1. INTRODUCTION

This paper proposes a stochastic congestion and pricing model that combines a bottleneck model with stochastic queuing to study road-way congestion and pricing. Two pricing schemes are developed: [1] Omniscient pricing for which the transportation administrative agency is assumed to have full knowledge of each individual traveler’s complete cost structure (this specific valuation of J, E, L), and [2] observable pricing, for which only observable queuing delay is considered. Travelers are characterized by their late-acceptance level and the effects of various compositions of late-averse, late-tolerant, and late-neutral travelers on congestion patterns with and without pricing are explored.

2. PROPOSED MODEL

Bottleneck

• Immediately before the destination
• Travel time to the bottleneck randomly distributed
• Limited maximum queue capacity and deterministic service time
• Queuing delay: time-dependent Markov-Poisson process

N travelers

• Distinguished origins and one single destination
• Desired destination arrival time randomly distributed over a certain period of time
• Individual cost structure
• Characterized by different valuation towards journey time (J), early time (E), and late time (L)

Expected Total Cost

\[
C_t = \sum_{k=0}^{\infty} (J_k + E_k + L_k) P_k
\]

Pricing Scheme

• Omniscient Pricing
  • Time dependent congestion fee that requires knowledge of individual traveler’s complete cost structure (his specific valuation of J, E, L)

• Observable Pricing
  • Time dependent congestion fee requires the knowledge of observable queuing delay only

3. NUMERICAL SIMULATION

Simulation Scenario (with and w/o pricing)

• Double truncated normal distributed travel time from origin to bottleneck
• Departure time between 14:00-16:00pm
• Desired arrival time uniformly distributed between 15:00~15:15
• Total number of travelers 30
• Bottleneck max queuing capacity 15
• Travelers differentiated by their late-acceptance level
  E > L (late-tolerant), E = L (late-neutral), E < L (late-averse)

Simulation Results

4. SUMMARY

• Omniscient pricing is most effective in suppressing peak hour congestion
• Congestion pricing is more effective when travelers have diverse cost structures
• Congestion is better reduced with heterogeneous travel composition than with single composition
• Omniscient pricing generally reduces social costs (with and without return of revenues)
• Ultimate benefits of a pricing scheme depend on traveler cost structure as well as the composition of late-averse, late-tolerant and late-neutral travelers