A **Toolkit** for Anticipating & Evaluating the Impacts of Roadway Improvements

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Outline

Part 1: Understanding the Toolkit

Motivation

- Transportation needs exceed available **funding**, nationwide.
- Engineers & planners need tools to quickly assess scenario impacts, **prioritize** potential projects, & compete for limited funds.
- TxDOT-funded research has developed a **Toolkit** to:
  - Anticipate **long-term project impacts**,
  - Evaluate & **compare multiple scenarios** in term of multiple performance measures
  - Enable **optimal allocation** of limited resources.
  - Be an **easy-to-use**, **quick-response** tool

Just *What* is this Toolkit?

The Project Evaluation Toolkit (PET)…

- Is a **quick-response**, computationally efficient tool that approximates full-scale planning model results, while providing a **comprehensive** picture of **project impacts**.
- **Impacts** include traveler **welfare, emissions, crash counts** (by type), travel time **reliability**, & **toll revenues**.
- To evaluate **many project types**, including road **capacity expansion** & road **pricing** (by mode and/or time of day), as well as many operations strategies (e.g., **ATIS**, **shoulder use**, **ramp metering**, **speed harmonization** & **incident mgmt**).
- Allows for **sensitivity analysis** (of all impacts, including **B/C ratios & NPVs**) using Monte Carlo simulation **& optimal multi-project budgeting**.

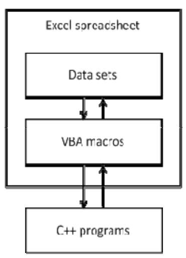
How does it work?

The Toolkit…

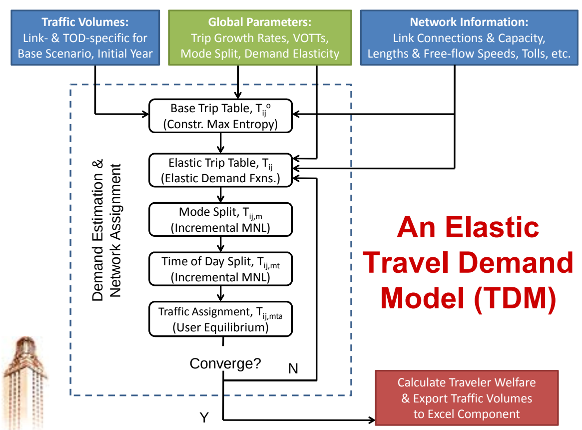
- Takes an **abstracted network & link counts** (the only ***absolutely necessary*** inputs) + region's mode & time-of-day (TOD) traffic shares (& other parameters);
- **Estimates a trip table** between all nodes using a maximum entropy-based optimization method;
- Applies **elastic-demand** functions on all OD pairs, **incremental logit** functions across modes & TODs, **multi-class, user-equilibrium traffic assignment** method to quickly equilibrate the new & old networks; &
- Estimates welfare changes at the O-D level – & crashes, emissions & reliability at the link level; then generates **summary measures** (NPV, B/C ratio etc).

Toolkit Software Design

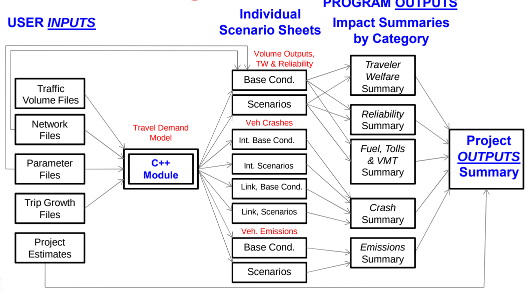
- **Software Modules**
  - ***Excel spreadsheet***: For data storage, manipulation, & visualization
  - ***C++ programs***: Travel demand estimation (estimating trip tables & network flow patterns across modes, times of day & routes)
  - ***VBA macros***: Data & parameter communication between Excel & C++ programs



An Elastic Travel Demand Model (TDM)



Data Flow Diagram



Note: Network Info & Global Parameters directly influence all Scenarios (including Base Conditions), across all Impact Categories. Data link flows are not shown here (to each Individual Scenario) to enhance diagram clarity.

O-D Trip Matrix Estimation (Base Scenario)

- **Maximize Entropy** of path-based O-D flow rates, subject to link flow rates equaling observed traffic counts.

$$\max\left(-\sum_{ij} x^{b}_{ij,t}\ln\left(x^{b}_{ij,t}\right) - x^{b}_{ij,t}\right) \qquad \forall t$$

$$s.t. \sum_{ij}\sum_{p} f^{b}_{ij,p,t}\,\delta^{a}_{ij,p} = \theta_{a,t} \qquad \forall a, t$$

- where $x^{b}_{ij,t}$ is the **flow rate** from **origin *i*** to **destination *j*** during TOD **period *t*** for the base case (***b***) scenario,
- $f^{b}_{ij,p,t}$ is the **path *p* flow rate** connecting OD pair *ij*,
- $\delta^{a}_{ij,p}$ is a **link-path indicator** (0 or 1) if **link *a*** is part of path *p*, and
- $\theta_{a,t}$ is the **measured link flow** on link *a* during TOD period *t*.

Convergence Criteria: $\sum_{ij}\frac{\left|x^{b,n+1}_{ij,t} - x^{b,n}_{ij,t}\right|}{x^{b,n+1}_{ij,t}} \Big/ \sum_{ij}\left|P_{ij}\right| < 0.0001$

O-D Trip Matrix Estimation (2)

- This ME problem is solved by using a modified version of the **Frank-Wolfe** algorithm with column generation:
- Step 0: Find a feasible initial O-D matrix ($x_{ij,t}$).
- Step 1: Find an auxiliary **matrix** ($y_{ij,d}$) by solving:

$$\min\left(\sum_{ij} y_{ij,t} \ln(x^{n}_{ij,t})\right) \quad s.t. \sum_{ij}\sum_{p} f_{ij,p,t}\,\delta^{a}_{ij,p} = \theta_{a,t}$$

- Step 2: Find optimal step size for $\theta \in (0,1)$.
- Step 3: Update solution: $x^{n+1}_{ij,t} = x^{n}_{ij,t} + \theta(y_{ij,t} - x^{n}_{ij,t})$
- Step 4: Test for convergence (& return to Step 1 till converged).

Travel Demand Pattern Estimation

- **Elastic O-D Demand**
  - Travel cost-dependent elastic O-D demand function.
  - Demand elasticities based on time of day.
  - Elasticities η_d for all times of day set at -0.69

$$\ln\frac{x^{k}_{ij,d}}{x^{b,k}_{ij,d}} = \eta_d \ln\frac{g^{k}_{ij,d}}{g^{b,k}_{ij,d}}$$

- **Mode Split & Time-of-Day Split**
  - Incremental logit model (next slide)
- **Traffic Assignment**
  - User-equilibrium traffic assignment (shortest paths)
- **Traffic flow-travel cost consistency**
  - Realized by Method of Successive Averages (MSA)

Incremental Logit Model

$$P^{k}_{ij,m} = \frac{p^{b,k}_{ij,m}\, e^{-\lambda_m \Delta g^{k}_{ij,m}}}{\sum_m p^{b,k}_{ij,m}\, e^{-\lambda_m \Delta g^{k}_{ij,m}}}$$

- where $p^{b,k}_{ij,m}$ is the **base probability** for each mode m, **traveler class** k (with differing VOTTs, etc.) & **OD pair** ij.
- λ_m is **mode-choice scale parameter**.
- $\Delta g^{k}_{ij,m}$ is the **change in generalized costs** between the base case & alternative scenario.
- A very similar equation used model **TOD** shifting.

Sensitivity Analysis

- **21 parameters** allowed to vary
- **65 values assessed** (B/Cs & NPVs, crash counts, emissions totals, key-link volumes, toll revenues, etc.).
- **Average ± 1 SD values** summarized (& analyst has access to all runs' predictions).
- Toolkit assumes **lognormal distribution** of parameters.
- **Up to 100 trials** may be conducted during sensitivity testing.

Value of Time	Free Flow Speed	Avg. Veh Occupancy
Veh. Operating Costs	Reliability Par.	Base User Class %'s
Value of Reliability	Crash Rate	Base Mode Split %'s
Value of Crashes	Emissions Rate	Trip Growth Rate
Value of Emissions	Mode Scale Par.	Demand Elasticity
Link Capacity	TOD Scale Par.	Initial Project Costs
Capacity Par.	Temperature	Add. Maint. & Op. Costs

Budget Allocation

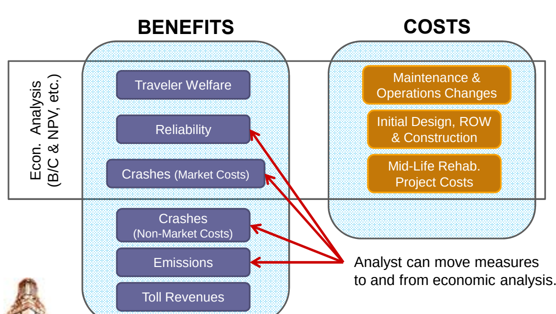
- Toolkit provides framework for maximizing traveler benefits from a selection of available projects.
- Constraints may include:
  - Budget constraints
  - Regional constraints - *optional* (ex: each region assigned min. $)
  - Project type constraints - *optional* (ex: non-motorized, capacity, safety)

Total cost	$659,703
Total benefit	$1,685,028

Project	Name	Cost	Benefit	Region	Project Type	Recommended Projects for Funding (1/0)
1	Aus Hwy	$138,506	$262,191	1	1	1
2	Aus Trans	$95,905	$102,530	1	2	0
3	Aus PdBike	$141,893	$88,243	1	3	0
4	DFW ITS	$85,190	$162,184	2	4	1
5	DFW Maint	$126,280	$62,828	2	5	0
6	DFW Hwy	$105,494	$181,549	2	1	0
7	Hou Trans	$8,717	$22,055	3	2	1
8	Hou PdBike	$144,007	$143,497	3	3	1
9	Hou ITS	$104,161	$127,270	3	4	0
10	SA Maint	$48,320	$197,392	4	5	1
11	SA Hwy	$36,840	$274,041	4	1	1
12	SA Trans	$72,290	$166,783	4	2	1
13	Tyler PdBike	$26,177	$104,964	5	3	1
14	Tyler ITS	$76,726	$109,491	5	4	1
15	Tyler Maint	$22,910	$222,430	5	5	1

Budget	$700,000	
		Max Funding
$ of Projects in Region 1	$138,506	$200,000
$ of Projects in Region 2	$85,190	$200,000
$ of Projects in Region 3	$152,743	$200,000
$ of Projects in Region 4	$157,450	$200,000
$ of Projects in Region 5	$125,813	$200,000
		Max Funding
$ of Projects of Type 1	$175,347	$200,000
$ of Projects of Type 2	$81,027	$200,000
$ of Projects of Type 3	$170,184	$200,000
$ of Projects of Type 4	$161,916	$300,000
$ of Projects of Type 5	$71,230	$200,000

Multi-Criteria Decision Evaluation



How are *performance measures* and *Impacts* calculated?

