WisDOT Vissim Vehicle Fleet Study

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Executive Summary

The Wisconsin Department of Transportation (WisDOT) Bureau of Traffic Operations and Safety Unit (BTO-TASU) undertook this study to increase efficiency in the often time-consuming, but necessary, traffic model calibration process. Calibration helps avoid over or underpredicting capacity, which could lead to misguided conclusions regarding the effectiveness of improvements to the transportation system. The starting point for calibration often relies on software defaults that are not Wisconsin-specific and therefore require increased effort to collect data and produce a quality traffic model. This study developed a set of Wisconsin-specific defaults for PTV Vissim software that do not replace the need for project-level calibration but may expedite the process by providing a reasonable starting point. Establishing defaults also provides consistency amongst models being developed and reduces repeated questions regarding model parameters.

Vissim was developed in Germany and provides European and North American defaults, which do not differ significantly despite known and anecdotal differences in vehicle characteristics and driver behavior. This study developed Wisconsin default parameters by leveraging readily-available data from previous projects and research. The resulting defaults reflect a variety of conditions in Wisconsin, provide better estimates of capacity, and are also consistent with the Highway Capacity Manual. These changes should allow for default simulations to require less calibration to produce reasonable estimates. A summary of the Vissim parameters changed and their consequences is shown in Table E1.

Table E1. Overview of Changes Implemented by WisDOT Default Vissim Parameters

Vissim Parameter	Comparison to Vissim North America (NA) Default	Consequences
Vehicle Fleet Distribution (2d/3d model distribution)	- Lower percentage of pickup trucks. (6% WisDOT vs 24% NA Default)	- Better visual representation of traffic. (Most WisDOT Vissim models are in urban areas with fewer pickup trucks) - Negligibly reduced queue length (shorter by about 20 ft on a 20 vehicle queue if spacing between vehicles is ignored)
Desired Speeds Distributions	- Reflects expected "s-shape" distribution compared to linear distributions in the NA Defaults. - Specific distributions for various facility types (freeway, expressway, 2-lane rural, etc). - Separate speed distributions for passenger cars and heavy vehicles at faster posted speeds.	- Better representation of 50th and 85th percentile speeds on a variety of facility types. - Better representation of the range of vehicle speeds observed for any given posted speed. - Reflects slower trucks on faster facility types as the result of speed governors or vehicle weight.
Passenger Car and Heavy Vehicle Acceleration (Desired and Maximum Acceleration Functions)	- Split "Heavy Vehicles" into separate Single Unit (SU) and Tractor Trailer (TT) truck types. - Lowered acceleration for all vehicle types. The WisDOT 50th Percentile desired acceleration at 0 mph is: - PC 8.5 ft/s^2 (Vissim default: 9.84 ft/s^2) - SU 5.25 ft/s^2 (Vissim default: 8.2 ft/s^2) - TT 2.5 ft/s^2 (Vissim default: 8.2 ft/s^2)	- Lowers saturation flow rate to be consistent with previous WisDOT research. (NA default saturation flow is about 2040 pc/hr/ln, WisDOT defaults and field observed is about 1980 pc/hr/ln) - Provides better estimates of capacity and queue length. - Produces more realistic behavior where single unit and tractor trailer trucks have lower acceleration at slow speeds compared to passenger cars - Provides better estimates of start-up time required for semi-trucks at traffic signals

For Vissim Users

The "WisDOT Defaults inpx" file should be used instead of Vissim's European or North American default files. Using the WisDOT default file does not require any special effort; it can be used normally like any other model file. Users do not have to create the WisDOT default file from scratch, but sufficient detail to do so is included in Appendix A. The WisDOT default file uses Vissim version 2020.00-10 at the time of this report.

Users will need to do the following for their projects:

- **Defining vehicle compositions.** Two example compositions are included as shown in Figure E1. The user can see in these examples how passenger car and heavy vehicle speed distributions are used, as well as how heavy vehicles are divided into single unit (SU) and tractor trailer (TT) trucks.

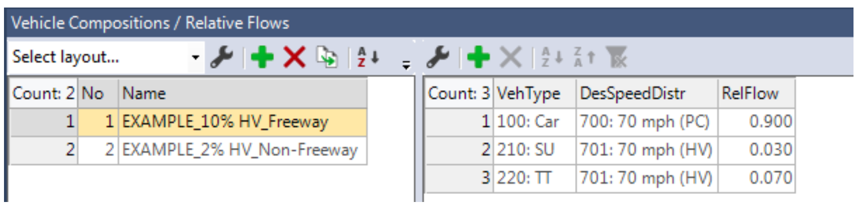


Figure E1. Example Vehicle Compositions (70 mph freeway shown)

  - **If project-specific data on the amount of SU and TT trucks is not available, use the following percentages that are representative of Wisconsin and the Highway Capacity Manual:**
    - Freeways – 70% of heavy vehicles are tractor trailer
    - Non-Freeways – 70% of heavy vehicles are single unit trucks

- **Setting desired speed decision points.** The default file contains desired speed distributions for the following posted speeds and facilities types. Passenger cars (PC) and heavy vehicles (HV) use separate distributions only for 50 mph freeways and faster facilities. The heavy vehicle speeds apply to both SU and TT trucks. 50 mph non-freeways and slower facilities use the same speed distribution for all vehicle types:

*Desired Speed Distributions using **separate** PC & HV*	*Desired Speed Distributions using **combined** PC & HV*
○ 70 mph	○ 50 mph – Non-Freeway
○ 65 mph	○ 45 mph
○ 55 mph – Freeway	○ 40 mph
○ 55 mph – Expressway	○ 35 mph
○ 55 mph – 2-lane rural	○ 30 mph
○ 50 mph – Freeway	○ 25 mph

- **Project Specific Calibration.** The default file does not replace the need to calibrate to local conditions. Users will need to adjust parameters, potentially modifying the Wisconsin defaults, in order to achieve a model calibrated in accordance to the WisDOT Traffic Engineering, Operations and Safety Manual (TEOpS) Chapter 16-20.

Users should be aware that the WisDOT defaults may result in the following:

- **Potential for more simulation runs.** Increased run-to-run variance may result from changes to the desired speed distributions and lowered acceleration. See TEOpS 16-20-7 for guidance on determining the number of simulation runs.

- **Adjustments to turning speed or ramp speed distributions.** Turning speeds and ramp speeds depend on curve radius and may need to be adjusted to reflect local conditions. Turning movement saturation flow is very sensitive to turning speed. Speeds should be adjusted to reflect saturation flow data where available.

- **Potential for the need to increase capacity.** The net effect of the WisDOT defaults is lower saturation flow at traffic signals. If local data indicates higher saturation flows, safety distance or headway parameters may need to be modified to achieve calibration. Reverting to Vissim default accelerations should be done as a last resort.

- **Potential non-transferability of calibration parameters.** Calibration parameters from projects that did not use the WisDOT default file may not produce the same results when implemented in model using the WisDOT defaults. This may include, but is not limited to:

    - Priority rule and conflict area parameters at roundabouts or other locations

    - Wiedemann 74 or 99 model parameters

    - Lane changing parameters

  Experienced modelers that have developed “rules-of-thumb” should revisit their values when using the WisDOT defaults.

- **Require the use of 0% gradient on links.** When using the gradient feature on links to reflect steeply-sloped roadways, Vissim adjusts the maximum acceleration by -0.1 m/s^2 for uphill grades and 0.1 m/s^2 for downhill grades. The WisDOT defaults modify vehicle acceleration. The combination of modified acceleration and link gradient was not investigated. Users should use caution if using the gradient feature on Vissim links. If local speed data indicates drivers slowing down due to steep gradients, using 0% link gradient and reduced speed areas may be advised.

- **Potential for error if copying parameters *from* the WisDOT defaults *to* other models**. Especially for heavy vehicles that have many inter-dependent parameters, users should be very careful if copying/pasting values to other files. Appendix A discusses all parameters that need to be changed to fully implement the WisDOT defaults.

Future Work

The WisDOT Vissim defaults establish by this study provide the foundation for future work to create additional efficiencies in calibrating simulations. Examples of future work include, but are not limited to:

- Investigating a range of intersection turning speeds at intersections and their impact to saturation flow. Speeds on interchange ramps could also be investigated.
- Investigating deceleration. Just as acceleration was found to differ from the software supplied defaults, deceleration may differ as well.
- Investigating Wiedemann 74 and 99 parameters and their impact on capacity.
- Investigating lane changing parameters and their impact on lane utilization and capacity.
- Establishing gap acceptance parameters for priority rules and conflict areas for roundabouts and other unsignalized intersections.

1 Introduction

This study aims to reduce calibration effort for Vissim models by providing Wisconsin-specific defaults to use a starting point for calibration. This study specifically focuses on vehicle fleet characteristics. Vissim software provides European and North American (NA) default parameters that have known and anecdotal differences from conditions in Wisconsin. Default parameters recommended by this study reflect objective research on a broad range of facility types in Wisconsin and can replicate state-wide saturation flow rates. Implementing the recommended parameters will allow more reasonable capacity estimates compared to using Vissim's defaults that may overestimate capacity if local calibration is not available. Better calibrated models ultimately lead to better informed decisions made within transportation planning and operations projects.

Vissim parameters adjusted in this study include:

- **Vehicle fleet distribution** (2d/3d model distribution)
  – Recommended parameters are in Section 2.3.
- **Desired Speed Distribution**
  – Recommended parameters are in Section 3.3.
- **Passenger Car and Heavy Vehicle Acceleration**
  (Desired and Maximum Acceleration Functions)
  – Recommended parameters are in Sections 4.3 and 5.3.

This study investigated these parameters in this order because they are fundamental to the car following models implemented in Vissim. Higher-level car-following parameters, such as the 'Wiedemann 74' or 'Wiedemann 79' parameters, are especially influenced by speeds and accelerations. Establishing reasonable values for speed and acceleration first provides a consistent foundation for future recommendations regarding other Vissim parameters.

Each chapter in this report contains sections regarding the objective, methodology, and results for the Wisconsin default parameters. "Sandbox" simulation models were used to isolate variables of interest when developing and testing the recommended parameters. Each of these sandbox models used the following unless otherwise specified:

- **Vissim Version 11.00-10.** Several service packs and the major version 2020 were released during the timespan of developing this report. None of the changes introduced in the newer service packs or version 2020 change the results of this study.
- **20 simulation runs for each scenario**
- **"WisDOT Default" scenarios implemented all recommended parameters** (vehicle fleet, speeds, and acceleration)
- **"Vissim Default" scenarios used the Vissim North American parameters installed with Vissim 11.00-10.** Vissim version 2020 includes the same default file as version 11.

The end-product for software users is an "inpx" Vissim model file that implements all recommendations. Users do not need to create this file from scratch; however, sufficient detail to do so is included in Appendix A. The inpx file uses Vissim version 2020.00-10 at the time of this report.

2 Vehicle Fleet Distribution

In Vissim, the vehicle fleet is the mix of different vehicle types and classes (e.g., Honda Accord, Ford F-150, GMC Yukon, WB-65 truck) that run through the model. Relative flows can be set for each type and class of vehicle (e.g., passenger vehicles vs. heavy vehicles). Vehicle attributes and driving characteristics can be changed as well.

2.1 Objective

The recommended vehicle fleet distributions aim to accomplish the following:

- Reflect fleet characteristics of a broad range of facility types commonly analyzed using microsimulation.
- Produce a reasonable typical length for passenger cars and heavy vehicles that can affect queue length results.
- Provide a realistic visual representation of the traffic stream.
- Setup the model to allow for customization of vehicle type parameters, such as separate acceleration behaviors for different truck types.

2.2 Methodology

Since the company that makes Vissim, PTV, is based in Germany, the default vehicle fleet is a European mix of vehicles such as those made by Mercedes-Benz, Peugeot, and Porsche. The default heavy vehicle mix is also European-style, and includes one truck type ("HGV - EU 04 Tractor.v3d") that is 33.5 ft. This truck is similar to a WB-30, but is half of the length of interstate semitrailers commonly seen in the US (WB-65 or WB-67 have an overall vehicle length of 73.5 ft).

Vissim's NA default fleet is composed of passenger and heavy vehicles more common in the US. However, the percentages for the class of vehicles are based on older data not from Wisconsin. While the NA default fleet has been used in Wisconsin Vissim models in the past, some aspects of it seemed questionable in terms of capturing the vehicle fleet seen on major roads in the state – particularly, the high percentage of pickup trucks (34.3%) and low percentage of small/medium SUVs (5.8% represented by the Jeep Grand Cherokee), as well as the low percentage of interstate semitrailers (10% WB-65 and WB-67).

To better understand the composition of vehicle fleets in Wisconsin, several datasets were used, including:

- 2018 vehicle registration data from the Wisconsin Division of Motor Vehicles (DMV).
- Two datasets of vehicle types derived from video of Interstate freeways that had been used by a consultant to calibrate Vissim models in the Southeast Region in 2017. (One set included almost 39,000 vehicles collected in the peak periods).
- Data on Federal Highway Administration (FHWA) classifications at Automatic Traffic Recorders (ATRs) statewide from 2004 to 2017 (The most recent subset from 2014-2017 was ultimately used for analysis).

2.3 Results

2.3.1 Passenger Cars

The recommended passenger car distribution for Wisconsin is shown in Table 1. The data to develop the distribution contained some discrepancies between the DMV vehicle registration data and the observed Interstate data from video, specifically in the percentages of sedans and pickup trucks. The video data showed a significantly higher share for sedans and a lower share for pickup trucks relative to the DMV vehicle registration data. While more pickup trucks may be registered, it seems that they are not driven as often in urban areas. Sedans may be more frequently used as commuter vehicles in urban areas than their share of the registrations would indicate. For the other categories of passenger vehicles (SUVs, minivans, and work vans), the registration and video data lined up well.

From these observations, the passenger car distribution in Wisconsin can be divided into urban and rural areas; however, the urban WisDOT distribution is recommended for all Wisconsin models for the following reasons:

- Most microsimulation models are developed in urban areas.
- The overall average vehicle length and effect on queue length does not significantly differ between urban and rural.
- Implementing one instead of two distributions greatly simplifies implementation in Vissim and reduces potential errors.

Rural percentages could be used for visualization purposes but is not necessary for traffic analysis.

Table 1. WisDOT Default Passenger Car Vehicle Distribution

Vissim Vehicle Model (v3d file)	Type	Length (ft)	Urban (WisDOT Default)	Rural (Wisconsin Data)
Car - Nissan Altima (2005).v3d	Sedan	16.0	**27.5%**	19.5%
Car - Honda Accord (2003).v3d	Sedan	15.6	**27.5%**	19.5%
SUV - Jeep Grand Cherokee (2002).v3d	Small/Medium SUV	15.2	**24.0%**	24.0%
SUV - Ford Explorer (2008).v3d	Large SUV	16.0	**4.0%**	4.0%
SUV - GMC Yukon XL (2008).v3d	Large SUV	17.8	**4.0%**	4.0%
Car - Plymouth Voyager (1999).v3d	Minivan	16.0	**4.0%**	4.0%
LtTruck - Chevrolet Silverado (2008).v3d	Pickup Truck	21.9	**3.0%**	11.0%
LtTruck - Ford F150 (2009).v3d	Pickup Truck	17.8	**3.0%**	11.0%
VAN - Stepvan 01.v3d	Work Van	20.3	**3.0%**	3.0%
			100%	100%
		Weighted Average Vehicle Length (ft)	**16.1**	16.8
		Average Length Comparison		
		Vissim European Default (Mercedes, Peugeot, Porsche, etc)	14.3	
		Vissim North America Default	17.1	
		Example 20 Vehicle Queue (excluding vehicle spacing)		
		WisDOT Default (Urban)	322 ft	
Compared to WisDOT Default		Rural Wisconsin	+14 ft	
		Vissim European Default	-36 ft	
		Vissim North America Default	+20 ft	

2.3.2 Heavy Vehicles

The recommended heavy vehicle distributions for Wisconsin are shown in Table 2 for single unit (SU) and Table 3 for tractor trailer (TT) trucks. Splitting heavy vehicles into separate distributions allows better representation of different facility types and the wide variety of truck types observed in Wisconsin.

The historical data on FHWA truck classifications from ATRs was particularly useful for determining statewide trends by facility type. Differences in the percentages of heavy vehicles in each of the FHWA heavy vehicle classes (Class 4 through Class 13) were found between freeways and other roadway classifications (non-freeways). Most of the differences occurred between two FHWA classes – Class 5 (two axle, six tire, single unit) and Class 9 (5-axle tractor semitrailer). Class 5 is difficult to count without manual inspection of videos because of the wide variety of trucks that fit in this class, and not often included in typical truck turning movement counts. Class 5 was also not the target for acceleration calibration (Section 5.2.1). For these reasons, the percentage of Class 5 trucks was redistributed to Class 6 as they can have similar overall vehicle lengths.

Vissim user can specify project-specific percentages of SU and TT trucks to reflect the facility types being modeled. **If only an overall truck percentage is available (e.x. "10% trucks"), the following subdivision into SU and TT trucks is recommended that is consistent with Wisconsin data and Highway Capacity Manual recommendations:**

- Freeways – 30% SU Trucks / 70% TT Trucks
- Non-Freeways – 70% SU Trucks / 30% TT Trucks

Table 2. WisDOT Default Heavy Vehicle Distribution – Single Unit Trucks

Single Unit (SU) Trucks			
Vissim Vehicle Model (v3d file)	**FHWA Class**	**Length (ft)**	**WisDOT Default**
Bus - C2 Standard 2-doors.v3d	4	40.7	**12%**
HGV - US Flatbed.v3d	5-6	33.6	**29%**
HGV - EU 04 Tractor.v3d	5-6	33.5	**29%**
HGV - US AASHTO WB-40 (includes tractor and trailer v3d files)	7	45.7	**6%**
HGV - US AASHTO WB-50 (includes tractor and trailer v3d files)	8	55	**24%**
Weighted Average Vehicle Length (ft)		40.3	**100%**

Table 3. WisDOT Default Heavy Vehicle Distribution – Tractor Trailer Trucks

Tractor Trailer (TT) Trucks			
Vissim Vehicle Model (v3d file)	**FHWA Class**	**Length (ft)**	**WisDOT Default**
HGV - US AASHTO WB-65 (includes tractor and trailer v3d files)	9	73.6	**94%**
HGV - US AASHTO WB-67D (includes tractor and trailer v3d files)	10-11	73.2	**6%**
Weighted Average Vehicle Length (ft)		73.6	**100%**

Table 7 compares the average heavy vehicle length using various distributions. The Vissim European default is about 50% to 66% shorter than the recommended WisDOT defaults. The Vissim NA default distribution is close to the recommended 70 / 30 SU / TT split for non-freeways, despite including fewer TT trucks. However, the Vissim NA default lacks the ability to model TT trucks accelerating slower than SU trucks.

Table 4. Heavy Vehicle Average Length Comparisons

Heavy Vehicle Distribution	Average Length (ft)
WisDOT Default (30%/70% SU/TT)	63.6
WisDOT Default (70%/30% SU/TT)	50.3
Vissim European Default (EU 04 Tractor)	33.5
Vissim North America Default (10% WB-65, WB-67D)	48.7

A side effect of increasing the proportion of WB-65 vehicles in Vissim is that the software shows these as “lowboy” trailers (Figure 1). The overall vehicle length is correct for traffic simulation purposes, but it does not visually represent the more typical 53 ft box trailer on interstate trucks. The WisDOT defaults desired to use models provided by the software for ease of use rather than relying on 3rd party files or custom made “v3d” files.

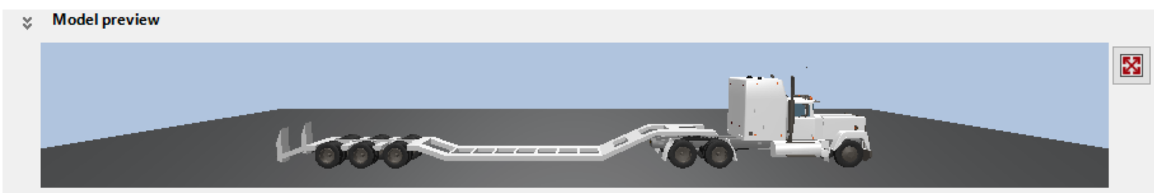


Figure 1. Default WB-65 Vehicle in Vissim

3 Desired Speed Distributions

Vissim uses “desired speed distributions” as inputs into the simulation for determining how fast vehicles should travel under ideal (unimpeded) conditions. Desired speed is analogous to free flow speed commonly discussed in traffic engineering. The speed distributions in Vissim typically correspond to posted speed limits as well as turning speeds at intersections or speeds on interchange ramps. The selected desired speeds directly impact model results including capacity, travel times, and delay (level of service).

3.1 Objective

The recommended desired speed distributions aim to accomplish the following:

- Reflect realistic driving speeds for posted speed limits and facility types commonly seen statewide.
- Provide a reasonable starting point for further local calibration.

3.2 Methodology

To estimate desired speeds commonly seen statewide, automatic traffic recorder (ATR) data from a variety of facility types and posted speed limits was analyzed as the best source of readily available speed data.

ATRs continuously record traffic volume and speed data, 24 hours per day, 7 days per week. Monthly speed data summaries were collected for 86 ATRs for years 2016 and 2017 during the months of April through October, and April-May 2020. For 50 mph and faster freeways, the April-May 2020 data reflected less recurring congestion due to COVID-19 stay-at-home orders. This allowed better estimates of free-flow speed compared to previous months where speed distributions were skewed due to congestion.

An example ATR monthly speed summary report is shown in Figure 2.

Site Names: 326116, 2753, SW
County: La Crosse
Funct. Class: U Minor Arterial
Location: STH 35 - NORTH OF MISSISSIPPI ST

	Roadway	Neg DIR	Pos DIR	Neg1	Neg2	Pos2	Pos1
0-20	1.0	0.6	1.4	0.8	0.6	1.0	2.0
21-25	4.5	4.8	4.3	5.3	4.4	3.5	5.4
26-30	36.3	43.5	28.7	44.1	43.0	25.5	33.3
31-35	46.9	44.7	49.2	43.4	45.6	51.1	46.5
36-40	10.2	5.9	14.7	6.0	5.8	17.1	11.4
41-45	0.9	0.4	1.4	0.4	0.4	1.6	1.2
46-50	0.1	0.1	0.2	0.0	0.1	0.2	0.2
51-55	0.0	0.0	0.0	0.0	0.0	0.0	0.0
56-60	0.0	0.0	0.0	0.0	0.0	0.0	0.0
61-65	0.0	0.0	0.0	0.0	0.0	0.0	0.0
66-70	0.0	0.0	0.0	0.0	0.0	0.0	0.0
71-75	0.0	0.0	0.0	0.0	0.0	0.0	0.0
76-80	0.0	0.0	0.0	0.0	0.0	0.0	0.0
81-85	0.0	0.0	0.0	0.0	0.0	0.0	0.0
86-90	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Average	31	31	32	30	31	32	31
Median	32	31	32	30	31	33	32
85th %tile	35	34	36	34	34	37	35
% over 55	0	0	0	0	0	0	0
% over 60	0	0	0	0	0	0	0
% over 65	0	0	0	0	0	0	0
% over 70	0	0	0	0	0	0	0
% over 75	0	0	0	0	0	0	0
% over 80	0	0	0	0	0	0	0
% over 85	0	0	0	0	0	0	0
Total	20,481	10,542	9,938	4,150	6,393	5,794	4,144

Figure 2. Example ATR Monthly Summary (MS02 Report)

ATR monthly speed data better reflects the faster percentile desired speeds than the lower percentiles because the data could have occurred under a variety of potential factors that influence speed (traffic volumes/congestion, truck percentages, weather, incidents). For example, an incident may cause drivers to go slower than they desire and thus underestimate desired speed, however a faster recorded speed probably occurred under free flow conditions. The ATR speeds also do not distinguish between heavy vehicles and passenger cars. Desired speed distributions developed from the ATR data compensated for these discrepancies between observed speed and desired speed by the following:

- Averaging percentile speeds across several ATR sites with the same posted speed limit.
- Capping the lower percentile desired speeds at 5-10 mph below posted speed, as well as capping maximum speed to 15-20 mph over posted. These caps were based on several factors:
  - Low occurrence of slow speeds on a monthly basis.
  - Unrealistic oscillations occur in simulation if the desired speed distribution has a large variance, especially if combined with modified vehicle acceleration.
- Estimating the difference between passenger cars and heavy vehicles based on engineering judgement and supplemental speed data collected from two Individual Vehicle Record (IVR) ATR sites:
  - ATR 130004 (NB I-39/90 at Cottage Grove Road in Madison)
  - ATR 400119 (WB I-94 between WIS 100 (Mayfair Road) and County O (Moorland Road)

  IVR data includes a timestamp, speed, and length-based vehicle classification for every vehicle detected. This data is extremely useful; however, very few ATRs save data at this level of detail. Differences between passenger car and heavy vehicle speeds were also checked against the National Performance Management Research Data Set (NPMRDS) and I-39/90 Madison-Illinois work zone data.

Desired speed distributions in Vissim were tested in a sandbox model under varying traffic conditions and compared to the original ATR data. This provided a check to verify that the Vissim inputs yielded the expected simulation outputs because there is not always a one-to-one correlation between inputs and outputs due to the interdependencies of parameters in Vissim. Figure 3 illustrates how the sandbox model was setup.

- The sandbox model was run with all WisDOT defaults implemented (Vehicle fleet distribution, speeds, and accelerations)
- 5% heavy vehicles were assumed, using an assumed 70/30 or 30/70 SU/TT split as recommended in Section 2.3.2.
- A variety of traffic flows were simulated with 250, 500, and 1000 veh/hr/ln.
- 10 runs with different random seeds used for each scenario.

Traffic entered the model using one of the desired speed distributions. A data collection point half-way along the network recorded individual vehicle speeds. Percentile speeds were obtained based on the individual vehicle speeds recorded in the raw data collection point output.

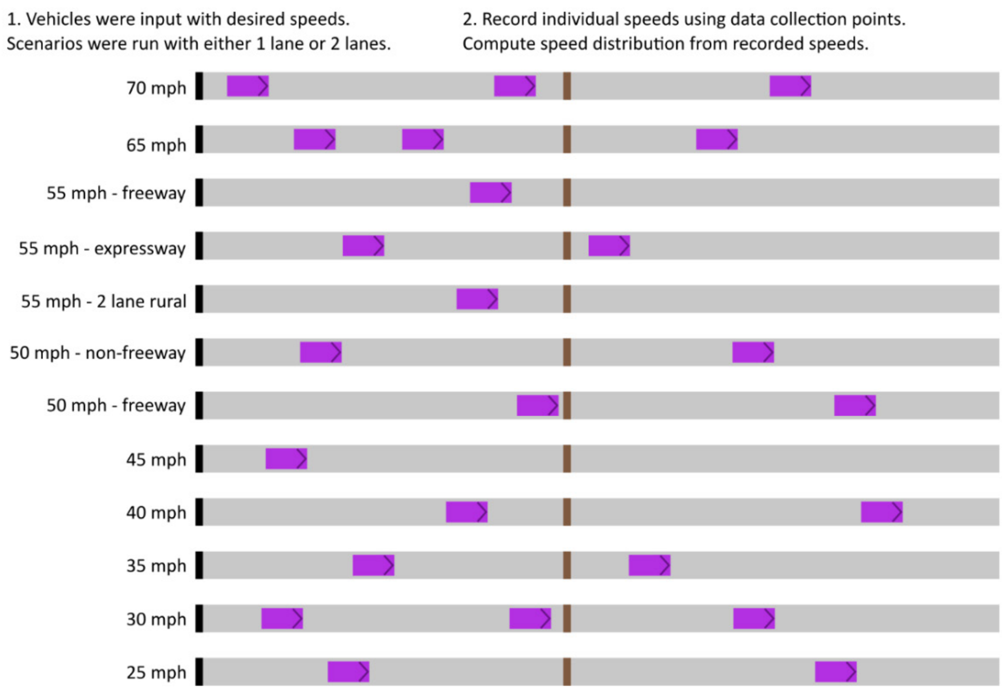


Figure 3. Desired Speed Sandbox Model

3.3 Results

The WisDOT defaults include desired speed distributions for twelve posted speeds and facility types. Table 5 shows summary statistics of the distributions. The desired speed distributions in WisDOT default file include intermediate percentiles beyond those shown in Table 5 that further refine the typical "s-curve" distribution shape (see Appendix A or the Vissim inpx file).

Heavy vehicles, which includes SU and TT trucks, were noted to exhibit slower speeds than passenger cars for higher posted speeds and facility types based on the speed data collected. This may be occurring due to speed governors or vehicle weight loading. For 50 mph freeways and faster facilities, separate speed distributions were created for heavy vehicles that are about 3-8 mph slower than passenger cars. This also has a side-effect of encouraging simulated passenger cars to pass heavy vehicles, which reflects the uncomfortableness that drivers experience behind large trucks.

Table 5. WisDOT Default Desired Speed Distributions

				WisDOT Speed (mph)				Vissim NA Default Speed (mph)				
Index	**Posted Speed**	**Facility Type**	**Vehicle Type**	**Min**	**50th**	**85th**	**Max**	**Posted Speed***	**Min**	**50th**	**85th**	**Max**
1	**70**	All	PC	60.0	74.3	79.5	90.0	**70**	65.0	69.1	72.0	90.0
			HV	55.0	67.0	71.8	80.0					
2	**65**	All	PC	55.0	71.4	75.6	85.0	**65**	60.0	64.1	67.0	85.0
			HV	55.0	64.1	67.9	80.0					
3	**55**	Freeway	PC	50.0	64.6	72.4	80.0	**55**	50.0	54.1	57.0	75.0
			HV	45.0	59.2	65.0	70.0					
4	**55**	Expressway	PC	50.0	59.9	65.6	75.0	**55**	50.0	54.1	57.0	75.0
			HV	45.0	54.9	60.6	70.0					
5	**55**	2-lane rural	PC	50.0	59.9	64.5	70.0	**55**	50.0	54.1	57.0	75.0
			HV	45.0	54.9	59.5	65.0					
6	**50**	Freeway	PC	45.0	62.4	69.3	80.0	**50**	45.0	49.1	52.0	70.0
			HV	45.0	57.0	61.9	70.0					
7	**50**	Non-Freeway	All	45.0	52.8	58.2	65.0	**50**	45.0	49.1	52.0	70.0
8	**45**	All	All	40.0	48.3	55.0	65.0	**-**	-	-	-	-
9	**40**	All	All	35.0	43.4	49.5	55.0	**40**	39.0	41.0	42.4	43.0
10	**35**	All	All	30.0	42.5	47.4	50.0	**-**	-	-	-	-
11	**30**	All	All	25.0	33.9	38.9	45.0	**30**	29.0	31.0	32.4	33.0
12	**25**	All	All	20.0	30.9	34.6	40.0	**25**	25.0	26.5	27.6	28.0

* Vissim NA Default does not distinguish between PC and HV speeds or facility types

\- Vissim NA Default does not provide speed distributions for 35 or 45 mph

Compared to the Vissim NA defaults, the WisDOT desired speeds tend to have 5 mph slower minimum desired speeds. WisDOT 50th and 85th percentile speeds are faster by 5 mph or more. For example, the 65 mph NA default has an 50h percentile speed of only 64 mph, which does not match the expectation that typical drivers go about 5 mph faster than posted. In comparison, the WisDOT 65 mph distribution has 50th percentile speeds of 71.4 mph for PC and 64.1 for HV.

Results from the sandbox simulation comparing the WisDOT desired speeds to the ATR percentile speeds returned reasonable results for each facility type. Simulated outputs were compared graphically against the ATR speed distributions. An example is shown in Figure 4 for a 2 lane 70 mph facility. Appendix B contains all comparisons.

