The Application of Transportation Modeling For USACE Flood Risk Management Projects

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U.S. Army Corps of Engineers

- Federal agency within the Department of the Army
  - World's largest public engineering agency
  - 37,000 employees in 130 countries (98% civilian)
- Major Missions
  - Military Construction Program
  - Civil Works Program:
    - Navigation
    - Flood Risk Management
    - Ecosystem Restoration
    - Hydropower
    - Recreation
    - Regulatory
    - Water Supply




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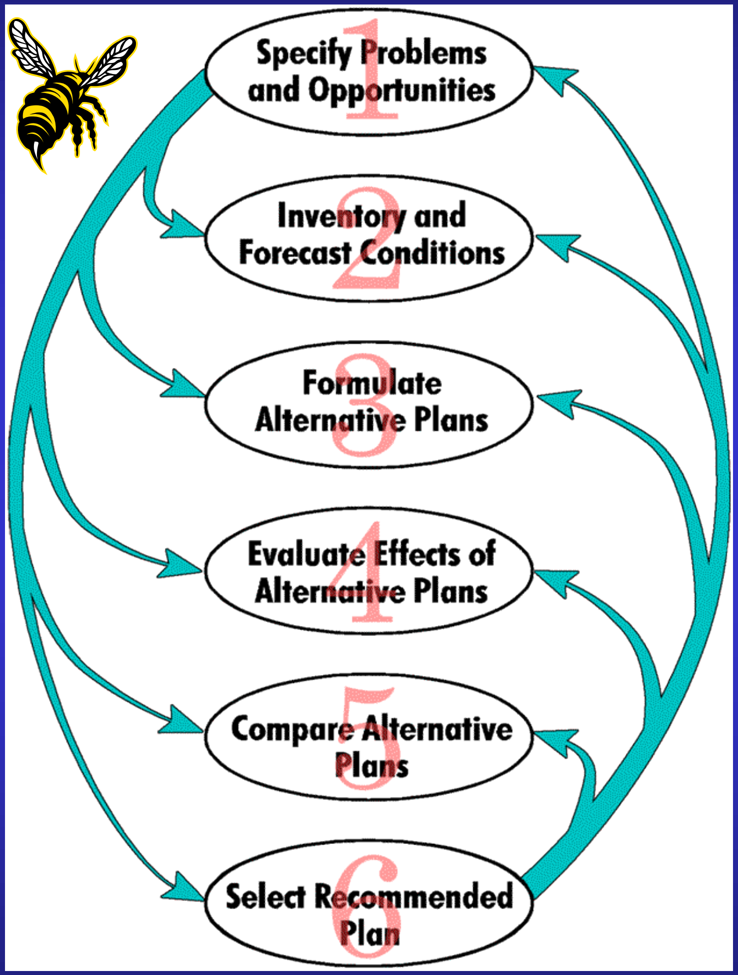
Civil Works Planning



- 1st step in CW process
- Structured Approach to Solving Problems
- Iterative Process
- Can we?... Should we?
- Planning Weaves Environmental, Social, Scientific and Engineering Challenges into Solutions
- Uses Interdisciplinary, Multiple Agency, Sponsor and Stakeholder Teams

Why Transportation Modeling?

- In urban areas (Chicagoland) roadway flooding can significantly affect transportation patterns
- Significant economic costs associated with increased travel times and mileage (comparable to structural damages)
- Considerations for emergency services/ evacuations
- Don't want to leave "benefits on the table"
- *USACE Policy does not allow formulation solely for transportation benefits

Earlier Transportation Models

- **In-house spreadsheet models based on HCM compared travel times of normal and selected detour routes**
  - **Upper Des Plaines River (1999)**
  - **Chicago Shoreline (1993)**
  - **CUP Thornton (1986)**
  - **Little Calumet River (1982)**

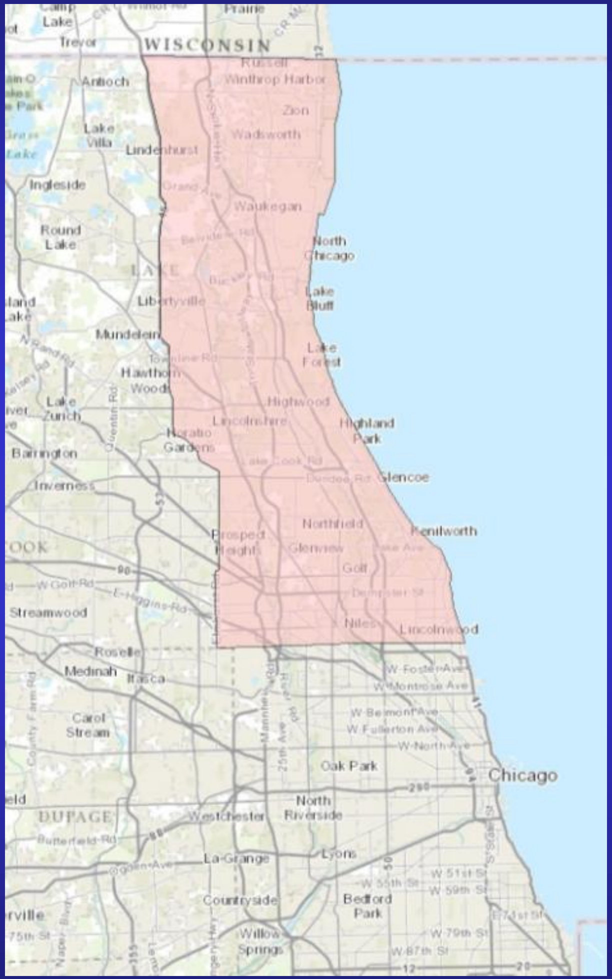
- **EMME/2 static traffic assignment model (UIC)**
  - **Upper Des Plaines River (2002)**

