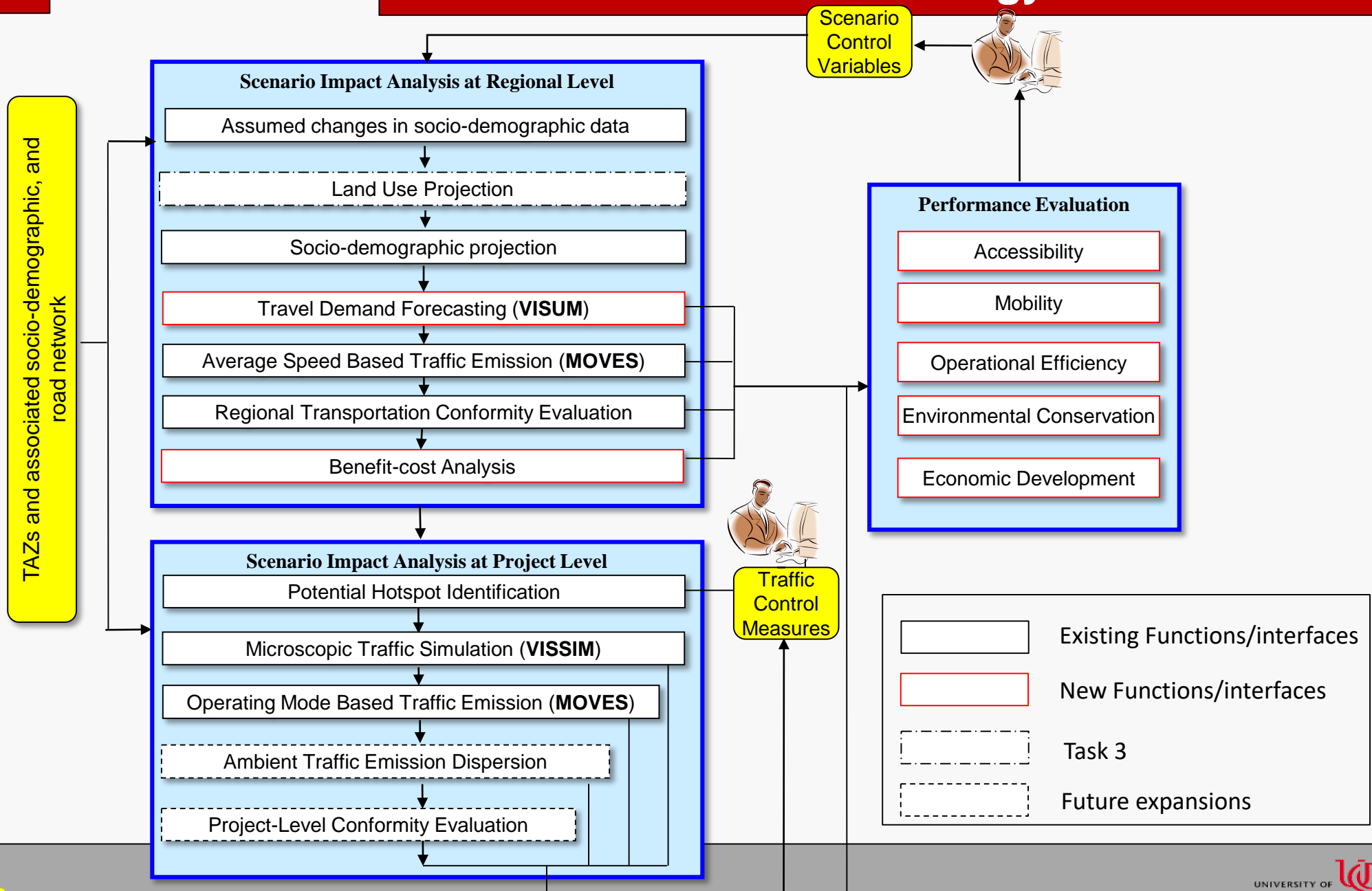


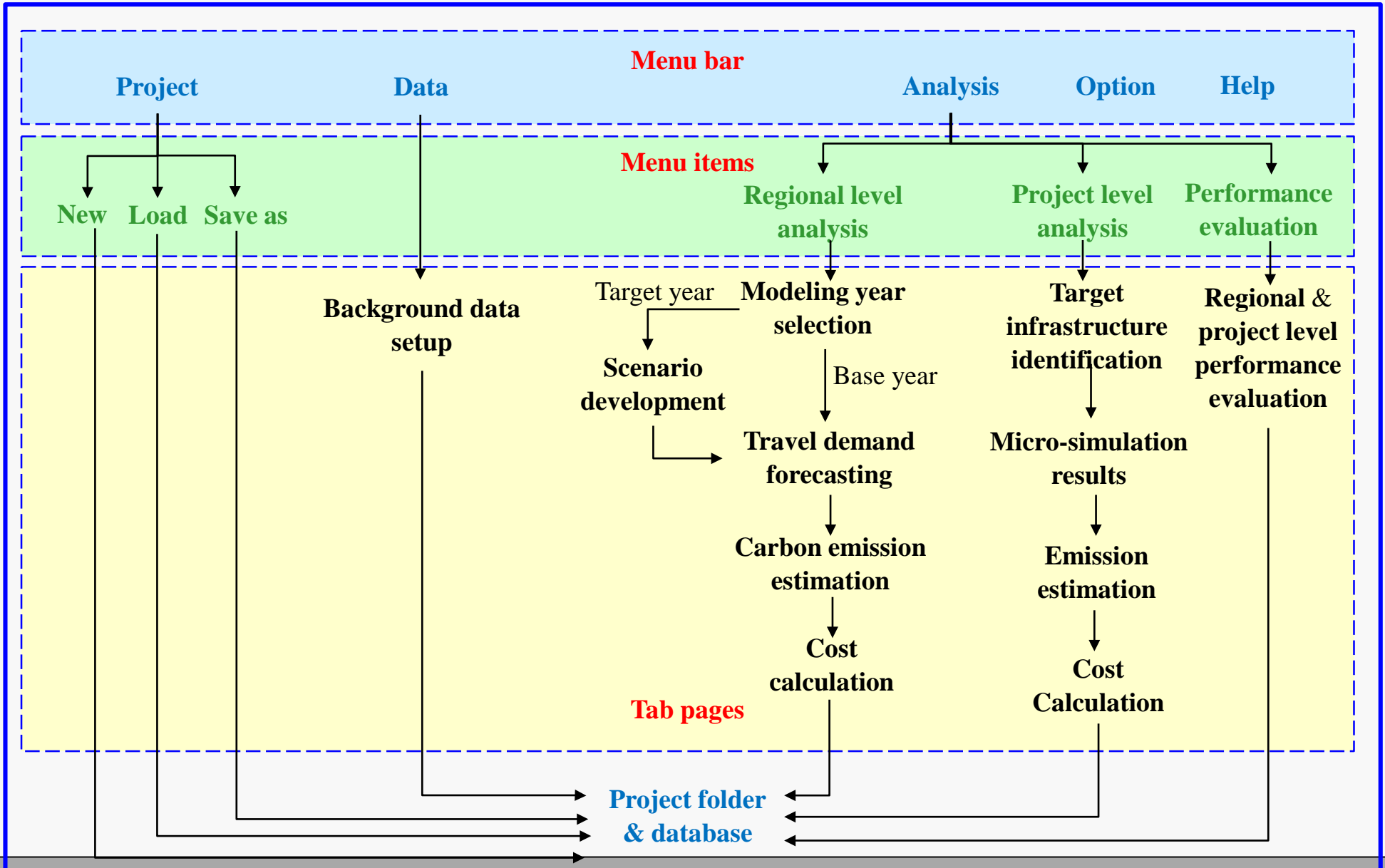
Infrastructure Adaptation Planning Tools

