Micro-simulation of Bicycles for Planning and Design

David Gerstle (presenting)
Daniel Morgan
Qi Yang

Caliper Corporation

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Executive Summary

- **Wide-area micro-simulation is an important planning and design tool for visualization and analysis**
- **TransModeler, specifically, micro-simulates bicycles rigorously, integrating state-of-the-art research on bicycles' traffic dynamics**

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Outline

- Outputs of micro-simulation
- Role of micro-simulation
- TransModeler for micro-simulation
- TransModeler for bicycle micro-simulation

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  - Analysis
  - Visualization
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Micro-Simulation for Analysis

		Bicycle Mode Share	
		0%	3%
Bicycle Infrastructure	No Build		
	Build		

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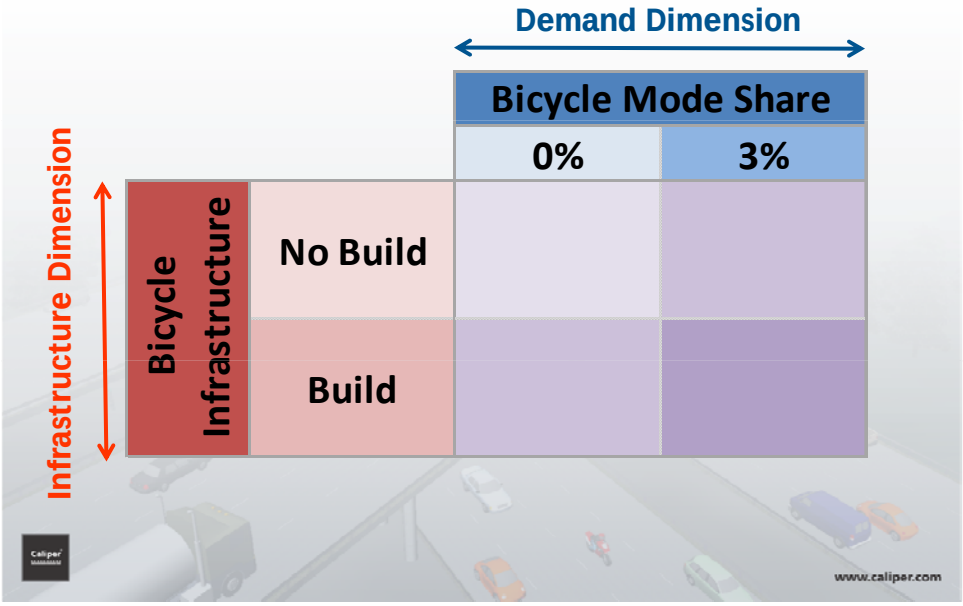
Micro-Simulation for Analysis



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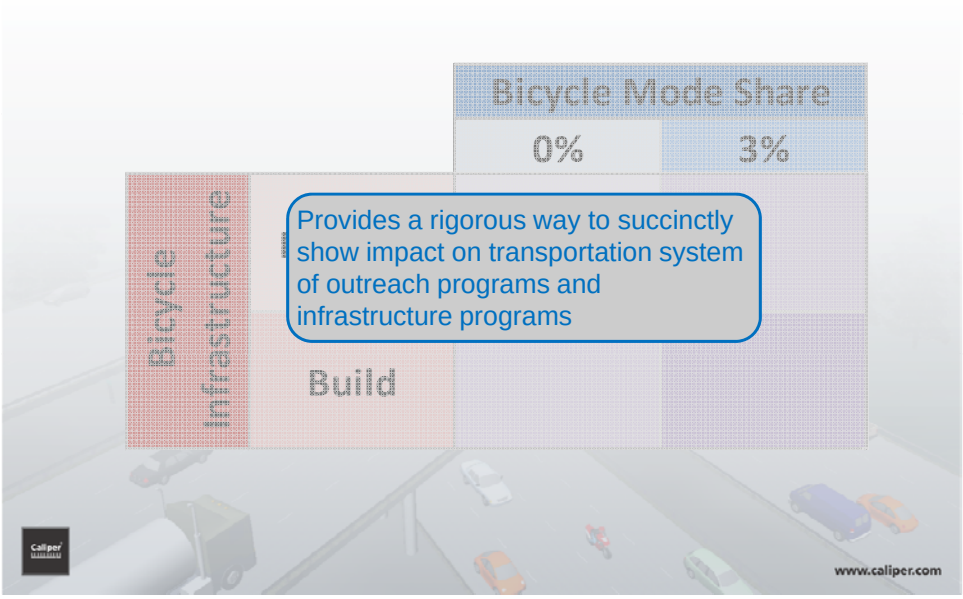

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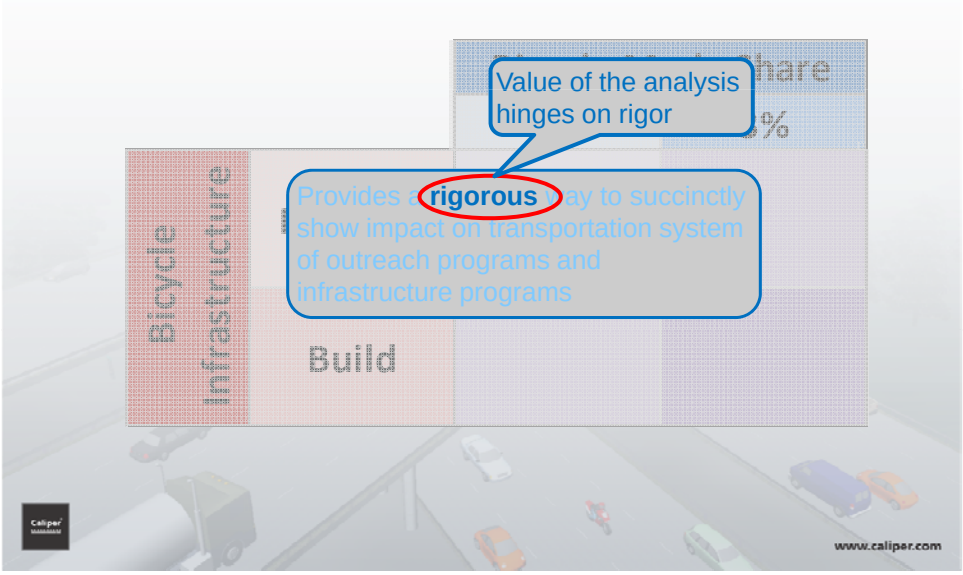

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  - Transportation Modeling: Travel Demand vs. Micro
  - Micro-simulation as a tool for analysts
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Transportation Modeling

- Travel Demand Modeling

vs.

- Micro-simulation

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Transportation Modeling

- **Travel Demand Modeling**

vs.

Why do micro-simulation?

- **Micro-simulation**

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Transportation Modeling

- **Travel Demand Modeling**

vs

- Used to forecast traffic volumes
- Used for large areas, such as a region or state
- Traffic on a road is treated in aggregate: travel times are a function of traffic volume
- Demand is generally time-invariant

