25 Years of OTDMUG

What We've Seen and What We Want to See

Gregory Giaimo
December 6, 2024

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In the beginning...

Rob Bostrom serves as the first speaker

Introducing...

The [Ohio] Travel Demand Forecasting Models

Users Group

Inaugural Session

Who
Anyone interested in being informed about travel demand modeling in Ohio
Invitations are being sent to people from ODOT, FHWA, MPOs and consultants
When
10:00 - 1:00
December 14, 1999
Where
Columbus, Ohio
Ohio Department of Transportation, Don Scott Airport
How
From south or west, take IR 270 to SR 161 exit in Dublin, take SR 161 east to Don Scott
From north or east, take IR 270 to SR 315 south to SR 161, take SR 161 west to Don Scott

Featured Speaker
Rob Bostrom, Kentucky Transportation Cabinet

Agenda
Introductions, Mark Byram, ODOT
Kentucky's TDF Model Users Group, Rob Bostrom, KYTC
Status Report; Ohio Statewide Travel Demand Forecasting Model, Greg Giaimo, ODOT
Organizational Issues
      Officers (Types, Nominations, Elections)
      Meeting Structure, Frequency, Duration
      Refreshments at Meetings, Need for a Treasury
      Users Group Web Site
      Subject and Date of Next Meeting
Open Discussion of Current Modeling Issues

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MUG Trivia

How Many MUG Meetings Have There Been?

Don't Answer if You Saw My Slides or Supporting Info!

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MUG Trivia

Answer: 94 (including today)

You can easily tell by adding up my attendance which is perfect

Though this is a trick question, the summer training sessions in 2008 and 2009 were logged as presentation sessions but no attendance was taken

We missed 4 meetings around Covid (Spr 20, Sum 20, 21, 23) and didn't have a Win 00 meeting either for some reason

Dan Slicker has highest non-ODOT attendance

Jonathan Avner highest private attendance

Full Name	Attend
Greg Giaimo	93
Rebekah Straub	87
Nino Brunello	86
Mark Byram	79
Sam Granato	78
Dan Slicker	72
Zhuojun Jiang	63
Jonathan Avner	50
Lisa Householder	49
R.P. Samulka	49
Josh Kieselbach	47
Lamar Daniel	44
Amy Prater	42
Andrew Rohne	42
Bryan Raderstorf	41
Dave Snelting	40
Saleem Salameh	38
Jody Sigmon	38
David Schmitt	37
Jamie Snow	36
Vince Bernardin	33
James Patterson	31
Rob Bostrom	30
Hwashik Jang	29
Ansen Wu	28
Leigh Oesterling	26
Ami Parikh	26

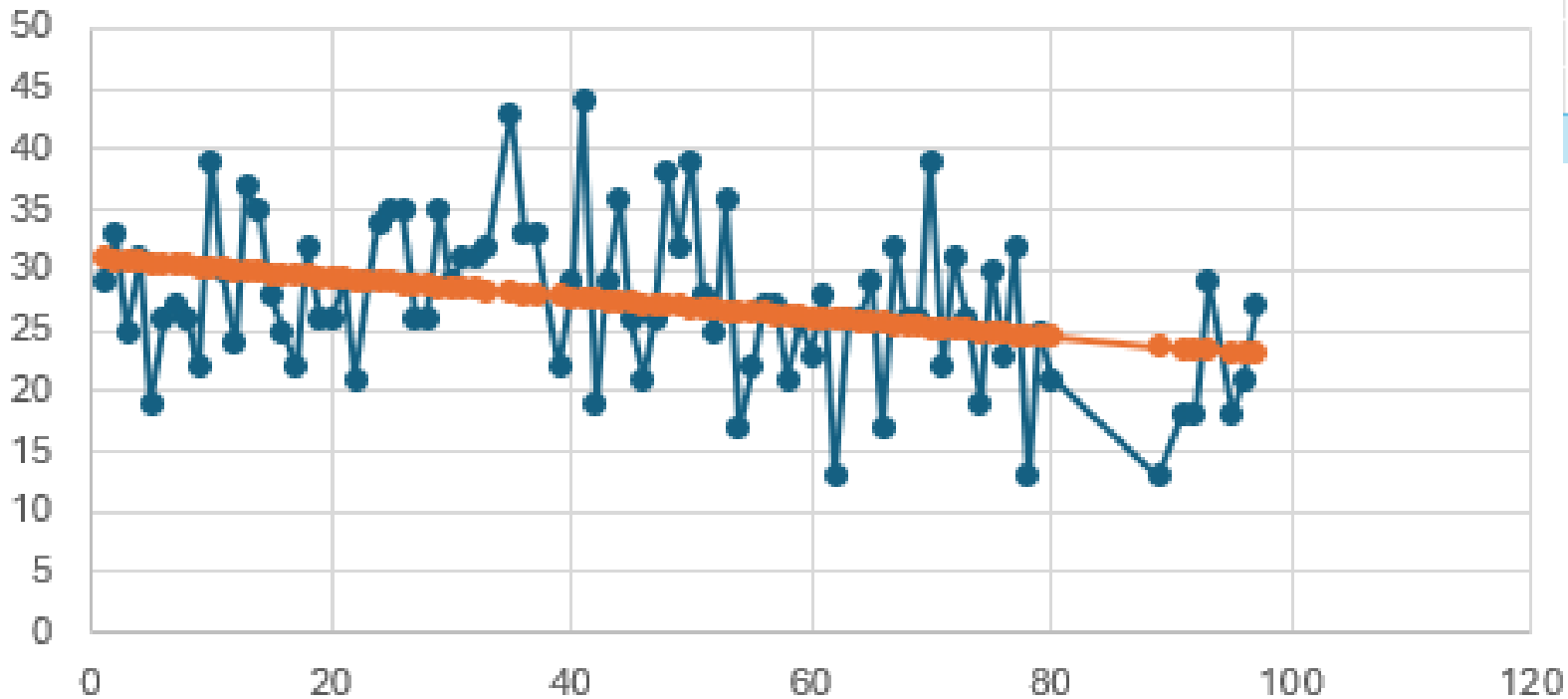**Attended over 25 meetings**

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MUG Trivia

How Many People Attend each MUG Meeting?

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MUG Trivia

Answer: 27

The average attendance of the 5 remote sessions during Covid was 35 while the average attendance of in person sessions is 26

MUG Attendance Over Time*

Row Labels ▾	Average of attend
Fall	27
Spring	29
Summer	24
Winter	27
Grand Total	**27**

- **2 extra people attend in spring to watch basketball**
- **3 people think they're too good for summer training**

MAX: 43
MIN: 12

*Excludes remote meetings

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MUG Trivia

Who Has Given the Most Presentations at MUG?

Bonus: Which Non-ODOT Person Has Given the Most?

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MUG Trivia

Answer: Me

Bonus Answer: Vince Bernardin
(and he padded the numbers for 3 companies)

Person	
Giaimo	28
Granato	21
Straub	21
Bernardin	14
Schmitt	12
Brunello	10
Avner	9
Bostrom	9
Rohne	8
Jiang	5
Erhardt	4
Luebbers	4
Paprocki	4
Gill	3
Kang	3
Makarachi	3
Martimo	3
Miquel	3
Ory	3
Pu	3
Reger	3
Schiffer	3
Sharma	3
Taylor	3
Uhlhorn	3
Vyas	3

Meeting	Org	Person	Topic
Jun-04	BLA	Bernardin	Application of UBA
Mar-09	BLA	Bernardin	Destination Choice Models
Sep-10	BLA	Bernardin	Complexity of Transit Tours
Dec-11	BLA	Bernardin	Economic Modeling Primer
Mar-15	RSG	Bernardin	Ohio Medium/Small MPO Model Version 2
Sep-15	RSG	Bernardin	Traffic Assignment
Dec-16	RSG	Bernardin	Icorporating Big Data in statewide and MPO travel demand models in TN
Sep-17	RSG	Bernardin	Streetlight Data, data representations and expansion
Sep-18	RSG	Bernardin	Implementations of Autonomous/Connected Vehicles Elsewhere
Dec-18	RSG	Bernardin	Seasonal Travel Models in Michigan Statewide Model
Mar-21	Caliper	Bernardin	Network Management Tools
Jun-22	Caliper	Bernardin	Recent Innovations: Truck Route Choice, Machine Learning, Nested Destination Choice and More
Sep-22	Caliper	Bernardin	Look at Toledo's Integrated ActivitySim-TransModeler ABM-DTA Model
Dec-23	Caliper	Bernardin	Network Management Tool for the Ohio Statewide Model

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MUG Trivia

What Organization Other Than ODOT Has Given the Most Presentations at MUG?

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MUG Trivia

Answer: MORPC

(14 different people!)

Meeting	Org	Person	Topic
Mar-00	MORPC	Song	Household Survey
Sep-02	MORPC	Gill	AQ
Mar-03	MORPC	Shoaib	Network Coding
Mar-03	MORPC	Straub	Network Coding
Jun-03	MORPC	Gill	Planning Apps Summary
Dec-03	MORPC	Straub	New MORPC Model
Mar-06	MORPC	Parasa	Corridor studies
Sep-06	MORPC	Reger	ACS data
Nov-07	MORPC	Reger	Regional Data Sets
Dec-09	MORPC	Jiang	On-board Surveys
Jun-10	MORPC	Reger	**Developing Base and Forecast Zonal Data**
Sep-17	MORPC	Shay	Various Applications for Streetlight Data
Sep-21	MORPC	Gill	COVID Traffic Volumes and Speed Changes
Mar-23	MORPC	Galdino	Python-based Tool for Automatic Transit Coding using GTFS for Travel Demand Models
Sep-23	MORPC	Mansperge	**Extracting Employment Data to TAZs and Consistency Checking**
Sep-23	MORPC	Porr	**MORPC's Land Use Data Forecasting**
Sep-23	MORPC	Roy	**MORPC's Land Use Data Forecasting**
Sep-24	MORPC	Schaper	The Power of Regionalism: Building a Regional Capital Improvement Program of Transit Supportive
Sep-24	MORPC	Lewis	The Power of Regionalism: Building a Regional Capital Improvement Program of Transit Supportive

MPOs with No MUG Presentations: ☹

CCSTS, ECRPC, LCATS, KYOVA, WWW

Organization	
ODOT	97
MORPC	19
OKI	15
CDM Smith	14
WSP	12
FHWA	11
RSG	11
NOACA	10
B&N	9
BLA	9
WRA	9
AECOM	8
Citilabs	8
Caliper	6
MVRPC	6
Bentley	5
BHJ	5
Corradino	5
AMATS	3
CamSys	3
Connectics	3
OSU	3
Stantec	3
TMACOG	3
UK	3
Baker	2
EASTGATE	2
ODOD	2

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MUG Trivia

What Topic Have We Seen the Most?

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MUG Trivia

Answer: Model Applications (but see next slide)

Breaking down further, project forecasts were the most common

Projects	12
Operations	5
Seasonal	4
General	4
Congestion	3
Plans	3
Simulation	3
Transit	3
Accessibility	2
Developments	2
Electic Vehicles	2
PDP	1
Performance Measures	1

Topic	Number
Application	45
Data	41
Training	39
Models	38
Software	17
Networks	16
Surveys	12
Operational Analysis	11
Air Quality	8
Processes	8
Economics	7
GIS	7
Land Use	7
Model Status	6
Validation	6
Conference Summary	5
Studies	4
Administrative	2
History	1

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MUG Trivia

Close 2nd and 3rd (besides training) are Data and Model Details which break down as shown

Note there are separate categories for networks which were presented 16 times and surveys which were presented 12 times so if you answered "Data" you were actually right

Data		41
	Big	16
	Socio-Economic	16
	General	4
	Counts	2
	Speed	2
	Freight	1

Model		38
	Overview	14
	Freight	5
	Assignment	4
	CAV	3
	Accuracy	2
	Mode Choice	2
	Telecommute	2
	General	2
	Covid	1
	Destination Choice	1
	MicroSim/DTA	1
	Pop/Estab Synthesizers	1

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Software Evaluation

- MUG handled evaluation of software for transition from Tranplan in early 2000's, had 61 evaluation criteria

Detailed Review Criteria

March 2002

Travel Demand Modeling Features

#	Criteria Description	Analysis	Notes
1	Ease of setup and use to perform Trip Generation for multiple purposes	Even/TP+	
2	East of setup and use for cross-classification trip generation for multiple purposes	Even/TP+	*"Ease of Use" questions are difficult to answer.* *TP+ and TransCAD have the abilities listed in #1-6.*
3	Ease of setup and use of survey data processing	Even/TP+	*If starting from scratch:*
4	Ease of setup and use to perform gravity model trip distribution for multiple purposes	Even/TP+	*TP+ and TransCAD are about equal for #1-6.* *TransCAD is easier with #5.*
5	Ease of setup and use to perform logit trip distribution for multiple purposes	TransCAD/TP+	*If converting from Tranplan:* *TP+ is much easier because it does not require changing the scripts.*
6	Ease of setup and use to perform mode choice for multiple purposes	Even/TP+	
7	Ease of setup and use to perform a nested logit mode choice for multiple purposes	TransCAD	*It is not recommended to run a mode choice model within these packages. A FORTRAN or similar program is far better suited for that task.* *Both TP+ and TransCAD have the ability to setup a mode choice model using the software. TransCAD's is easier if starting from scratch.*