Prepared by Hao Liu and Ting Zuo

10/19/2015

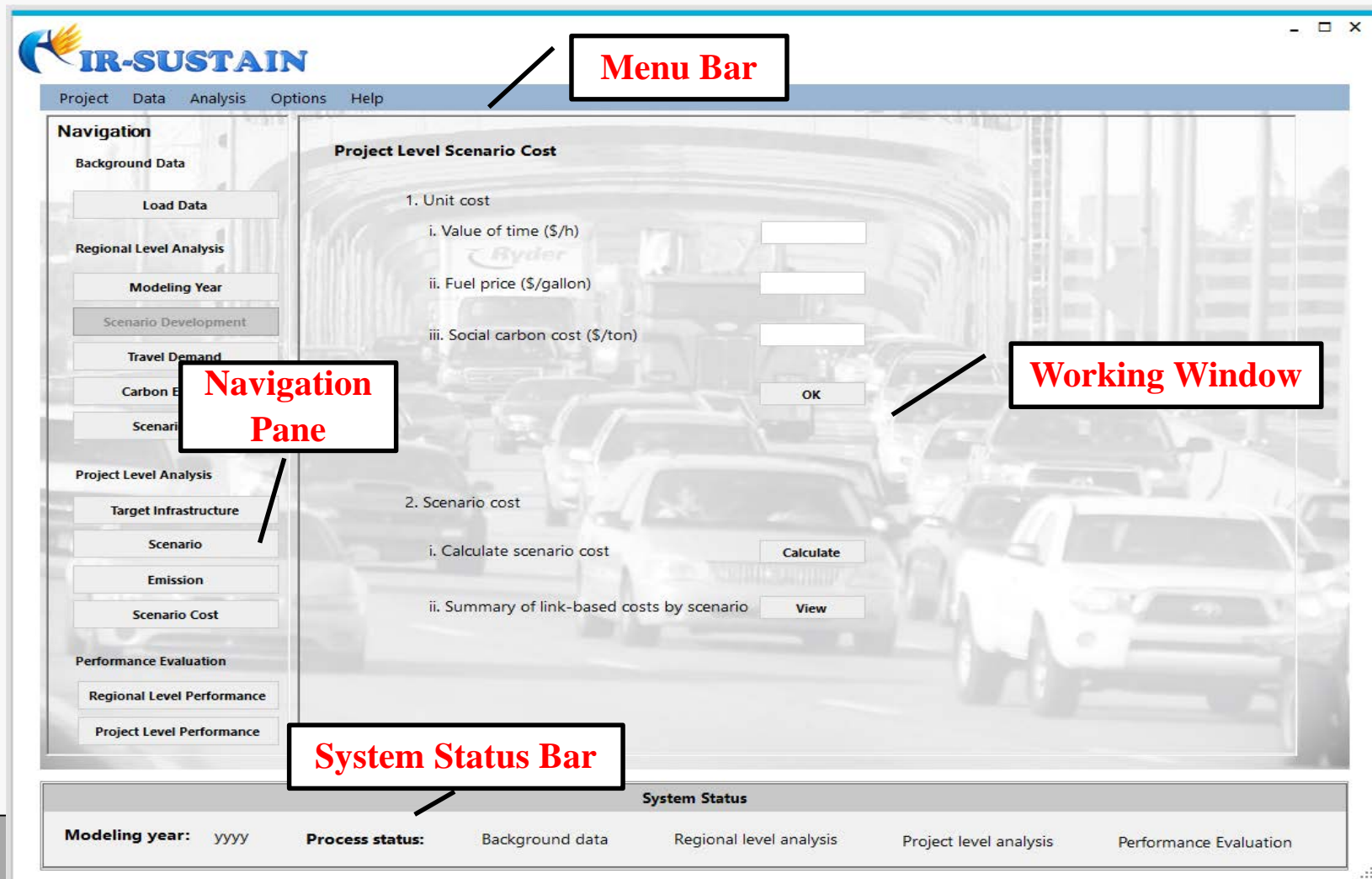
Methodology of AIR-SUSTAIN





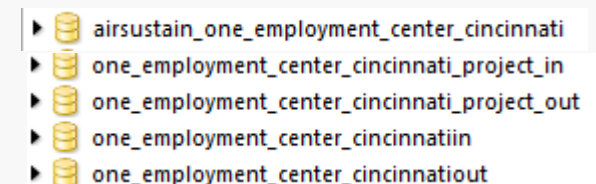
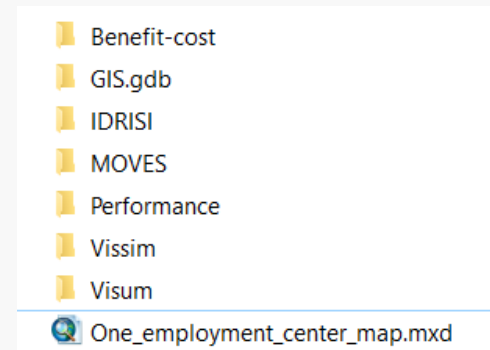
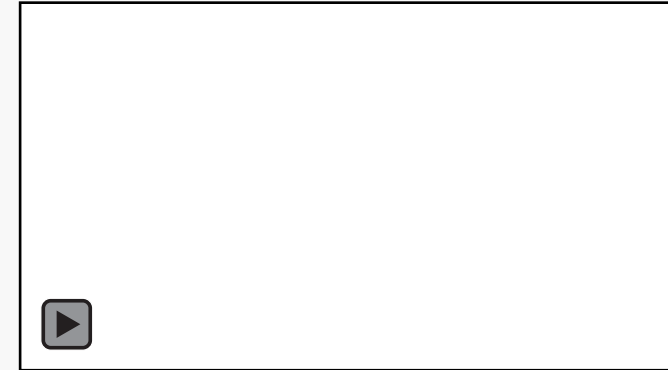
• Interface

- In the AIR-SUSTAIN desktop, there are four components: **menu bar**, **navigation pane**, **working window**, and **system status bar**.



• Project

- All the loaded inputs and calculation results are placed in a project folder and databases. Under the **Project** on the menu bar, there three items:
 - **New Project** allows the user to create a new project.
 - **Load Project** allows the user to load an existing project.
 - **Save Project As** allows the user to save current project as a new project.
- Once a project is created, a project folder is generated under the specified directory, and five MySQL databases are created automatically.
 - **A project folder** (*ProjectName*) contains: GIS.gdb (ArcGIS Geodatabase), *ProjectName_map* and four sub-folders (Benefit-cost, MOVES, Vissim, Visum, and Performance).
 - **Five MySQL databases**, including *AIR-SUSTAIN_ProjectName* database; and MOVES databases: *ProjectName_In* database; *ProjectName_Out* database; *ProjectName_Project_In* database; *ProjectName_Project_Out* database.



- **Background data setup**
- **Inputs:** 1) TAZ (feature class) and associated socio-demographic information of each TAZ; and 2) Road Network
- **Modeling year selection**
- The **Modeling Year Selection** panel allows the user to choose analysis year by checking either **Base Year (reference year)** or **Target Year** radio button.
- **Scenario development**
- **Inputs:** 1) project boundary, and 2) assumed demographic changes.
- **Calculation:** socio-demographics projection.
- **Outputs:** *TargetYearTAZ* (feature class) with associated target year socio-demographics.

- **Travel demand forecasting**

- **Inputs:** 1) *Household fraction* (.xlsx), and 2) *Activity pattern utility* (.xlsx)
- **Calculation:** the travel demand modeling with developed tour-based travel demand model.
- **Outputs:** 1) Link based travel information, such as volume, speed, travel time, fuel consumption, and etc., stored in the MySQL database and geodatabase; 2) a VISUM file *TargetTDF.ver* or *BaseTDF.ver*.

- **Carbon emission estimation**

- **Inputs:** Non-traffic inputs, including *Age Distribution* (.xlsx), *Fuel Formulation* (.xlsx), *Fuel Supply* (.xlsx), *Meteorology* (.xlsx), and *State and County* (.xlsx).
- **Calculations:** estimate the CO2 emission of each link.
- **Outputs:** link-based CO2 emission stored in MySQL database and ArcGIS database simultaneously.

- **Cost calculation**
- **Inputs:** unit costs of travel time, fuel price, and social carbon cost.
- **Calculation:** calculate the cost of travel time, fuel and CO2 emission.
- **Outputs:** travel time, delay, fuel and CO2 emission costs, which are stored in the MySQL database
- **Optional:** cost of other scenario(s) can be loaded to the AIR-SUSTAIN, and then compared with the cost of current scenario.

- **Target infrastructure identification**

- At the project level, two options are provided on the **Target Infrastructure** panel to identify/select target analysis infrastructure. Hotspot links can be either
 - identified from the regional network via a set of criteria; or
 - selected by the user from the road network directly.
- **Inputs:** hotspot identification criteria;
- **Calculations:** identify hotspots according to the criteria; or select hotspots directly from hotspots from road network.
- **Outputs:** hotspots (feature class);

- **Micro-simulation results**

- With the identified target infrastructure, the user needs to develop traffic control measures in micro-simulation environment, and then load the micro-simulation results to the AIR-SUSTAIN.
- **Inputs:** 1) The microscopic simulation links, which records a map between links in microscopic simulation network and links in VISUM; 2) Micro-simulation results under traffic control measures, which contains the sec-by-sec vehicle operating parameters, such as speed, acceleration and so forth.

- **Emission estimation**

- Hotspots' emissions are calculated by emission estimation model which is similar to the functions of emission estimation in regional level analysis.

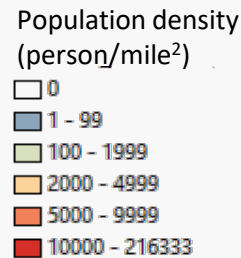
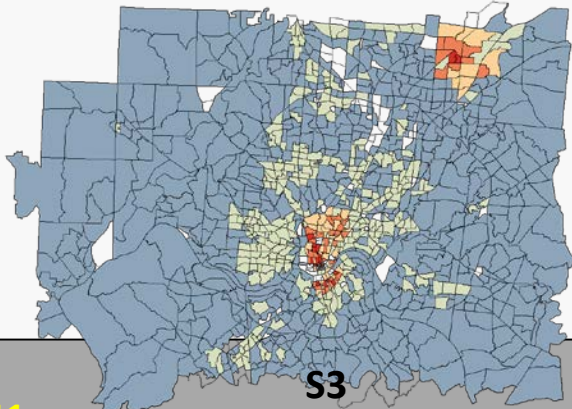
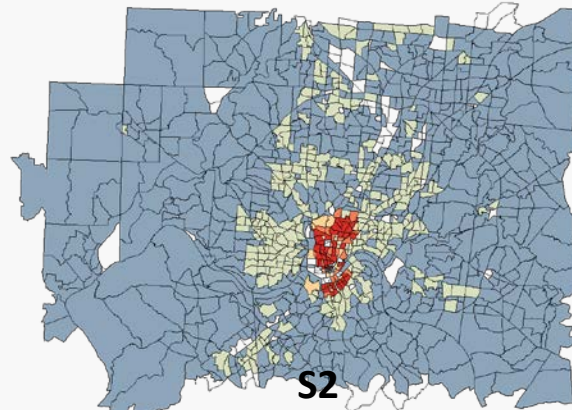
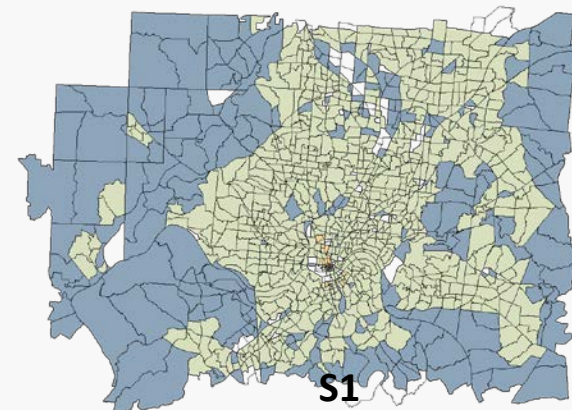
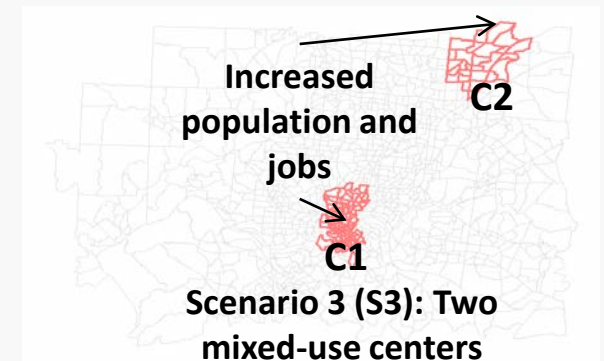
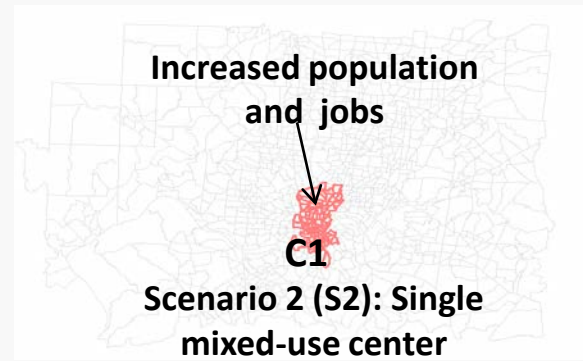
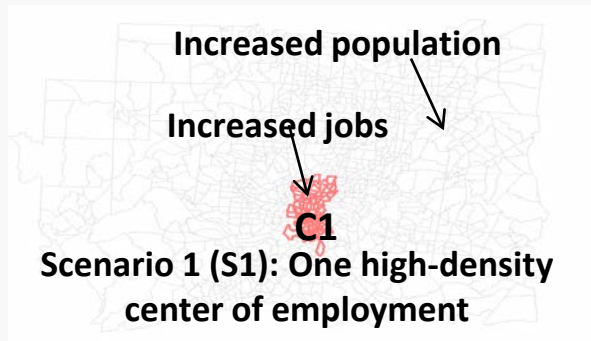
- **Scenario cost**

- The **Project Scenario Cost** provides a similar function to calculate travel time cost, delay cost, fuel cost, and social carbon cost in the **Scenario Cost** under regional level analysis.

