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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

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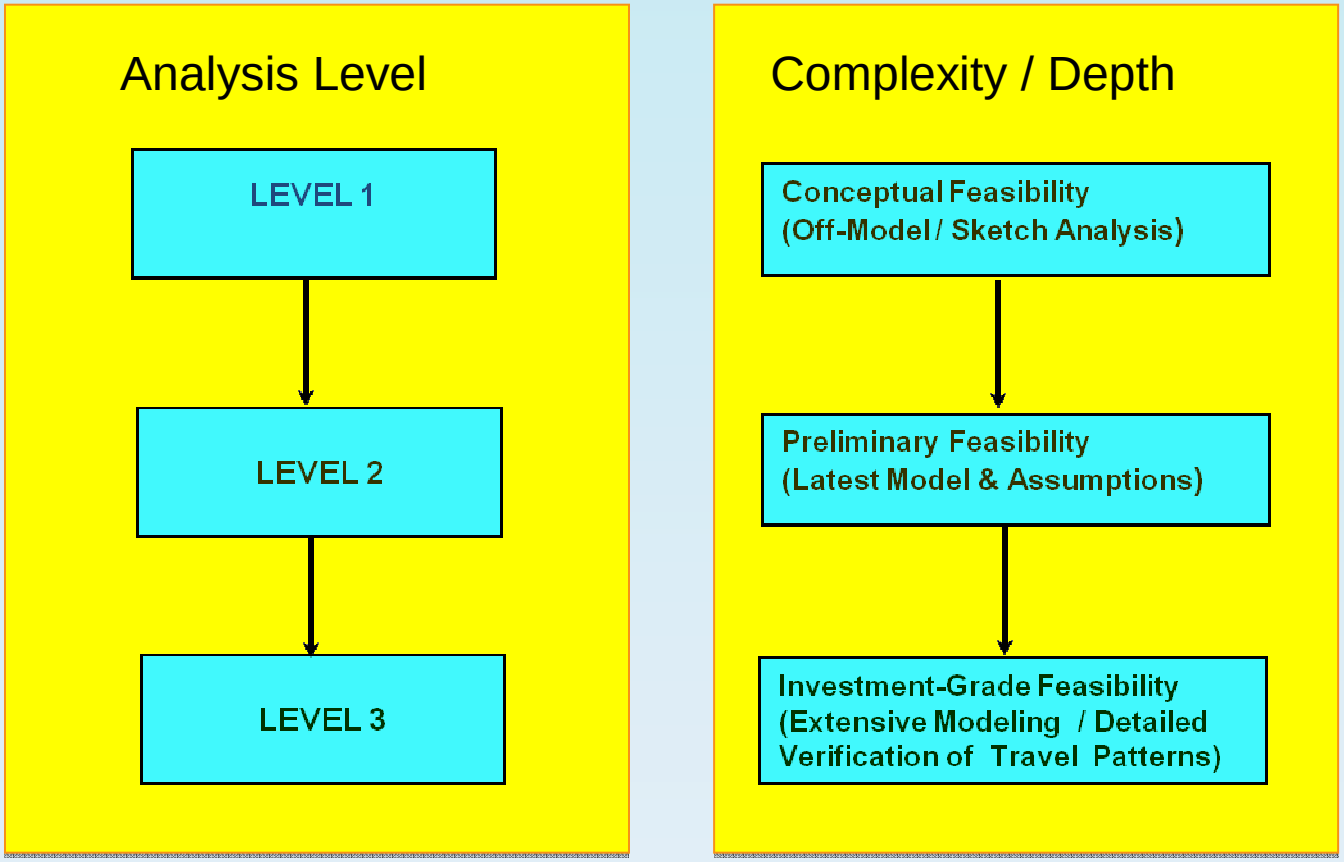
TOLL FEASIBILITY ANALYSIS



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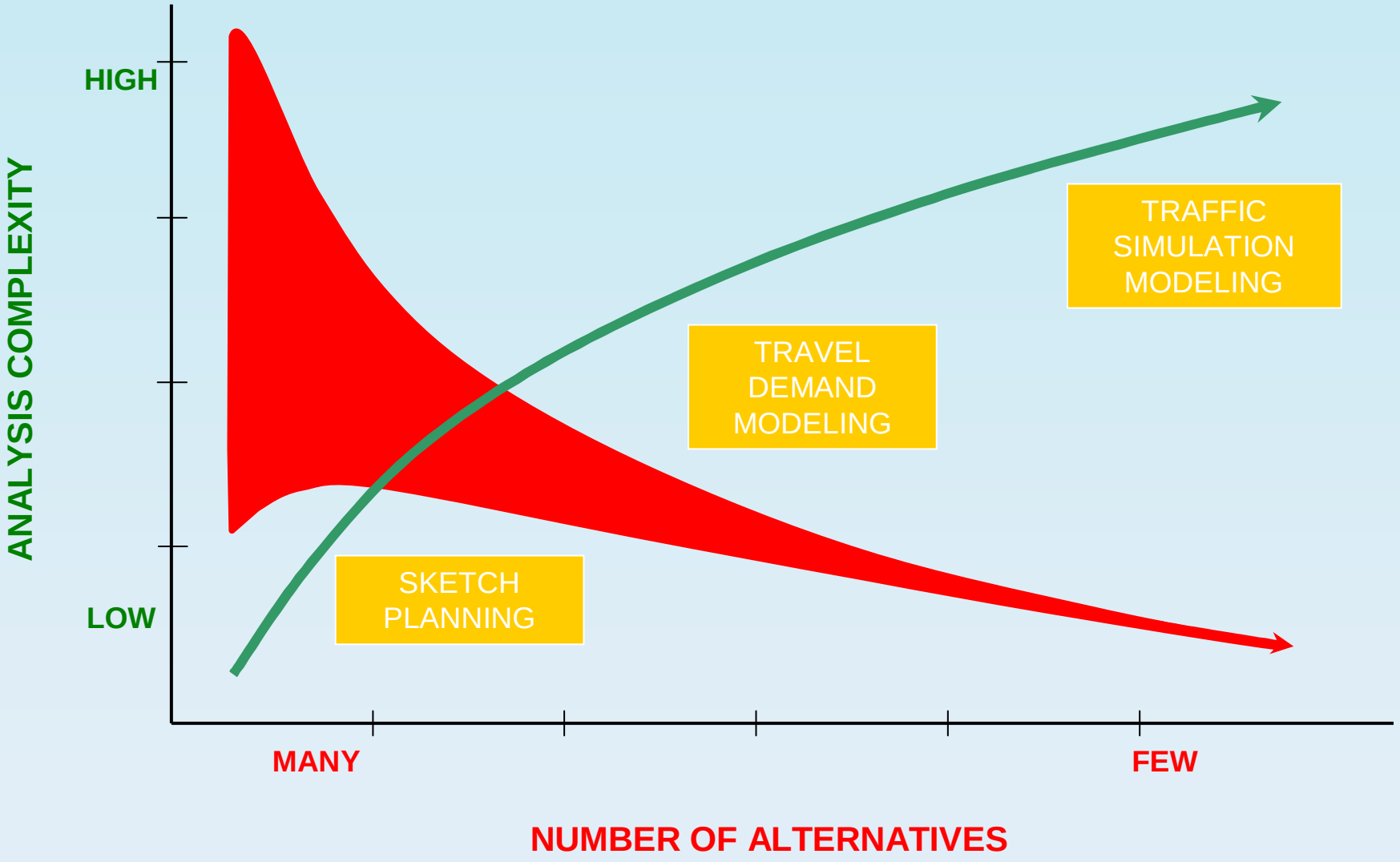
ANALYSIS PROGRESSION



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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

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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

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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

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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

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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

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PAST PRACTICE / EMERGING NEEDS

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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

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PREVIOUS TECHNIQUES

- 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

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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

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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

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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

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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

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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

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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.

