An Exploratory Parameter Sensitivity Analysis of Bicycle-Vehicle Conflicts Using the Surrogate Safety Assessment Model

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Abstract

The use of traffic microsimulation software has been an invaluable tool for analysis of operational performance at signalized intersections in recent decades. Microsimulation also offers opportunities to examine the safety performance of an intersection through analysis of surrogate measures of safety such as conflicts identified using post encroachment time (PET) or time to collision (TTC). The use of microsimulation and surrogate measures of safety provides a very promising avenue for analysis of the safety impacts of treatments aimed at improving bicyclist safety, particularly for new and/or developing treatments given the absence of police-reported crash data. However, the use of these tools for the analysis of bicycle-vehicle conflicts is lacking. To fill this gap, the following two objectives were addressed in this study: 1) perform a sensitivity analysis on the impacts of behavioral parameters in microsimulation on the frequency and severity of bicycle-vehicle conflict outputs from Surrogate Safety Assessment Model (SSAM) at a signalized intersection, and 2) perform a qualitative analysis on the ability of microsimulation to emulate realistic interactions between motor vehicles and bicycles.

Data Description

- Developed based on an existing signalized intersection in Flagstaff, Arizona - simplified to include one leg with the standard bicycle lane treatment
- simulation was then run for 75 minutes ten separate times for each treatment
- a total of 36,000 seconds of data was recorded for each simulation scenario
- 'undetermined' priority for all conflict areas related to the bike lane upstream of the intersection

Study Design

- Dashed Bicycle Lane = 75 ft
- Vehicle Lane Width = 12 ft
- Bicycle Lane Width = 4 ft
- Vehicle Speed = 40 kph
- Bicycle Speed = 15 kph
- Signal Timing (WB Approach):
  - 5 sec/45 sec min/max green time
  - 3.6 sec yellow time
  - 2.4 sec all-red clearance time
- Hourly westbound traffic volumes:
  - 300 through vehicles
  - 300 right turning vehicles
  - 90 through bicycles
  - 90 right turning bicycles