- **Performance evaluation**

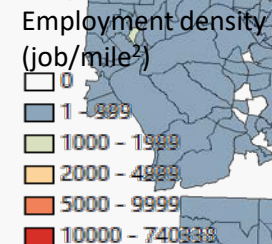
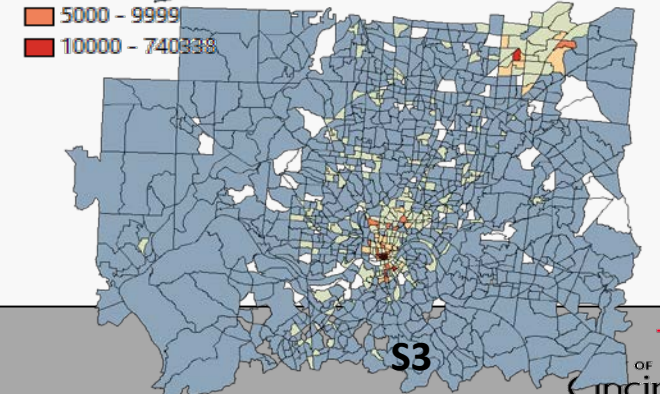
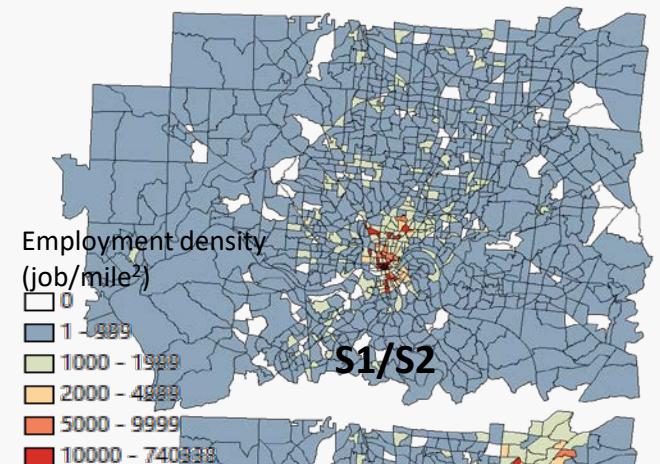
- the performance measures can be classified into five categories: accessibility, mobility, environmental conservation, economic development, and operational efficiency.

Assumed land use change



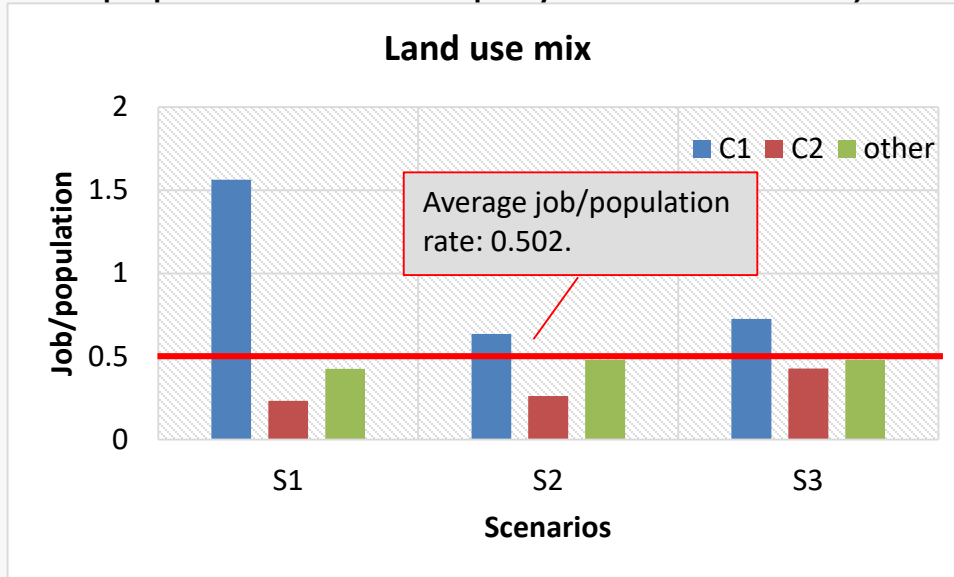
The distribution of increased population

The distribution of increased employment

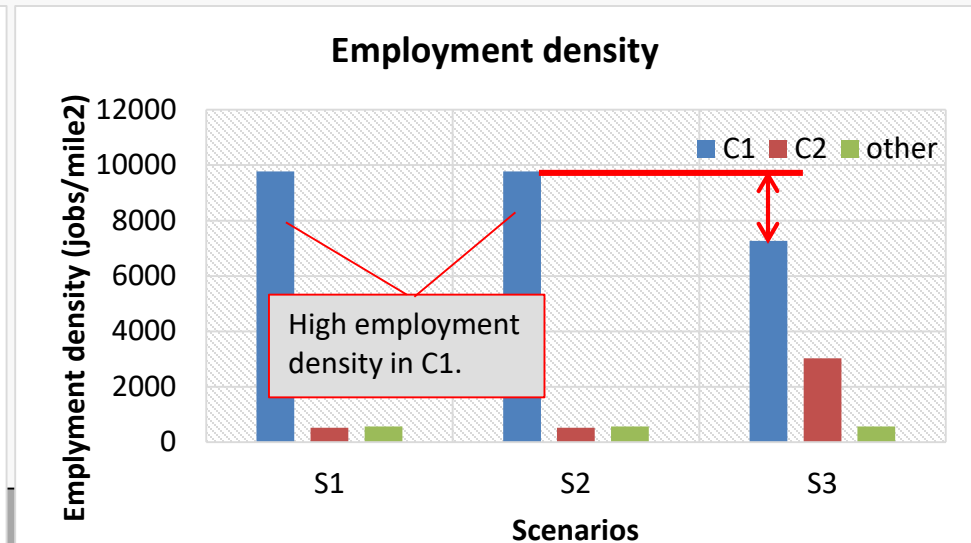
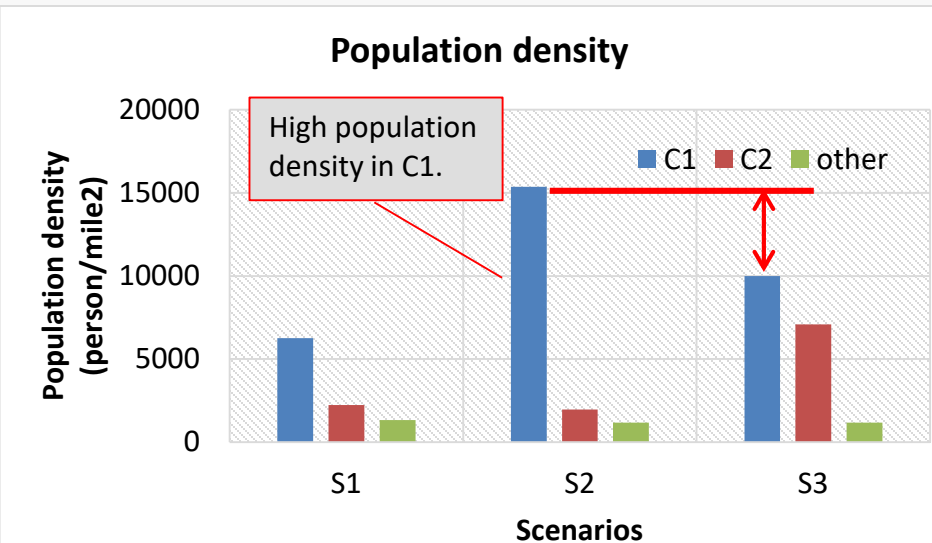


• Scenario land use

- The population and employ densities of C1, C2 and other TAZs are listed as following.



- Land use mix is represent by the balance measure. The balance is defined as the ration of employment to population at TAZ level. When jobs and housing mismatch, people have to commute farther. (S1 vs. S2)
- As densities increase, distances become shorter. However, increasing density results in more traffic congestion. (S2 vs. S3)



• Travel demand summary

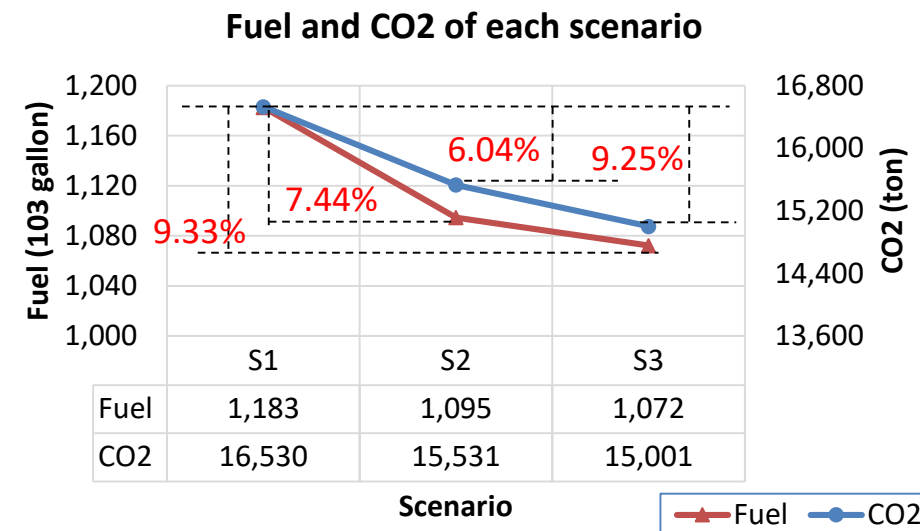
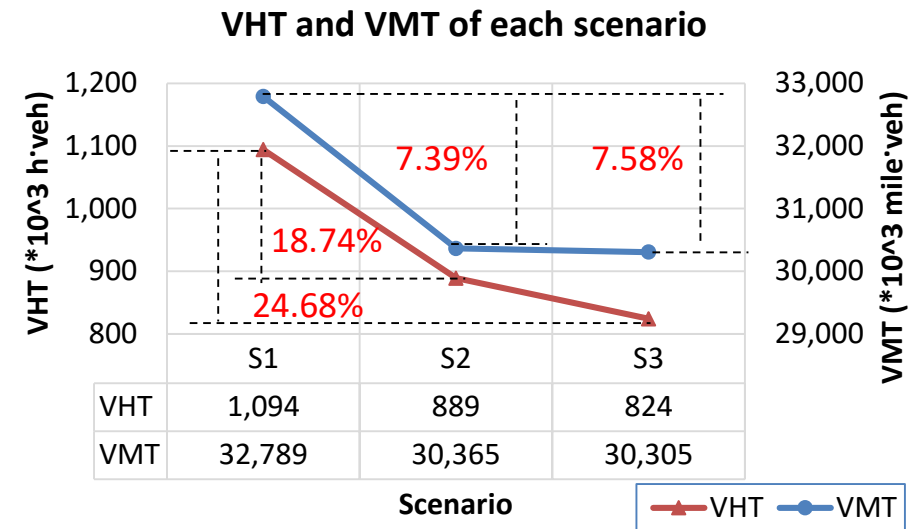
- The total number of trips, percentage of intrazonal trip, and average trip length of each scenario are summarized in the following table. Intrazonal trips are defined as the trips within a TAZ (Bhatta and Larsen, 2011). And the percentage of intrazonal trip is the percent of intrazonal trips to the total trips.

Scenarios	Trips	Percentage of intrazonal trip (%)	Average trip length (mile)	Percentage of intracenter trip (%)	
				C1	C2
S1	5.9023×10^6	11.01%	6.70	7.91	0.87
S2	5.9065×10^6	10.21%	6.28	12.19	0.78
S3	5.9067×10^6	11.89%	6.36	7.66	4.78

• Scenario performance

- The total VHT and VMT of each scenario are shown as the figure on the right.
- Then set the S1 as the base case. VMT and VHT of S2 and S3 are compared to S1 relatively. The percentage changes of VMT and VHT are listed as following two figures.