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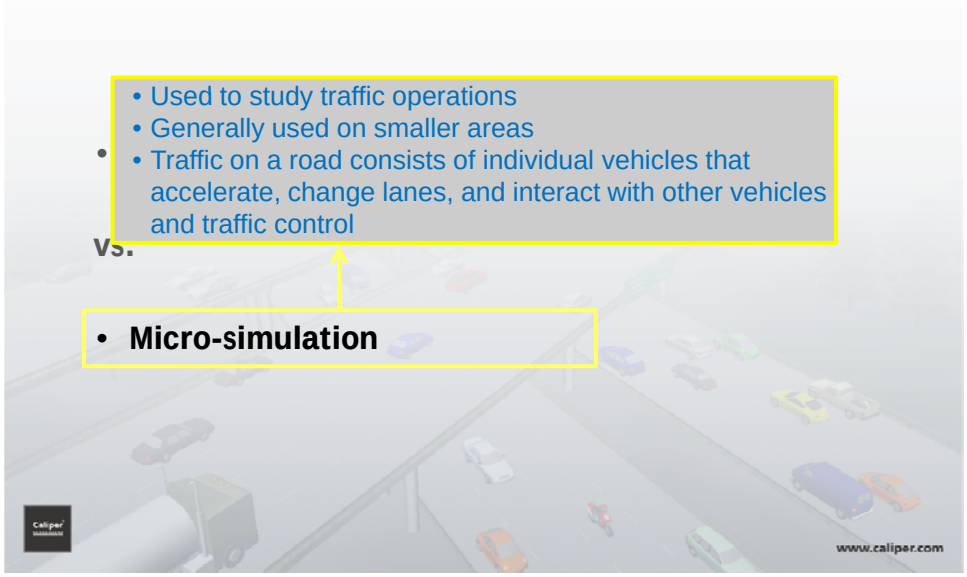
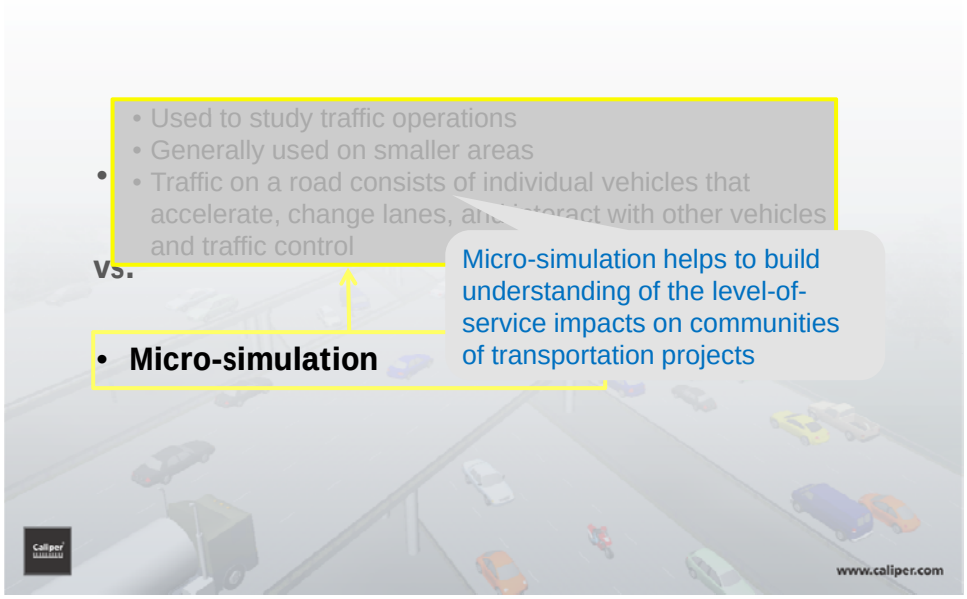
Transportation Modeling



Transportation Modeling



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Micro-Simulation Modeling

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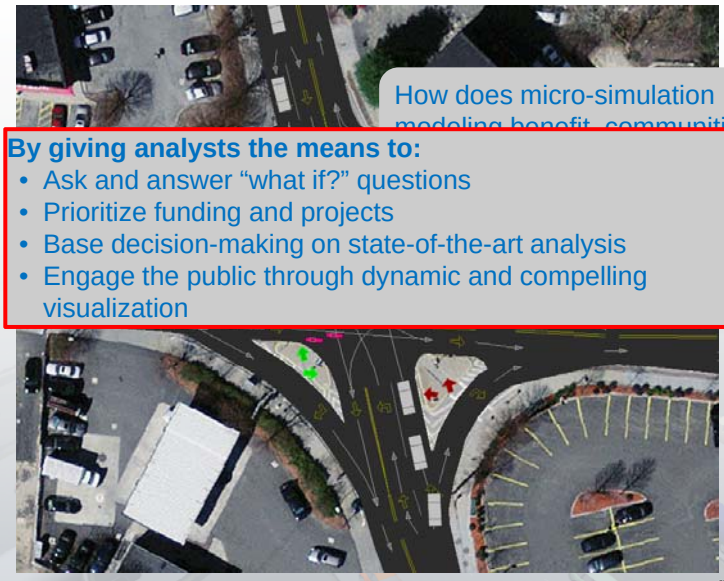

How does micro-simulation modeling benefit communities

By giving analysts the means to:

- Ask and answer “what if?” questions
- Prioritize funding and projects
- Base decision-making on state-of-the-art analysis
- Engage the public through dynamic and compelling visualization

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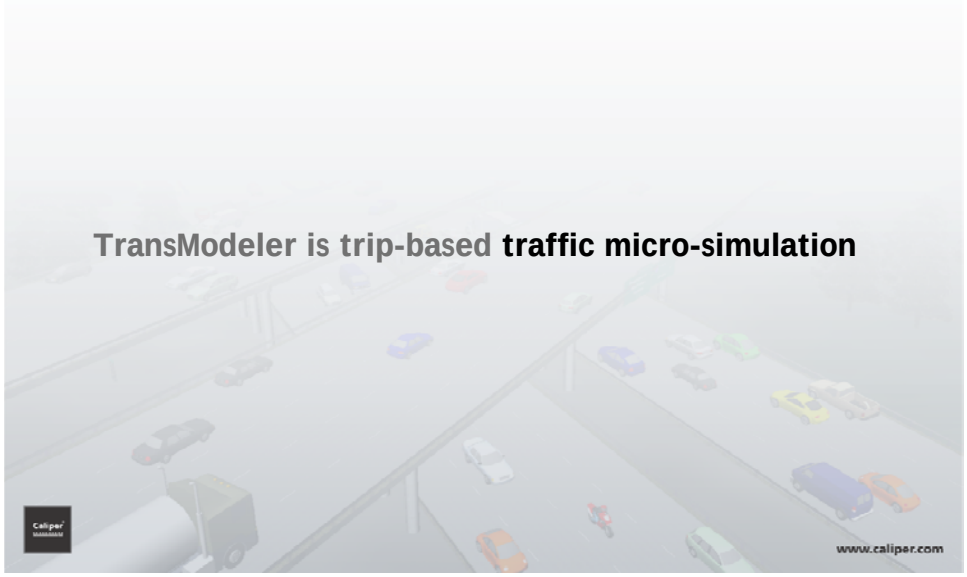
TransModeler

TransModeler is

TransModeler

TransModeler is **trip-based**

TransModeler



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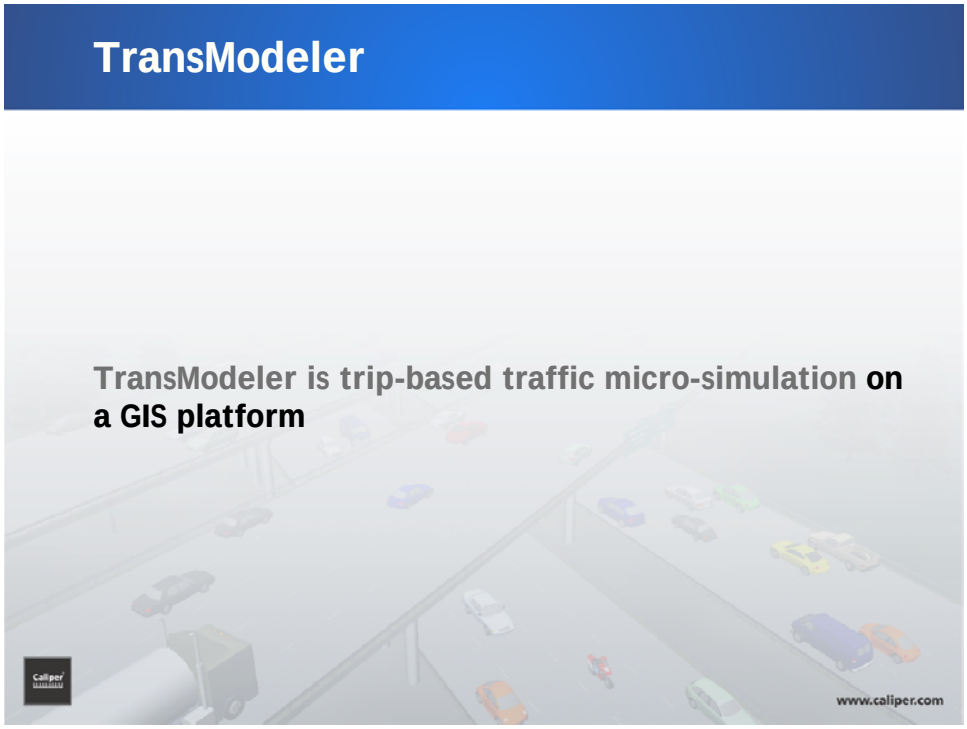

