Predicting Lane Change Intensity within Urban Interchange Influence Areas (IIA)

Webinar
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Topic Outline

- Project motivation and objectives
- Project outcomes
- Methods
- Modeling Results
- Tool demonstration
- Case study
- Q&A

Project Motivation and Objectives

- Lane changes – especially discretionary ones-- near interchange influence areas (IIAs) contribute to turbulence and have negative mobility and safety effects
- Lane changes cannot be detected using current infrastructure detection systems, possibly in the future with the advent of AV's
- To develop a tool to predict the expected intensity of lane changes at interchange influence areas (IIAs)
- To enable the identification of variables and control strategies at the IIAs that might induce fewer discretionary lane changes and thus, reduce unnecessary traffic turbulence

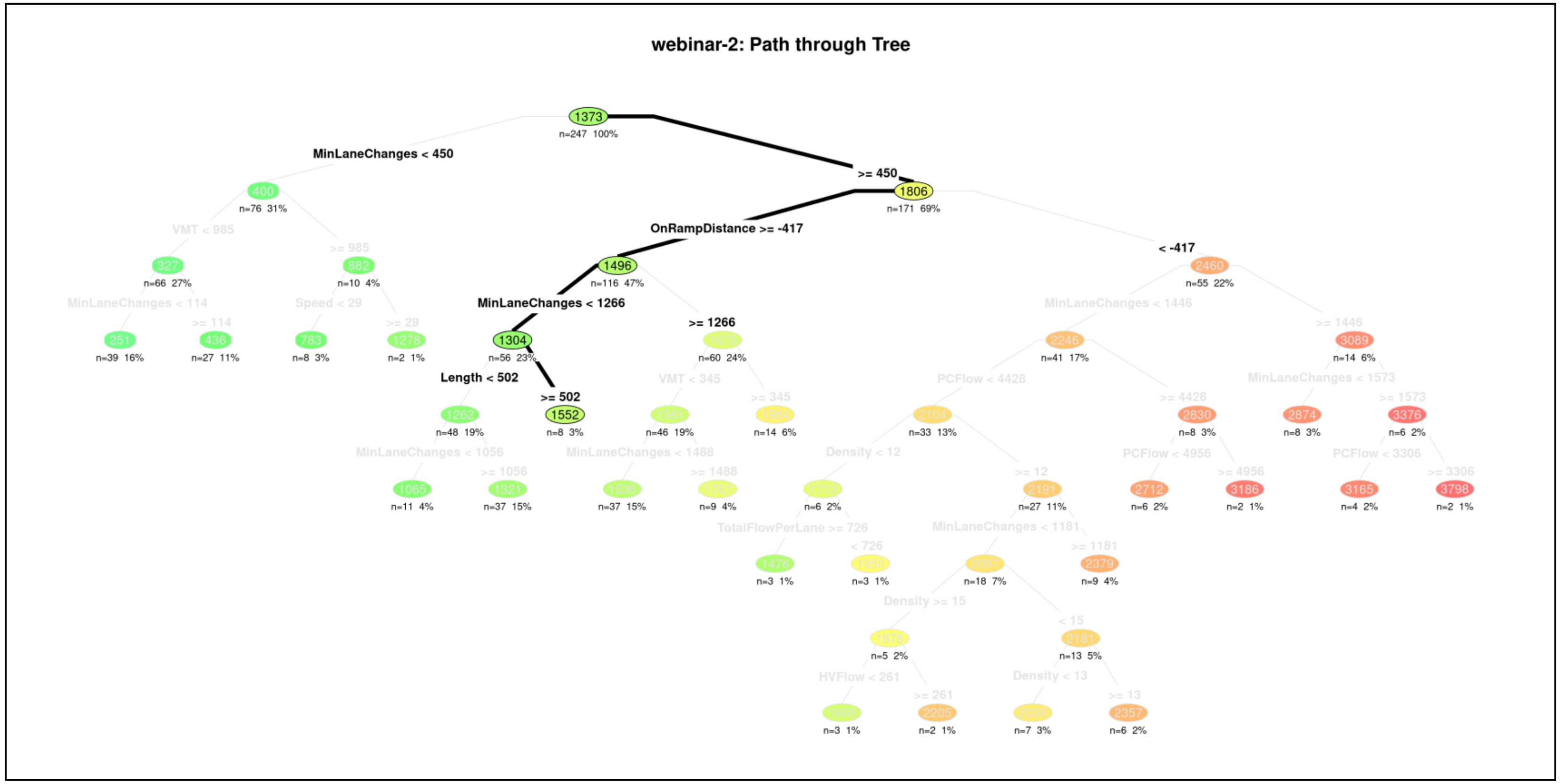
Outcomes: Model and Tool Development

Results

Predicted Hourly Lane Changes: 1551.75

Approximate Standard Error: 159.74

Confidence Bounds: (1392.01, 1711.49)



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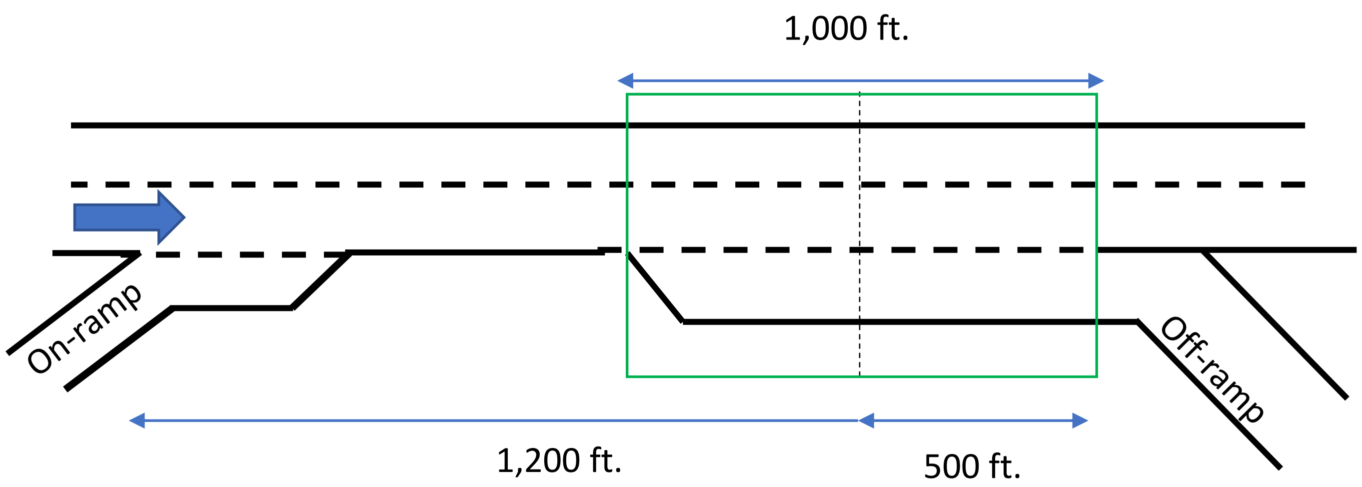
Research Methodology

- Based on empirical observations of lane changes at IIAs
- Project Tasks
  - Data collection
  - Data extraction process
  - Database summary
  - Model development
  - Tool architecture
  - Tool development and dissemination