Transition to DTA Modeling

- Static models not robust enough for scenario analysis in urban areas
- Considerations for system wide effects of road closures (secondary roadway impacts)
- Time dependent nature of flooding in large watersheds (main stem vs. tributaries)
- More advanced simulation capabilities
  - Driver behavior
  - Driver knowledge
  - Queuing

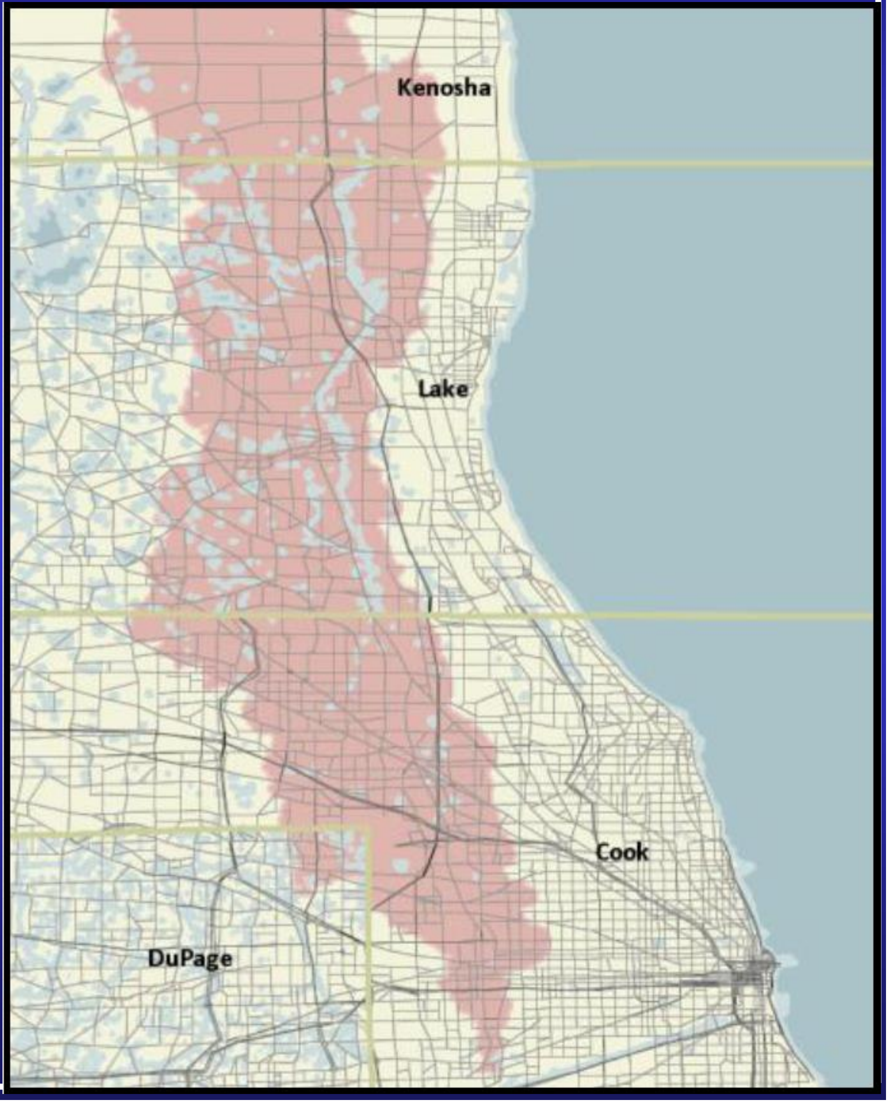
North Branch Chicago River (2005)

- Pilot VISTA model
  - 3,000 nodes
  - 8,600 links
  - 1.3 million vehicles
  - 24-hour simulation of 8 flooding scenarios
- 100-year flood scenario
  - Travel delays of 1.1 million hours
  - Mileage increases of 388,000 miles
  - $3.4 million in damages



Upper Des Plaines River and Tributaries, IL&WI (2009)

- **VISTA model:**
  - 6,300 nodes
  - 19,500 links
- **2 Conditions:**
  - Base 2006
  - Future 2020
- **8 flood scenarios:**
  - 1-yr, 2-yr, 5-yr, 10-yr, 25-yr, 50-yr, 100-yr, 500-yr



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Baseline Conditions Results

Demand	2006 Model Year		2020 Model Year			
Car Trips		8,147,245		8,790,106	+642,861	+7.9%
Truck Trips		734,060		873,980	+139,920	+19.1%
Total Trips		8,881,305		9,664,086	+782,781	+8.8%
Travel Time	Total *hours*	Average *minutes*	Total *hours*	Average *minutes*	Total *hours*	Total *percent*
Cars	1,431,737	10.54	1,697,422	11.58	+265,685	+18.6%
Trucks	123,033	10.12	195,821	13.44	+72,788	+59.2%
All	1,554,770	10.50	1,893,243	11.75	+338,473	+21.8%
Mileage	Total *miles*	Average *miles*	Total *miles*	Average *miles*	Total *miles*	Total *percent*
Cars	54,465,055	6.68	45,846,573	5.21	-8,618,482	-15.8%
Trucks	5,337,763	7.27	5,586,258	6.39	+248,495	+4.7%
All	59,802,818	6.73	51,432,831	5.32	-8,369,987	-14.0%

