Toll Feasibility Analysis and Toll Diversion Modeling

North Carolina Model Users Group
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Presentation Overview

- Focused on Toll Modeling in a Regional Setting
- Toll Feasibility Analysis Levels
- Past Practice / Emerging Needs
- Technical Issues
- Applications - CUBE Voyager Features
TOLL FEASIBILITY ANALYSIS

Analysis Level

- LEVEL 1
- LEVEL 2
- LEVEL 3

Complexity / Depth

- Conceptual Feasibility (Off-Model / Sketch Analysis)
- Preliminary Feasibility (Latest Model & Assumptions)
- Investment-Grade Feasibility (Extensive Modeling / Detailed Verification of Travel Patterns)
ANALYSIS PROGRESSION

ANALYSIS COMPLEXITY

HIGH

LOW

MANY

FEW

NUMBER OF ALTERNATIVES

SKETCH PLANNING

TRAFFIC SIMULATION MODELING

TRAVEL DEMAND MODELING
TOLL FEASIBILITY ANALYSIS TECHNIQUES

• Three Levels of Toll Feasibility Analysis
  – Level 1 – Sketch Methods or readily-available models
  – Level 2 – Models with some enhancements
    • Zone system
    • Additional Data (counts, socioeconomic data revisions)
  – Level 3 – Models / Investment Grade
    • Surveys – Stated Preference / Origin-Destination
    • Independent Assessment of Socioeconomic Forecasts
    • Extensive Validation & Sensitivity Testing
ANALYSIS ISSUES

• Significant Variation in Estimates by Analysis Level
  – Potential Discontinuous / Conflicting Results
• Sketch Method Limitations for Addressing Emerging Policies
  – Congestion Pricing
  – Complex Tolling Schemes
AGENCY REQUIREMENTS

- Near-Term Implementation of Multiple Projects
  - Significant Project Interaction
- Projects in Various Stages of Approval/Design
  - Conceptual Stage Projects
  - Conversion of Existing Improvement Projects to Toll Roads
- Variation in Tolling Concepts
  - By Project Type
  - Variation in Tolling Policy by Agency
MODELING APPROACH

• Adopt Regional Model – With Enhancements
  – Additional Detail / Zonal Disaggregation

• Retain Existing Procedures
  – Trip Generation
  – Trip Distribution
  – Mode Choice

• Utilize Advanced Highway Assignment Process
  – Reflect Travel Conditions by Time of Day & Market Segment
  – Provide Robust Toll Diversion Process
BENEFITS

• Utilizes Approved MPO Model
  – Facilitates Agency Approval
• Consistent Platform for Multiple Projects
• Sensitive to Availability of Competing Services/Policies
  – Transit Options
  – Land Use Policies
• Facilitates the Analysis of Projects Advancing Through Feasibility Levels
PAST PRACTICE / EMERGING NEEDS
TOLL DIVERSION PROCESS FOR TYPICAL REGIONAL MODEL S

- Function of Highway Assignment
  - Equilibrium Based
  - Single 24-Hour assignment
  - Toll Diversion Estimated Via “Equivalent Time” Penalties
  - Suitable / Consistent with Uniform Tolling Policies
Limitations

- Provides only a “generic” estimate of congestion based on a daily assignment.
- Estimates sensitive to minor changes in network conditions.
- Assumes that all travelers evaluate time savings equally (equal “Value of Time”).
- Assumes equal tolls for all time periods & payment types.
EMERGING TOLL POLICY REQUIREMENTS

• Potential Tolling Policies
  – Variation by Payment Type
  – Variation by Frequency
  – Variation by Agency / Operator

• Use Restrictions
  – Restrictions by Payment Method
  – Restrictions by Vehicle Type

• Variation in Pricing
  – Time of Day Pricing (Peak/Off-Peak/Weekend)
  – Congestion Pricing
POTENTIAL TOLLING POLICIES

• Variation by Payment Type
  – Cash
  – Transponder
  – Video Tolling

• Variation by Frequency
  – Commuter / Frequent Use Discount Plans
  – Restricted by Payment Method

• Variation by Agency / Operator
  – Multiple Agencies / Payment Policies
TOLL FACILITY USE RESTRICTIONS

• Restrictions by Payment Method
  – ETC Only
    • Transponder Only
    • Transponder & Video Billing

• Restrictions by Vehicle Type
  – Auto Use
    • General Use
    • HOT Lane
  – Truck Use
    • Exclusive Truck Toll Roads
VARIATION IN PRICING

• Time-of-Day Pricing
  – Peak/Off-Peak Rates
    • Linked to Transponder Usage
  – Weekend Surcharges / Discounts

• Congestion Pricing
  – Pricing Based on Facility Usage
  – Pricing Based on Conditions of Competing Non-Tolled Roadways
OTHER ISSUES INFLUENCING DIVERSION

• Diversion Sensitive to Traveler Characteristics
  – Income
  – Trip Purpose

• Traveler Biases
  – Dislike Toll Roads
  – Favor Electronic Toll Collection

• Market Segmentation
  – Travelers Acceptance of New Tolling Mechanisms
CRITICAL QUESTIONS

• What Options Exist to Forecast Toll Diversion that are Sensitive to the Wide Array of Policy Issues and Traveler Characteristics?