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POTENTIAL DIVERSION FORECASTING TECHNIQUES

- 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

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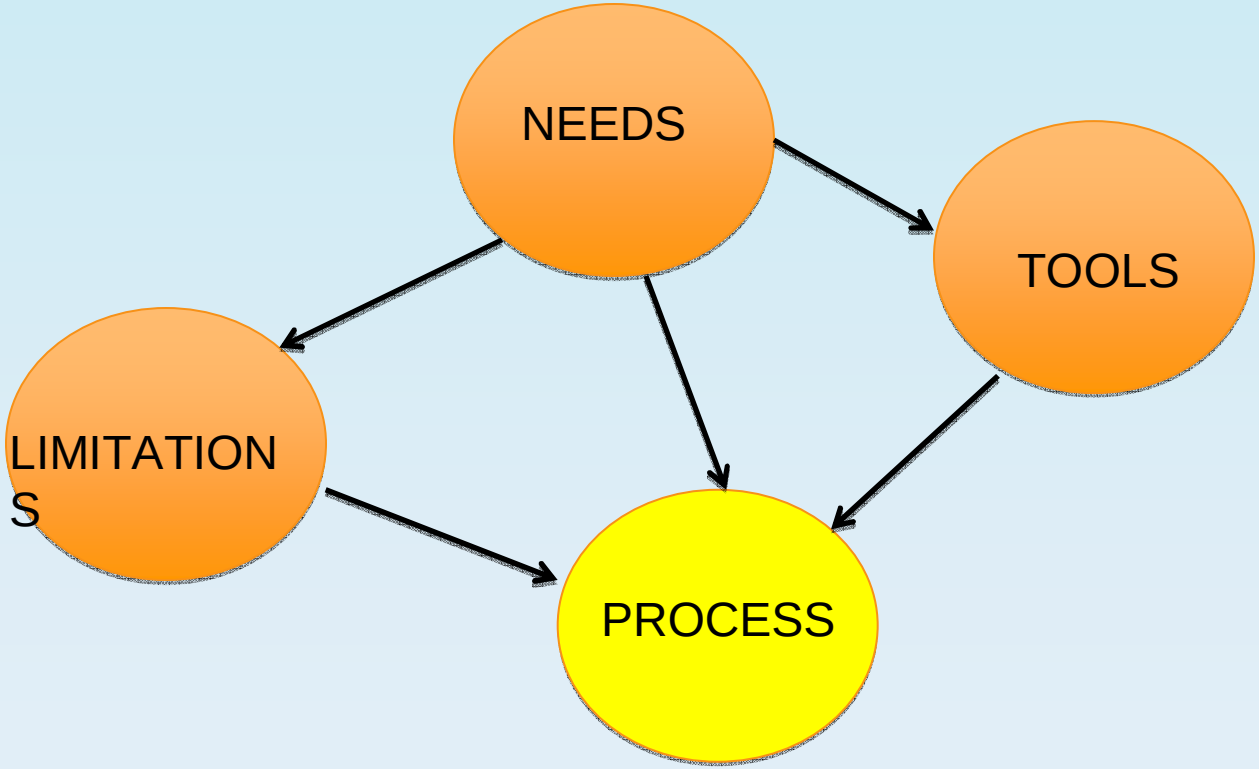
TECHNICAL ISSUES



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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

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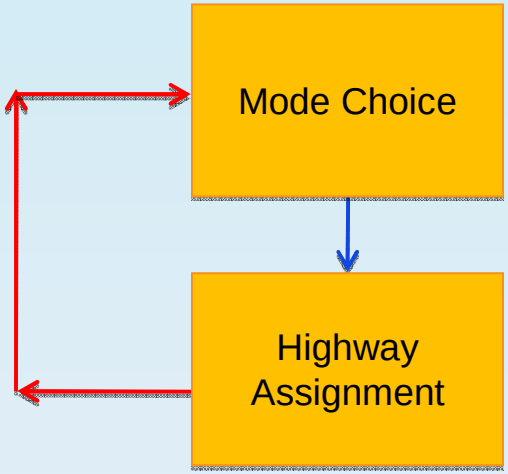
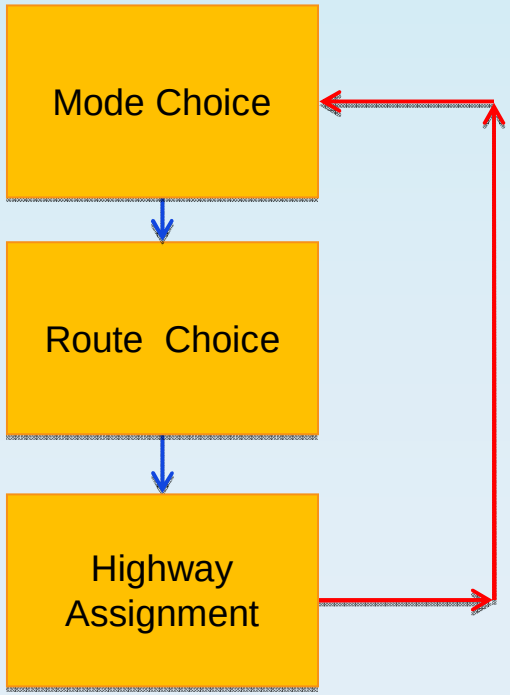
EXTERNAL ROUTINE CONSISTENCY

- Under Either Method Feedback is Required
- Consistency not Assured
- Convergence Difficult under Certain Conditions





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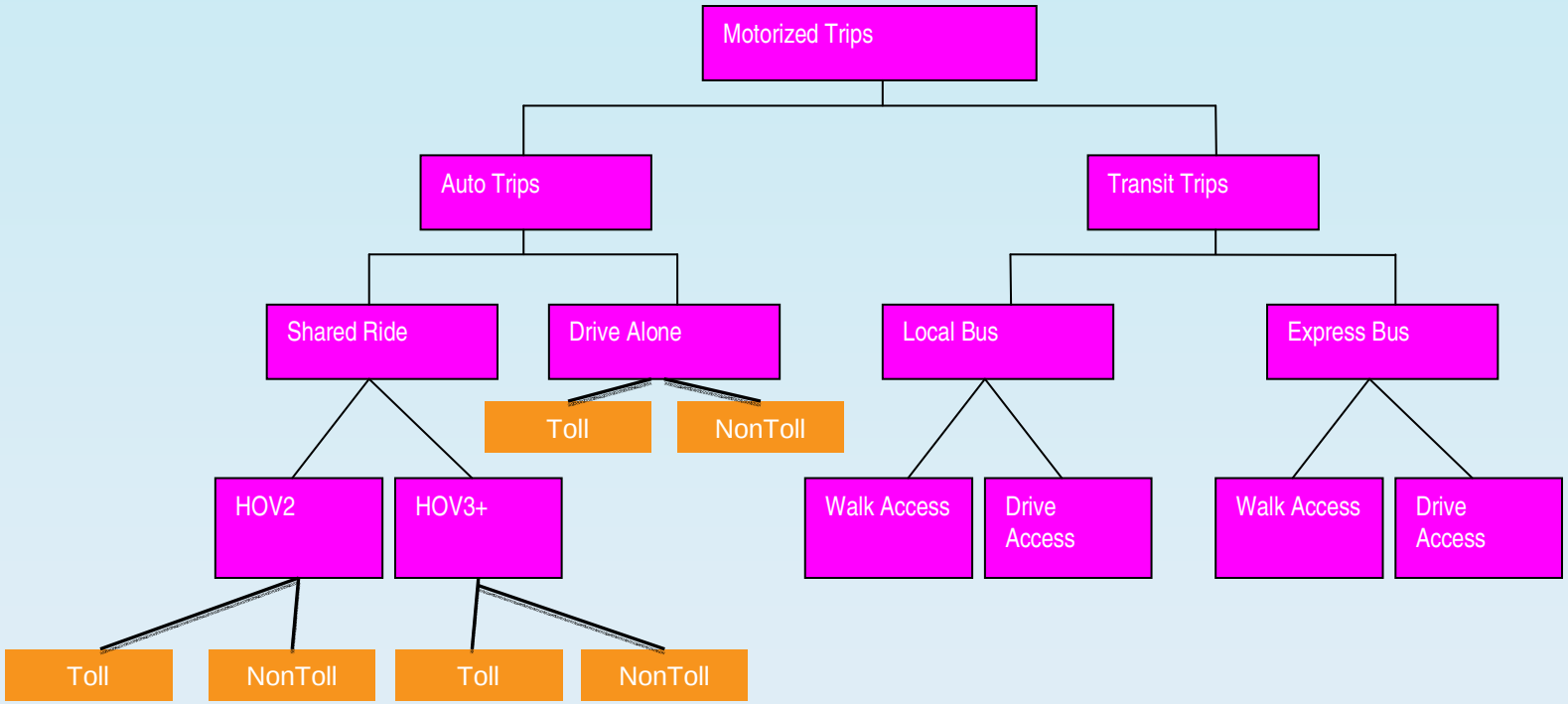
TYPICAL MODE CHOICE MODEL WITH TOLL CHOICE



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MODE CHOICE ISSUES

- Internal Consistency
- Practical Limits on Treatments of "Submode" Choices
- Threshold Issues
- New Mode Bias Cases
- Value of Time Estimates

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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.