Note: cumulative values over 25 days

Flooding is Time Dependent

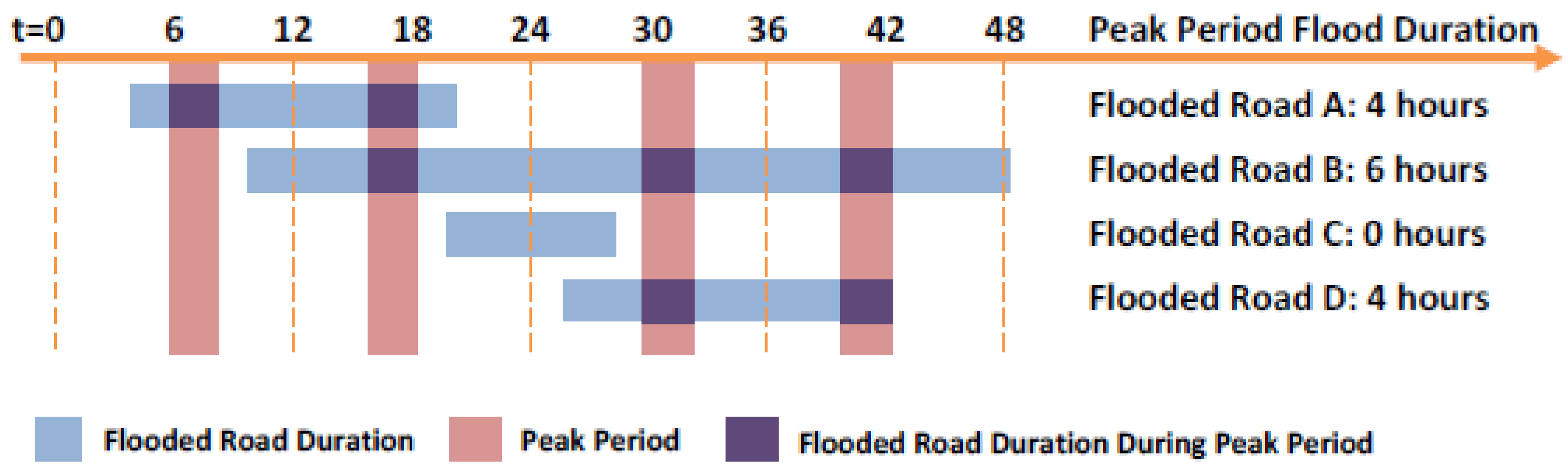


Figure 2: Example Peak Period Flood Durations

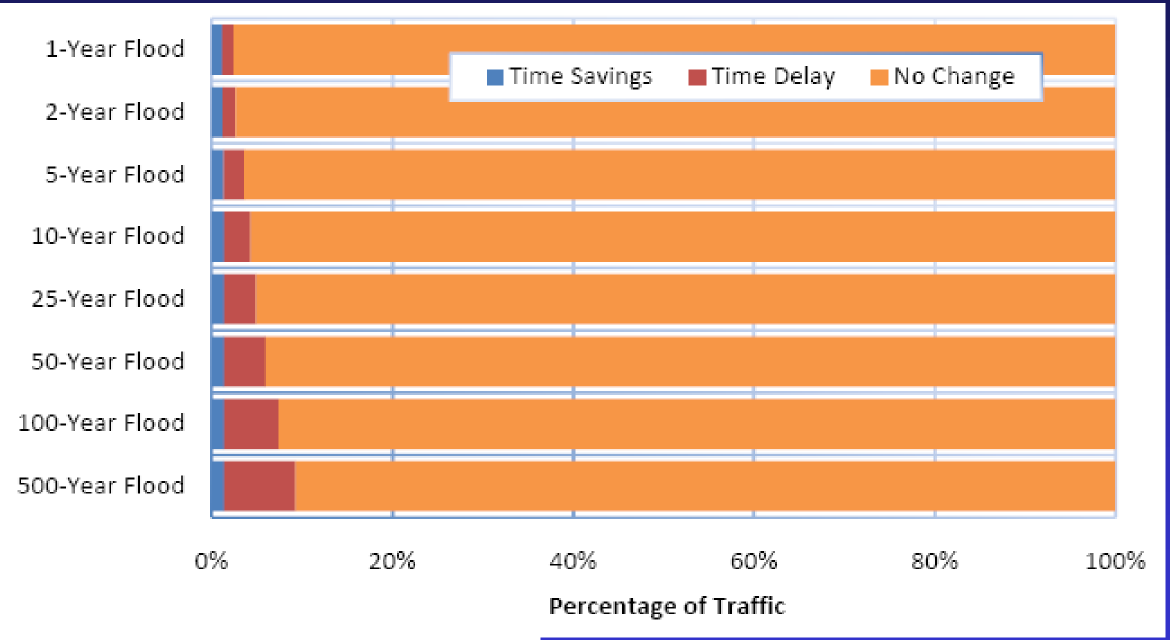
Road Closure Flood Schedules

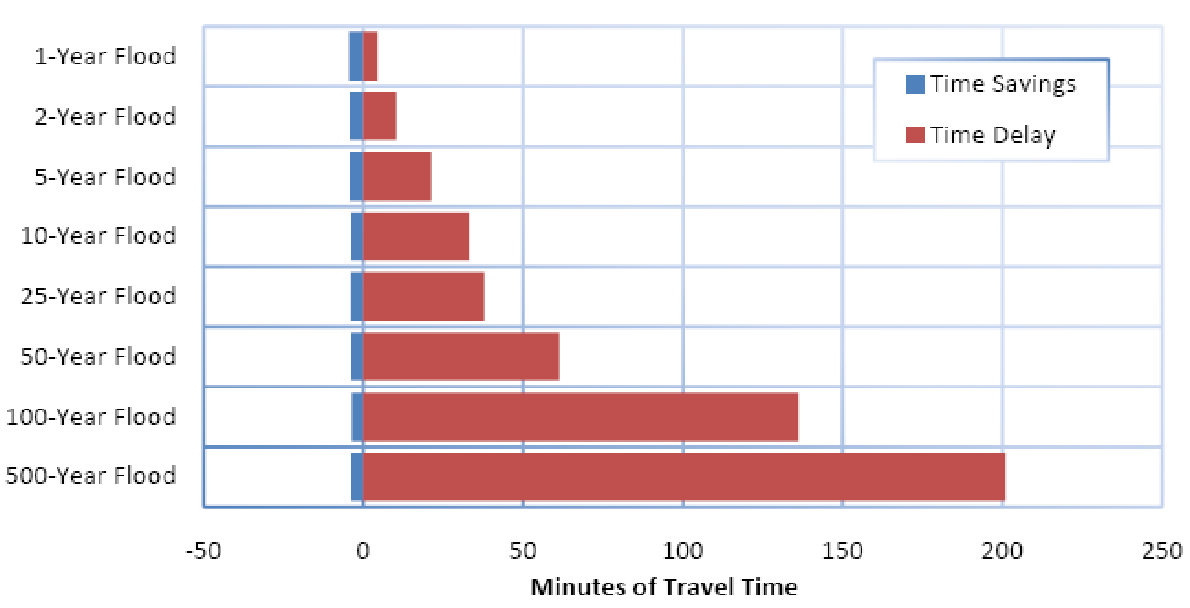
- **H&H Analysis Over Entire Watershed is Critical**
  - **Must capture all potential road closures in network**
- **Storm Duration Sensitivity Due to Watershed Shape**
  - **Mainstem vs. Tributaries Critical Duration: 10-day vs. 24-hr**