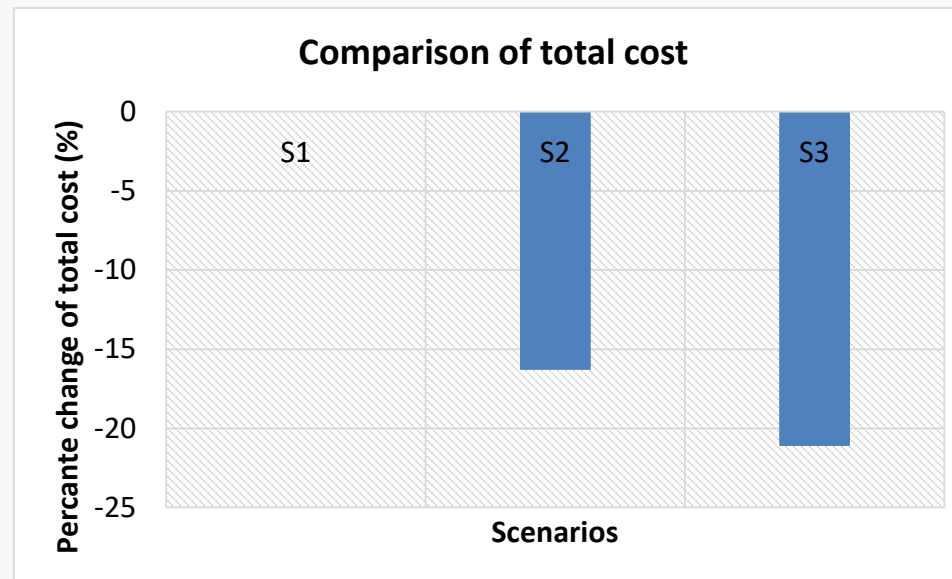
Scenario	Delay (h)
S1	344,876
S2	185,191
S3	117,686



- **Scenario performance**
- The cost of each scenario are illustrated as followings.

Scenario	Travel time cost (\$)	Fuel cost (\$)	Social carbon cost(\$)	Total cost (\$)
S1	17,831,518	3,987,566	702,194	22,521,278
S2	14,498,288	3,690,762	659,757	18,848,807
S3	13,446,315	3,682,897	637,242	17,766,454

- Set the total cost of S1 as the base case, the percentage changes of total cost of S2 and S3 compared to S1 are calculated. The percentage change of total cost of each scenario is listed as follows.



• Scenario performance summary

- S1, S2 and S3 are evaluated by the performance measures, and the results are summarized in the following table.

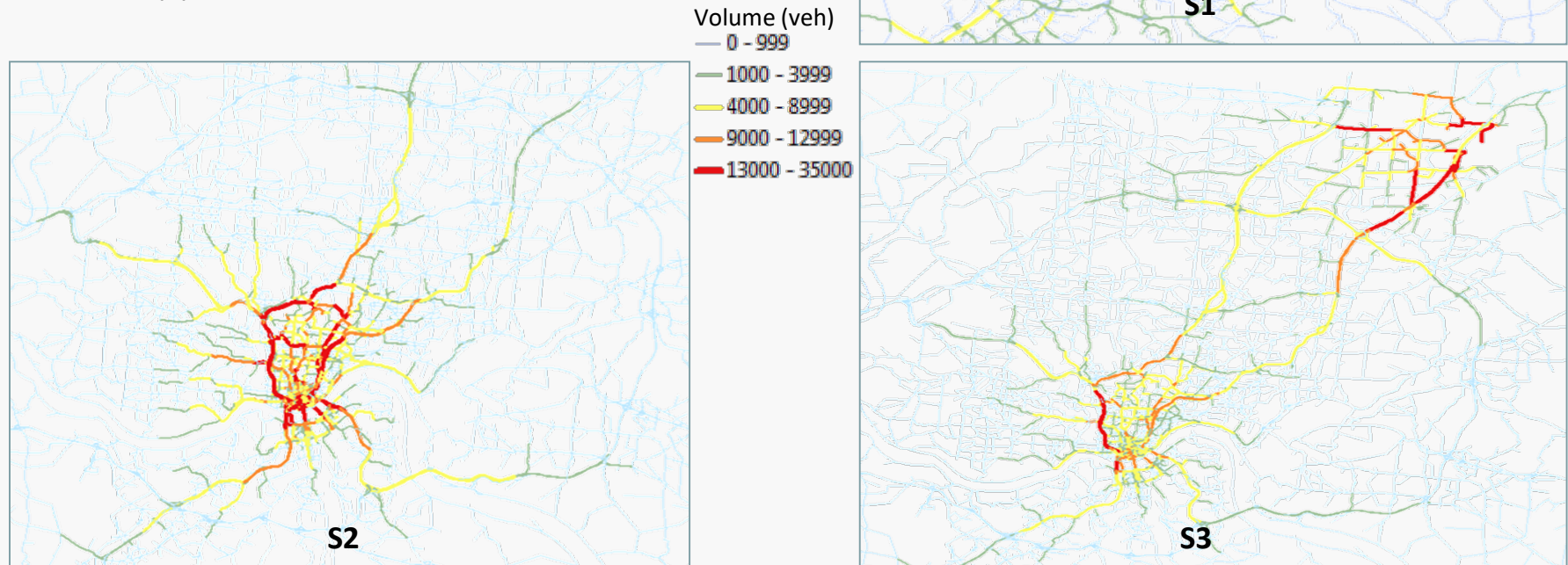
Scenario	Accessibility		Mobility						
	O-D travel time (min)	O-D travel cost (\$)	VMT (10 ³ veh·mile)	VHT (10 ³ veh·h)	TTI	Total volume (10 ³ pcu)	Average speed (mile/h)	Link D/C	Link delay (h)
S1	31.33	3.70	32,789	1,094	1.20	988,213	29.97	0.166	344,876
S2	29.62	3.08	30,365	889	1.19	947,098	34.16	0.162	185,191
S3	27.45	2.90	30,305	824	1.18	901,164	36.78	0.156	117,686
Scenario	Operational efficiency		Environmental conservation		Economic development				
	Cost per VMT (\$/veh/mile)	Cost per VHT (\$/veh/h)	CO2 emissions (ton)	Fuel consumption (10 ³ gallon)	Travel time cost (10 ³ \$)	Fuel cost (10 ³ \$)	SCC cost (10 ³ \$)	Total cost (10 ³ \$)	Delay cost (10 ³ \$)
S1	0.69	20.59	16,530	1,083	17,832	3,988	702	22,522	5,656
S2	0.62	21.19	15,531	1,095	14,498	3,691	660	18,849	3,016
S3	0.59	21.55	15,001	1,072	13,446	3,683	637	17,766	1,907

From S1 to S3, as the traffic congestion reduces, vehicles can travel further in an hour. The longer average distance traveled in an hour results in the increase in cost per VHT.

- From the above table, it's obvious that S3 outperforms other two scenarios.

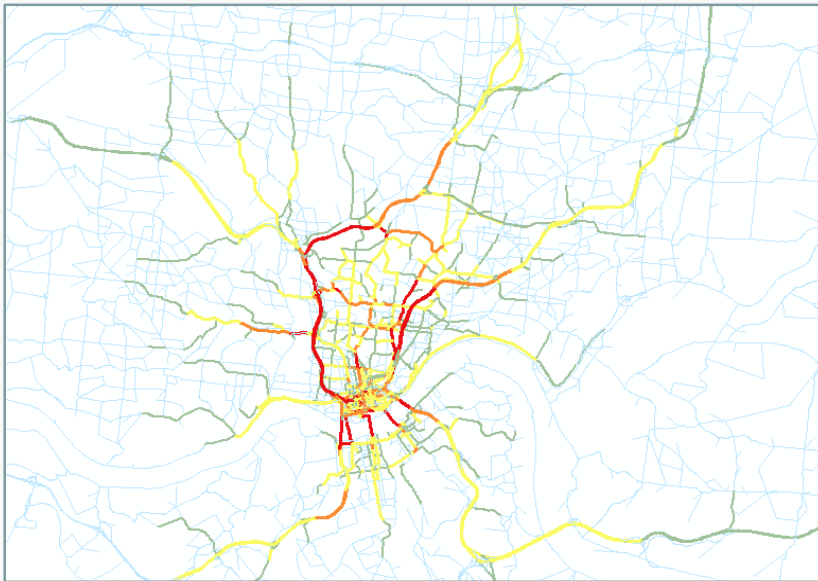
• Changes of link traffic volume

- Figures of S1, S2 and S3 show the amount of difference of daily traffic volume after there are assumed land use changes of each scenario.
- In S1, the increased traffic is more widely distributed than S2 and S3. In S2 and S3, increased traffic is distributed around and within the center(s).



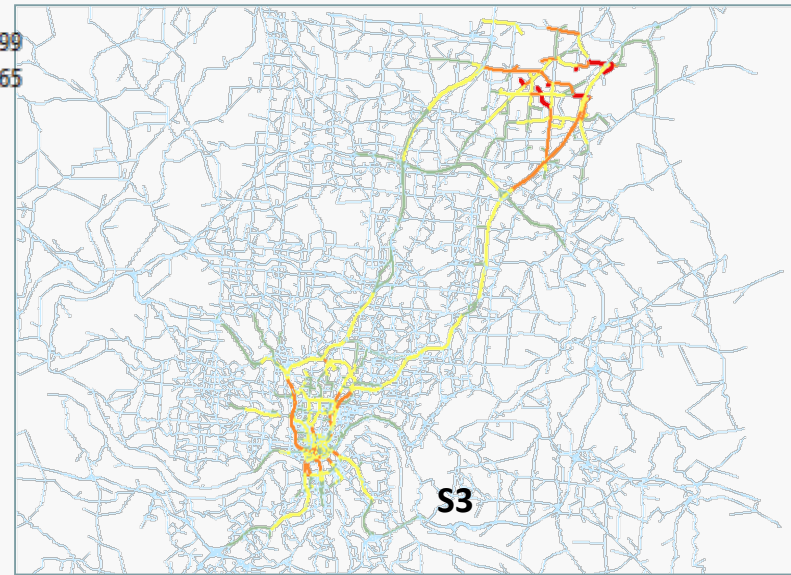
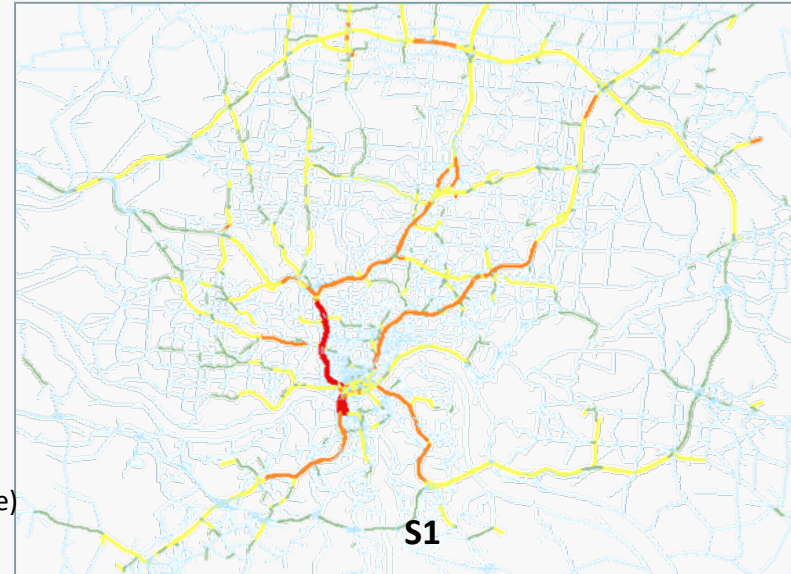
- **Changes of link CO2 emission**

- Figures of S1, S2 and S3 show the amount of change of link CO2 emission after the land use change of each scenario.
- In S1, the increased CO2 emission is more evenly distributed compared with S2 and S3. In S2 and S3, CO2 emission is distributed around and within the center(s).