Data Collection

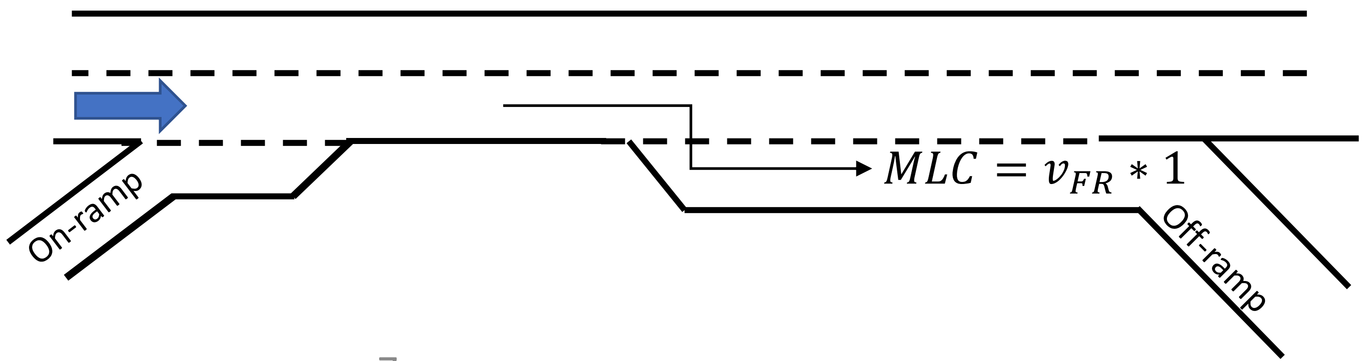
- Collection Method
  - Drone videos (untethered, 300-400 ft. above ground)
  - Google maps
  - Automated extraction and manual verification
- Observations
  - Taken in 5 min intervals, expanded to hourly rates
- Freeway Segments and definitions
  - Type (basic, merge, diverge, weave)
  - Length (ft)
  - Number of lanes
  - Lane configuration
  - Distance to nearby on-ramp $\pm$
  - Distance to nearby off- ramp $\pm$



$$Segment\ Length = 1{,}000\ ft.$$
$$Number\ of\ lanes = 3$$
$$Nearest\ on\text{-}ramp = -1{,}200\ ft.$$
$$Nearest\ off\text{-}ramp = +500\ ft.$$

Data Collection (continued)

- <u>Traffic characteristics</u>
  - Vehicle counts (at mid-segment)
  - Origin-destination volumes (e.g., freeway-to-ramp and ramp-to-freeway volumes)
  - Heavy vehicle percentage
  - Overall space mean speed (SMS)
  - Lane change counts within the segment, including minimum number of lane changes per hour



Data Collection Sites: ~ 20 hrs. overall

Serial	Site	Duration (min)	HCM6 Segment type
1	I-440 EB at Western Blvd (Pilot)	895	Upstream of Merge
2	I-40 WB at Wade (facing east)	50	Downstream of Merge
3	I-40 WB at Wade (facing west)	55	Downstream of Merge
4	I-440 EB at Hillsborough St Exit	90	Upstream of Diverge
5	I-40 EB at S. Saunders St and Hammond Rd	85	Weave
6	I-40 WB at S. Saunders St and Hammond Rd	85	Weave
7	I-440 EB at Poole Rd and US-64	35	Weave
8	I-440 WB at Poole Rd and US-64	30	Weave
9	Wade Ave. WB at Blue Ridge & I-440	125	Weave
10	I-440 EB at Ridge Rd	475	Weave
11	**US-101 in Los Angeles, CA (NGSIM)**	40	Weave
12	I-40 EB at I-440 (MM 293)	35	Basic
13	I-40 WB at I-440 (MM 293)	35	Basic
14	I-40 EB at I-440 (MM 309)	40	Basic

Video Data Extraction

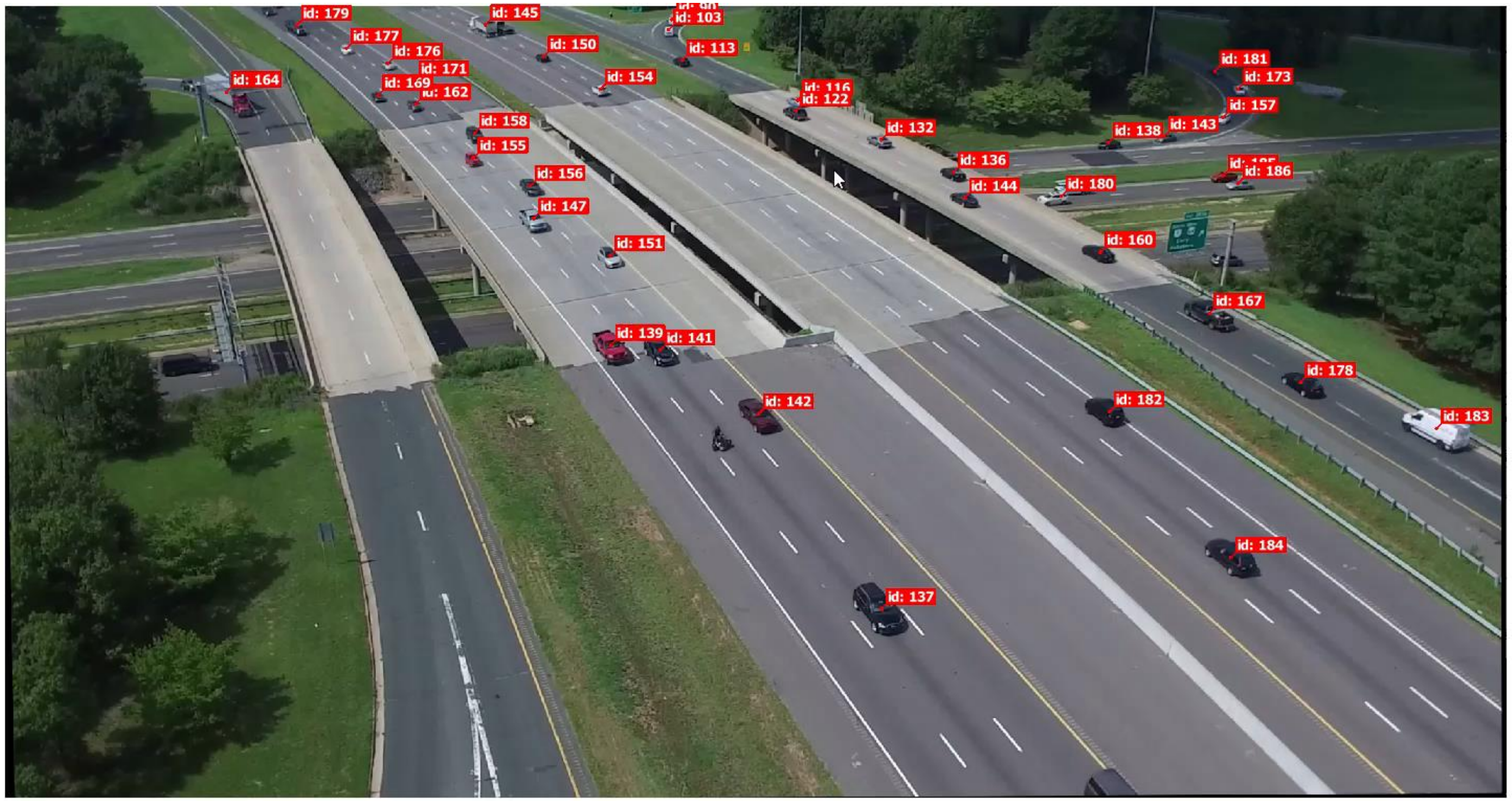
- Automated tool (DataFromSky)
  - Fast
  - Stabilizes drone videos
  - Tracks vehicles
  - Accuracy test for lane change count showed satisfactory results for passenger cars