• Can Methods be Developed to Yield Plausible and Consistent Results as Projects are Advanced through the Feasibility Analysis.
Toll Choice within Mode Choice
– Production-Attraction Methods provide mechanism to relate traveler characteristics such as income
– Responsive to policies that will alter mode usage (SOV vs. HOV)

Toll Choice within Assignment
– Capable of addressing wide range of toll conditions
– Internally consistent results
– Capable of forecasting dynamic pricing options
TECHNICAL ISSUES

LIMITATIONS

NEEDS

TOOLS

PROCESS
CHOICE – BASED PROCEDURES

- Choice Options:
  - Toll Choice as Part of Mode Choice Model
  - Toll Choice via a Route Choice Model

- Desired Feature
  - Simultaneous Choice and Assignment ensures consistency of results
EXTERNAL ROUTINE CONSISTENCY

- Under Either Method Feedback is Required
- Consistency not Assured
- Convergence Difficult under Certain Conditions
TYPICAL MODE CHOICE MODEL WITH TOLL CHOICE

Motorized Trips

Auto Trips
- Shared Ride
  - HOV2
  - HOV3+
    - Toll
    - NonToll
- Drive Alone
  - Toll
  - NonToll

Transit Trips
- Local Bus
  - Walk Access
  - Drive Access
- Express Bus
  - Walk Access
  - Drive Access

Drive Access

Walk Access
MODE CHOICE ISSUES

- Internal Consistency
- Practical Limits on Treatments of “Submode” Choices
- Threshold Issues
- New Mode Bias Cases
- Value of Time Estimates
CHOICE & ASSIGNMENT CONSISTENCY

- Requires Feedback between Mode Choice and Assignment.
- Constrain Toll Trips Estimated by Mode Choice to Utilize Toll Roads in Assignment.
- Consistency of Paths Skimmed for Mode Choice with Paths used for Assignment.
PATH CONSISTENCY ISSUES

Preload or Favored Path Implies $2.00

Choice Skim is $1.00

Toll Trips May be Assigned to Non-toll Paths
USE OF “CHOICE” SUBMODES

- Option of Submodes for Payment Types
  - Additional nesting of choices
  - Additional path-building for each payment option

Diagram:
- Drive Alone
  - Toll
  - No Toll
    - Cash
    - ETC
    - Video
Toll Choice Must Meet Certain Thresholds
- Must Save Minimum Time Amount
- Must Travel Minimum Distance on Toll Roads

Convenient Assumption

Some Conflict with Choice Theory

Causes “Cliff” effect where minor change in condition can result in a large reaction.
- 4.9 Minutes – 0 % Toll Diversion
- 5.0 Minutes – 20 % Toll Diversion
NEW MODE BIAS CASES

- Nested Mode Choice Models Influenced by the Number of Submodes Available
- Potential Illogical Results
  - Conversion of Existing Road to Toll Facility Introduces New “Mode”
  - New Mode Causes Unexpected Reduction in Other Modes such as Transit
VALUE OF TIME

• Mode Choice Models Use Common Value of Time for all Modes
• Tends to be 25%-40% of Wage Rate
• Does not reflect Higher Values associated with Route Choice (50+%)
ROUTE CHOICE PROCESS

PATH A-B

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<th>ROUTE</th>
<th>TIME</th>
<th>COST</th>
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<tbody>
<tr>
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<tr>
<td>NONTOLL</td>
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ROUTE CHOICE MODELS

- Assumes Toll Options Will not Impact the Selection of Travel Modes.
- Internal Consistency Issue
- Allows for the Development of Choice Functions and Parameters Specific to Auto Modes.
- Allows for Treatment by Market Segments, Similar to Mode Choice
POTENTIAL SOLUTION ??