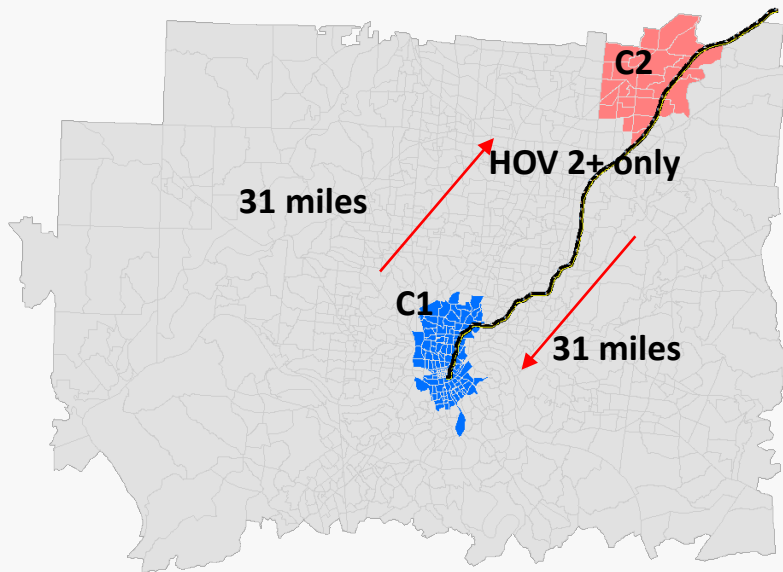
CO2 (kg/mile)

- 0 - 999
- 1000 - 2999
- 3000 - 9999
- 10000 - 15999
- 16000 - 34165

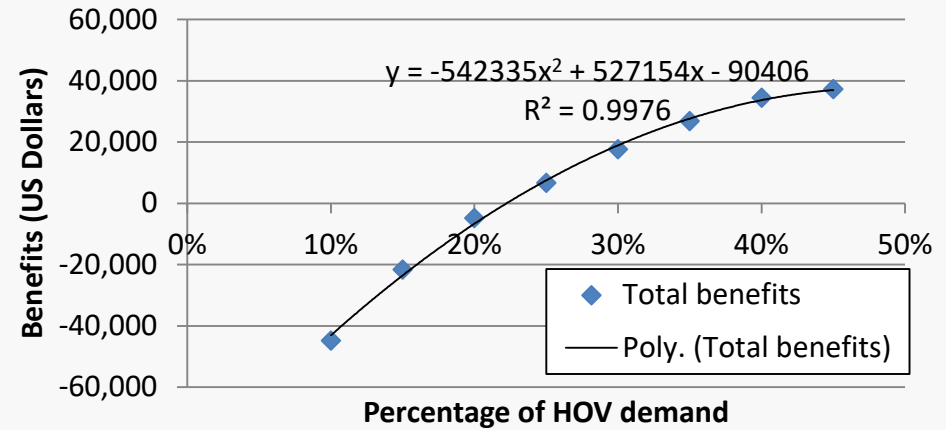


- **HOV lanes**

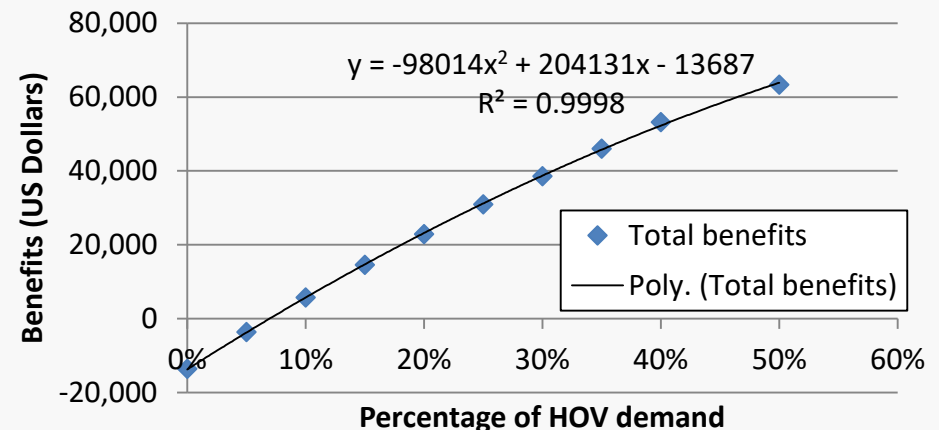
- To conduct a benefit-cost analysis, based on Scenario 3 (S3), a scenario (referred as scenario 4 (S4)) in which two centers are connected with HOV lanes is developed (shown as the figure on the left). In S4, there is a HOV lane of each direction converted from a mixed-flow (MF) lane of I-71 connecting two centers.



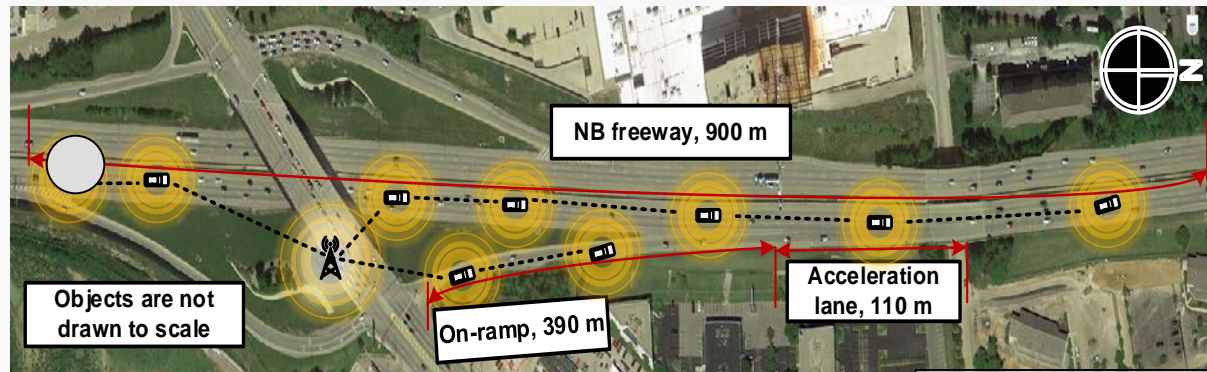
**Total benefits during the peak hours
(7 am~9 am and 5pm~7pm)**



**Total benefits during the non-peak hours
(7pm~7am and 9 am~5pm)**



• Project level case study



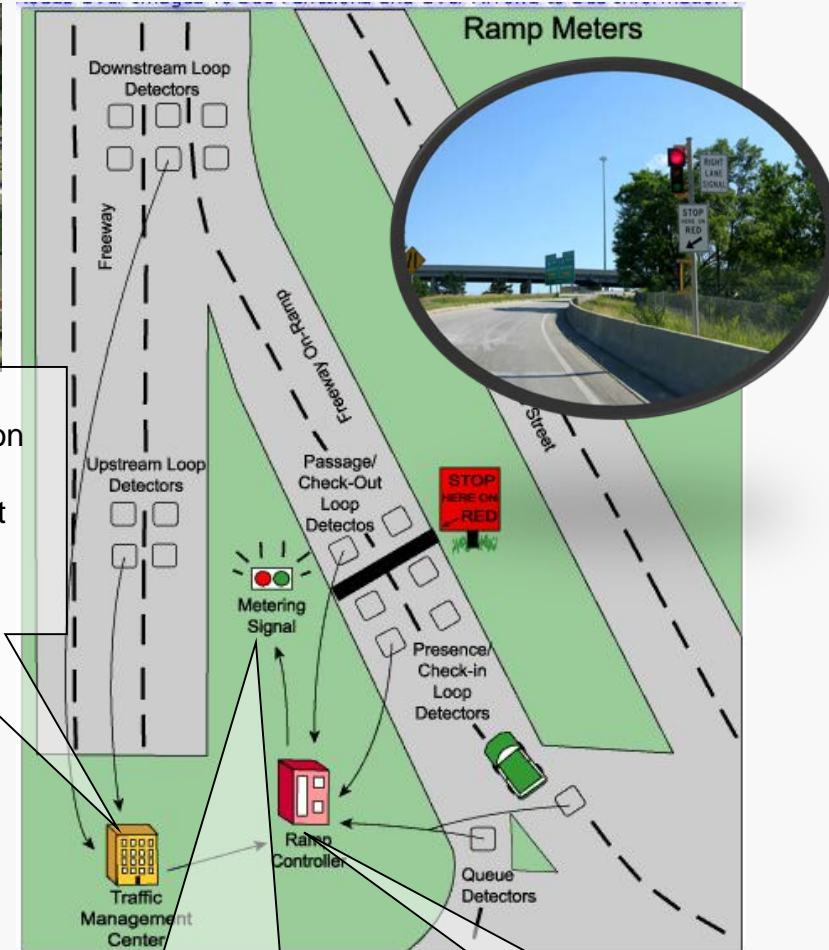
Site description:

- NB I-71, near Exit 12 in greater Cincinnati area, Ohio.
- 3 freeway lanes, 1 on-ramp lane.
- Mean freeway peak hour volume 4400 veh/hr, 4.5% truck; mean ramp peak hour volume 950 veh/hr, 1% truck.
- Recurrent congestions, isolated bottleneck.

Case study setups

- Base case → no ramp meters
- Ramp metering (RM) case → traditional ramp meters
- V2I case → RM controller takes CV information
- V2I + V2V case → RM controller takes CV information and driver behaviors adapted

Collects vehicle presence information of upstream, downstream, and at ramp entrance (i.e., queues)