Travel Demand Growth

- Assumed **exponential** (though analyst can specify linear).
- All nodes serve as potential **origins** & **destinations**.
- Analyst can **vary** expected **growth** for each individual **node** (e.g., high growth in developing areas & low growth in built-out neighborhoods).

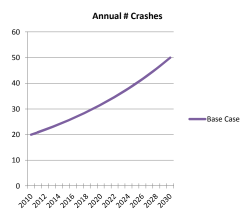
Base Annual Growth Rate	1.0%
Growth Rate is	Exponent
Project Life (Years)	20
Base Traffic Growth over Project Life	22.72%

Go To Navigation Panel

	Initial Year				Design Year			
	Production Growth		Attraction Growth		Production Growth		Attraction Growth	
Node	Base Initial Growth	Initial Growth	Base Initial Growth	Initial Growth	Alternate Growth Rate	Life Growth	Alternate Growth Rate	Life Growth
1		0.0%		0.0%		22.7%		22.7%
2		0.0%		0.0%	2.0%	48.6%	2.0%	48.6%
3		0.0%		0.0%	2.0%	48.6%	2.0%	48.6%
4		0.0%		0.0%		22.7%		22.7%
5		0.0%		0.0%		22.7%		22.7%
6		0.0%		0.0%		22.7%		22.7%

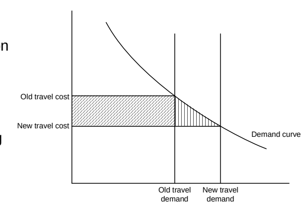
Impact Assessment Over Time

- Impacts are assessed for every scenario, in the **Initial Year** (of project) & (final) **Design Life Year**.
- Impacts are **exponentially interpolated** for Interim Years by answering the question,
- "At **what rate** do impacts need to grow in order to reach the final year value?"



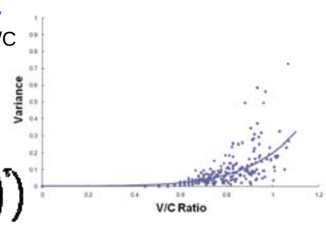
Traveler Welfare Estimation

- **User Surplus**: Amount of money that travelers are willing to pay for new travel context (relative to base case context), approximated by **Rule of Half** (applied to each **O-D pair**, for each **TOD, User Class & Mode**).
- RoH is applied on **the O-D level**.
- Calculated based on a combination of **travel time** ($/hr) & **operating costs** ($/mi).
- **Multiple values of time** (across user classes) & different operating costs (light vs. heavy vehicles).



Travel Time Reliability

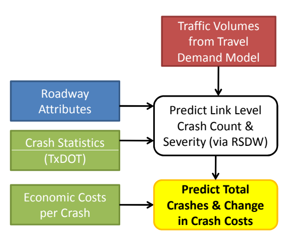
- Measured as estimates of **travel time variance** on each link (due to congestion).
- Estimated from **freeway traffic data** based on V/C ratios.



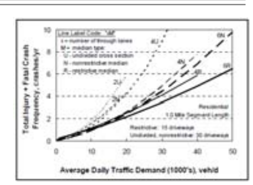
Functional Form:

$$\tau_a = \tau_a^0\left(1+\sigma\left(\gamma+\frac{x_a}{c_a}\right)^{\eta}\right)$$

Crash Estimates



- Crashes predicted at the individual link & intersection levels.



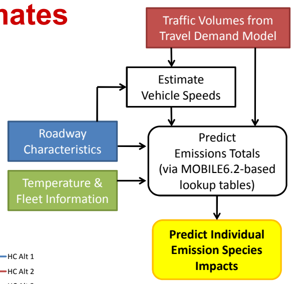
Source: Roadway Safety Design Workbook (RSDW)

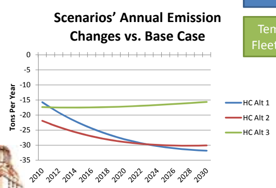
Default Costs
- Fatal: $1,130 k
- Incapacitating: $65 k
- Non-Incapacitating: $21 k
- Possible Injury: $11.9 k
- PDO: $7.5 k

Source: NHTSA's Economic Costs of MV Crashes (2002)

Emissions Estimates

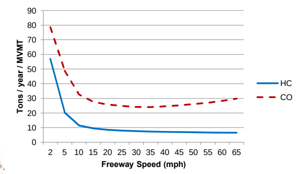
- 13 Species: HC, CO, NO_x, CO_2, SO_2, NH_3, PM10, PM2.5, & 5 MSATs





Emissions vs. Speed & Cost

- **Bowl-shaped** emissions rates (gm/mi vs. mph)
  - **CO** minimized at 35 mph & **NO_x** minimized at 15 mph
  - **Most Toxics** (BUTA, FORM, ACET & ACRO) minimized at 55 mph
- **Downward** sloping emissions:
  - HC & BENZ – high emissions at low speeds



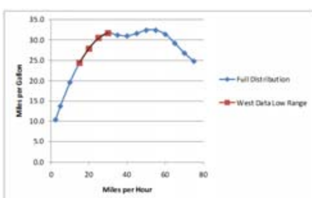
Cost Estimates Per Ton

Pollutant	Urban	Rural
CO	$145	$70
VOCs	$5,900	$3,900
NO_x	$7,800	$5,200
SO_2	$18,000	$12,000
PM2.5	$6,900	$3,450
PM10	$6,900	$3,450

(EU Example Costs, Defaults = $0)

Fuel Efficiency

- General fuel efficiency relation to speed:



- Toolkit adjusts trend to account for fleet mix (heavy & light vehicles) and average fuel efficiencies.

Fuel Use & Tolling Revenues

- Fuel use is based on **vehicle speeds** & **average fuel efficiency** by year (including heavy trucks).
- Toll revenues help determine project **financing feasibility**.
- **Reported** for analyst use (but not included as individual components in B/C, NPV & other summary measures).
  - Fuel use reflected in operating costs & emissions.
  - Tolling costs reflected in traveler welfare.

ATIS, Speed Harmonization & Incident Management

- These strategies are assumed to influence **nonrecurring events** & therefore the model assumes that these strategies will **not significantly impact travel patterns**.
- Therefore, analysts do **not re-run the demand model** to evaluate these strategies.
- Frequency of events estimated based on # crashes per year, on the impacted links, as predicted by the Toolkit.
- Assessed impacts are in the form of changes in **emissions, travel times & crashes**, depending on the strategy.

Advance Traveler Information Systems (ATIS)

- Includes Variable Message Signs, Hwy Advisory Radio, Internet-based ATIS, In-vehicle route guidance, etc.
- **Travel time savings** estimate =
  # of **crashes** per year × **#** of **major incidents** per crash
  × **%** of incidents during **congested times**
  × **#** of **travelers** on road **exposed to ATIS** strategy
  × **%** of those **travelers** who **change route & save time**
  × **Avg. time savings** per traveler who changes route.
- Final $ Benefit = Avg. VOTT * Total Travel Time Savings

Speed Harmonization

- Assumes implementation during **heavy traffic** periods only, & **no** substantial average **speed change**.
- Benefits estimated using a **10 to 30% crash reduction factor** on impacted links during times when SH is active.
- For example, if…
  - 100 crashes expected on the target links under normal conditions, &
  - 60% of crashes expected to occur during peak times when SH active…
- Then, SH will result in approx. **6 to 18 fewer crashes:**
  - 60 * (1 – 0.10) = 6
  - 60 * (1 – 0.30) = 18

Incident Management

- Estimates impacts based on **incident duration reduction**.
- **Applicable** where a lane-blocking incident will cause travel **demand** to **exceed capacity**.
  - This will cause a queue to build & extra delay to be incurred by travelers.
- # Lane-blocking incidents estimated based on predicted # Crashes during peak times.
- In addition to **travel time savings**, **emissions** changes are also estimated by estimating vehicle speeds & using emissions lookup tables.