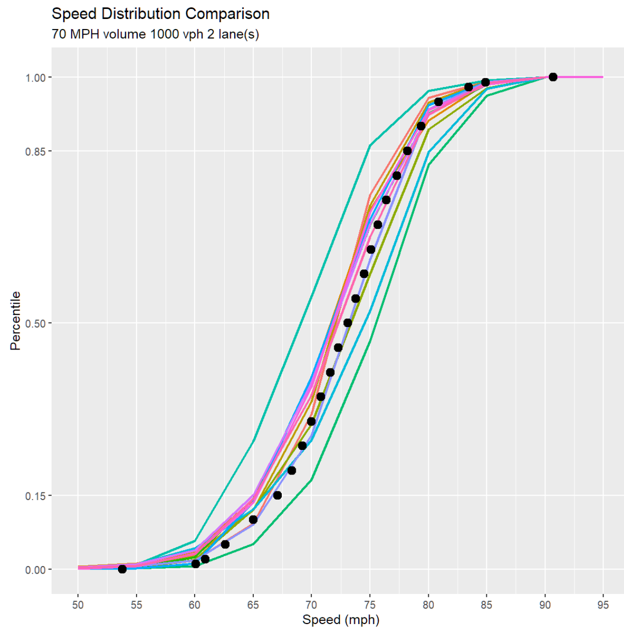


Figure 4. Example Comparison of Vissim Output Speed Distribution versus Observed ATR Speeds (black points = Vissim 70 mph - 1000 vph - 2 lanes, colored lines = data from individual ATR sites)

3.3.1 Walking Speed

Pedestrians are typically used in WisDOT Vissim models to activate push buttons at traffic signals and traverse crosswalks. To model a realistic walking speed distribution, data from Gates et al (1) are recommended for the WisDOT Vissim defaults, shown in Table 6. Gates' research measured walking speeds of 1,947 pedestrians at 10 intersections in Madison, WI and 1 intersection in Milwaukee, WI. The sample contained about 21% of pedestrians classified as "slower" (age 65+, children requiring assistance, physically disabled) compared to 15% in the year 2000 US Census data. However, adjusting Gates' data to the US population does not significantly change the results shown in Table 6. The results are also reasonable when compared to signal timing guidance for the "flashing don't walk" interval that typically uses 3.5 ft/s to accommodate slow pedestrians, as well as other research studies summarized by Gates.

Table 6. WisDOT Default Walking Speed

Percentile	Speed (ft/s)	Speed (mph) For Vissim
0%	3.00	2.05
15%	3.78	2.58
50%	4.10	2.80
75%	4.65	3.17
85%	5.09	3.47
100%	6.20	4.23

Note: 0% and 100% capped at +/- 2 standard deviations for modeling in Vissim

3.3.2 Limitations

The WisDOT desired speed distributions were developed from ATR sites to reflect a wide-variety of facility types and posted speeds. This introduces known limitations that may need project-specific calibration:

- **Low speed routes** – for 35 mph and slower facilities there was limited ATR data because state highways are typically higher speed routes.
- **Loop ramp or other interchange ramp speeds** – Only posted speeds were investigated in this study. Speeds on ramps may have differing distributions than those shown in Table 5 and could use the Volume, Speed, and Occupancy (V-SPOC) Application provided by the Wisconsin Traffic Operations and Safety (TOPS) Laboratory if available in the project area, or collect other project-specific data.
- **Turning Speeds** – Turning radii at intersections controls speeds and is project specific. The WisDOT default Vissim file includes generic “left turn” and “right turn” speeds, but these should be reviewed and calibrated to local conditions because of their effect on turning saturation flow rate.

4 Passenger Car Acceleration

4.1 Objective

The recommended passenger car acceleration inputs aimed to accomplish the following:

- Reflect typical car accelerations starting from a stop.
- Avoid over or underestimating roadway capacity by resulting in realistic saturation flow rates.
- Provide a starting point for further local calibration.

4.2 Methodology

Vissim uses two acceleration functions for passenger cars:

- **Desired Acceleration** – Describes how cars accelerate under normal conditions.
- **Maximum Acceleration** – Describes the theoretical acceleration limits of the car. Acceleration is constrained in the simulation to these limits when vehicles are on sloped roadways.

This study focused on desired acceleration as it can be directly observed in the field when a vehicle accelerates away from a traffic signal. The first vehicle in queue is unimpeded when the traffic signal turns green and is assumed to be accelerating as desired.

The University of Wisconsin Traffic Operations and Safety (TOPS) Laboratory collected vehicle trajectory data from a microwave radar unit at the signalized intersection of Wisconsin Avenue & Meade Street in Appleton, WI. This trajectory data was collected as part of a different study analyzing intersection delay. However, the data was repurposed to specifically analyze vehicle acceleration for this study. Basic facts about the trajectory data collection include:

- PM peak analysis 3:00 – 6:00 PM on Tuesday, November 18, 2014.
- Trajectory data (speed and position) recorded by the microwave radar in 0.5 second increments on the southbound Meade Street approach.
- 25 mph posted speed on Meade Street.
- A video camera was also setup to record traffic during this time as shown in Figure 5. Video data allowed correlation between the numeric trajectory data and visual identification of which vehicle the trajectory belonged to.
- 98 passenger cars were used for the acceleration analysis. Trajectory data and video data was manually reviewed to identify the first vehicle in queue and its acceleration when the traffic signal turned green; 101 candidate vehicles were identified. Further inspection of the data eliminated two passenger cars from the dataset as outliers, and one vehicle was eliminated from the dataset as a school bus.

Figure 5. Example Video Screenshot from Wisconsin & Meade Data Collection

The acceleration was determined from the trajectory data by analyzing the speed-time relationship of each vehicle after the signal turned green. The slope of the speed-time relationship is acceleration. An example vehicle trajectory is shown in Figure 6. All vehicles are shown in Appendix C. Timestamps for all vehicles were unified to have time zero as the last datapoint when the radar recorded zero speed for the vehicle after the signal turned green. This eliminated reaction time as a factor. By manual inspection, the speed-time relationship appeared linear between seconds 1 and 3. A linear regression was fit between these datapoints to determine desired acceleration from rest. As the vehicle gets closer to the radar unit, the speed and position data appeared to become less accurate, potentially due to the “cosine effect” as the angle between the vehicle and radar becomes closer to 90 degrees.

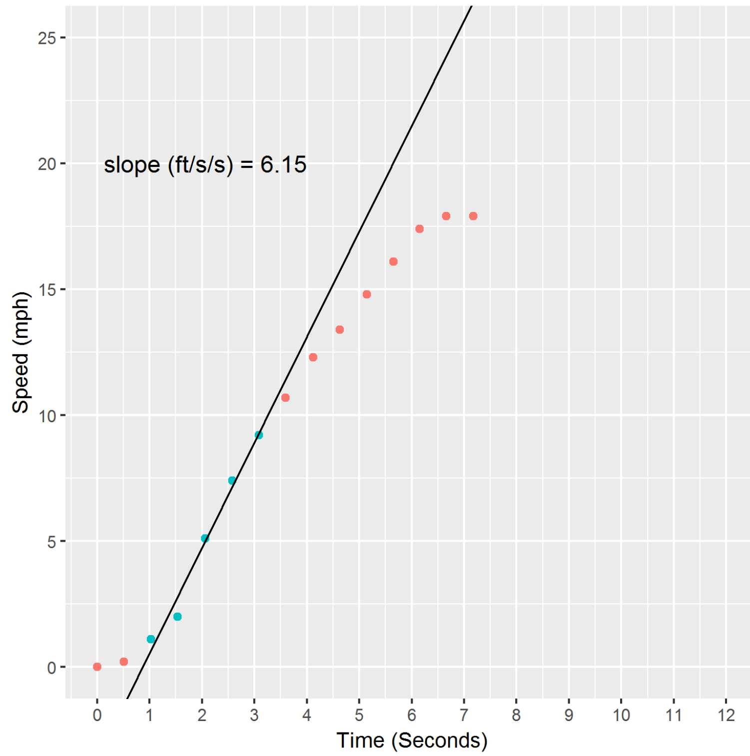


Figure 6. Example Speed-Time Data from Wisconsin Avenue & Meade Street

The field data collection approximates acceleration at zero speed. However, there was not a one-to-one relationship between field data and Vissim inputs. Acceleration in Vissim is not a single value, but rather a function as shown in Figure 7. Desired acceleration (y-axis) varies by speed (x-axis). There are three desired acceleration curves, from which simulated vehicles are randomly assigned a percentile:

- Minimum Acceleration, 0 percentile (Lower green line)
- 50th percentile Acceleration (middle red line)
- Maximum Acceleration, 100th percentile (Upper green line)

Each curve has an exponential-like form with a high initial acceleration tapering off to lower accelerations as speed increases. Default acceleration decreases linearly after approximately 60 mph.

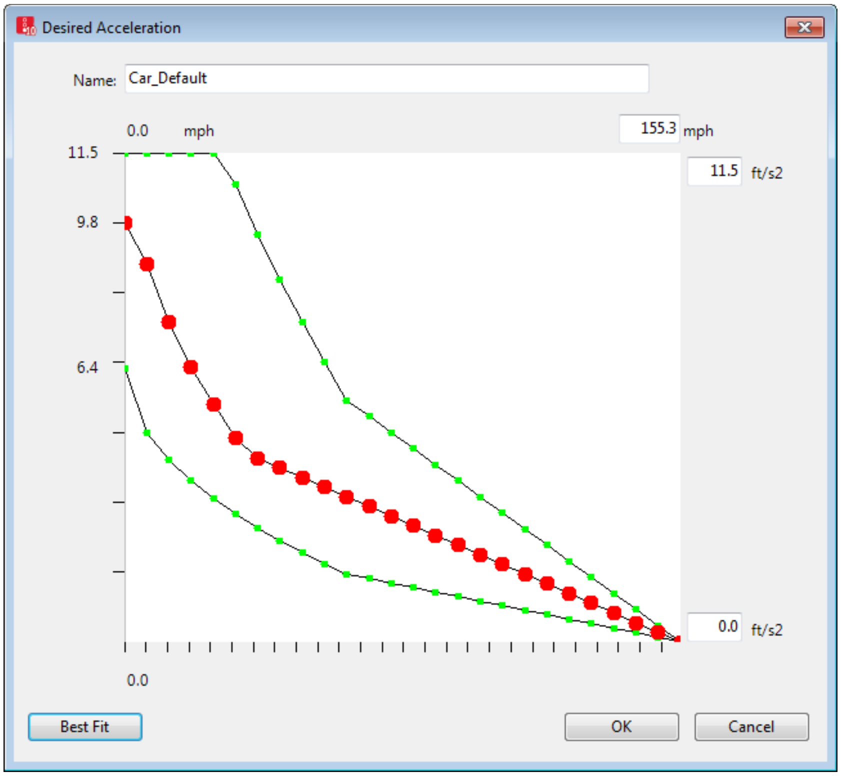


Figure 7. Default Vissim Desired Acceleration Function (Vissim Version 2020)

Acceleration curves were adjusted by trial-and-error using an exponential equation to represent acceleration as shown in Equation 1. This is a similar to the approach used by Appiah to adjust Vissim acceleration functions (2).

$$f(x) = Ae^{-Bx} \tag{1}$$

where:

$f(x)$ = acceleration (ft/s^2) as a function of speed (mph)
A = acceleration (ft/s^2) at 0 mph
B = Coefficient
x = speed (mph)

The trial-and-error process used a sandbox simulation to isolate vehicles accelerating from a stop and record their speed-time relationship. The sandbox model is illustrated in Figure 8. It contains a 90 second cycle pre-timed traffic signal and high vehicle input demand to guarantee a long queue at the start of each cycle. The simulation duration allowed 50 cycles. Repeating the simulation for 20 random seeds allowed returned 1000 saturation flow measurements (50 cycles * 20 runs).

The sandbox model was used for two purposes:

- **Compare simulated versus observed speed-time relationships and trajectory.** Data from the simulation was obtained and processed in the same manner as the field data trajectory data collection.

- **Compare simulated versus observed saturation flow rates.** Simulated saturation flow rates were obtained in the same manner as a separate statewide study (3). The saturation flow rate calculation is shown in Figure 8. All saturation flow rate results are shown for 40 mph desired speeds based on testing the relationship between saturation flow and speed shown in Figure 9. In this figure, each run was conducted with all vehicles having the same desired speed to eliminate speed variance as a variable. Simulated saturation flow rates were observed to be relatively constant with desired speeds of about 35 mph and higher.

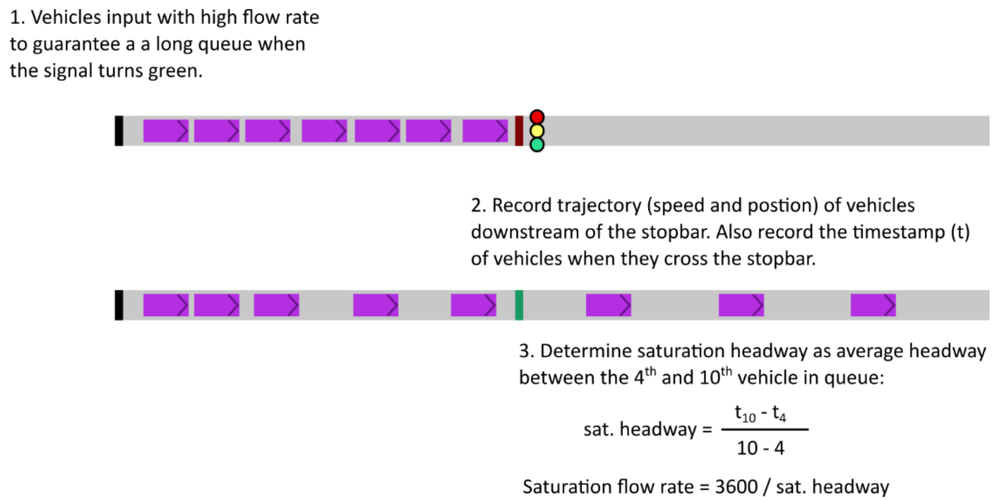


Figure 8. Vissim Sandbox Model for Saturation Flow Measurement

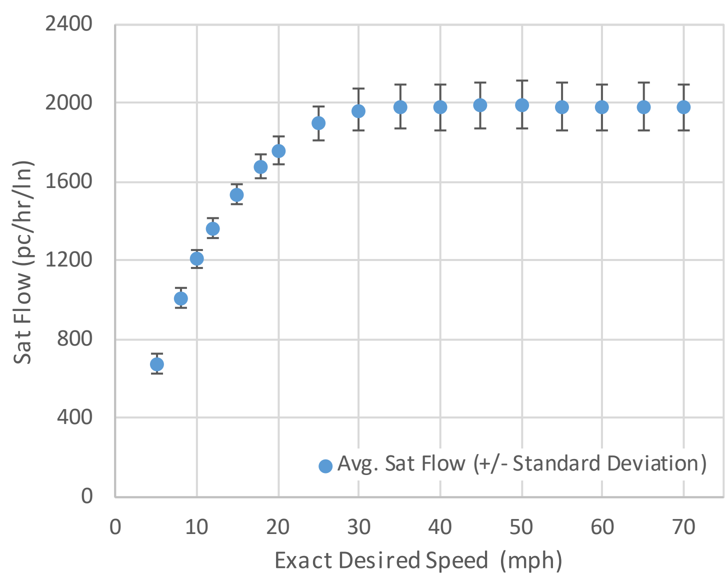


Figure 9. Relationship between Simulated Speed and Saturation Flow
(Simulated results use WisDOT default acceleration and exact (identical) desired speed for all vehicles)

4.3 Results

The field data collected from Appleton, WI had an average of 6.66 ft/s^2 for passenger car acceleration. This result compared favorably to other research as shown in Table 7, where other studies found acceleration to range from about 3.3 to 7.2 ft/s^2.

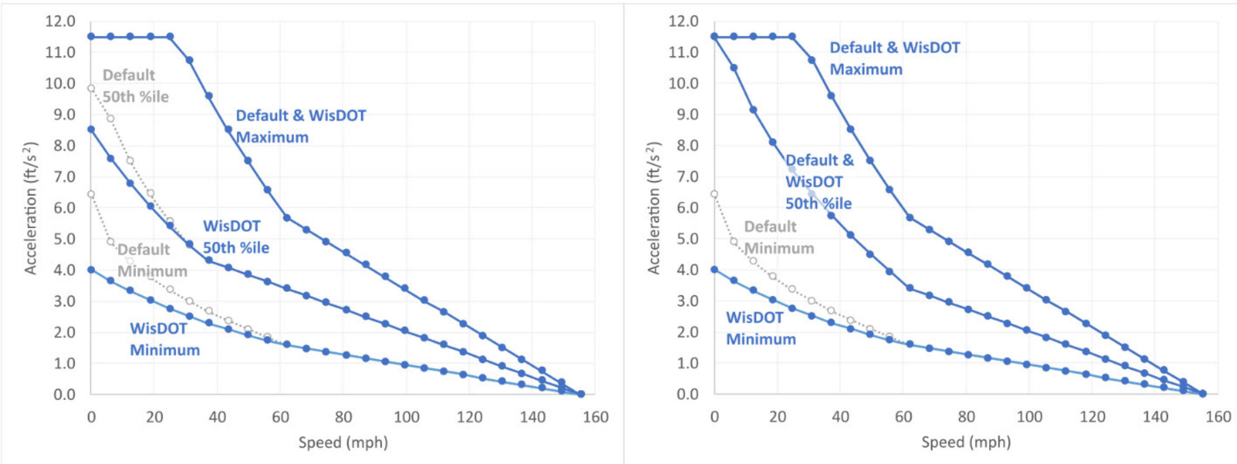
Table 7. Passenger Car Research from Other Research Studies

Research Study	Passenger Car Acceleration (ft/s^2)
Hu et al - *Field Investigation of Vehicle Acceleration at the Stop Line with a Dynamic Vision Sensor* (4)	**3.3 – 6.6**
Long - *Acceleration Characteristics of Starting Vehicles* (5)	*Recommended Design Values:* Above Avg - **7.2** Avg - **6.6** Below Avg - **6.0**
Lu et al - *A Video-Based Approach to Calibrating Car-Following Parameters in VISSIM for Urban Traffic* (6)	*At 0 mph:* **7.9**
Arpan et al - *Speed and Acceleration Characteristics of Different Types of Vehicles on Multi-Lane Highways* (7)	*6 ln road* Standard - **6.2** Big - **6.7** *4 ln road* Standard – **5.6** Big - **6.7**
ITE Traffic Engineering Handbook, 6th Ed (8)	"typical" 3.6 No source is given as to how the typical value was obtained.

Because the field acceleration data collected appeared reasonable, a trial-and-error process was conducted to try and match simulated passenger car acceleration with field data. However, there was not a one-to-one relationship between field data and Vissim inputs. Inputting the 6.66 ft/s2 acceleration at zero miles per hour yielded unreasonable saturation flow rates. Acceleration was ultimately modified to match expected saturation flow rates while still striving for reasonable acceleration values. The trial-and-error process resulted in the following WisDOT default acceleration settings in Vissim as illustrated in Figure 10:

- Lowered the 50th percentile desired acceleration at zero speed to 8.5 ft/s^2 (Default = 9.84 ft/s^2)
- Lowered the minimum desired acceleration at zero speed to 4.0 ft/s^2 (Default = 6.43 ft/s^2). This change was applied to both the desired and maximum acceleration functions.

The adjustments made to the acceleration functions recognize that the field data collected is a limited sample of one location. Adjustments do not preclude faster accelerating cars. The acceleration adjustments are consistent with field observations by increasing the variance and lowering the typical acceleration.



(a) Desired Acceleration Function (b) Maximum Acceleration Function

Figure 10. Passenger Car Acceleration Functions – WisDOT vs Vissim Default

The effect of lowering the acceleration functions decreases saturation flow as shown in Table 8, as well as brings the acceleration closer to the field observed acceleration as shown in Table 9 and Figure 11. If the Vissim acceleration functions were further lowered to better match the field acceleration, the saturation flow would become unrealistic and underpredict capacity.

Table 8. Saturation Flow Rates – Vissim NA Default vs WisDOT Default

	Vissim NA Default	WisDOT Default
Saturation Flow Rate (pc/hr/ln)	2043	1983
Standard Deviation (pc/hr/ln)	100	113

Table 9. Passenger Car Acceleration from 1 s to 3 s after starting From Zero Speed

	Acceleration (ft/s^2)		
	Vissim NA Default	WisDOT Default	Field Observed
Minimum	5.62	4.50	3.58
50th percentile	7.82	7.04	6.64
Mean	7.85	7.11	6.66
Maximum	10.76	11.26	10.29

Simulated acceleration obtained in the same manner as the field data discussed in Section 4.2

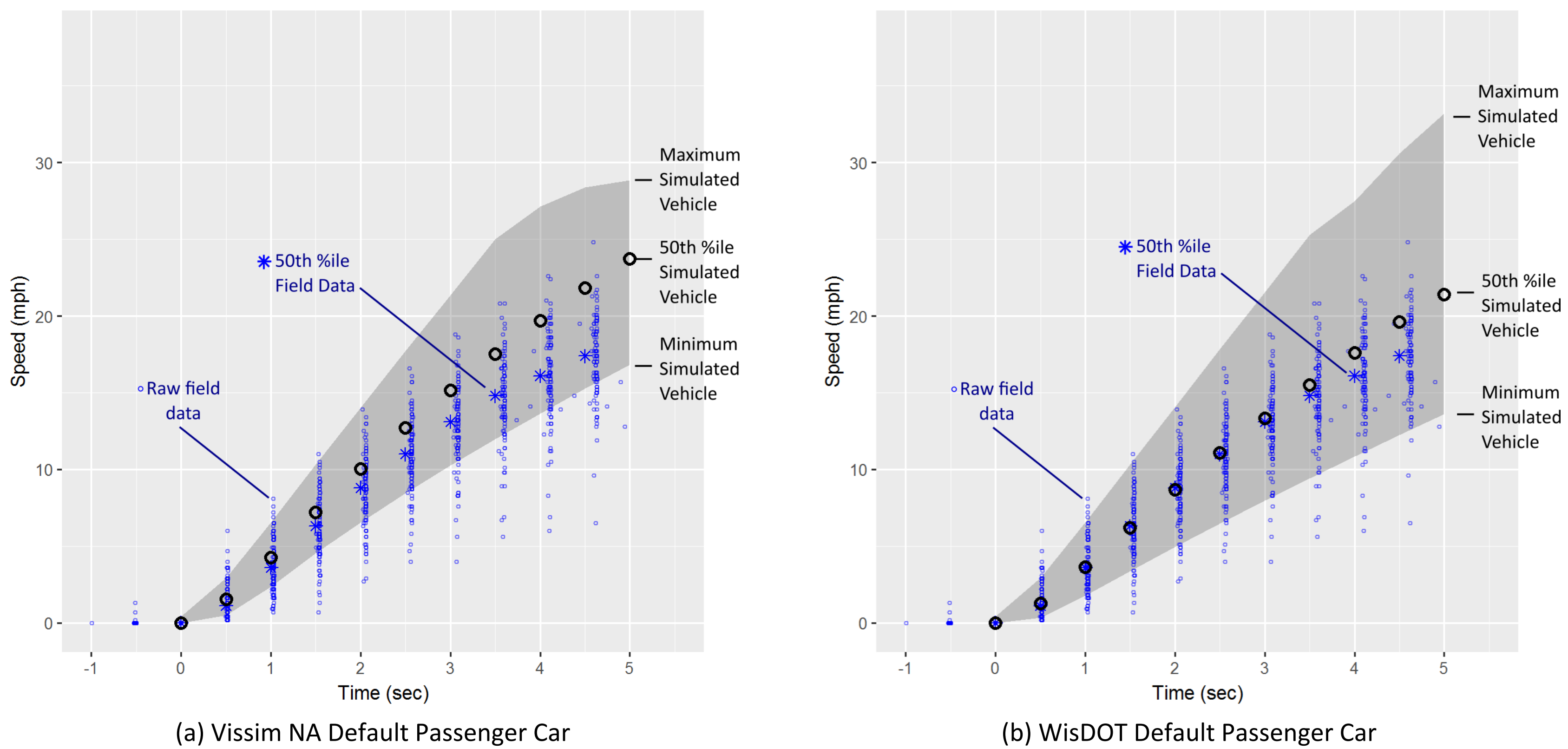


Figure 11. Passenger Car Speed-Time Relationship – Vissim vs Field Data

5 Heavy Vehicle Acceleration

5.1 Objective

The recommended heavy vehicle acceleration inputs aimed to accomplish the following:

- Reflect typical truck accelerations starting from a stop.
- Avoid over or underestimating roadway capacity by resulting in passenger car equivalents consistent with Highway Capacity Manual values.

Heavy vehicles, such as semi-trucks, have anecdotally been suspected of having too high of an acceleration in Vissim to represent typical large trucks in the United States. However, there is little published research on heavy vehicle simulation in Vissim. One such research study from the Texas Transportation Institute at Texas A&M in 2006 investigated truck-only freeway lanes and attempted to calibrate Vissim truck power, weight, acceleration, and deceleration (9). However, the study ultimately used default Vissim values citing that the defaults were "the most reliable current source of this information" and that literature was "primarily geared toward design rather than based on measured vehicle performance" as needed inputs for Vissim (9). The following sections describe another attempt at calibrating heavy vehicle performance characteristics in Vissim using more current research observing truck acceleration from a stop at ramp meters in California (10).

5.2 Methodology

Heavy vehicle (truck) acceleration in Vissim is more complex than passenger cars because there are five inputs affecting acceleration:

- Desired Acceleration
- Maximum Acceleration
- Power Distribution
- Weight Distribution
- "Specific Power for HGV" Vissim network settings

Each of these inputs is a potential parameter to calibrate. This study focused on all parameters except maximum acceleration because it primarily affects simulating vehicles on a grade (uphill/downhill). Common Vissim simulations assume 0% grade as a simplifying assumption to ease model coding, and instead use reduced speed areas to simulate known grades that significantly impact traffic flow.

5.2.1 Acceleration

The methodology to calibrate truck acceleration followed a similar approach to calibrating car acceleration by observing vehicle trajectory starting from a resting position. Acceleration curves in Vissim were adjusted until simulation outputs matched field observed data from a research study in California (10). While this is not Wisconsin-specific data, commercial vehicles are assumed to be similar as they often cross state lines.

Yang et al recorded first-in-queue trucks accelerating from a stop at ramp meters along the I-880 freeway near Newark and Haward, California. Video cameras were setup along the ramp to record timestamps of trucks passing the stop-line and other known distances, up to 500 ft downstream of the stop-line. Speeds were determined by interpolated between the timestamps and known camera distances. The primary results from the study produced speed-distance relationships for heavy trucks (considered Federal Highway Administration (FHWA) tractor trailer classes 8 and 9) as well as medium trucks (considered FHWA single unit truck classes 6 and 7). Other outputs from the study included distributions of truck acceleration at different distances away from the stop-line.

Passenger Car Equivalent Values

Passenger car equivalent (PCE or E_T) values and heavy vehicle adjustment factors (f_{HV}) were also investigated to ensure that the acceleration adjustments would produce reasonable reductions in saturation flow. The effect on saturation flow was simulated by using the same sandbox model shown in Figure 8 using varying levels of truck percentages from 0% to 100%.

Calculating PCE involves the following equations. Equation 2 is the typical method to convert a volume (V) of mixed traffic into an equivalent passenger car volume (V_{PCE}) based on a heavy vehicle adjustment factor (f_{HV}).

$$V_{PCE} = \frac{V}{f_{HV}} \tag{2}$$

Equation 3 is the method for calculating the heavy vehicle adjustment factor given a known percentage of heavy vehicles (P_T) and a PCE factor E_T (1 truck = E_T passenger cars).

$$f_{HV} = \frac{1}{1 + P_T(E_T - 1)} \tag{3}$$

Equation 4 is achieved by substitution of f_{HV} using Equation 2 and Equation 3.

$$E_T = \frac{\frac{V_{PCE}}{V} + (P_T - 1)}{P_T} \tag{4}$$

If the percentage of heavy vehicles (P_T) is 100%, then Equation 4 simplifies to Equation 5 to achieve the PCE factor (E_T).

$$E_T = \frac{V_{PCE}}{V} \tag{5}$$

Using Equation 4 or 5 to estimate the passenger car equivalent (E_T) involves simulating two scenarios. One simulation uses 100% passenger cars to output the V_{PCE} volume. The second scenario simulates a mix of passenger cars and heavy vehicles with known percentages (up to 100% HV) to output the mixed traffic volume (V). Outputs from these scenarios can be input into Equation 4 or 5, depending on the heavy vehicle percentage, in order to obtain the estimated passenger car equivalent.

Heavy Vehicle Adjustment Factors at Signalized Intersections

The Highway Capacity Manual 6 (HCM) includes heavy vehicle adjustment factors for saturation flow rate at signalized intersections (11). For level terrain, HCM 6 equation 19-10 simplifies to Equation 6 and is valid up to 50% trucks:

$$f_{HV} = \frac{100 - 0.78P_T}{100} \tag{6}$$

HCM results from Equation 6 can be compared Equation 7 using two simulated scenarios: one scenario with 100% passenger cars to obtain a base saturation flow rate (s_0), and the second scenario with the same heavy vehicle percentage used in Equation 6 to obtain the mixed saturation flow rate (s). The simulated heavy vehicle factor can be obtained from Equation 7 given that all other saturation flow adjustment factors are held constant in the two scenarios.

$$f_{HV} = \frac{s}{s_0} \tag{7}$$

5.2.2 Truck Power and Weight

Unlike passenger cars, Vissim considers power and weight when determining truck acceleration. For truck weight distribution, the calibration methodology used FHWA research from the Vehicle Travel Information System (VTRIS) database (12) as a readily available public resource. This database contains truck weight information by FHWA vehicle class. Wisconsin-specific data was obtained for year 2014 (latest available data for Wisconsin), as well a national data as summarized by the National Research Council and Jones. (13, 14). Truck power was calibrated by engineering judgement based on power-weight ratios discussed in various literature sources (15, 13).

The truck power and weight distributions in Vissim have a complex relationship to truck acceleration that makes the exact power and weight values difficult to interpret. The “specific power for HGV” network settings provide the basis for all truck calibration and were adjusted first. Figure 12 shows the network settings dialog in Vissim and default minimum and maximum power/weight ratios[1]. The default range is 7 kW/t to 30 kW/t.

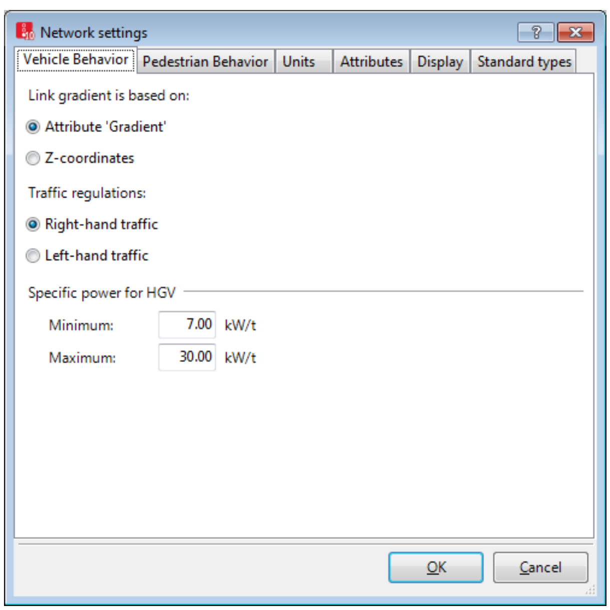


Figure 12. Default Vissim Specific Power for HGV Network Settings

[1] The power/weight settings are always in metric units regardless of choosing imperial units. This document uses metric units to describe power/weight for consistency with the software.

The specific power minimum and maximum values are fundamental to truck simulation in Vissim for two reasons:

1. All trucks are randomly assigned an acceleration percentile that is determined relative to the network settings.
2. All trucks must have a power/weight ratio that falls within the network settings.

Reason 1 demonstrates the complexity of factors affecting truck acceleration and calibration. All trucks in Vissim are independently assigned a random power and random weight from the power and weight distributions. The truck power/weight ratio is determined by dividing the values. Vissim compares the assigned truck power/weight value to the minimum and maximum network settings, and takes one of three actions:

1. **The truck power/weight ratio is below the network minimum.** Vissim assigns the vehicle to the minimum acceleration function.

2. **The truck power/weight ratio is above the network maximum.** Vissim assigns the vehicle to the maximum acceleration function.

3. **The truck power/weight ratio falls within the network minimum and maximum range.** Vissim compares the vehicle power/weight to the *average* network setting and assigns an interpolated acceleration percentile. For example, the default network range is from 7 to 30 kW/t, which results in an average of 18.5 kW/t. If Vissim generates a truck with an 18.5 kW/t power/weight ratio, it would be assigned the 50^{th} percentile acceleration. A truck below 18.5 kW/t would be assigned an acceleration percentile interpolated between the minimum and 50^{th} percentile, and similar interpolation if larger than 18.5 kW/t.