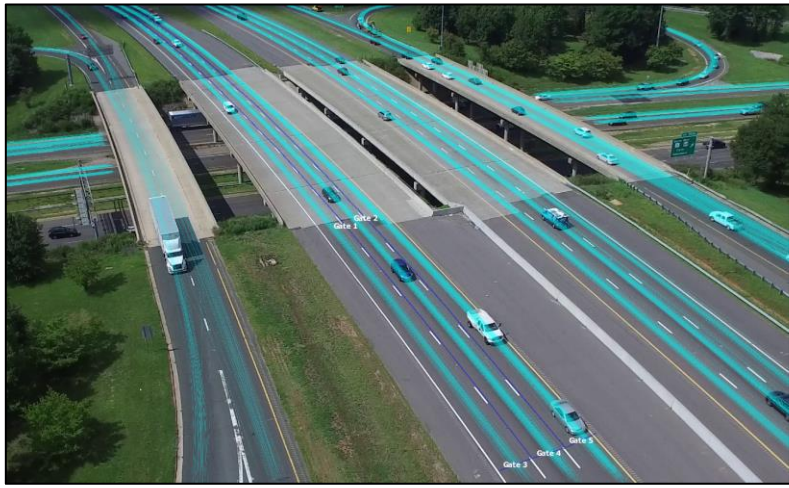
DATA FROM SKY
https://ai.datafromsky.com/aerial

- Manual counting
  - Very labor intensive
  - Limited to heavy vehicle lane change count
  - Also used for accuracy testing of the automated tool

DATA FROM SKY

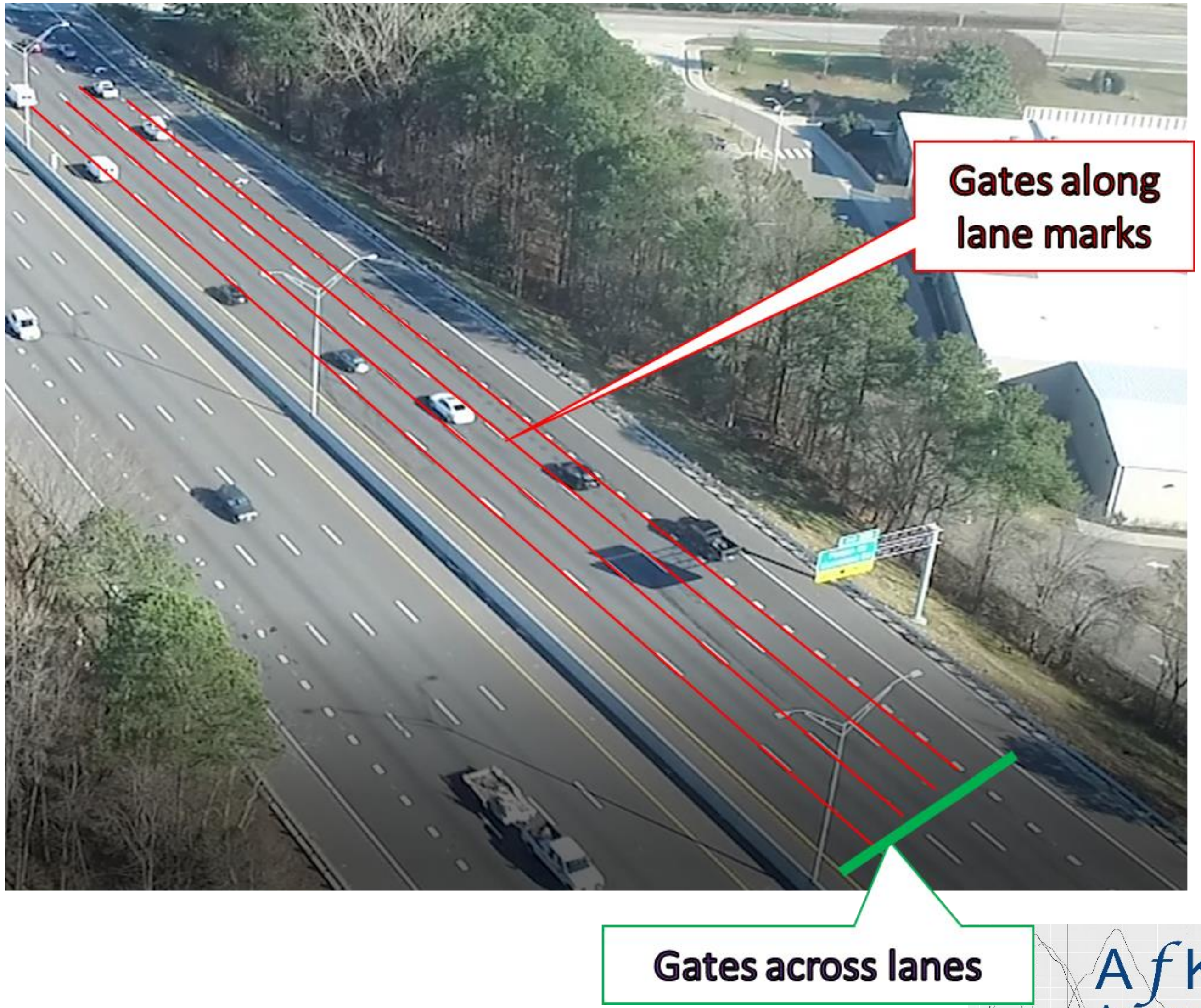
Example of a processed video





Extracting Lane Changes

- Method
  1. Works with “DFS-Processed Videos”
  2. Create gates *along* and *across* the lane markings using the offline DFS software
  3. Extract gate crossing events and their timestamps
  4. Track origin-destination lane for each lane change
- This method works very well for passenger cars (error < 5%)
- Lane changes by heavy vehicles are manually extracted



Create the Analysis Database

- Database summary
  - Number of directional sites: 15
  - Number of data points: 247, aggregated in 5-minute observations
  - Range of 5-minute observations across sites: 6 to 95
  - For modeling purpose, all observations expressed in an hourly rate
  - Response of interest: **Total segment lane changes per hour**

- **Total lane changes** are expressed in two components
  - Mandatory (minimum number of) lane changes
    - Observed range over all sites: 0% to 89% of all lane changes
  - Discretionary lane changes
    - Observed range over all sites: 11% to 100% of all lane changes