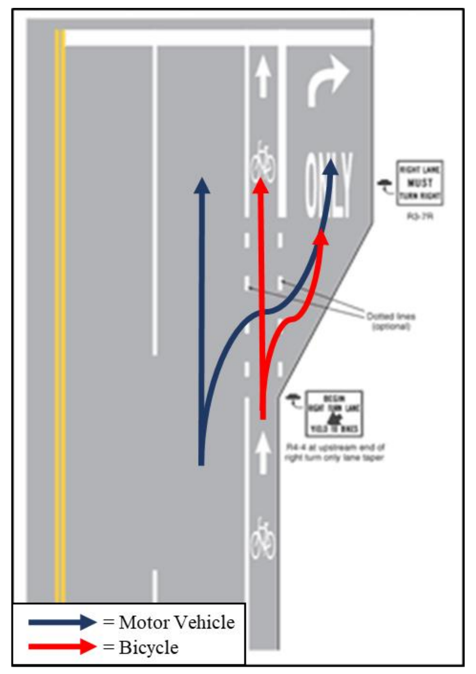

Fig. 1 Example of bicycle lane scenario analyzed *(MUTCD 2012)*

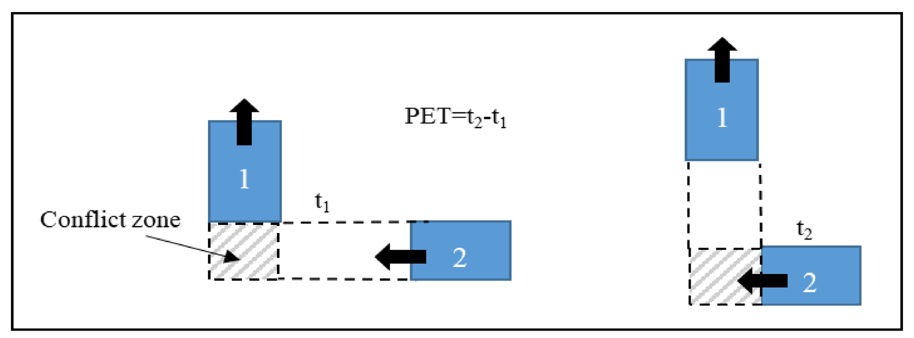

Fig. 2 Example showing concept of PET

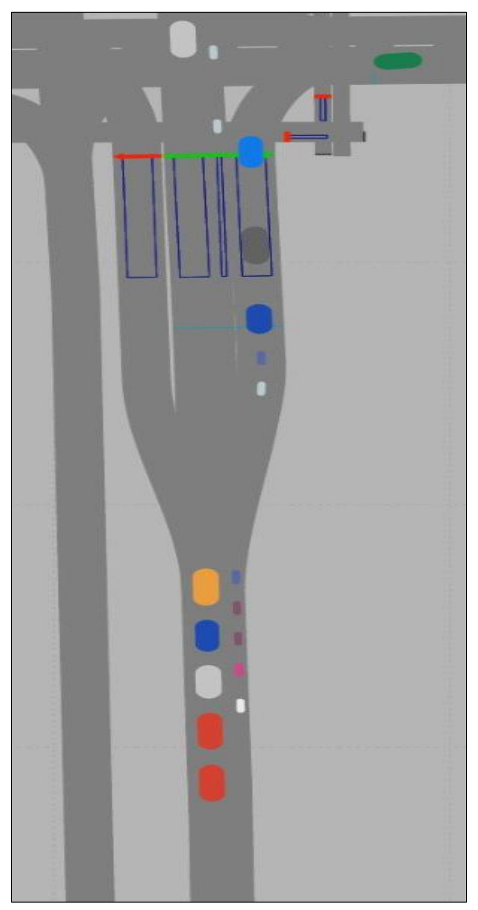

Fig. 3 Screen shot of unreasonable behavior observed in microsimulation (both bicycle and vehicle are stopped at front of queue).

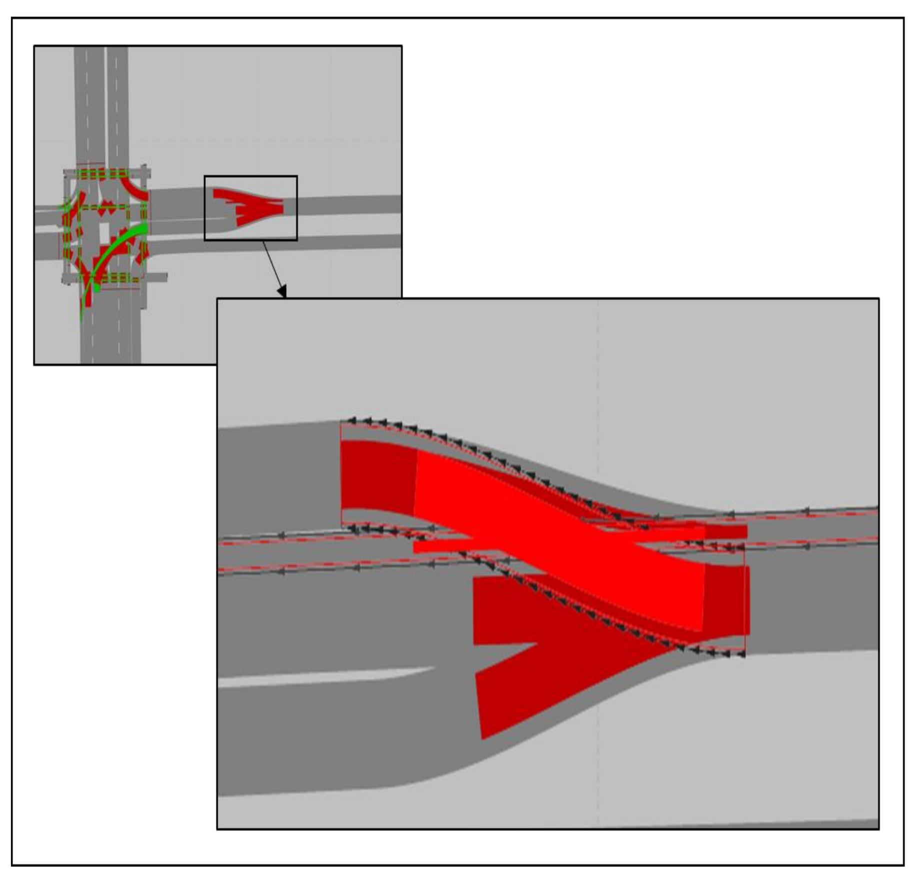

Fig. 4 Microsimulation conflict areas and priority rules for the study intersection