A side effect of these cases is that the *exact* values of power and weight do not matter – only their values relative to the network settings matter. For example, assume two scenarios are created and Vissim generates the same truck in each scenario. The two trucks have identical power and weight values, resulting in a power/weight ratio of 18.5 kW/t. The first scenario uses the default network minimum and maximum settings (averaging to 18.5 kW/t). The second scenario uses minimum and maximum settings averaging to 15 kW/t. The same truck will accelerate faster in the second scenario because it is above the average network setting, even though the truck has identical power and weight values in both scenarios. This means that truck power and weight values cannot be understood in isolation; the impact of their values only make sense in the context of the network settings.

5.3 Results

The WisDOT defaults implement the following changes for heavy vehicles in Vissim:

- **Two new vehicle types are created** instead of a single "Heavy Goods Vehicle" (HGV) class used by default:
  - Single Unit (SU) Trucks
  - Tractor Trailer (TT) Trucks

  These separate vehicle classes better reflect the wide range of truck operating characteristics.

- **The minimum specific power for HGV network setting was lowered to 5 kW/t** (329 lb/hp) power-weight ratio in order to simulate heavier and slower trucks. The default value is 7 kW/t (235 lb/hp).

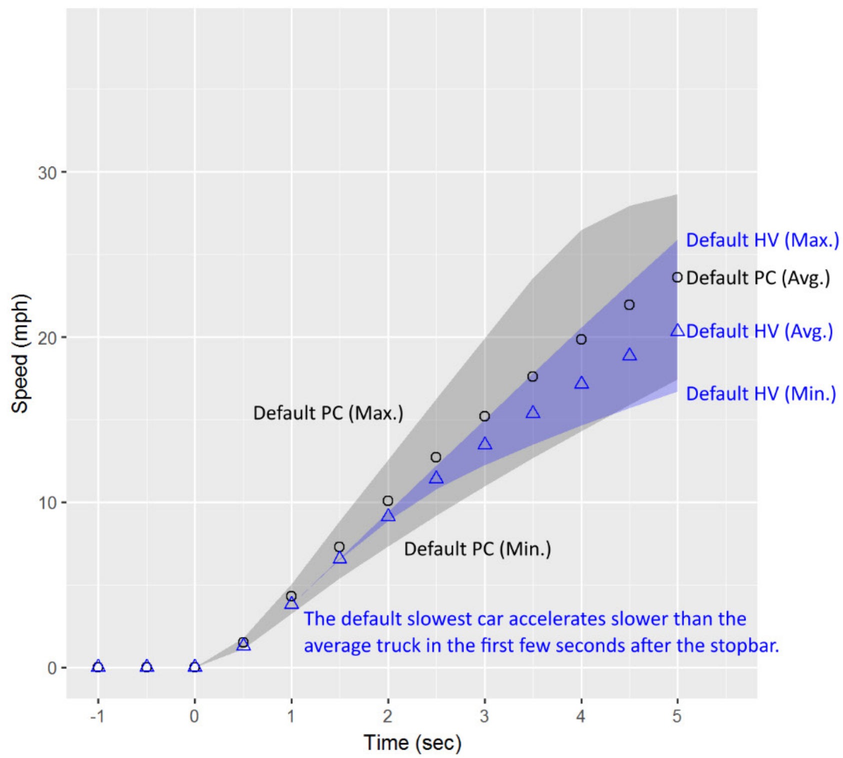
- **Created separate power and weight distributions for both SU and TT vehicle types.** The distributions used in calibration had the following characteristics and are shown in Appendix A:
  - SU power 50th percentile: 205 kW (275 hp), and weight of 11.8 t (26,000 lbs)
  - TT power 50th percentile: 336 kW (450 hp), and weight 23.8 t (52,400 lbs)

  The choice of SU and TT power and weight values is somewhat arbitrary because the values are normalized to the average network specific power for HGV setting, which is 17.5 kW/t in the WisDOT defaults. The power and weight values were chosen to minimize "clipping" where simulated vehicles would exceed the network settings.

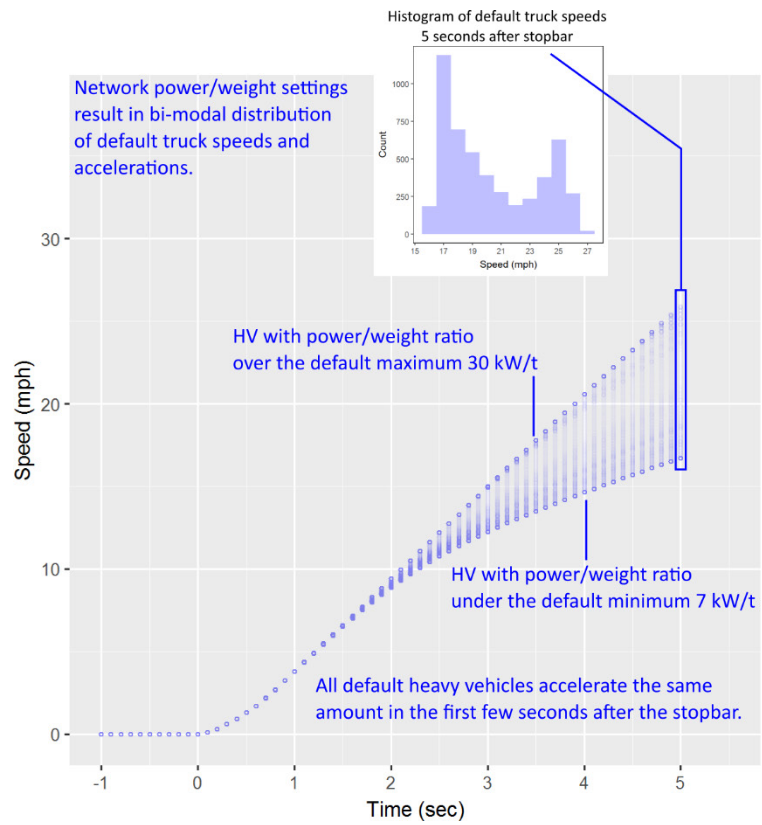
- **Created separate desired acceleration functions for SU and TT vehicle types.** These functions lowered each of the minimum, 50th percentile, and maximum desired accelerations. Figure 14, Figure 15, and Appendix A show details of the acceleration functions. The 50th percentile is lowered from the default of 8.2 ft/s^2 at zero speed for all trucks, down to 5.25 ft/s^2 for SU, and 2.5 ft/s^2 for TT.

The combined effect of the above significantly changes heavy vehicle characteristics in Vissim. Figure 13 (a) shows default heavy vehicle acceleration (speed vs time) in comparison to passenger cars, and (b) shows the distribution of default heavy vehicle speeds when accelerating from zero mph. The single default heavy vehicle type appears to be a compromise of trying to represent both heavier and lighter trucks all in one vehicle type. This compromise can be seen from several trends in Figure 13:

- All default trucks accelerate the same amount from about 0 - 2 seconds from rest, until the trucks reach about 10 mph. This is because the default 50th percentile acceleration and maximum desired acceleration have the same values until about 10 mph.
- The slowest default passenger car accelerates slower than all heavy vehicles until about 4 seconds after starting from rest. This may not match user expectation of how a heavy vehicle accelerates from field experience.
- The default power and weight distributions frequently result in values that exceed the default "Specific Power for HGV" network settings. This results in the simulation clamping truck acceleration to the minimum or maximum accelerations, and creates a bi-modal distribution of speeds as can be seen in Figure 13b.



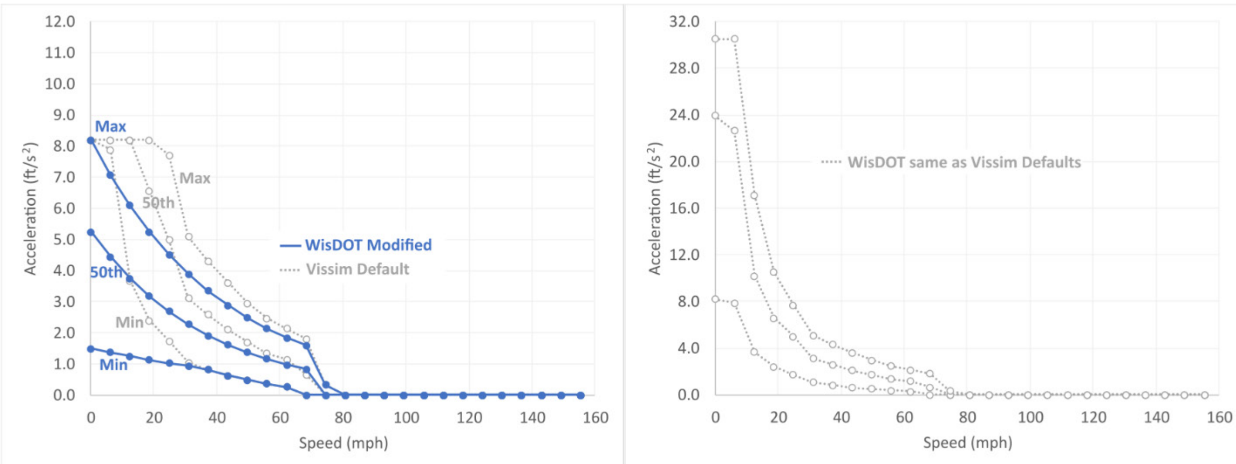
(a) Default PC vs Default heavy vehicle



(b) Default heavy vehicle – raw data

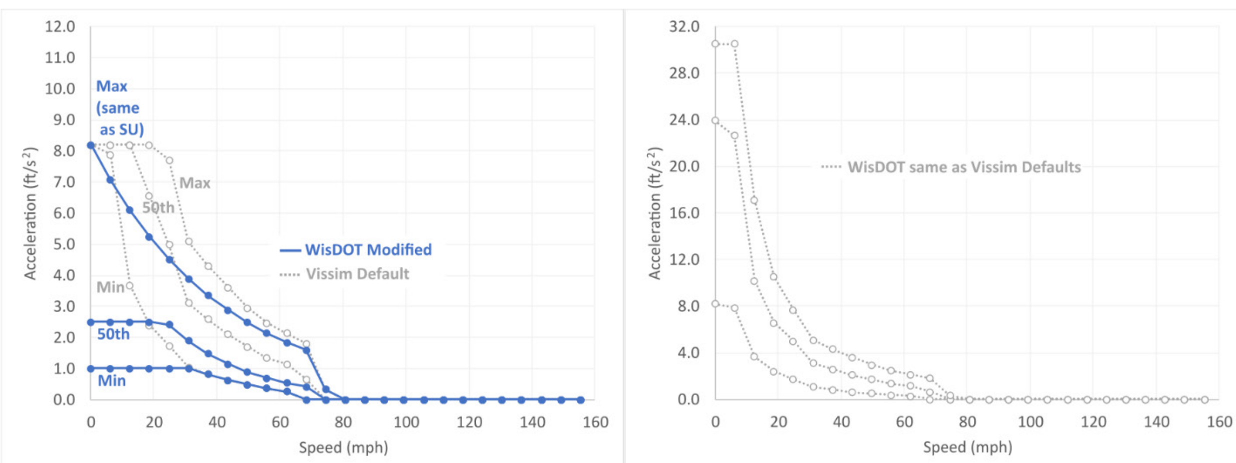
Figure 13. Default Vissim Speed-Time Relationship for PC and HV (40 mph desired speed distribution)

Separating the default heavy vehicle type into SU and TT vehicle types allowed explicit modeling of their performance characteristics. Figure 14 and Figure 15 show the modified desired acceleration functions for each truck type. Appendix A contains tables of the acceleration functions. The modifications typically result in SU trucks slower than passenger cars, but faster than TT trucks. Acceleration for TT trucks are the slowest of all vehicle types.



(a) Desired Acceleration Function (b) Maximum Acceleration Function

Figure 14. WisDOT Modified Single Unit Truck Acceleration



(a) Desired Acceleration Function (b) Maximum Acceleration Function

Figure 15. WisDOT Modified Tractor Trailer Truck Acceleration

The modified truck acceleration distributions were obtained through trial-and-error adjustment until Vissim outputs mimicked field data from the California ramp meter study (10) and passenger car equivalent values from the HCM. Figure 16 and Figure 17 show the speed-distance relationship from the simulation as compared to the field data. The default heavy vehicle type appears similar to SU truck field data after 500 ft, despite the initially higher acceleration. WisDOT TT trucks accelerate significantly slower than the default trucks, reaching about 30 mph after 500 ft compared to the default truck reaching 35 mph after 500 ft. Figure 18 and Figure 19 compare the speed-distance relationship to the Vissim default heavy vehicle for distances up to 5000 ft. WisDOT SU trucks outpace the Vissim default trucks after 500 ft. WisDOT TT trucks take about 250 to 1000 ft longer to reach the same speeds as default trucks.

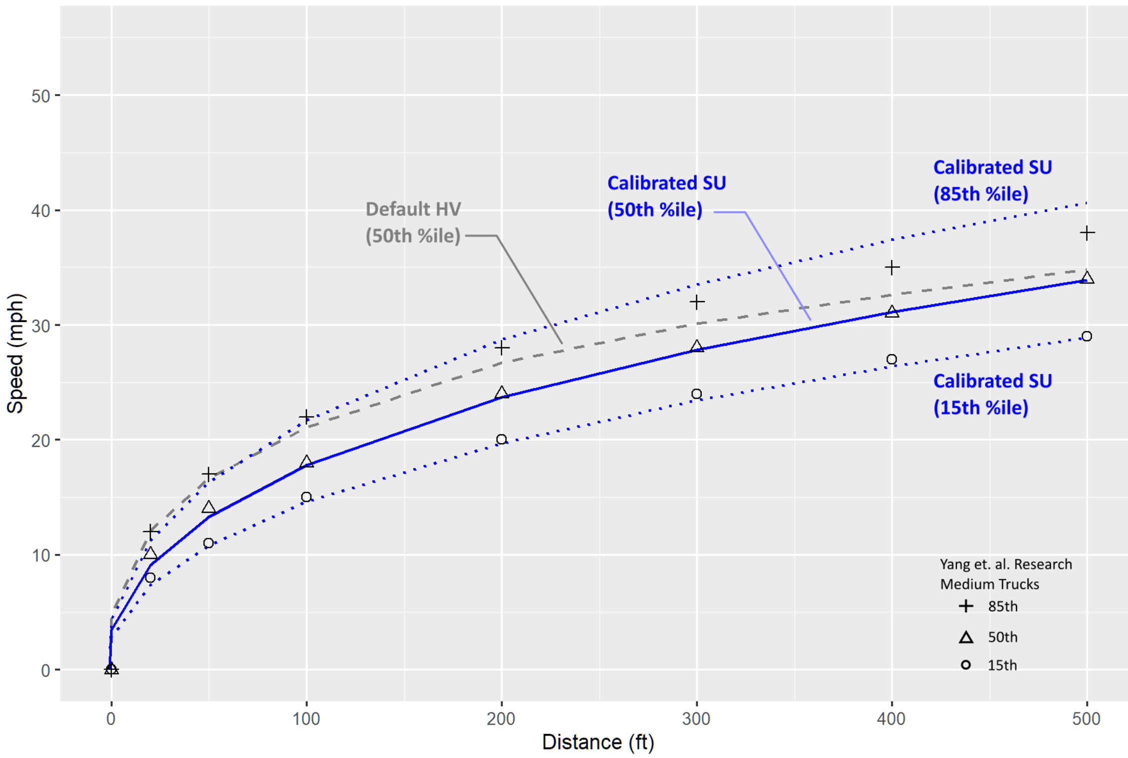


Figure 16. Speed-Distance - WisDOT Single Unit Truck vs Yang et. al. Medium Truck (65 mph desired speed distribution)

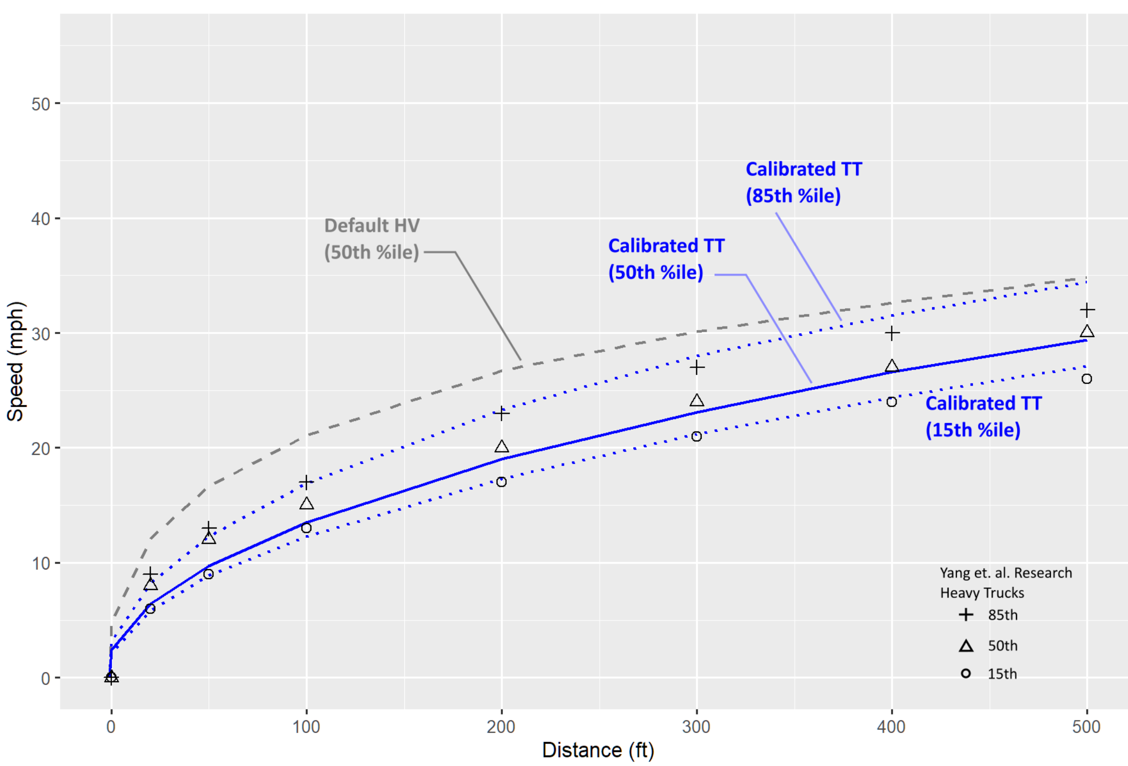


Figure 17. Speed-Distance - WisDOT Tractor Trailer Truck vs Yang et. al. Heavy Truck (65 mph desired speed distribution)

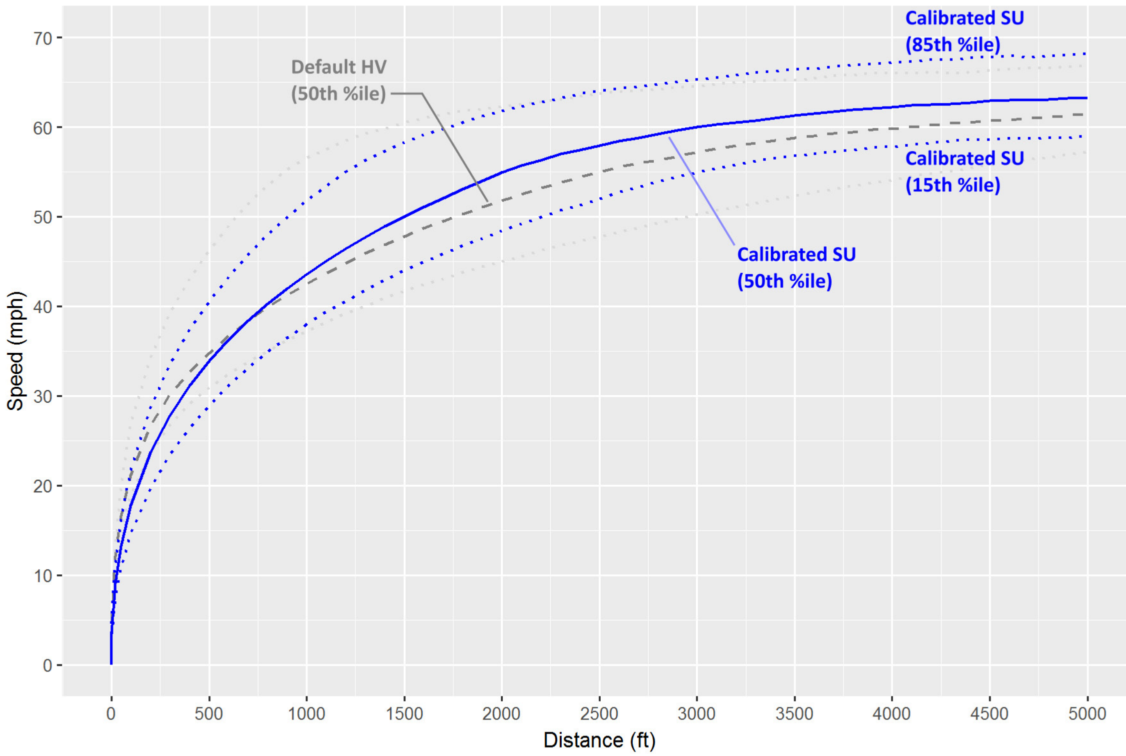


Figure 18. Speed-Distance - WisDOT Single Unit Truck vs Vissim Default HV (65 mph desired speed distribution)

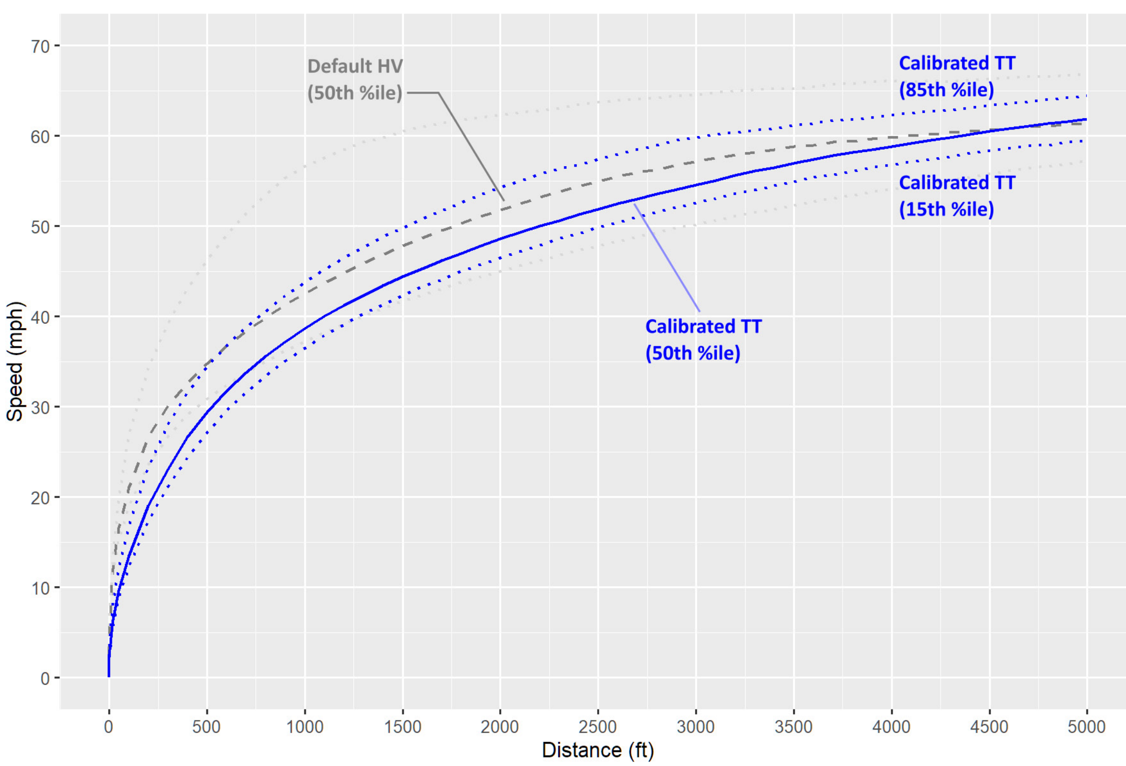


Figure 19. Speed-Distance - WisDOT Tractor Trailer Truck vs Vissim Default HV (65 mph desired speed distribution)

Table 10 shows the effect on saturation flow rate with the modified truck vehicle types. The SU type results in a passenger car equivalent (E_T) of about 1.76, and about 2.69 for TT. The resulting simulated saturation flow adjustment factors closely match the HCM values. By comparison the default HGV vehicle type is equivalent to about 1.6 passenger cars and saturation flow adjustment factors are higher than HCM value.

Table 10. Simulated Saturation Flow and Passenger Car Equivalents versus HCM Values

Vissim NA Default Vehicle Types and Acceleration					
	Sat Flow (veh/hr/ln)		Sat Flow Adjustment		
% Heavy Vehicles	Avg	SD	Sim.	HCM	Sim. E_T
0%	**2043**	100	1.000	1.000	NA
2%	2025	122	0.991	0.984	1.45
5%	2000	146	0.979	0.961	1.43
10%	1954	165	0.957	0.922	1.45
100%	1258	96	0.616	NA	**1.62**

WisDOT Default Vehicle Types and Acceleration					
	Sat Flow (veh/hr/ln)		Sat Flow Adjustment		
% Heavy Vehicles	Avg	SD	Sim.	HCM	Sim. E_T
0%	**1983**	113	1.000	1.000	NA
2%*	1949	206	**0.983**	**0.984**	1.89
5%*	1916	276	**0.966**	**0.961**	1.70
10%*	1832	342	**0.923**	**0.922**	1.83
100% SU	1128	134	0.569	NA	**1.76**
100% TT	736	74	0.371	NA	**2.69**

Notes:

- Avg, SD = Average and Standard Deviation of simulated (Sim.) results using 40 mph desired speed distribution
- *Calibrated simulations with 2%, 5%, and 10% heavy vehicles (HV) include an equal mix of calibrated Single Unit (SU) and Tractor Trailer (TT) trucks.
- Saturation Flow Rate Adjustment Factor = [scenario sat flow] / [0% HV scenario sat flow]
- Truck Equivalent Factor (E_T) = ([0% HV scenario sat flow] / [scenario sat flow] + (%HV – 1)) / %HV

6 Effect on Freeway Capacity

Acceleration affects traffic operations on all facility types, including freeways where vehicles need to accelerate at on-ramps or accelerate after congested bottleneck locations. The effect of the WisDOT default parameters on freeway capacity was investigated by using two “sandbox” freeway models discussed in the following sections:

- **Circular Test Track Model** – Isolates variables to determine their effect on capacity. Capacity is measured as the maximum flow rate on the test track.
- **Merge Model** – Simulates a hypothetical congested on-ramp location. Capacity is measured as the maximum discharge from the bottleneck location.

6.1 Circular Test Track Model

Circular test track experiments have been done in real life to investigate traffic flow theory and phenomena (16, 17). A one lane circular test track was setup in Vissim as illustrated in Figure 20. Using one lane eliminates the effect of lane changing on capacity. Passenger cars were incrementally loaded into the test track to simulate conditions from free-flow to oversaturated. Speed, flow, and density was collected in 100 ft subsegments in 15 minute increments. The circumference of the circle was arbitrarily drawn at just under 1 mile. Using 100% passenger cars allowed the results to reflect the HCM freeway capacity units of passenger cars/hour/lane. All simulations used the default Wiedemann 99 car following parameters (Default "Freeway (free lane selection)" driver behavior).

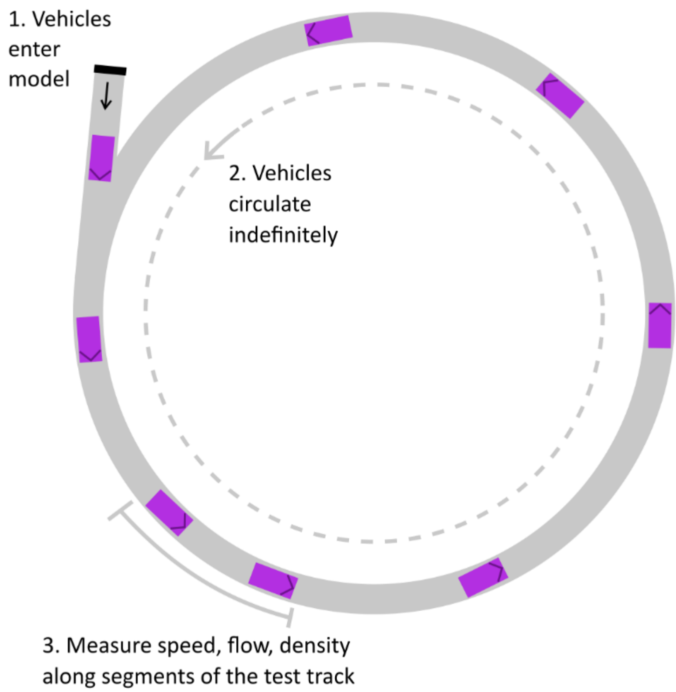


Figure 20. Circular Test Track Model

6.1.1 Effect of Desired Speed

The WisDOT default parameters modify desired speeds as well as acceleration. The effect of speed on capacity was first isolated by simulating scenarios where all passenger cars had identical desired speeds and used the WisDOT default passenger car acceleration. Having all vehicles with the same desired speed is not realistic but allows investigation of the general trend of speed versus capacity. More realistic test cases are discussed in Section 6.1.2 and 6.2.

Scenarios were run for desired speeds of 55 to 80 mph in 5 mph increments. Speed-flow results are shown in Figure 21. Each graph is titled by the desired speed assigned to all vehicles in the scenario. Each dot represents a 15 minute speed-flow observation along the test track. Results were classified as uncongested (pink) or congested (grey). The vertical dotted line is the average maximum flow of the 20 simulation runs for each desired speed scenario. From these results, the following trends can be observed:

- **Under idealized conditions, the speed at capacity is the same as free-flow speed.** Vissim uses the Wiedemann car following model, which under steady-state conditions reverts to the Pipes car following model as mathematically shown by Rakha (18) and demonstrated by the horizontal uncongested speed-flow relationship Figure 21. By contrast, the HCM speed-flow relationship decreases speed with increasing density of traffic in uncongested conditions (HCM 6 Exhibit 12-16). Speed at-capacity for a 70 mph freeway in the HCM decreases by about 75% to 53 mph.

- **Capacity increases with increasing speed**. Maximum 15 minute flow rates ranged from about 2450 pc/hr/ln at 55 mph up to about 2600 pc/hr/ln at 70 mph. Higher flows up to 2800 pc/hr/ln were also observed in some simulation runs. These values are high in comparison to the HCM 2,250 to 2,400 pc/hr/ln range, but the simulated scenarios do not include lane changing or desired speed variance. High simulated flow rates can be expected from Vissim in isolated conditions.