Software Evaluation Ongoing

SOFTWARE UPDATES – OPTIONS AND HISTORY

- 25 years ago, OTDMUG reviewed software
  - MinuTP/TP+
  - TransCad
- Non-vendor members volunteered to develop simple models and report back to the MUG
  - Possible to do this process again if desired and members volunteer

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Rebekah's Mar 2023 Future Software Discussion

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Software Question and Answer Session

- MUG assembled a list of nearly 40 question about the inner working of Cube Voyager Highway and had Citilabs come explain in Sept 2015

CUBE HIGHWAY QUESTIONS

1. Can you clarify some details of HIGHWAY?
    a. Documentation states "most" LW variables are recalculated in the ADJUST phase. Can you clarify which portions of LINKREAD is redone in ADJUST? Can you clarify why and how this takes place? Perhaps providing an explanation of how LW variables are intended to be used vs LI would be helpful.
    b. Is there any difference between variables V1, V2, etc., and VOL[1], VOL[2], etc. in ADJUST?
    c. Is there a difference / what is the difference between the impedance used for path building and the impedance used for lambda estimation? For example is one the result of the prior iteration vs a weighted value?
    d. In general, which statements are processed in the order listed in the script versus which occur in their own internal order?
    e. We have concerns that given LINKREAD is referenced in ADJUST, we are resetting some LW variables used in the COST function which would be incorrect. What is the best practice to avoid this concern? Can you elaborate by looking at existing OMS scripts?
    f. In the case that we want to warm start assignment by beginning with congested travel times rather than free-flow times including junction delays, as we discussed previously, this requires the non-trivial reformatting of output junction delays (from TURNPENO) into JUNCTIONI format. Do you have any plans to add new built-in/standard functionality to allow us to get output junction delays back into the next round of junction assignment?
2. How does Citilabs calculate Relative Gap?
    a. How does this differ from the way others calculate Relative Gap?
    b. What the implications of these different formulations?
    c. Why would a user use a convergence measure other than Relative Gap (e.g., gap, AAD, etc.)? What are the dangers of using other measures?
    d. Are calculations of Relative Gap from MSA comparable to those from Frank-Wolfe or Bi-conjugate Frank-Wolfe?

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Software Overviews

ActivitySim Project Goals & Principles

Goals

- Create an activity-based travel modeling platform
- Unify best practices
- Reduce development costs
- Reduce maintenance costs
- Collaborate

Principles

- Open Source
- User-friendly
- Documented
- Stable
- Extensible / Flexible
- Optimized

http://www.activitysim.org
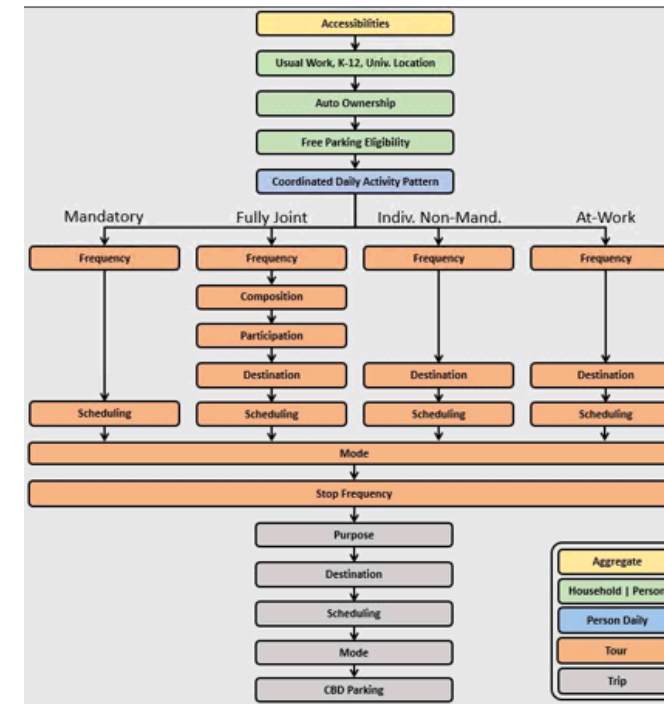
Data Requirements

- Works with open data formats

Implementation Requirements

- Runs under Windows, Linux, or Mac

Ben Stabler's Nov 2019 ActivitySim overview

Installing

- Get and install Anaconda 64bit Python 2 or 3
  - Pre-built collection of performant Python libraries (and underlying C/C++)

- Get and install other libraries
  - using conda to ensure compatibility and performance

- Get and install ActivitySim
  - using pip to download the package from the Python Package Index

Activitysim getting started guide:
https://activitysim.github.io/activitysim/gettingstarted.html

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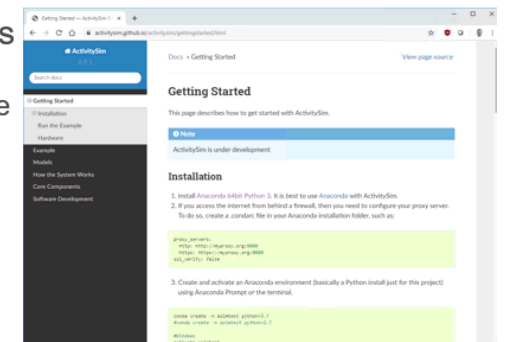
Software Updates

CUBE 7: Voyager

- Native use of GIS formats and relational databases throughout the system (great for tour-based and activity-based modelling) – no conversion to CUBE binary first!
- 32K zone limit increased to "virtually unlimited"
- Improved data formats and I/O performance and speed
- Full Unicode support throughout CUBE 7; this will allow for seamless uses of international character sets for purposes of filenames, strings, comments, etc
- Further Speed Enhancements for Highway, PT and other Voyager modules

CUBE 7: CubePy

- A next generation alternative model scripting system based on Voyager technology
- Utilizes Python, for an easy to learn and integrate experience
- Greatly enhanced flexibility in the assignment algorithm processes with more control over individual phases
- Powerful capabilities for manipulating matrices and networks
- Able to perform GIS analyses directly within CubePy
- Interoperate between popular Python libraries such as SciPy and NumPy , as well as other libraries callable from Python

CUBE 7: Application Manager

- Application Manager will have a new look and have more powerful visual capabilities such as:
  - Zooming / scaling,
  - Application navigation view
  - Hover over group displays preview of that group's flowchart
  - Ability to view the entire application group tree hierarchy and navigation
  - Edit history and undo / redo
- Users will have more control over model design e.g. how far up a group hierarchy that an input file may be "public"
- Model run mode; AM will allow running of an application and all of its subgroups in a read-only view that highlights the currently running program and various statistics about the current run (similar to Task Monitor but more detailed)

Chris Simon's Nov 2020 Update on Cube 7

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Training Rotation

- Project Modeling
- Turning Model Results Into Information
- Developing Base and Forecast Zonal Data
- Highway and Transit Network Coding

MUG Training Sessions are a longer more in-depth session from the standard MUG meeting

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Project Modeling Training

- Process for using models to create forecasts for projects and corridor studies

- First conducted 2008, then again 2014

- Converted to part of design traffic training class and given in 2019 and 2022

Course Overview

- Definitions and Processes
- Model Checking
- Exercises on Model Checking
- Model Refining/Adjusting
- Exercises on Model Refining/Adjusting
- Advanced Topics

Model Checking

- Model checking is generally conducted at two levels
  - For the entire regional model
  - Within the project study area

Study Area

Project Location

- **Turning Model Results Into Information**

- Covers post processing model results for air quality, congestion management, economic analysis and environment justice as well as other useful model output manipulation tricks

- First conducted 2009, then again 2013 and 2019

Output Junction Files – LOS

- Delay will show you delay by turning movement and LOS

Node Number : 581; Intersection Type : Adaptive Signal; Model Period : 231 minutes

| Initial Queue |
| Final Queue |
| Capacity |
| Randomness |
| Delay |
| Low Flow Delay |
| Volume 1 |
| Volume 2 |
| Combined Volume |

LOS: B

□ Show Signal Times
☑ Regular display layout
□ Divide By Capacity
□ Hourly units

Value / Pixel : 0.017   Print   Setup   OK
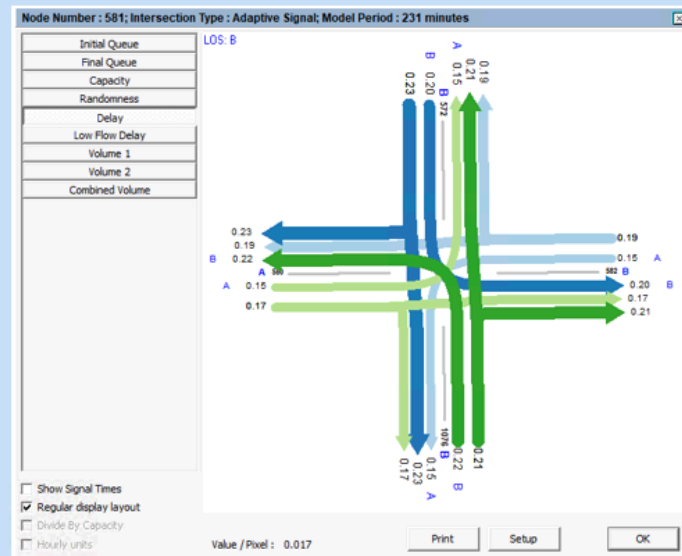
MOtor Vehicle Emissions Simulator

- Estimates emissions for on-road and nonroad mobile sources
- Covers a broad range of pollutants
  - CO, NO_2, HC, PM, MSATs, etc.
- Allows multiple scale analysis
  - National
  - County
  - Project Level

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- **Developing Base and Forecast Zonal Data**

- Focuses on techniques to assemble socio-economic data in the base year and then forecasting same

- First conducted 2010, conducted the second time last year (2023)

Extracting Census Data to TAZs

June 17, 2010

Sources of Data

Sources	Update Frequency	Smallest Geography	Data
Decennial Census	10 years	Block	Demographic/ Socioeconomic
ACS	1-5 year	1 60,000+ 3 20,000+ 5 smaller	Demographic/ Socioeconomic
CTPP	5 years (future)	Block Group/TAZ	Demographic/ Socioeconomic/ Special Transportation Tabulations

Extracting Employment Data to TAZs

(and Checking the Results)

Pact of Death (aka Confidentiality)

- This includes Employment Variables!!!

- Only those agencies/consultants who have signed the Pact of Death may see:
  – Disaggregate QCEW records
  – Full Model Employment Variables
- Be wary when a consultant or other agency "needs" employment data.