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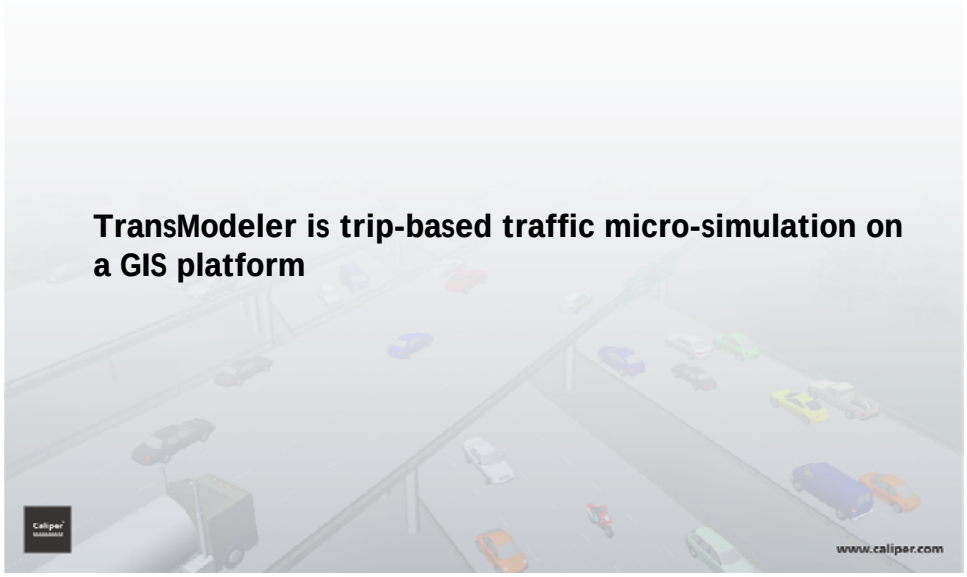

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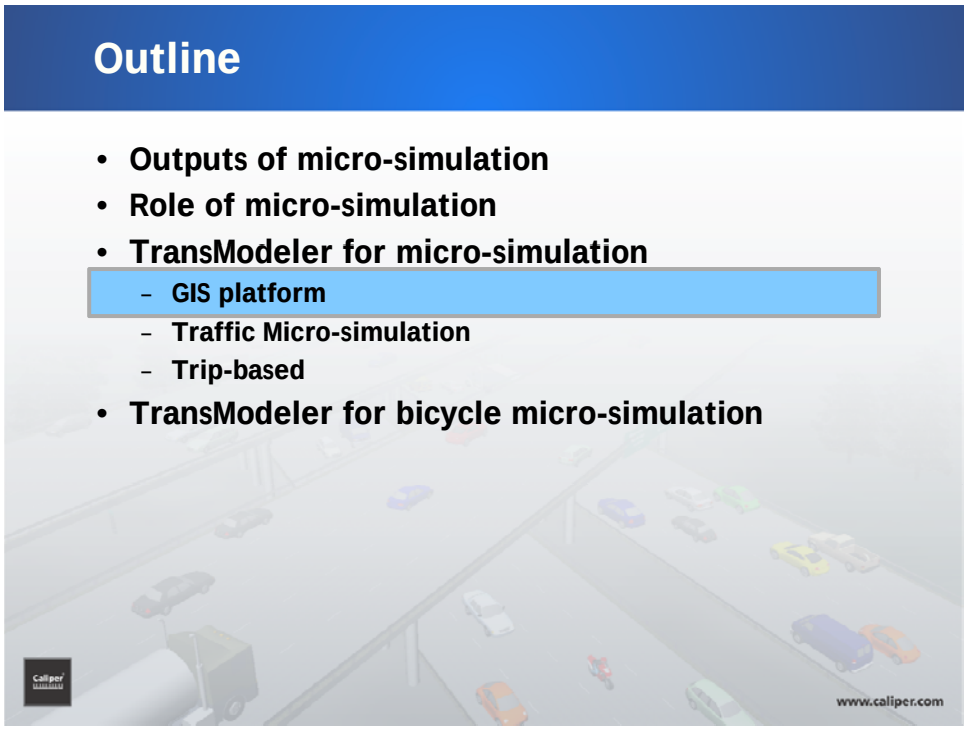
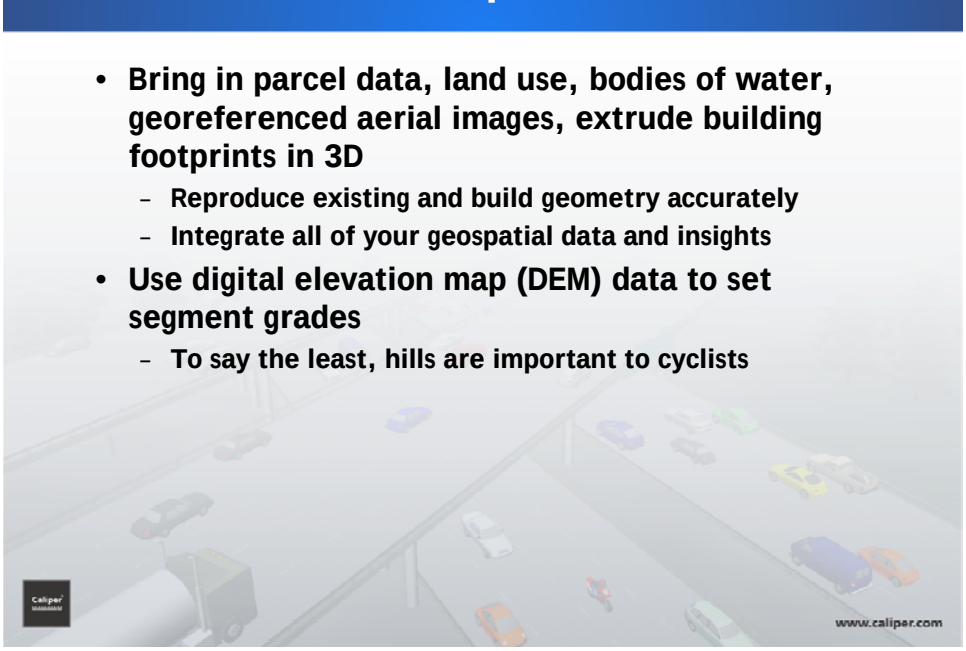


TransModeler's GIS platform

- **Bring in parcel data, land use, bodies of water, georeferenced aerial images, extrude building footprints in 3D**
  - **Reproduce existing and build geometry accurately**
  - **Integrate all of your geospatial data and insights**
- **Use digital elevation map (DEM) data to set segment grades**
  - **To say the least, hills are important to cyclists**