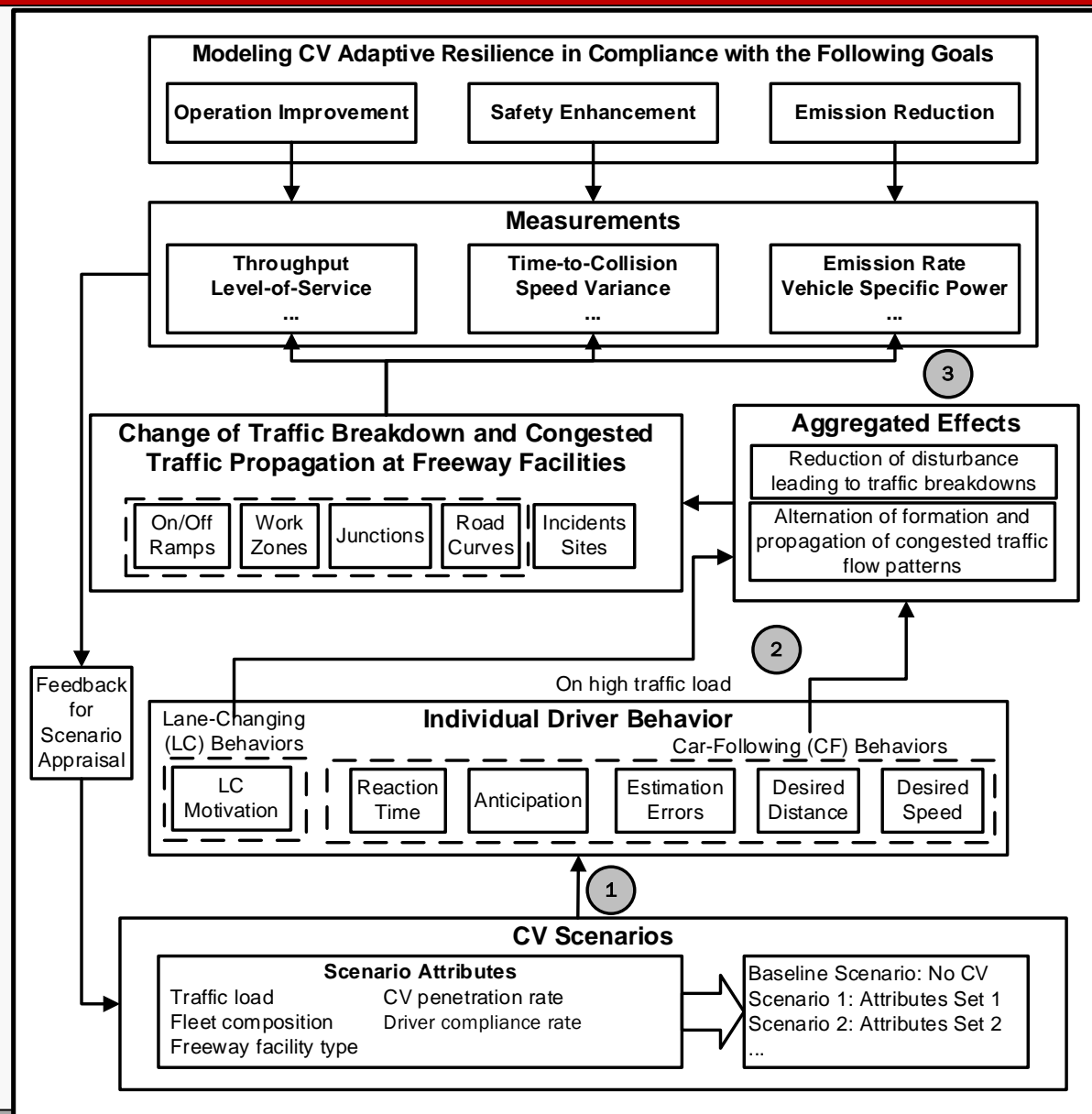
Indicates to drivers when they can enter the ramp using a green light (go) and red light (wait)

Controlling ramp metering rate

• Methodology—framework

The proposed research focuses on three major components:

- 1) Development of a human driver model that captures the behaviors affected by CV information.
- 2) Incorporation of the human driver model into the state-of-the-art traffic flow models.
- 3) Development of the measurement system that captures the aggregated effect of driver behavior adaptation on traffic flow dynamics.



• Model calibration

Calibration objective:

- After calibration, the model should be able to reproduce *calibration performance parameters* compatible to real-world observations.
- Calibration performance parameters: travel time and speed measured at the start of acceleration lane (entry speed).

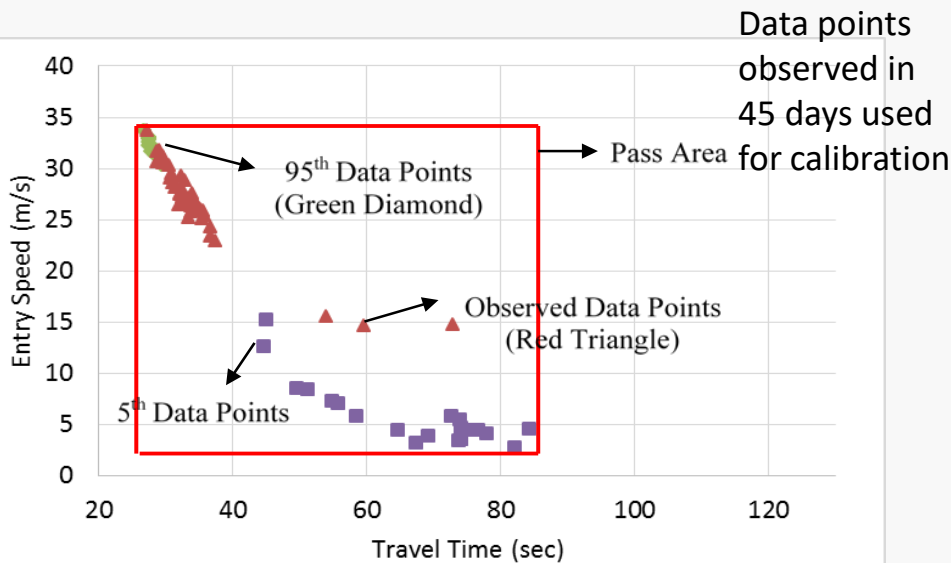
Pass calibration?

- If observed data is within the 90 percent boundary defined by the modeled data.

Optimized model parameters?

- Use a genetic algorithm to search the parameter sets that produce the minimum fitness values (FV).

$$FV = \frac{|V_{Field} - V_{Simulation}|}{V_{Field}}$$



(b) Pass Area Computed from Optimized Parameter Set

Default parameters: $FV_{travel\ time} = 0.47$ and

$FV_{entry\ speed} = 0.36$

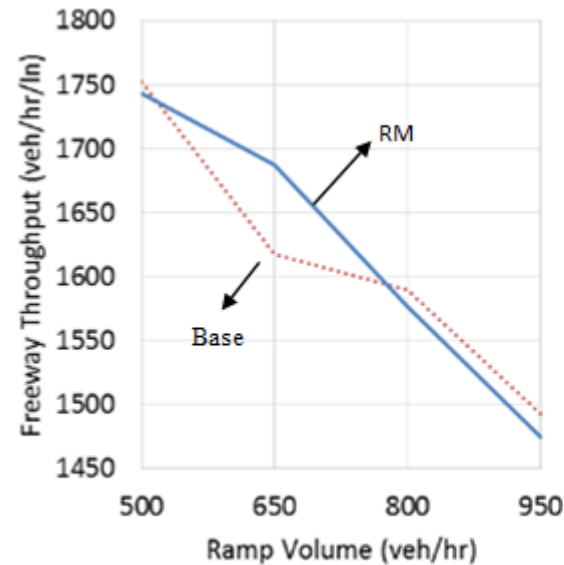
Optimized parameters: $FV_{travel\ time} = 0.29$ and

$FV_{entry\ speed} = 0.25$

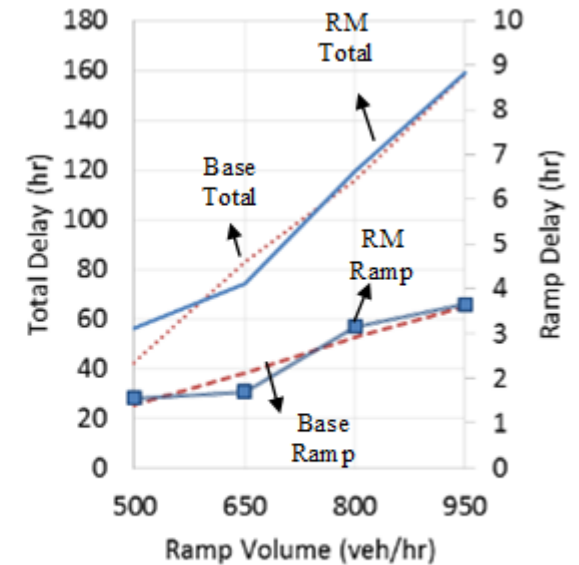
• Base Case vs. RM Case

A new set of observed data is adopted for validation.

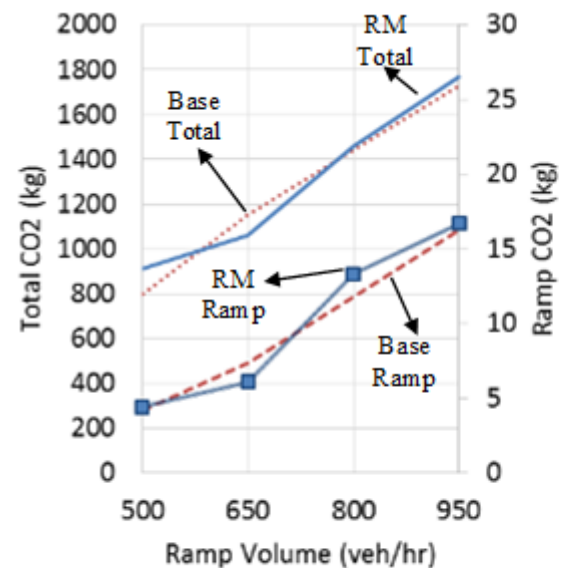
- Overall traffic operation and emission improved when the ramp volume is around 650 vehicles per hour.
- For the rest ramp demand, the performance of the RM case is not better than the base case.