Max Duration
3 days
7 days
12 days
15 days
19 days
21 days
21 days
25 days

Severity	2006 Model Year		2020 Model Year	
1-year	29 hours	2 roads	30 hours	2 roads
2-year	156 hours	7 roads	233 hours	8 roads
5-year	1,436 hours	25 roads	1,824 hours	33 roads
10-year	3,205 hours	42 roads	3,772 hours	44 roads
25-year	5,529 hours	71 roads	6,248 hours	73 roads
50-year	7,609 hours	83 roads	8,206 hours	87 roads
100-year	9,523 hours	112 roads	10,225 hours	116 roads
500-year	14,286 hours	165 roads	15,503 hours	173 roads

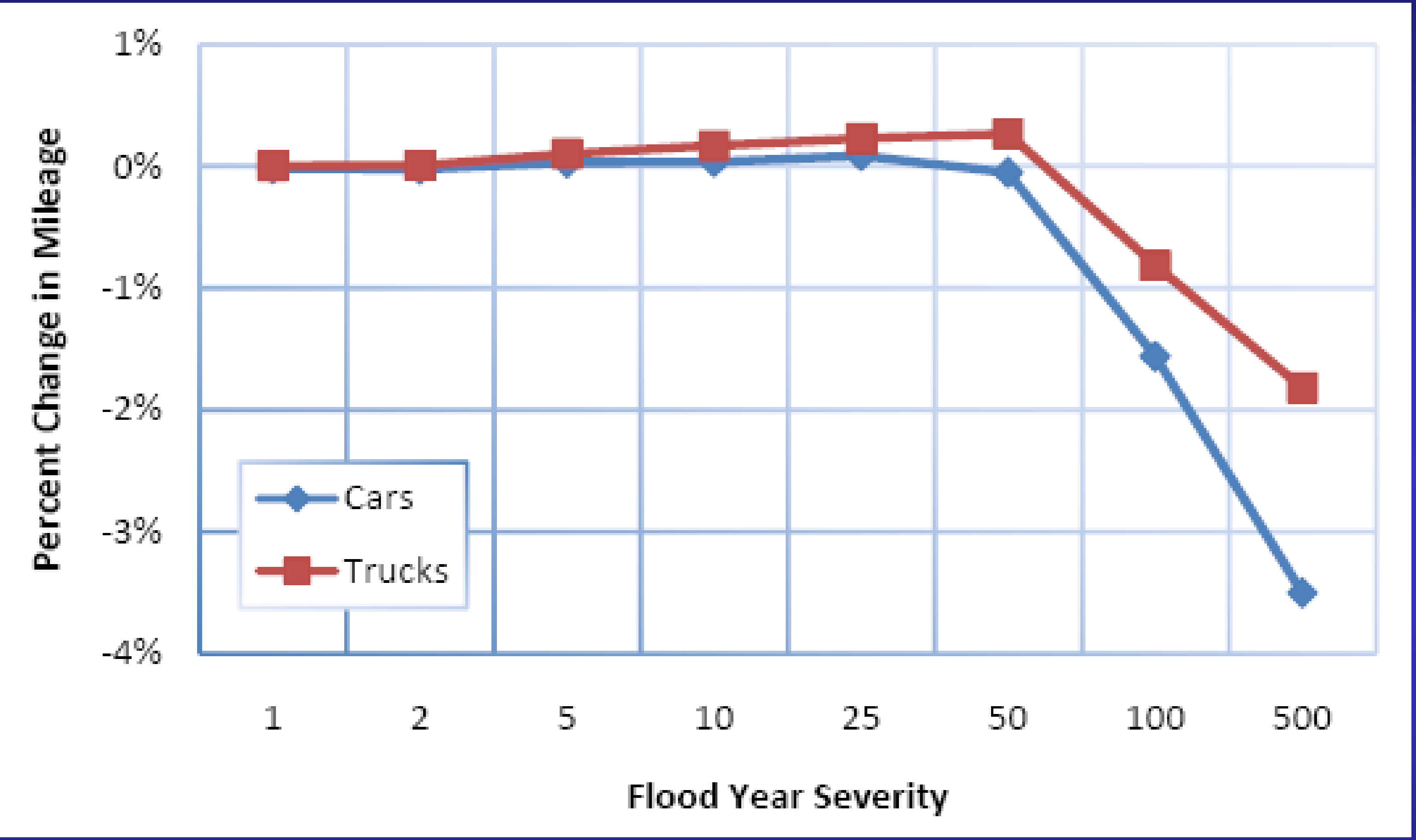
System-Wide Flood Detours





Note: Average Value Results

System-Wide Flood Detours



Note: Artificial Mileage Decreases at 100 & 500-yr events due extreme congestion preventing some vehicles from reaching destination by end of 24-hr simulation

Allocate System-Wide Results to Individual Flooded Crossings

- **System Impacts-Based Aggregation (SIBA) Method**
  - **Weighting Vehicle Delays Based on Proportion of non-Flood Conditions Traffic Volumes**
  - **Weights are Apportioned among total daily delay and aggregated over all delays by location**