Art and Politics: Forecasting Land Use and Primary Control Variables

morpc MORPC's Grid Based Land Use Model

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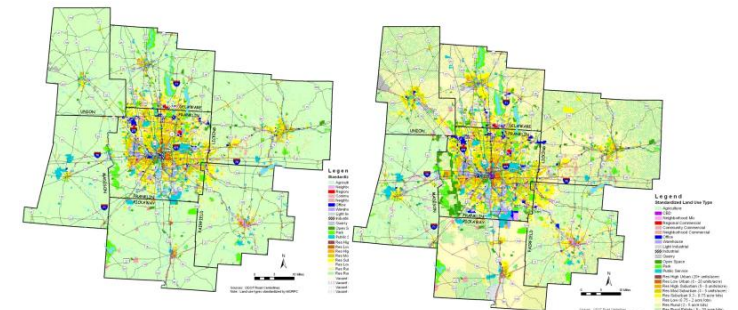
- **Highway and Transit Network Coding**

- Covers network coding
- First conducted 2011,
  then again 2016 and 2022

Transit Layer

◆ All transit lines
  displayed
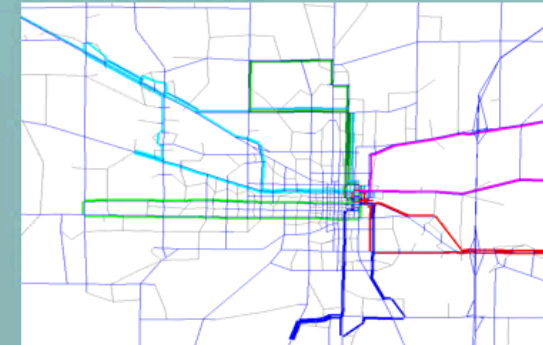
◆ Transit Tools
  – Display Transit Line(s)
  – Display All
  – Transit Lin
    ◆ Add oth

Link Attributes

A	A Node Number
B	B Node Number
RTENAME	Denotes the name of the roadway in the model
RTENUMB	Denotes the route number of the roadway
DIST	Distance (miles)
POSTSPD	Posted speed limit (mph)
SPDMOD	Positive or negative modifica
SPDMOD_TK	Positive or negative modifica applied in ADDITION to the s
SCRN_PEN	Screen line penalty in minute
FACTYPE	Operational class or modifie
AREATYPE	Area Type
LANES	Number of mid link through l
WIDTH	Directional roadway width m
TURNLANE	Turn lanes, 2 possible forma
IXTYPE	Intersection type
MEDTURN	Mid link median turn lane
PARKING	Presence of on-street parkin
CARTOLL	Toll per mile for autos in ce
TRKTOLL	Toll per mile for trucks in ce

Intersections

◆ Divided Highways
  (at-grade signal)

◆ Divided High
  (end of divisio

Turn Prohibitors

◆ View (Edit) Prohibitors
◆ First use pointer to select a node
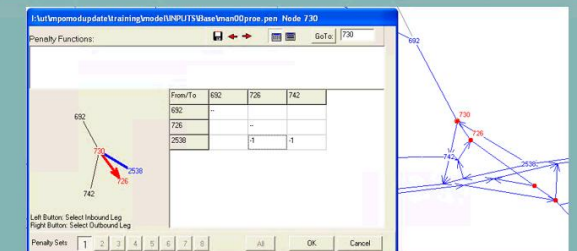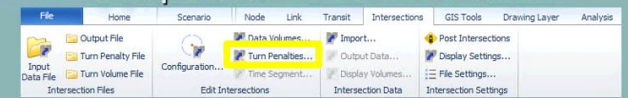
Additional Training Sessions

- Besides the standard training rotation, several one-off extended training sessions have been held:
  - ✓ *Introduction to Cube 6 (2012)*
  - ✓ *MORPC/OSU Land Use Model (2015)*
  - ✓ *Performance Based Planning (2017)*
  - ✓ *R Programming (2018)*

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Application and Process RoundTable

MUG held a roundtable of all participants showcasing processes

Congestion/Safety/Freight Locations

PERFORMANCE-BASED MEASURES

- High Crash Intersections
- Congested Intersections
- High Crash Roadway Sections
- Level of Service "E"
- High Crash Freeway Segments
- Level of Service "D"
- Truck Volume 5% or Higher
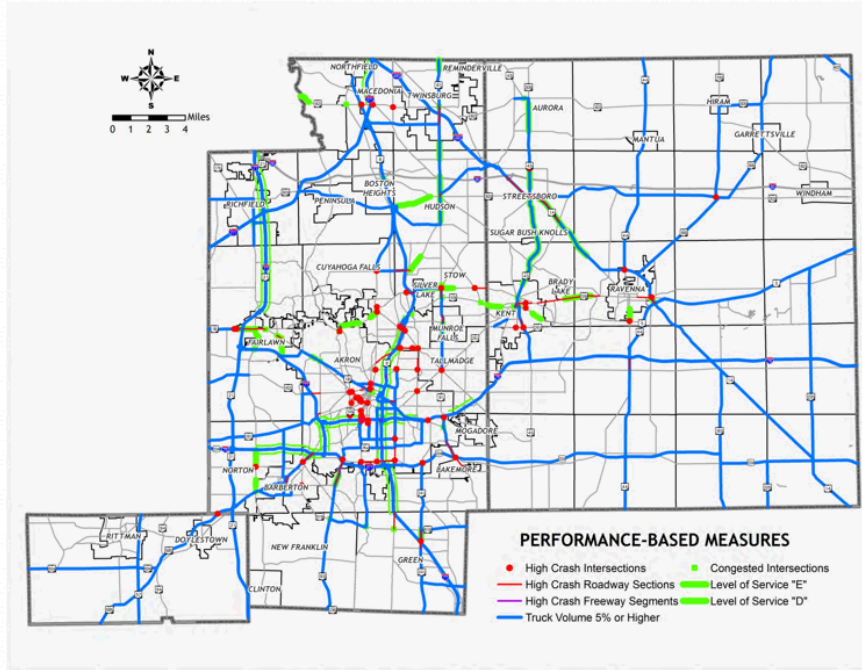
AMATS Performance Based Measures

Amy's Dec 2014 Presentation from the Model Use/Performance Based Planning Roundtable

Worst Freeway & Arterial Locations

- Central Interchange
- I-76 from Barber Rd to SR 59
- SR 8 from I-77 to Howe Ave
- I-77 from Arlington Rd to Central Interchange
- I-77 from Ghent Rd to Cuyahoga County Line
- I-271 from SR 82 to Cuyahoga County Line

Upcoming Freeway Projects

- Main/Broadway Interchange – FY 2016
- Grant/Wolf Ledges Interchange – FY 2015
- I-76/77 from Brown St to Central Interchange – FY 2015
- I-76 from Medina Co Line to SR 619 – FY 2017
- I-76/SR 619/State St interchange – FY 2019
- I-271 from SR 8 to Cuyahoga Co Line – FY 2014

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Transit Forecasting Seminar

49 USC § 5309 Capital Investment Grants Program ("New Starts Program")

- The federal government's primary vehicle for funding major capital fixed-guideway transit projects (effectively began in 1976)

Topics

- What is transit?
- What is the New Starts/Small Starts program?
- Methods to forecast impacts from transit projects

STOPS: General characteristics

- Modified 4 step trip-based model
  - Highway impedances and SE inputs from regional models maintained by MPOs
  - Transit paths and impedances directly from transit schedules in GTFS format
  - Trip generation and distribution replaced by CTPP seed matrix used to develop person trip tables
  - Standard nested logit mode choice model
- Automatic calibration
  - User-specified region-wide unlinked transit trips
  - Transit shares by attraction district from CTPP or
  - Observed transit boardings by station group

Slide from: "STOPS Workshop", Federal Transit Administration & RSG, May 2015.

4 Forecasting Options

- Regional Travel Model: MPO's model or derivative
- Incremental / Data-Driven Methods: Simplified model based mostly on data from existing riders and system
- FTA's Simplified Trips on Project Software (STOPS)
- Warrants: corridor ridership levels

Deciding on an Approach
Other Aspects to Consider (Remember: No Absolutes!)

	Regional Travel Model	Data-Driven	STOPS	Warrants
Scope	Regional	Corridor or Sub-regional or Regional	County or Regional	Corridor
Project Mode / Riders	New mode / Mostly new riders	Some existing + some new riders	All modes & rider types	All modes & rider types
Available ridership data	Route-level ridership + O/D survey	O/D, On-to-off data (preferred) On/off counts by stop	Boarding counts by stop (preferred)	On/off data by stop in corridor only
Funding source	Applicable to federal or non-federal sources		5309 funding, either by itself or in conjunction with another approach	Only applicable to 5309 funding
Forecasting resources	$$$	$$	$$	0.3 x $ (may require data collection)

Dave's Mar 2016 Presentation on Transit Forecasting for FTA

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Planning and Forecasting Processes

At a minimum every MPO is expected to perform the following model related tasks:

- Produce forecast zonal variables, consultant can be used to provide technical assistance here, but the MPO must provide local knowledge, local plans, zoning etc. to inform that process
- Develop TIP/LRP project lists to a level of detail that can be coded in the models

Greg and Rebekah's Sept 2016 Presentation on Model Support Consultants

In most cases we plan to give the consultant little room for creativity, we will provide examples of past work (a lot of which will be totally undocumented spreadsheets I did in the past, ha ha, good luck to them) and expect it to be followed closely
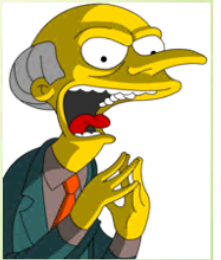
The Future

Is this permanent?
- Don't know, depends how well it goes and future staff levels

FYI: It wasn't, we just don't mess with the models as much anymore and it takes forever

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Model Status Updates

OMS

- All OMS models up to 2010 base year
- Soon time to think about 2021(ish) base year

STATEWIDE MODEL

- Changing the economic engine to directly use Tredis (currently uses stand alone Tredis generated data that is no longer supportable)
- Changing formats of household and employment files to include more variables and to include a unified set of data on both internal and external zones
- Changing how those files related to the model's control totals (from DSA and Tredis)
- Changing external models to use a unified and user modifiable set of SE data and sized terms (think cordon counts)
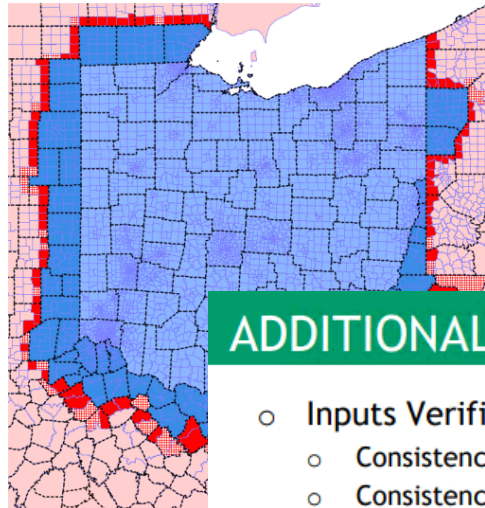
ADDITIONAL STAND-ALONE APPS IN THE 3C MODEL

- Inputs Verification
  - Consistency in TAZ/MAZ ZSED files
  - Consistency in transit line and highway network
  - Existence of extracted SW trip tables and base-year external volumes

- Highway Assignment Only

- Subarea Validation Reports

- Power BI (dashboard/report)
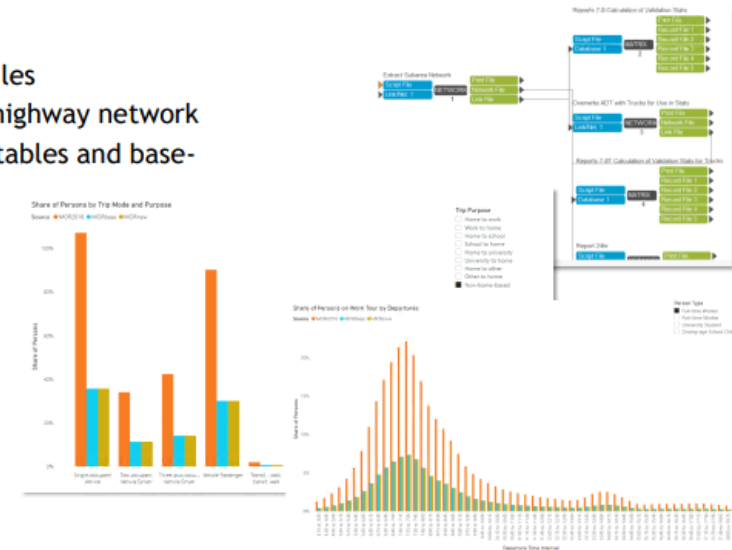
Greg, Jonathan and Zhuo Jun's Nov 2022 Status Update on the Ohio Models

Model Overviews-ABM

Overview Information

- 2001 MORPC initiated the design of a new travel demand model
  - Expand the Modeling Area
  - Update the model to include current research
  - Include Time of Day
- Tour-based / Sample Enumeration (Microsimulation) model was proposed, which the Advisory Committee accepted