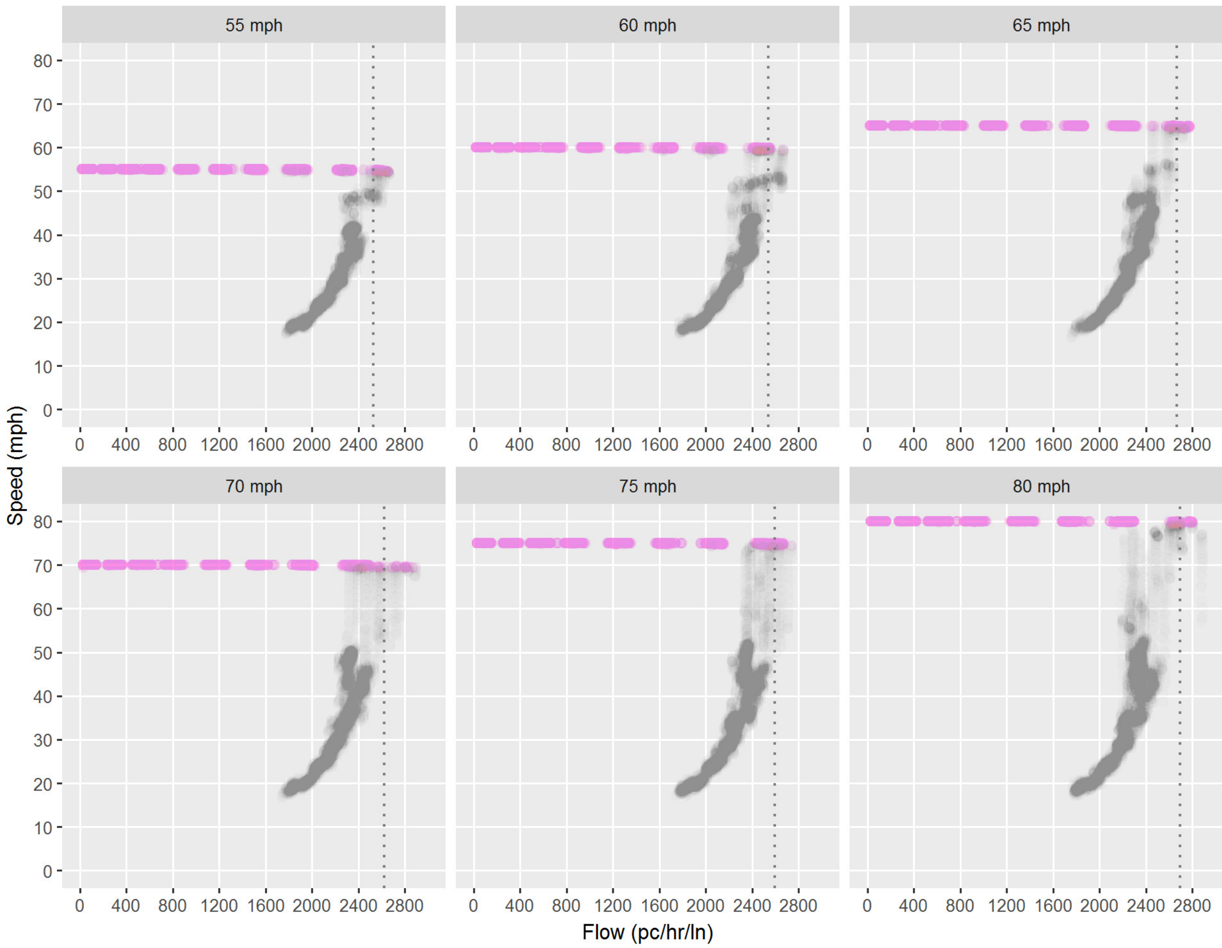


Figure 21. Circular Test Track Speed-Flow Results with Constant Desired Speeds 55 – 80 mph

6.1.2 Effect of Acceleration

Scenarios were run with the circular test track with and without the WisDOT default acceleration to determine the relationship between acceleration and capacity. These scenarios also used the WisDOT 70 mph desired speed distribution after understanding the effect that speed has on capacity (discussed in Section 6.1.1). Speed-flow results are shown in Figure 22. Red points are from the scenario with WisDOT default acceleration, black points are from the Vissim default acceleration. From these results, the following trends can be observed:

- **Maximum freeway capacity is not affected by acceleration.** Both scenarios with and without WisDOT default acceleration resulted in a maximum flow of about 2500 pc/hr/ln.
- **Acceleration slightly lowers flow rates in congested flow.** Comparing the points in the congested flow regime (lower part of the graph) in Figure 22 shows that the WisDOT acceleration scenario is shifted slightly toward lower flows. This is logical because vehicles stopping and starting have slower acceleration in the WisDOT acceleration scenario.
- **The speed-flow relationship is constrained by the slowest vehicle in desired speed distribution.** The circular test track does not allow for lane changing. Faster vehicles eventually catch up to the slowest vehicle. 60 mph is the slowest desired speed for passenger cars in the 70 mph WisDOT desired speed distribution. The speed at capacity is also 60 mph, which is expected given the trend from Figure 21 where the speed at capacity is constrained to free-flow speed.

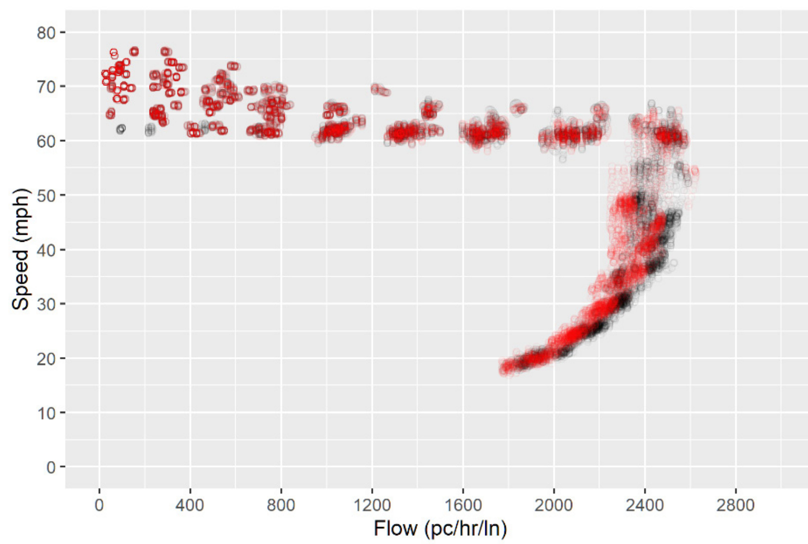


Figure 22. Circular Test Track Speed-Flow Results with and without WisDOT Acceleration (Black = Vissim Default Acceleration, Red = WisDOT Default Acceleration. Both use 70 mph WisDOT Desired Speeds)

6.2 Merge Model

A more realistic test of freeway capacity was investigated by simulating a freeway merge bottleneck as shown in Figure 23.

The segment immediately downstream of the merge measured capacity as the discharge of the bottleneck. In this model, the capacity is affected by lane changing parameters in Vissim as well as the car following model parameters. Other choices for modifying the merge link behavior may produce different freeway capacity results than shown. Parameters of the model included:

- Model includes 3 lanes with an approximately 0.5 mile segment upstream of the merge and 2200 ft segment downstream of the merge. The merge segment is 1000 ft long.
- All links in the Vissim model used the default Vissim freeway driver behavior and lane changing.

- The merge link used -30 ft/s^2 for the maximum deceleration for cooperative braking. (Increasing the cooperative braking deceleration from the default of -9.84 ft/s^2 minimizes the number of "stuck" vehicles coming to a full stop at the end of the merge.)
- Speed, flow, and density were collected throughout the model limits in 100 ft segments, except for in the auxiliary merge lane.
- 70 mph WisDOT desired passenger car speeds were used for the simulation. Simulated ramp volumes varied from 800 to 1750 pc/hr. Mainline volumes upstream of the merge ranged from 1500 to 2450 pc/hr/ln.

The purpose of the merge model was more of an exploratory exercise into freeway capacity as the impact of acceleration on capacity was already proven minimal in Figure 22. The merge model showed similar trends with and without WisDOT acceleration. Results for the scenarios with the modified acceleration are discussed below.

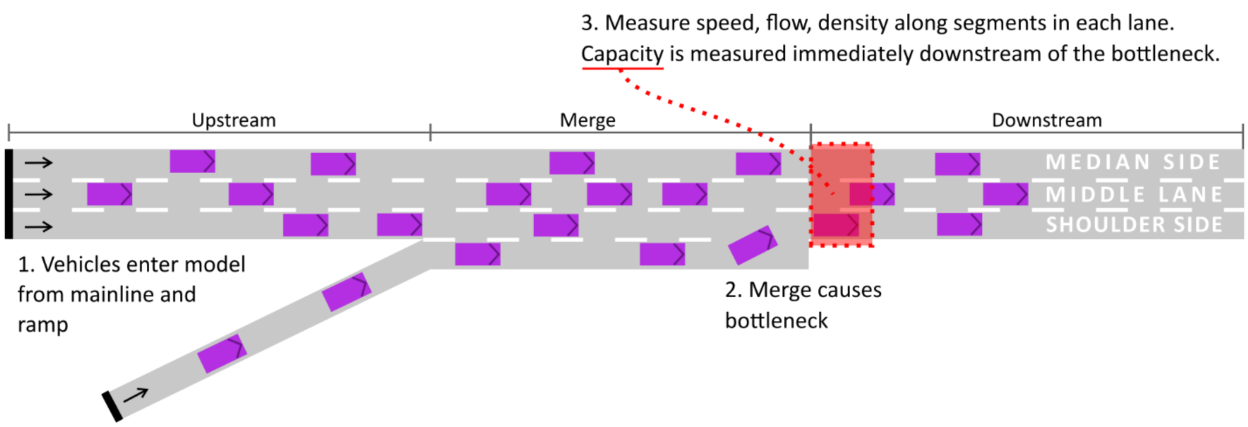


Figure 23. Merge Test Model

Speed-flow results from the merge test model are shown in Figure 24 for each segment and lane group in the model with the 70 mph WisDOT speeds and acceleration parameters. Discharge from the merge bottleneck is shown in red. Several observations can be made from these results:

- **Capacity varies by lane.** The median side lane furthest from the merge had the highest throughput of about 2450 pc/hr/ln (red points in Downstream, Median Side graph). The shoulder side lane nearest the merge had a maximum of about 2250 pc/hr/ln. The results were not investigated to determine if it was a coincidence that the median side maximum volume matches the maximum per lane mainline input volume.
- **The location of the speed-flow measurement is critical.** Measuring too far upstream or downstream of the bottleneck location only captures part of the speed-flow relationship and may not capture the maximum throughput. Interesting patterns can also be seen from the simulation because the speed-flow data was collected every 100 ft in the model. The merge section shoulder side lane exhibited the same speed-flow curve shape seen in the circular test track model. The downstream shoulder side section showed a "stair case" pattern due to slow vehicles accelerating after merging into the mainline – the vehicles get progressively faster

every 100 ft downstream of the bottleneck as there are no other downstream constraints in the model.

- **Calibration beyond the WisDOT default acceleration and desired speed parameters is likely required to replicate field-observed capacity.** While this simulation did not compare to observed field data, replicating field data would likely require additional adjustments beyond the WisDOT default parameters due to the number of factors affecting freeway capacity. Car following parameters (CC0, CC1, etc) and lane changing parameters (deceleration and cooperative braking, etc) may have more of an effect on freeway capacity.

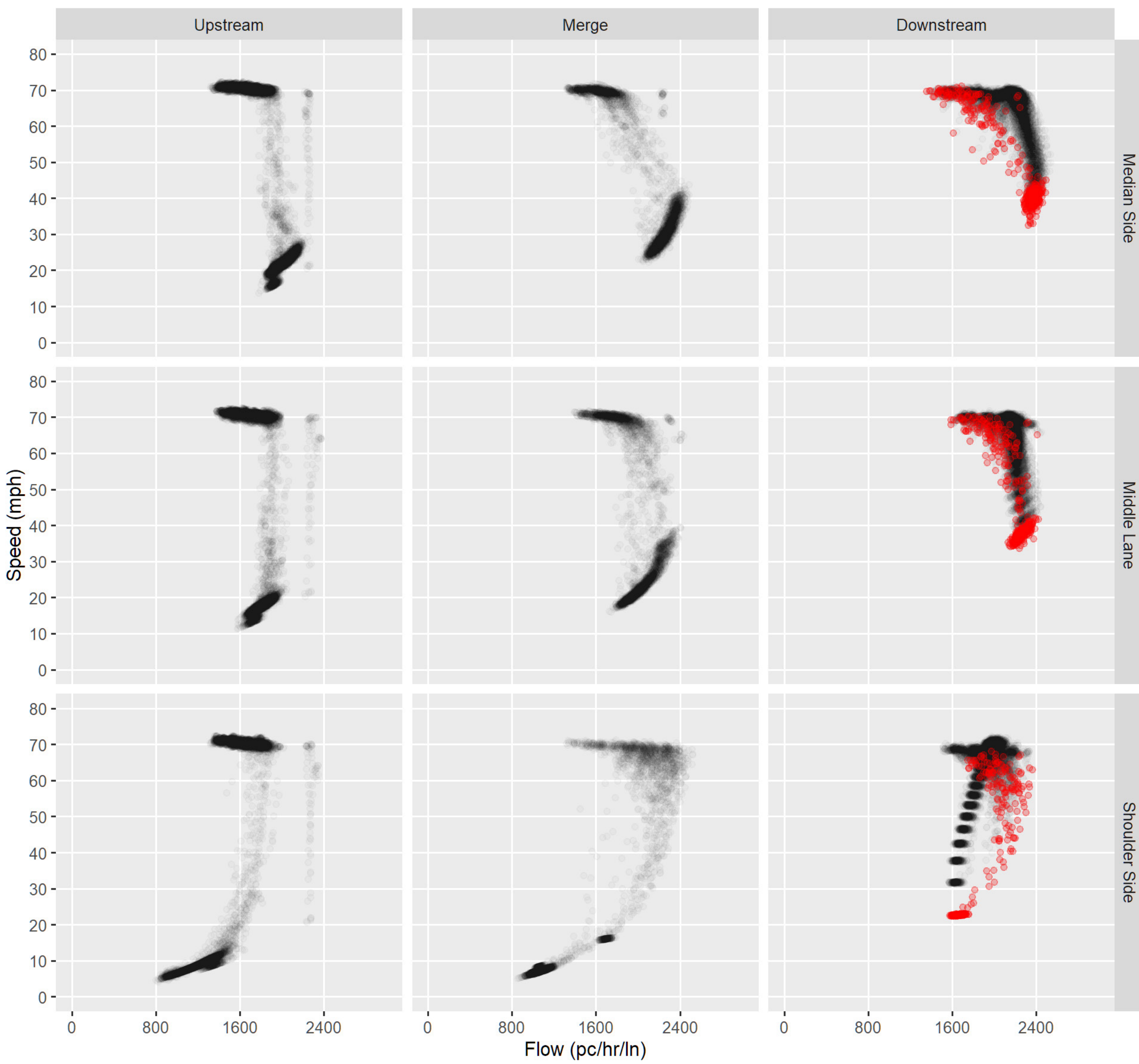


Figure 24. Merge Model Speed-Flow Results
(With WisDOT Acceleration and 70 mph WisDOT Desired Speeds. Bottleneck discharge shown in red)

7 Effect on Intersection Queue

The effect of the WisDOT default settings on intersection queue length was investigated using a "sandbox" signalized intersection model shown in Figure 25. Two scenarios were run: one with the WisDOT defaults (speed, acceleration, and vehicle compositions), and the other scenario with Vissim NA defaults. Each scenario included the following assumptions:

- 40 mph speed limit
- Volumes vary by approach as shown in Figure 25
    - 5% heavy vehicles on each approach (70/30% SU/TT split for the WisDOT scenario)
    - Peak Hour Factor = 1.0
- No turning vehicles – all vehicles go straight through the intersection
- Signal timing as shown in Figure 25
- 4500 s simulation duration, 900 s warm-up period

The test intersection was also modeled in Synchro for comparison purposes using both the Synchro Standard (percentile delay method) and HCM 6 method. The Synchro model did not apply any special adjustments; all parameters were left at defaults.

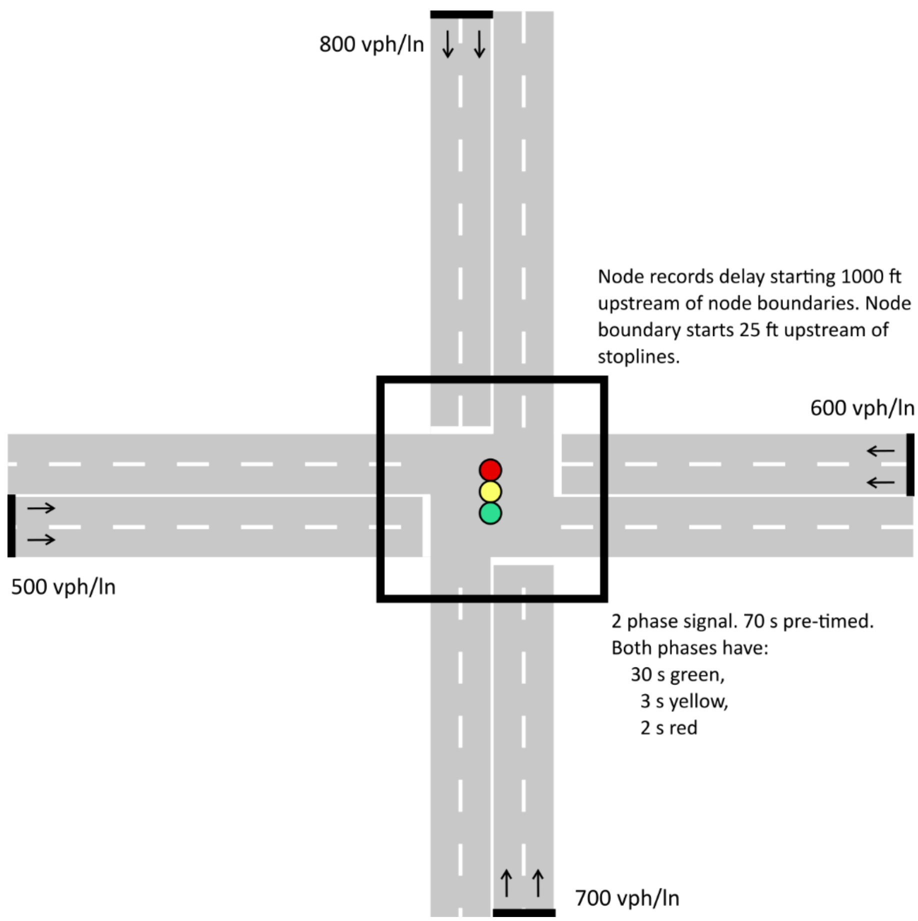
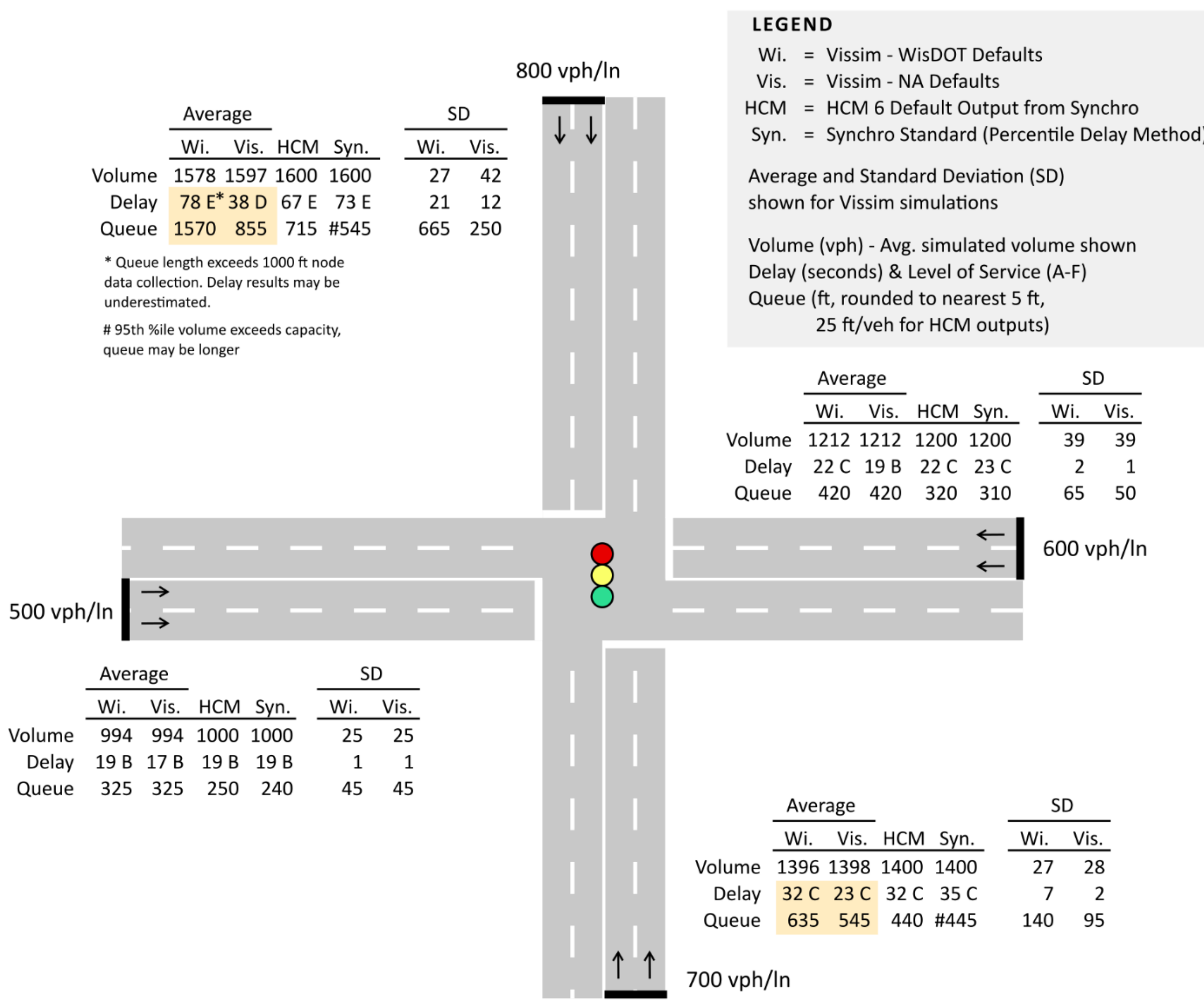


Figure 25. Intersection Test Model

Results from the test intersection scenarios are shown in Figure 26. Differences between the Vissim NA default scenario and WisDOT default scenario increase as volumes increase. From these results, the following observations can be made:

- **WisDOT defaults increase average delay in oversaturated conditions.** The highest volume SB approach showed at least double the delay when using the WisDOT defaults. The NB approach also showed about 10 s more delay compared to the Vissim NA defaults.
- **WisDOT defaults increase queue length standard deviation.** Using the statistical t-test to compare the WisDOT and NA default scenario, the difference between the average SB queue is about 390 ft (p-value = 0.0518). Larger standard deviation means that more simulation runs would be required to obtain reliable results from the simulation.
- **Simulated queue lengths are longer than Synchro or HCM queue lengths.** On all approaches, the simulated queue lengths were longer those predicted by the macroscopic models. This is likely due differences between micro and macroscopic methods, as well as differences in reporting (maximum from the simulation, 95th percentile from macroscopic methods).



Southbound (800 vph/ln):

	Average Wi.	Average Vis.	Average HCM	Average Syn.	SD Wi.	SD Vis.
Volume	1578	1597	1600	1600	27	42
Delay	78 E*	38 D	67 E	73 E	21	12
Queue	1570	855	715	#545	665	250

Westbound (600 vph/ln):

	Average Wi.	Average Vis.	Average HCM	Average Syn.	SD Wi.	SD Vis.
Volume	1212	1212	1200	1200	39	39
Delay	22 C	19 B	22 C	23 C	2	1
Queue	420	420	320	310	65	50

Eastbound (500 vph/ln):

	Average Wi.	Average Vis.	Average HCM	Average Syn.	SD Wi.	SD Vis.
Volume	994	994	1000	1000	25	25
Delay	19 B	17 B	19 B	19 B	1	1
Queue	325	325	250	240	45	45

Northbound (700 vph/ln):

	Average Wi.	Average Vis.	Average HCM	Average Syn.	SD Wi.	SD Vis.
Volume	1396	1398	1400	1400	27	28
Delay	32 C	23 C	32 C	35 C	7	2
Queue	635	545	440	#445	140	95

Figure 26. Intersection Test Model Results

8 Summary and Future Work

This study presented recommended WisDOT default vehicle fleet parameters for Vissim. Establishing local default parameters should help provide a better starting point for calibration compared to Vissim's European-based or North American defaults. The recommended WisDOT defaults also promote consistency for models produced for WisDOT projects. This study used Wisconsin-based research to establish defaults for the following parameters in Vissim:

- **Vehicle Fleet Distribution** – Used Wisconsin DMV and local projects to estimate typical amounts of various vehicle makes/models. Resulted in generally lower amounts of pickup trucks compared to Vissim's North American defaults.

- **Desired Speed Distributions** – Used Automatic Traffic Recorder data to develop speed distributions observed for a variety of posted speeds and facility types. Resulted in more realistic s-shape distributions that capture drivers' tendencies to travel at greater than posted speeds.

- **Passenger Car and Heavy Vehicle Acceleration** – Used Wisconsin and national research to model characteristics of different vehicle types. Resulted in generally lower acceleration that better matches observed saturation flow rates in Wisconsin.

A Vissim model file (inpx file) was created that implements the recommendations. Appendix A contains details of all the parameters and values changed.

The WisDOT Vissim defaults establish by this study provide the foundation for future work to create additional efficiencies in calibrating simulations. There are many more parameters in Vissim that could be investigated in future work, including but not limited to:

- Investigating a range of intersection turning speeds at intersections and their impact to saturation flow. Speeds on interchange ramps could also be investigated.

- Investigating deceleration. Just as acceleration was found to differ from the software supplied defaults, deceleration may differ as well.

- Investigating Wiedemann 74 and 99 parameters and their impact on capacity.

- Investigating lane changing parameters and their impact on lane utilization and capacity.

- Establishing gap acceptance parameters for priority rules and conflict areas for roundabouts and other unsignalized intersections.

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Appendix A
WisDOT Default Vissim File Creation

Table of Contents

1 Introduction

This document shows the software settings that were changed from the Vissim North American (NA) default file in order to implement the recommended WisDOT default settings. Users do not have to create the WisDOT default file from scratch; the file can be obtained from WisDOT. At the time of this document creation, Vissim Version 11.00-10 was used.

This document assumes users are familiar with using “lists” in Vissim, including: adding, deleting, and editing items. An example is shown in Figure 1. The green plus icon is for adding items, pencil icon for editing, and red “x” for deleting. Items and values may need to be edited on both the left and right hand lists, depending on what is being edited. See the Vissim Manual for additional help.

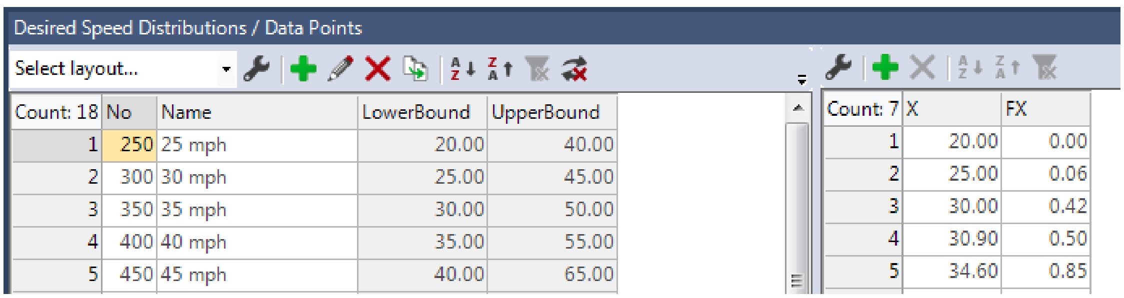


Figure 1. Example List Editor in Vissim

The WisDOT default file deletes many of the Vissim NA defaults, such as desired speeds. If the user is starting from the NA default file, and depending on the order that items are deleted, Vissim may generate an error message warning that dependent items will be deleted. These messages can be safely accepted (click “continue”). Deleted items are replaced with WisDOT defaults as appropriate.

2 Vehicle Fleet Distribution

2.1 2D/3D Models

2D/3D models can be edited from the *Base Data -> 2D/3D Models* menu (Figure 2).

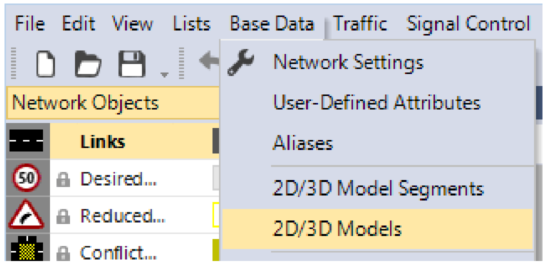


Figure 2. 2D/3D Model Menu

Additional vehicle model files (v3d files) can loaded from the software installation folder, typically: "C:\Program Files\PTV Vision\PTV Vissim 11\Exe\3DModels\Vehicles\Road" The following files are needed in addition to those implemented in the Vissim NA default file:

- Bus - C2 Standard 2-doors.v3d
- VAN - Stepvan 01.v3d

2.2 2D/3D Model Distributions

The 2D/3D model distributions can be edited from the *Base Data -> Distribution -> 2D/3D Model* menu (Figure 3).

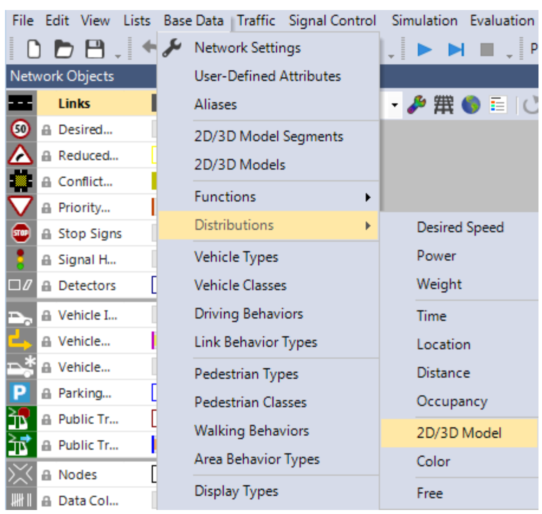


Figure 3. 2D/3D Model Distribution Menu

The passenger car distribution requires the following models and percentages (columns use Vissim nomenclature):

Table 1. Default WisDOT Passenger Car 2D/3D Model Distribution

Share	Model2D3D
0.275	Car - Nissan Altima
0.275	Car - Honda Accord
0.240	SUV - Jeep Grand Cherokee
0.040	SUV - Ford Explorer
0.040	SUV - GMC Yukon
0.040	Car - Plymouth Voyager
0.030	LtTruck - Chevrolet Silverado
0.030	LtTruck - Ford F150
0.030	Work Van

The NA Default "HGV" distribution is removed and replaced with two distributions: one for single-unit (SU) trucks, and one for tractor-trailer (TT) trucks.

Table 2. WisDOT Default Single Unit Truck 2D/3D Model Distribution

Share	Model2D3D
0.120	Bus - C2 Standard 2-doors
0.290	HGV - US Flatbed
0.290	HGV - EU 04 Tractor
0.060	HGV - US AASHTO WB-40
0.240	HGV - US AASHTO WB-50

Table 3. WisDOT Default Tractor Trailer Truck 2D/3D Model Distribution

Share	Model2D3D
0.94	HGV - US AASHTO WB-65
0.06	HGV - US AASHTO WB-67D

The default Bus distribution is changed to no longer use the European default bus.

Table 4. WisDOT Default Bus 2D/3D Model Distribution

Share	Model2D3D
1.00	Bus - C2 Standard 2-doors

After assigning the 2D/3D models to the appropriate distributions, the following vehicle models can be deleted:

- Car - Toyota Avensis (2006).v3d
- Car - Nissan Quest (1995).v3d
- Bus - EU Standard.v3d
- Bus - EU Articulated (Bus - EU Bendy front.v3d, Bus - EU Bendy rear.v3d)

3 Vehicle Types

Vehicle types can be modified from the *Base Data -> Vehicle Types* menu (Figure 4).

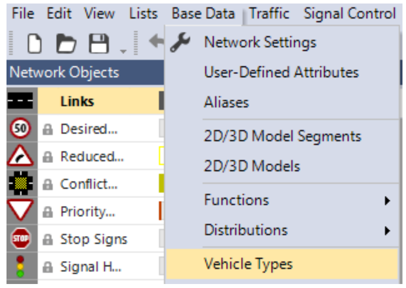
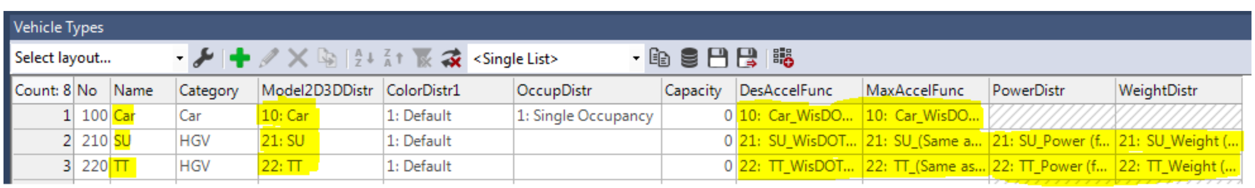


Figure 4. Vehicle Types Menu

The Vissim NA default HGV vehicle type is removed and replaced with separate classes for SU and TT trucks. Figure 5 highlights the vehicle types and parameters that need be modified. The wrench icon can be used to add columns in the list editor if not shown by default, or the pencil icon can be used to edit each vehicle type individually as shown in Figure 6 and Figure 7.