	Midnight						Noon					
A	100	200	400	700	900	600	400	600	700	600	400	300
B	800	900	1300	1700	1600	1400	1500	1700	1800	1600	1300	1100
C	500	800	1700	2100	1900	1400	1200	1500	1900	1400	900	700

	Day 1	Day 2	Total
Delay	25 hours	15 hours	40 hours

	Day 1	Day 2	Total
A	$\frac{4000\times25}{10000}=10$ hours	$\frac{0\times15}{9000}=0$ hours	10 hours
B	$\frac{6000\times25}{10000}=15$ hours	$\frac{3000\times15}{9000}=5$ hours	20 hours
C	$\frac{0\times25}{10000}=0$ hours	$\frac{6000\times15}{9000}=10$ hours	10 hours

Monetizing Transportation Impacts

- **Delays and detour mileage monetized:**
  - **Time value of delay per Corps guidance**
  - **Vehicle per-mile operating costs from DOT**
- **Depth damage functions developed for each flooded crossings**
- **50-year equivalent annual damages from HEC-FDA**
  - **Structural damages - $9.6 million**
  - **Transportation damages - $42.6 million (82% of total damages)**

Time Value of Delay

Table D-4: Value of Time Saved by Trip Length and Purpose

		Value of Time Saved Adjusted to Hourly Basis ($/hr)	Value of Time Saved Adjusted to Hourly Basis (% of hourly family income of driver)
Low Time Savings (0-5 min)	Work Trips	$1.54	6.4%
	Social/ Recreation Trips	$0.31	1.3%
	Other Trips	$0.02	0.1%
Low Time Savings (0-5 min)	Work Trips	$7.74	32.2%
	Social/ Recreation Trips	$5.55	23.1%
	Other Trips	$3.49	14.5%
Low Time Savings (0-5 min)	Work Trips	$12.93	53.8%
	Social/ Recreation Trips	$14.42	60.0%
	Other Trips	$15.50	64.5%
	Vacation		
	All Time Savings	$18.05	75.1%

* Work trips is on per person basis while all other trip purpses are on a per vehicle basis
* This example assumes $50,000 median family income

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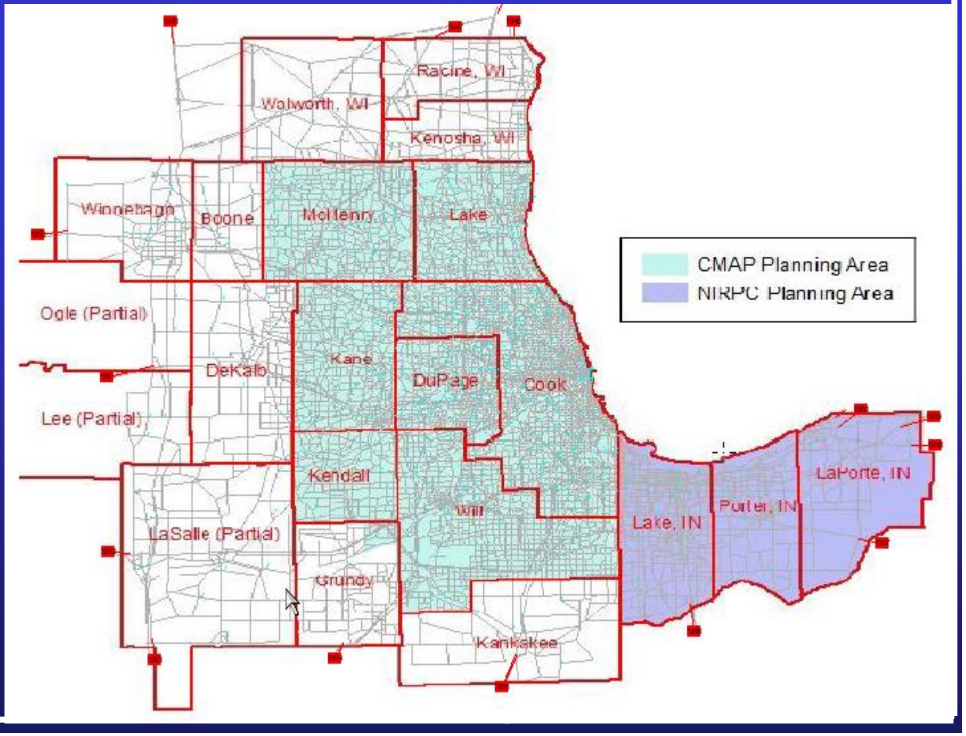
Limitations of VISTA Analysis

- Massive computing power requirements
  - Could not model run in-house
  - Continuous contractor support
- Very long run times
- Proprietary model
  - USACE model certification
  - Beholden to single contractor

Regional DTA Model (2013)

- DynusT Model
  - Developed in partnership with FHWA
  - Supported by University of Arizona (open source)
  - Runs on a powerful PC (64 GB RAM)
  - Need transparency for USACE model certification
- Baseline model for entire CMAP region
  - 20,000 nodes
  - 40,000 links
  - 20,500,000 vehicles
  - One of largest DynusT models ever developed