Methodology

- Table 1 below describes the behavioral parameters that were considered during the experiment, including their definition, default values, and the values that were tested as part of the experiment.
- Note that for each parameter, values both higher and lower than default values were tested. Values that were changed were changed for all simulated objects, both bicycles and vehicles:
- The experiment was conducted by changing behavioral parameters from their default values one at a time, and the effects on both operational (e.g. travel time), and surrogate safety measures (e.g. conflict frequency and severity in terms of PET and TTC) were summarized for each parameter change.
- Average hourly conflicts, average TTC, average PET, and minimum PET were calculated separately for each type of conflict:
- A manual review of video for one hour of each simulation scenario was conducted, the purpose of which was to qualitatively observe how well the simulations were emulating real-world behavior in terms of bicycle-vehicle interactions.

Table 1: VISSIM Behavior Parameters Tested

Parameter	Description	Default Value	Values Tested
1. Max Lookback Distance	Maximum distance a vehicle can see behind it in order to react to other vehicles behind it on the same link. (PTV AG, 2018)	492.13 ft	100 ft 300 ft 700 ft
2. Max Deceleration of Trailing Vehicle	The maximum deceleration for changing lanes for the trailing vehicle. (PTV AG, 2018)	-9.84 ft/s²	-8 ft/s² -9 ft/s² -11 ft/s²
3. Safety Distance Reduction Factor (Signals)	Defining the behavior of vehicles close to a stop line. If a vehicle is located in an area between Start upstream of stop line and End downstream of stop line, the factor is multiplied by the safety distance of the vehicle. The safety distance used is based on the car following model. For lane changes in front of a stop line, the two values calculated are compared. VISSIM will use the shorter of the two distances. (PTV AG, 2018)	0.6	0.2 0.4 0.8
4. Safety Distance Reduction Factor (Lane Change)	Is taken into account for each lane change. It concerns the following parameters: the safety distance of the trailing vehicle on the new lane for determining whether a lane change will be carried out, the safety distance of the lane changer itself, and the distance to the preceding, slower lane changer. (PTV AG, 2018)	0.6	0.2 0.4 0.8
5. Min Headway	The minimum distance between two vehicles that must be available after a lane change, so that the change can take place. A lane change during normal traffic flow might require a greater minimum distance between vehicles in order to maintain the speed-dependent safety distance (PTV AG, 2018)	1.64 ft	1 ft 2 ft 2.5 ft
6. Average Standstill Distance (Wiedemann 74)	Defines the average desired distance between two cars. (PTV AG, 2018). The same definition would apply to bicycles.	6.56 ft	9.84 ft 4.10 ft 1.64 ft
7. Additive Part of Safety Distance (Wiedemann 74)	Value used for the computation of the desired safety distance d. Allows to adjust the time requirement values. (PTV AG, 2018)	2	2.2 1.8 1.6
8. Multiplicative Part of Safety Distance (Wiedemann 74)	Value used for the computation of the desired safety distance d. Allows to adjust the time requirement values. Greater value = greater distribution (standard deviation) of safety distance. (PTV AG, 2018)	3	3.3 2.7 2.4

Results

- The results of the microsimulation/SSAM outputs for the experiment are shown in Tables 2, Table 3 shows average travel times (TT) by movement and vehicle type, Table 4 shows a summary of the observations of unrealistic behavior observed in the microsimulations, and box plots for average PET and TTC for bicycle-vehicle conflicts are shown in Figures 5 and 6, respectively.