Parameters that need to be edited for each vehicle type include:

- 2D/3D Model Distribution (Discussed in Section 2.2)
- Desired and Maximum Acceleration (Discussed in Section 5)
- Power and Weight Distributions (Discussed in Section 5.1) – SU and TT vehicles only



Vehicle Types

Select layout... <Single List>

Count: 8	No	Name	Category	Model2D3DDistr	ColorDistr1	OccupDistr	Capacity	DesAccelFunc	MaxAccelFunc	PowerDistr	WeightDistr
1	100	Car	Car	10: Car	1: Default	1: Single Occupancy	0	10: Car_WisDO...	10: Car_WisDO...		
2	210	SU	HGV	21: SU	1: Default		0	21: SU_WisDOT...	21: SU_(Same a...	21: SU_Power (f...	21: SU_Weight (...
3	220	TT	HGV	22: TT	1: Default		0	22: TT_WisDOT...	22: TT_(Same as...	22: TT_Power (f...	22: TT_Weight (...

Figure 5. WisDOT Default Vehicle Types List

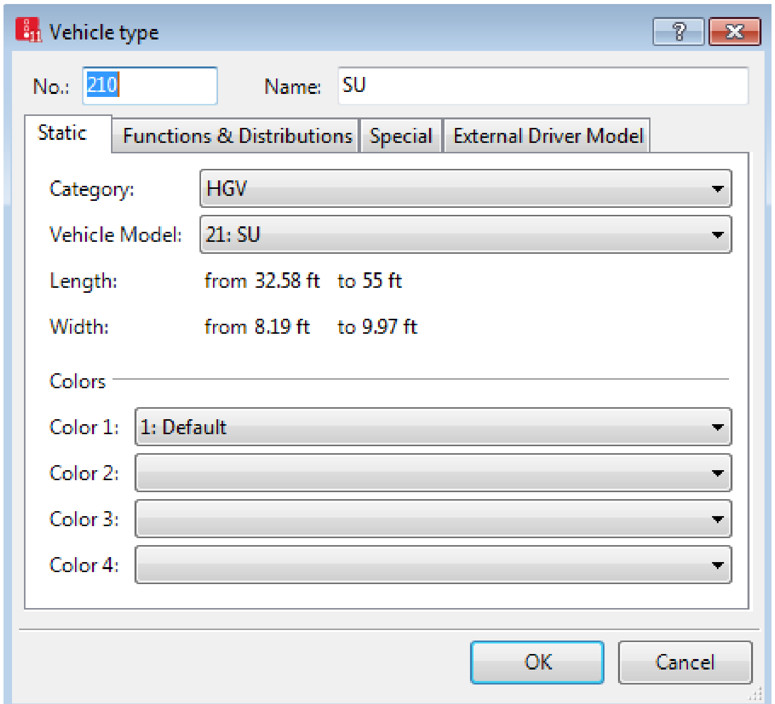


Figure 6. Example Vehicle Type Dialog ("Static" Tab) - for Assigning Vehicle Model Distributions

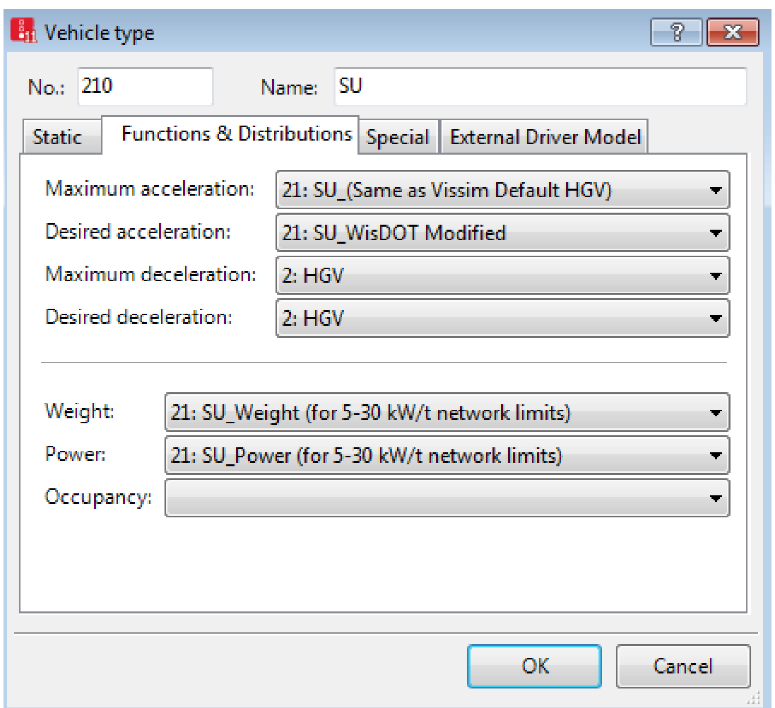


Figure 7. Example Vehicle Type Dialog ("Functions & Distributions" Tab) - for Assigning Acceleration, Weight, and Power

4 Vehicle Classes

Vehicle classes can be modified from the *Base Data -> Vehicle Classes* menu (Figure 8).

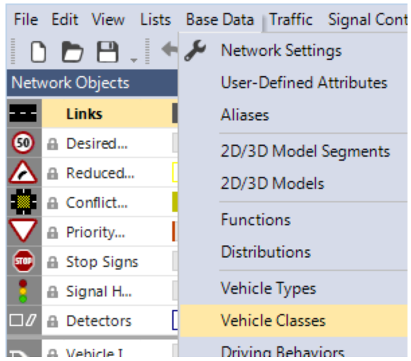


Figure 8. Vehicle Classes Menu

The default "HGV" vehicle class is renamed to the more commonly used "HV" terminology. This vehicle class is edited to include SU and TT truck types. Figure 9 shows the modified vehicle classes list. If a user needed to record simulation outputs specific to SU or TT trucks, additional vehicle classes can be added including only the desired vehicle type.

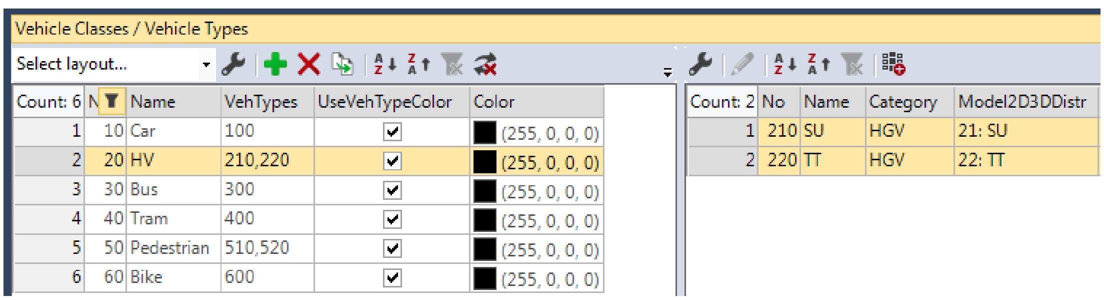


Figure 9. WisDOT Modified Vehicle Classes

5 Acceleration

Vissim uses desired and maximum acceleration functions to control the limits of vehicle acceleration. These functions can be modified from the *Base Data -> Functions -> Maximum Acceleration* and *Desired Acceleration* menus (Figure 10). The WisDOT Defaults file modifies both maximum and desired acceleration.

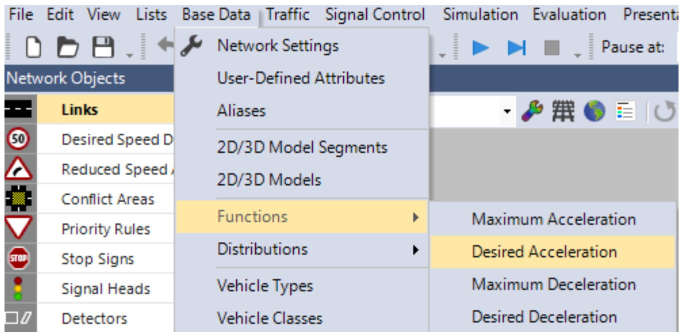
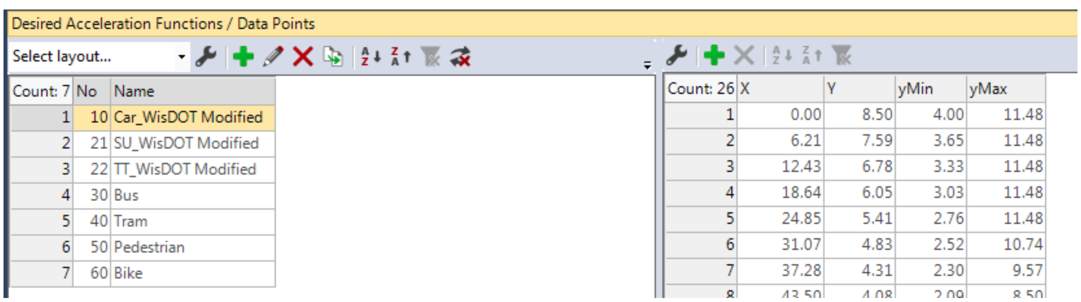


Figure 10. Acceleration Functions Menu (Desired Acceleration Highlighted)

Figure 11 and Figure 12 list the WisDOT default desired and maximum acceleration functions respectively. These acceleration functions are assigned to the appropriate vehicle types discussed in Section 3 and shown in Figure 5.

For passenger cars, both desired and maximum functions are modified from default values. For heavy vehicles, only the desired function is modified. Copies of the default maximum acceleration for heavy vehicles were made for SU and TT truck types and named appropriately.

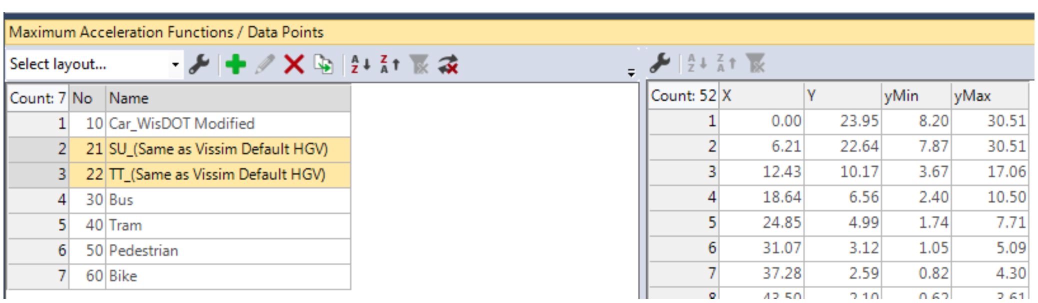


Desired Acceleration Functions / Data Points

Count: 7	No	Name
1	10	Car_WisDOT Modified
2	21	SU_WisDOT Modified
3	22	TT_WisDOT Modified
4	30	Bus
5	40	Tram
6	50	Pedestrian
7	60	Bike

Count: 26	X	Y	yMin	yMax
1	0.00	8.50	4.00	11.48
2	6.21	7.59	3.65	11.48
3	12.43	6.78	3.33	11.48
4	18.64	6.05	3.03	11.48
5	24.85	5.41	2.76	11.48
6	31.07	4.83	2.52	10.74
7	37.28	4.31	2.30	9.57

Figure 11. WisDOT Default Desired Acceleration List



Maximum Acceleration Functions / Data Points

Count: 7	No	Name
1	10	Car_WisDOT Modified
2	21	SU_(Same as Vissim Default HGV)
3	22	TT_(Same as Vissim Default HGV)
4	30	Bus
5	40	Tram
6	50	Pedestrian
7	60	Bike

Count: 52	X	Y	yMin	yMax
1	0.00	23.95	8.20	30.51
2	6.21	22.64	7.87	30.51
3	12.43	10.17	3.67	17.06
4	18.64	6.56	2.40	10.50
5	24.85	4.99	1.74	7.71
6	31.07	3.12	1.05	5.09
7	37.28	2.59	0.82	4.30

Figure 12. WisDOT Default Maximum Acceleration List

Exact values of each acceleration function are shown in Table 5. Column headers in Table 5 match those shown when viewing acceleration as a list in Vissim. Grey shaded cells have the same values as Vissim defaults.

Table 5. WisDOT Default Passenger Car Acceleration – Desired and Maximum

Passenger Car (PC)			
Desired Acceleration			
X	Y	yMin	yMax
mph	ft/s^2	ft/s^2	ft/s^2
0.00	8.50	4.00	11.48
6.21	7.59	3.65	11.48
12.43	6.78	3.33	11.48
18.64	6.05	3.03	11.48
24.85	5.41	2.76	11.48
31.07	4.83	2.52	10.74
37.28	4.31	2.30	9.57
43.50	4.08	2.09	8.50
49.71	3.86	1.91	7.50
55.92	3.63	1.74	6.56
62.14	3.41	1.59	5.68
68.35	3.18	1.48	5.30
74.56	2.95	1.38	4.92
80.78	2.72	1.27	4.54
86.99	2.50	1.16	4.16
93.21	2.27	1.06	3.78
99.42	2.04	0.95	3.41
105.63	1.81	0.85	3.02
111.85	1.59	0.74	2.65
118.06	1.36	0.64	2.27
124.27	1.14	0.53	1.89
130.49	0.91	0.42	1.51
136.70	0.68	0.32	1.14
142.92	0.45	0.21	0.76
149.13	0.23	0.10	0.38
155.34	0.00	0.00	0.00

Passenger Car (PC)			
Maximum Acceleration			
X	Y	yMin	yMax
mph	ft/s^2	ft/s^2	ft/s^2
0.00	11.48	4.00	11.48
6.21	10.50	3.65	11.48
12.43	9.14	3.33	11.48
18.64	8.10	3.03	11.48
24.85	7.22	2.76	11.48
31.07	6.44	2.52	10.74
37.28	5.74	2.30	9.57
43.50	5.10	2.09	8.50
49.71	4.50	1.91	7.50
55.92	3.94	1.74	6.56
62.14	3.41	1.59	5.68
68.35	3.18	1.48	5.30
74.56	2.95	1.38	4.92
80.78	2.72	1.27	4.54
86.99	2.50	1.16	4.16
93.21	2.27	1.06	3.78
99.42	2.04	0.95	3.41
105.63	1.81	0.85	3.02
111.85	1.59	0.74	2.65
118.06	1.36	0.64	2.27
124.27	1.14	0.53	1.89
130.49	0.91	0.42	1.51
136.70	0.68	0.32	1.14
142.92	0.45	0.21	0.76
149.13	0.23	0.10	0.38
155.34	0.00	0.00	0.00

Single Unit Truck (SU)			
Desired Acceleration			
X	Y	yMin	yMax
mph	ft/s^2	ft/s^2	ft/s^2
0.00	5.25	1.50	8.20
6.21	4.44	1.37	7.06
12.43	3.75	1.24	6.09
18.64	3.17	1.13	5.24
24.85	2.68	1.03	4.52
31.07	2.27	0.94	3.89
37.28	1.92	0.82	3.35
43.50	1.62	0.62	2.89
49.71	1.37	0.49	2.49
55.92	1.16	0.36	2.14
62.14	0.98	0.26	1.85
68.35	0.83	0.00	1.59
74.56	0.00	0.00	0.33
80.78	0.00	0.00	0.00
86.99	0.00	0.00	0.00
93.21	0.00	0.00	0.00
99.42	0.00	0.00	0.00
105.63	0.00	0.00	0.00
111.85	0.00	0.00	0.00
118.06	0.00	0.00	0.00
124.27	0.00	0.00	0.00
130.49	0.00	0.00	0.00
136.70	0.00	0.00	0.00
142.92	0.00	0.00	0.00
149.13	0.00	0.00	0.00
155.34	0.00	0.00	0.00

Tractor-Trailer Truck (TT)			
Desired Acceleration			
X	Y	yMin	yMax
mph	ft/s^2	ft/s^2	ft/s^2
0.00	2.50	1.00	8.20
6.21	2.50	1.00	7.06
12.43	2.50	1.00	6.09
18.64	2.50	1.00	5.24
24.85	2.42	1.00	4.52
31.07	1.89	1.00	3.89
37.28	1.47	0.82	3.35
43.50	1.15	0.62	2.89
49.71	0.89	0.49	2.49
55.92	0.70	0.36	2.14
62.14	0.54	0.26	1.85
68.35	0.42	0.00	1.59
74.56	0.00	0.00	0.33
80.78	0.00	0.00	0.00
86.99	0.00	0.00	0.00
93.21	0.00	0.00	0.00
99.42	0.00	0.00	0.00
105.63	0.00	0.00	0.00
111.85	0.00	0.00	0.00
118.06	0.00	0.00	0.00
124.27	0.00	0.00	0.00
130.49	0.00	0.00	0.00
136.70	0.00	0.00	0.00
142.92	0.00	0.00	0.00
149.13	0.00	0.00	0.00
155.34	0.00	0.00	0.00

Grey shaded cells same as Vissim defaults

5.1 Truck Power and Weight

Vehicle power and weight can be modified from the *Base Data -> Distributions -> Power* and *Weight* menus (Figure 13).

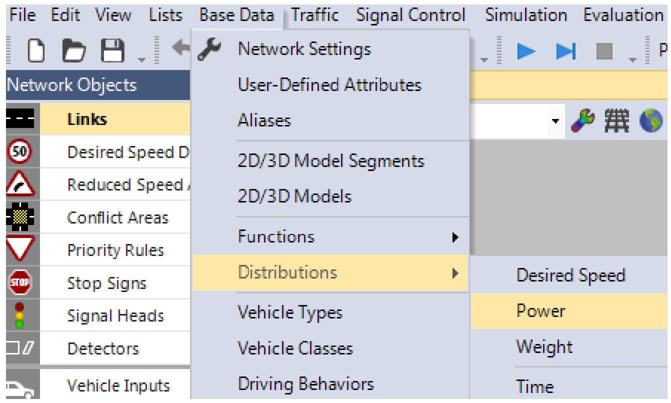
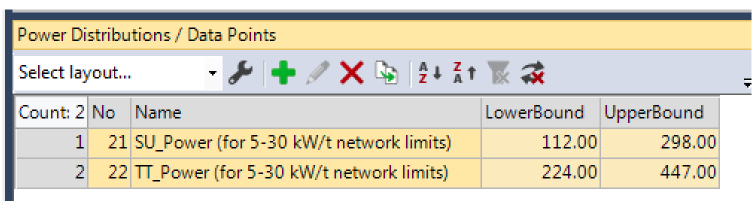


Figure 13. Power and Weight Menus

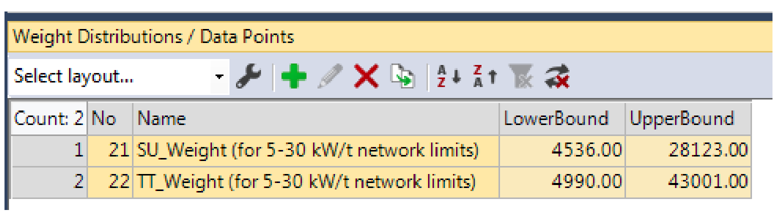
All default power and weight distributions are deleted and replaced with distributions for SU and TT truck types as shown in Figure 14 and Figure 15 respectively. These power and weight distributions are assigned to the appropriate vehicle types discussed in Section 3 and shown in Figure 5.


Power Distributions / Data Points

Select layout...

Count: 2	No	Name	LowerBound	UpperBound
1	21	SU_Power (for 5-30 kW/t network limits)	112.00	298.00
2	22	TT_Power (for 5-30 kW/t network limits)	224.00	447.00

Figure 14. WisDOT Default Power Distributions


Weight Distributions / Data Points

Select layout...

Count: 2	No	Name	LowerBound	UpperBound
1	21	SU_Weight (for 5-30 kW/t network limits)	4536.00	28123.00
2	22	TT_Weight (for 5-30 kW/t network limits)	4990.00	43001.00

Figure 15. WisDOT Default Weight Distributions

Table 6 shows the exact values used in the power and weight distributions. These distributions are intended only to be used in combination with the WisDOT modified truck acceleration and WisDOT modified network power-weight limit settings shown in Figure 16. Edit the network settings from the *Base Data -> Network Settings* menu. The “Minimum specific power for HGV” is changed to 5 kW/t (Vissim default is 7 kW/t)

Table 6. WisDOT Default Power and Weight Distributions for Truck Acceleration Calibration

	Power (kW)	
Percentile	SU	TT
0%	112	224
5%	144	274
10%	157	288
20%	174	304
30%	186	316
40%	196	326
50%	205	336
60%	215	345
70%	225	355
80%	236	367
90%	253	383
95%	266	397
100%	298	447

Weight (metric tons, t)			
Percentile	SU	Percentile	TT
0%	4536	0.0%	4990
10%	7258	0.2%	6985
20%	8165	0.8%	8981
50%	11794	2.2%	11022
75%	15423	6.0%	13018
85%	18144	13.6%	15014
100%	28123	23.2%	17010
		31.7%	19006
		39.4%	21001
		46.9%	22997
		54.7%	24993
		63.2%	26989
		71.7%	28985
		81.2%	30980
		92.2%	33022
		96.7%	35017
		98.8%	37013
		99.5%	39009
		99.9%	41005
		100.0%	43001

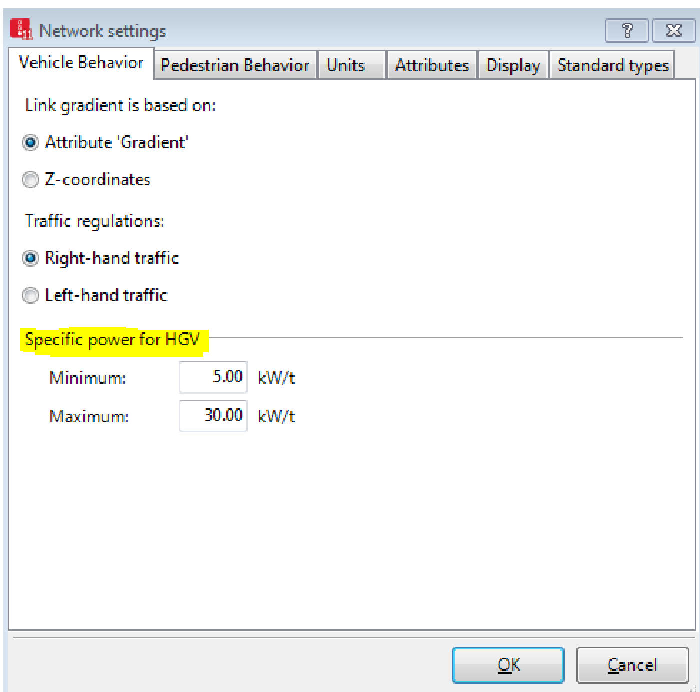


Figure 16. WisDOT Default Specific Power for HGV Network Settings

6 Desired Speed Distributions

Desired speed distributions can be edited from the *Base Data -> Distributions -> Desire Speed* menu (Figure 17). All of the NA Default desired speed distributions are deleted and replaced with the Wisconsin defaults shown in Table 7. Column headings in Table 7 match Vissim (X = speed in mph, FX = percentile).

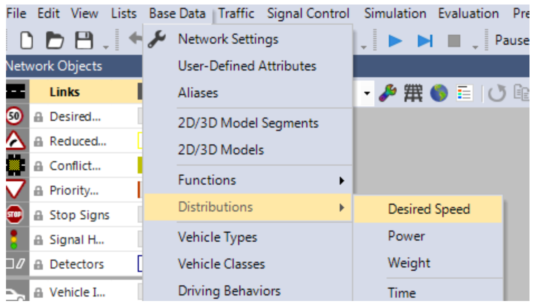


Figure 17. Desired Speed Distribution Menu

Table 7. WisDOT Default Desired Speeds

25 mph		30 mph		35 mph		40 mph		45 mph		50 mph Non-Freeway	
X	FX	X	FX	X	FX	X	FX	X	FX	X	FX
20.0	0.00	25.0	0.00	30.0	0.00	35.0	0.00	40.0	0.00	45.0	0.00
25.0	0.06	30.0	0.16	35.0	0.05	40.0	0.29	45.0	0.30	50.0	0.26
30.0	0.42	33.9	0.50	40.0	0.29	43.4	0.50	48.3	0.50	52.8	0.50
30.9	0.50	35.0	0.60	42.5	0.50	45.0	0.60	50.0	0.60	55.0	0.69
34.6	0.85	38.9	0.85	45.0	0.71	49.5	0.85	55.0	0.85	58.2	0.85
35.0	0.89	40.0	0.92	47.4	0.85	50.0	0.88	60.0	0.96	60.0	0.94
40.0	1.00	45.0	1.00	50.0	1.00	55.0	1.00	65.0	1.00	65.0	1.00

50 mph Freeway (PC)		50 mph Freeway (HV)		55 mph 2-lane rural (PC)		55 mph 2-lane rural (HV)		55 mph Expressway (PC)		55 mph Expressway (HV)		55 mph Freeway (PC)		55 mph Freeway (HV)	
X	FX	X	FX	X	FX	X	FX	X	FX	X	FX	X	FX	X	FX
45.0	0.00	45.0	0.00	50.0	0.00	45.0	0.00	50.0	0.00	45.0	0.00	50.0	0.00	45.0	0.00
50.6	0.02	47.4	0.02	55.6	0.13	50.6	0.13	55.6	0.13	50.6	0.13	55.6	0.07	52.2	0.07
55.6	0.12	52.0	0.12	59.9	0.50	54.9	0.50	59.9	0.50	54.9	0.50	60.6	0.26	56.1	0.26
60.6	0.38	55.5	0.38	60.6	0.56	55.6	0.56	65.6	0.85	60.6	0.85	64.6	0.50	59.2	0.50
62.4	0.50	57.0	0.50	64.5	0.85	59.5	0.85	70.6	0.97	65.6	0.97	72.4	0.85	65.0	0.85
65.6	0.71	59.3	0.71	65.6	0.93	60.6	0.93	75.0	1.00	70.0	1.00	75.6	0.94	67.4	0.94
69.3	0.85	61.9	0.85	70.0	1.00	65.0	1.00					80.0	1.00	70.0	1.00
70.6	0.90	63.0	0.90												
75.6	0.97	67.4	0.97												
80.0	1.00	70.0	1.00												

65 mph (PC)		65 mph (HV)		70 mph (PC)		70 mph (HV)		Right Turn		Left Turn		Walking Speed	
X	FX	X	FX	X	FX	X	FX	X	FX	X	FX	X	FX
55.0	0.00	55.0	0.00	60.0	0.00	55.0	0.00	7.5	0.00	12.4	0.00	2.05	0.00
62.3	0.03	57.3	0.03	68.0	0.13	62.3	0.13	15.5	1.00	18.6	1.00	2.58	0.15
68.1	0.17	61.9	0.17	71.9	0.34	65.2	0.34					2.80	0.50
71.4	0.50	64.1	0.50	74.3	0.50	67.0	0.50					3.17	0.75
75.6	0.85	67.9	0.85	76.5	0.68	68.8	0.68					3.47	0.85
80.7	0.98	72.9	0.98	79.5	0.85	71.8	0.85					4.23	1.00
85.0	1.00	80.0	1.00	80.5	0.92	73.0	0.92						
				85.6	0.99	77.2	0.99						
				90.0	1.00	80.0	1.00						

7 Vehicle Compositions

Vehicle compositions can be edited from the *Traffic -> Pedestrian Compositions* menu (Figure 18). The WisDOT default Vissim file includes two example vehicle compositions to demonstrate how users can define a mix of passenger cars and trucks and assign appropriate desired speeds. Users should modify or add their own vehicle compositions and delete the examples if they are not being used in their model.

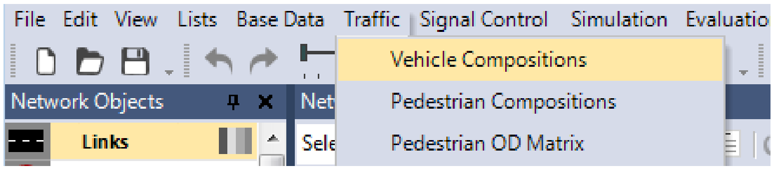


Figure 18. Vehicle Compositions Menu

Figure 19 shows an example vehicle composition for a 70 mph freeway with 10% heavy vehicles. The 10% heavy vehicles are subdivided into 30% single unit trucks and 70% tractor trailer trucks, as recommended default values for freeways if field data is not available. For 70 mph, the WisDOT defaults include separate desired speed distributions for passenger cars and heavy vehicles.

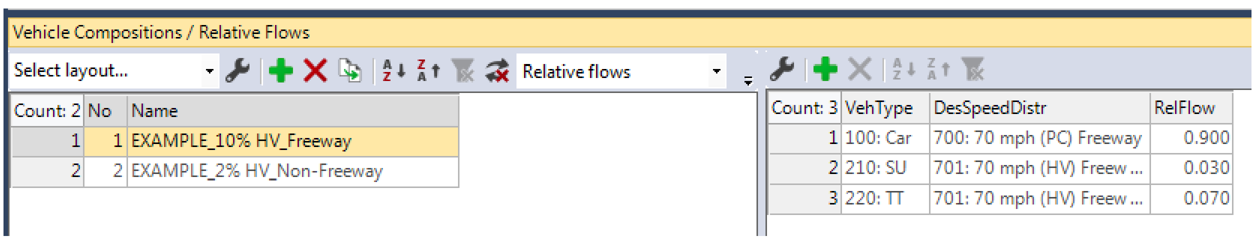


Figure 19. Example 70 mph Freeway Vehicle Composition

Figure 20 shows an example vehicle composition for a 40 mph facility with 2% heavy vehicles. The 2% heavy vehicles are subdivided into 70% single unit trucks and 30% tractor trailer trucks, as recommended default values for non-freeway facilities if field data is not available. For 40 mph, the WisDOT defaults use the same desired speed distribution for passenger cars and heavy vehicles.

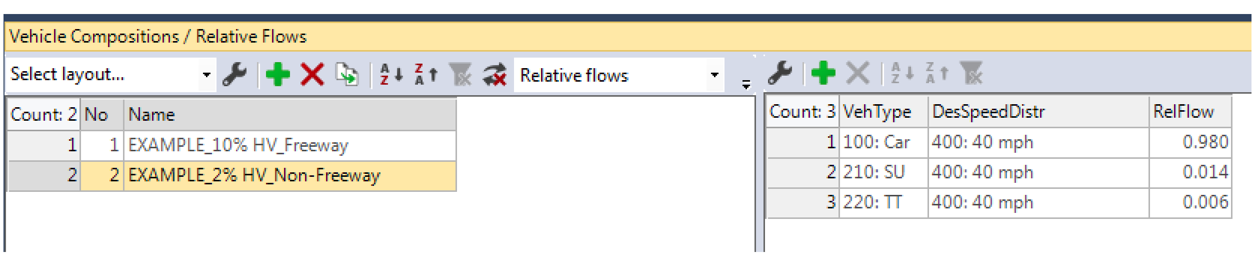


Figure 20. Example 40 mph Vehicle Composition

8 Pedestrian Compositions

Pedestrian Compositions (for Viswalk) can be modified from the *Traffic -> Pedestrian Compositions* menu (Figure 21).

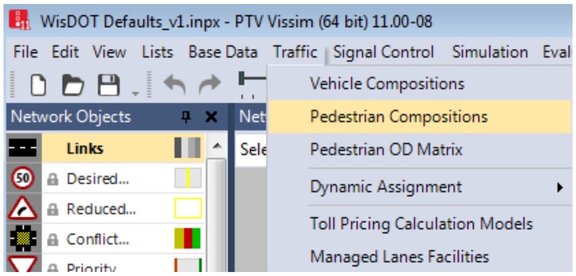


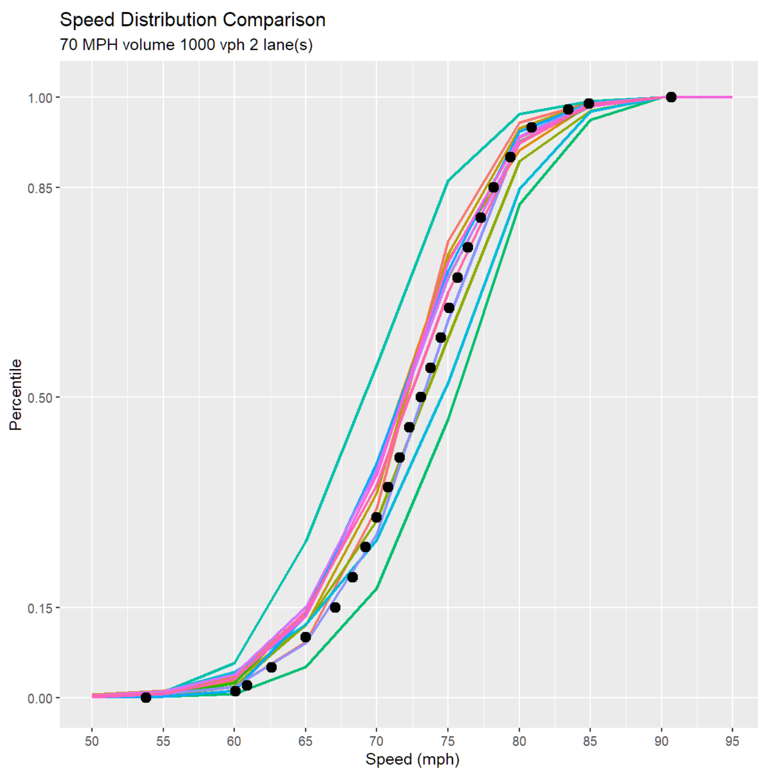
Figure 21. Pedestrian Composition Menu

The WisDOT default file deletes all Viswalk pedestrian compositions from this menu. Viswalk (purchased separately from Vissim) is not needed for the typical use-case for WisDOT where pedestrians are used to activate push buttons at traffic signals. The WisDOT default file relies on the default pedestrian vehicle type shown in Figure 9 that can be used for mimicking pedestrian behavior with the Wiedemann car following model.