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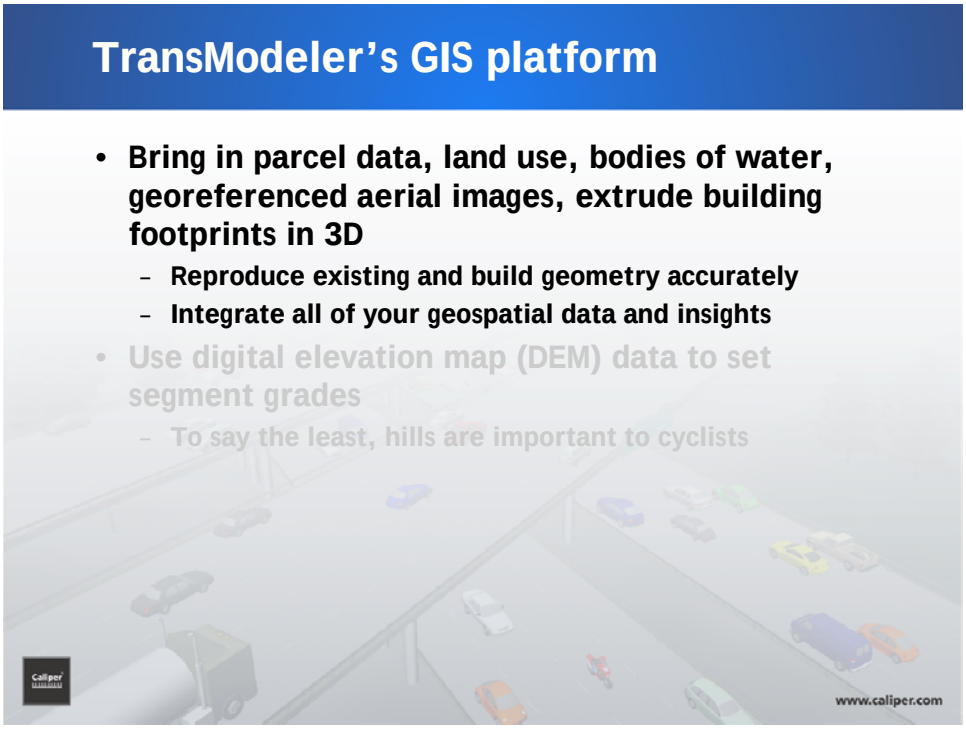

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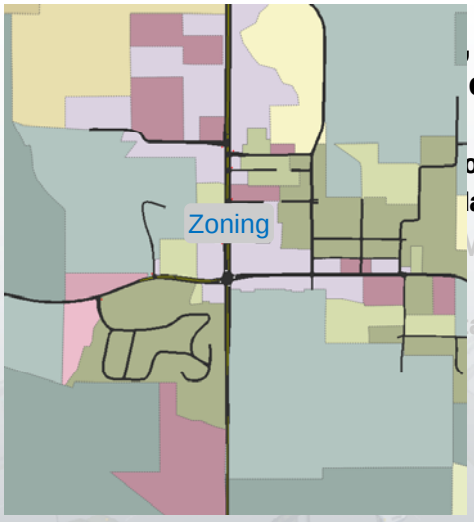

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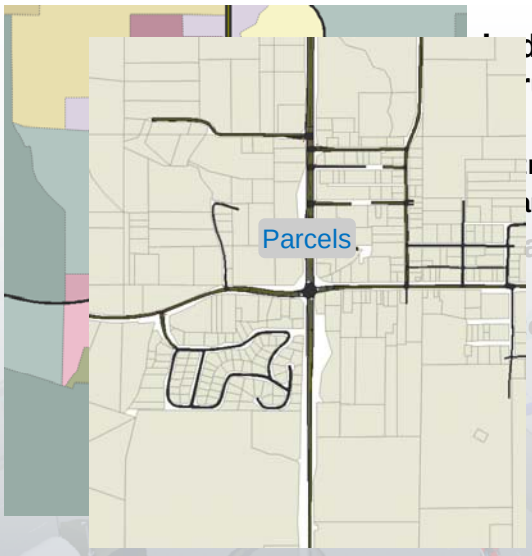

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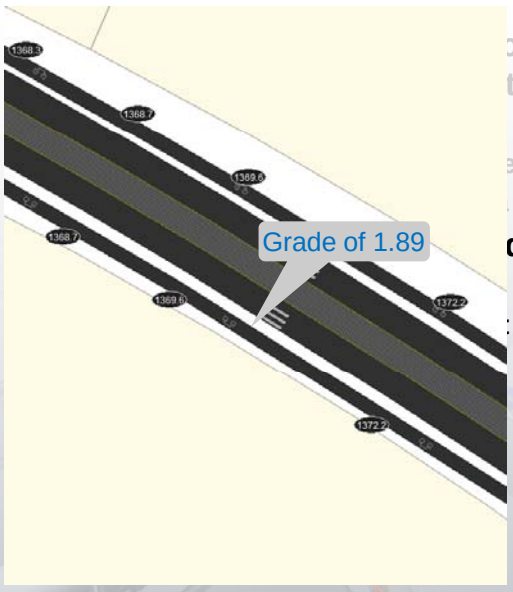

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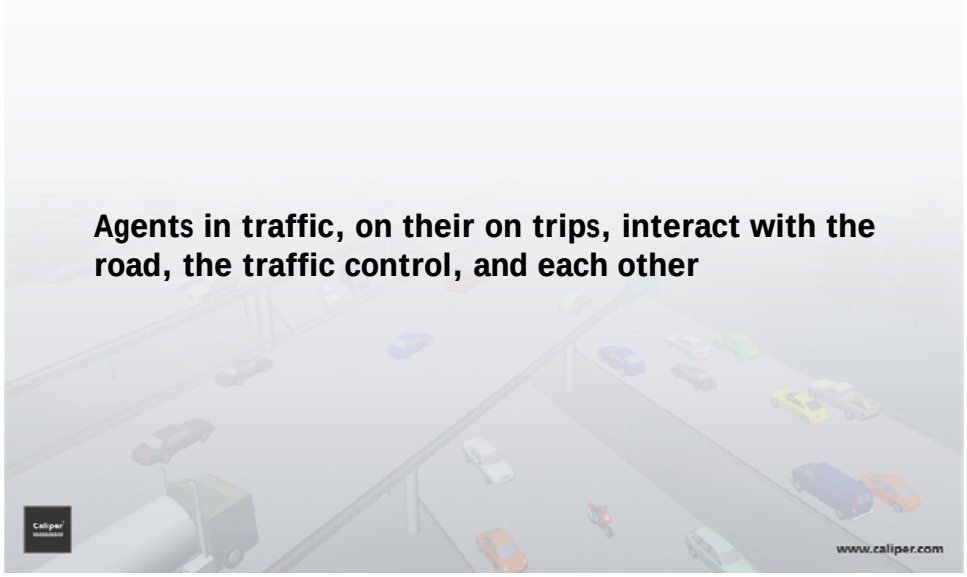
TransModeler's Traffic Micro-simulation



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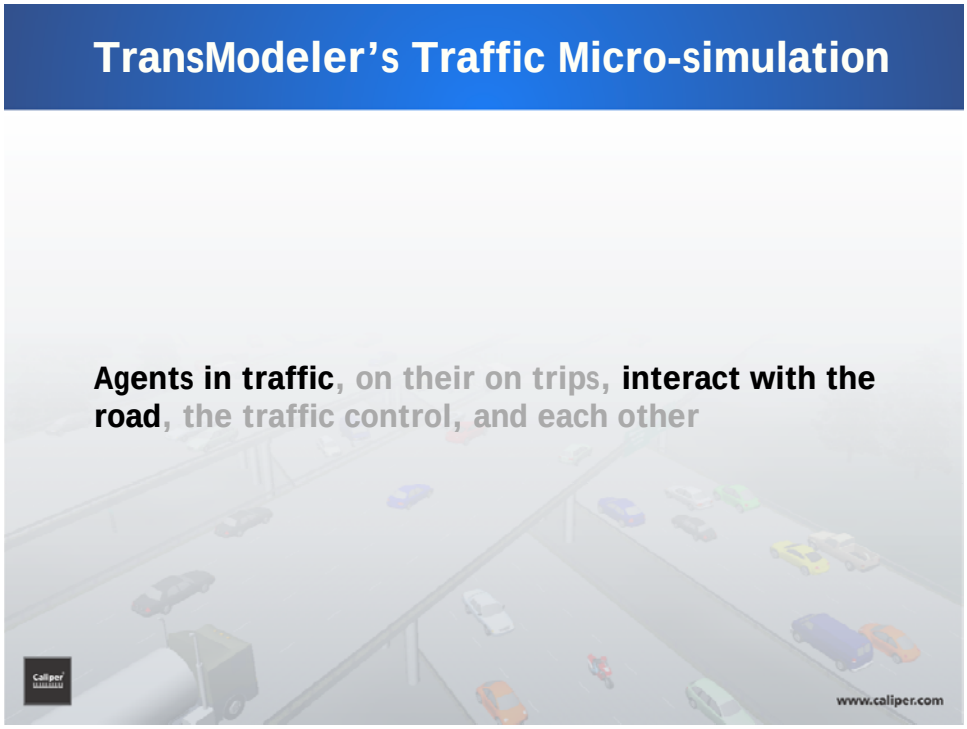