Part 2: Case Study Applications

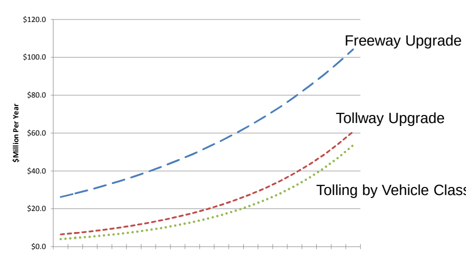
Austin Case Study:
US 290 Upgrade

- **194-Link Network**
- **Trips grow 1.0%/yr over 20 yrs**
- **4 Scenarios:**
  - Base-Case (No Build)
  - Freeway Upgrade
  - Tollway Upgrade ($1)
  - Tollway w/ Variable Mode Pricing
    - (SOV $1, HOV $0.50, Transit free, Truck $3)
- **Toolkit estimates each scenario's impacts & lists results for comparisons.**

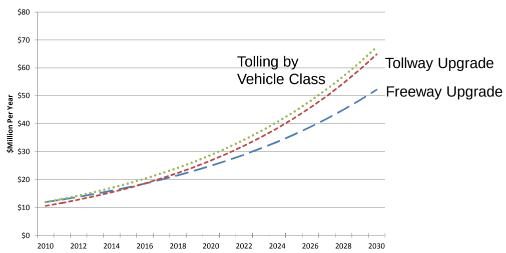
Project Costs & Capacity Benefits

Scenario	Project Cost	Added Maint. Costs	Section Capacity
Base Case (No Build)	$0	$0	3080 veh/hr
Freeway Upgrade	$71.8 M	$430 k/yr	7640 veh/hr
Tollway Upgrade	$80.5 M	$1,200 k/yr	7640 veh/hr
Tollway w/ var. Pricing	$80.5 M	$1,200 k/yr	7640 veh/hr

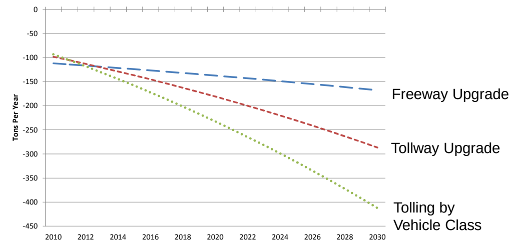
Results: Impacts over Time – Relative to Base Case: Traveler Welfare



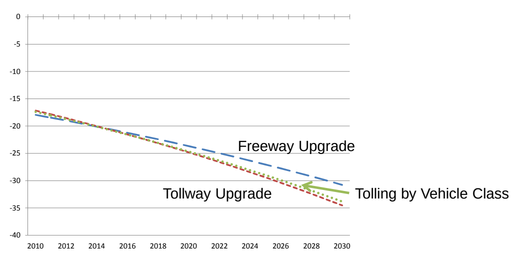
Results: Reliability Savings



Results: Hydrocarbon Emissions



Results: Fatal & Injury Crashes



Results: Net Benefits by Category

- Main impacts come from **Traveler Welfare** & **Reliability**.
- **Safety** values are small in comparison.
- Note: Safety changes represent Market or Economic Costs *only* (not pain & suffering or value of life).

	Base Case: No Build	Grade Sep. Freeway	Grade Sep. Tollway	Tolling by Veh. Class
Initial Year Monetary Benefits	**$0 M**	**$31 M**	**$0.9 M**	**$12 M**
Traveler Welfare	$0	$23.7	-$0.1	$5.0
Reliability	$0	$7.0	$0.4	$6.3
Crashes	$0	$0.7	$0.6	$0.7

	Base Case: No Build	Grade Sep. Freeway	Grade Sep. Tollway	Tolling by Veh. Class
Design Life Year Monetary Benefits	**$0 M**	**$130 M**	**$85 M**	**$98 M**
Traveler Welfare	$0	$77	$22	$49
Reliability	$0	$52	$62	$47
Crashes	$0	$1.4	$1.5	$1.3

Results: Summary Measures

- Preferred Alternative: **Freeway Upgrade**
- However both the **Tollway Upgrade** or the **Tolling by Vehicle class** alternative scenarios deliver substantial traveler benefits while providing funds to finance the project.

	Base Case: No Build	Freeway Upgrade	Tollway Upgrade	Tolling by Veh. Class
Total Initial Costs	**$0**	**$71.8 M**	**$80.5 M**	**$80.5 M**
Change in Maint. & Operations Costs	**$0**	**$0.43 M**	**$1.18 M**	**$1.18 M**
Interim Project Cost	**$30 M**	**$0**	**$0**	**$0**
Interim Project Year	**2020**	**N/A**	**N/A**	**N/A**
Net Present Value	**$0**	**$734 M**	**$223 M**	**$378 M**
Internal Rate of Return	**N/A**	**90%**	**17%**	**30%**
Benefit / Cost Ratio	**N/A**	**14:1**	**4:1**	**6:1**
Payback Period	**N/A**	**2.3 years**	**10.9 years**	**6.1 years**

Economic Summary Measures of Project Alternatives

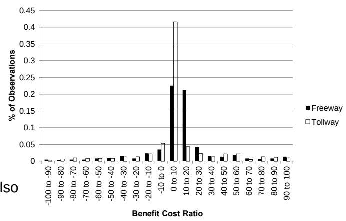
Project Financing Evaluation

Project Financing ($M)	No Build	290 Freeway Upgrade	290 Tollway Upgrade	290 Tolling by Vehicle Class
NPV of New Tolling Revenues	$0	$1.6	$216	$209
NPV of Initial and Future Project Costs	$0	$56	$73	$73
Project Financing Perspective NPV	$0	-$56	$144	$136
Project Financing Perspective IRR	N/A	N/A	24.1%	22.8%
Project Financing Perspective PP	N/A	> 20 years	6.1	6.5
NPV of Project Impacts	$0	$790	$295	$450
Agency Perspective NPV	-$18	$736	$440	$587

- 290 Tolling by Veh. Class: Much better benefits while still
- significant charges exceed project costs.
- project costs.

Sensitivity Testing: B/C Ratios

- **600 Iterations** Conducted on the Freeway Upgrade & Tollway Upgrade (by veh. Class).
- 55% of all B/C ratio outcomes were between **-20 and +30**.
- Median B/C Values:
  - Freeway: 10.3
  - Tollway: 4.0
- Link **capacity** & link performance param's were most influential (**α** and **β**).
- **Value of Travel Time**, **Trip Growth** Rate, & **Demand Elasticity** were also important.

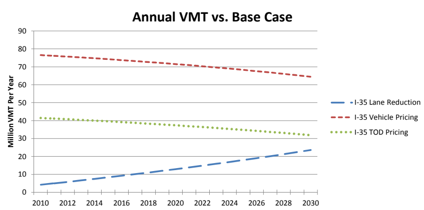


Austin Case Study:
I-35 Demand Management

- **I-35 Corridor, 8 lane freeway**
- **218k to 250k AADT**
- **5 mile segment**
  - Base-Case (No Build)
  - Convert to 6-Lane Freeway
  - Pricing by Mode
    - (SOV: $0.50 / mi, Truck: $1.50 / mi)
  - Pricing by Time of Day
    - ($0.50 / mi: AM Peak, Mid Day & PM Peak)

Unintended Consequences?

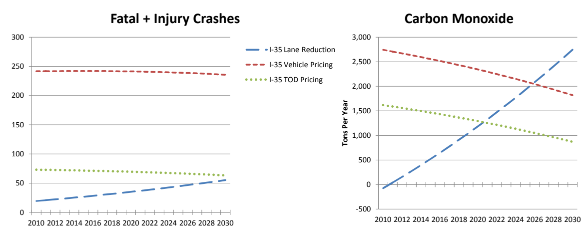
- **VMT** falls on I-35, but **Increases system-wide.**



	Base	Lane Reduction	Tolling by Class	Tolling by TOD
I-35 VMT (k), Init. Yr.	1211	1204	919	1054
% Change vs. Base	-	0.6%	24.2%	13.0%
I-35 VMT (k), Des. Yr.	1492	1441	1211	1354
% Change vs. Base	-	3.4%	18.8%	9.2%

VMT Reduction on I-35

Crashes and Emissions Increase



- Caused by increased VMT, but also by traffic to arterials which have greater emissions (due to more stop-and-go traffic) & crashes (due to more vehicle conflicts).

What Happened?

- Instead of foregoing trips or switching to better times of day or modes, travelers took longer, alternate routes to reach their destinations.

Break:
Coffee & Snacks

Part 3:
Using the Toolkit

Toolkit Components

- **Main Toolkit File** (Excel, *sketch_toolkit.xlsm*)
  - Holds transportation network, parameters, & project costs.
  - Calls Trip Table Estimator & TDM to estimate traffic flows & TW.
  - Facilitates sensitivity testing processes.
  - Estimates reliability, crashes, emissions, fuel use & summary measures.
  - Develops summary measures & presents results.
- **Operational Toolkit File** (Excel, *op_sketch_toolkit.xlsm*)
  - Used for Speed Harmonization, Incident Management & ATIS.
  - Similar to Main Toolkit file, but does not use a TDM.
  - Utilizes Main Toolkit File network, AADTs & formulas to estimate results.

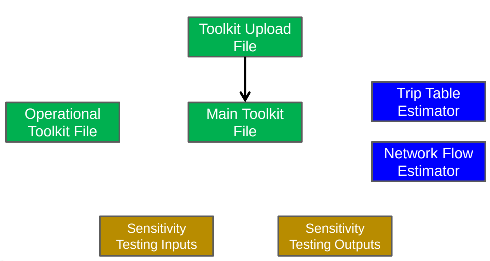
Toolkit Components (2)

- **Trip Table Estimator** (application, *tdm_matrix.exe*)
  - Estimates a base Trip Table based on the existing network & traffic volumes.
- **Network Flow Estimator** (application, *tdm_flow.exe*)
  - Estimates traffic flows by user class, mode & time of day.
  - Estimates traveler welfare.
- **Toolkit Upload File** (Excel, *Upload_toolkit_file.xls*)
  - Source file for user inputs to be automatically uploaded to Main Toolkit File.
  - Contains reference cells for network & new parameter value source documentation.

Toolkit Components (3)

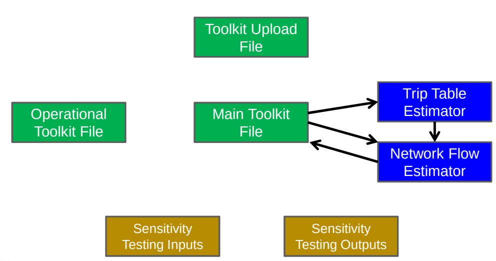
- **Budget Allocation Module** (Excel *budget_allocation_module.xlsx*)
  - Used to assess best allocation of funds among multiple potential project candidates.
- **Sensitivity Testing I/O Folders** (*STInputs* & *STOutputs*)
  - Folders for storing sensitivity testing files & results.