If a model required more complex pedestrian simulation with Viswalk, pedestrian compositions would have to be imported from the Vissim NA default file, or re-created by the user.

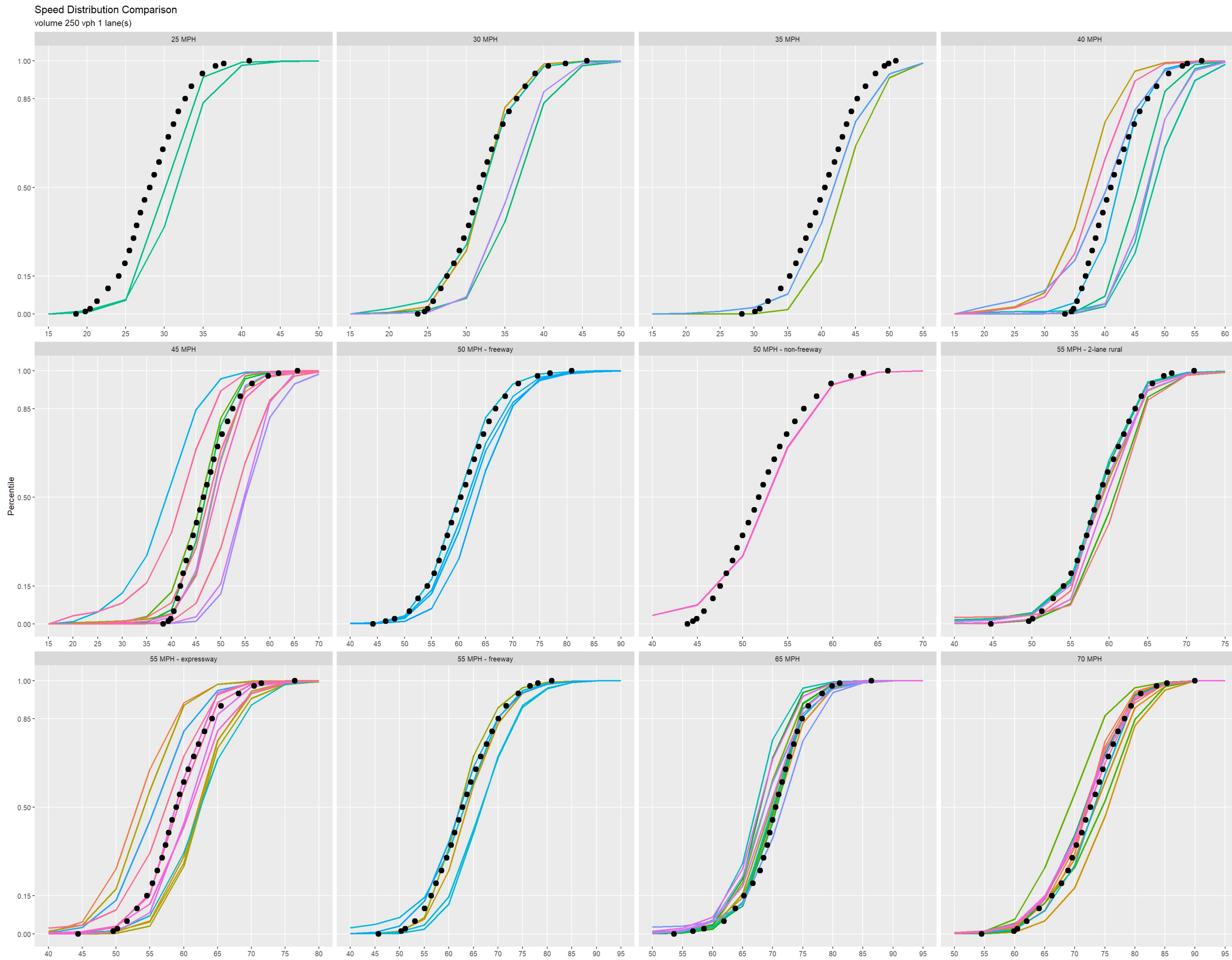
Appendix B
Simulated Speeds versus ATR Speeds

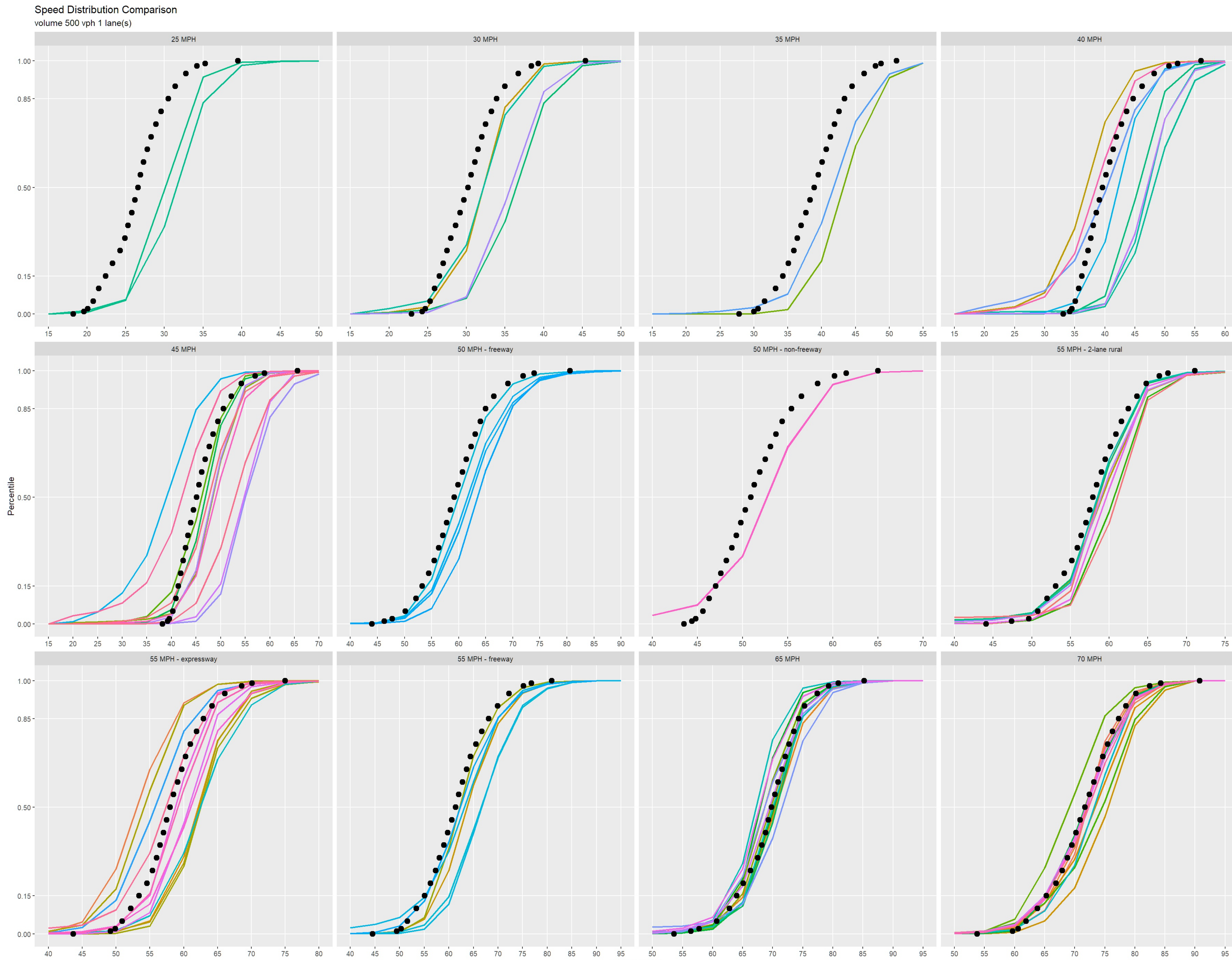
The following pages show simulated speed versus field measured speeds from Automatic Traffic Recorder (ATR) locations for various posted speeds and facility types. Each graph shows the cumulative speed distribution for the simulation (black points) and field data (colored lines). An example is shown below for a 70 mph facility. The simulation in this example had 2 lanes and used 500 vph/ln (1000 vph total) vehicle input.



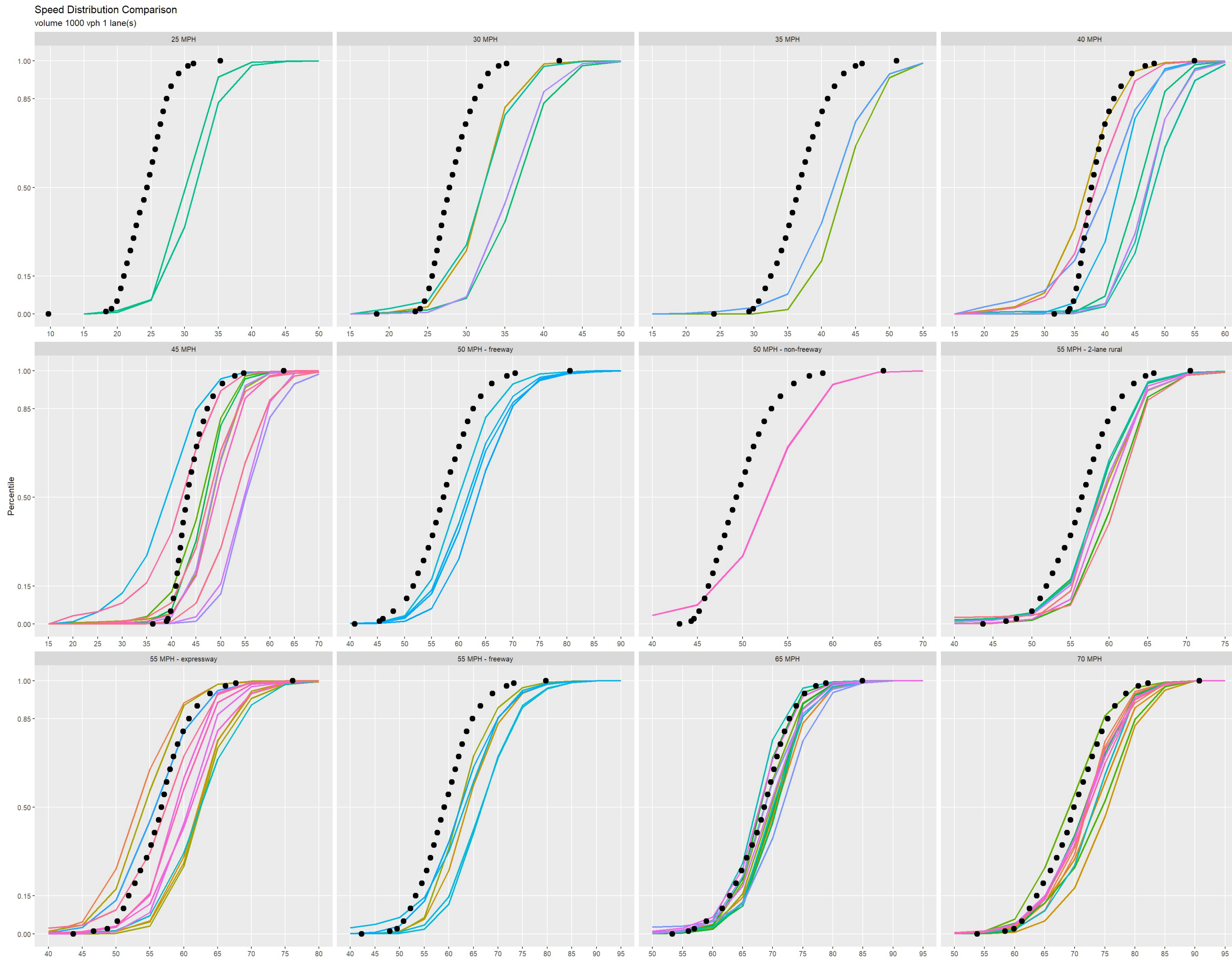
Simulations were conducted for various volumes (250 vph/ln, 500 vph/ln, 1000 vph/ln) and 1 or 2 lane facilities. Not all combinations are logical (for example: 1 lane, 1000 vph, 70 mph), but were simulated anyway to see the general effects.

Field data includes observations for an month, 24 hrs, 7 days per week, which can include congestion, crashes, and weather effects. The simulation results are from an ideal scenario and should not be expected to match the lower percentile speeds of the field data.

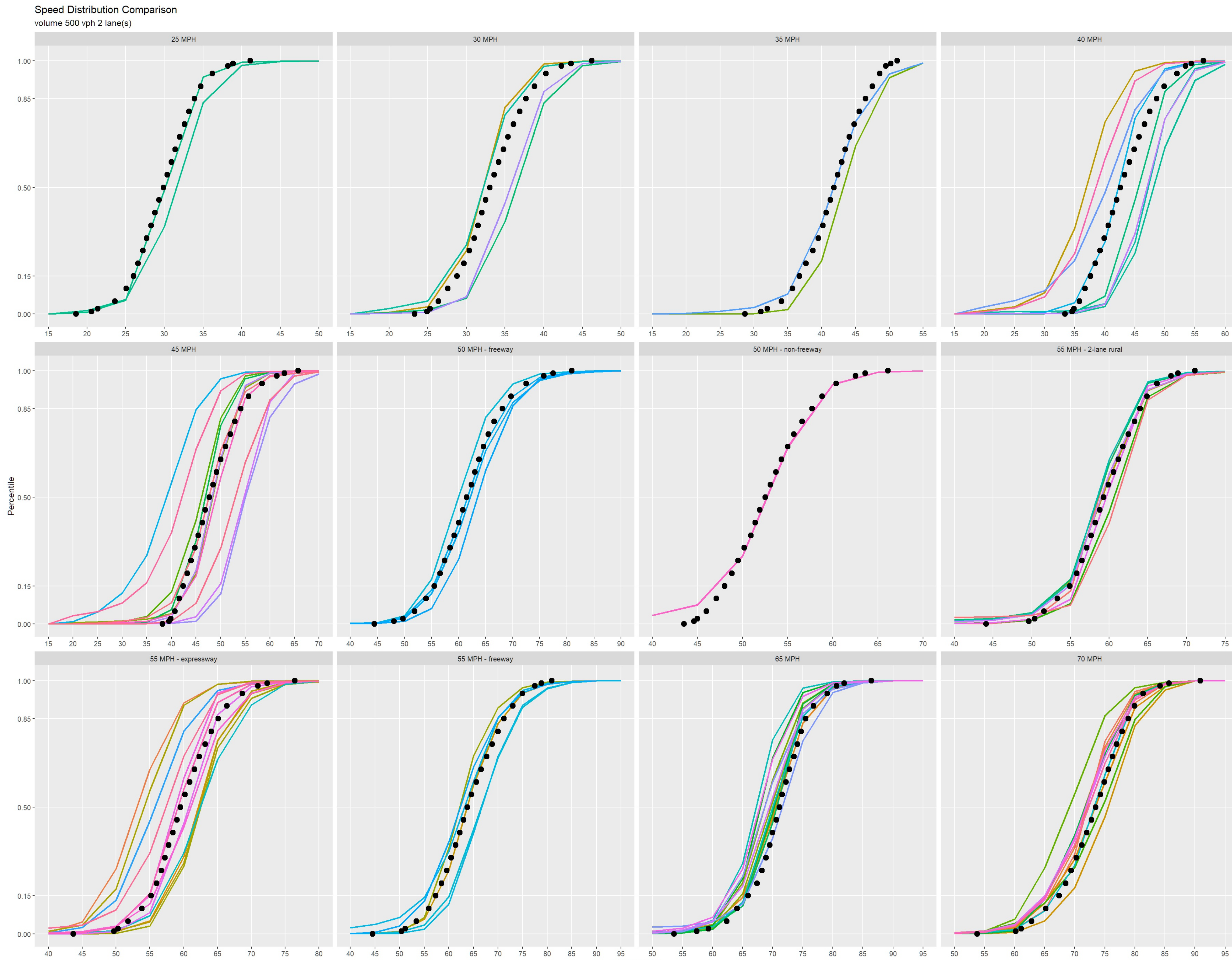

Speed Distribution Comparison
volume 250 vph 1 lane(s)
25 MPH
30 MPH
35 MPH
40 MPH
45 MPH
50 MPH - freeway
50 MPH - non-freeway
55 MPH - 2-lane rural
55 MPH - expressway
55 MPH - freeway
65 MPH
70 MPH
Percentile
Speed (mph)



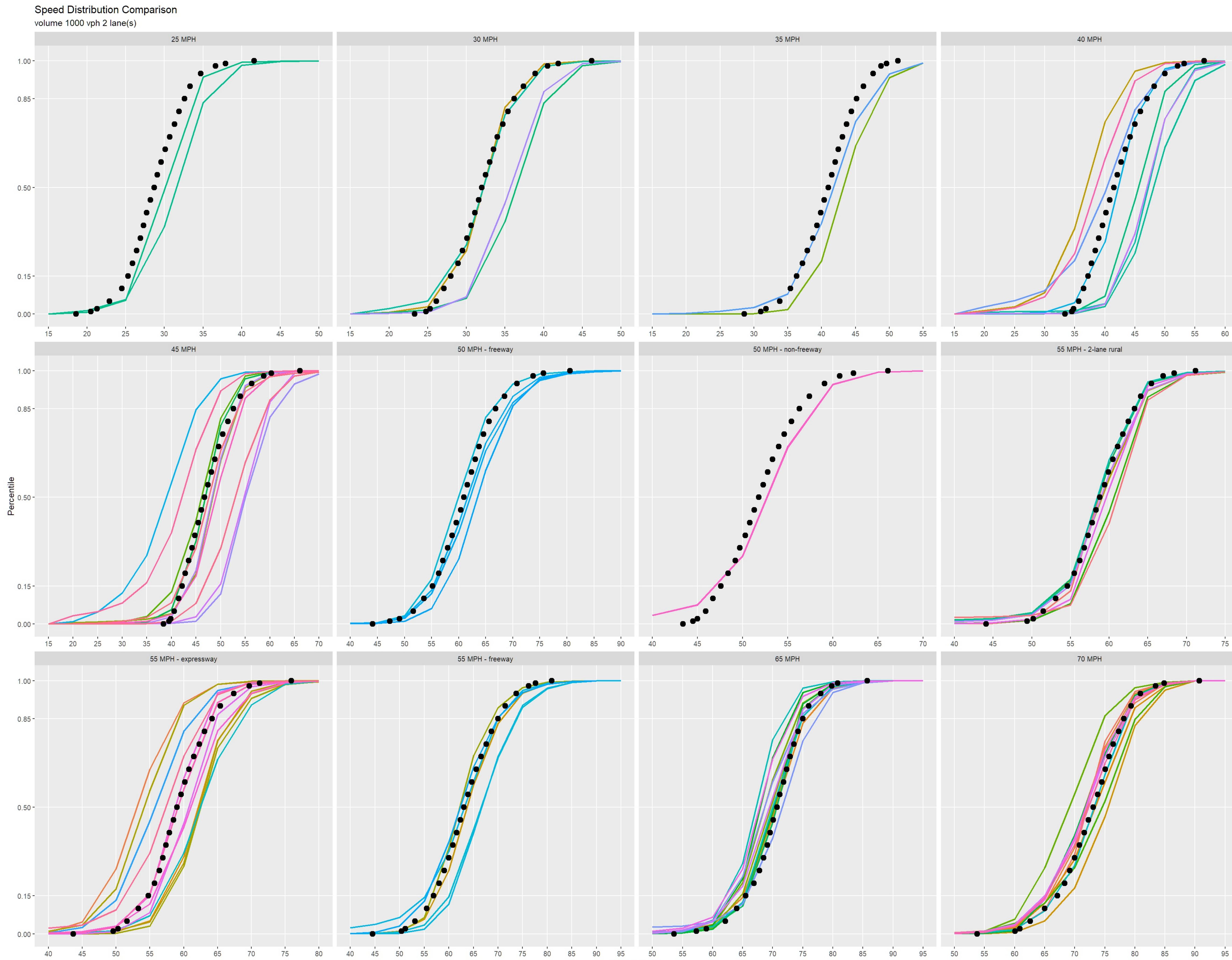
Speed Distribution Comparison
volume 500 vph 1 lane(s)
25 MPH
30 MPH
35 MPH
40 MPH
45 MPH
50 MPH - freeway
50 MPH - non-freeway
55 MPH - 2-lane rural
55 MPH - expressway
55 MPH - freeway
65 MPH
70 MPH
Percentile
Speed (mph)



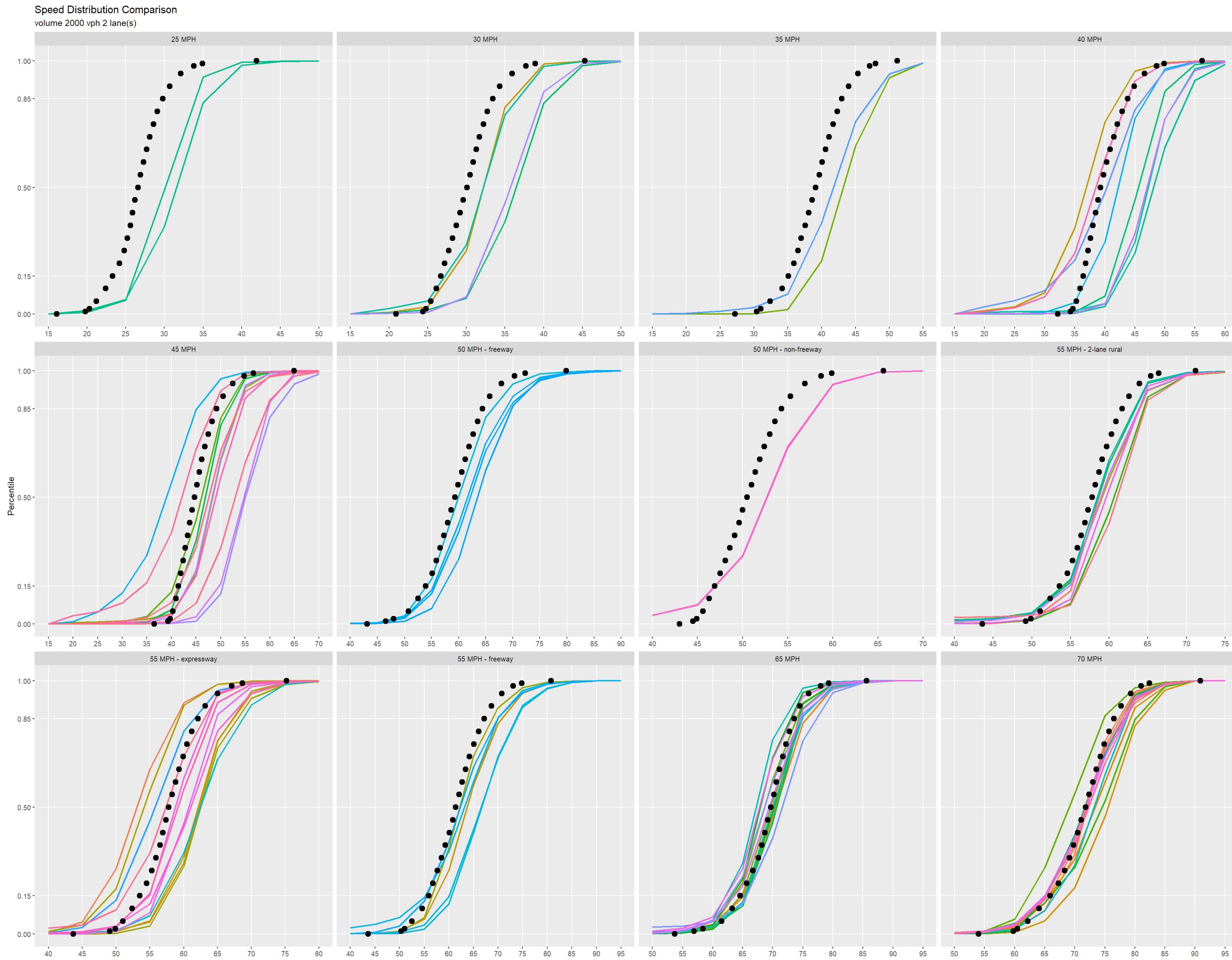
Speed Distribution Comparison
volume 1000 vph 1 lane(s)
25 MPH
30 MPH
35 MPH
40 MPH
45 MPH
50 MPH - freeway
50 MPH - non-freeway
55 MPH - 2-lane rural
55 MPH - expressway
55 MPH - freeway
65 MPH
70 MPH
Percentile
Speed (mph)



Speed Distribution Comparison
volume 500 vph 2 lane(s)
25 MPH
30 MPH
35 MPH
40 MPH
45 MPH
50 MPH - freeway
50 MPH - non-freeway
55 MPH - 2-lane rural
55 MPH - expressway
55 MPH - freeway
65 MPH
70 MPH
Percentile
Speed (mph)



Speed Distribution Comparison
volume 1000 vph 2 lane(s)
25 MPH
30 MPH
35 MPH
40 MPH
45 MPH
50 MPH - freeway
50 MPH - non-freeway
55 MPH - 2-lane rural
55 MPH - expressway
55 MPH - freeway
65 MPH
70 MPH
Percentile
Speed (mph)


Speed Distribution Comparison
volume 2000 vph 2 lane(s)
25 MPH
30 MPH
35 MPH
40 MPH
45 MPH
50 MPH - freeway
50 MPH - non-freeway
55 MPH - 2-lane rural
55 MPH - expressway
55 MPH - freeway
65 MPH
70 MPH
Percentile
Speed (mph)

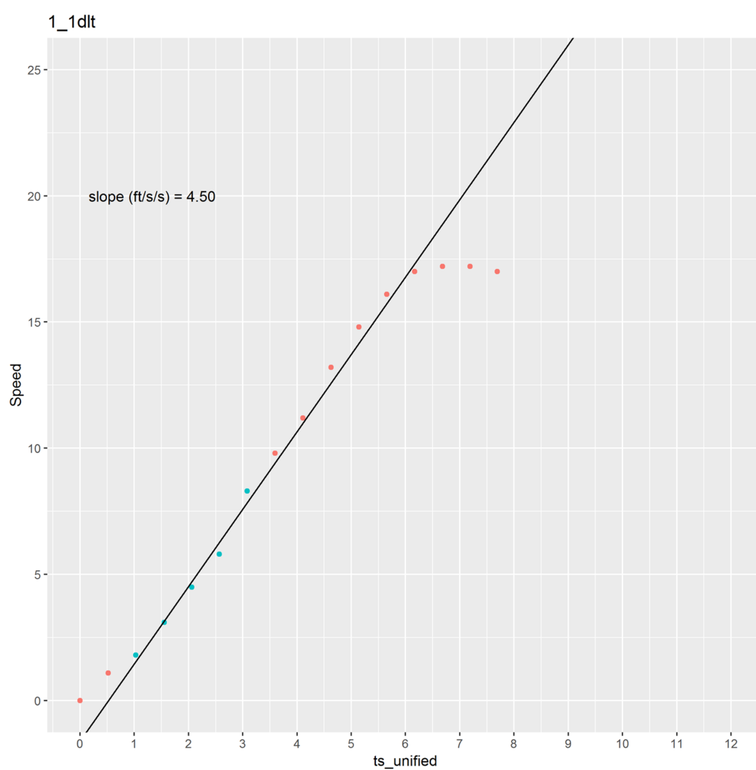
Appendix C
Wisconsin Avenue & Meade Street
Field Speed-Time Data

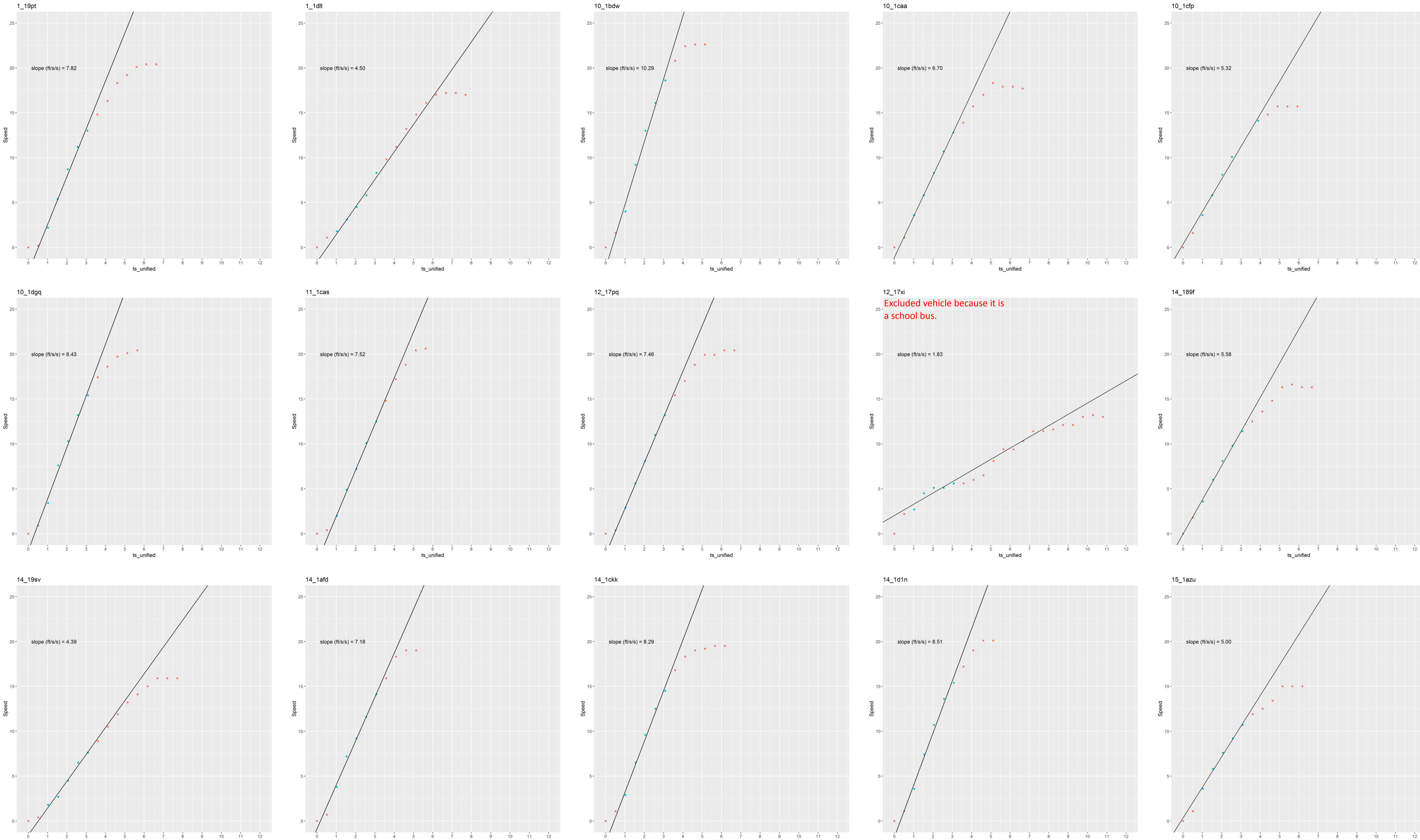
The following pages show speed-time plots for each observed vehicle in the Wisconsin Avenue & Meade Street trajectory data. 101 vehicles were observed. 3 were discarded as outliers. A total of 98 vehicles, all passenger cars, were included in the final data set. All 101 vehicles are shown on the following pages.