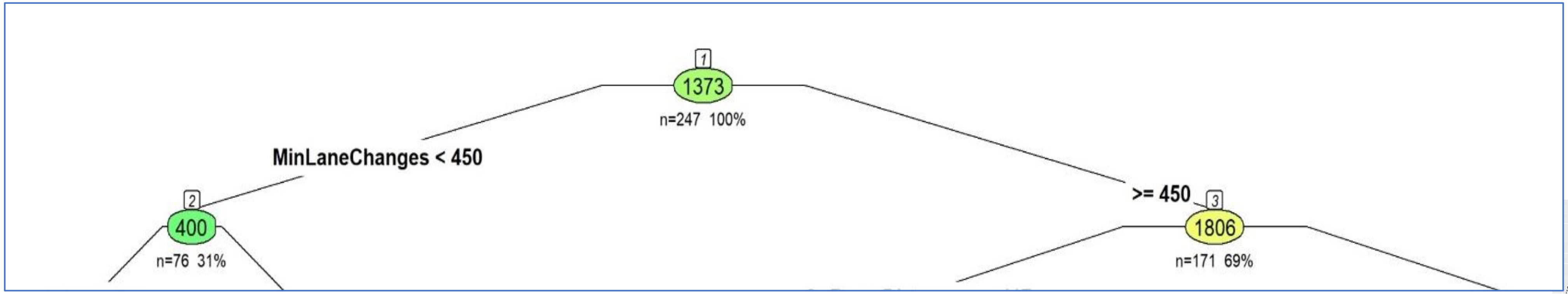
Database Summary

Variable type	Variable name	Mean	Median	St. deviation	Minimum	Maximum
Geometric	Segment length (ft)	625	-	-	213	1,610
	Number of lanes	4	-	-	3	6
	Min. lane change required (freeway-to-ramp)	1	-	-	0	2
	Min. lane change required (ramp-to-freeway)	1	-	-	0	2
	Signed distance to nearby on-ramp (±ft)	-126	-	-	-2,720	3,132
	Signed distance to nearby off-ramp (±ft)	649	-	-	-2,960	6,369
Traffic	Passenger car flow rate (pc/hr)	4,965	5,200	1,598.9	1,416	8,376
	Heavy vehicle flow rate (v/hr)	263	192	240.5	0	1,560
	Total flow rate per lane (v/hr/ln)*	1,248	1,284	276.8	336	1,731
	VMT per hr*	562	451	334.8	193	1,808
	Avg. speed (mi/hr)	50	52	17.8	6	81
	Avg. density (v/mi/ln)*	33	27	27.2	10	206
	Minimum lane changes per hr. *	878	1,110	572.0	0	1,896
	Total lane changes per hr.	1,373	1,392	828.4	108	4,128

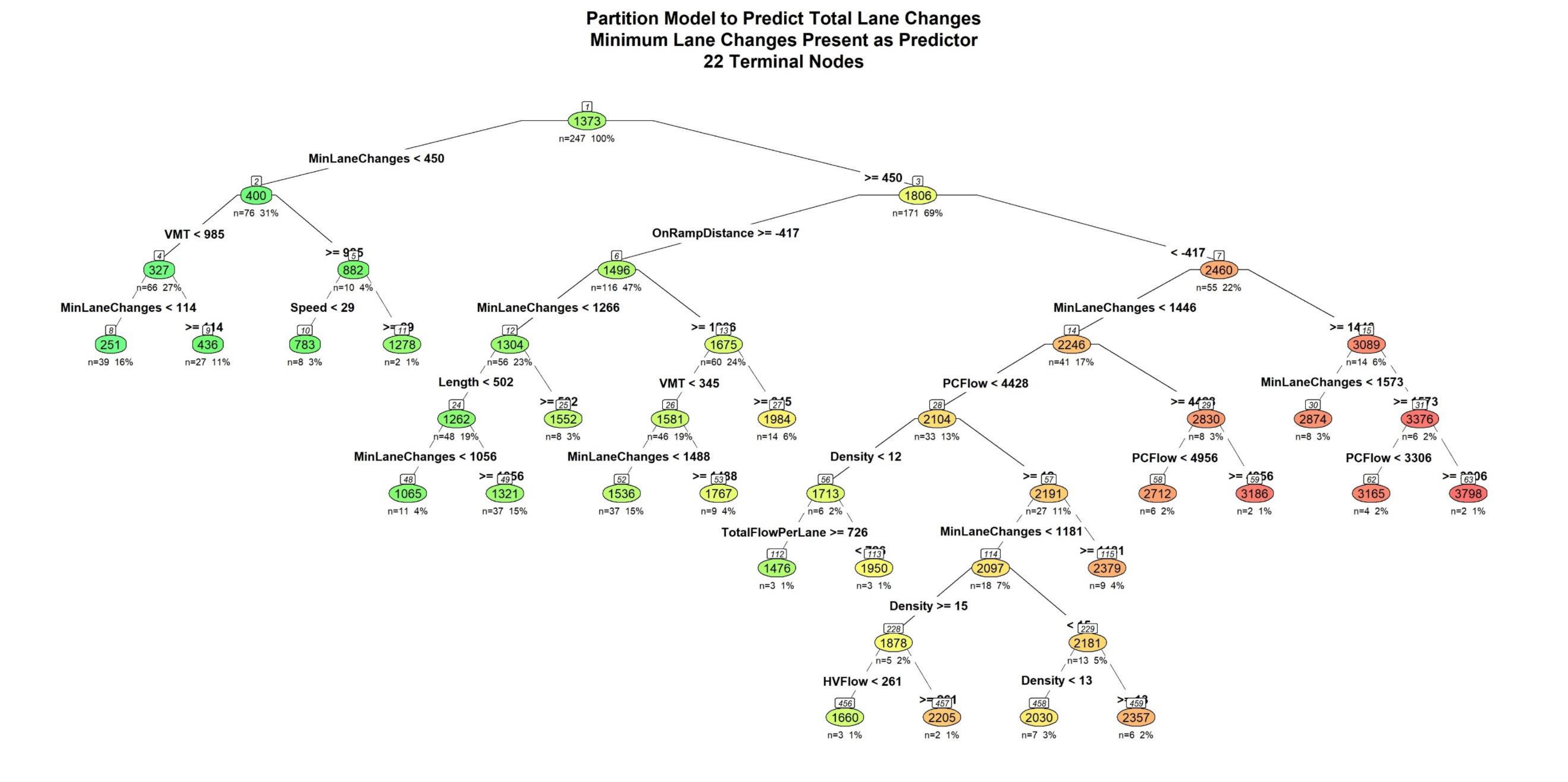
Modeling Approach for Lane Change Prediction

- Tested various types of statistical models
- Recommended Regression tree approach
  - Observations are split into multiple homogeneous sets based on most significant splitters in the input variables
- Validation
  - Self-validated as the tree is developed by a 10-fold cross validation technique
  - Site-specific validation

Total Lane changes



Modeling Results



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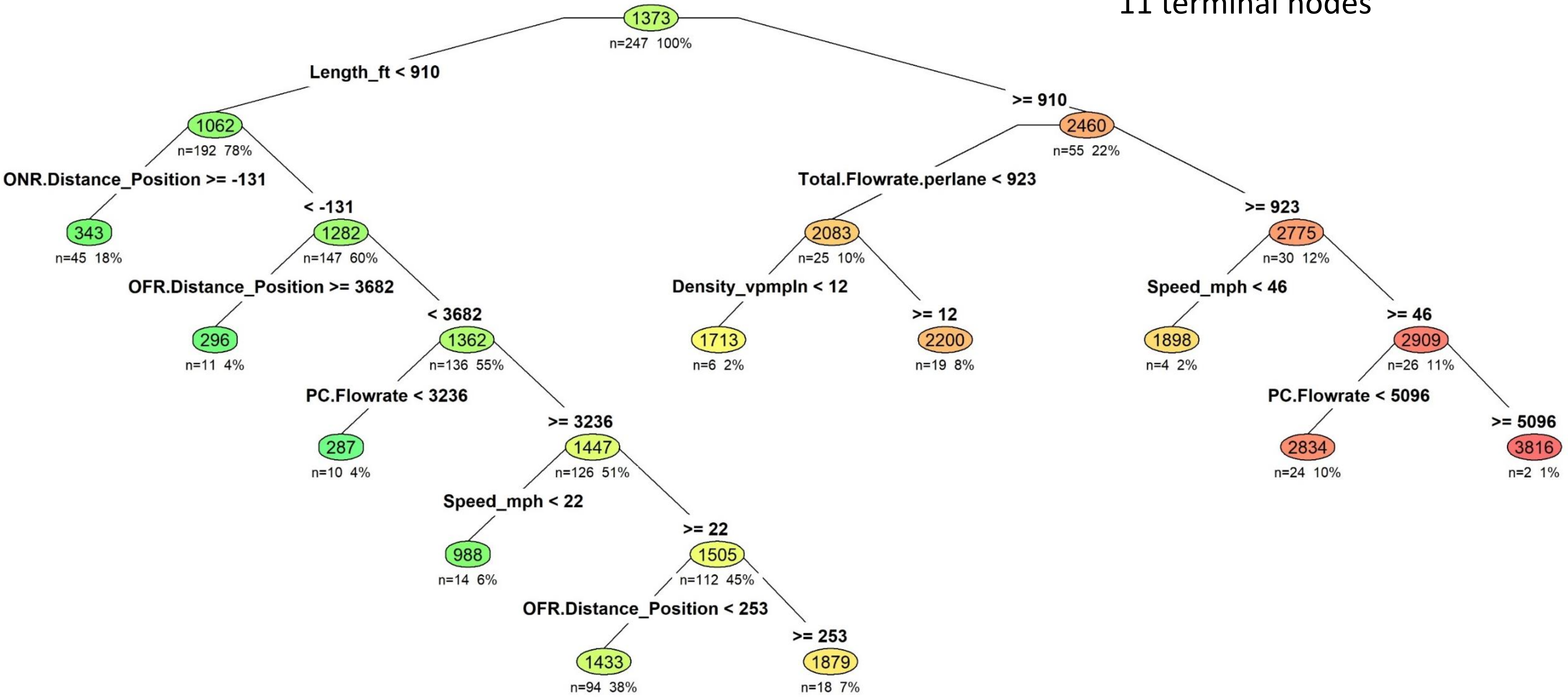
Modeling Results