TransModeler's Traffic Micro-simulation

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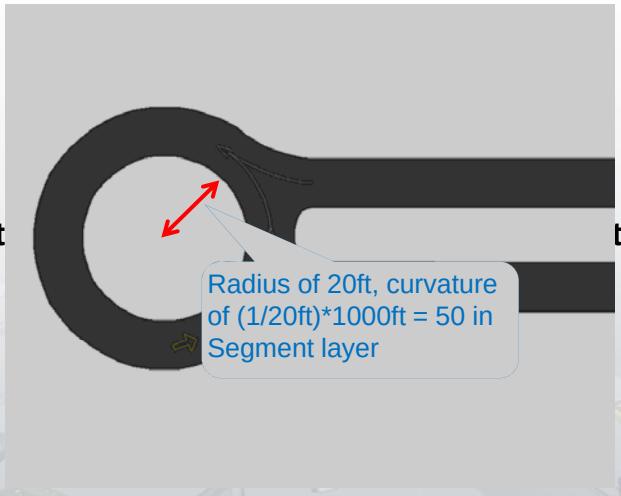

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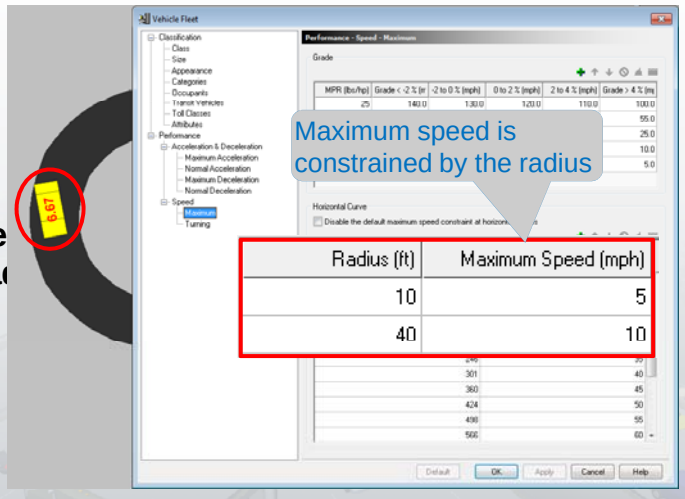

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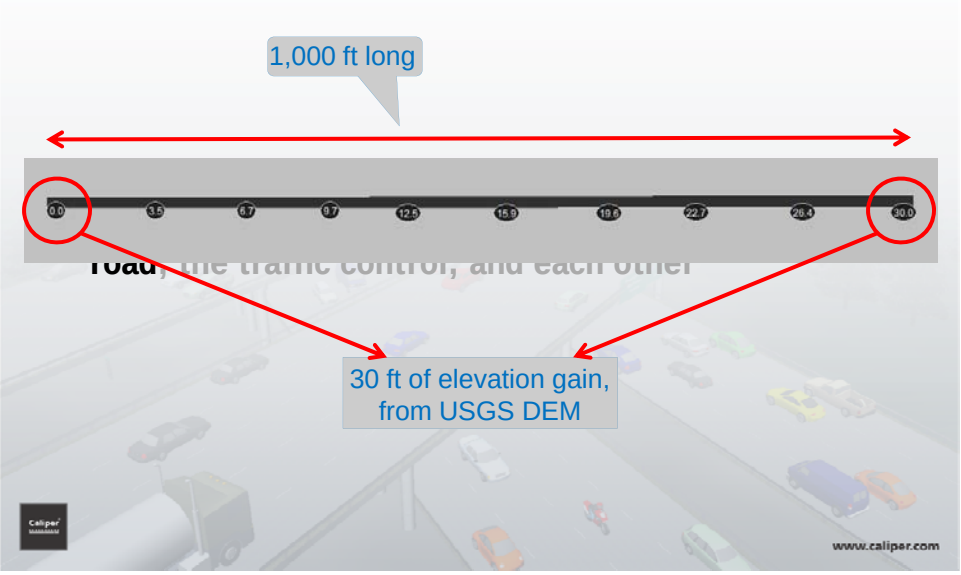

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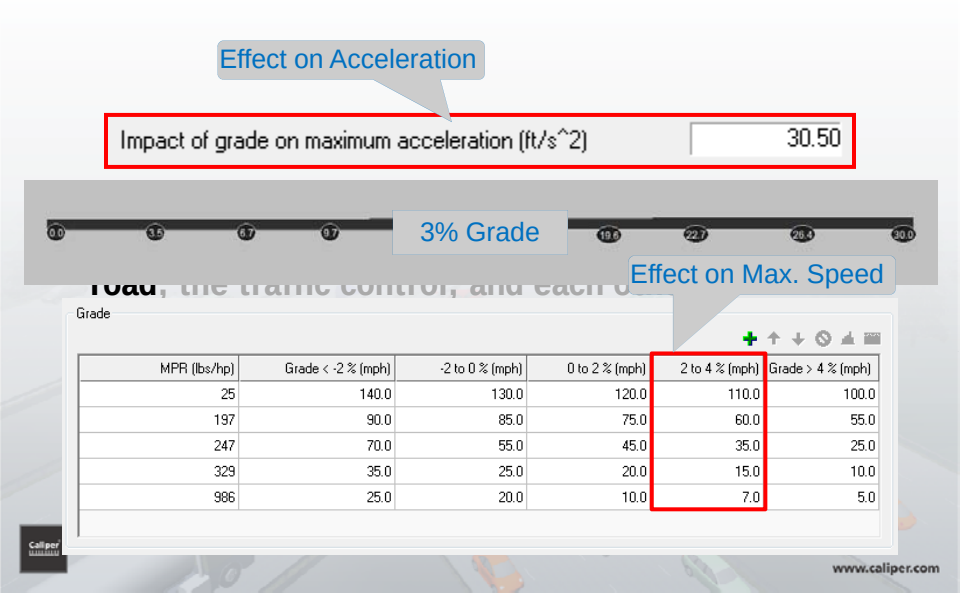

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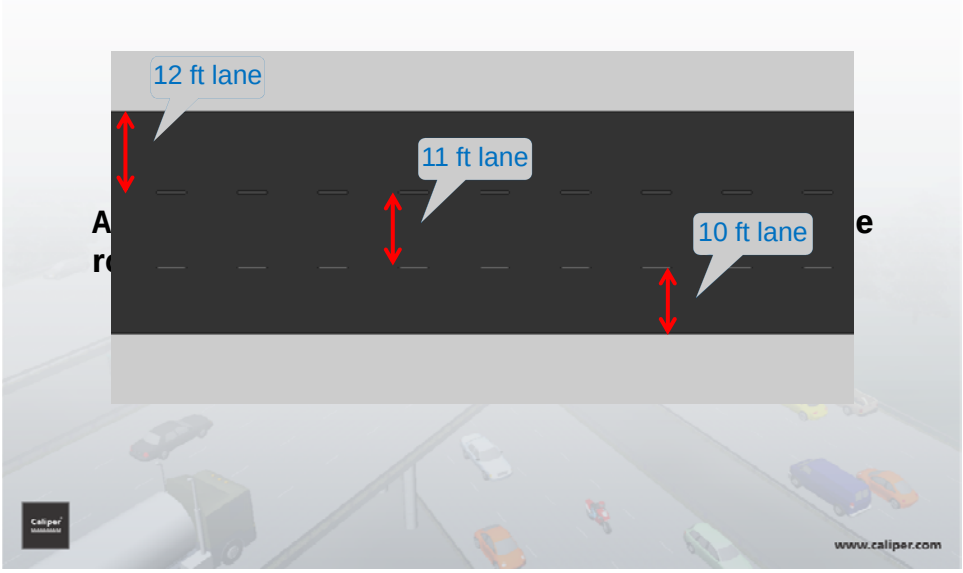