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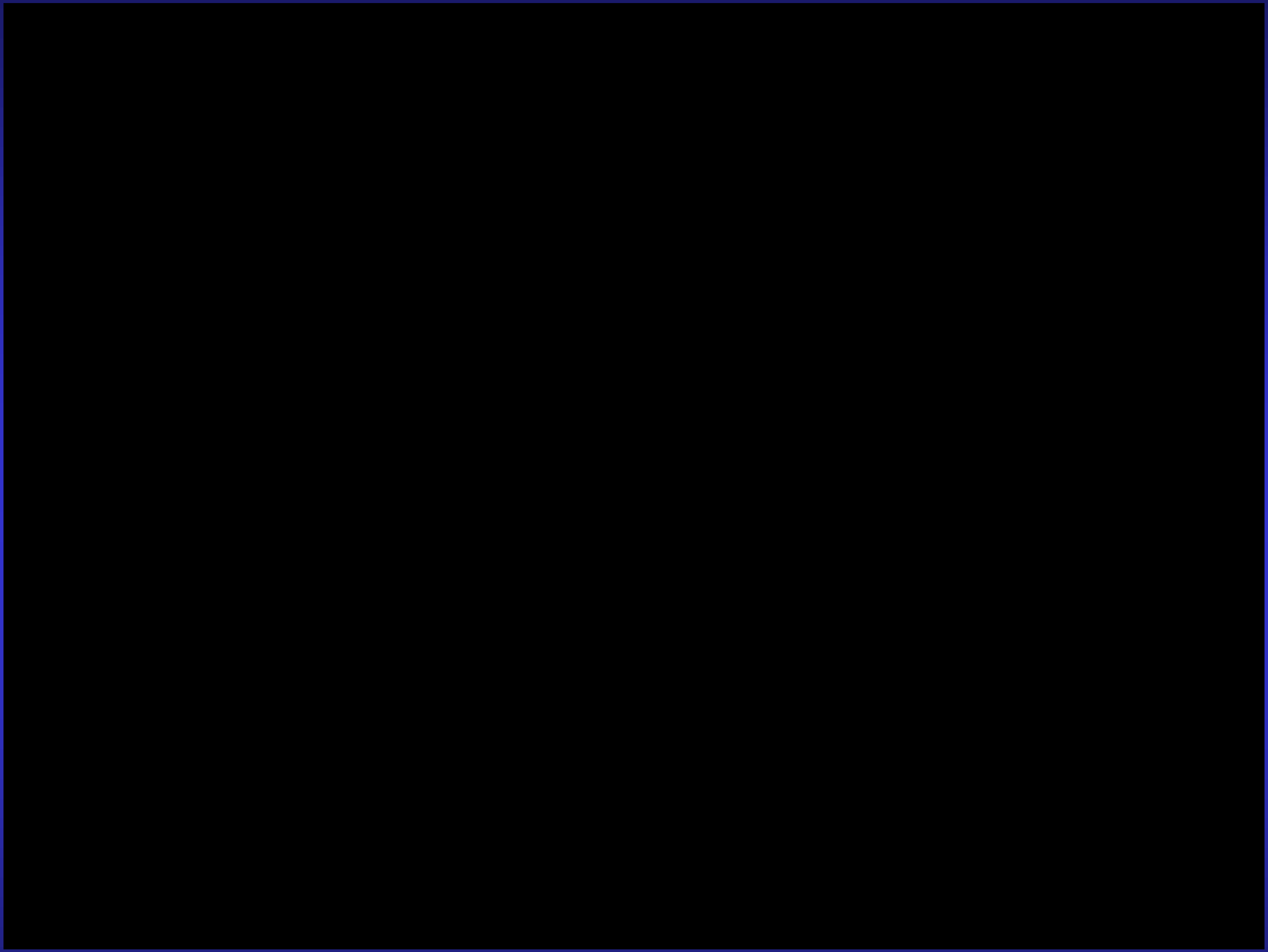