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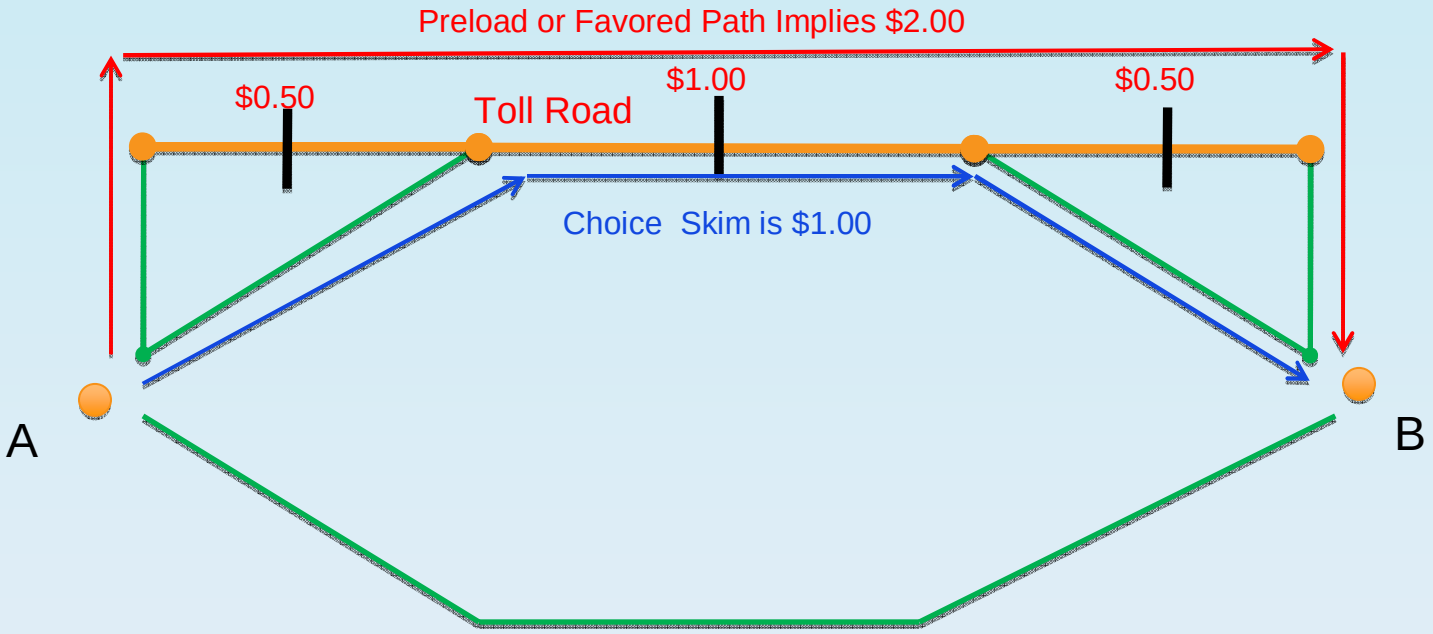
PATH CONSISTENCY ISSUES



Toll Trips May be Assigned to Non-toll Paths

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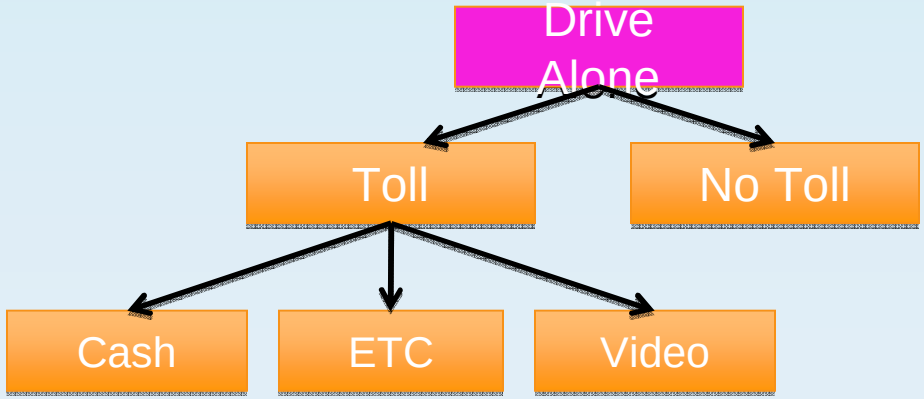
USE OF "CHOICE" SUBMODES

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



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THRESHOLD ISSUES

- 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

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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

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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+%)

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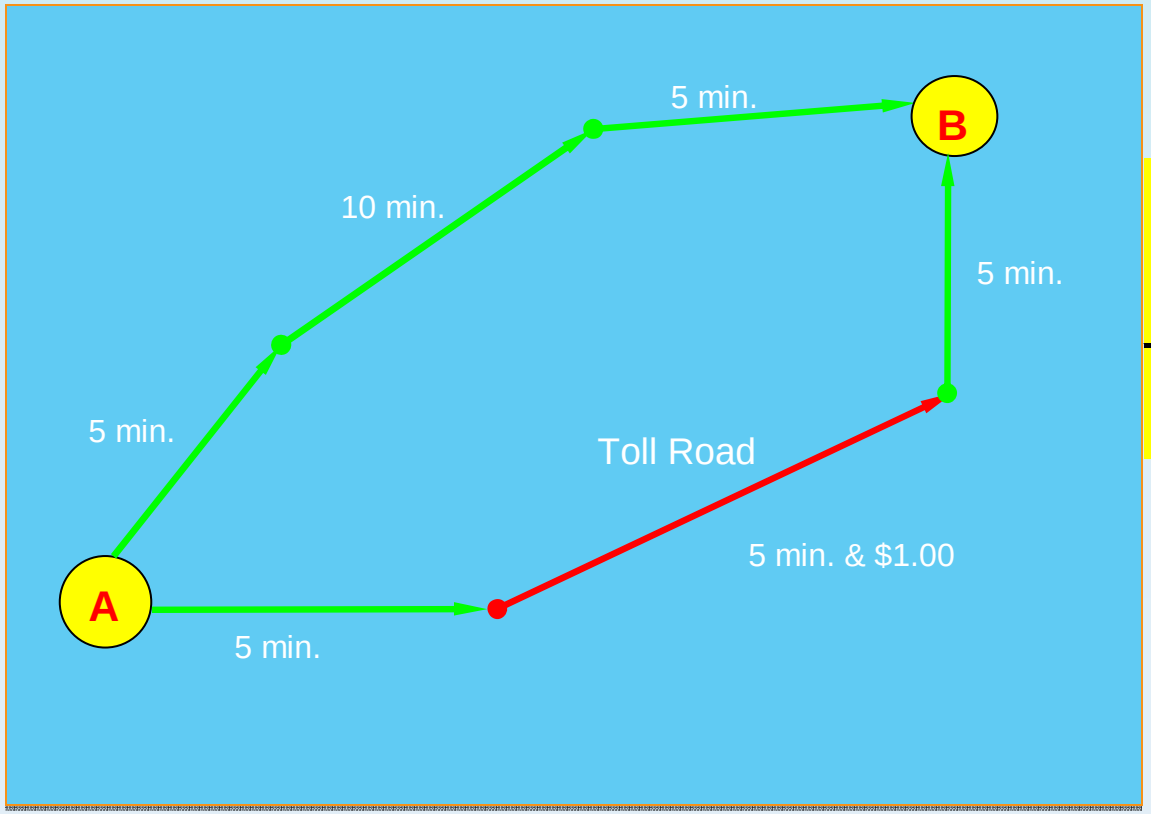
ROUTE CHOICE PROCESS



PATH A-B

ROUTE	TIME	COST
TOLL	15 MIN.	$1.00
NONTOLL	20 MIN	$0.00

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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

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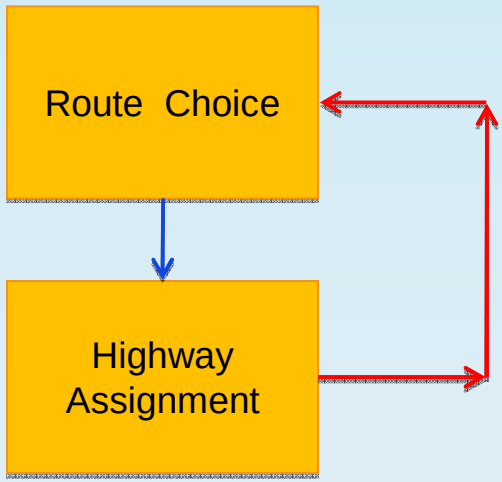
POTENTIAL SOLUTION ??