MORPC

Rebekah's Nov 2003 Presentation on "New" MORPC Tour Based Model

Daily Activity Pattern
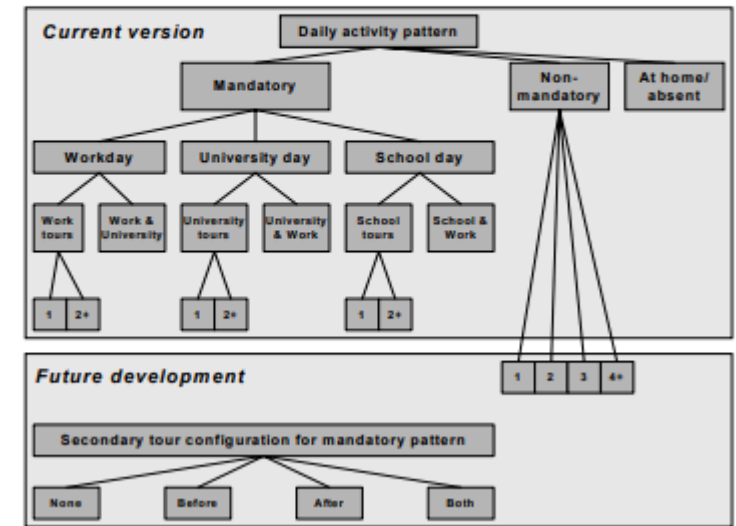
Stop Frequency
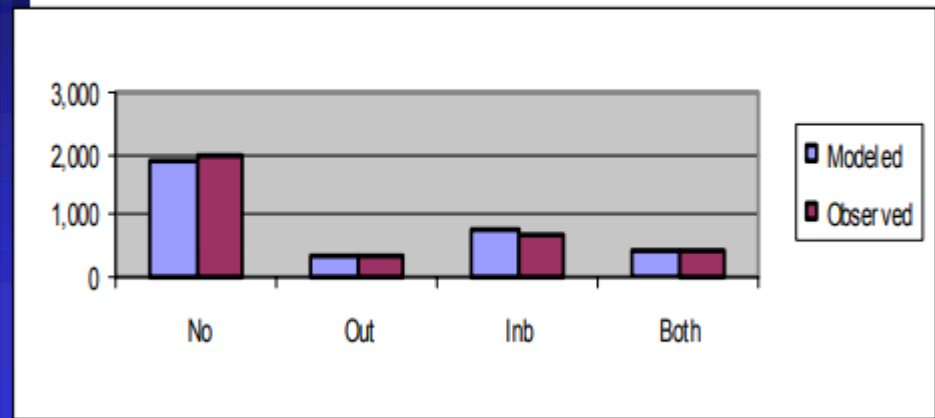
Model Overviews-Freight

STAND-ALONE FREIGHT MODEL

OTDMUG Presentation
March 12th, 2015
Christi Willison and Ashish Kulshrestha

WSP | PARSONS BRINCKERHOFF

Christi's Mar 2015 Presentation on Stand Alone SW Freight Model

MAIN COMPONENTS

→ **Land Use**
  - Simplified Land Use Model 1 (SLUM1)
  - Simple Economic Allocation Model (SEAM)
  - Simplified Land Use Model 2 (SLUM2)

→ **Skimming** – truck and auto peak and off-peak skims along with freight rail skims

→ **Freight**
  - Freight Analysis Framework (FAF)
  - Aggregate Commercial Model (ACOM)

→ **Assignment**
  - Person trip tables
  - Truck trip tables

WHAT CAN I GET OUT OF IT?

→ **Assignment results**
  - Truck VMT by County
  - Additional congestion
  - Corridor flows
→ **Development overides** – what happens if you add (Ashish)
→ **Additional intermodals** – what happens if you add (Rebekah)
→ **Tolling scenarios** – what happens if you change toll price by truck class (Greg)
→ **Cube Sub-area extraction** (Rebekah)
→ **User is responsible for producing statistics, summaries and maps of output data**

Making Models Sensitive to Future Conditions

AV impacts reflected in travel model
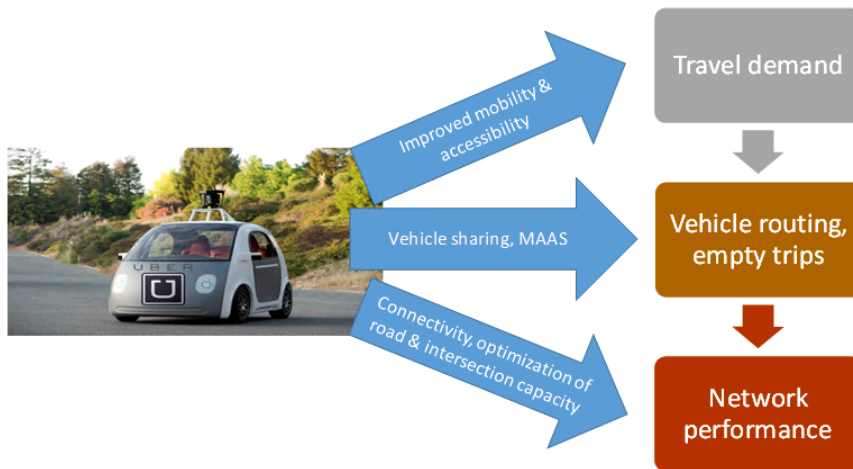
AV parking and repositioning options
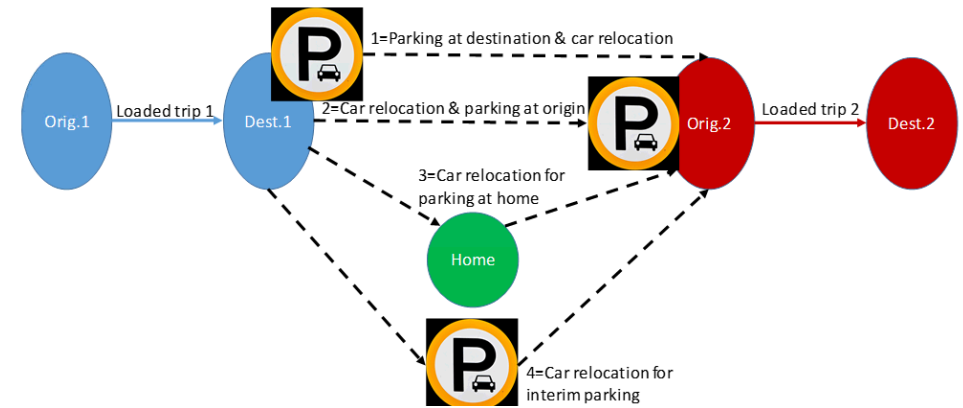
Impact on regional VMT
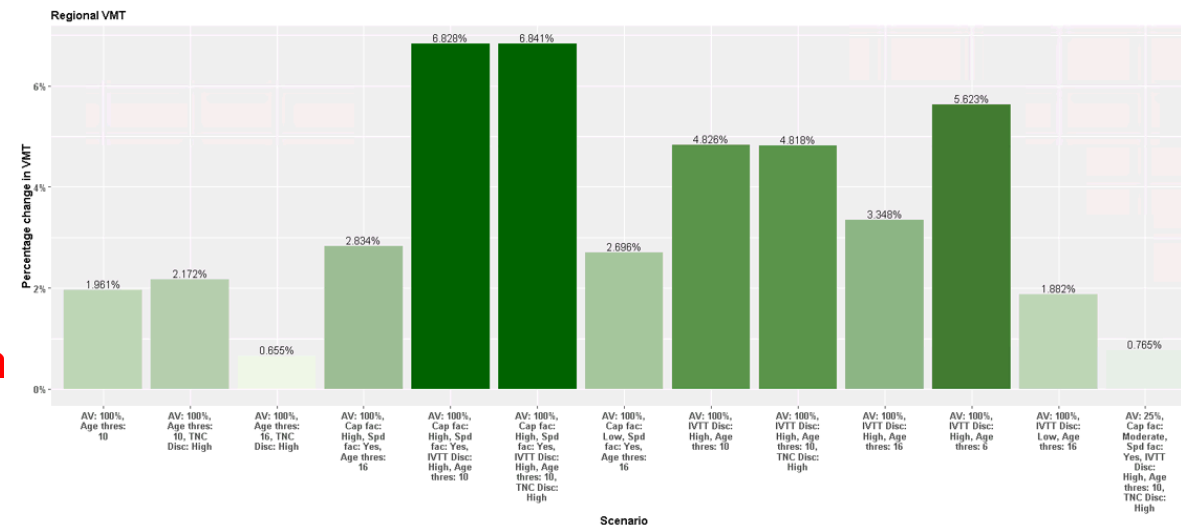
Peter and Gaurav's Sept 2018 Presentation on Incorporating CAV in Travel Model

Making Models Sensitive to Emerging Conditions

- **Who.** Telecommuters should be explicitly identified in the simulation.

- **What.** Time spent working at home should be identified as such, i.e., a work activity.

- **When.** Time spent telecommuting at home should be explicit, i.e., scheduled.

- **Where.** Telecommuters should have a usual work location, i.e., we know where they are *not* traveling to.

- **Why.** Telecommuters' occupations and industries should align with ability of those types of jobs to telecommute; commute impedance should influence telecommuting choice.

Commuting Type	base telecommute
at-home worker	45,902
not working	118,311
out-of-home worker	697,058
telecommuter	16,247
Grand Total	877,518

Define: Telecommute Rate = telecommuter / (telecommuter + out-of-home worker)

trip departure distribution by purpose
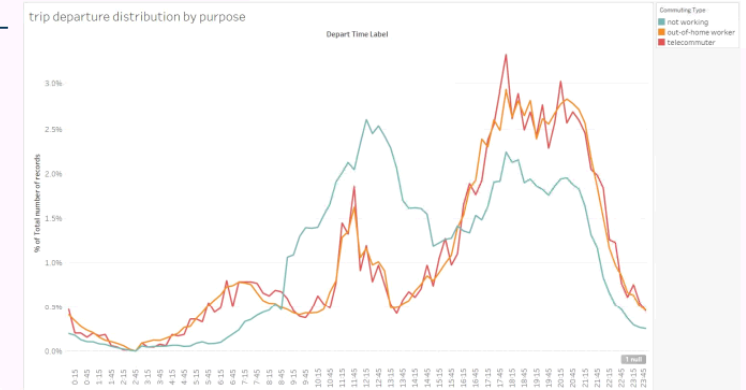
Shopping Trip Departure Time - Not like workers taking a day off, Telecommuters' other activities should still be constrained by their work schedule

Option 1
Separate Module for Telecommuters - More Effort

Option 2 (Shortcut)
Trick the Mode Choice Model by Adding a "Telecommute" Mode, and do not include such trips in Assignment

persType label	work trips per person			non-work trips per person		
	base telecommute	higher telecommute	% Difference	base telecommute	higher telecommute	% Difference
Full-time Worker	1.14	1.06	-7.0%	2.56	2.56	0.1%
Part-time Worker	0.82	0.79	-3.6%	2.87	2.87	0.2%
University Student	0.07	0.07	-0.1%	2.66	2.66	-0.2%
Non-worker	0.00	0.00	0.0%	3.21	3.20	-0.6%
Retiree	0.00	0.00	0.0%	2.45	2.45	-0.1%
Driving-age School Child	0.04	0.04	-5.8%	2.56	2.55	-0.4%
Pre-driving-age School Child	0.00	0.00	0.0%	2.65	2.64	-0.5%
Pre-school Child	0.00	0.00	0.0%	1.86	1.87	0.6%
Grand Total	0.52	0.49	-6.5%	2.64	2.63	-0.1%

Sijia Wang and Dave Ory's Dec 2021 Presentation on Telecommuting in the 3C Models

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Model Accuracy

College of Engineering
Department of Civil Engineering

March 15, 2019

Interim Findings from NCHRP 08-110 Traffic Forecasting Accuracy Assessment Research

Estimating Uncertainty

Draw lines so 95% of dots are between the lines
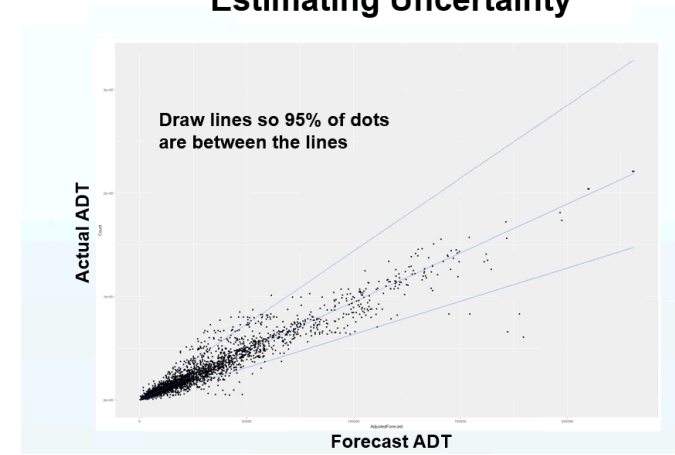
Actual ADT

Forecast ADT

Archive & Information System

Desired features:
- Stable, long-term archiving
- Ability to add reports or model files
- Enable multiple users and data sharing
- Private/local option
- Mainstream and low-cost software

Standard data fields!

Greg Erhardt, Jawad Hoque and Dave Schmitt's Mar 2019 presentation on forecast accuracy

Large N Results

- 95% of forecasts reviewed are "accurate to within half of a lane."
- Traffic forecasts show a modest bias, with actual ADT about 6% lower than forecast ADT.

Deep Dives

General Conclusions

- The reasons for forecast inaccuracy are diverse.
- Employment, population and fuel price forecasts often contribute to forecast inaccuracy.
- External traffic and travel speed assumptions also affect traffic forecasts.
- Better archiving of models, better forecast documentation, and better validation are needed.