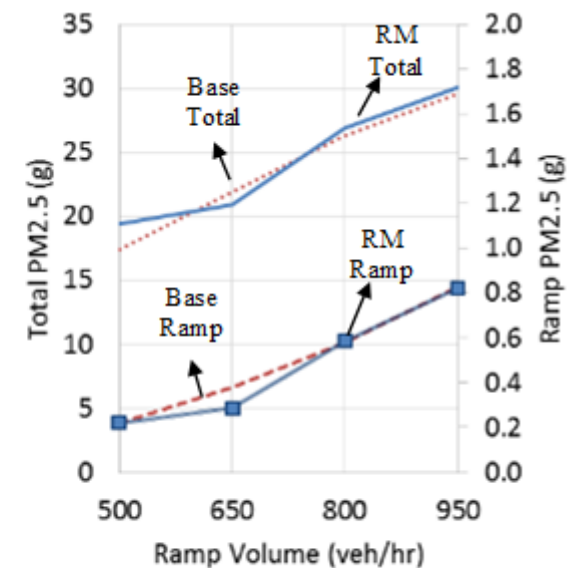
(a) Freeway Throughput



(b) Delay

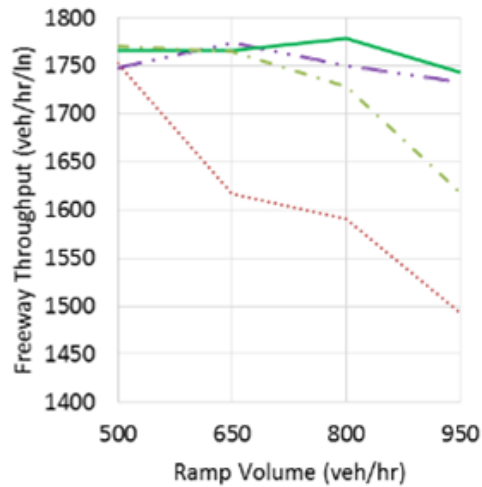


(c) CO₂ Emission

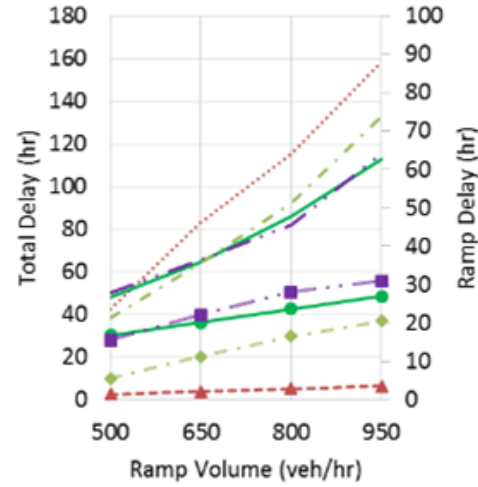


(d) PM_{2.5} Emission

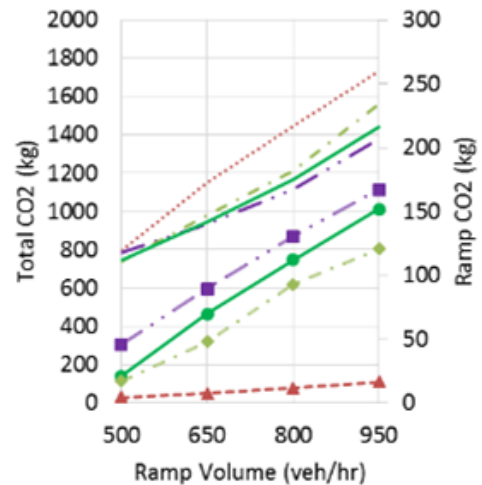
• V2I Case



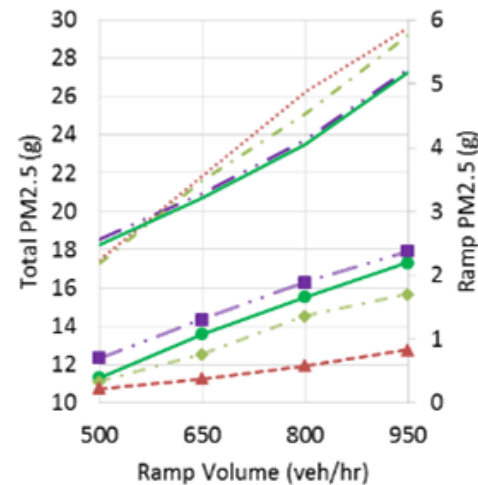
(a) Freeway Throughput



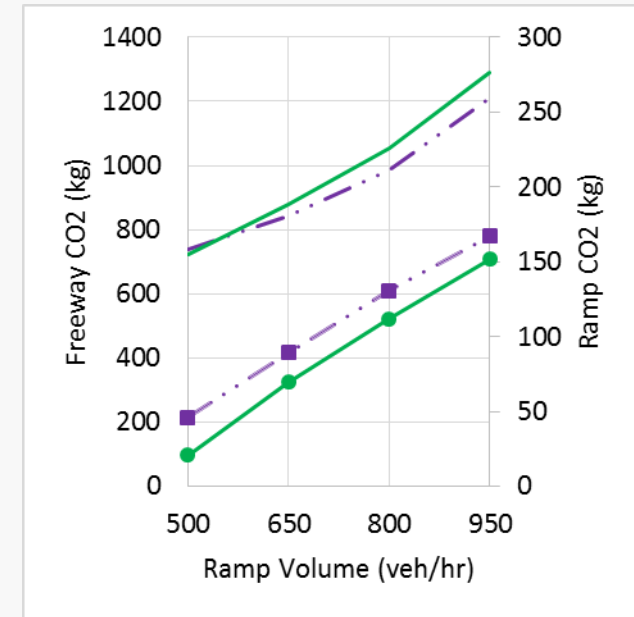
(b) Delay



(c) CO₂ Emission



(d) PM_{2.5} Emission



- In the V2I case, the performance is not greatly improved.

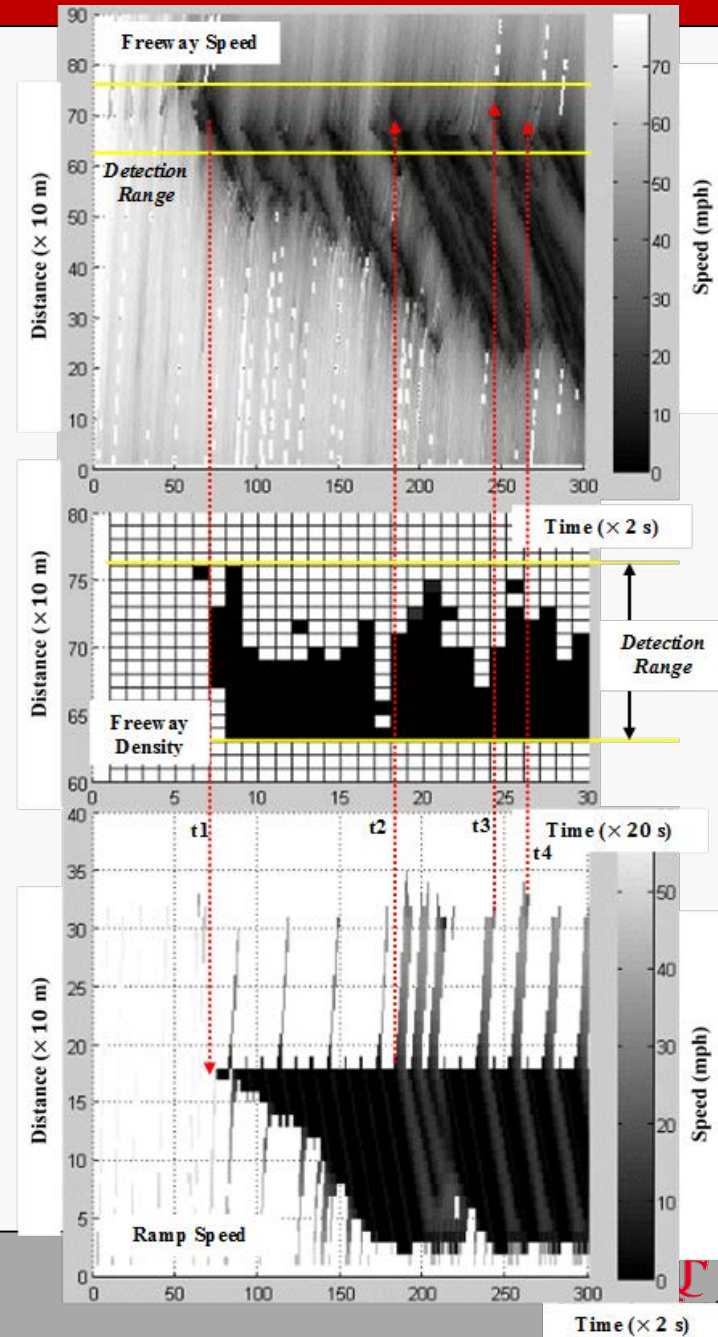
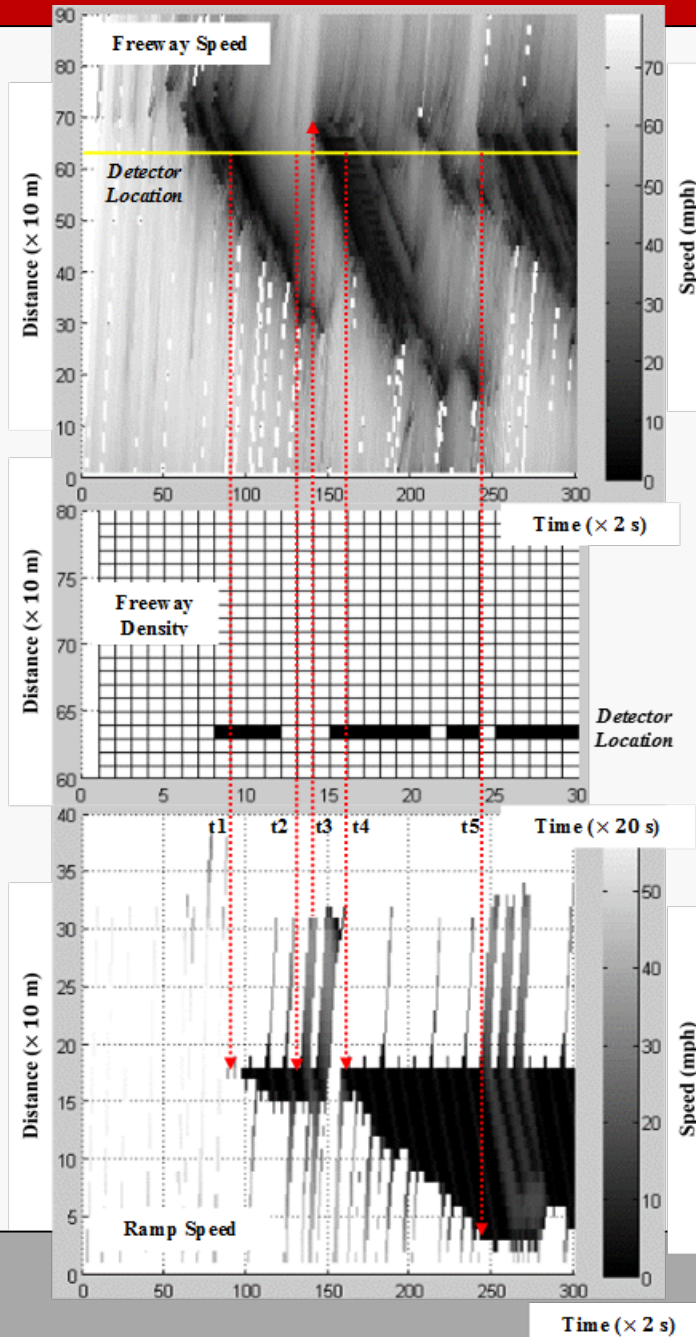
- Comparing freeway and ramp performance separately.
- V2I improves freeway performance.
- The freeway improvement is neutralized by worse ramp performance.

..... Base — RM_Up - - - RM_Middle - - - V2I

Lines with markers represent ramp results.

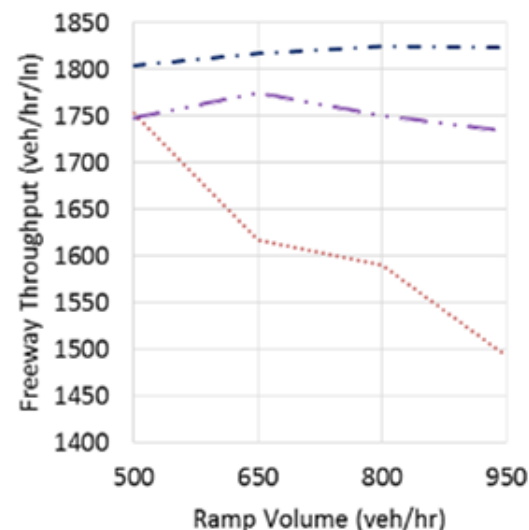
• V2I Case

- In the V2I case, the traffic over the entire merging area is detected.
- The ramp signal is activated once congestion first emerges.
- Ramp traffic is strictly controlled.
- Ramp storage space is soon used up.
- Release of the queued ramp vehicles causes freeway traffic breakdown.
- Above cycle occurs more frequently in the V2I case → the cost of ramp vehicles is increased.