SEQUENTIAL PROCESS



"EMBEDDED" ROUTE CHOICE MODEL

HIGHWAY ASSIGMENT ROUTINE

ROUTE CHOICE SUBMODEL: PURPOSE/VEHICLE TYPE /PAYMENT TYPE

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TOLL DIVERSION MODELING USING CUBE VOYAGER

"It's All About the Tool Box"

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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

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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

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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

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MARKET SEGMENTATION TECHNIQUES

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

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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.

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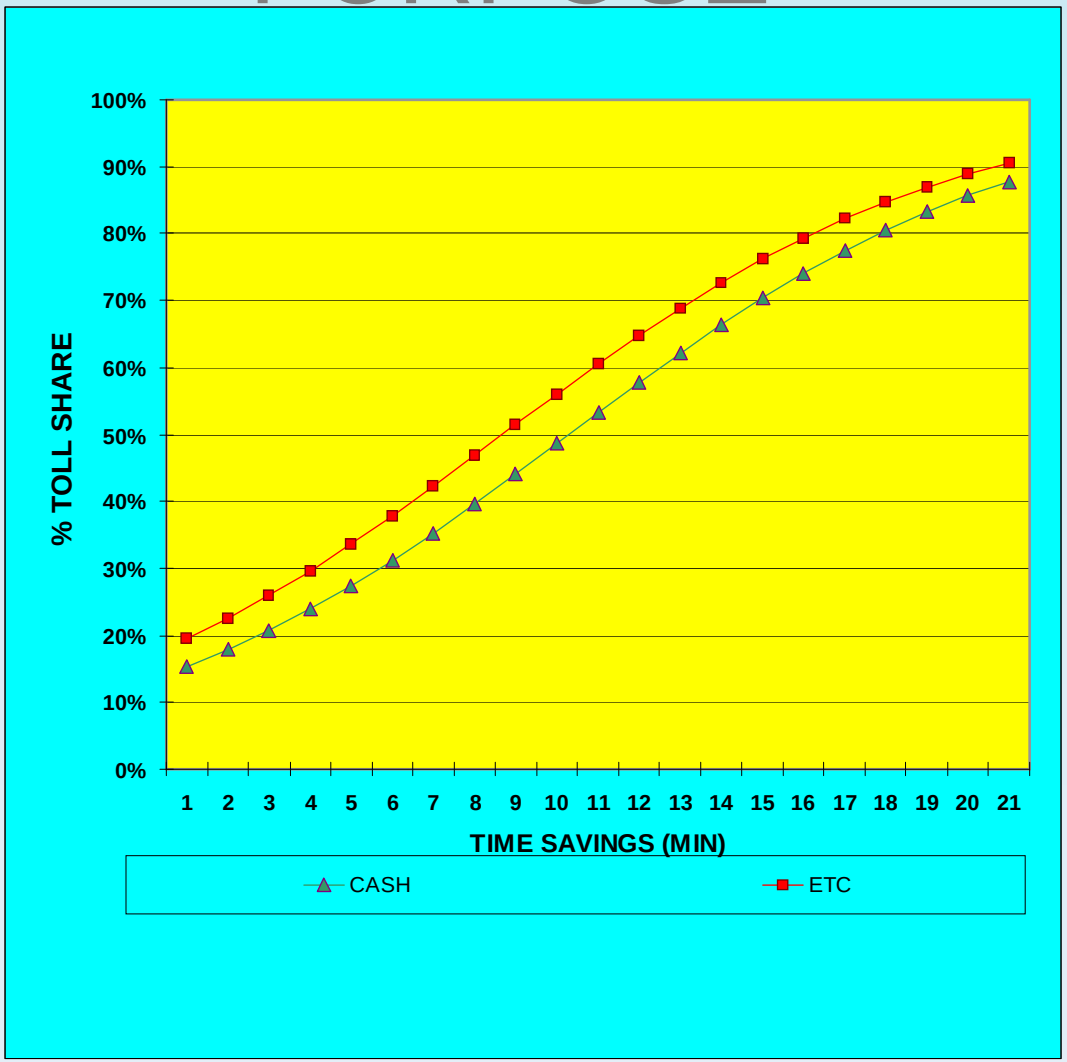
TOLL DIVERSION MODEL STRUCTURE

$$\textit{Toll Share} = (1 / (1 + e^{U}))$$

Where:

Toll Share	=	**Probability of selecting a toll road**
e	=	**Natural Logarithm**
U	=	**"Utility" of Toll Route**
		$a * (Time_{TR} - Time_{FR}) + b * Cost + C_{TR}$
$Time_{TR}$	=	**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



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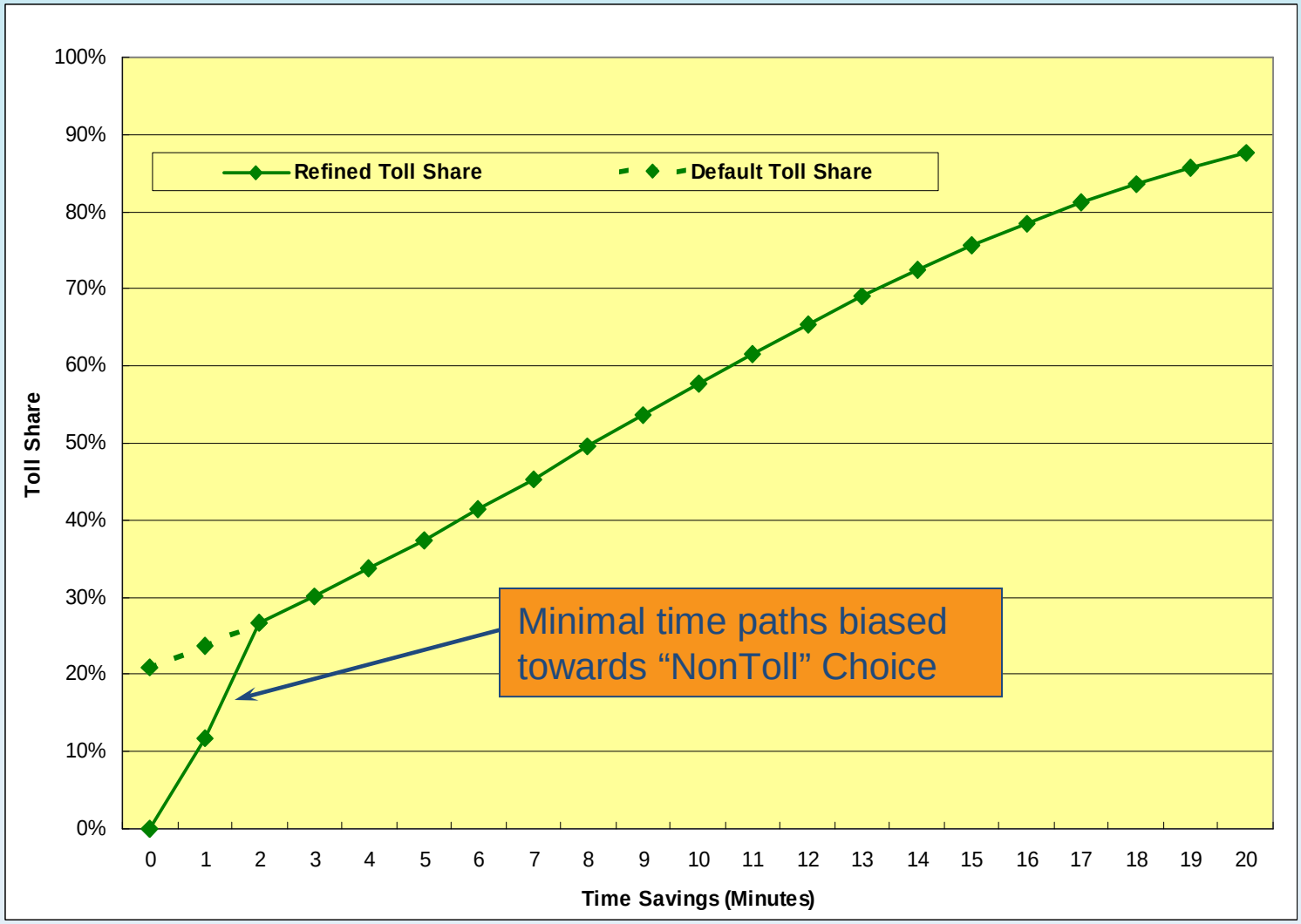
TOLL SHARE VS. TIME SAVINGS