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Tips and Tricks Mini Presentations

Tips and Tricks-Turn Lane Coding

- You can also get into trouble if you code no through lane but there is a through movement, calculators will work fine but junc. assignment will crash

Good   Bad
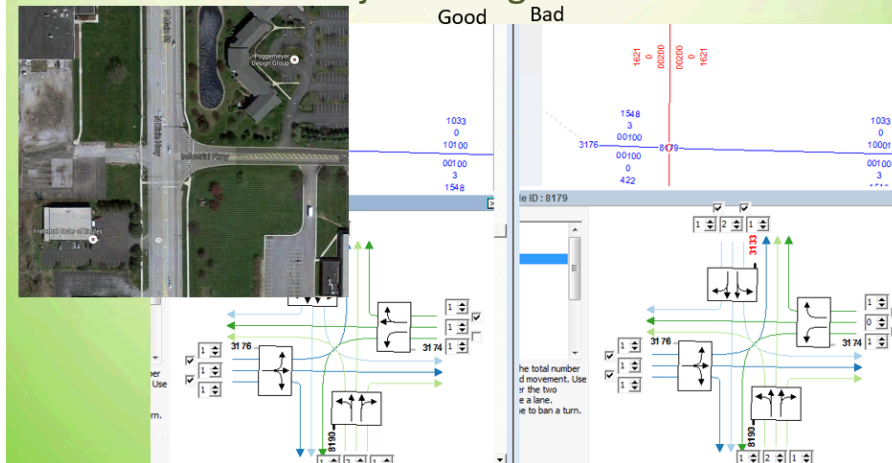
Greg's Sept 2016 Tips and Tricks

Tips and Tricks-Evacuation Modeling

- Free planning tool for evacuation modeling is available at:

http://rtepm.vmasc.odu.edu/

Tips and Tricks-Air Quality Webinar

TRB Webinar: Models Used in Air Quality Analysis
TRB will conduct a webinar on Thursday, September 15, 2016 from 2:00PM to 3:30PM ET that will discuss specific model types generally used in the analysis of transportation-related air quality analysis of fleets. These include transportation analysis models, emission factor models, and dispersion models.

Webinar Presenters Madhusudhan Venugopal, *Texas A&M Transportation Institute*
Paul Heishman, *Federal Highway Administration*
Mike Claggett, *Federal Highway Administration*
Moderated by: Kevin Black, *Federal Highway Administration*

Webinar Outline Transportation planning and traffic engineering
Emission factor models
Dispersion models
Question and answer session
The first 60 minutes of the webinar will be for presentations and the final 30 minutes will be reserved for audience questions. The Registered Continuing Education Program (RCEP) categorizes this webinar activity as relating to health, safety, and welfare including core technical.

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Model Innovations From Other Areas

THE NC RESEARCH TRIANGLE

- Raleigh-Durham Metro

A HYBRID TRIP-BASED MODEL

- Disaggregate front end, aggregate back end

- Trips, but segmented by tour type

Vince's June 2022 Presentation on Model Innovations

TRIP GENERATION

- Tested classical stats & plain AI methods
  - Cross-classification
  - GLM (up to and including zero-inflated negative binomial)
  - Logit (ordered logit)
  - Extreme Gradient Boosted Decision Trees (XGBoost) / Random Forests

Example: School Trips

Model Type	Pseudo R^2
Ordered Logit	0.03
GLM	0.22
Cross-Class	0.33
XGBoost	0.60
XAI ANOVA Decision Tree	**0.53**

- Chosen approach: **Explainable Artificial Intelligence (XAI)**
  - ANOVA-based Rationalized Decision Trees
  - **Explainable**, reasonable relationships between trip rates and explanatory variables
  - Confidence that the model is not over-fit to the data

TransCAD | TransModeler
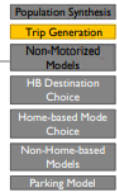
HIERARCHICAL DESTINATION CHOICE

- **First**, travelers choose a destination district
- **Second**, travelers choose the exact zone
- Significant district level effects
- Allows much better representation of travel in the multinucleated Triangle region

TransCAD | TransModeler
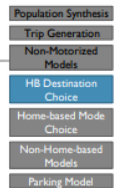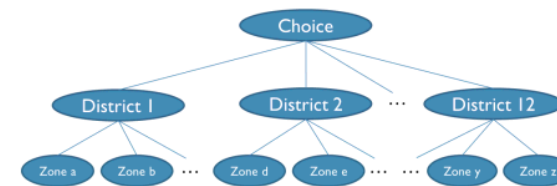
Models to Forecast Demographics and Employment

Design Objectives

» General purpose business establishment synthesizer

» Analog to population synthesizers

» Respect TAZ control totals for employment by industry sector

» Reflect statistical trends found in longitudinal establishment records

» Preserve heterogeneity – carry forward establishments from prior ye[ars] than synthesizing all new establishments for each year

» Implies an evolutionary model

System Design and Components

Number of Establishments
Employment Category: Trans Equipment

Fitted curve : a= 0.0083, k=-0.0250

Observed year-over-year pct change

r^2: 0.117
Observed 2020: 738
Predicted 2050: 726
Change 2020-2050: -1.63%

John Gliebe's Nov 2022 Presentation on the Establishment Synthesizer
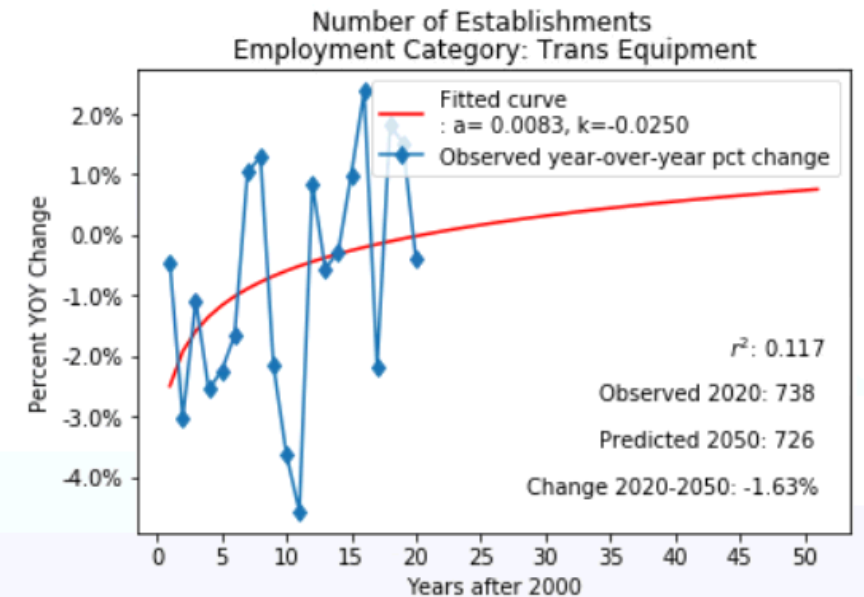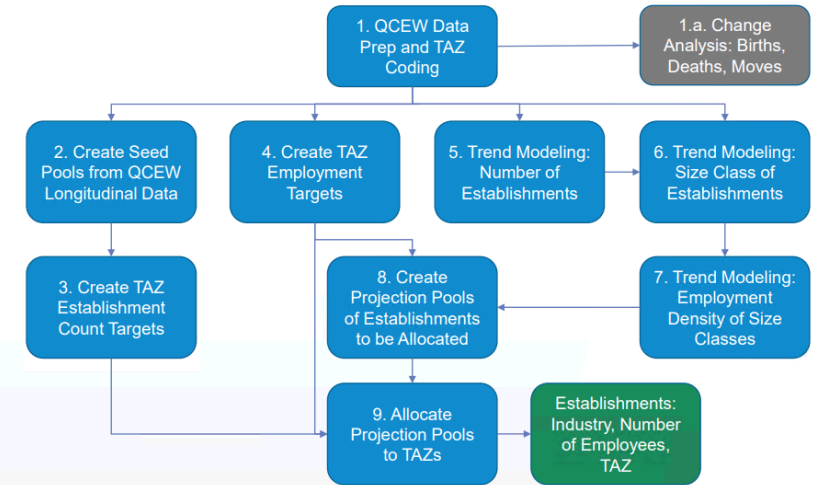
Data Source Decisions

Employment data

- QCEW data confidentiality (U.S. BLS)
- ODJFS contract restrictions
- Alternate data sources reviewed to date:
- LEHD (Census/LMI)
- Dun & Bradstreet
- InfoUSA / ReferenceUSA

Sam's Sept 2012 Presentation on Different Employment Data Sources

Detailed Comparison

- Reference USA, D&B manually update but leave many defunct businesses in file resulting in duplication (problem is much more severe with # of employers than number of employees since most duplicates are small (for example in reference USA found 26% duplicated businesses amounting to 6% of employment-this is a low estimate)

Number of Employees and Employers in Reference USA Subarea

	Duplicate or Bad			Total	Good			Total
Employees	1-3	4-20	20+		1-3	4-20	20+	
QCEW	0	0	0	0	15	377	2361	2753
REFUSA	74	105	0	179	41	559	2402	3002
DB	0	12	315	327	0	226	2066	2292
HARRIS	0	0	0	0	0	0	2025	2025
Employers								
QCEW	0	0	0	0	6	48	40	94
REFUSA	29	16	0	45	19	69	41	129
DB	0	2	2	4	0	27	32	59
HARRIS	0	0	0	0	0	0	27	27
Ignore								

Decisions:

- Which direction to go, and starting when?
- Update to ODJFS contract affects 2012-16
- Access to 2010 QCEW data unaffected, _for those on previous contract_
- Potential for use of multiple sources in future

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Traffic Count Coordination

GOALS/NEEDS

- Goals/Needs
  - Screenline/Cordon Line Counts
    - ODOT to collect up to 4,500 counts for this effort in 2019, 2020 and 2021.
    - Traffic Monitoring working with Modeling and Forecasting to indentify.
  - HPMS Collector Routes
    - ODOT asked MPO's to count in the urban areas:

Allen	215	Hamilton	1150	Portage	162
Butler	338	Jefferson	173	Richland	285
Clark	239	Lake	204	Stark	736
Belmont	94	Licking	209	Summit	667
Cuyahoga	1306	Lorain	347	Trumbull	233
Delaware	185	Lucas	676	Warren	130
Erie	127	Mahoning	416	Washington	9
Franklin	1152	Medina	171	Wood	292
Geauga	83	Miami	184		10993
Greene	278	Montgomery	932		

    - Is anyone collecting this data?
    - The locations need to be re-evaluated. Original numbers are high.

**Dave Gardner's Sept 2018
Presentation on Count Coordination**

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Traffic Count Coding

- TOD periods are defined:
  - AM: 6 am to 9 am (green)
  - MD: 9 am to 3 pm (blue)
  - PM: 3 pm to 7 pm (yellow)
  - NT: 7 pm to 6 am (red)
- Vehicle classification:
  - By FHWA Vehicle Classification Scheme F Report:
    - Cars: <= 3 (Motorcycles, pass cars, small trucks)
    - Trucks: >= 4 (buses, trucks, 3+ axes)
  - By length:
   - Cars: < 29 ft (varies from mid 20s to mid 30s)
    - Trucks: >= 29 ft

Diego and Zhuo Jun's Dec 2023 Presentation on Automated Count Coding

Not perfect

PROPAGATING TRAFFIC COUNTS ON FREEWAYS AND RAMPS

- Count on a link can be derived if counts are available on all its direct upstream (or downstream) links because of the law of conservation of traffic flows:
  - Upstream: $AADT_{AB} = AADT_{U0} + AADT_{U1} - AADT_{U2}$
  - Downstream: $AADT_{AB} = AADT_{D0} + AADT_{D1} - AADT_{D2}$
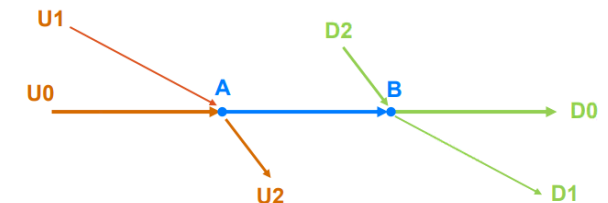
Network Coordination Discussions

NETWORK UPDATES – 2 GOALS

- Goal 1 is to not duplicate network coding efforts
  - Base Year attribute updates
  - TIP projects
  - LRP projects
- Goal 2 is to have ODOT network mirror MPO network
  - Projects at boundaries of MPO
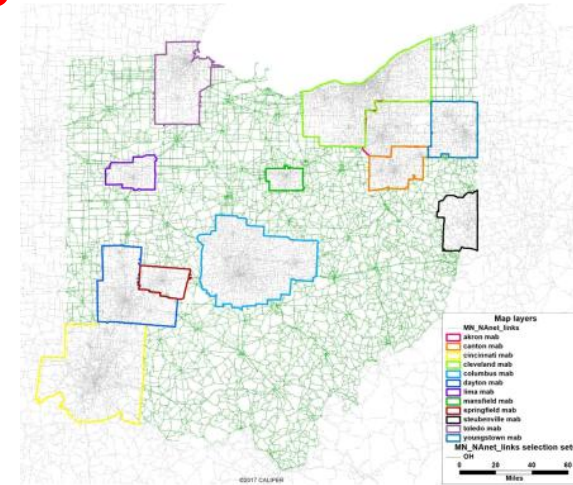 - Large corridor projects

Rebekah's Mar 2023 Presentation on Network Coordination

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Network Management Tools

User Requirements

- Manage networks in a stable way
- Documentation of projects included in a network
- Option to use latest information from the MPOs and or Statewide network
- Build upon latest information

System Requirements

- Create networks to be consumed by the Statewide Model
  - Binary File
  - TrueShape
  - Turn Prohibitions
- Work with existing software (Cube & TransCAD)

- MPO vs OSWM Maintained Areas

Project Management
- How code and manage highway projects?