Mandatory/minimum lane changes <u>not present</u> as a predictor
11 terminal nodes



Model Performance

Item	No Model	Model with Mandatory Lane Changes	Model without Mandatory Lane Changes
Number of terminal nodes in tree	NA	22	11
RMSE* (LC per hour)	828.4**	121.9	216.3
Relative RMSE***	60%	8.8%	15.8%

Mean number of lane changes across all observations: 1,373 lc./hr.

** RMSE= Root Mean Square Error (in lane changes per hour)*

*** For NO Model, RMSE equivalent to standard deviation*

**** Relative RMSE = RMSE / Mean # of lane changes per hour*

Site-specific Validation

Model with **Mandatory Lane Changes**

Omitted Site	Relative RMSE	
	Full Model	Omitted Model
I-40 S Saunders E	0.07	0.18
I-40 S Saunders W	0.11	0.22
I-40/440 Basic E	0.28	0.29
I-40/440 Basic W	0.49	0.48
I-40/440 East Split	0.18	0.32
I-40W Weave E	0.34	0.33
I-40W Weave W	0.20	0.47
I-440 at Poole Rd E	0.08	0.22
I-440 at Poole Rd W	0.08	0.18
I-440E at Hillsborough Ext.	0.21	0.20
RidgeRd	0.06	0.25
US101_Dnstrm	0.14	0.78
US101_Upstrm	0.29	0.68
US101_Wve	0.12	1.68
Wade W at I-440	0.05	0.30

Key Findings from Models

- Overall, low levels of lane changing are associated with:
  - Low mandatory lane change frequency, low VMT, and low speed(congested conditions)
- Other important variables effecting the prediction:
  - Segment length, distance to nearby ramps, and total and passenger car flow rate
- Range of relative RMSE across all sites:
  - With mandatory lane changes known : 0.05-0.49
  - Without mandatory lane changes : 0.1-0.98
  - Higher values are associated with basic segments as all lane changes are discretionary

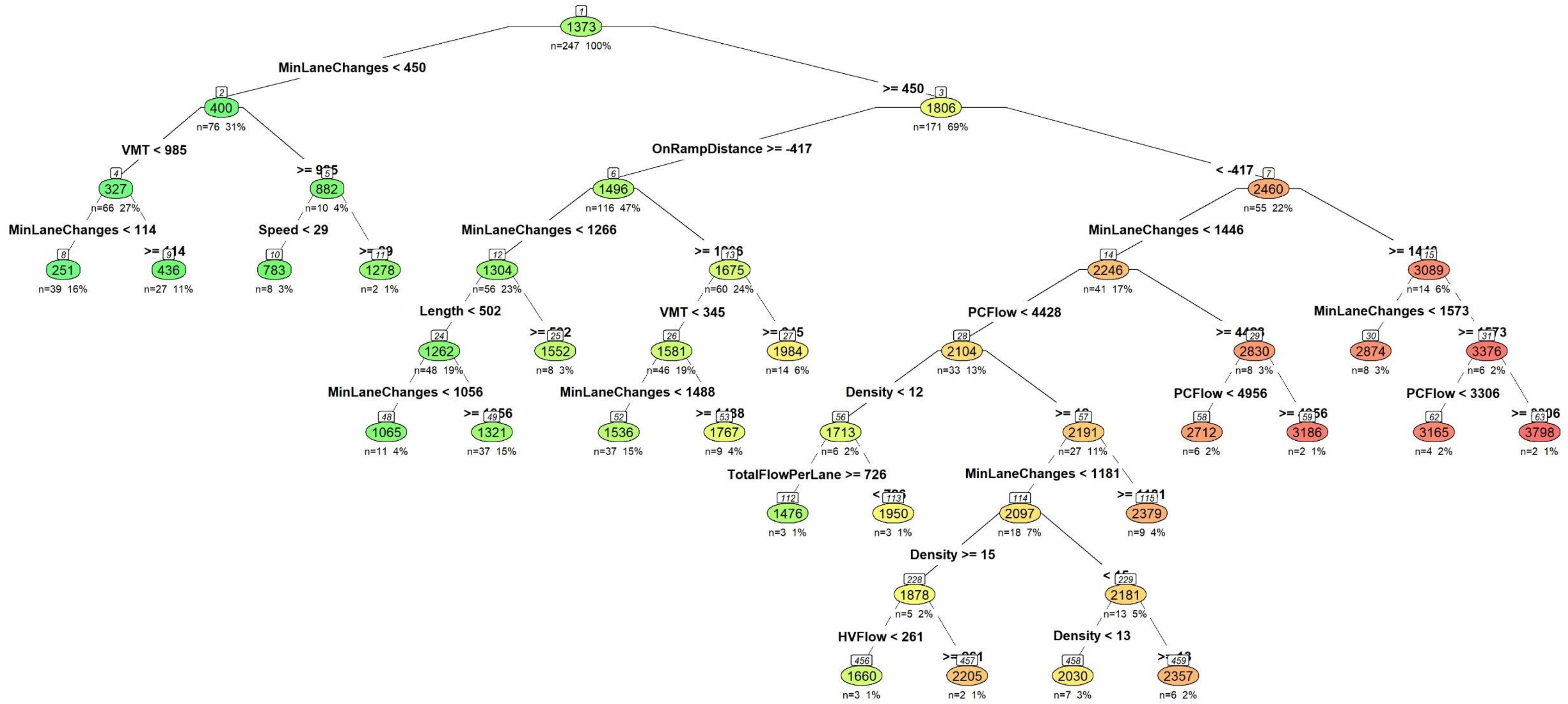
Model Limitations: Statistical

- Most important: sparsity of data
  - 247 data points
  - 11 input variables
  - $2^{11} = 2048$
- Discrete (therefore, discontinuous) predictions
  - Nearly equal inputs may result in quite different predictions
- Some terminal nodes entail large confidence bounds
  - Surrogate standard errors range from 59 to 467
- Potentially unreliable predictions
  - Out-of-range inputs produce warnings, inputs near “boundaries” do not

Model Limitations: Generalizability

- Dataset DOES NOT contain
  - Some site geometries (e.g., left entrances)
  - Bad weather (reflects use of drones)
  - Construction
  - Incidents
- Prospective evaluation of treatments should be done with care
- Model does not predict locations of lane changes