Toolkit Component Interaction



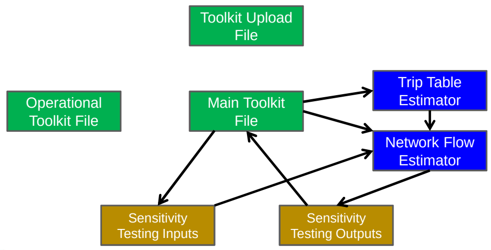
Upload Network Information & Parameters

Toolkit Component Interaction (2)



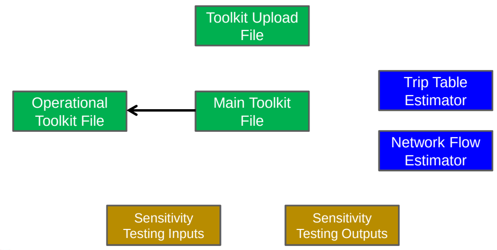
Run a project in the Main Toolkit File (e.g. capacity expansion)

Toolkit Component Interaction (3)



Run a project with Sensitivity Testing

Toolkit Component Interaction (4)



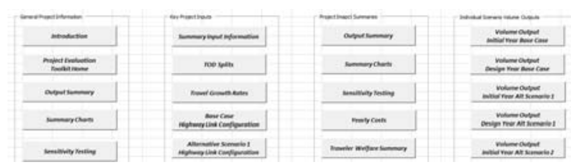
Run an operational project (Inc. Mgt, Spd Hrm, ATIS)

Toolkit Color Coding

- White ☐ Labels & Equations
- Green ☐ Parameters
- Blue ☐ User Inputs
- Yellow ☐ Key Results
- Pink ☐ Travel Demand Model Outputs

Toolkit Navigation

- There are **over 70 worksheets** in the Main Toolkit File
- The Navigation Panel allows for easy Toolkit navigation



- A [Go To Navigation Panel] button is located in the upper-left corner of every Toolkit sheet

The Toolkit Upload File

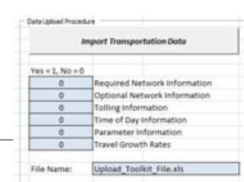
- **Purpose**
  - Ease of data entry
  - Document network & parameter sources
- **User Input Categories**
  - Required Link Information
  - Optional Link Information
  - Tolling Information
  - Time of Day Information
  - Parameter Information
  - Travel Growth Rates

The Toolkit Upload File (2)

- **Enter Data** in the Toolkit Upload File

Link	Free Flow Speed	Crash Mod. Factor	Variable Capacity (1/0)	# Entr Ramps (Freeway)	# Exit Ramps (Freeway)	AM Peak Capacity	Mid Day Capacity	PM Peak Capacity	Evening Capacity	Off Peak Capacity
1										
2										
3										
4										
5										
6										
7										

- Then **Import** it back into the Main Toolkit File



Developing Projects in the Main Toolkit File

- **Project Types:**
  - Capacity Expansion (incl. new links)
  - Roadway Pricing
  - Reversible Lanes
  - Managed Lanes
  - Shoulder Lane Use
  - Traffic Safety Enhancement
  - Ramp Metering
  - Speed Limit Changes (via. FFS)

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Project Development in the Main Toolkit File
Step 1: Verifying Parameters

Key Project Inputs
General Information
Summary Input Information

- *General Project Information*
  - Initial year, project life, base growth rate, discount rate
- *Capacity & Reliability Parameters*
  - Free flow speeds, BPR alpha & beta, heavy veh. psg. car equiv. (PCE)

Project Evaluation Toolkit - Parameter Input Information

Go To Navigation Panel

General Project Information

Project Name: Austin 290 Highway Expansion
Analyst: D. Fagnant
Date: 5/9/2011

Total # Alternative Scenarios (not incl. no-build)	3	Project Costs (thousands)				
		Design	ROW	Construct	Add. Annual Maintenance	Salvage Value
	No Build	$0	$0	$0	$0	$0
Scenario 1	290 Freeway Upgrade	$4,528,000	$0	$49,280,000	$409,133	$0
Scenario 2	290 Tolled Freeway	$7,318,000	$0	$73,180,000	$1,130,283	$0
Scenario 3	290 Tolling by Vehicle Class	$7,318,000	$0	$73,180,000	$1,130,283	$0

Projected Traffic Growth Rate	
Annual Growth Rate	1.0%
Linear Growth (0) or Exponential Growth (1)	1
Total Traffic Growth over Project Life	22.72%

Initial Year	2010
Future Year	2030
Discount Rate	5%
Proj. Design Life (yrs)	20

Max Proj Design Life = 50 yrs

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Step 1: Verifying Parameters

- *Operating Costs, User Groups & Modes*
  - Values of time & reliability, avg. veh. occ., pop. distributions
- *Safety Parameters*
  - Crash valuation, severity distributions
- *Temperature, Emissions & Fuel Use*
  - Summer & winter temperatures, fuel use-speed relationship
- *Sensitivity Testing*
  - Varying parameters & # of iterations

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Vehicle Modes & User Classes

- **User Classes** – each assumed a base % of population with unique VOTTs and VORs
  - Heavy truck driver
  - Work-related travel
  - Commuter
  - Traveler - non-work-related

Value of Time and Reliability ($/hr)			
Total # User Types Used:			4
User Type	VOT	VOR	% of Pop.
1*	$50.00	$50.00	5%
2	$30.00	$30.00	10%
3	$10.00	$10.00	20%
4	$5.00	$5.00	65%
5	$0.00	$0.00	0%
Average	$10.75	$10.75	-

- **Vehicle Modes** – each User Class assigned a base probability of selecting a given mode
  - Heavy Truck
  - SOV
  - HOV (2)
  - HOV (3)
  - Bus

Base Mode Split Probabilities and Mode Characteristics					
User Type	SOV	HOV 2	HOV 3+	Transit	Heavy Truck
1*	0	0	0	0	1
2	0.359	0.333	0.296	0.012	0
3	0.359	0.333	0.296	0.012	0
4	0.359	0.333	0.296	0.012	0
5	0.359	0.333	0.296	0.012	0
Operating Cost ($ per mi)	$0.20	$0.20	$0.20	$0.50	$0.50

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Step 2: Setting Time of Day Traffic Distribution

Key Project Inputs
General Information
Summary Input Information
TOD Splits

- Up to 6 References may be used
- Distributions usually based on ATR stations
- Each Network Link will refer to one of the distributions
- Analyst sets % AADT, period start times & elasticity

Project Evaluation Toolkit - Time of Day Splits

Go To Navigation Panel

Ref #		AM Peak	Mid Day	PM Peak	Evening	Off Peak	Equal to 1
		Time of Day Splits (% of AADT in Period)					
1	US 175, 1.2 MI SE of IH 635	25.0%	17.0%	33.1%	15.4%	9.5%	1
2	IH 35E, 1.6 MI SE of SH 356	27.0%	18.8%	36.0%	13.5%	4.7%	1
3	IH 30, .5 MI W of Loop 635	27.4%	16.6%	34.9%	13.8%	7.3%	1
4	SH 180, 2.7 MI W of FM 157	27.8%	14.8%	35.7%	13.3%	8.4%	1
5	IH 30, 3.2 MI W of IH 35W	24.2%	17.8%	29.3%	17.3%	11.4%	1
6	IH 820 W End of L Worth Bridge	27.5%	18.8%	32.8%	15.1%	5.8%	1

Time of Day Settings		Demand Elasticity
AM Peak Begins	6:00 AM	-0.69
Mid Day Begins	11:00 AM	-0.69
PM Peak Begins	2:00 PM	-0.69
Evening Begins	7:00 PM	-0.69
Off Peak Begins	11:00 PM	-0.69

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Step 3: Developing the Base Network

Network Information
Base Case Highway Link Configuration

Sample Network Map: Waco, TX

- Create a **Network Map**
  - Determine links & label nodes
  - Remember, links are directional
- Ensure **No Parallel Links**
  - Can model frontage roads using on & off ramps
- All links must have **Capacity** & **AADT** of **at least 0.1**.

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Step 3: Developing the Base Network (2)

- For each link, the analyst ***must*** enter:
  - From Node, To Node, Length, Class (Freeway, Arterial, Collector, Ramp), Area Type (Urban, Suburban, Rural), # Lanes, Land Use & Median (arterial only), Capacity, TOD Reference
- For each link, the analyst ***may*** enter:
  - Free Flow Speed, Crash Mod. Factor (CMF), Var. Capacity, # Entr. & Exit Ramps (FW), and Time of Day-Specific Capacity

Link Characteristics												
Link #	From Node #	To Node #	Link Name	Length (mi)	Link Class	Area Type	FF Speed (User Entered)	FF Speed	FF Time	# Lanes	CMF	AADT
1	51	1	183: N of TT45 - TT45	1	1	1		55	1.1	3		16500
2	1	51	183: TT45 - N of TT45	1	1	1		55	1.1	3		16500
3	1	10	183: TT45 Loop 1	7.8	1	1		55	8.5	3		75000
4	10	1	183: Loop 1 - TT 45	7.8	1	1		55	8.5	3		75000
5	10	15	183: Loop 1 - Lamar	2.9	1	1		55	3.2	3		69500
6	15	10	183: Lamar - Loop 1	2.9	1	1		55	3.2	3		69500

*** NOTE: Easiest to enter using the **Toolkit Upload File** ***

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Step 4: Setting Tolling Rates

Tolling Information

Base Case Tolls

- Set Tolling Rates to Current Prices, by link, Time of Day, and Vehicle Class (Mode)