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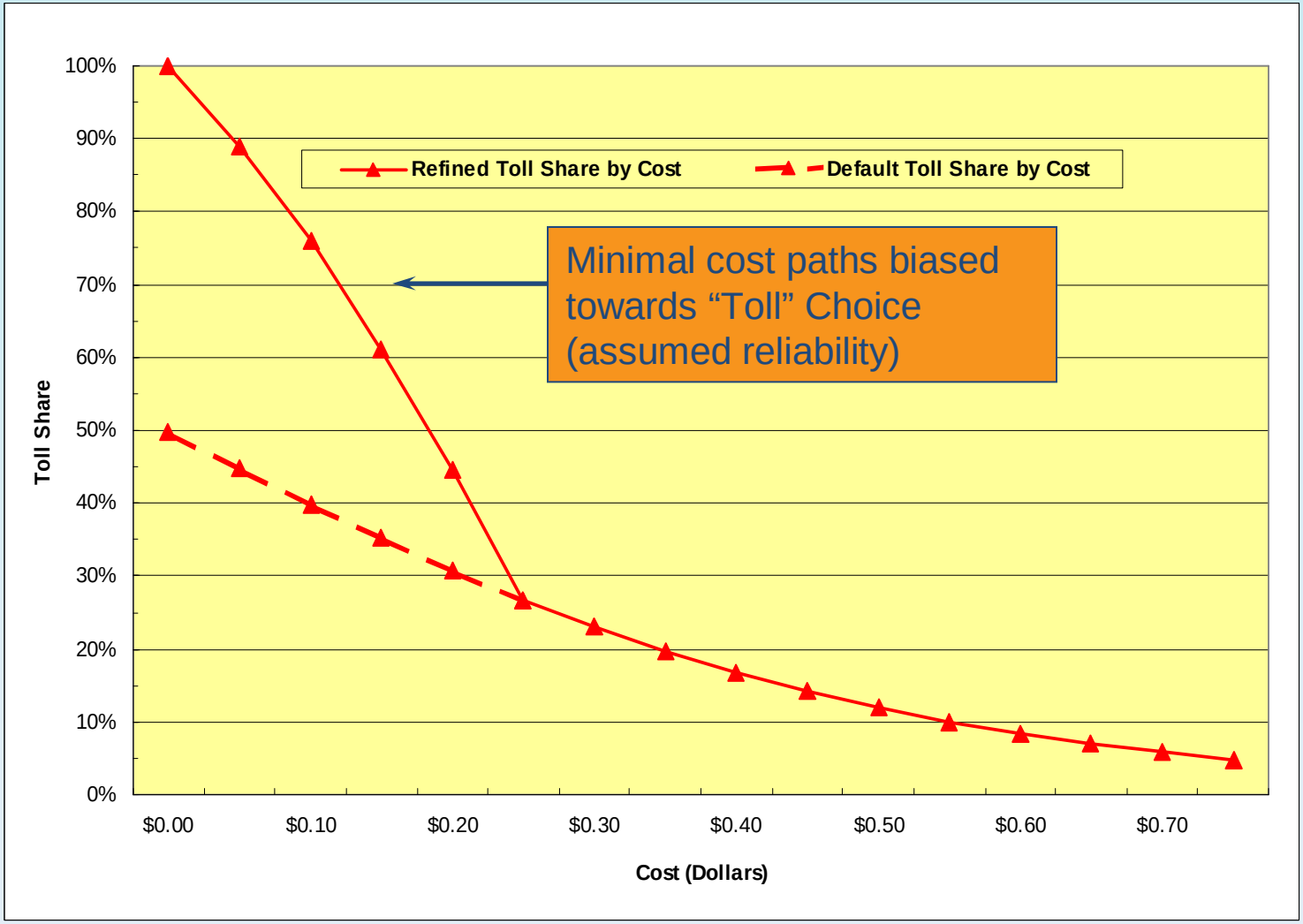
TOLL SHARE VS. COST



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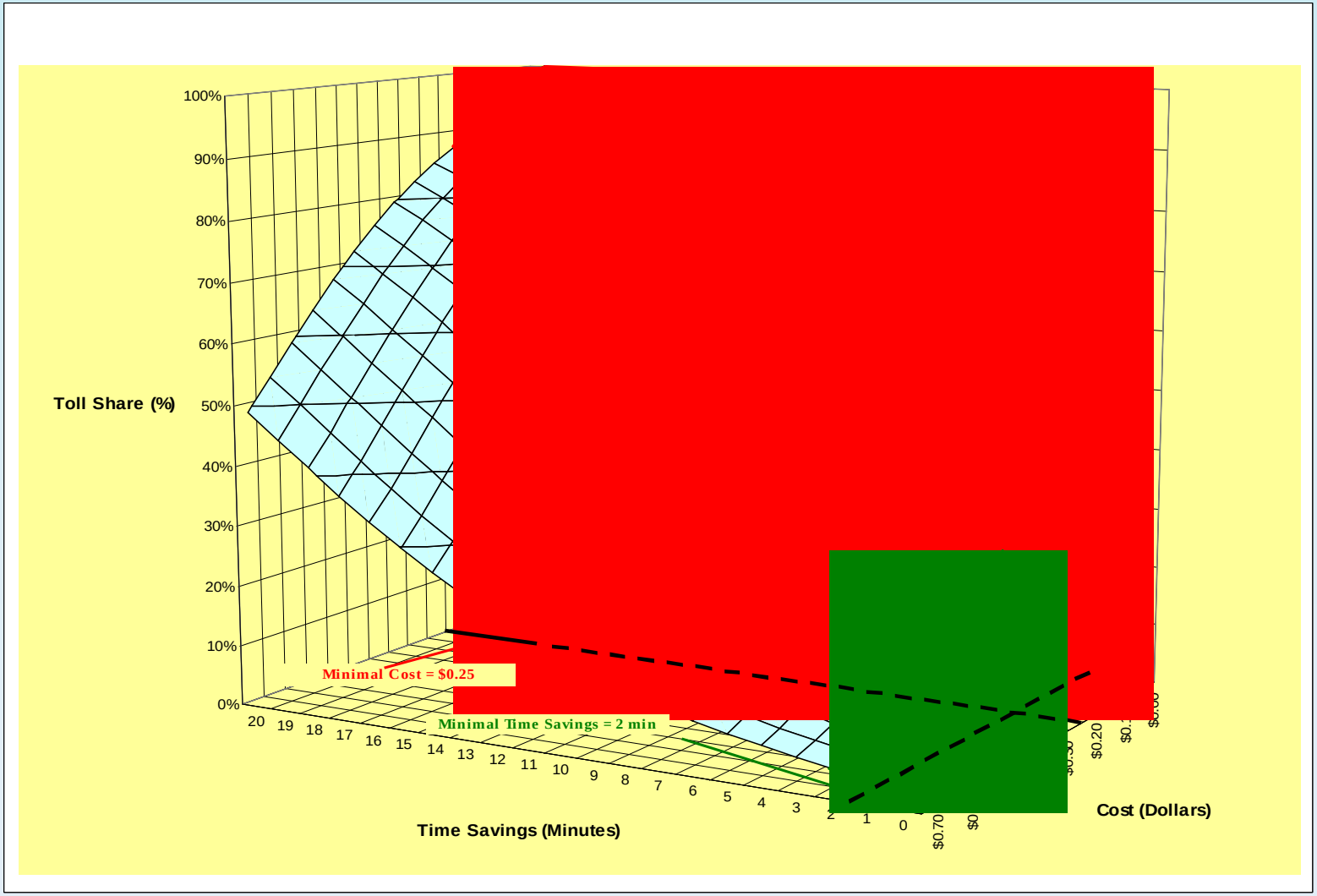
CHOICE FUNCTIONS BY TIME/COST CONDITIONS



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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.