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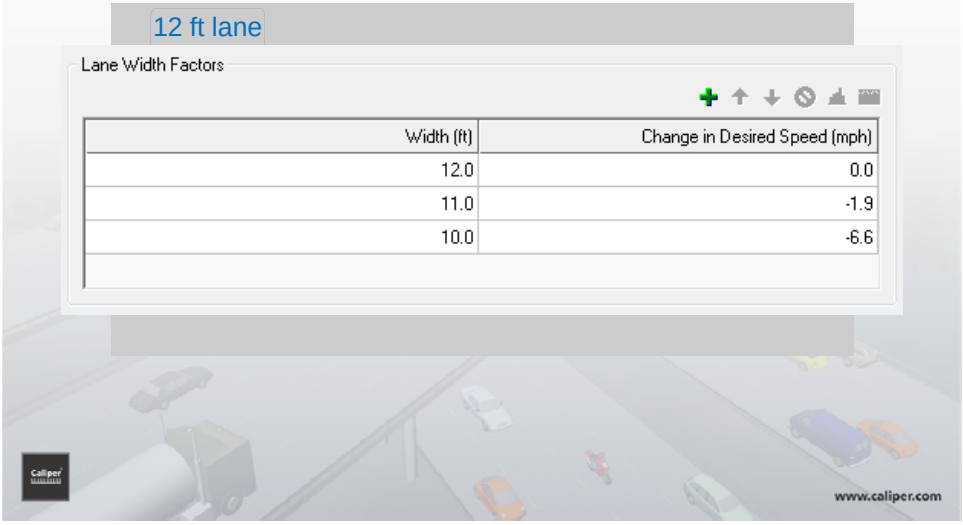

TransModeler's Traffic Micro-simulation

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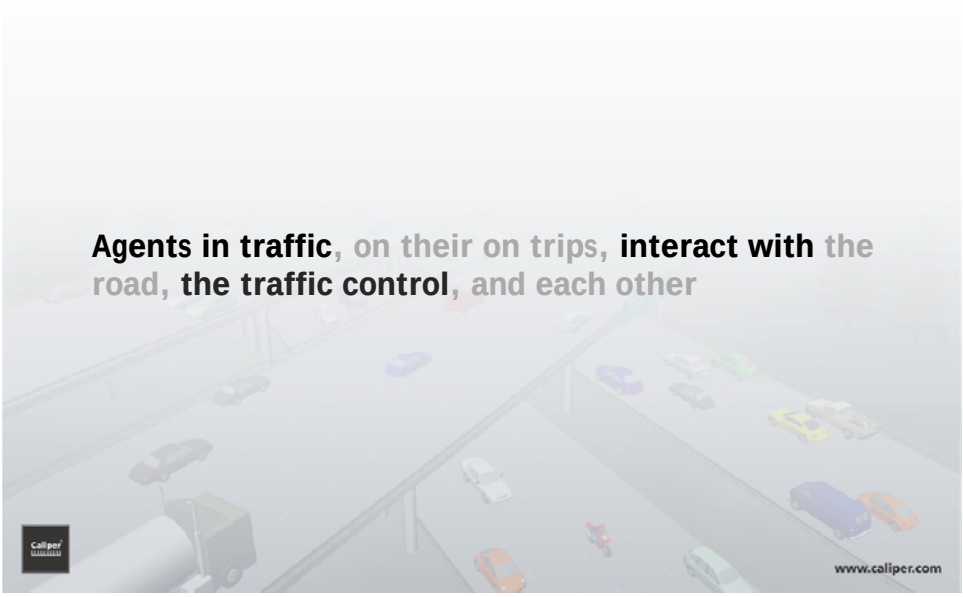
Agents in traffic, on their on trips, **interact with** the road, **the traffic control**, and each other



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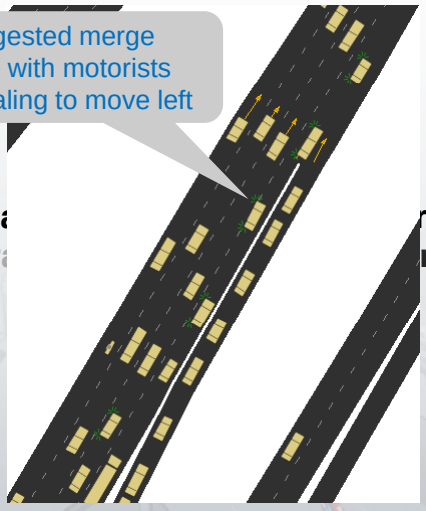

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TransModeler's Trip-Based Demand

- Every vehicle has an origin, destination, departure time, and attributes, such as vehicle type and proclivity for speeding, which are all drawn from probability distributions
- Vehicles route themselves on their dynamic, stochastic shortest path

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TransModeler's Trip-Based Demand

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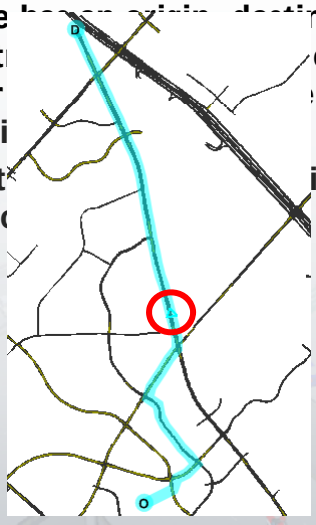

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Finally, some bicycles!

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Bicycles on the GIS Platform

- Bike lanes
- Configuring signal detector actuation

Bicycles on the GIS Platform

- **Bike lanes**
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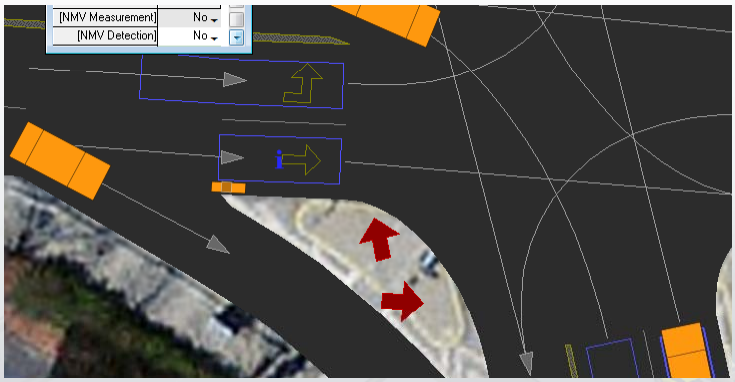

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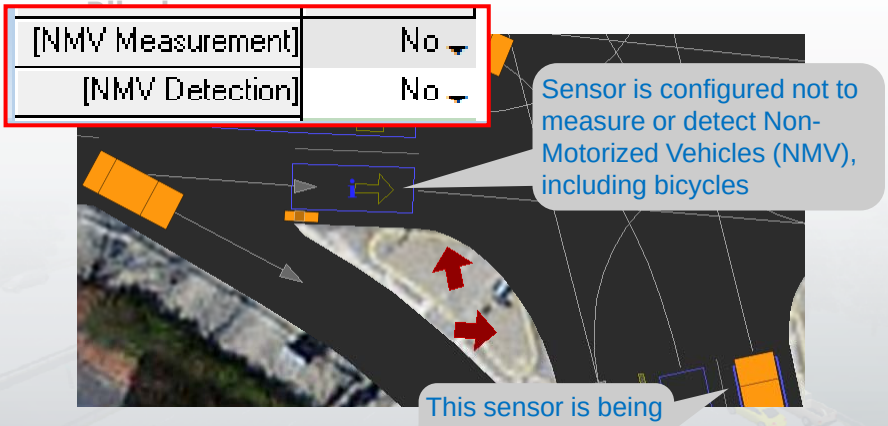

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This is the big stuff, the complicated stuff: how vehicles, motorized and not, interact with each other

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Bicycle Traffic Micro-Simulation