					AM Toll Settings					Mid Day Toll Settings				
Link #	From Node #	To Node #	Link Name	Length	Vehicle Class 1	Vehicle Class 2	Vehicle Class 3	Vehicle Class 4	Vehicle Class 5	Vehicle Class 1	Vehicle Class 2	Vehicle Class 3	Vehicle Class 4	Vehicle Class 5
1	51	1	183: N of TT45 - TT45	1	$2.00	$2.00	$2.00	$2.00	$2.00	$2.00	$2.00	$2.00	$2.00	$2.00
2	1	51	183: TT45 - N of TT45	1	$2.00	$2.00	$2.00	$2.00	$2.00	$2.00	$2.00	$2.00	$2.00	$2.00
3	1	10	183: TT45 Loop 1	7.8										
4	10	1	183: Loop 1 - TT 45	7.8										

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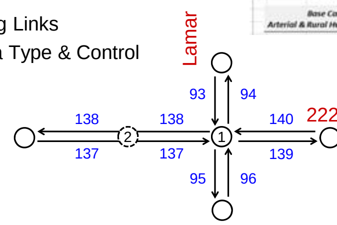
Step 5: Adding Intersections, Example

Step 5: Adding Intersections, Example (2)

Intersection Information

Base Case Arterial & Rural Hwy Intersects

- Identify Entering Links
- Determine Area Type & Control



					Links and Volumes - Fill in EITHER the connecting link reference # OR the link AADT (when link is not modeled)							
Node #	Node / Intersection Name	Area Type	Control	CMF	Link 1 (Major)	Use Link 1 AADT	Link 2 (Major)	Use Link 2 AADT	Link 3 (Minor)	Use Link 3 AADT	Link 4 (Minor)	Use Link 4 AADT
1	2222 & Lamar	1	1		137		140		93		96	
2												

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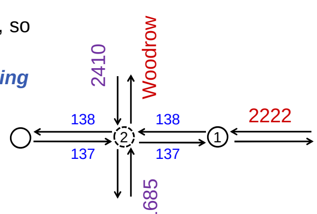
Step 5: Adding Intersections, Example (3)

- No Link #'s for Woodrow, so estimate AADTs
- Be sure to use the ***Entering*** Traffic Volume



					Links and Volumes - Fill in EITHER the connecting link reference # OR the link AADT (when link is not modeled)							
Node #	Node / Intersection Name	Area Type	Control	CMF	Link 1 (Major)	Use Link 1 AADT	Link 2 (Major)	Use Link 2 AADT	Link 3 (Minor)	Use Link 3 AADT	Link 4 (Minor)	Use Link 4 AADT
1	2222 & Lamar	1	1		137		140		93		96	
2	2222 & Woodrow	1	1		137		138			2410		1685

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Project Development in the Main Toolkit File

Now that the **Base Case Scenario** has been developed, it is time to develop **Alternative Scenarios**

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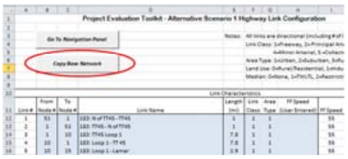
Step 6: Modify the Alternative Scenario Network

- Go to [Alternative Scenario 1 Highway Link Configuration] using the Navigation Panel
- **Copy** the Base Network



- Then **modify** capacity, free flow speed, link type or any other highway link characteristic, as desired.

Step 6: Modify the Alternative Scenario Network (2)

- Important note:
  - If **adding a link or a node** in an alternative scenario, be sure to also add it in the base case scenario.
  - Analyst may use capacity & AADT of 1 for the new link in the base case scenario.

Step 7: Modify Alternative Scenario Intersections

- Go to [Alternative Scenario 1 Arterial & Rural Hwy Intersects] using the Navigation Panel.
- **Copy** the Base Case Intersections.
- Then **modify** control type, crash modification factors or other link characteristics, as desired.

- If **adding** an intersection, ensure that the intersection **physically does not exist** in the base case scenario.
- If **removing** an intersection, ensure that the intersection is **physically** being **removed** (e.g. via grade separation or street closure).

Step 8: Modify Alternative Scenario Tolling Rates

- Go to [Alternative Scenario 1 Tolls] using the Navigation Panel.
- **Copy** the Base Toll Settings.
- Then **modify** tolling rates, by time of day & vehicle class, as desired.

Step 9: Develop Project Cost Estimates

- Go to [Engineer's Estimate] using the Navigation Panel.
- Enter **Initial costs** for each scenario.

	Lane Miles	Const Cost per Lane Mile	ITS / Signal / Electrical	Bridges & Structures	Utility & Other Fixed Costs	Construction Subtotal	Traffic Control	Environmental Construction
No Build	0.0	$0	$0	$0	$0	$0	0.0%	0.0%
290 Freeway Upgrade	20.4	$3,200,000	$0	$0	$0	$65,280,000	0.0%	0.0%
290 Tolled Freeway	20.4	$3,200,000	$7,900,000	$0	$0	$73,180,000	0.0%	0.0%
290 Tolling by Vehicle Class	20.4	$3,200,000	$7,900,000	$0	$0	$73,180,000	0.0%	0.0%

	Design as % of Const Costs	Design	ROW Purchase	Construction Engineering	Construction Engineering	Contingencies	Contingencies	Overhead & Indirect Costs
No Build	10%	$0	$0	0.0%	$0	0.0%	$0	0.0%
290 Freeway Upgrade	10%	$6,528,000	$0	0.0%	$0	0.0%	$0	0.0%
290 Tolled Freeway	10%	$7,318,000	$0	0.0%	$0	0.0%	$0	0.0%
290 Tolling by Vehicle Class	10%	$7,318,000	$0	0.0%	$0	0.0%	$0	0.0%

- If only a **single value** is needed, you can use Fixed Costs only.

Step 9: Develop Project Cost Estimates (2)

- Enter **Additional Annual Maintenance** costs & Salvage Value.
- If a **Maintenance & Rehabilitation** project is required, enter the year and M&R project cost.

	Design	ROW Purchase	Construction Engineering	Construction Cost	Contingencies	Overhead & Indirect Costs	Total Initial Project Costs
No Build	$0	$0	$0	$0	$0	$0	$0
290 Freeway Upgrade	$6,528,000	$0	$0	$65,280,000	$0	$0	$71,808,000
290 Tolled Freeway	$7,318,000	$0	$0	$73,180,000	$0	$0	$80,498,000
290 Tolling by Vehicle Class	$7,318,000	$0	$0	$73,180,000	$0	$0	$80,498,000

	Add. Annual Maintenance	Salvage Value	Maint & Rehab Project Year	Maint & Rehab Project Cost
No Build	$0	$0	2020	$30,000,000
290 Freeway Upgrade	$409,233	$0		
290 Tolled Freeway	$1,130,263	$0		
290 Tolling by Vehicle Class	$1,130,263	$0		

Step 10: Estimate Projected Travel Growth

- If certain areas are predicted to grow faster than other areas, navigate to [Travel Growth Rates]
- All traffic will assume growth at the base rate, unless otherwise specified by the analyst.
- Traffic Growth estimated at **average** of production & attraction rates.

	Initial Year				Design Year			
	Production Growth		Attraction Growth		Production Growth		Attraction Growth	
Node	Base Initial Growth	Initial Growth	Base Initial Growth	Initial Growth	Alternate Growth Rate	Life Growth	Alternate Growth Rate	Life Growth
1	5.0%	5.0%	5.0%	5.0%		22.7%		22.7%
2		0.0%		0.0%	2.0%	48.6%	2.0%	48.6%
3		0.0%		0.0%	2.0%	48.6%	2.0%	48.6%

Step 10: Estimate Projected Travel Growth (2)

- In this example, traffic originating at Node 1 and traveling to Node 2 will be:
  - 2.5% higher than the base rate in the initial year.
  - 35.65% higher than the base rate in the design year.

	Initial Year				Design Year			
	Production Growth		Attraction Growth		Production Growth		Attraction Growth	
Node	Base Initial Growth	Initial Growth	Base Initial Growth	Initial Growth	Alternate Growth Rate	Life Growth	Alternate Growth Rate	Life Growth
1	5.0%	5.0%	5.0%	5.0%		22.7%		22.7%
2		0.0%		0.0%	2.0%	48.6%	2.0%	48.6%
3		0.0%		0.0%	2.0%	48.6%	2.0%	48.6%

Step 11: Running the Travel Demand Model

- Now that the alternative Scenarios have been developed, navigate to [Project Evaluation Toolkit Home] and review the **Input Summary Checklist**:

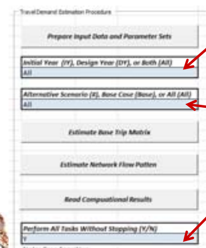
Input Summary Checklist

Summary Input Information		TOD Splits		Hwy Link Configuration - Alt Scenario 1	
3	Number of Scenarios	5	# TOD Periods	OK	From Link Entered on All Links
2010	Initial Year	6	# TOD Ref. Stations	OK	To Link Entered on All Links
20	Design Life (Years)	OK	Non-zero TOD Period	OK	Link Lengths Entered on All Links
1.0%	Annual Growth Rate	OK	Non-zero split in TOD reference	OK	Road Class Entered on All Links
76	Summer Temperature			OK	Area Type Entered on All Links
56	Winter Temperature			OK	# Lanes Entered on All Links
7	# of Summer Months			OK	Capacity Entered on All Links

- If everything is **OK**, and parameters look properly set, you can begin the Travel Demand Modeling process.

Step 11: Running the Travel Demand Model (2)

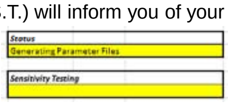
- Check and set the Travel Demand Modeling Settings:



- **Analysis Year**: Do you want to run the TDM for the Initial Year (IY), Design Year (DY) or both (All)?
- **Scenario**: Do you want to run the TDM for one alternative scenario (1, 2, or 3), the Base Case scenario (Base) or all scenarios (All)?
- **TDM Process**: Do you want the TDM to run one process at a time or all processes without stopping?

