Deploying Electronic Tolls

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Abstract

This paper examines issues around deploying electronic toll collection (ETC) and develops a model to maximize social welfare associated with the toll plaza. A payment choice model estimates the share of traffic using ETC as a function of delay, price, and a fixed cost of acquiring the in-vehicle transponder. Delay in turns depends on the relative number of ETC and Manual Collection Lanes. Price depends on the discount given to users of the ETC Lanes. The fixed cost of acquiring the transponder (not simply a monetary cost, but also the effort involved in signing up for the program) is a key factor in the model. Once a traveler acquires the transponder, the cost of choosing ETC in the future declines significantly. Welfare, which depends on the market share of ETC, includes the delay and gasoline consumption incurred by travelers, the costs to the toll agency, and the social costs such as air pollution accruing to society. Finding the best combination of ETC Lanes and toll discount maximizes welfare. Too many ETC lanes cause excessive delay to non-equipped users. Too high a discount costs the highway agency revenue needed to operate the facility. The model is applied to California’s Carquínex Bridge. We conclude by recommending the pace of deployment of ETC on the bridge in terms of the number of dedicated ETC lanes and the appropriate ETC discount.
Introduction

- How quickly should manual toll lanes be converted to electronic toll collection?
- Should users of ETC be given a discount, and if so, how much?
- Resistance to adopting ETC by users: Is it fixed? Does it depend on exposure? Or is it random
- Dynamic optimization required, simple enumeration not feasible.
Network Growth Process

- Technology Level
- Vehicle
- Infrastructure

Time
ETC: Benefits and Costs

- Users
  - Time,
  - Money,
  - Fuel

- Agency
  - Staff Savings,
  - Installation Costs

- Community
  - Pollution Savings
Payment Choice and Disposition

- Logit Model,
- \( U_e = f(\text{Time, Cost, Disposition}) \)
  \[ = \alpha_0 + \alpha_1 T_e + \alpha_2 M_e \]
  \[ = -3.08 - 0.3T_e \text{ (min)} - 1.03 M_e ($) \]
- Disposition of “Manual” population changes over time.
  - Confidence
  - Learning
  - Opportunities to Choose
  - Background Effect
Survival Model

- Irreversibility Assumption: All ETC users stay with ETC, except those who move
- Manual users reassess annually
- 16% of population of ETC users does not survive, they are replaced by new (manual) users who are pooled with old manual users.

\[
S_{e,n} = S \cdot S_{e,n-1} + (1 - S \cdot S_{e,n-1}) \cdot \frac{\exp\left\{-3.0828 - 0.3(T_e - T_m) - 1.034(M_e - M_m)\right\}}{\exp\left\{-3.0828 - 0.3(T_e - T_m) - 1.034(M_e - M_m)\right\} + 1}
\]
ETC Share as Survival Rate Varies

Assumptions:
\( \alpha_0: -3.0828 \) in year 1, 0 in year 20
constant decreasing
\( \alpha_1: -0.3 \quad \alpha_2: -1.0340 \)
value of time: $17.41/hr-vehicle
capacity rule: myopic
changing survival rate
original model: survival rate = 84%
ETC Share as Optimization Rules Vary

As assumptions:

- $\alpha_0$: -3.0828 in year 1, 0 in year 20 constant decreasing
- $\alpha_1$: -0.3
- $\alpha_2$: -1.0340
- value of time: $17.41/hr-vehicle
- survival rate: 84%
- progressive optimization rule
Net Benefits

Net Present Value of Different Groups over the 20 Years under different Optimization Rules

- 4-year
- 3-year
- 2-year
- myopic

Assumptions:
- $\alpha_0$: -3.0828 in year 1, 0 in year 20 constant decreasing
- $\alpha_1$: -0.3, $\alpha_2$: -1.0340
- value of time: $17.41/\text{hr-veh}$
- survival rate: 84%
Conclusions

- Conversion of manual toll collection to ETC is inevitable, its pace is unclear.
- Rate of opening lanes drives adoption of transponders by users.
- To be successful: supply must lead demand, marketing is required.
- Myopic decisions will lead to a slower pace.
- Research questions on “reluctance” term.