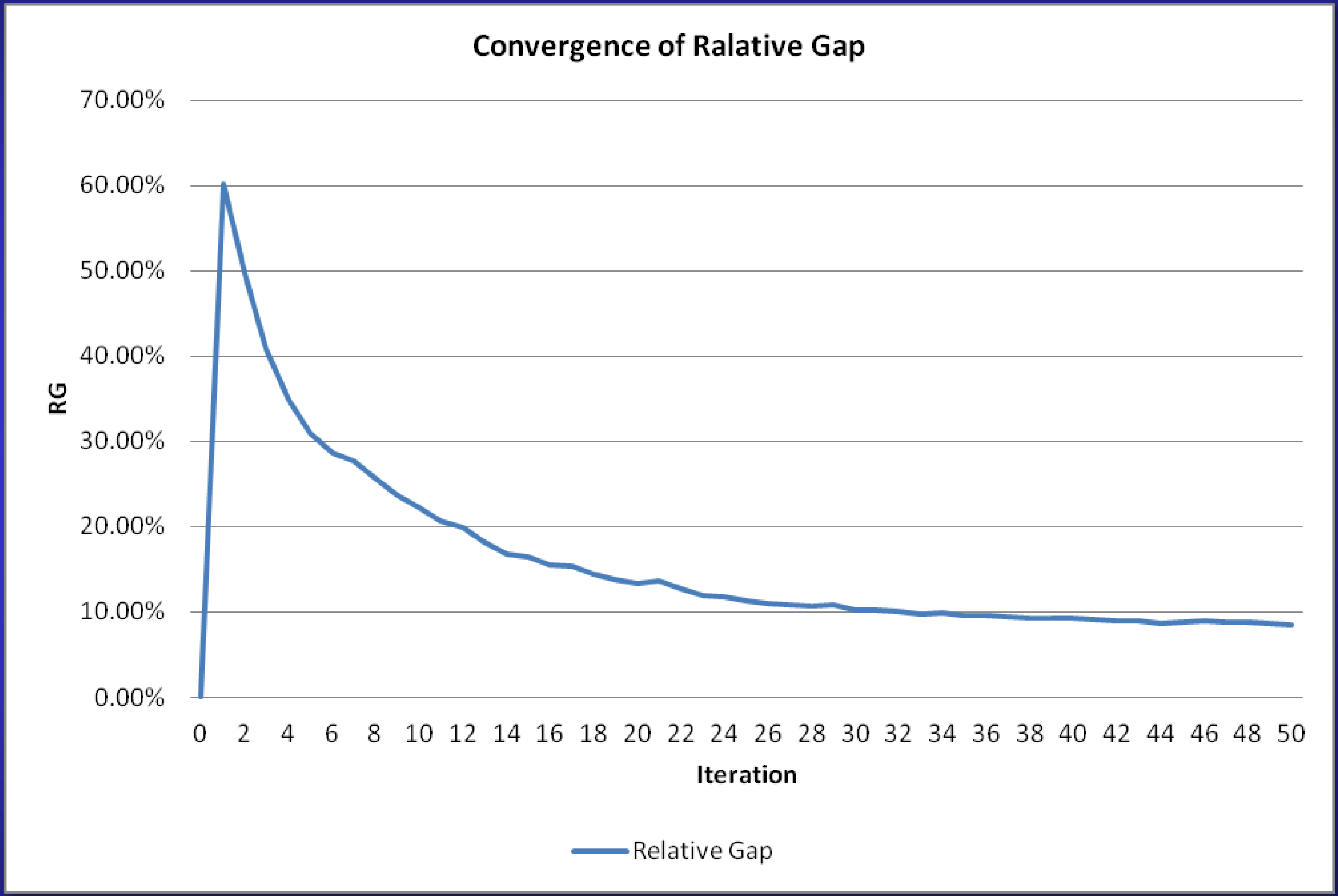
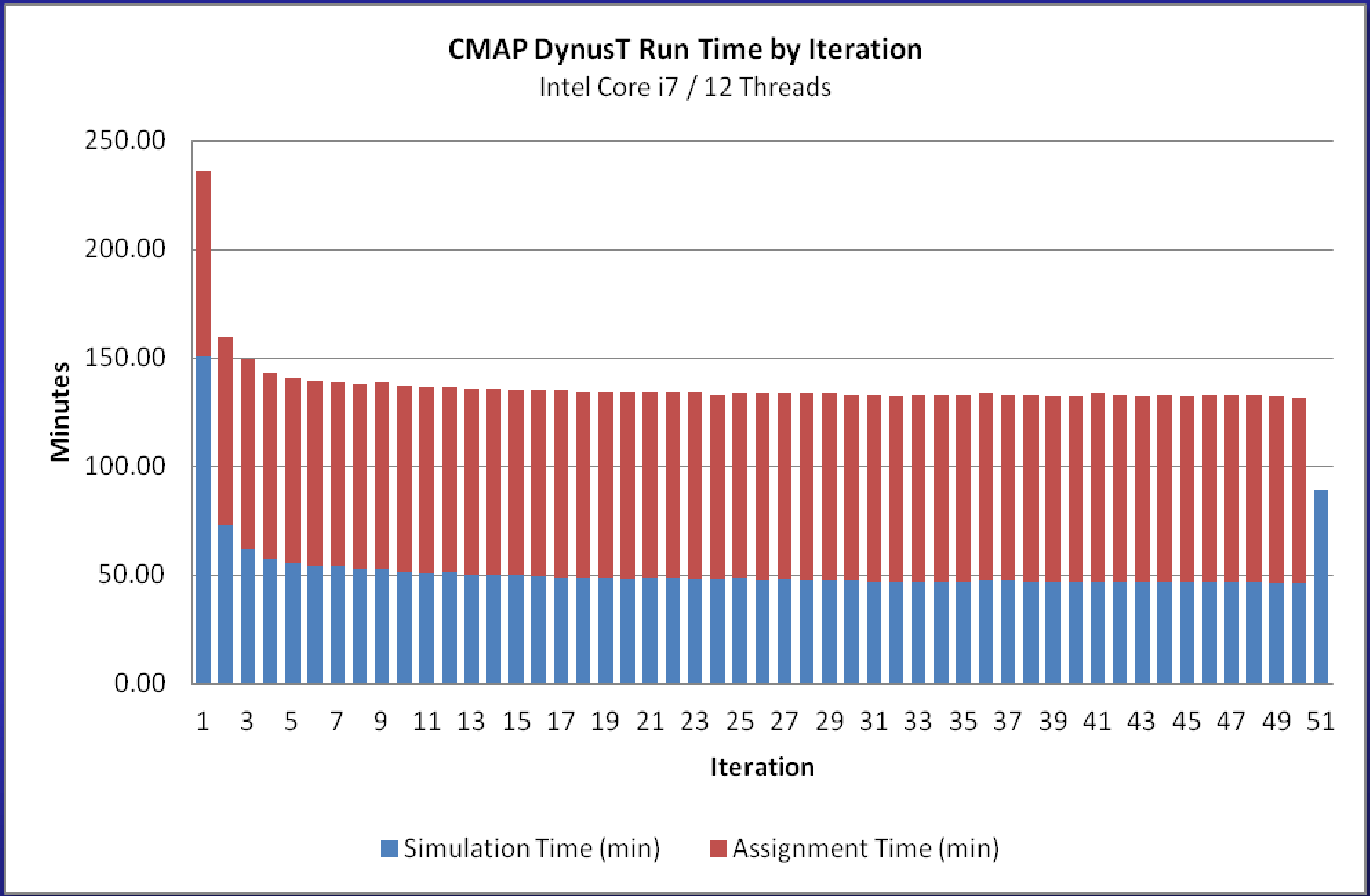