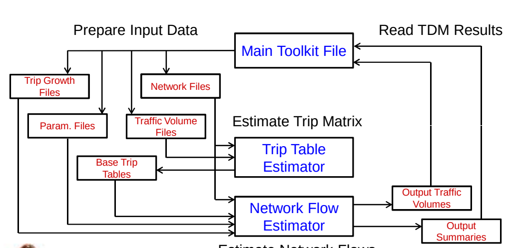
Step 11: Running the Travel Demand Model (3)

- Press [Prepare Input Data and Parameter Sets] to begin.
- The **Status Bar** & **Sensitivity Testing Bar** (if conducting S.T.) will inform you of your progress.



- For a 194 link network, initial & design years for base case scenario + 3 alternative scenarios, this may take **~1 hour**.

Travel Demand Modeling Process



If conducting **Sensitivity Testing**, *N* input files will be generated, the TDM will run *N* times and results will be read and recorded *N* times.

Break:
Coffee & Snacks

Project Development in the Main Toolkit File
Step 12: Interpreting Results

- 6 types of **Toolkit Output** results:
  - Toolkit Output Summary
  - Summary Charts
  - Traffic Link Comparisons
  - Impact Category Summaries
  - Individual Scenario Sheets
  - Sensitivity Testing Results

Step 12: Interpreting Results
Output Summary

- Reports scenario **cost** information (taken from user entry)

		Scenarios: No Build	290 Freeway Upgrade	290 Tolled Freeway	290 Tolling by Vehicle Class
Initial Project Costs	Right of Way	$0	$0	$0	$0
	Design	$0	$6,528,000	$7,318,000	$7,318,000
	Construction	$0	$65,280,000	$73,180,000	$73,180,000
	Other	$0	$0	$0	$0
Total Initial Costs		$0	$71,808,000	$80,498,000	$80,498,000

	No Build	290 Freeway Upgrade	290 Tolled Freeway	290 Tolling by Vehicle Class
Total Initial Year Costs	$0	$71,808,000	$80,498,000	$80,498,000
Change in Annual Maint. & Operations Costs	$0	$409,233	$1,130,263	$1,130,263
Annualized End of Life Salvage Value	$0	$0	$0	$0
Interim Project Cost	$30,000,000	$0	$0	$0
Interim Project Year	2020	0	0	0

Step 12: Interpreting Results
Output Summary (2)

- Reports monetary **benefits** & **summary measures**

	No Build	290 Freeway Upgrade	290 Tolled Freeway	290 Tolling by Vehicle Class
Initial Year Monetary Benefits	$0	$22,262,068	$2,289,177	$1,959,306
Traveler Welfare	$0	$14,250,951	-$5,706,191	-$6,015,091
Reliability	$0	$7,296,550	$7,298,079	$7,297,628
Crashes	$0	$714,567	$697,290	$676,768

	No Build	290 Freeway Upgrade	290 Tolled Freeway	290 Tolling by Vehicle Class
Design Life Year Monetary Benefits	$0	$75,178,848	$43,636,550	$53,175,156
Traveler Welfare	$0	$29,713,993	$3,279,426	$7,081,037
Reliability	$0	$44,429,506	$39,317,391	$45,002,714
Crashes	$0	$1,035,348	$1,039,732	$1,091,406
Net Present Value	$0	$449,553,640	$116,195,343	$147,567,514
Internal Rate of Return	N/A	53.77%	13.57%	14.90%
Benefit / Cost Ratio	N/A	9.07	2.60	3.03
Payback Period	N/A	3.2	11.7	11.1

Step 12: Interpreting Results
Output Summary (3)

- Contains **project financing measures**, comparing scenario cost information against projected revenues.

	No Build		290 Freeway Upgrade	
Annual Tolling Revenues (Thousands $)	Initial Yr	Design Yr	Initial Yr	Design Yr
Total	$122,046	$141,480	$122,046	$141,636
Change vs No Build Scenario	$0	$0	$0	$156

Project Financing (Thousands $)	No Build	290 Freeway Upgrade	290 Tolled Freeway	290 Tolling by Vehicle Class
NPV of New Tolling Revenues	$0	$782	$199,087	$231,440
NPV of Initial and Future Project Costs	$17,540	$73,246	$90,080	$90,080
Project Financing Perspective NPV	-$17,540	-$72,464	$109,007	$141,361
Project Financing Perspective IRR	N/A	N/A	22.2%	26.6%
Project Financing Perspective PP	N/A	> 20 years	6.6	5.5
NPV of Project Impacts	$0	$505,259	$188,735	$220,107
Agency Perspective NPV	-$17,540	$432,795	$297,742	$361,467

Step 12: Interpreting Results
Output Summary (4)

- Reports changes in **crashes** & **emissions**, measures that the analyst may choose to not monetize, or fully monetize (e.g. value of life).

		No Build		290 Freeway Upgrade	
Average Annual Crash Changes		Initial Yr	Design Yr	Initial Yr	Design Yr
Severity Category:	Fatal	0	0	-0.2	-0.3
	Major Injury	0	0	-0.6	-0.9
	Minor Injury	0	0	-5.4	-7.8
	Possible Injury	0	0	-11.1	-16.1
	Property Damage Only	0	0	-26.9	-39.0
Total Injury + Fatal		0	0	-17.3	-25.0

		No Build		290 Freeway Upgrade	
Average Annual Emissions Changes (tons)		Initial Yr	Design Yr	Initial Yr	Design Yr
Emissions (Tons)	HC	0	0	-83.3	-849.2
	CO	0	0	142.4	-484.6
	NOx	0	0	10.8	0.5
	CO_2	0	0	7.9	-775.6
	PM10	0	0	0.0	0.0

Step 12: Interpreting Results
Output Summary (5)

- Reports **travel behavior** changes, for time of day and mode splits.

VMT Splits by Time of Day		No Build Initial Yr	No Build Design Yr	290 Freeway Upgrade Initial Yr	290 Freeway Upgrade Design Yr
	AM Peak	26.1%	26.1%	26.1%	26.1%
	Mid Day	17.5%	17.5%	17.5%	17.5%
	PM Peak	33.1%	33.1%	33.1%	33.1%
	Evening	11.0%	11.0%	11.0%	11.0%
	Off Peak	6.0%	6.0%	6.0%	6.0%
	Total VMT	5315.6	6142.0	5315.6	6143.6

VMT Splits by Travel Mode		No Build Initial Yr	No Build Design Yr	290 Freeway Upgrade Initial Yr	290 Freeway Upgrade Design Yr
	Mode 1	72.5%	72.5%	72.5%	72.5%
	Mode 2	12.7%	12.7%	12.7%	12.7%
	Mode 3	3.2%	3.2%	3.2%	3.2%
	Mode 4	0.2%	0.2%	0.2%	0.2%
	Mode 5	11.3%	11.3%	11.3%	11.3%

Step 12: Interpreting Results
Summary Charts

- 19 Automatically generated charts for…
  - Traveler Welfare
  - Reliability Costs
  - Crash Costs
  - # of Fatal and Injury Crashes
  - Emissions Quantities
  - Tolling Revenues
  - VMT
  - Fuel Use
- Charts generated for total values & change vs. base case scenario.

Step 12: Interpreting Results
Traffic Link Comparisons

- May be used to quickly compare traffic volumes & speeds on certain links across scenarios.
- Reports **AADT**, Avg. **Speed**, **PM Peak Speed** & **Changes** vs. Base Case Scenario.

Initial Year

Link #	From Node #	To Node #	Link Name	Length (mi)	AADT Base Case	AADT 290 Freeway Upgrade	AADT 290 Tolled Freeway	AADT 290 Tolling by Vehicle Class	Average Daily Link Speed Base Case	Average Daily Link Speed 290 Freeway Upgrade	Average Daily Link Speed 290 Tolled Freeway
141	17	19	290: 35 - Dessau / Cameron	0.5	30367	30367	30367	30367	53.2	53.2	53.2
142	19	17	290: Dessau / Cameron - 35	0.5	31001	31001	31001	31001	53.2	53.2	53.2
143	19	20	290: Dessau / Cameron - 183	1.3	29501	29501	29501	29501	53.6	53.6	53.6
144	20	19	290: 183 - Dessau / Cameron	1.3	29501	29501	29501	29501	53.6	53.6	53.6
145	20	21	290: 183 - Springdale	1.2	20500	20500	20500	20500	35.4	54.8	54.8
146	21	20	290: Springdale - 183	1.2	20500	20507	20500	20500	35.4	54.8	54.8

- Enter Link #'s **here** to see different link comparisons.

Step 12: Interpreting Results
Impact Category Summaries

- Reports estimated costs in each year for a given **impact category**, including…
  - Traveler Welfare
  - Reliability
  - Crashes
  - Emission
  - Fuel Use, Tolls & VMT

Base Condition	Annual Reliability Costs	
Initial Year Costs	$236.45	(Millions)
Design Year Costs	$647.37	(Millions)
Average Annual Costs	$409.60	(Millions)
Reliability Cost Growth Rate	5.16%	

290 Freeway Upgrade	Annual Reliability Costs	
Initial Year Costs	$229.57	(Millions)
Design Year Costs	$608.35	(Millions)
Average Annual Costs	$390.19	(Millions)
Annual Reliability Benefit	$19.50	(Millions)
Reliability Cost Growth Rate	4.99%	

Annual Reliability Costs

Year	Base Cond	Sc 1	Sc 2	Sc 3
0	$236	$230	$230	$230
1	$249	$241	$242	$242
2	$262	$253	$254	$254
3	$275	$266	$268	$268
4	$289	$279	$282	$282
5	$304	$293	$297	$296
6	$320	$308	$312	$312
7	$336	$323	$328	$328
8	$354	$339	$346	$345
9	$372	$356	$364	$363
10	$391	$374	$383	$383
11	$411	$392	$403	$403
12	$433	$412	$424	$424
13	$455	$433	$447	$446
14	$479	$454	$470	$469
15	$503	$477	$495	$494
16	$529	$501	$521	$520
17	$557	$526	$548	$547
18	$585	$552	$577	$576
19	$616	$579	$607	$606
20	$647	$608	$639	$637

Step 12: Interpreting Results
Individual Scenario Sheets

- Each sheet estimates impacts for a given scenario & year
  - Volume Outputs
    - ***Foundation of all other results***
    - Receives link-volume TDM results & TW estimates
    - Estimates fuel use, speeds & reliability
  - Link Crashes
  - Intersection Crashes
  - Emission
- CAUTION: **Please refrain from reporting these results!** The Toolkit is intended to be much more accurate at the aggregate level than at the link-specific level.