Partition Model to Predict Total Lane Changes
Minimum Lane Changes Present as Predictor
22 Terminal Nodes

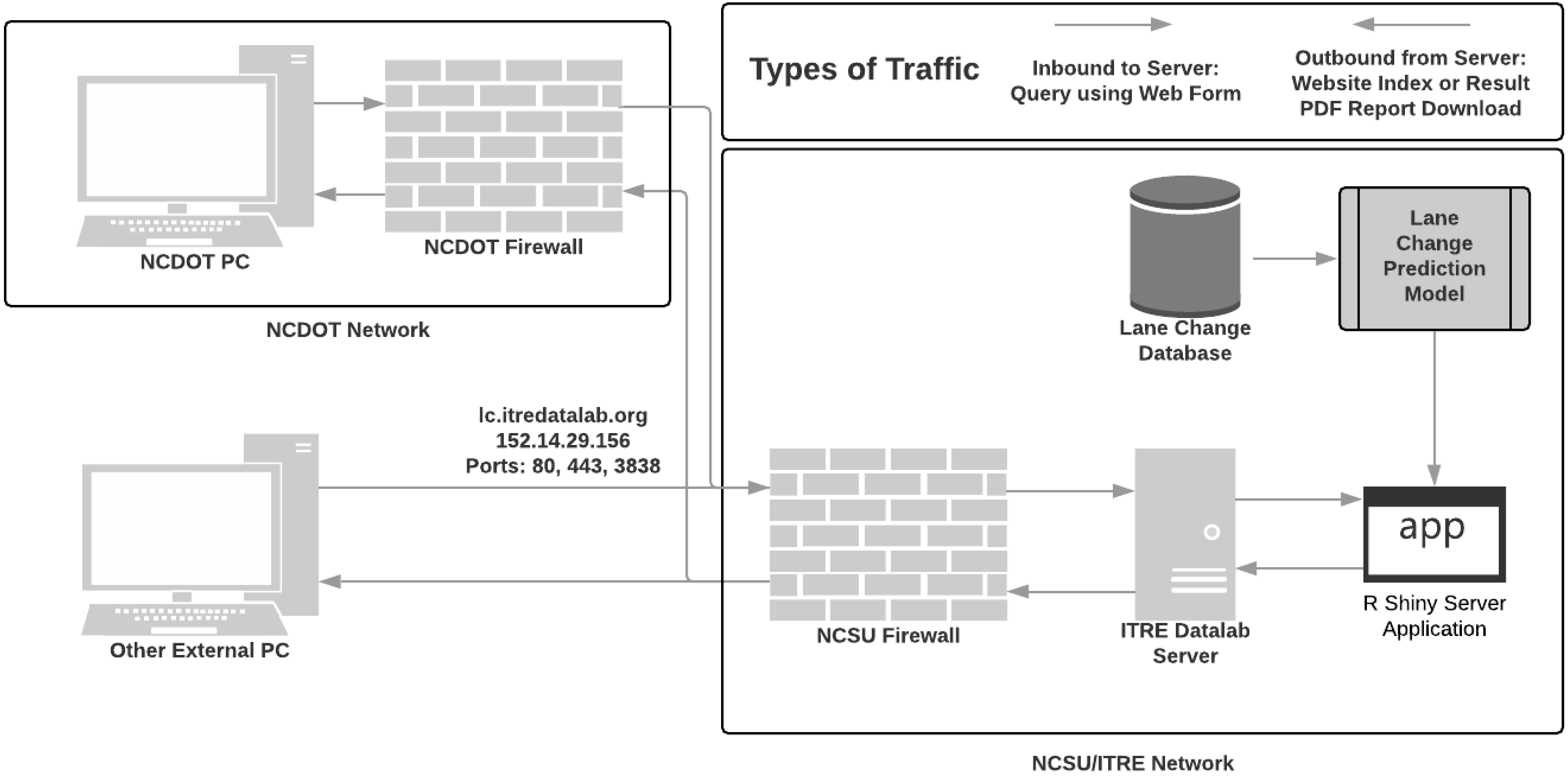


Tool Description and Demonstration

Tool Description

- Architecture
- Web-based interface of the lane change prediction tool
- User guide for the tool
  - Description and explanation of inputs and outputs of the tool
- Excel-based calculator
  - HCM-based estimates of minimum lane changes and space mean speed
  - Recommended to use only when field data are unavailable
- ReadMe file for the calculator
  - Description and explanation of inputs and outputs of the calculator

Tool Architecture



Web Interface Demonstration

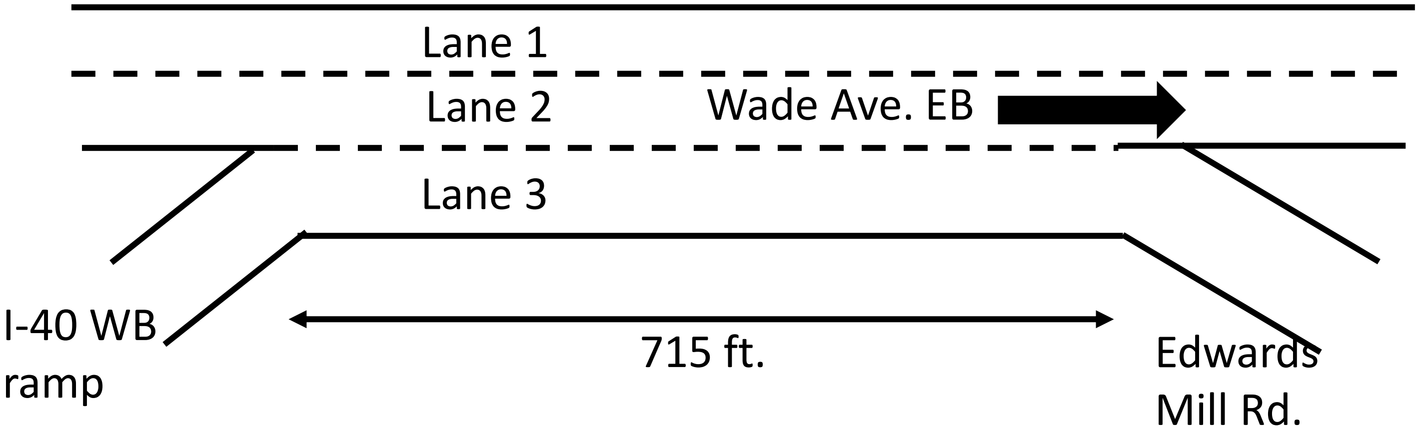
http://itredatalab.org/

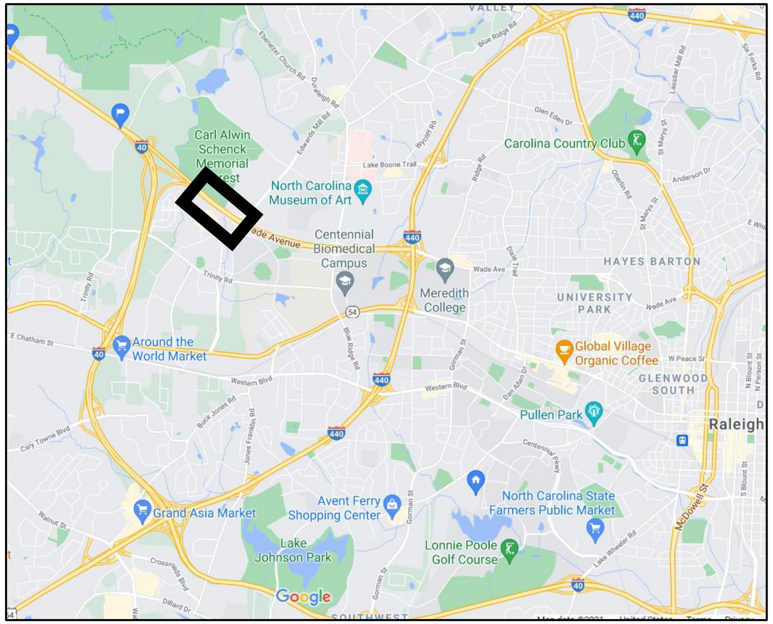
Password: **IIAlcpt2020)%**

User Guide & Excel-based Calculator

Case Study

- Site Description
  - Wade Ave. EB between I-40W & Edwards Mill Rd.
  - Distance to nearest on-ramp: -357.5 ft
  - Distance to nearest off-ramp: +357.5 ft