Speeds are directly from the microwave data collection unit. Times have been normalized so that time zero is the last datapoint when the radar recorded zero speed for the vehicle after the signal turned green. An example is shown below.

- A linear regression was fit through the data between time 1 s and 3 s (green data points). The slope of the linear regression was used as the acceleration of the vehicle starting from rest.

- Each vehicle was given a unique ID. The example below is vehicle ID "1_1dlt." This ID is short-hand for the raw dataset ID "SB_1_2014_11_18_17_51_29." The shorthand ID was created by:
  - Extract the first number in the raw dataset (SB_1) and convert to base 36 (1)
  - Extract the last 3 parts of the raw dataset ID, which are a timestamp, and converted to seconds since midnight (64289), then converted to base 36 (1dlt).
  - The resulting shorthand ID is 1_1dlt.

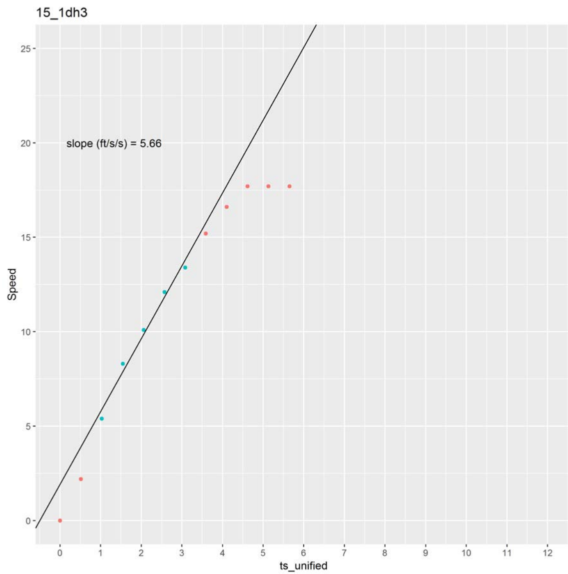


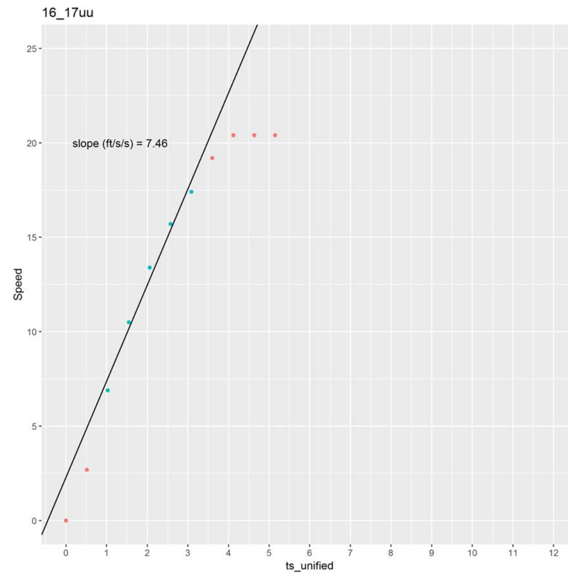


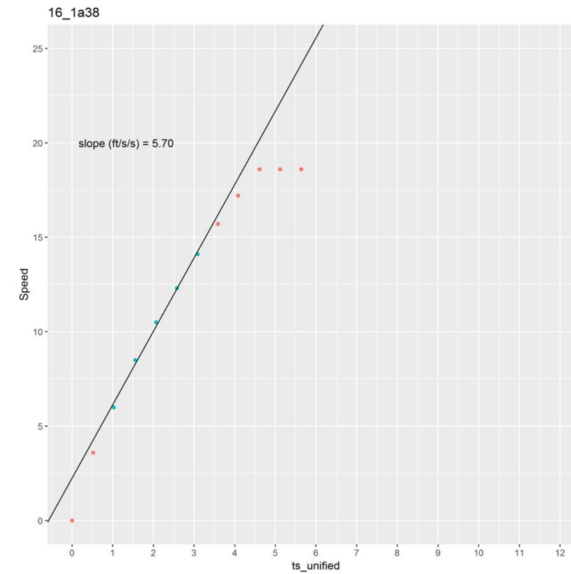
Field Speed-Time Data

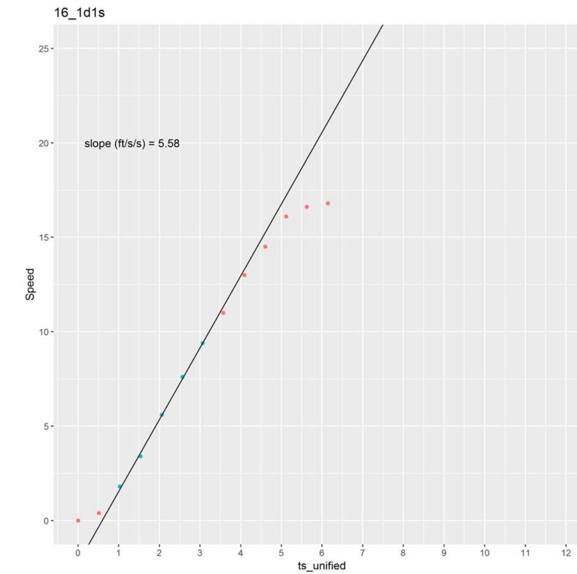
Individual vehicles at Wisconsin Avenue & Meade Street, Appleton WI

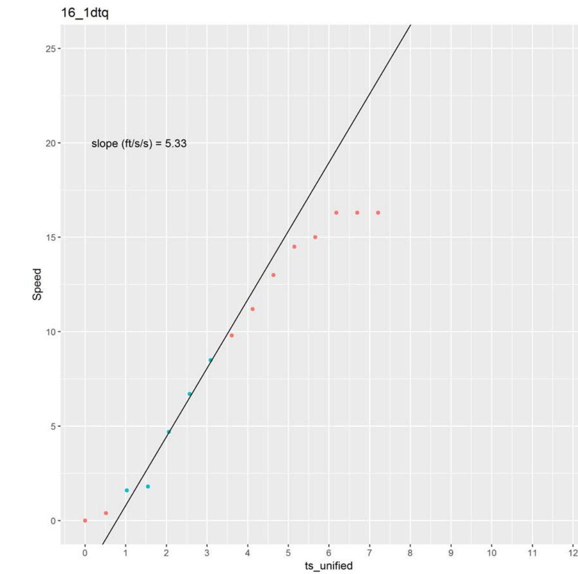
Appendix C-2

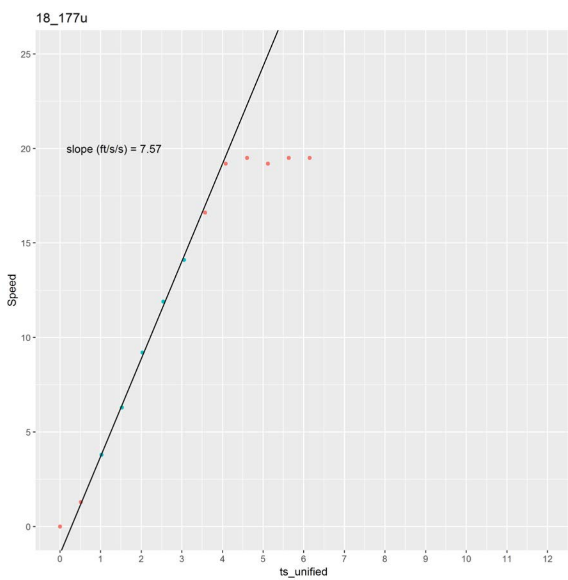

15_1dh3
slope (ft/s/s) = 5.66
Speed
ts_unified

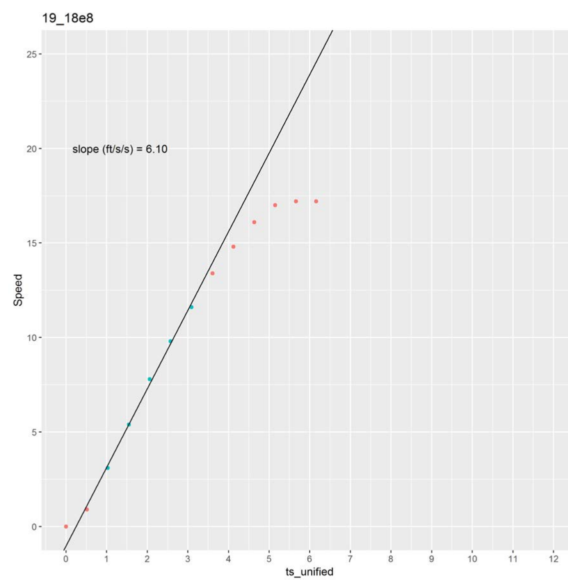

16_17uu
slope (ft/s/s) = 7.46
Speed
ts_unified

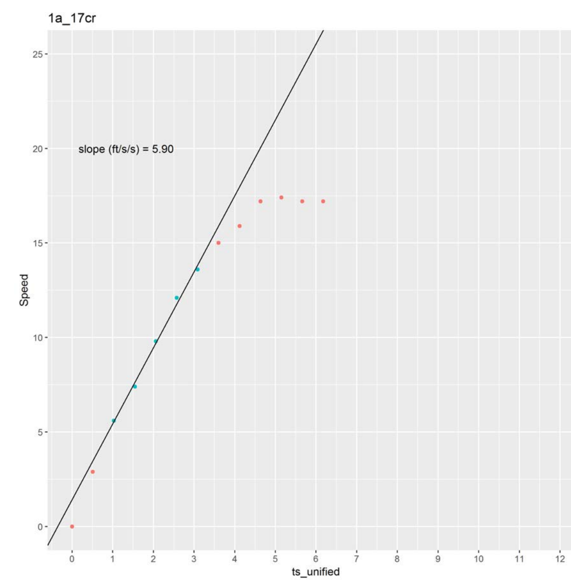

16_1a38
slope (ft/s/s) = 5.70
Speed
ts_unified

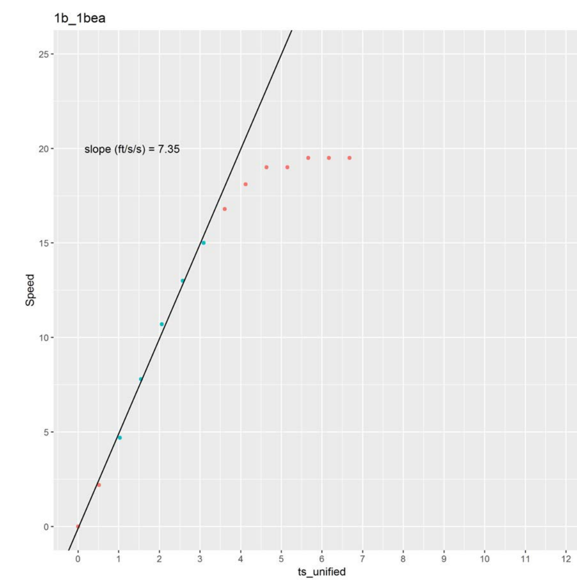

16_1d1s
slope (ft/s/s) = 5.58
Speed
ts_unified

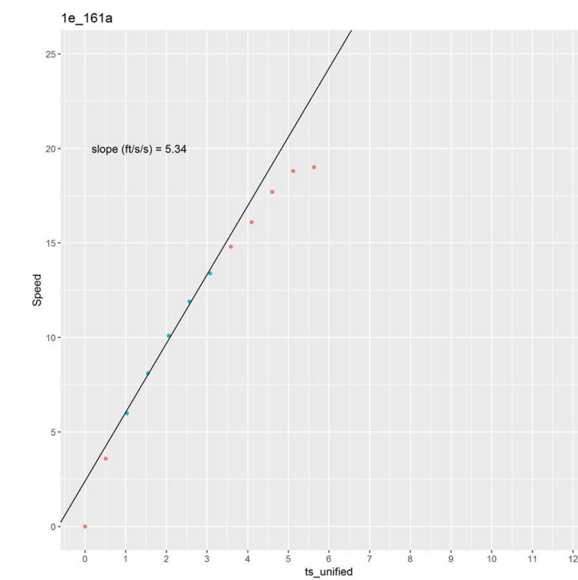

16_1dtq
slope (ft/s/s) = 5.33
Speed
ts_unified

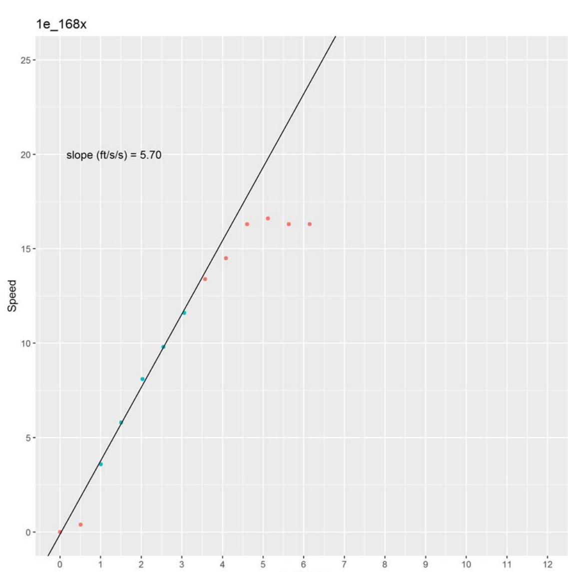

18_177u
slope (ft/s/s) = 7.57
Speed
ts_unified

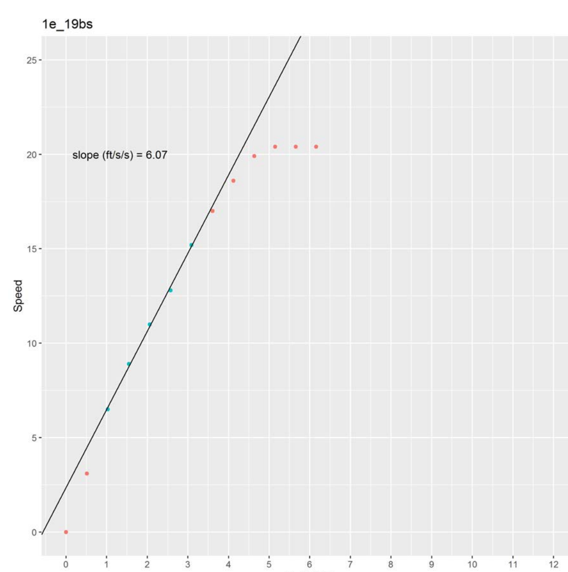

19_18e8
slope (ft/s/s) = 6.10
Speed
ts_unified

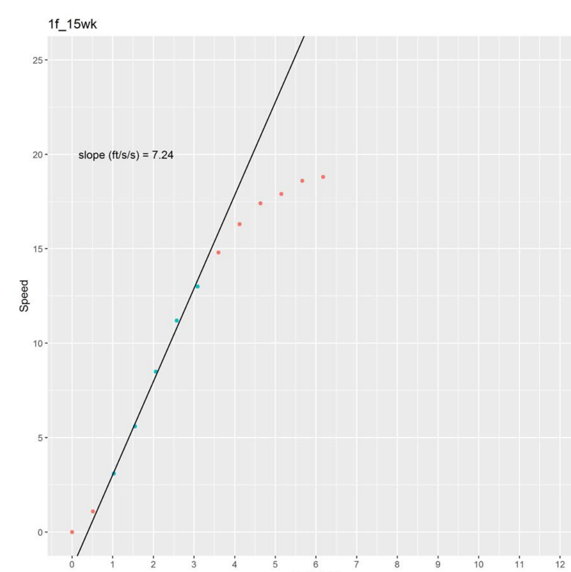

1a_17cr
slope (ft/s/s) = 5.90
Speed
ts_unified

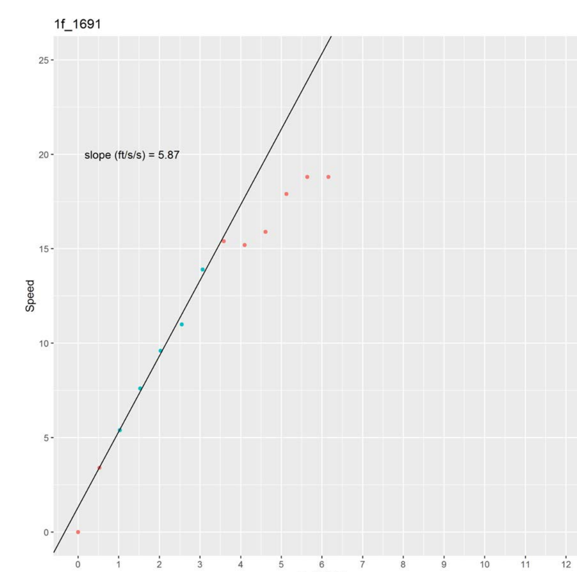

1b_1bea
slope (ft/s/s) = 7.35
Speed
ts_unified

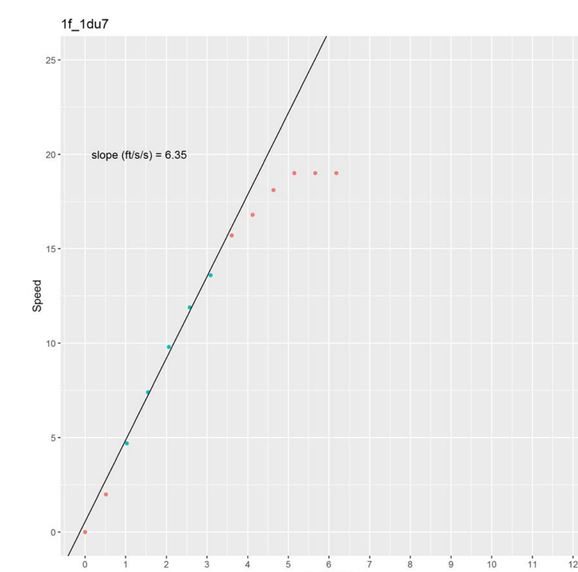

1e_161a
slope (ft/s/s) = 5.34
Speed
ts_unified

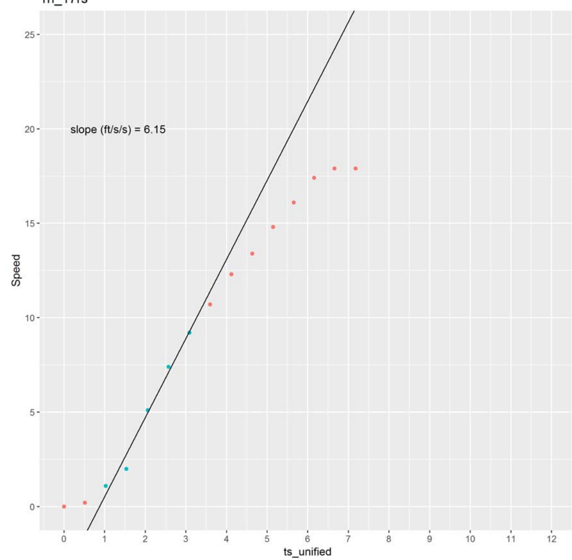

1e_168x
slope (ft/s/s) = 5.70
Speed
ts_unified

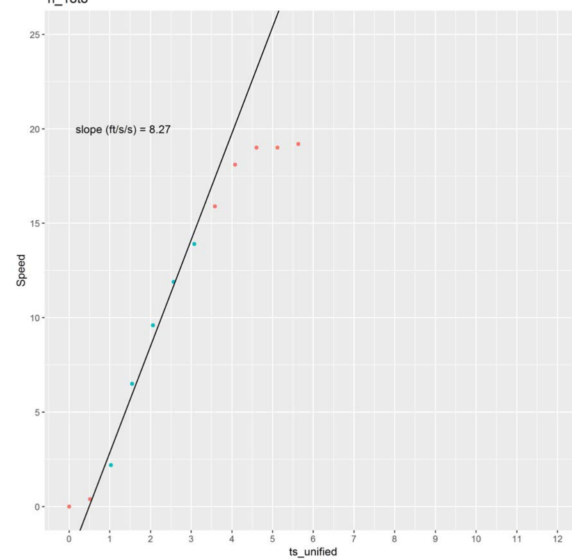

1e_19bs
slope (ft/s/s) = 6.07
Speed
ts_unified

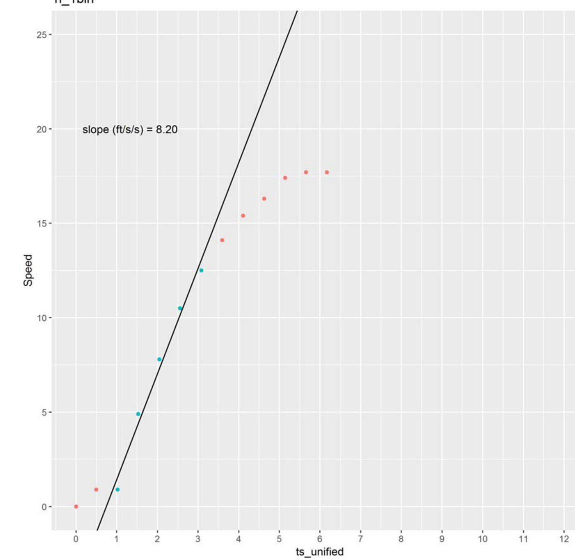

1f_15wk
slope (ft/s/s) = 7.24
Speed
ts_unified

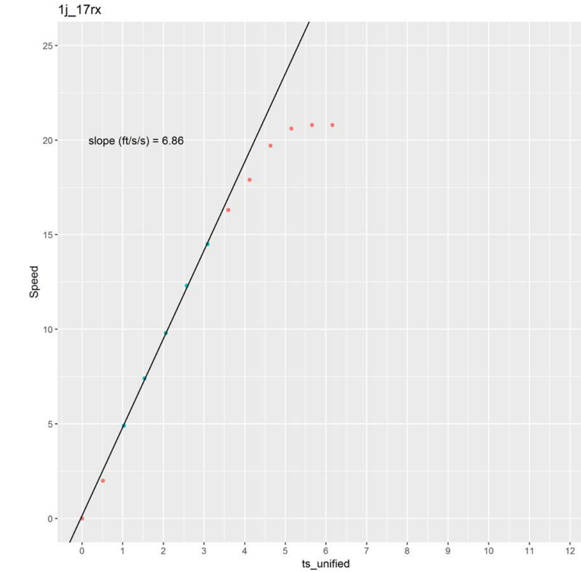

1f_1691
slope (ft/s/s) = 5.87
Speed
ts_unified

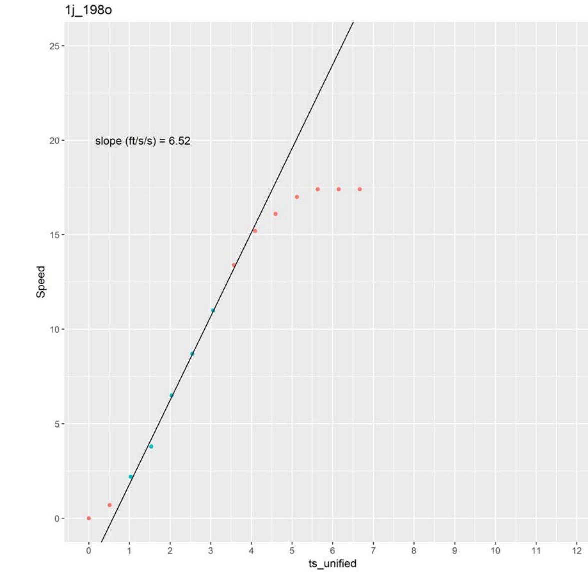

1f_1du7
slope (ft/s/s) = 6.35
Speed
ts_unified

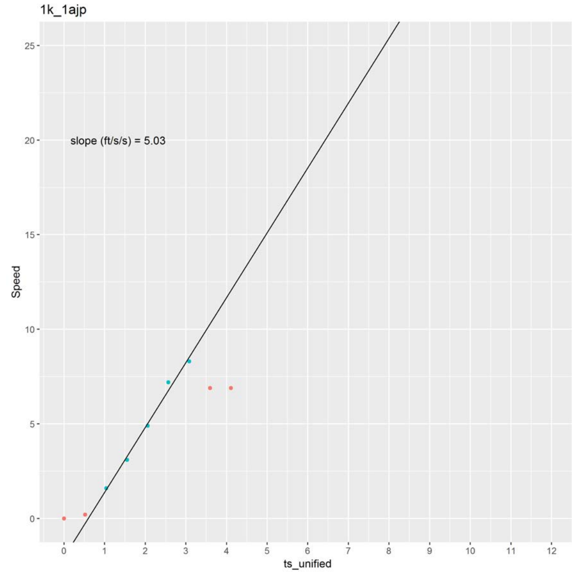
1h_17rs


1i_18t8


1i_1blh


1j_17rx


1j_198o


1k_1ajp


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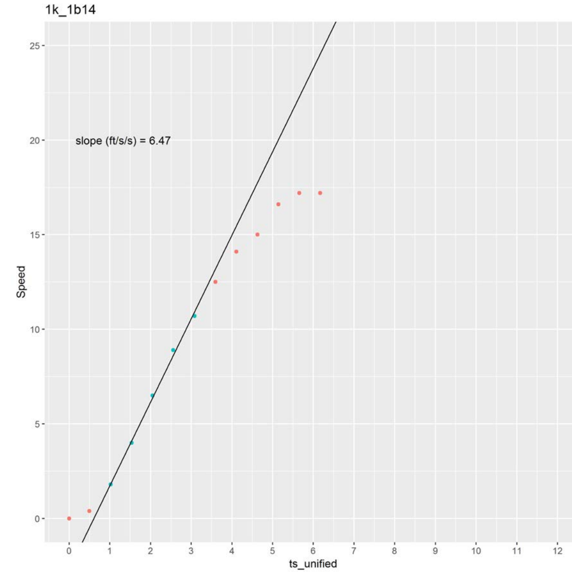
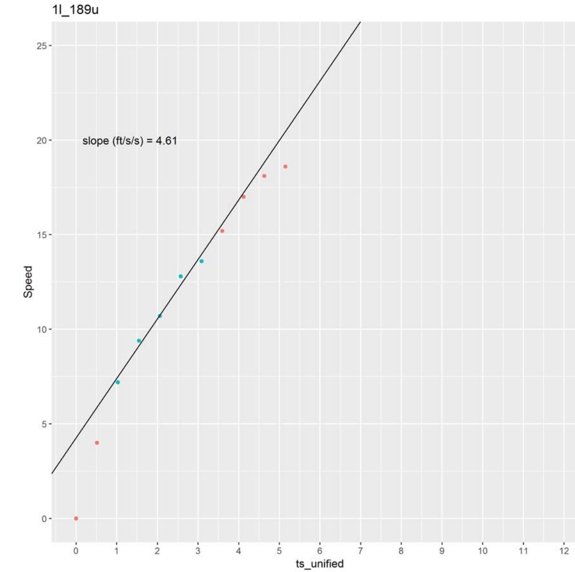


1l_189u


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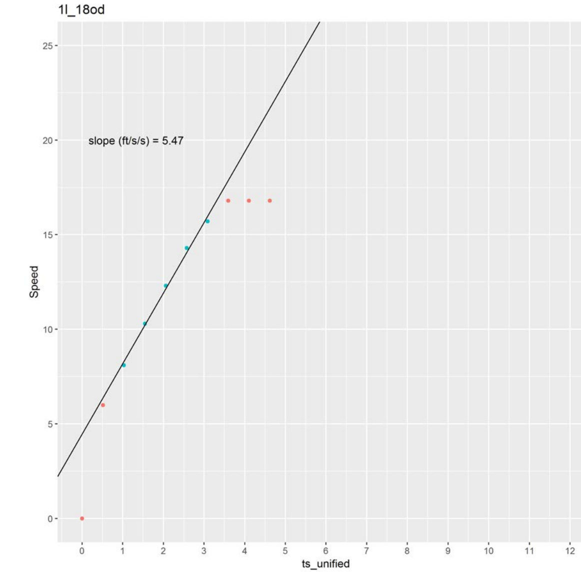
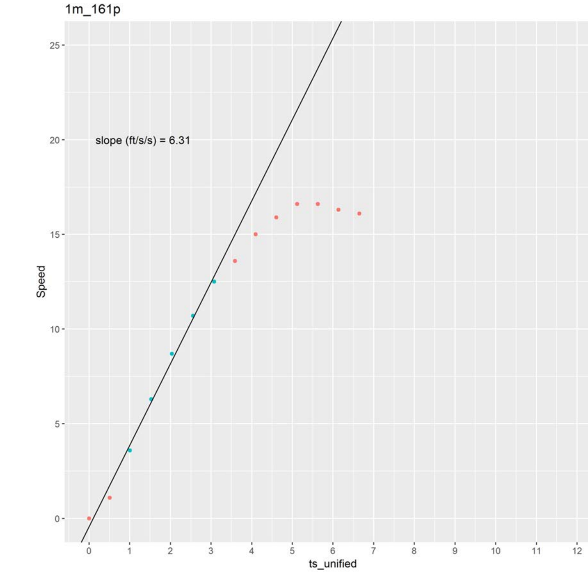
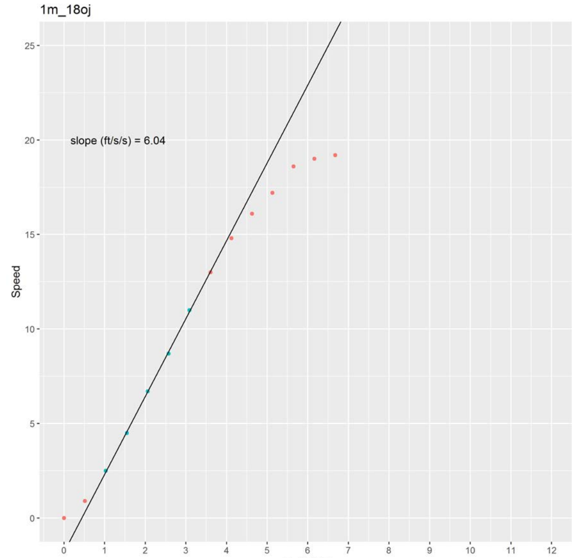
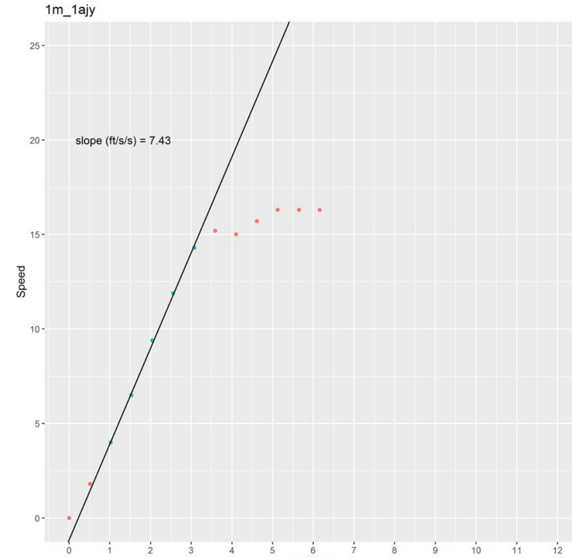
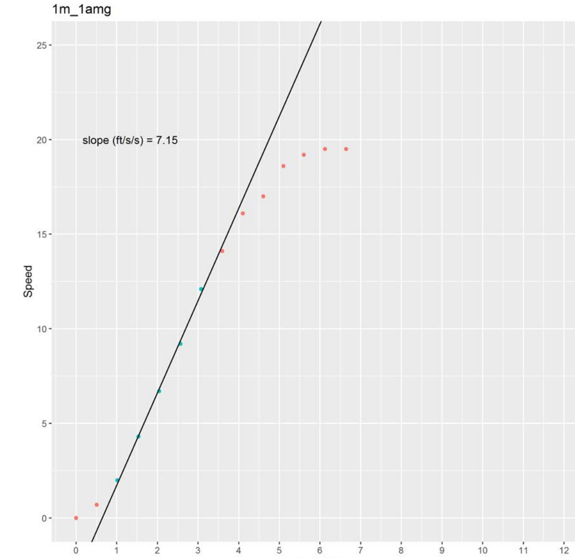
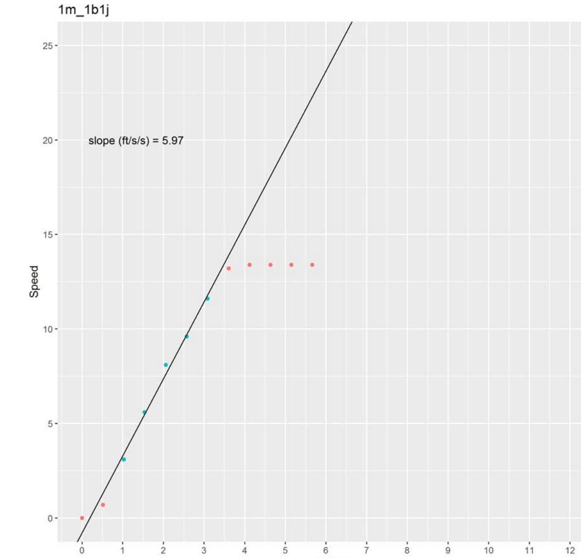