- **Lateral Movement Within a Lane**
- **Stopped Gaps**
- **Desired Speed**
- **Following Distance & Acceleration**
- **Lane Changing Gap Acceptance**
- **Critical Distance**

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Bicycle Traffic Micro-Simulation

- **Lateral Movement Within a Lane**
- Stopped Gaps
- D
- F
- L
- C

$$w_i = L + \frac{1 - e^{-\beta v_i}}{1 + e^{-\beta v_i}} (U - L)$$

Bicycles and Motorcycles - Lateral Movement

Vehicles Allowed to Move Laterally within Lanes

Class	Outside Lane	Lower	Upper	Beta	Gamma
M	☐	0.50	4.00	0.2500	10.0
BK	☑	0.30	2.50	0.2000	10.0

Distance to start shifting when passing in the same lane (ft)	85.0
Maximum search distance for faster vehicles behind (ft)	98.4
Faster vehicles threshold (%)	10.0

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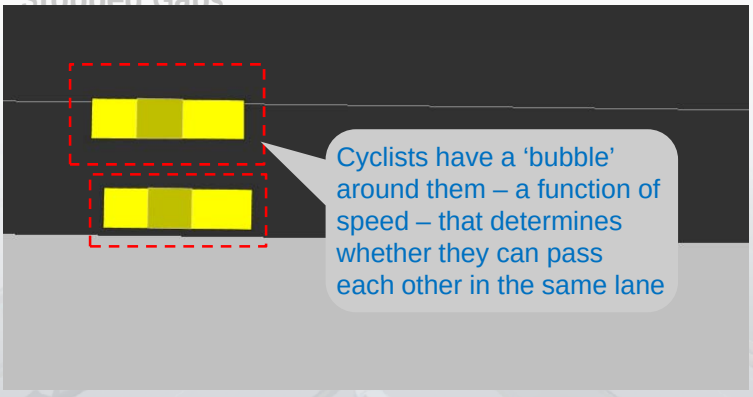

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- Critical Distance
- Grade
- Lane Choice

Bicycle Traffic Micro-Simulation

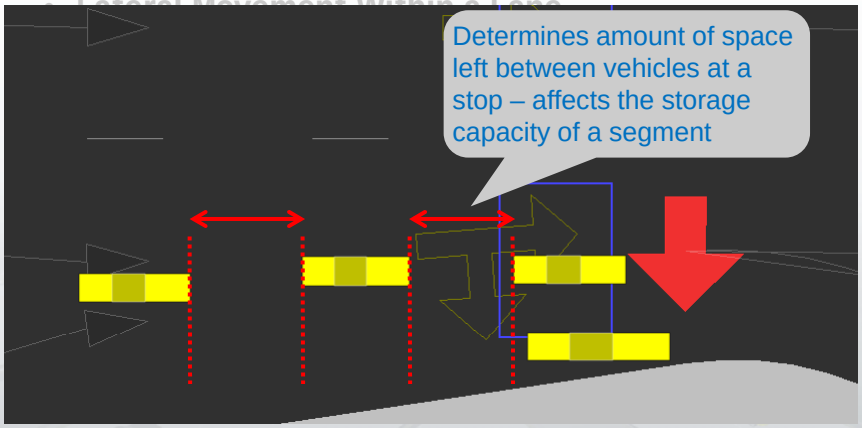
- Lateral Movement Within a Lane
- **Stopped Gaps**

Gaps between Stopped Vehicles

Minimum (ft): 1.0

Scenario	Mean (ft)	Standard deviation (ft)
Non-motorized vehicle in front	4.0	2.0
Motorized vehicle in front	6.0	2.0

Bicycle Traffic Micro-Simulation



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Bicycle Traffic Micro-Simulation

- Lateral Movement Within a Lane
- Stopped Gaps
- [illegible]

Bicycles and Motorcycles - Desired Speed

Distribution of Desired Speed for Non-motorized Vehicles (NMV)

Deviation from Maximum Speed (mph)	Driver Population (%)
-5.0	40.0
-3.0	30.0
-2.0	15.0
-1.0	10.0
0.0	5.0

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Bicycle Traffic Micro-Simulation

- Lateral Movement Wi
- Stopped Gaps
- [illegible]

Desired speed is generally defined as a deviation from the speed limit – bicycles operate in a different paradigm

Bicycles and Motorcycles - Desired

Distribution of Desired Speed for N

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Bicycle Traffic Micro-Simulation

Bicycles and Motorcycles - Forward Movement

Non-motorized Vehicles and Following Distance

Class	Lower (ft)	Upper (ft)	Beta	Gamma (%)
BK	0.65	25.00	0.5000	25.0

Maximum speed passing non-motorized vehicle in the same lane (mph) 25.0

Maximum speed passing non-motorized vehicle in the next lane (mph) 35.0

Distance Headway Thresholds and Variance of Acceleration

Percentage (%)	Distance (%)	Decelerating (f/s^2)	Cruising (f/s^2)	Accelerating (f/s^2)
30.0	5.0	-0.10	0.00	0.10
50.0	5.0	-0.10	0.00	0.10
20.0	5.0	-0.10	0.00	0.10

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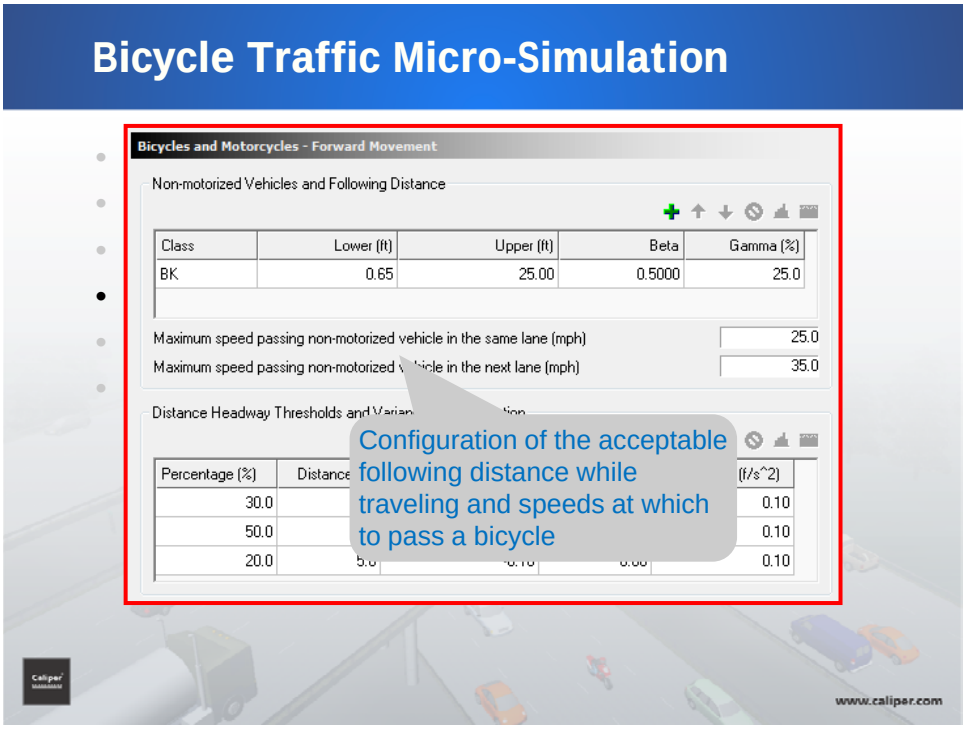