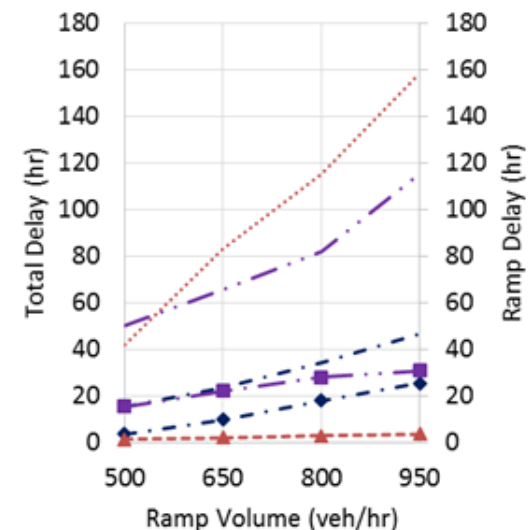


• V2I + V2V Case

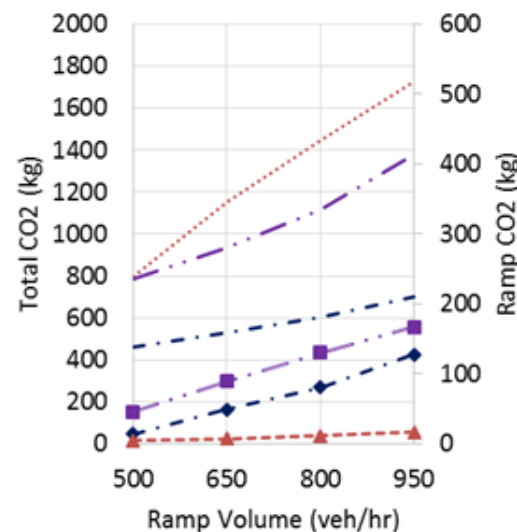
- In V2I+V2V case, the freeway throughput is increased and the high throughput is maintained even at high ramp volume.
- The total delay, total CO₂ and PM_{2.5} emission in the V2I+V2V case decrease by more than 50%, comparing to the base case.
- The ramp performance in the V2I+V2V case is improved in comparison to the CV case, suggesting the negative impact of the ramp flow control is reduced once the CV affects the ramp drivers' behavior.



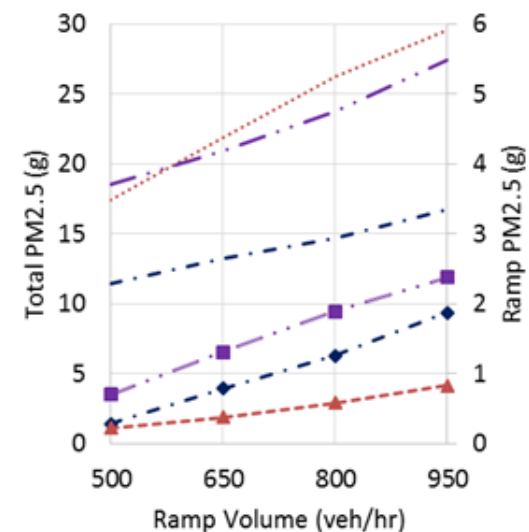
(a) Freeway Throughput



(b) Delay



(c) CO₂ Emission



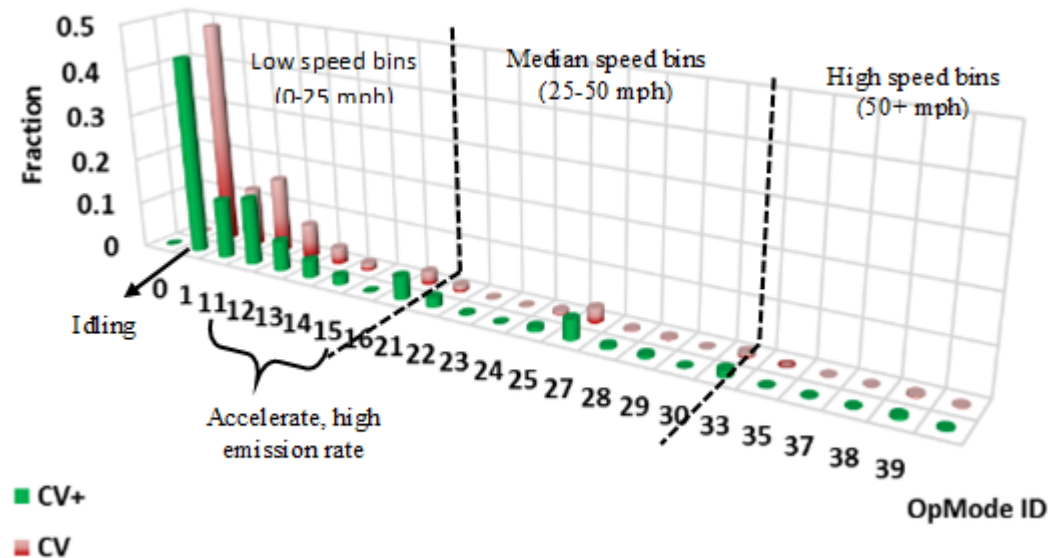
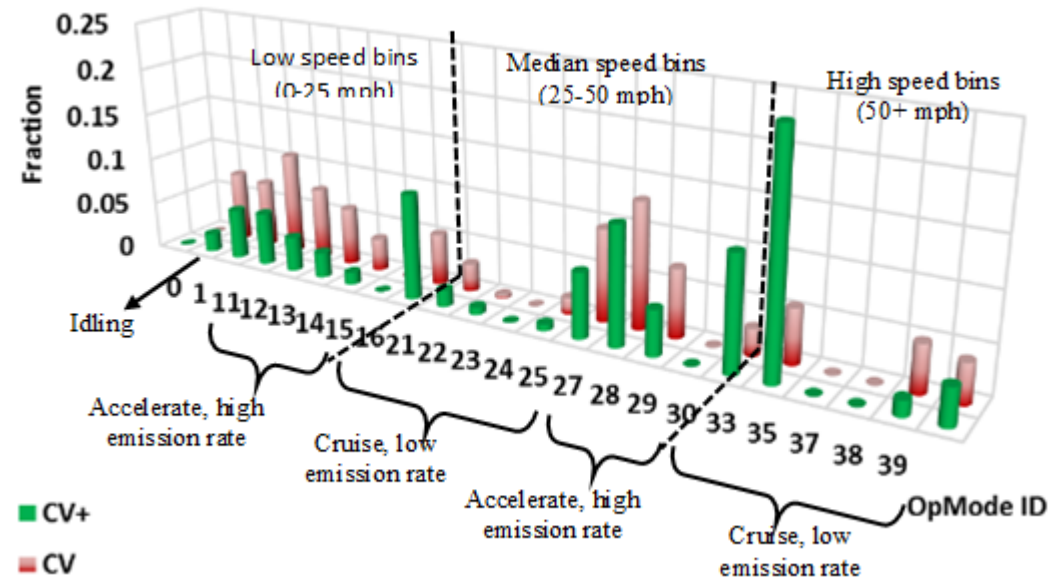
(d) PM_{2.5} Emission

..... Base -.- V2I - - - V2I+V2V

... with markers represent ramp results.

• V2I + V2V Case

- Vehicle emission rate is the highest when it is idling.
- Emission rate is also high when vehicles accelerate to higher speed.
- The best fuel efficiency and lowest emission rate is achieved when the vehicle is cruising at high speed.
- The fraction of high speed cruising bins (e.g., bin 33) is much greater in the V2I+V2V case, indicating that the majority of observed freeway vehicles travel in a consistent high speed (i.e., free flow speed).
- The low speed bins of the V2I+V2V case are substantially less.
- The fraction of the idling bin in the V2I+V2V case is about one fourths of the fraction in the CV case.
- Ramp vehicles in the V2I+V2V case almost have identical operation status as vehicles in the V2I case.



- **Case study summary**

- The performance of the ramp metering control is greatly affected by the location of its traffic sensors.
- The ramp meters with the fixed traffic sensors are not able to promptly capture the traffic congestion conditions all the time.
- In the V2I case, the ramp meter controller makes sensitive response, which makes the ramp queues grow fast.
- In the V2I+V2V case, the traffic operation and emission performance of the entire traffic flow is greatly improved. This is because the reduced response time causes faster dissipation of traffic congestions and interrupts the growth of the heavy congested areas.

- Vrtic, M., Fröhlich, P., Schüssler, N., Axhausen, K.W., Lohse, D., Schiller, C., Teichert, H. (2007). *“Two-dimensionally constrained disaggregate trip generation, distribution and mode choice model: Theory and application for a Swiss national model.”* Transportation Research Part A: Policy and Practice, 41(9): 857-873.
- Transportation Research Board (TRB). (2014). *“Activity-based travel demand models: a primer.”*
- Ben-Akiva, M., and Lerman, R.M. (1985). *“Discrete choice analysis.”* The MIT Press, Cambridge, Massachusetts-London, England.
- Bowman, J.L. and Ben-Akiva, M.E. (2000). *“Activity-based disaggregate travel demand model system with activity schedules.”* Transportation Research Part A 35: 1-28.
- Horowitz, J. (1980) *“A utility maximizing model of the demand for multi-destination non-work travel.”* Transportation Research Part B: Methodological, 14(4): 369-386.
- Goulias, K.G., Pendyala, R.M., and Kitamura, R. (1990). *“Practical method for the estimation of trip generation and trip chaining.”* Transportation Research Record, 1285: 47-56.
- Goulias, K.G., and Kitamura, R. (1989) *“Recursive model system for trip generation and trip chaining.”* Transportation Research Record 1236: 59-66.
- Zhou, Z, Chen, A., and Wong, S.C. (2009). *“Alternative formulations of a combined trip generation, trip distribution, modal split, and trip assignment model.”* European Journal of Operational Research, Volume 198, Issue 1, 1 October 2009, Pages 129-138.
- Ortuzar, J.D., and Willumsen, L.G. (2001). *“Modeling Transport.”* Wiley, New York.
- McNally, M.G. (2000). *“Activity-based models.”* University of California, Irvine.
- Cambridge Systematics, Inc. (2010). *“Travel model validation and reasonableness checking manual”.* Cambridge, Massachusetts.

- Bhatta, P.B., and Larsen, I.O. (2011). *“Are intrazonal trips ignorable?”* Transport Policy, 18(1), 13-22.
- Giaimo, G. (2002) *“Travel demand forecasting – manual 1, traffic assignment procedures.”* Ohio Department of Transportation. Columbus, Ohio.
- Kim, J.T. (1983). *“A combined land use-transportation model when zonal travel demand is endogenously determined.”* Transportation Research Part B: Methodological, 17(6): 449-462.
- Cambridge Systematics, Inc. (2010). *“Travel model validation and reasonableness checking manual”*. Cambridge, Massachusetts.
- Giaimo, G. (2002). *“Travel demand forecasting – manual 1, traffic assignment procedures.”* Ohio Department of Transportation. Columbus, Ohio.
- Coley, N. (2012). *“Spotlight on Benefit-Cost Analysis”*. Public Roads, 75(5).
- Minnesota Department of Transportation (MnDOT), <http://www.dot.state.mn.us/planning/program/benefitcost.html>.
- Charles River Associates. (1982). *“Allocation of federal transit operating subsidies to riders by income group.”* U.S. Department of Transportation, Washington, D.C.
- Texas A&M Transportation Institute.(2012). *“2011 Urban mobility report”*.
- United States Government (USG). (2010). *“Technical support document: social cost of carbon for regulatory impact analysis under executive order 12866”*.
- Transportation research board (TRB), 2000. *“A guidebook for performance-based transportation planning.”* National Academy Press, Washington, D.C.
- FHWA, 2014.Travel Reliability.
- Parsons, R.G. (2003). *“The travel cost model.”* Nonmarket Valuation: 269-329. http://works.bepress.com/george_parsons/18