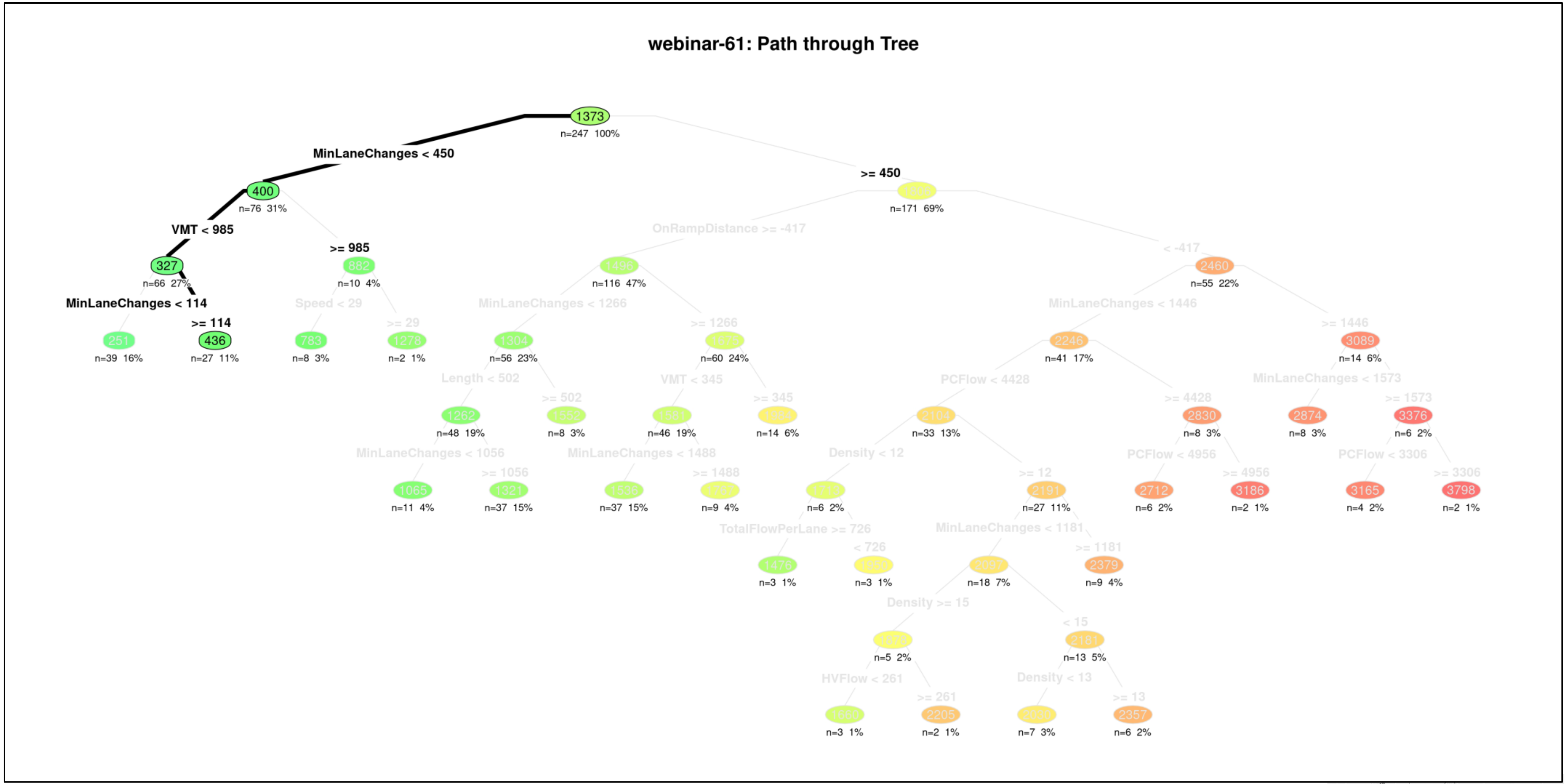


Data Collection

- 35 minutes of drone footage (=7 data points)
- Total flow rate: 2,300-3,035 vph
- Heavy vehicle: 7-15%
- Minimum lane changes: 380-694 per hour (65-90% of total lane changes)
- Avg. speed: 65-69 mph
- Total lane changes: 432-794 per hour

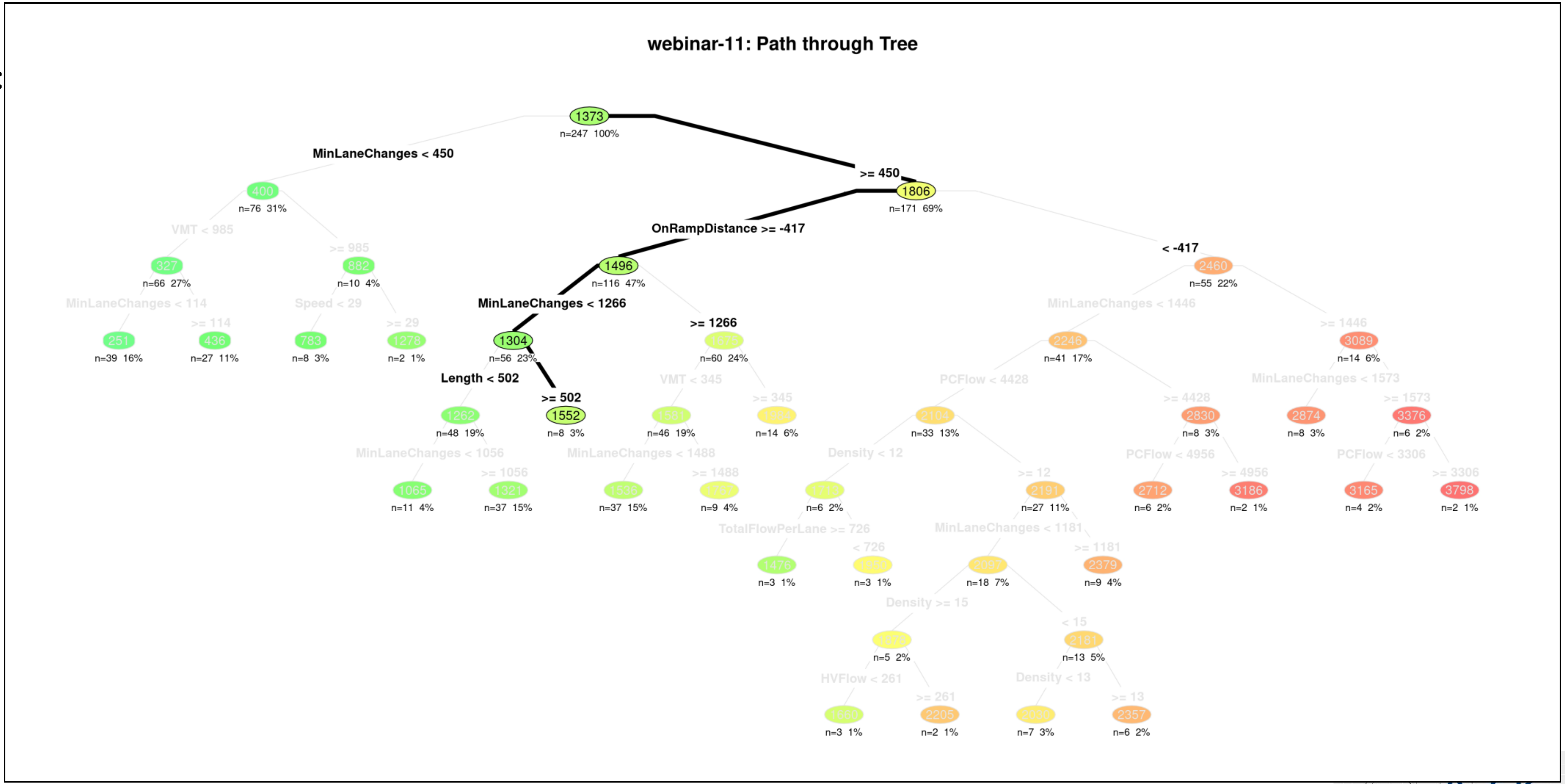
Model with MLC (Data 6-7)