Network Integration
- Combine information maintained by the State and MPOs

Network Export
- Create networks to be used by the Statewide Model

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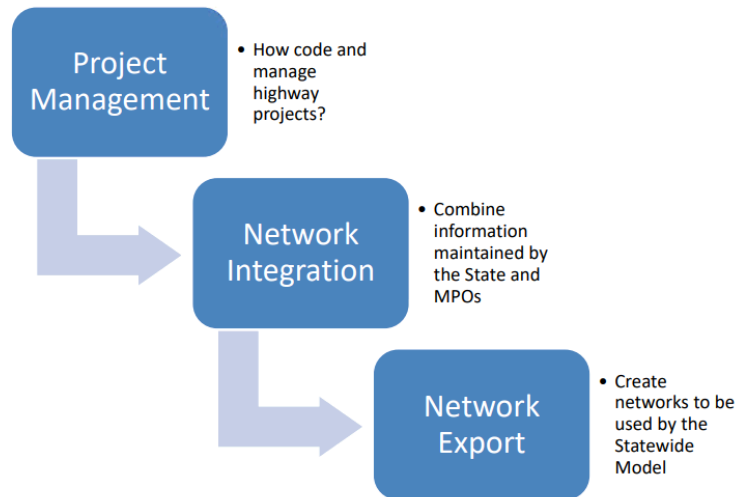
Network Integration: Custom Tool

- Developed in TransCAD GISDK
  - Why TransCAD and GISDK vs Cube?
- Graphical User Interface (GUI)
  - Easy User Interaction
  - Control for Options in Network Development
    - MPOs for Integration
    - Network Resolution (Centroid Connectors)
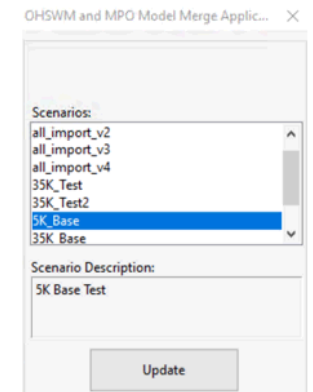
Jonathan's Dec 2023 Presentation on Network Management

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Travel Surveys

- On Board Surveys were conducted in Cleveland and Columbus in Spring 2013 and Fall 2013
- 2 Surveys were conducted
  - Boarding to Alighting Survey
  - Full On-Board Survey

Rebekah's Mar 2014 Presentation on Transit On-Board Surveys

Columbus
- 7,987 OB surveys
- 4,525 Reverse Surveys
- 12,512 Total
- ~60k daily boardings

Cleveland
- 20,502 OB surveys
- 12,595 Reverse Surveys
- 31,753 Total
- ~164k daily

Access Mode	Cleveland	Columbus
Walk	88%	94%
Park and Ride	6%	2%
Kiss and Ride	4%	4%
Other	2%	0%

Auto Avail	Cleveland	Columbus
Yes	21%	24%
No	79%	76%

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Travel Surveys

Trip Rates

OKI Establishment Survey (etc)

Andrew Rohne
Ohio Travel Demand Model User Group
March 2018

- Surveyed 220 Establishments
  - Employees
  - Visitors
  - Commercial Vehicles
- In-person Interviews – Tablet
- Person Counters – automatic and manual
- Commercial Vehicles Counted Manually
- Traffic Counts at Some Locations

Andrew's Mar 2018 Presentation on OKI Establishment Survey
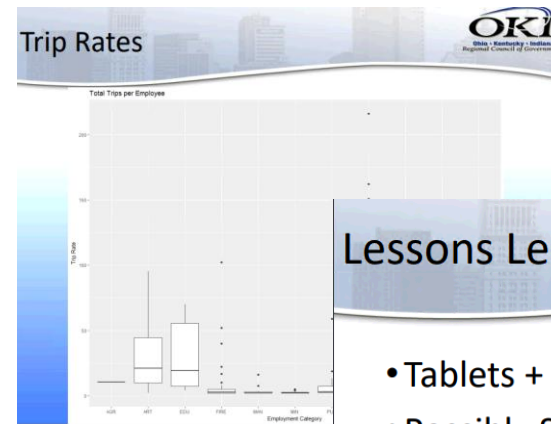
Lessons Learned (1/2)

- Tablets + Interviews Worked Well
- Possibly Stratify by Establishment Size
  - Perhaps combine employment categories
- Vehicle counts not useful
- Surveyor comments VERY useful (in most cases)
- Automated person counts not very useful
  - MANUAL!!!

YOU'RE NOT SUPPOSED TO BE FANS, YOU'RE SUPPOSED TO BE SKEPTICS, YOU'RE SUPPOSED TO ASK ME TOUGH QUESTIONS.

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Big Data in Studies

**Nathan Shay's Sept 2017
Presentation on Rickenbacker Study**

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Background

- Comprehensive study of the area surrounding the Rickenbacker Airport
- Many community stakeholders
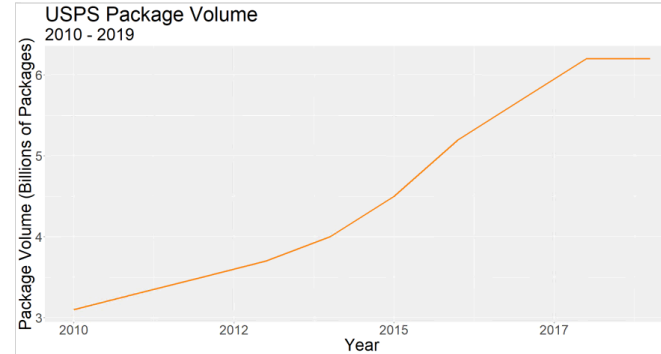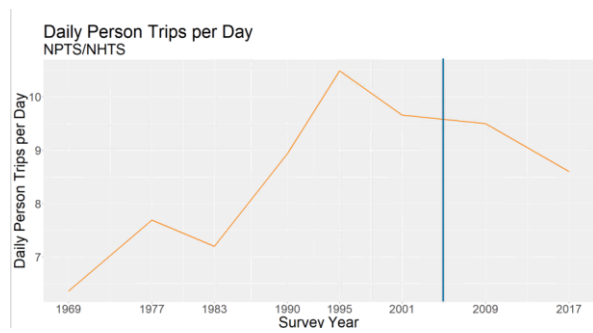- Study in conjunction with the Rickenbacker Airport Master Plan

morpc

Using Streetlight

- Investigate overall traffic patterns and interaction with the larger region
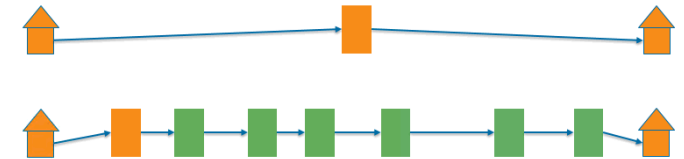- Examine seasonal concerns
- Identify freight patterns and access to major routes
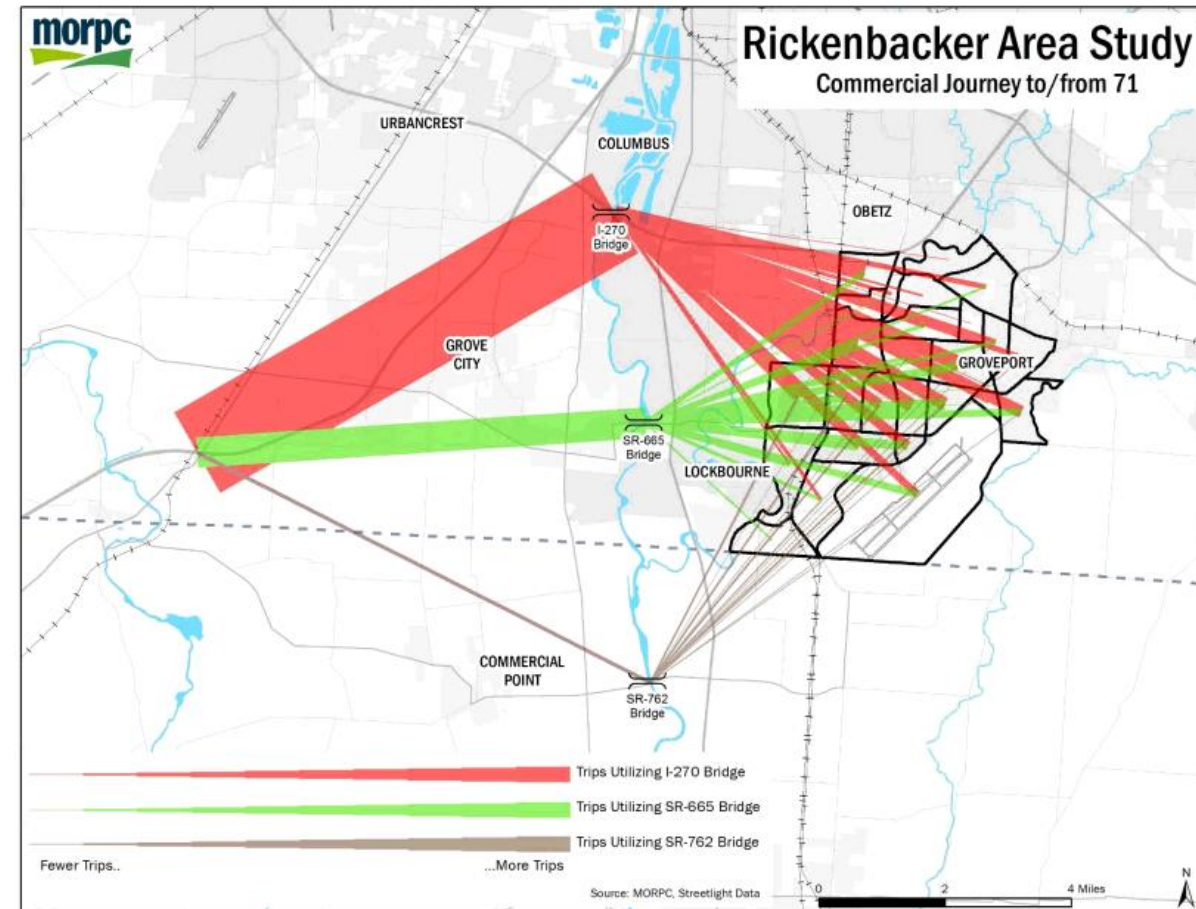
Filling Knowledge Gaps with Big Data

Trips to Tours

- Use purpose info (HBW, HBNW, NHBW, NHBO) to determine tours
- Group trips by tour id variable
  - Get number of stops, distance of tour, time of tour
  - Maintain resident vs. visitor

Amazon (and others) Normal Deliveries

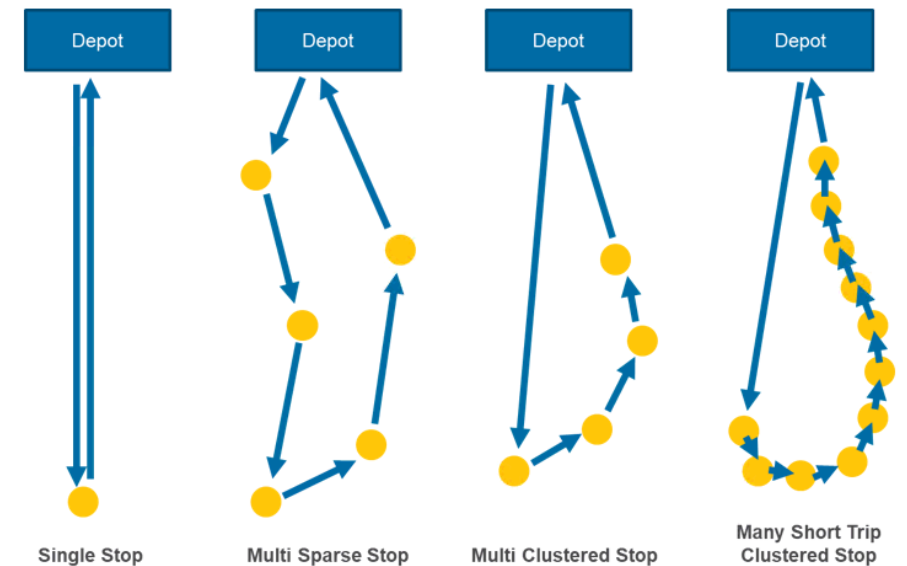Cargo Van

Class Counts:
FHWA Class 3 (2 axle, 4 tire)

Class shared with the proliferation of pickups on the road!