Table 2: Summary of Bicycle-Vehicle (BV) Conflict Outputs from SSAM

Parameter Tested	Average Hourly No. of Conflicts		Avg. TTC (sec)		Avg. PET (sec)		Min PET (sec)	
	No. of Conflicts	Percent Change from Baseline	Avg. TTC	Percent Change from Baseline	Avg. PET	Percent Change from Baseline	Min PET	Percent Change from Baseline
Baseline Simulation (All Default Values)	6.7	N/A	1.30	N/A	0.68	N/A	0.30	N/A
Max Lookback Distance* 100, 200, & 700 ft	6.7	0.0%	1.30	0.0%	0.68	0.0%	0.30	0.0%
Max Decel. of Trailing Veh* -8, -9, & -11 ft/s²	6.7	0.0%	1.30	0.0%	0.68	0.0%	0.30	0.0%
Safety Distance Reduction Factor (signals) 0.2	8.6	28.4%	1.25	-3.5%	0.95	40.0%	0.30	0.0%
Safety Distance Reduction Factor (signals) 0.4	8.9	32.8%	1.31	0.8%	1.00	48.6%	0.40	33.3%
Safety Distance Reduction Factor (signals) 0.8	6.7	0.0%	1.30	-0.1%	0.63	-6.2%	0.40	33.3%
Safety Distance Reduction Factor (lane change)* 0.2, 0.4, & 0.8	6.7	0.0%	1.30	0.0%	0.68	0.0%	0.30	0.0%
Min headway* 1 ft, 2 ft, & 3 ft	6.7	0.0%	1.30	0.0%	0.68	0.0%	0.30	0.0%
Average Standstill Distance** 9.84 ft	2.4	-64.2%	1.47	13.3%	0.81	20.2%	0.60	100.0%
Average Standstill Distance** 4.10 ft	10.9	62.7%	1.20	-7.3%	1.12	65.9%	0.20	-33.3%
Average Standstill Distance** 1.64 ft	19.9	197.0%	0.85	-34.5%	0.68	0.8%	0.00	-100.0%
Additive Part of Safety Distance** 2.2	5.8	-13.4%	1.30	-0.2%	0.76	11.7%	0.40	33.3%
Additive Part of Safety Distance** 1.8	5.9	-11.9%	1.31	1.2%	0.77	13.3%	0.40	33.3%
Additive Part of Safety Distance** 1.6	7.2	7.5%	1.32	1.8%	0.87	28.0%	0.40	33.3%
Multiplicative Part of Safety Distance** 3.3	4.9	-26.9%	1.30	0.3%	0.69	2.6%	0.40	33.3%
Multiplicative Part of Safety Distance** 2.7	6.8	1.5%	1.29	-0.8%	0.96	42.0%	0.00	-100.0%
Multiplicative Part of Safety Distance** 2.4	7.5	11.9%	1.30	0.4%	0.82	21.7%	0.40	33.3%

*Parameter had no effect on bicycle-vehicle conflicts; all values tested had the same outputs and match the baseline model.
**Parameter adjusted within Wiedemann 74 car following model attributes.