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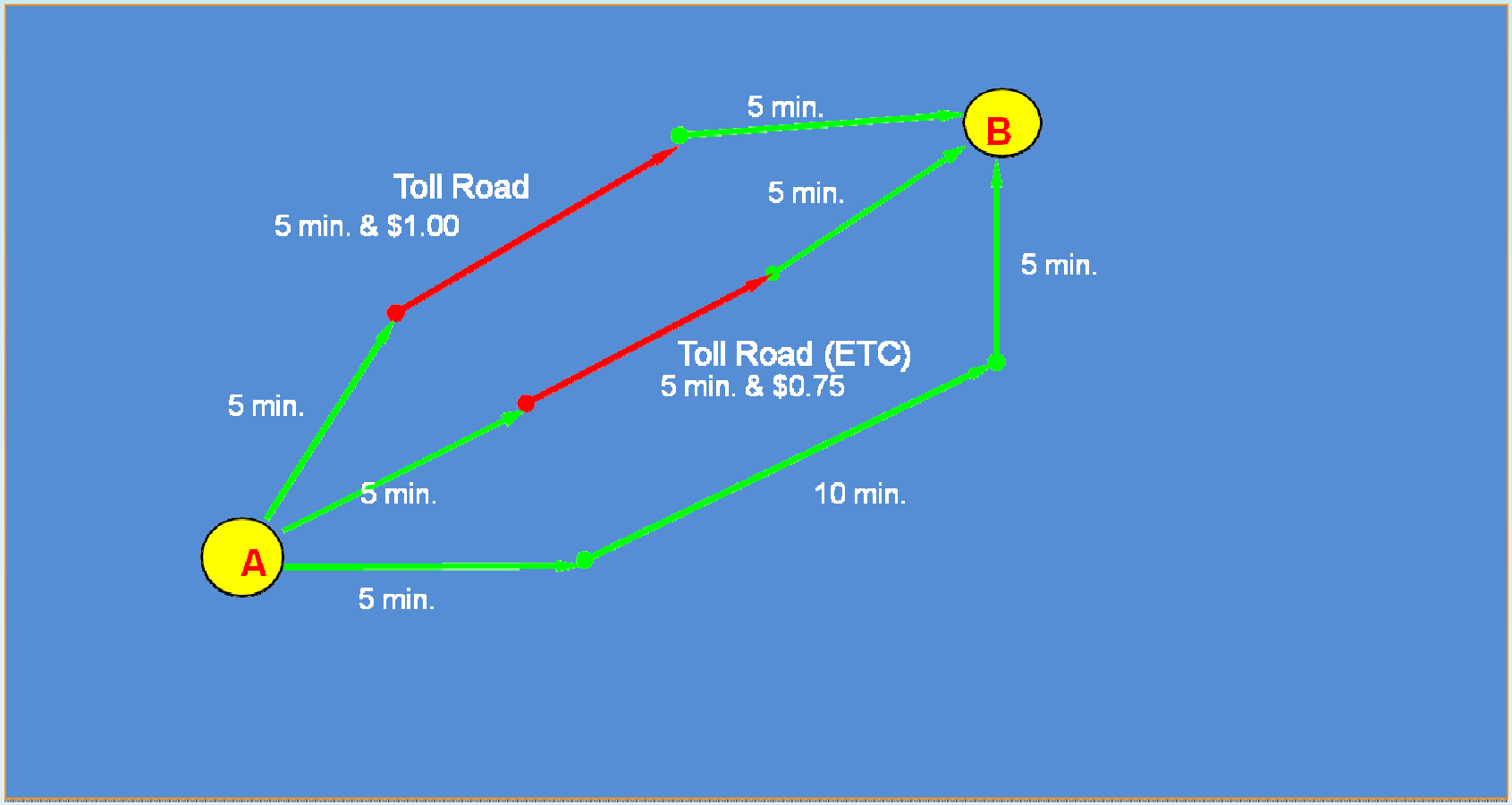
ROUTE CHOICE PATH BY PAYMENT TYPE



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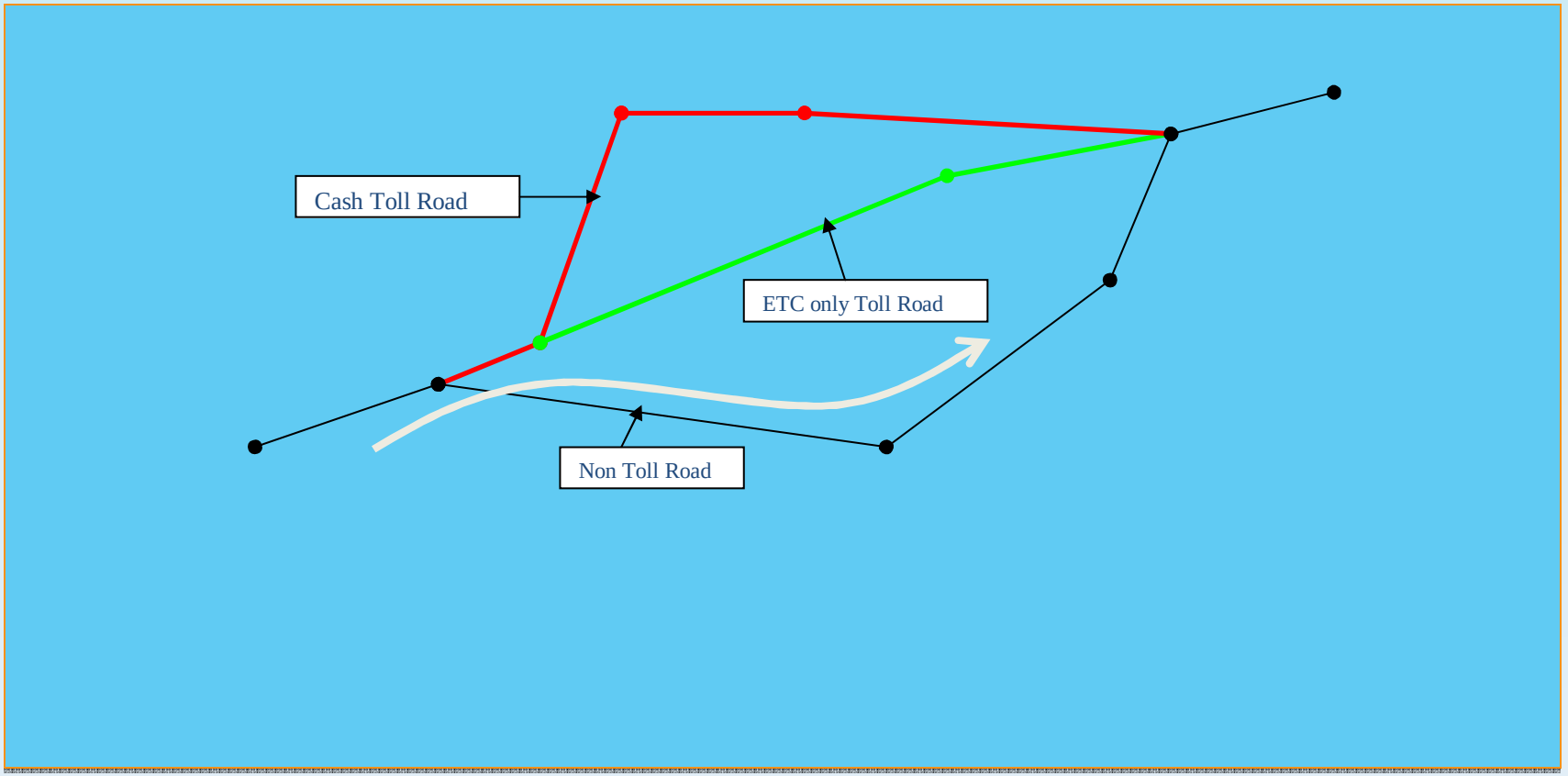
NON-TOLL PATH