We cannot rely on traffic counts for LCV numbers!

Andrew's Sept 2020 Presentation on Imputing Commercial Vehicles

LCV & Truck Tours by Tour Type

Single Stop

Multi Sparse Stop

Multi Clustered Stop

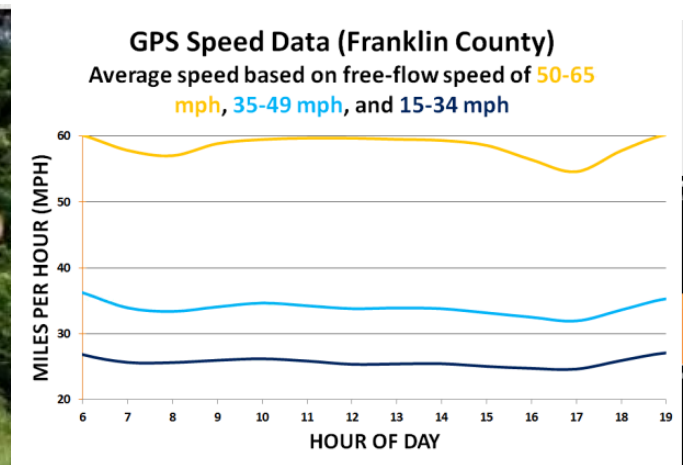Many Short Trip Clustered Stop

Validation and Big Data

Using Both NPMRDS (Performance Measurement) and New XD Network Data for Network Speed Fields/model validation for the 2020 Base Year:
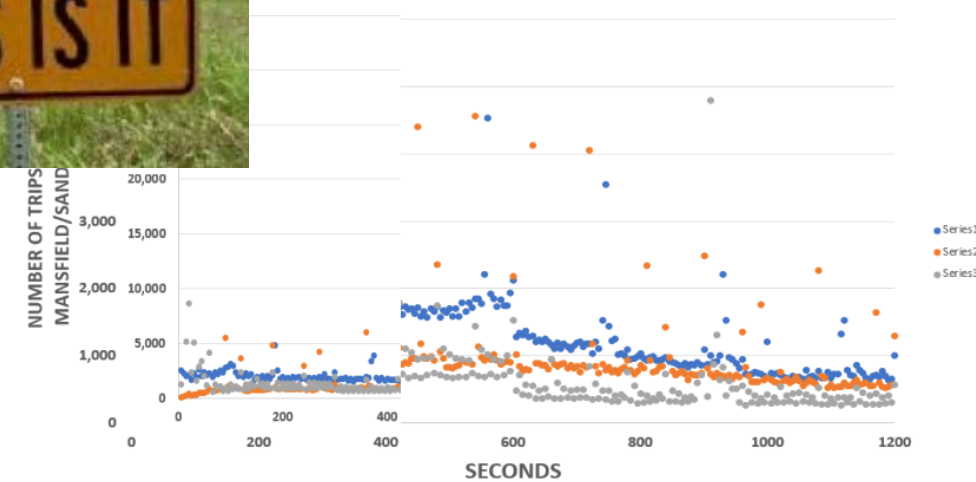
Sam Granato, Ohio DOT

- **Floating car** data still good for the initial speed coding.
- On freeways & rest of NHS – **NPMRDS** data (already used for PM3) has separate speeds for auto and truck.
- Rest of road system –**XD network** has both more granularity than TMC (0.42 m average segment length vs 1.35 m) & more roadway coverage (53,000 directional miles statewide vs 35,000), especially in smaller MPOs.

Sam's Sept. 2020 presentation on speed validation

IF YOU WERE WAITING FOR A SIGN

THIS IS IT

GPS Speed Data (Franklin County)
Average speed based on free-flow speed of 50-65 mph, 35-49 mph, and 15-34 mph

MILES PER HOUR (MPH)

HOUR OF DAY

...GTH FREQUENCY DISTRIBUTION (IN 5-SECOND BINS)

NUMBER OF TRIPS MANSFIELD/SAND...

SECONDS

- So far, minimizing travel time still more important than minimizing distance for traffic assignment, with the impact of the variability (reliability) of travel time somewhat smaller (light congestion levels in tested regions).
- Observed variability in O/D travel time considerably less than estimates used for modeling. (Likely due to little or no heterogeneity in sampled vehicle drivers by O/D pairing.)

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MPO SE Forecasting

2050 Population and Employment Projections
for
Long Range Transportation Planning

Rob Uhlhorn's Mar 2018 Presentation on SE Forecasts

POPULATION	Census		MVRPC
County	2000	2010	2050
Greeene	147,886	161,573	189,875
Miami	98,868	102,506	117,295
Montgomery	559,062	535,135	490,819
Warren*	158,383	212,693	239,060
	805,816	799,214	797,989

HOUSEHOLDS	Census		MVRPC
County	2000	2010	2050
Greeene	55,312	62,770	75,247
Miami	38,437	40,917	43,735
Montgomery	229,229	223,943	216,909
Warren*	55,966	76,424	89,046
	322,978	327,630	335,891

EMPLOYMENT	MVRPC		
County	2000	2010	2050
Greeene	77,175	97,406	131,034
Miami	51,317	49,607	64,023
Montgomery	308,437	298,018	328,224
Warren*	66,469	77,414	101,487
	436,929	445,031	523,282

Source: U.S. Census, MVRPC, OKI
* Warren County projections are for 2040

MIAMI VALLEY Regional Planning Commission

Adjustments

	2010 MV	2010
TOTAL EMPLOYMENT	445,031	446,434
Agriculture, Forestry, Fishing and Hunting	976	3,310
MINING EMPLOYMENT	197	525
UTILITIES EMPLOYMENT	2,818	1,340
CONSTRUCTION EMPLOYMENT	17,881	17,858
MANUFACTURING EMPLOYMENT	37,052	37,079
WHOLESALE TRADE EMPLOYMENT	13,490	12,804
RETAIL TRADE EMPLOYMENT	45,816	45,663
TRANSPORTATION and WAREHOUSING EMPLOYMENT	15,860	12,484
INFORMATION EMPLOYMENT	15,602	11,307
FINANCE and INSURANCE EMPLOYMENT	15,804	18,337
REAL ESTATE and RENTAL and LEASE EMPLOYMENT	5,243	14,445
PROFESSIONAL and TECHNICAL SERVICES EMPLOYMENT	26,201	29,312
MANAGEMENT of COMPANIES and ENTERPRISES EMPLOYMENT	7,365	5,707
ADMINISTRATIVE and WASTE SERVICES EMPLOYMENT	23,518	26,152
EDUCATIONAL SERVICES EMPLOYMENT	47,349	12,679
HEALTH CARE and SOCIAL ASSISTANCE EMPLOYMENT	70,263	62,437
ARTS, ENTERTAINMENT, and RECREATION EMPLOYMENT	7,106	7,084
ACCOMMODATION and FOOD SERVICES EMPLOYMENT	33,963	33,551
OTHER SERVICES, EXCEPT PUBLIC ADMINISTRATION EMPLOYMENT	13,595	23,400
Public Administration	44,933	70,960

Issues with Woods & Poole Data:
- Greene County 2050 jobs-to-population ratio too high
  - Original ratio: 0.73
- Base-year (2010) estimate discrepancies
  - e.g. Education

Solutions:
- Adjust Greene employment estimates down to be more realistic
  - Adjusted ratio: 0.69
  - Each category adjusted proportionally
- Use MVRPC's 2010 estimates and apply W&P's 2010 to 2050 increase

Our 2010 Data:
- Quarterly Census of Employment and Wages (QCEW) from Ohio Department of Jobs & Family Services
- Quality-Controlled
- Adjusted to BEA totals
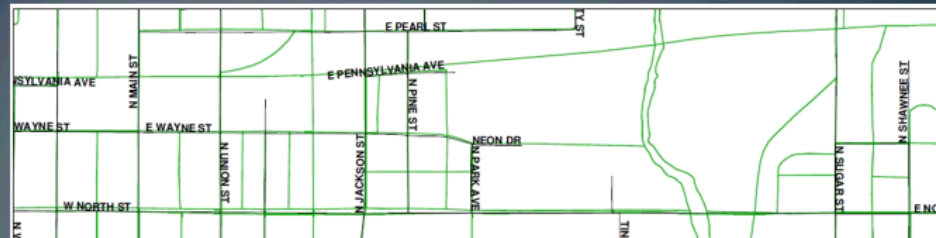
Updating Zone Boundaries

Employment Data and Zone Reconciliation Using LBRS

Drew Hurst

ODOT

Location Based Response System

The Ohio Location Based Response System (LBRS) is a component of the e-SecureOhio initiative intended to address needs for coordinated data access between state agencies. The LBRS will provide a statewide, current, accurate, and accessible street centerline and addressing system that will be collaboratively maintained as an Ohio Asset by local and state resources.

Compare LBRS to 2010 census blocks

Automated Geocode

Aggregate blocks to new TAZ

Manual geocoding remaining records

Drew Hurst's Sept 2011 presentation on updating zone boundaries for 2010

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MPO Project Forecasting
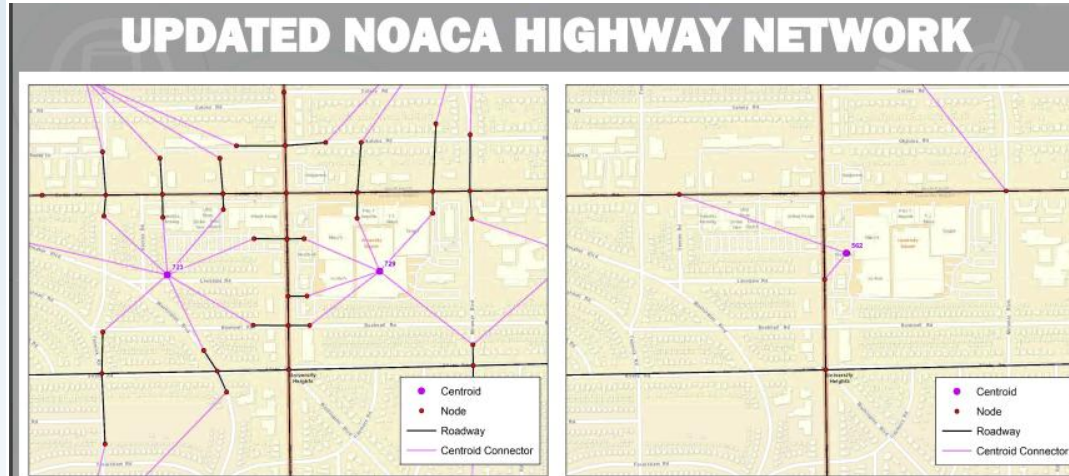
Ali's Mar 2018 Presentation on Project Forecasts
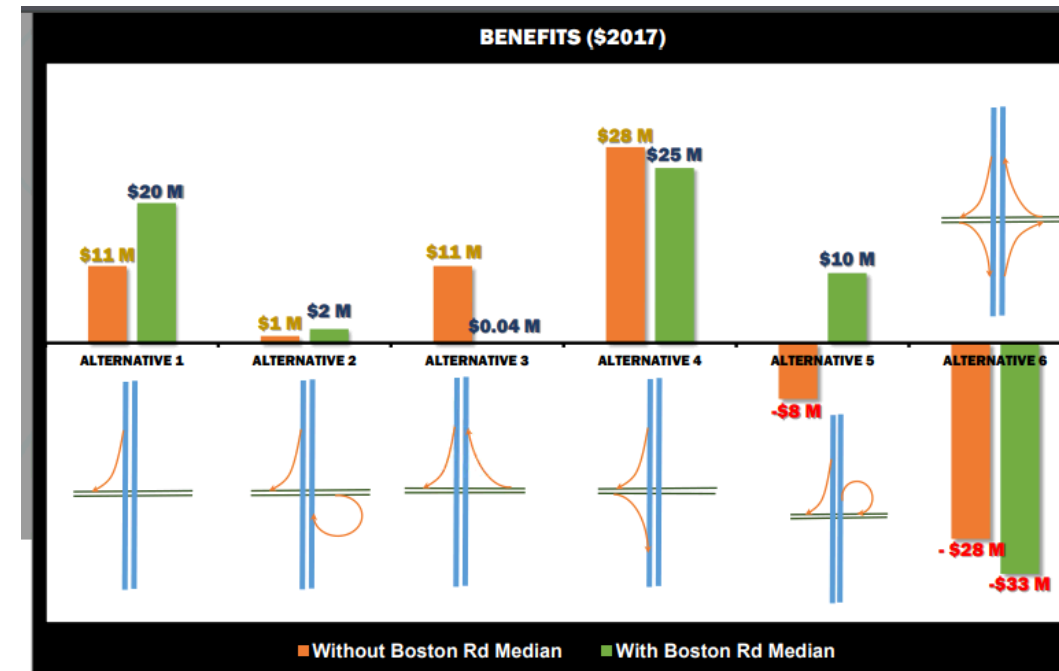
MPO Planning Analyses