Convergence



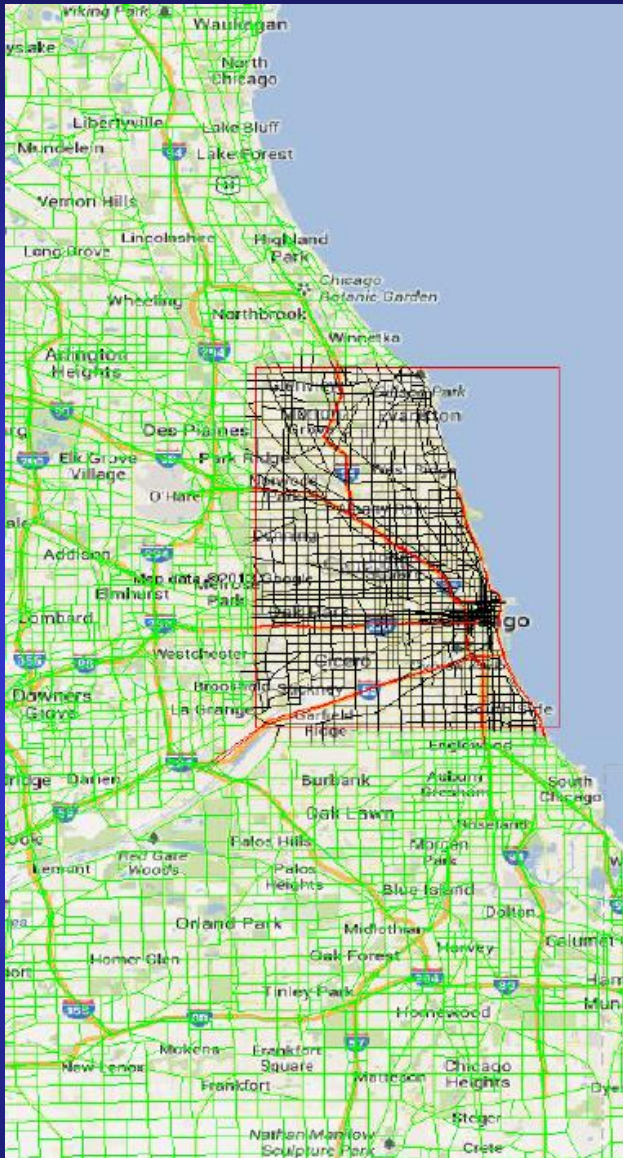
Run Times – 24 hr Run (~130 min per iteration)



Baseline Conditions Results

Table 3.3: Performance Measures from 24h DTA Model

DTA	Total Veh	Total VMT	Total VHT	Avg Time	Avg VMT
6AM-7AM	901,948	11,717,398	321,485	21.39	12.99
7AM-9AM	2,842,342	37,039,212	1,215,081	25.65	13.03
9AM-10AM	1,235,103	15,564,740	524,106	23.73	11.75
2PM-4PM	3,118,837	34,581,352	1,178,682	22.68	11.09
4PM-6PM	2,930,357	30,745,333	1,032,591	21.14	10.49
6PM-8PM	1,658,462	15,034,794	412,888	14.94	9.07
AM+PM	12,690,049	144,682,829	4,684,833	22.14	11.40
Diff to CMAP	-1%	-4%	-5%	-5%	-3%



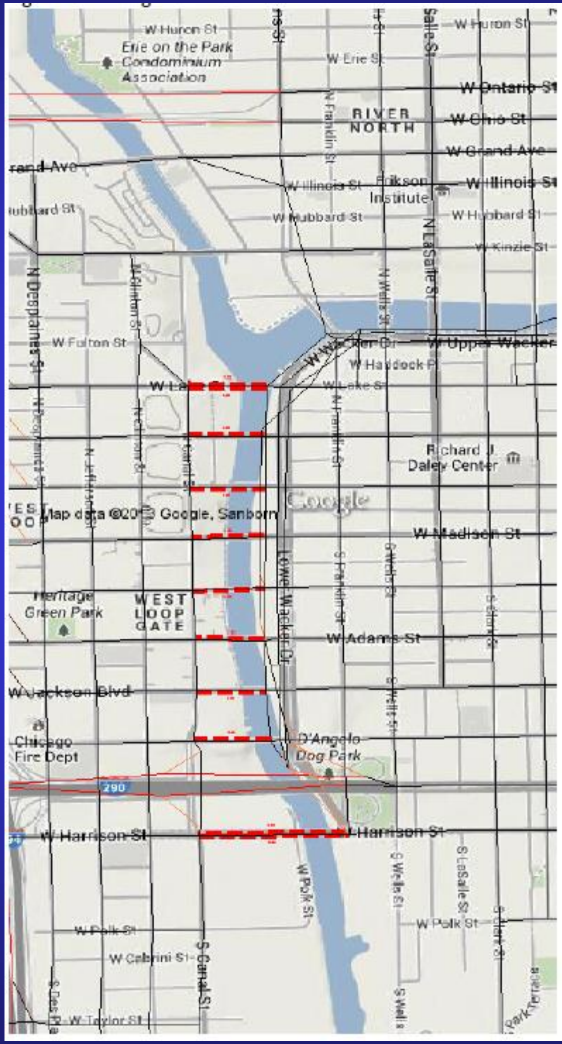
Subarea Cut Analysis

- ~¼ the trips/ ¼ the run time
- Maintain boundary conditions

Direction	Trips	% of Total
Internal -> Internal	2,641,696	57.40%
Internal -> External	903,479	19.63%
External -> Internal	917,940	19.94%
External - > External	142,264	3.09%
	4,605,379	

Start Time	PC	TRUCK	HOV
0	216,050	41,425	15,731
360	155,590	29,935	19,632
420	445,648	161,389	43,094
540	191,145	102,038	7,434
600	880,258	337,375	20,250
840	494,533	160,237	24,110
960	565,385	77,457	39,843
1080	342,631	25,985	15,390
1200	150,466	28,826	10,646
Total	**3,441,706**	**964,667**	**196,130**

Bridge Closure Scenario Test



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Transportation Impacts of Closures

- Average travel time increased by 1.5 minutes (~10%)
- Average travel distance relatively unchanged

Scenario	Vehicles	Total Time (min)	Total Distance (miles)	Total Delay (min)	Avg Time (min)	Avg Distance (miles)	Avg Delay (min)
Base	3,440,889	800,766	20,093,886	13,333,186	13.96	5.84	3.87
Closure	3,440,889	884,216	20,042,604	18,683,014	15.42	5.82	5.43
Change%	0%	10.42%	-0.30%	40.12%	10.45%	-0.35%	40.31%

DynusT Moving Forward

- Advantages of DynusT
  - Free/ open source (DynuStudio is proprietary)
  - Ability to run model on powerful PC
  - Growing community of practice
- Next Steps
  - Develop in-house capabilities
  - Application of model for actual project scenarios
  - USACE model certification
- Potential model improvements
  - High resolution GIS network
  - ABM-based demands inputs
  - Transit simulations
  - Signal Optimization
  - Future conditions

QUESTIONS?
COMMENTS?

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