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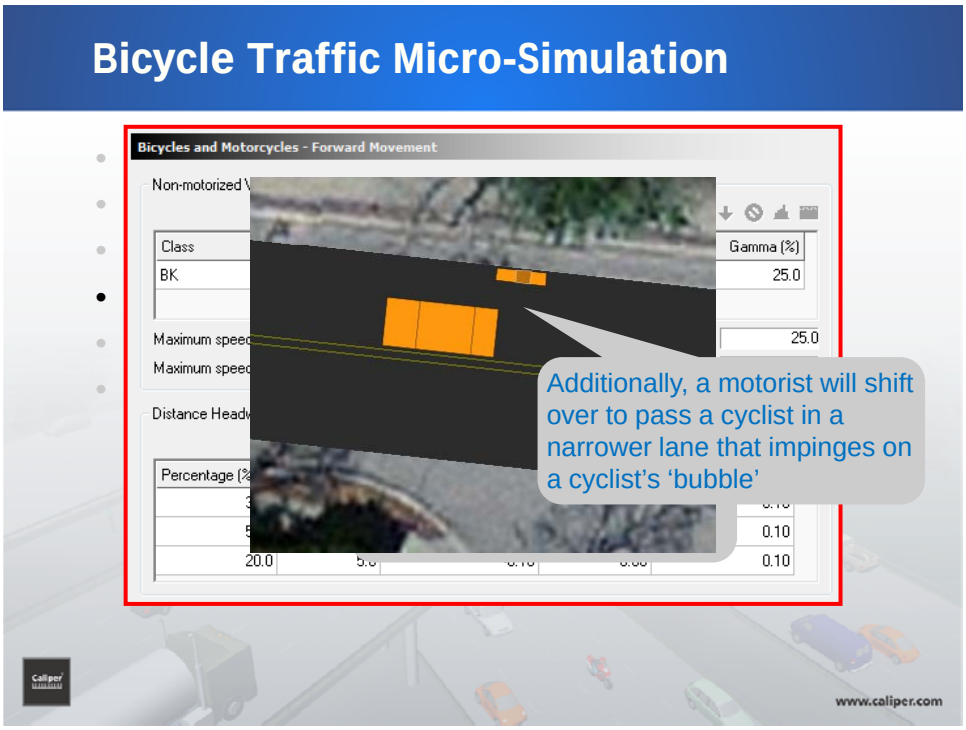

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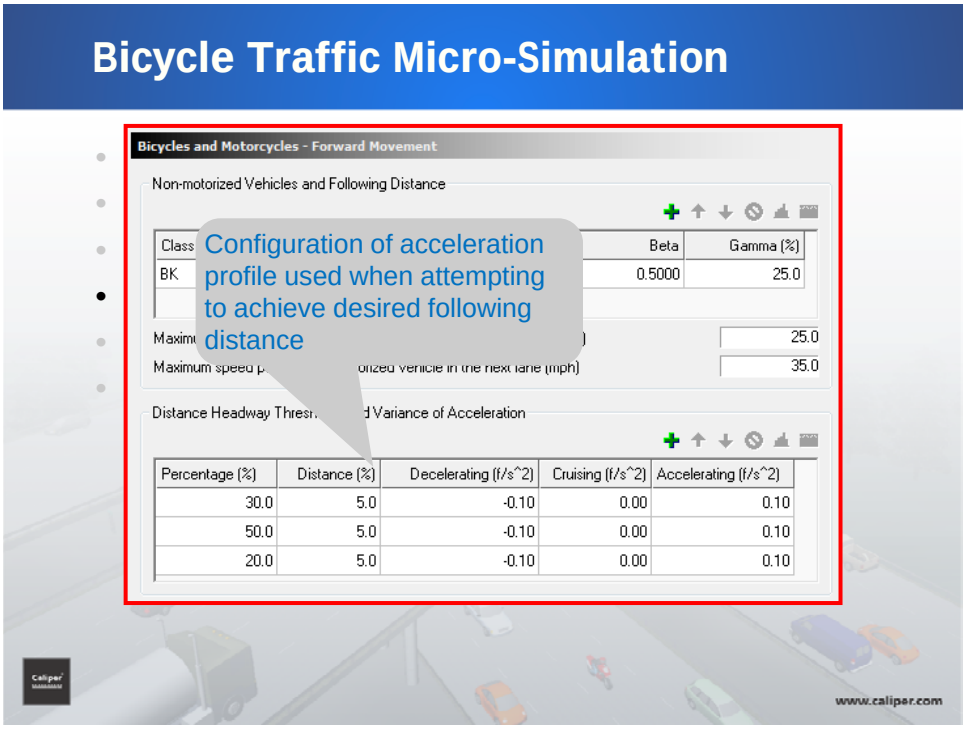

Bicycle Traffic Micro-Simulation

- Lateral Movement Within a Lane
- Stopped Gaps
- Desired Speed
- Following Distance & Acceleration
- **Lane Changing Gap Acceptance**
- Critical Distance

Bicycle Traffic Micro-Simulation

- Lateral Movement Within a Lane
- Stopped Gaps

Gap Acceptance Model

	NMV/Lead*	NMV/Lag*	Motorized/Lead	Motorized/Lag
Minimum (ft)	3.28	4.92	6.56	13.12
Follower slower (/fps)	0.061	0.046	0.046	0.030
Follower faster (/fps)	0.107	0.137	0.152	0.305
Follower speed (/fps)	0.076	0.091	0.152	0.305
Sigma (ft)	3.281	4.921	3.281	4.921

* NMV = Non-Motorized Vehicle

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Bicycle Traffic Micro-Simulation

- Lateral Movement Within a Lane
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Lane-changing takes into account the types, speeds, and locations of the vehicles in the neighboring lane

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Bicycle Traffic Micro-Simulation

- Lateral Movement Within a Lane
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Bicycle Traffic Micro-Simulation

- Lateral Movement Within a Lane

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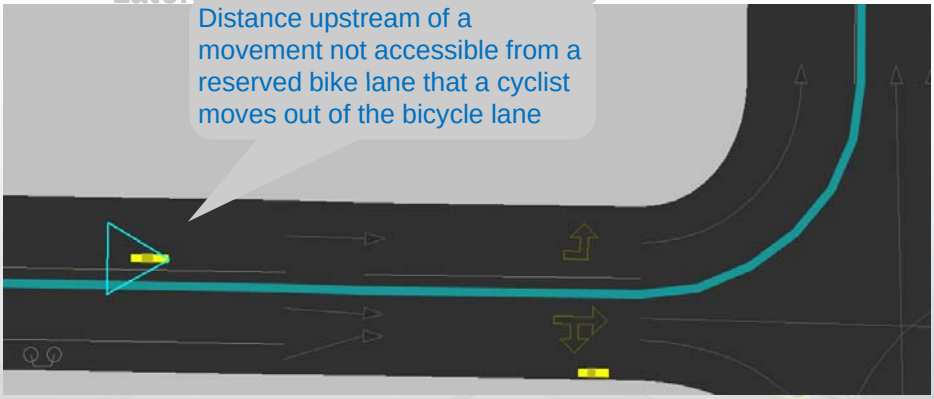
Bicycle Traffic Micro-Simulation

- Lateral Movement Within a Lane



Bicycle Traffic Micro-Simulation

- **Lateral Movement Within a Lane**
- **Stopped Gaps**
- **Desired Speed**
- **Following Distance & Acceleration**
- **Lane Changing Gap Acceptance**
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Bicycle Traffic Micro-Simulation

- **Work to be done:**
  - **Very high density situations are difficult to properly simulate:**

Outline

- **Outputs of micro-simulation**
- **Role of micro-simulation**
- **TransModeler for micro-simulation**
- **TransModeler for bicycle micro-simulation**
  - **GIS platform**
  - **Traffic Micro-simulation**
  - **Trip-based demand**

Bicycles as Trip-Based Demand

- **Vehicles calculate shortest path across specified link travel times and turning movement delays**
- **These costs can be generalized to reflect the perceived cost to a cyclist**
  - **Presence of bicycle lane or cycletrack**
  - **Segment grades**
  - **Volume of traffic**

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Some research exists (e.g. Hood, Sall, & Charlton 2011) and more would be nice on bicycle path choice: what is a cyclist's cost function?

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TransModeler is flexible enough to easily integrate this research once it is completed

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Conclusion

TransModeler's bicycle micro-simulation can be used as a tool for the visualization and analysis of cycling-related transportation projects.

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Conclusion

Bicycle Infrastructure	Bicycle Mode Share: 0%	Bicycle Mode Share: 3%
No Build		
Build		

Conclusion

Thank you

david@caliper.com