Observed lane changes:
432 & 460 per hr

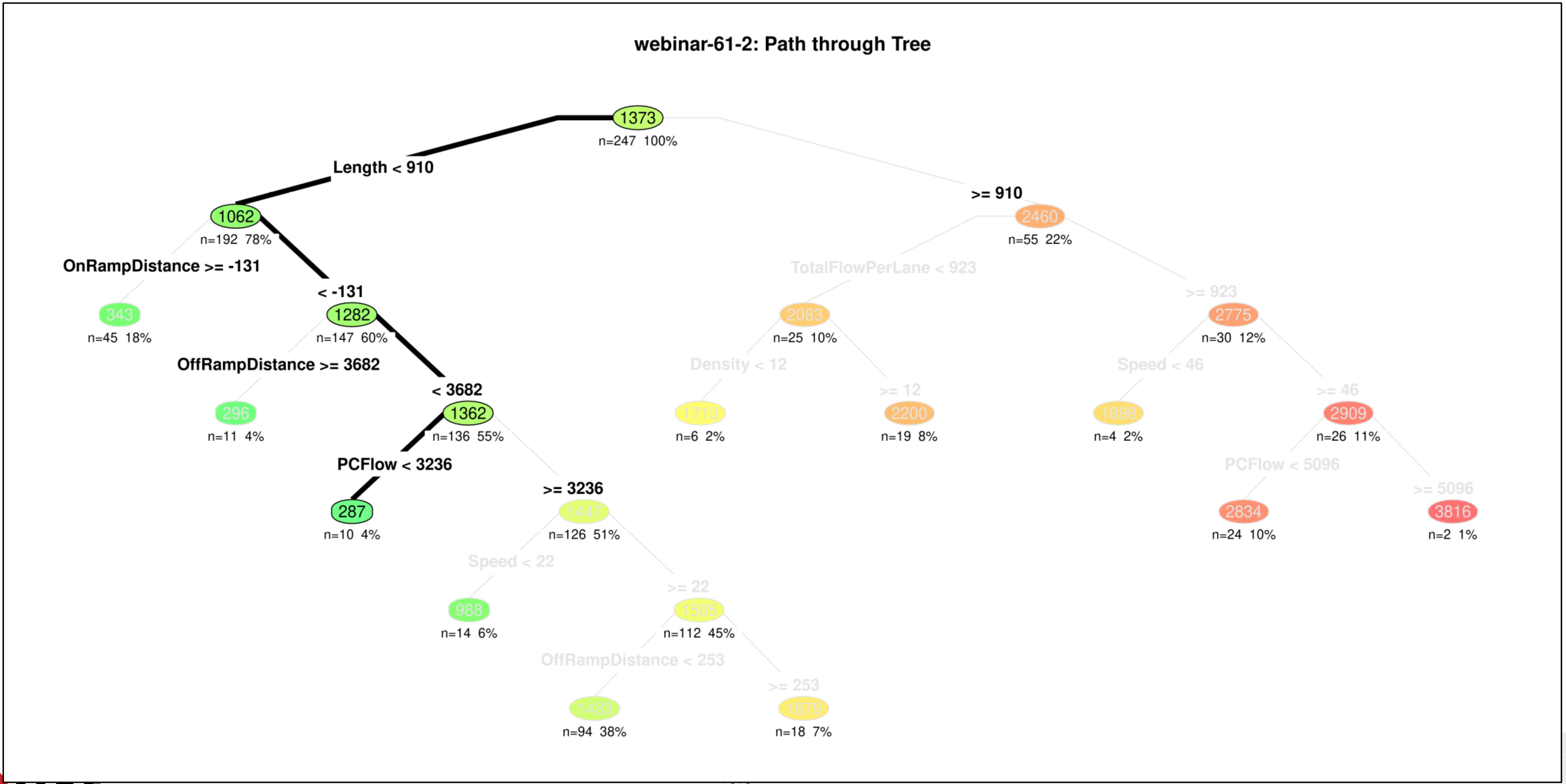


Model with MLC (Data 1-5)

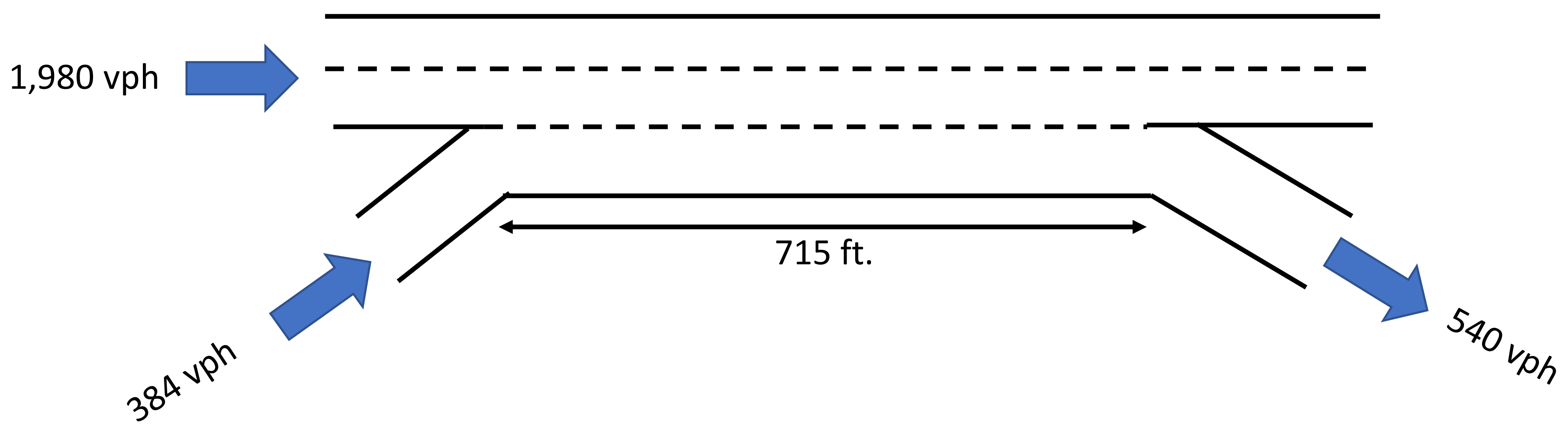
Observed lane changes: 636-793 per hr



Model without MLC (Data 1-7)



Demonstrate the Excel-based Calculator



THANK YOU

Questions?