Step 12: Interpreting Results
Individual Scenario Sheets (2)

- Volume Outputs

Notes: All links are directional (including # of lanes in each link)

Tot Ann. Traveler Welfare	$1
Total Variance Cost	$236,446,471
Total Ann. Toll Revenue	$123,751,306
Total Annual Fuel Use	62,904,636
Annual Million VMT	5,309.93

% AM Peak Traffic	% Mid Day Traffic	% PM Peak Traffic	% Evening Traffic	% Off Peak Traffic
26.1%	17.5%	33.1%	11.7%	6.3%

% Mode 1	% Mode 2	% Mode 3	% Mode 4	% Mode 5
77.1%	8.8%	2.9%	0.3%	10.8%

Link #	From Node #	To Node #	Link Name	Link Length	FF Speed	AM Peak Total Flow Veh/Hr	AM Peak Avg Speed	Mid Day Total Flow Veh/Hr	Mid Day Avg Speed	PM Peak Total Flow Veh/Hr	PM Peak Avg Speed	Evening Total Flow Veh/Hr	Evening Avg Speed	Off Peak Total Flow Veh/Hr	Off Peak Avg Speed	AADT
1	51	1	183: N of TT45 - TT45	1	55	917	55.0	814	55.0	1178	55.0	423	55.0	153	55.0	16501
2	1	51	183: TT45 - N of TT45	1	55	918	55.0	814	55.0	1178	55.0	423	55.0	153	55.0	16502
3	1	10	183: TT45 Loop 1	7.8	55	4150	45.0	3628	49.5	5329	29.3	1867	54.3	693	55.0	74343
4	10	1	183: Loop 1 - TT45	7.8	55	3700	48.3	3700	48.2	4797	35.1	1923	54.3	668	55.0	69619

- Emissions Outputs

Total Predicted Emissions (Tons)

#	Pollutant	Average Summer Daily	Average Winter Daily	Annual Quantity	Annual Cost	#	Pollutant	Average Summer Daily	Average Winter Daily	Annual Quantity	Annual Cost
01	HC	113.87	144.17	46,171	$0	13	NH3	2.09	2.09	764	$0
02	CO	350	566	160,499	$0	16	BENZ	1.015	1.124	387.12	$0
03	NOx	38.58	40.06	14,308	$0	18	BUTA	0.188	0.179	61.17	$0
04	CO2	10,881	10,881	3,875,176	$0	19	FORM	0.388	0.472	153.71	$0
05	PM2.5	0.48	0.48	175	$0	20	ACET	0.117	0.376	103.19	$0
06	PM10	0.85	0.85	309	$0	21	ACRO	0.01768	0.02330	7.31	$0
12	SO2	0.19	0.19	71	$0						

Daily Summer (lbs/day)

Link	From Node #	To Node #	Facility Type	Segment Length	01 HC	02 CO	03 NOx	04 CO2	05 PM2.5	06 PM10	12 SO2	13 NH3
1	51	1	1	1	236	835	91	24,828	1	2	0	5
2	1	51	1	1	236	835	91	24,828	1	2	0	5
3	1	10	1	7.8	9,117	27,381	3,026	875,358	39	69	16	168

Step 12: Interpreting Results
Sensitivity Testing Results

- Results provided for 65 **key measures**
- Also provides **individual trial outcomes** for further analysis (for example, histograms)

Total # Crashes	Initial Year Total Average	+1 S.D.	-1 S.D.
Base Case (No Build)	1473	1649	1297
290 Freeway Upgrade	1455	1629	1281
290 Tolled Freeway	1453	1628	1278
290 Tolling by Vehicle Class	1464	1651	1276

Total Initial Year Emissions (Daily Summer, Tons)	HC Average	+1 S.D.	-1 S.D.
Base Case (No Build)	98.72	114.11	83.33
290 Freeway Upgrade	98.35	113.69	83.01
290 Tolled Freeway	98.26	113.54	82.98
290 Tolling by Vehicle Class	99.31	115.36	83.25

B/C Ratio

290 Freeway Upgrade	##########	15.52183	1.13915	1.982228
	##########	12.26585	0.634471	2.884778
	##########	24.25484	10.73136	1.098318
	##########	9.032564	0.455833	3.764644
	##########	-5.731638	0	>20 years
	##########	702.3451	>100%	<1 year
	##########	13.20374	1.103969	1.999915
	##########	10.30698	0.555392	3.171644
	##########	7.417223	0.387138	4.32818
	##########	9.296439	0.465496	3.706803

7 outcomes	7-15
1 outcome	24
1 outcome	702
1 outcome	-5.7

Analyst can accept the probable range, or explore what caused the outliers.

Developing Projects in the Operational Toolkit File

- **Project Types:**
  - *Advance Traveler Information Systems*
    - Impacts: Travel time savings
  - *Incident Management*
    - Impacts : Travel time savings & emissions
  - *Speed Harmonization*
    - Impacts : Crash reduction

Developing Projects in the Operational Toolkit File
Step 1: Code the Network in the Main Toolkit File

- In order for the Operational Toolkit File to run properly, the **targeted links** must be coded in the Main Toolkit.
- Users must input link information for the **base case scenario**, including traffic volumes, # of lanes, etc.
- Record the link numbers, then close the Main Toolkit File.

Link #	From Node #	To Node #	Link Name	Link Ch... Length (mi)
1	51	1	183: N of TT45 - TT45	1
2	1	51	183: TT45 - N of TT45	1
3	1	10	183: TT45 Loop 1	7.8
4	10	1	183: Loop 1 - TT 45	7.8
5	10	15	183: Loop 1 - Lamar	2.9
6	15	10	183: Lamar - Loop 1	2.9
7	15	16	183: Lamar - 35	1
8	16	15	183: 35 - Lamar	1

Step 2: Verify the Summary Input Information

- What is the project design life?
- What are the projected traffic & incident growth rates?
- When will the strategy be active?
- What is the average duration of lane blocking incidents?
- How much traffic is present during peak times?

Max Proj Life = 50 yrs	Project Life
No Build	0
ATIS	5
Incident Management	10
Speed Harmonization	20

Avg. Vehicle Occupancy	1.60
Avg. Value of Travel Time ($/hr)	$12.00

	Temp	% of Incidents
Summer Avg	78	0.5
Winter Avg	58	0.5

Projected Traffic Growth Rate	
Annual Growth Rate	1.0%
Incident Growth Rate	1.0%
Linear Growth (0) or Exponential Growth (1)	1

Crash Costs by Severity	
Severity	Cost/Crash
Fatal	$1,130,000
Major Injury	$65,000
Minor Injury	$21,000
Possible Inj.	$11,900
PDO	$7,500

Initial Year	2011
Discount Rate	5%

	% Total Crashes in Period	Peak Period Hours	% Crashes During Peak
Midnight - 3AM	4.6%	0	0.0%
3AM - 6AM	3.2%	0	0.0%
6AM - 9AM	12.5%	3	12.5%
9AM - Noon	13.4%	0	0.0%
Noon - 3PM	19.3%	3	19.3%
3PM - 6 PM	24.4%	3	24.4%
6PM - 9 PM	14.3%	1	4.8%
9PM - Midnight	8.3%	0	0.0%
Total % of Crashes During Peak Period			60.9%
Lane Blocking Incidents per Crash			2.07
Current Average Duration of Lane Blocking Incident (min)			65

# Hours Congested	10
# Hours Uncongested	14
Hourly Traffic / AADT Congested	6.50%
Hourly Traffic / AADT Uncongested	2.50%

Step 3: Modify strategy-specific parameters

- ATIS
  - % Travelers informed by ATIS
  - % Informed travelers changing route
  - Average travel time savings for travelers changing route
- Incident Management
  - Average incident duration with incident management
- Speed Harmonization
  - Crash Reduction Factor

	Initial Year	Design Year
	2011	2021
Incidents per Year on Impacted Links	348	179
Total # Vehicles on Impacted Links (AADT)	740,000	777,747
% of Incidents during Congested Times	61%	61%
Lane Blocking Incidents per Crash	2.07	2.07
Average Incident Duration (hours)	1.08	1.08
Average Incident Duration with Incident Management (hours)	0.833	0.833
Arrival Rate per Hour as % of AADT	6.50%	6.50%
Average % Truck Traffic	10%	10%
Annual Travel Time Savings (hours)	173,377	920,431
Annual Travel Time Monetary Benefits ($)	$3,328,832	$17,672,281
Warnings	None	None

Step 4: Modify link-specific characteristics

- If individual links are assumed to have different characteristics than the default, they may be modified by the analyst.
- ATIS:

Alt Avg Incident Duration	Avg Incident Duration	% Incidents Peak Hour	Alt ATTI	ATTI	Alt % Informed	% Travelers Informed	Alt % Travelers Changing Route	% Travelers Changing Route
	1.0833333	0.6090722		4		0.25		0.05
	1.0833333	0.6090722		4		0.25		0.05
	1.0833333	0.6090722		4		0.25		0.05
	1.0833333	0.6090722		4		0.25		0.05
	1.0833333	0.6090722		4		0.25		0.05

- IM:

Alt Avg Incident Duration	Avg Incident Duration	Alt Avg Incident Duration w IM	Avg Incident Duration w IM	% Incidents Peak Hour	Alt Arrival Rate (% of AADT)	Arrival Rate (% of AADT)
	1.083333333		0.833	0.6090722		6.50%
	1.083333333		0.833	0.6090722		6.50%
	1.083333333		0.833	0.6090722		6.50%
	1.083333333		0.833	0.6090722		6.50%

- SH:

Initial Year		Design Year	
Alt % Crashes when Active	% Crashes when Active	Alt % Crashes when Active	% Crashes when Active
	61%		61%
	61%		61%
	61%		61%

Step 5: Develop the Engineer's Estimate

- Cost information layout is identical to the Engineer's Estimate in the Main Toolkit File.