Defining Vulnerable Populations

- **Persons in Poverty**
  - Household population plus non-institutionalized group quarters
- **Disabled Population**
  - Difficulties with: Hearing, Vision, Cognitive, Ambulatory, Self-care, Independent living
- **Zero-Car Households**
  - No automobiles at home and available
- **Minority Population**
  - All races other than Caucasian
- **Hispanic Population**
  - e.g. Mexican, Mexican-American, Puerto Rican origin
  - Any race
- **Elderly Population**
  - 65+

	County	Total
People in Poverty	Greene	20,714
	Miami	12,366
	Montgomery	87,503
	Warren	3,929
Disabled Population	Greene	16,647
	Miami	11,897
	Montgomery	73,416
	Warren	4,396
Zero-Car Households	Greene	3,037
	Miami	2,112
	Montgomery	21,304
	Warren	2,047
Minority Population	Greene	21,903
	Miami	5,784
	Montgomery	139,881
	Warren	20,262
Hispanic Population	Greene	3,439
	Miami	1,341
	Montgomery	12,177
	Warren	4,784
Elderly Population	Greene	21,998
	Miami	15,731
	Montgomery	81,041
	Warren	22,936

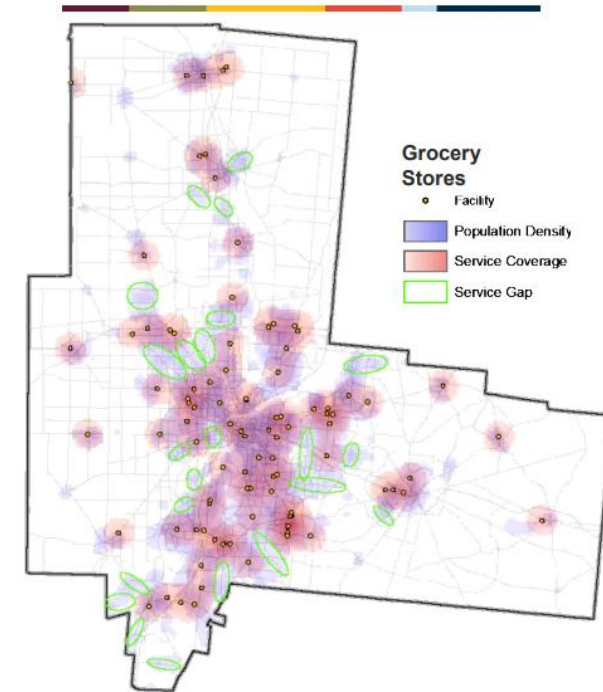MVRPC Celebrates 55 Years

Rob Uhlhorn's Sept 2019 presentation on equitable transportation access

Service Gap Analysis – Grocery Stores

Grocery Stores
- Facility
- Population Density
- Service Coverage
- Service Gap

- **Access is generally better for target populations, for a given mode**
  - Especially minority, people in poverty, and zero-car households
  - Elderly track closely with general population
    - Explained by geographic distribution
  - Lack of a car alters accessibility significantly
- **Rural areas have least access**
- **Some areas lack services; others have concentrations of services**
  - Leads to higher vehicle miles traveled and congestion
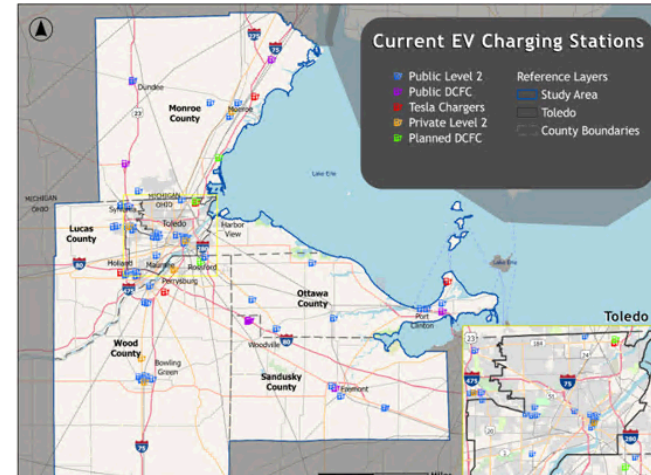
MPO Planning Analyses

Erin and Lisa's Sept 2024 Presentation on EV Siting

Eclipse Traffic Modeling

Background

- There will be a total solar eclipse passing through Ohio in 2024.
- ODOT wants to be able to assist in planning for and positioning resources on eclipse day to facilitate smooth traffic operations.
- Due to the extent of the geographic impact of the eclipse on Ohio, the Ohio Statewide Model is the only tool of suitable scale for this analysis.
- Goal is to create an Eclipse Day event model for Ohio using data collected from the 2017 eclipse in Kentucky and Tennessee

Map of 2024 Path of Totality

Jonathan and Roberto's Nov 2022 on Statewide Eclipse Model

Average Trip Lengths – KY/TN

	Travel Time (Min)					
	Residents		Visitors		Combined	
	Regular	Eclipse	Regular	Eclipse	Regular	Eclipse
Overall	18	17	23	21	21	19
II	14	13	11	10	13	12
IE	35	42	72	116	46	63
EI	39	42	74	90	49	55
EE	17	15	22	19	21	18

Diurnal Distribution of IE Trips

Traffic Operations Modeling

Cube Avenue Dynamic Traffic Assignment

- Cube Avenue is an Extension to Cube Voyager Highway

- Uses same algorithms but breaks assignment into small (user defined) time slices and keeps track of link storage, queues, and vehicle location at end of each time slice

- Currently, I've been using it to check network coding prior to using matrix estimation to refine volume estimates for detailed operational level planning

- Reasonably simple to apply

Greg's Sept 2009 Presentation on "New" Cube Avenue DTA

Mansfield CBD Dynamic Traffic Assignment Test

Queue Formation at Failed Intersections

Parameters
- 1 hour model
- 5 time slices of 15 min
- 15 min warm up
- 1.09 x hrly in slice 2 corresponds to PHF 0.92
- 0.97 x hrly in other slices
- 20 Iterations of ASN needed

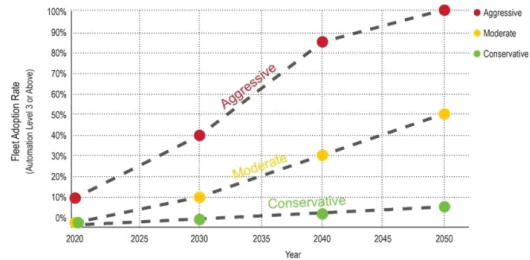Period 1 warm up

Period 2

Period 3 peak

Period 4

Period 5

Traffic Operations Modeling with CAV

ODOT CAV Simulation Literature Review

- Spreadsheet of relevant documents
- Results published in TFResource Wiki
  - https://tfresource.org/topics/Content_Charrette_Autonomous_Vehicles.html

AV Adoption Rate Scenario Levels

Simulation of CAVs in Ohio

- *Vissim*
- Adjustments to internal parameters and Car Following made. Used in numerous CAV-related research studies.
- Marysville corridor (US-33 near Columbus)

- *TransModeler*
- Allows new vehicle classes equivalent to SAE levels. Used with adjustments documented in FHWA study
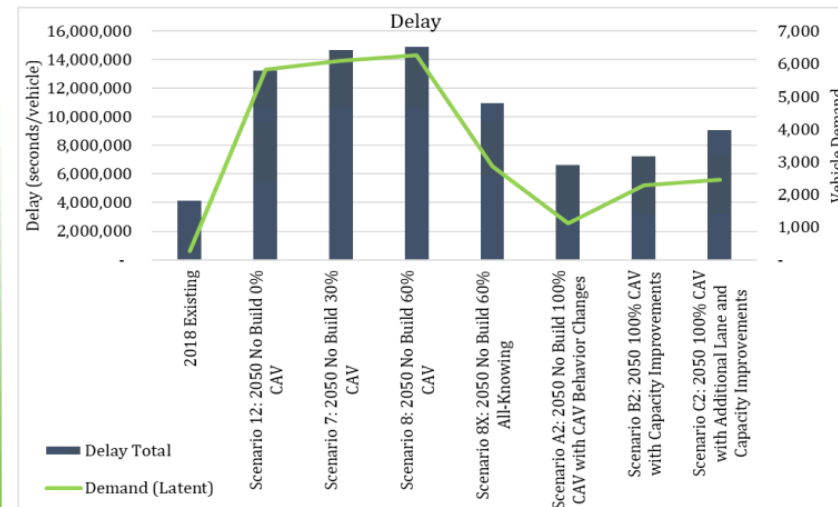- Brent Spence Bridge (I-75/I-71 in Cincinnati)

Travel Demand Models can be enhanced to handle most CAV uncertainties:

- Models help understand range of futures and potential policies
- CAV treated as a mode
- This study utilized the 3C models developed by ODOT and WSP

Regionwide TDM Results: Total Trips
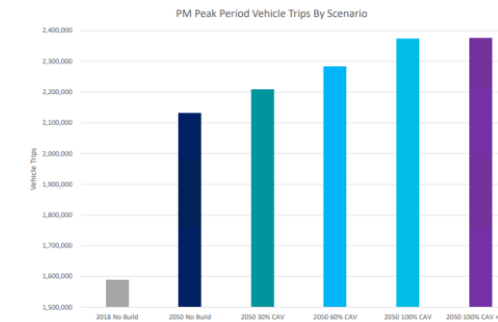
Systemwide Results for Delay Total

Rob's Sept 2022 Presentation on ODOT CAV Research
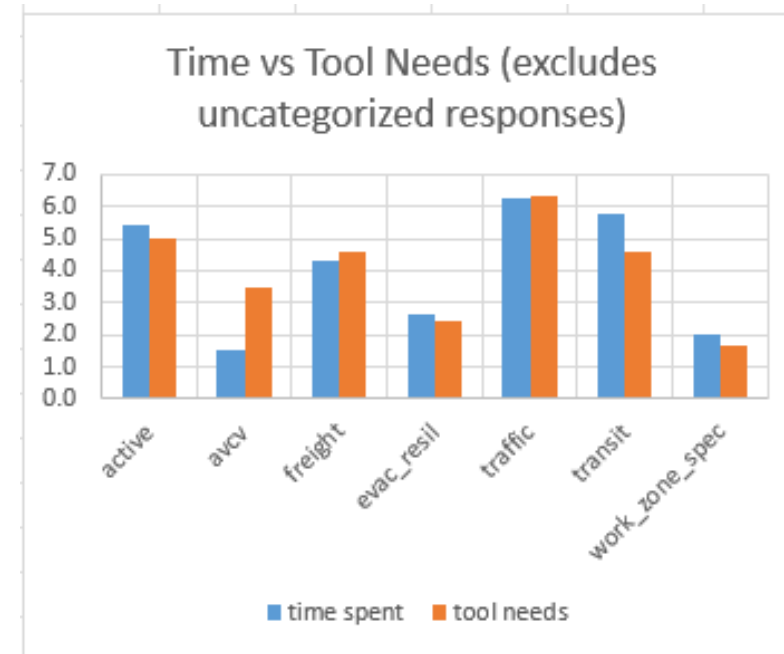
Topic Surveys

- Surveys were conducted in 2003 and 2017

OTDMUG·Topic·Survey¶
¶
¶
This·report·briefly·summarizes·the·OTDMUG·Topic·Survey·from·the·June·meeting·and·presents·recommendations·for·future·
sessions.··The·survey·contained·3·main·part.··Part·1·asked·for·a·list·of·general·topic·session·ideas.··Table·1·summarizes·the·
respones.¶
¶

General Topics	Relevance Tier Per Part 3
Air Quality	2
Applications of Model Output	1
Freight	?
GIS	3
Microsimulation Models	2
New MPO Model Development Updates	1
Post Processing	1
Statewide Model Development Updates	1
Training (modeling in general & software	?
Transit	?

Table 1

From 2003 MUG Topics Survey Report

Time vs Tool Needs (excludes uncategorized responses)

■ time spent ■ tool needs

From 2017 MUG Tools Survey

WSP

Future Topics Open Discussion