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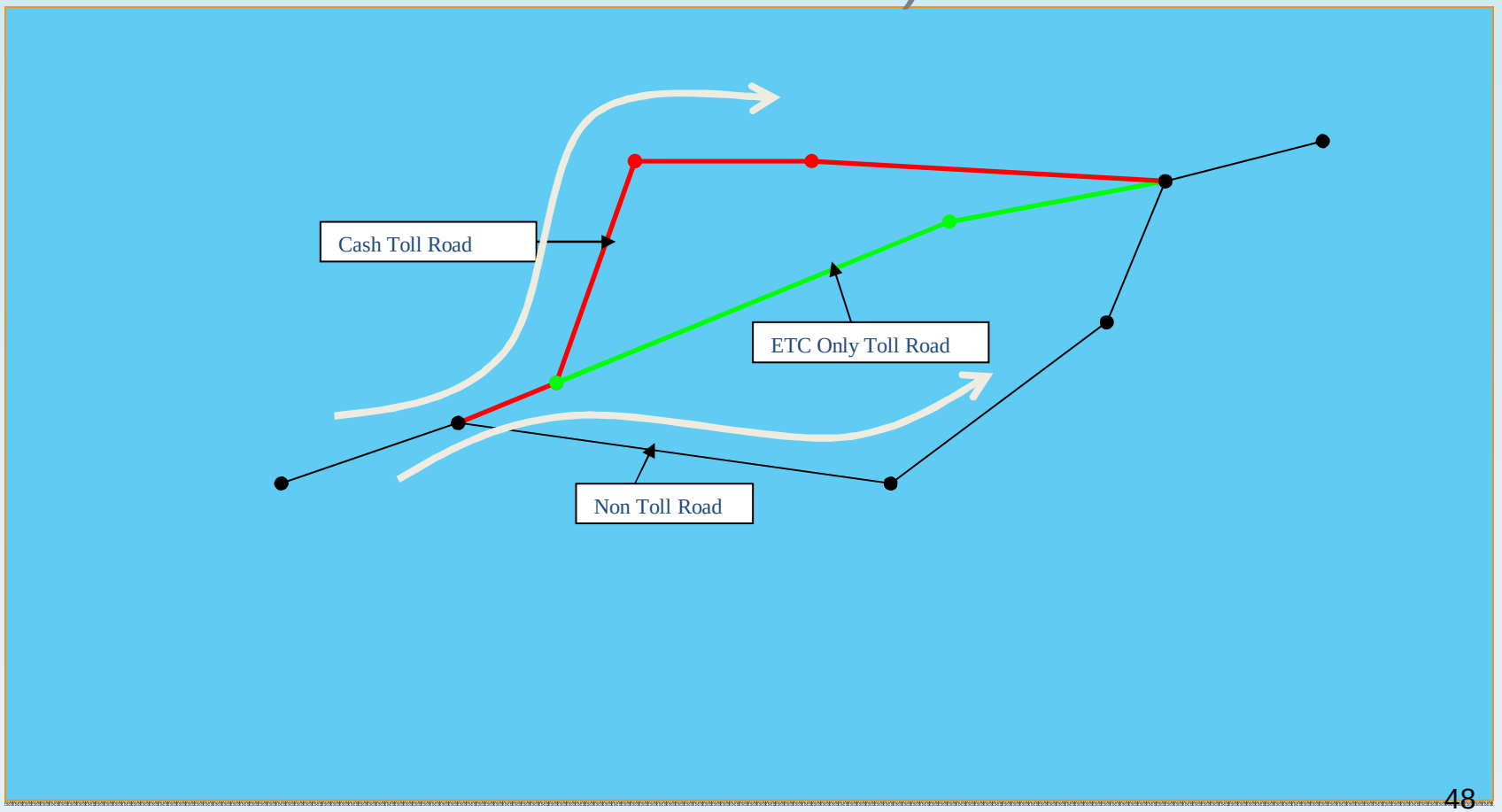
CASH-TOLL PATH
(CASH TOLL ROAD AND NON-TOLL AVAILABLE)



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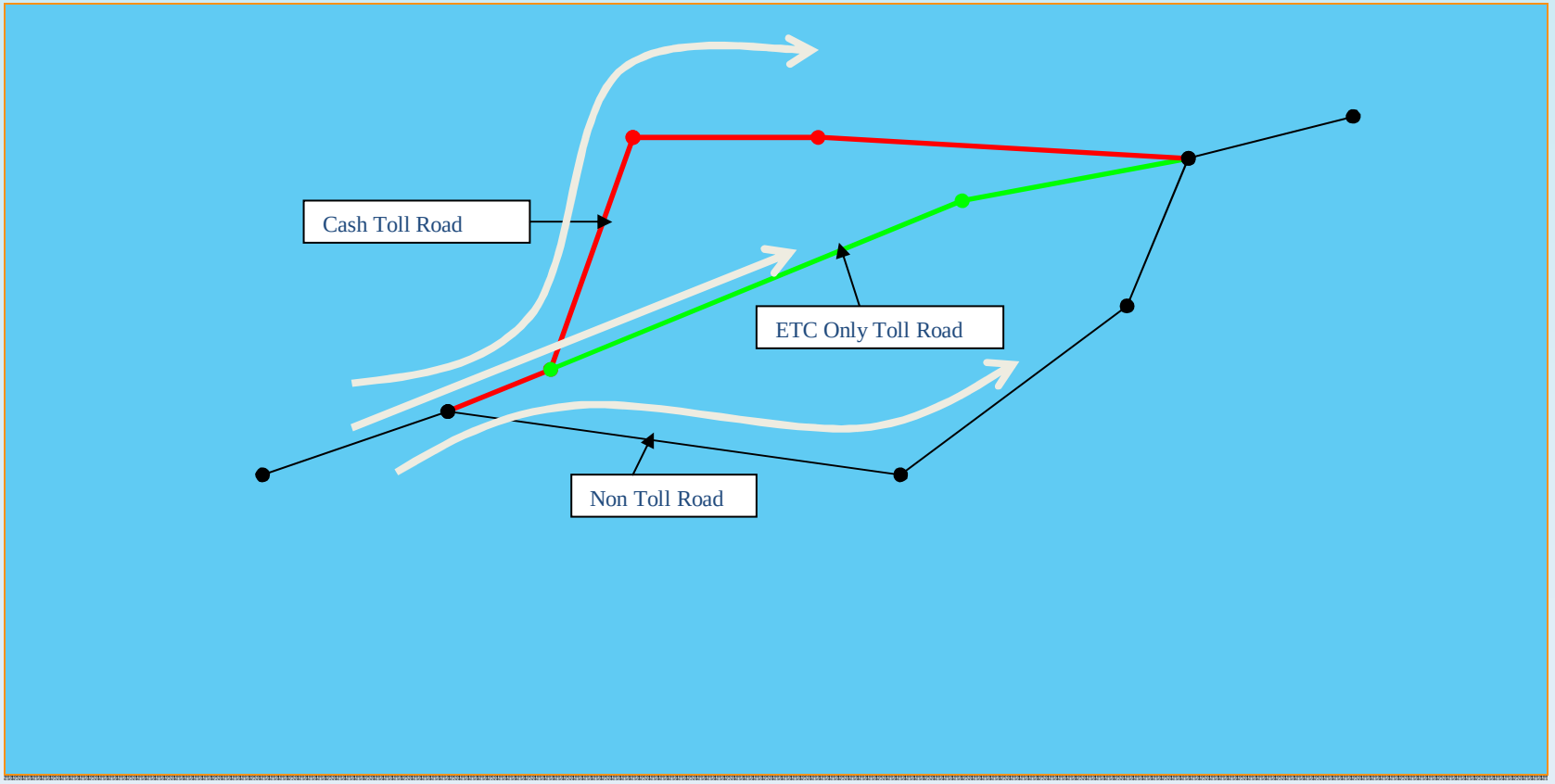
ETC-TOLL PATH
(ALL ROUTES AVAILABLE)