SEQUENTIAL PROCESS

Route Choice

Highway Assignment

“EMBEDDED” ROUTE CHOICE MODEL

HIGHWAY ASSIGNMENT ROUTINE

ROUTE CHOICE SUBMODEL: PURPOSE/VEHICLE TYPE /PAYMENT TYPE
TOLL DIVERSION MODELING USING CUBE VOYAGER

“It’s All About the Tool Box”
BENEFITS OF VOYAGER FOR MODELING DIVERSION

- Voyager Highway Assignment Capabilities
  - Choice-Based Procedures Embedded within Assignment Process
  - Complex Modeling of Costs by Payment Type
  - Extensive Segmentation Possible
  - Integrate Traveler Characteristics (such as Income Levels)
  - Dynamic Toll Estimation
ADVANCED TOLL DIVERSION MODELING

- Enhanced Highway Assignment Process
  - Multiple “Time-of-Day” Assignments
    - Permits varying toll rates / usage options
    - Enhanced estimation of traffic delays
  - Customized Toll Diversion Procedure
    - Embedded Route Choice Submodels sensitive to payment methods and traveler characteristics.
    - Trip purposes have individual Values of Time
    - Permits separate treatment for cash, video, and ETC Patrons
    - Permits separate treatment by vehicle type (SOV, HOV, Truck)

- Dynamic Pricing Analysis
  - CUBE Voyager or CUBE Avenue Options
MULTIPLE TOLLING SCHEMES

• Defined by Agency and Plaza and/or Toll Road Distance

• Plaza locations Contain:
  • Toll Rates by Vehicle Type (SOV/HOV/Truck)
  • Payment Options (Cash /ETC/Video )
  • Frequent Use Discounts / Surcharges
  • Base – Maximum Value (congestion pricing)

• Distance-Based Systems:
  • Supports “urban/rural” variation
  • Used to Approximate Ticket-based Systems

• Entry-Exit Systems
MARKET SEGMENTATION TECHNIQUES

- Vehicle Types
- Trip Purposes
  - Separate Values of Time
  - Pricing Options
- Transponder Availability
  - Zone
  - Region
  - Purpose
TRAVELER CHARACTERISTICS

- Diversion for Some Purposes is a function of Income
- Requires knowledge of “home” zone income
- Solution:
  - Partition Purpose into Production → Attraction & Attraction → Production Movements
  - Utilize “Production” Zone to Reference Zonal Income Values.
TOLL DIVERSION MODEL STRUCTURE

\[ \text{Toll Share} = \left( \frac{1}{1 + e^U} \right) \]

Where:

- **Toll Share** = Probability of selecting a toll road
- **e** = Natural Logarithm
- **U** = “Utility” of Toll Route
- **Time}_{TR} = Toll road travel time in minutes
- **Time}_{FR} = Nontoll road travel time in minutes
- **Cost** = Toll in dollars
- **C}_{TR} = Constant for toll road bias
- **a,b** = Coefficients
TOLL SHARES – HBW

PURPOSE

TIME SAVINGS (MIN)

% TOLL SHARE

CASH

ETC
TOLL SHARE VS. TIME SAVINGS

Minimal time paths biased towards “NonToll” Choice
TOLL SHARE VS. COST

Minimal cost paths biased towards “Toll” Choice (assumed reliability)
CHOICE FUNCTIONS BY TIME/COST CONDITIONS

- Minimal Cost = $0.25
- Minimal Time Savings = 2 min
SEGMENTATION BY PAYMENT METHOD

- Establish the Market Segment of Vehicles by Mode Equipped with Transponders
- Allow Path-Building Process to Generate Paths Available by Payment Type.
- Route Choice Model Selects Best Set of Path Choices (toll & non-toll) for Each Segment.
ROUTE CHOICE PATH BY PAYMENT TYPE

- **Toll Road**: 5 min. & $1.00
- **Toll Road (ETC)**: 5 min. & $0.75
NON-TOLL PATH

Cash Toll Road

ETC only Toll Road

Non Toll Road
CASH-TOLL PATH
(CASH TOLL ROAD AND NON-TOLL AVAILABLE)
ETC-TOLL PATH
(ALL ROUTES AVAILABLE)
DYNAMIC TOLL ESTIMATION

- Potential Approaches:
  - Adjusted Toll Cost based on Volume/Capacity Ratio
    - Processed as part of “Link Adjust” Phase
  - Adjustment to Toll Cost based on Volume/Capacity of Adjacent Roadway Links
    - Processed with the “LinkLoop” Option
  - Either Method Can be Constrained if Necessary
SUMMARY DIAGNOSTICS

- Reporting Options:
  - Summarize Toll Diversion Statistics during Execution of Route Choice Submodel
  - Summarize Tolled Trips using Final Loaded Conditions
EXAMPLE OF DIAGNOSTICS

COST PER MILE - 2011 ISOLATION CASE
AM PEAK - CASH TOLL TRIPS

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<th>TRIPS</th>
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QUESTIONS ??