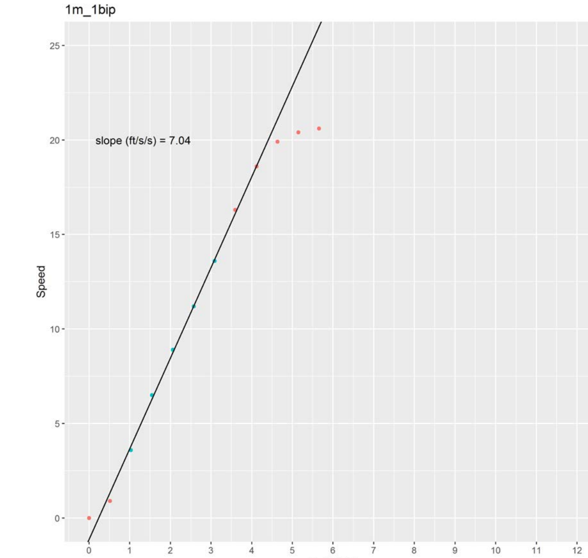
1m_161p


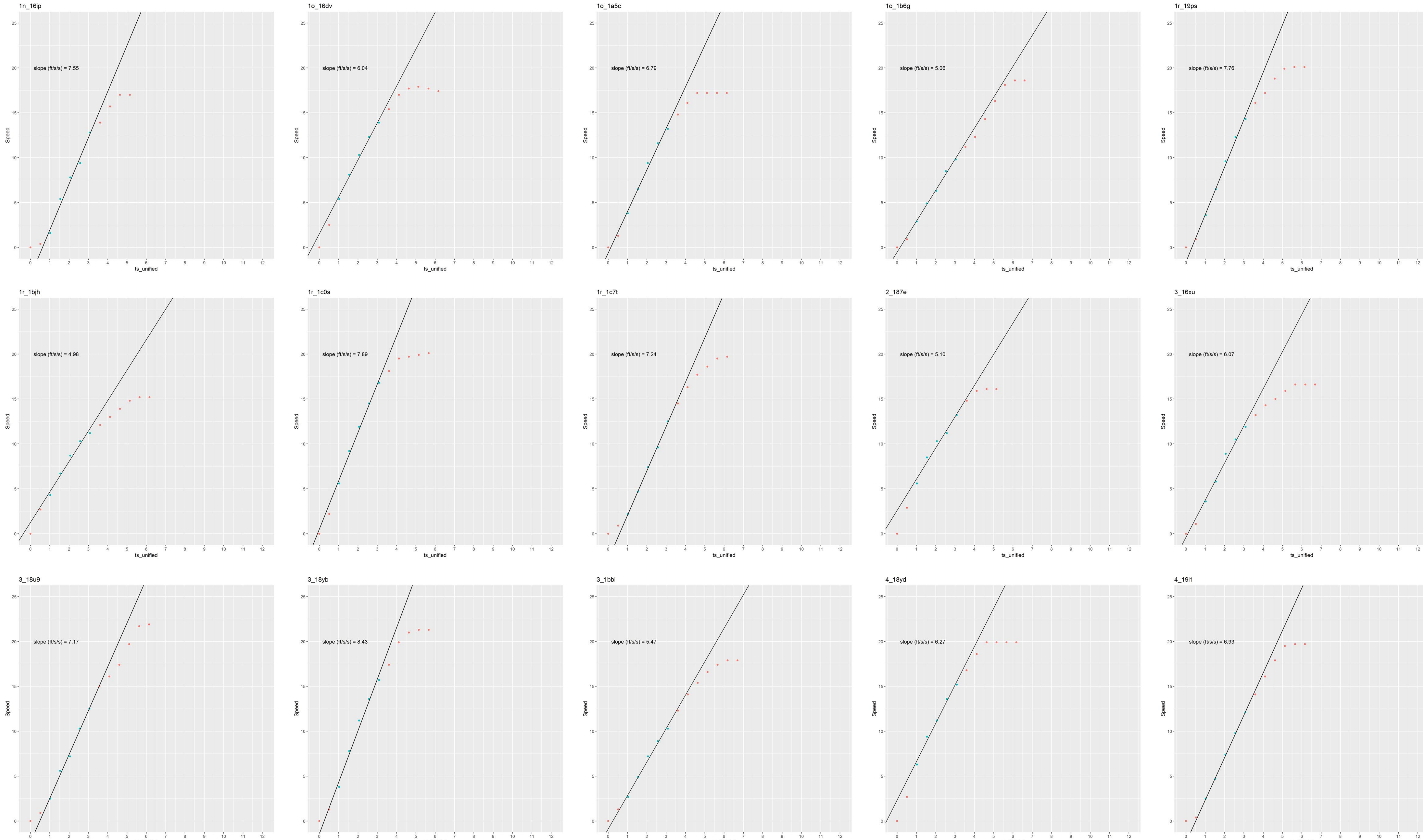
1m_18oj


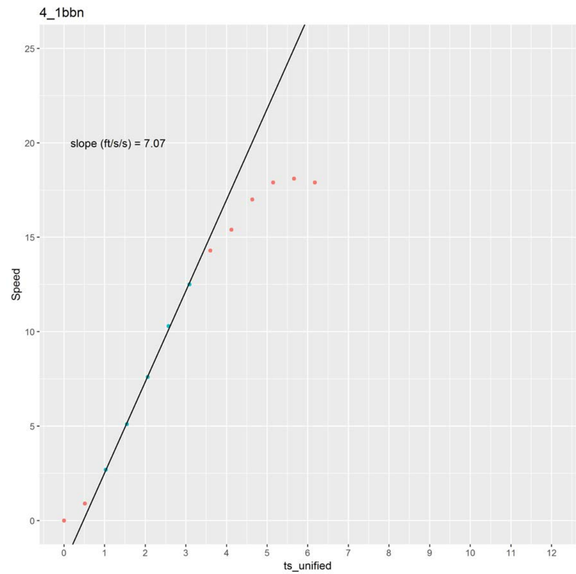
1m_1ajy


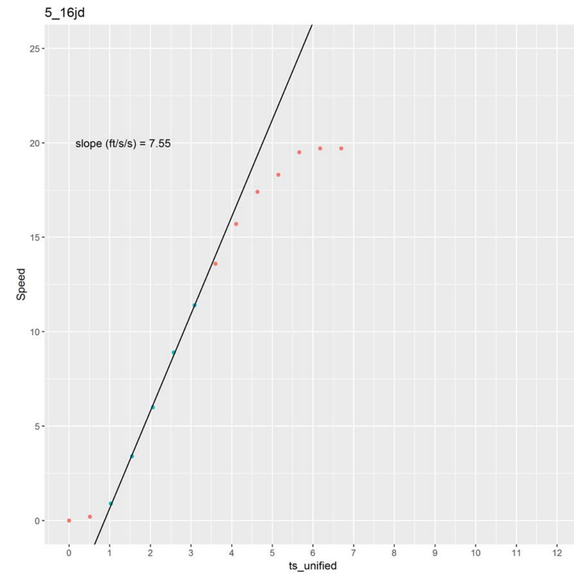
1m_1amg


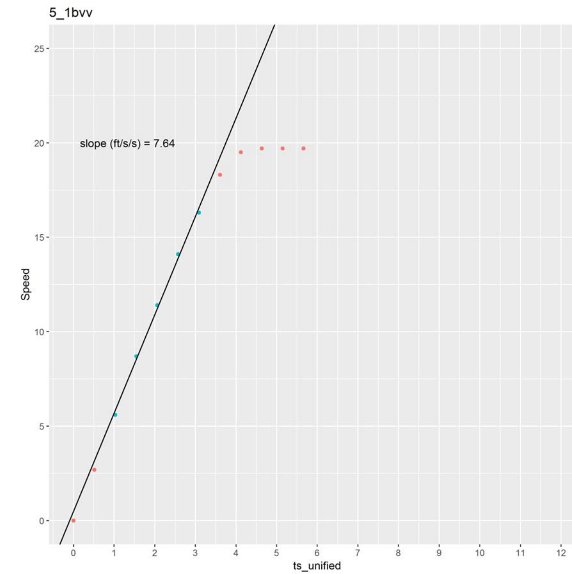
1m_1b1j


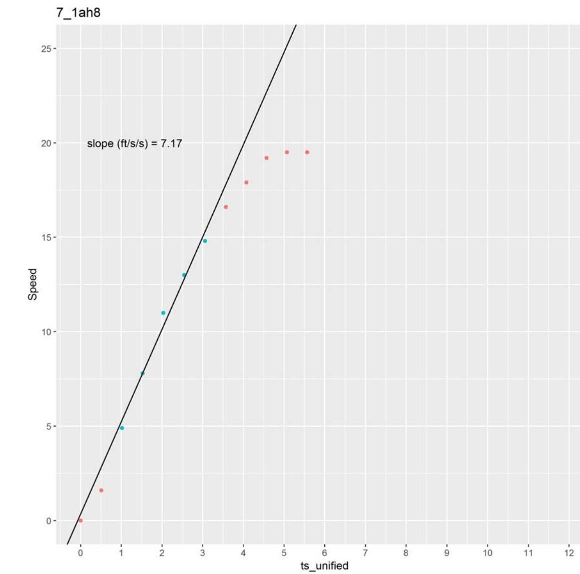
1m_1bip


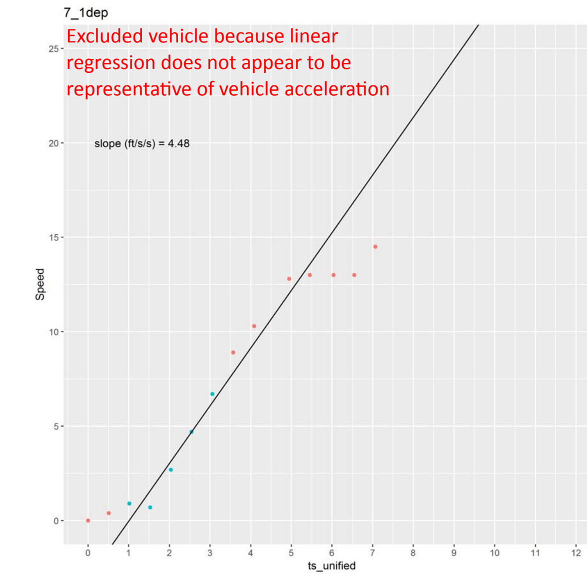

1n_16ip
slope (ft/s/s) = 7.55
1o_16dv
slope (ft/s/s) = 6.04
1o_1a5c
slope (ft/s/s) = 6.79
1o_1b6g
slope (ft/s/s) = 5.06
1r_19ps
slope (ft/s/s) = 7.76
1r_1bjh
slope (ft/s/s) = 4.98
1r_1c0s
slope (ft/s/s) = 7.89
1r_1c7t
slope (ft/s/s) = 7.24
2_187e
slope (ft/s/s) = 5.10
3_16xu
slope (ft/s/s) = 6.07
3_18u9
slope (ft/s/s) = 7.17
3_18yb
slope (ft/s/s) = 8.43
3_1bbi
slope (ft/s/s) = 5.47
4_18yd
slope (ft/s/s) = 6.27
4_19l1
slope (ft/s/s) = 6.93
Speed
ts_unified

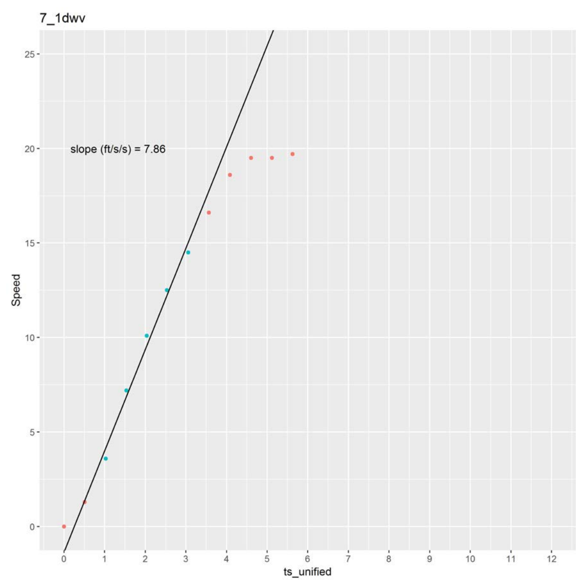

4_1bbn
slope (ft/s/s) = 7.07
Speed
ts_unified

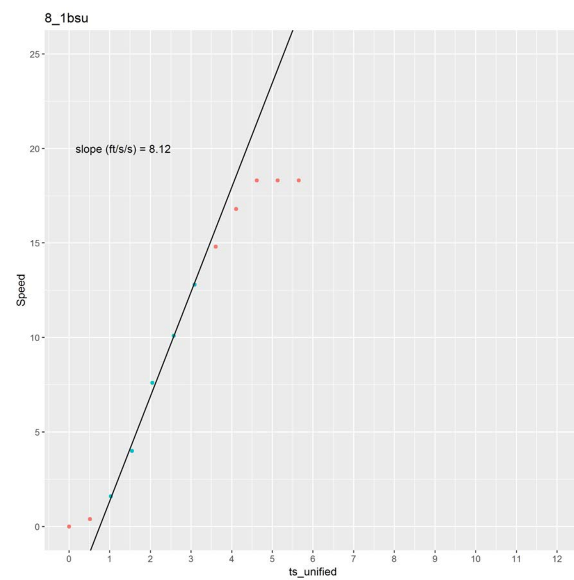

5_16jd
slope (ft/s/s) = 7.55
Speed
ts_unified

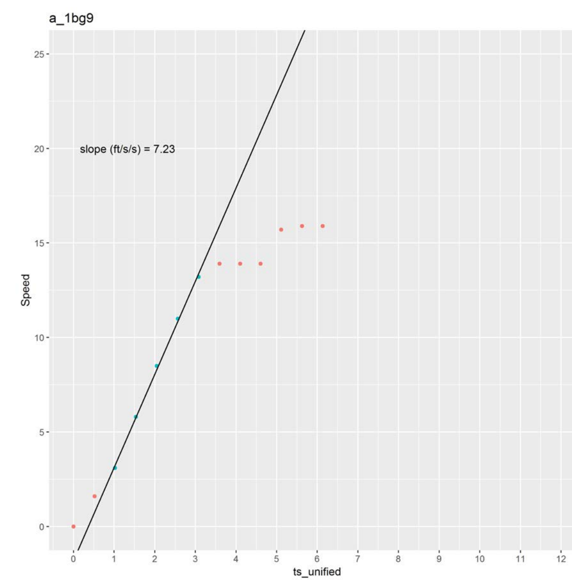

5_1bvv
slope (ft/s/s) = 7.64
Speed
ts_unified

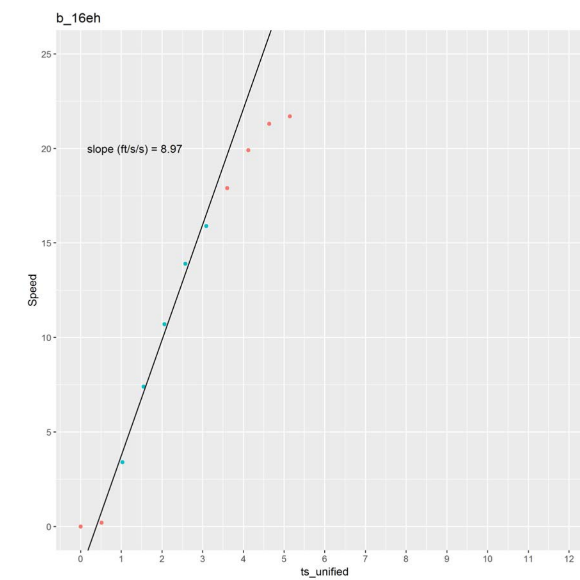

7_1ah8
slope (ft/s/s) = 7.17
Speed
ts_unified

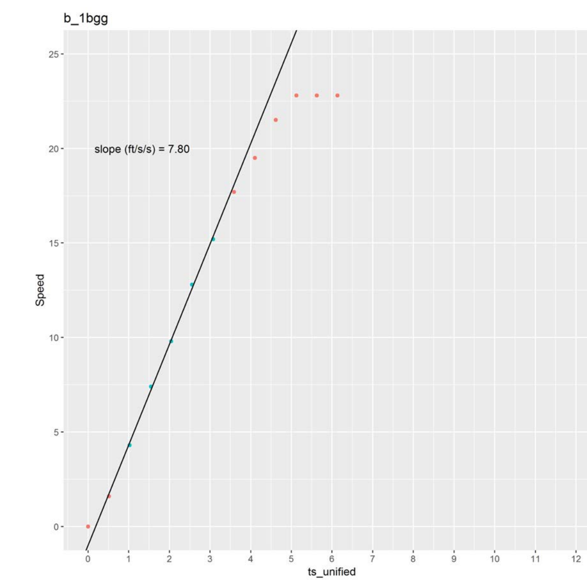

7_1dep
Excluded vehicle because linear regression does not appear to be representative of vehicle acceleration
slope (ft/s/s) = 4.48
Speed
ts_unified

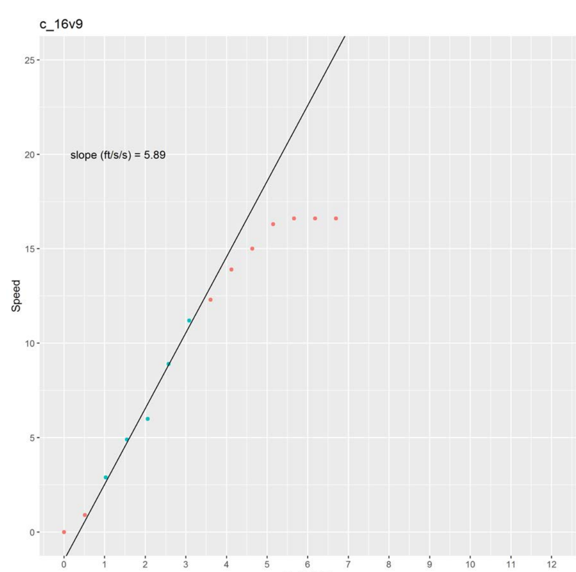

7_1dwv
slope (ft/s/s) = 7.86
Speed
ts_unified

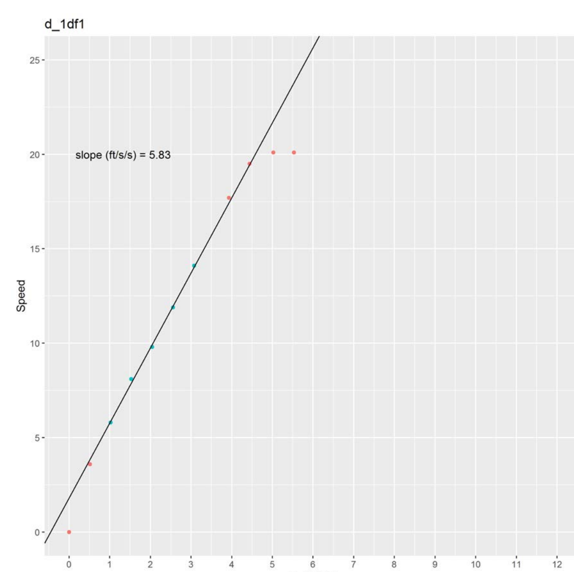

8_1bsu
slope (ft/s/s) = 8.12
Speed
ts_unified

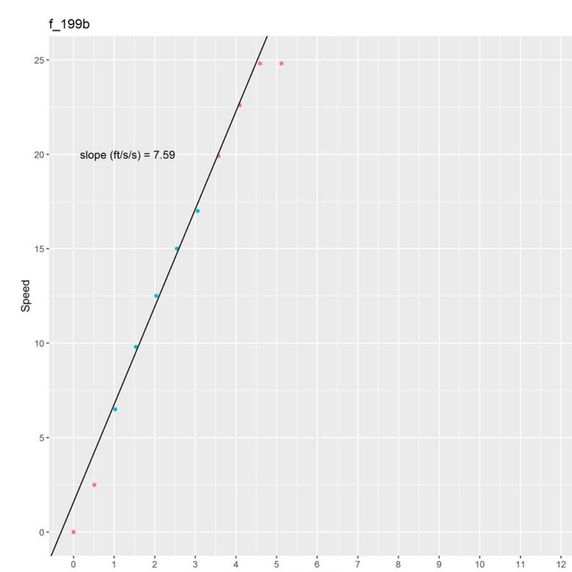

a_1bg9
slope (ft/s/s) = 7.23
Speed
ts_unified

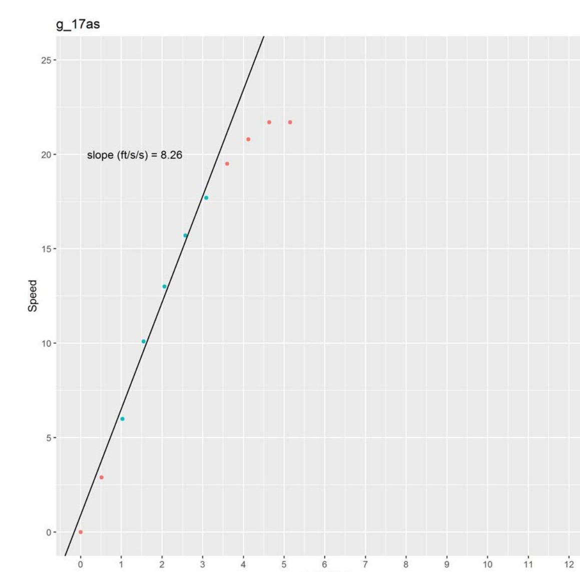

b_16eh
slope (ft/s/s) = 8.97
Speed
ts_unified

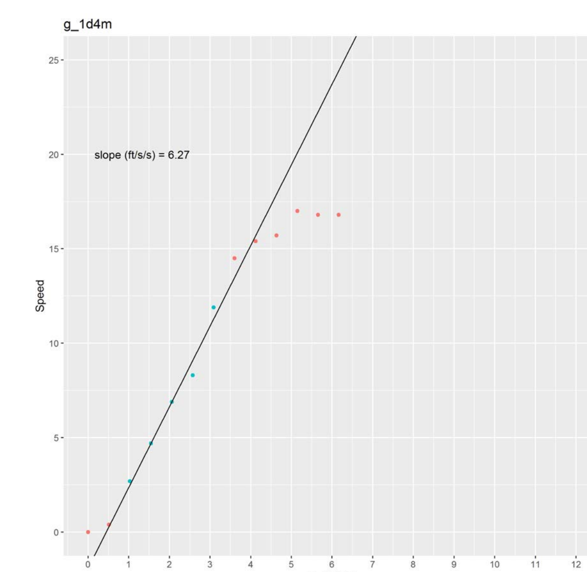

b_1bgg
slope (ft/s/s) = 7.80
Speed
ts_unified

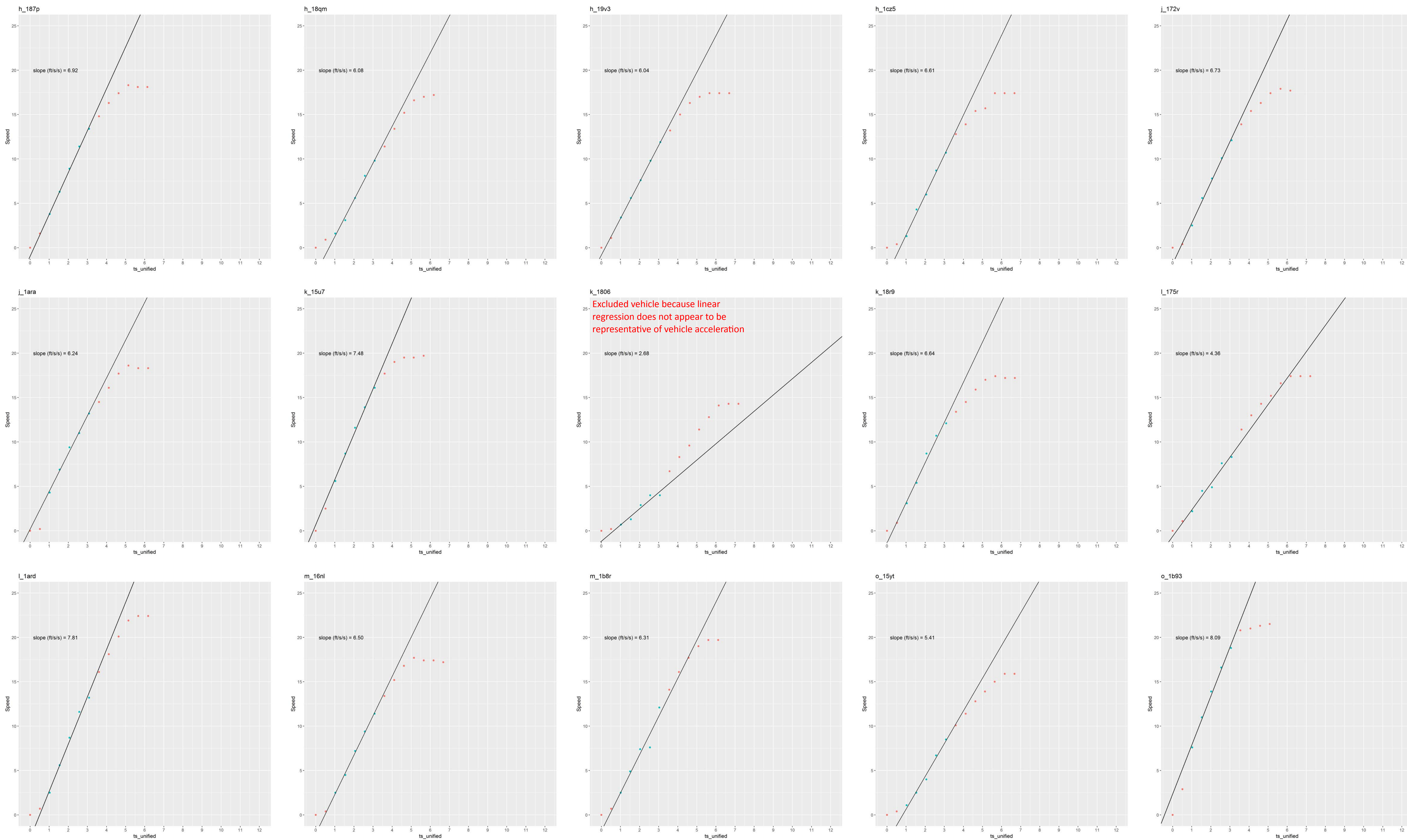

c_16v9
slope (ft/s/s) = 5.89
Speed
ts_unified

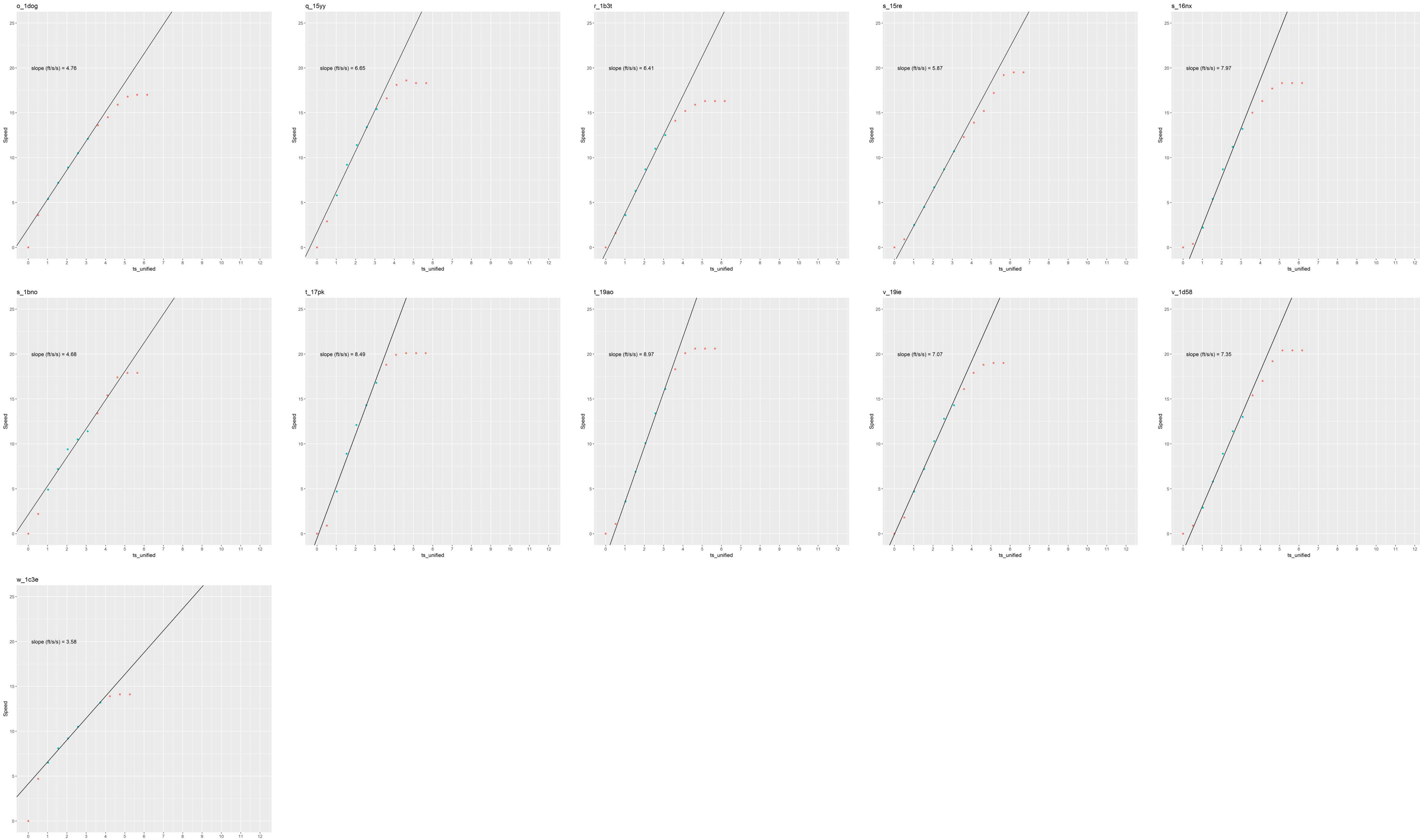

d_1df1
slope (ft/s/s) = 5.83
Speed
ts_unified


f_199b
slope (ft/s/s) = 7.59
Speed
ts_unified


g_17as
slope (ft/s/s) = 8.26
Speed
ts_unified


g_1d4m
slope (ft/s/s) = 6.27
Speed
ts_unified


h_187p
slope (ft/s/s) = 6.92
h_18qm
slope (ft/s/s) = 6.08
h_19v3
slope (ft/s/s) = 6.04
h_1cz5
slope (ft/s/s) = 6.61
j_172v
slope (ft/s/s) = 6.73
j_1ara
slope (ft/s/s) = 6.24
k_15u7
slope (ft/s/s) = 7.48
k_1806
Excluded vehicle because linear regression does not appear to be representative of vehicle acceleration
slope (ft/s/s) = 2.68
k_18r9
slope (ft/s/s) = 6.64
l_175r
slope (ft/s/s) = 4.36
l_1ard
slope (ft/s/s) = 7.81
m_16nl
slope (ft/s/s) = 6.50
m_1b8r
slope (ft/s/s) = 6.31
o_15yt
slope (ft/s/s) = 5.41
o_1b93
slope (ft/s/s) = 8.09
Speed
ts_unified


o_1dog
slope (ft/s/s) = 4.76
q_15yy
slope (ft/s/s) = 6.65
r_1b3t
slope (ft/s/s) = 6.41
s_15re
slope (ft/s/s) = 5.87
s_16nx
slope (ft/s/s) = 7.97
s_1bno
slope (ft/s/s) = 4.68
t_17pk
slope (ft/s/s) = 8.49
t_19ao
slope (ft/s/s) = 8.97
v_19ie
slope (ft/s/s) = 7.07
v_1d58
slope (ft/s/s) = 7.35
w_1c3e
slope (ft/s/s) = 3.58
Speed
ts_unified