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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

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SUMMARY DIAGNOSTICS

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

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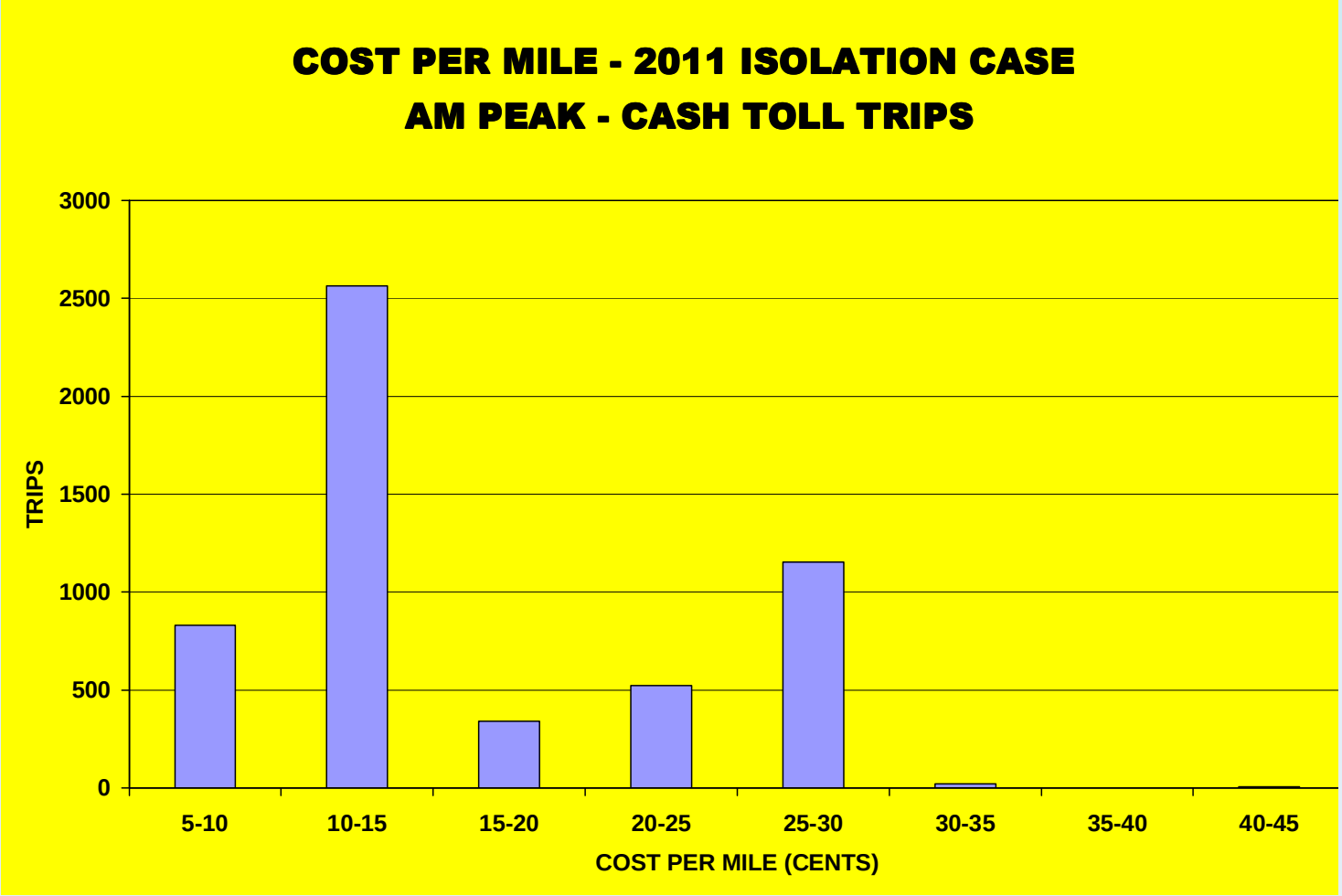
EXAMPLE OF DIAGNOSTICS



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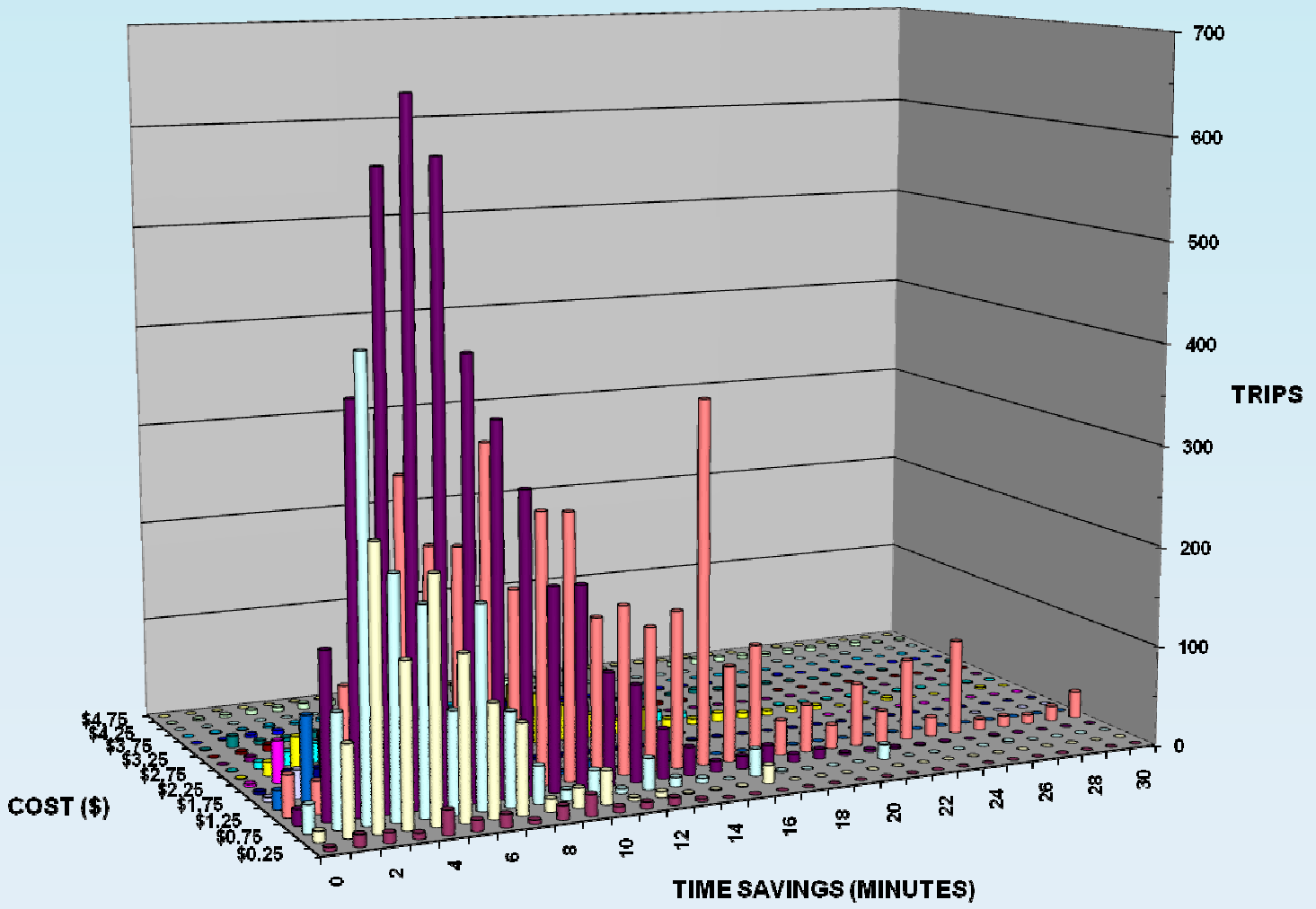
SOV TRIPS BY COST & TIME SAVINGS
San Antonio Loop 1604 Model Demo
2014 AM PEAK



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QUESTIONS ??