	Lane Miles	Const Cost / Lane Mile	ITS / Signal / Electrical	Bridges & Structures	Utility & Other Fixed Costs	Construction Subtotal	Traffic Control	Environmental Construction	Additional Costs Subtotal	Construction Cost Total
No Build	0.0	$0	$0	$0	$0	$0	0.0%	0.0%	$0	$0
ATIS	0.0	$0	$100,000	$0	$0	$100,000	0.0%	0.0%	$0	$100,000
Incident Management	0.0	$0	$100,000	$0	$0	$100,000	0.0%	0.0%	$0	$100,000
Speed Harmonization	0.0	$0	$100,000	$0	$0	$100,000	0.0%	0.0%	$0	$100,000

	Design as % of Const Costs	Design	ROW Purchase	Construction Engineering	Construction Engineering	Contingencies	Contingencies	Overhead & Indirect Costs	Overhead & Indirect Costs
No Build	0%	$0	$0	0.0%	$0	0.0%	$0	0.0%	$0
ATIS	0%	$0	$0	0.0%	$0	0.0%	$0	0.0%	$0
Incident Management	0%	$0	$0	0.0%	$0	0.0%	$0	0.0%	$0
Speed Harmonization	0%	$0	$0	0.0%	$0	0.0%	$0	0.0%	$0

	Design	ROW Purchase	Construction Engineering	Construction Cost	Contingencies	Overhead & Indirect Costs	Total Initial Project Costs
No Build	$0	$0	$0	$0	$0	$0	$0
ATIS	$0	$0	$0	$100,000	$0	$0	$100,000
Incident Management	$0	$0	$0	$100,000	$0	$0	$100,000
Speed Harmonization	$0	$0	$0	$100,000	$0	$0	$100,000

	Add. Annual Maintenance	Salvage Value	Maint & Rehab Project Year	Maint & Rehab Project Cost
No Build	$0	$0		
ATIS	$100,000	$0		
Incident Management	$100,000	$0		
Speed Harmonization	$100,000	$0		

Step 6: Import Data from the Main Toolkit File

- Ensure that the **Full Toolkit Worksheet Name** in the Summary Input Information sheet is correct.

Full Toolkit Worksheet Name	sketch_toolkit.xlsm

- Press the "Import <Operational Strategy> Data" Button.

Import Incident Management Data

- The Operational Toolkit File will open the Main Toolkit File, import **traffic volumes** and estimate **crashes** & **incidents**.

Step 7: Review Results

- Project Summary Sheet is similar to that in the Main Toolkit File.

Initial Project Costs	Right of Way	$0	$0	$0	$0
	Design	$0	$0	$0	$0
	Construction	$0	$100,000	$100,000	$100,000
	Other	$0	$0	$0	$0
Total Initial Costs		$0	$100,000	$100,000	$100,000

	No Build	ATIS	Incident Management	Speed Harmonization
Total Initial Year Costs	$0	$100,000	$100,000	$100,000
Change in Annual Maint. & Operations Costs	$0	$100,000	$100,000	$100,000
Annualized End of Life Salvage Value	$0	$0	$0	$0
Interim Project Cost	$0	$0	$0	$0
Interim Project Year	0	0	0	0

	No Build	ATIS	Incident Management	Speed Harmonization
Initial Year Monetary Benefits	$0	$143,919	$1,328,832	$469,479
Travel Time Savings	$0	$143,919	$1,328,832	$0
Crashes	$0	$0	$0	$469,479

	No Build	ATIS	Incident Management	Speed Harmonization
Design Life Year Monetary Benefits	$0	$161,692	$17,672,281	$502,447
Traveler Welfare	$0	$161,692	$17,672,281	$0
Crashes	$0	$0	$0	$502,447

Net Present Value	$0	$264,763	$66,613,051	$4,909,106
Internal Rate of Return	N/A	> 100%	> 100%	> 100%
Benefit / Cost Ratio	N/A	1.52	81.19	4.83
Payback Period	N/A	< 1 year	< 1 year	< 1 year

How are different *Project Types* modeled?

Capacity Addition

- [illegible] time of day.

Link Characteristics								
Link #	From Node #	To Node #	Link Name	Length (mi)	Link Class	Area Type	# Lanes	Variable Capacity (0/1)
1	51	1	183: N of TT45 - TT45	1	1	1	3	0
2	1	51	183: TT45 - N of TT45	1	1	1	3	0
3	1	10	183: TT45 Loop 1	7.8	1	1	3	0
4	10	1	183: Loop 1 - TT 45	7.8	1	1	3	0
5	10	15	183: Loop 1 - Lamar	2.9	1	1	3	0
6	15	10	183: Lamar - Loop 1	2.9	1	1	3	0
7	15	16	183: Lamar - 35	1	1	1	3	0
8	16	15	183: 35 - Lamar	1	1	1	3	0
9	16	18	183: 35 - Dessau / Cameron	0.9	1	1	3	0

Capacity & Link Performance Parameters			Managed Lanes with Variable Capacity			
Link Capacity (pc/hr)	BPR Formula Alpha	BPR Formula Beta	AM Peak Capacity	Mid Day Capacity	PM Peak Capacity	Evening Capacity
5730	0.83	5.5				
5730	0.83	5.5				
5730	0.83	5.5				
5730	0.83	5.5				
5730	0.83	5.5				
5730	0.83	5.5				

Road Pricing

- Tolls can be set vary by **time of day** & by **vehicle class** for each highway network link.
- **Adjust Base Toll Settings** as applicable.

Go To Navigation Panel | Copy Base Toll Settings

AM Toll Settings					Mid Day Toll Settings					PM	
Vehicle Class 1	Vehicle Class 2	Vehicle Class 3	Vehicle Class 4	Vehicle Class 5	Vehicle Class 1	Vehicle Class 2	Vehicle Class 3	Vehicle Class 4	Vehicle Class 5	Vehicle Class 1	Vehicle Class 2
$0.25	$0.13	$0.13	$0.00	$0.75	$0.25	$0.13	$0.13	$0.00	$0.75	$0.25	$0.13
$0.25	$0.13	$0.13	$0.00	$0.75	$0.25	$0.13	$0.13	$0.00	$0.75	$0.25	$0.13
$0.35	$0.18	$0.18	$0.00	$1.05	$0.35	$0.18	$0.18	$0.00	$1.05	$0.35	$0.18
$0.35	$0.18	$0.18	$0.00	$1.05	$0.35	$0.18	$0.18	$0.00	$1.05	$0.35	$0.18
$0.20	$0.10	$0.10	$0.00	$0.60	$0.20	$0.10	$0.10	$0.00	$0.60	$0.20	$0.10
$0.20	$0.10	$0.10	$0.00	$0.60	$0.20	$0.10	$0.10	$0.00	$0.60	$0.20	$0.10
$0.20	$0.10	$0.10	$0.00	$0.60	$0.20	$0.10	$0.10	$0.00	$0.60	$0.20	$0.10
$0.20	$0.10	$0.10	$0.00	$0.60	$0.20	$0.10	$0.10	$0.00	$0.60	$0.20	$0.10

Ramp Metering & Shoulder Lane Use

- Ramp Metering:
  - **Reduce on-ramp** link **capacity** (to protect main-lane flow).
  - Reflects extra time required to access freeway.
- Shoulder Lane Use:
  - **Increase Freeway Capacity** during peak periods using variable capacity feature of Toolkit.

Experiences with Shoulder Lane Use Use

Strategy	**Location**	***Capacity Increase Observed***
11.5' lanes & 10' shoulders	Hessen, Germany	Increase of 1150 vph in each direction
Four 11.5' lanes & 6.5' shoulders converted to one 10' lane & four 10.5' lanes.	Paris, France	660 vph in one direction & 1070 vph in the other.
11.5' lanes w/10.5' shoulders	Netherlands	Up to 50% capacity increase (similar to regular lane add).

Future Work

- Recognize **fixed node-specific costs**
  - Analysts to specify ***parking costs***, **access times** & **headways**.
- **Testing** & **Verification**
  - Test more scenarios to ensure results make intuitive sense.
  - Compare Toolkit results to full-scale, demand model results.
- Texas **Implementation**
  - **Code** additional **networks** for Texas cities & regions.
  - Conduct toolkit **training** for on-site planning staff.
  - Enable **MPO-model** predictions as inputs to NPV calculations.

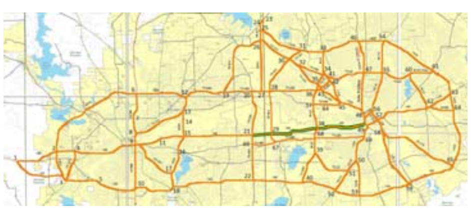
Future Work (2)

- Develop a **transit module**
  - Fixed routes and stops, variable service frequency, bus capacity and comfort, and more realistic cost structures.
  - Mixed assignment of highway-transit traffic assignment.
- Desired Other Work
  - Rely on **MOVES** emissions rates.
  - Implement **HSM** & **historical crash rates** for crash prediction.
  - Non-motorized travel.

Conclusions

- With shrinking budgets and expanding needs, we must **invest** our transportation funds **wisely**.
- The PET allows one to anticipate & compare a variety of **operational** & **capacity expansion** strategies' outcomes.
- PET evaluates **project impacts** in the form of travel time savings, operating costs, reliability, crashes & emissions.
- PET **quickly identifies project alternatives** with greatest potential to positively impact transport systems.
- For capacity-expansion projects, emissions & crash benefits appear dwarfed by traveler **welfare & travel-time reliability** impacts.

Thank you for your time!



Questions & Suggestions?

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