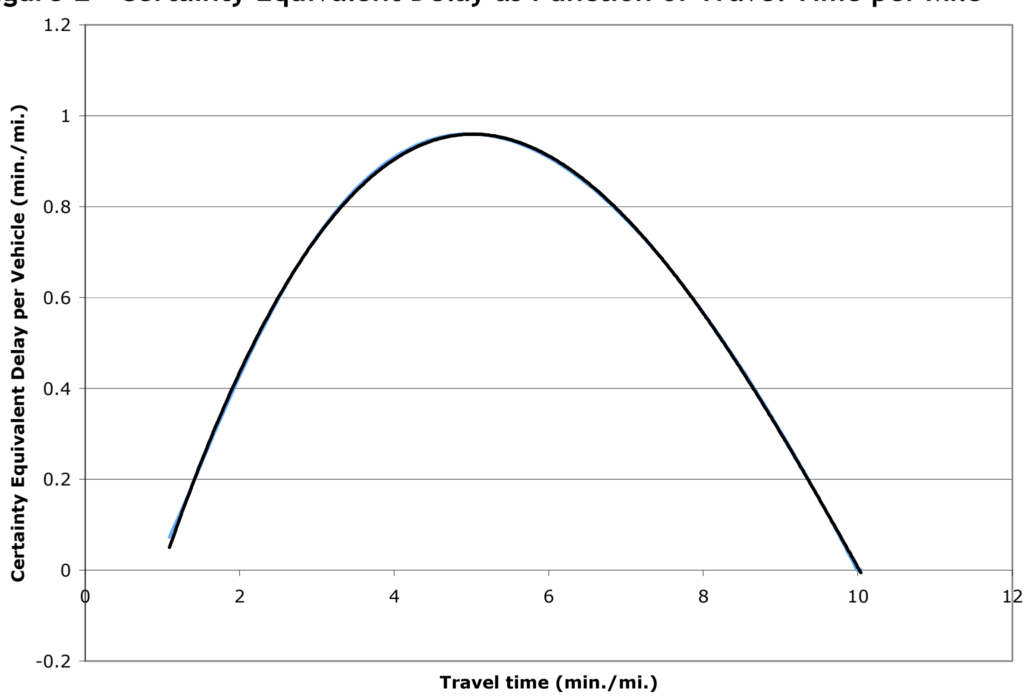
The data for this analysis already exist. For many years the Washington State DOT has collected five-minute vehicle counts and speeds at many locations on the region's highway network. The Puget Sound Regional Council hired EcoNW to analyze a subset of the data for the "certainty-equivalent value of unreliability." The analysis compared the lowest 1% speeds with the mean speeds at several locations for hundreds of time periods. Figure 1 clearly shows the relationship between (the logs of) the 1% and mean speeds at one particular location.

Figure 1 – Lowest 1% Speed (log) vs. Average Speed (log) – I-405 @ I-90, SB



EcoNW applied the certainty equivalence methodology to determine a function, using travel time per mile instead of speed, which relates the equivalent added minutes-per-mile (from the lower "absolutely certain speed") to the mean congested travel speed (such as that calculated within the travel demand model). Figure 2 is a graph of the resulting fourth degree function.

Figure 2 - Certainty Equivalent Delay as Function of Travel Time per Mile



Because all the data used in this analysis are from freeway sensors, the results apply only to freeways. One can see from this graph that at 60mph (1 min./mi.) there is virtually no Certainty Equivalent Delay. That is, if the freeway is flowing at an average speed of 60mph for a specified time period, then on any given day there is near certainty that the speed will be 60mph. At the other end, when the freeway is flowing at an average speed of 6mph (10 min./mi.) for a specified time period there also is no Certainty Equivalent Delay. On any given day there is little probability that the freeway will flow any slower. Between 30mph (2 min./mi.) and 7mph (8.5 min./mi.) the Certainty Equivalent Delay is above 0.4 min./mi., with the maximum (nearly 1 min./mi.) occurring at about 12mph (5 min./mi.).

Future Application

Because reliability characteristics may vary from one facility to another, ideally the coefficients for the Certainty Equivalent Delay function should be determined independently for each facility. The Puget Sound Regional Council is currently investigating the impact of including a term for the Certainty Equivalent Delay in the function used for calculating delay on a link. Accounting separately for reliability in the model will allow consideration of reliability along with cost and travel time in Mode Choice, and more widely in Benefit Cost Analyses.