Table 3: Summary of Average Travel Times (seconds) by Movement and Vehicle Type

Parameter Tested	Thru Vehicles		Thru Bikes		Right Turning Vehicles		Right Turning Bikes	
	Average Travel Time	Percent Change from Baseline	Average Travel Time	Percent Change from Baseline	Average Travel Time	Percent Change from Baseline	Average Travel Time	Percent Change from Baseline
Baseline Simulation (All Default Values)	62.3	N/A	119.9	N/A	64.5	N/A	114.7	N/A
Max Lookback Distance* 100, 200, & 700 ft	62.3	0.0%	119.9	0.0%	64.5	0.0%	114.7	0.0%
Max Decel. of Trailing Veh* -8, -9, & -11 ft/s²	62.3	0.0%	119.9	0.0%	64.5	0.0%	114.7	0.0%
Safety Distance Reduction Factor (signals) 0.2	59.6	-4.3%	117.7	-1.9%	62.0	-3.9%	110.9	-3.3%
Safety Distance Reduction Factor (signals) 0.4	61.8	-0.9%	119.7	-0.2%	65.1	1.0%	114.2	-0.4%
Safety Distance Reduction Factor (signals) 0.8	66.6	6.9%	122.4	2.0%	68.1	5.6%	116.7	1.8%
Safety Distance Reduction Factor (lane change)* 0.2, 0.4, & 0.8	62.3	0.0%	119.9	0.0%	64.5	0.0%	114.7	0.0%
Min headway* 1 ft, 2 ft, & 3 ft	62.3	0.0%	119.9	0.0%	64.5	0.0%	114.7	0.0%
Average Standstill Distance** 9.84 ft	68.1	9.3%	123.1	2.6%	69.7	8.1%	117.7	2.7%
Average Standstill Distance** 4.10 ft	62.2	-0.2%	116.6	-2.8%	63.7	-1.2%	111.4	-2.8%
Average Standstill Distance** 1.64 ft	57.9	-7.1%	112.8	-5.9%	59.8	-7.3%	106.8	-6.8%
Additive Part of Safety Distance** 2.2	62.9	1.0%	122.6	2.2%	64.5	0.1%	115.3	0.5%
Additive Part of Safety Distance** 1.8	62.7	0.6%	120.3	0.3%	64.5	0.1%	113.6	-0.9%
Additive Part of Safety Distance** 1.6	62.7	0.6%	119.2	-0.6%	63.8	-1.1%	112.7	-1.7%
Multiplicative Part of Safety Distance** 3.3	63.4	1.7%	122.0	1.8%	65.6	1.7%	115.6	0.8%
Multiplicative Part of Safety Distance** 2.7	63.7	2.2%	122.1	1.8%	65.1	0.9%	115.1	0.4%
Multiplicative Part of Safety Distance** 2.4	62.9	0.9%	120.7	0.7%	64.2	-0.4%	113.8	-0.8%

*Parameter had no effect on average travel times; all values tested had the same outputs, match the baseline model, and are shown in one row.
**Parameter adjusted within Wiedemann 74 car following model attributes.

Table 4: Summary of Unreasonable Bicycle-Vehicle Interaction Behavior Observed

Summary of Unreasonable Bicycle-Vehicle Interaction Behavior Observed						
Parameter Tested	Bicycle Only[1]		Vehicle Only[2]		Bicycle & Vehicle[3]	
	No. of Events	Average Duration of Events (sec)	No. of Events	Average Duration of Events (sec)	No. of Events	Average Duration of Events (sec)
Baseline Simulation (All Default Values)	2	13.6	2	8.7	3	30.4
Safety Distance Reduction Factor (signals) 0.2	4	13.4	1	27.7	1	5.6
Safety Distance Reduction Factor (signals) 0.4	6	28.6	2	11.3	3	21.4
Safety Distance Reduction Factor (signals) 0.8	2	55.6	1	8.0	8	25.3
Average Standstill Distance* 9.84 ft	8	34.3	1	8.8	3	20.6
Average Standstill Distance* 4.10 ft	4	18.7	2	8.8	3	17.1
Average Standstill Distance* 1.64 ft	4	17.3	2	16.5	1	32.3
Additive Part of Safety Distance* 2.2	5	41.4	0	0.0	6	29.0
Additive Part of Safety Distance* 1.8	6	23.9	3	23.7	1	12.7
Additive Part of Safety Distance* 1.6	7	25.3	3	15.4	4	30.5
Multiplicative Part of Safety Distance* 3.3	11	25.9	3	5.8	6	16.4
Multiplicative Part of Safety Distance* 2.7	6	32.3	4	14.3	4	26.4
Multiplicative Part of Safety Distance* 2.4	5	47.8	2	11.9	8	17.5

[1]Bicyclist waited an unreasonable amount of time (>5.0 sec) to proceed at conflict point
[2]Vehicle waited an unreasonable amount of time (>5.0 sec) to proceed at conflict point
[3]Bicyclist and vehicle both waited an unreasonable amount of time (>5.0 sec) to proceed at conflict point
*Parameter adjusted within Wiedemann 74 car following model attributes

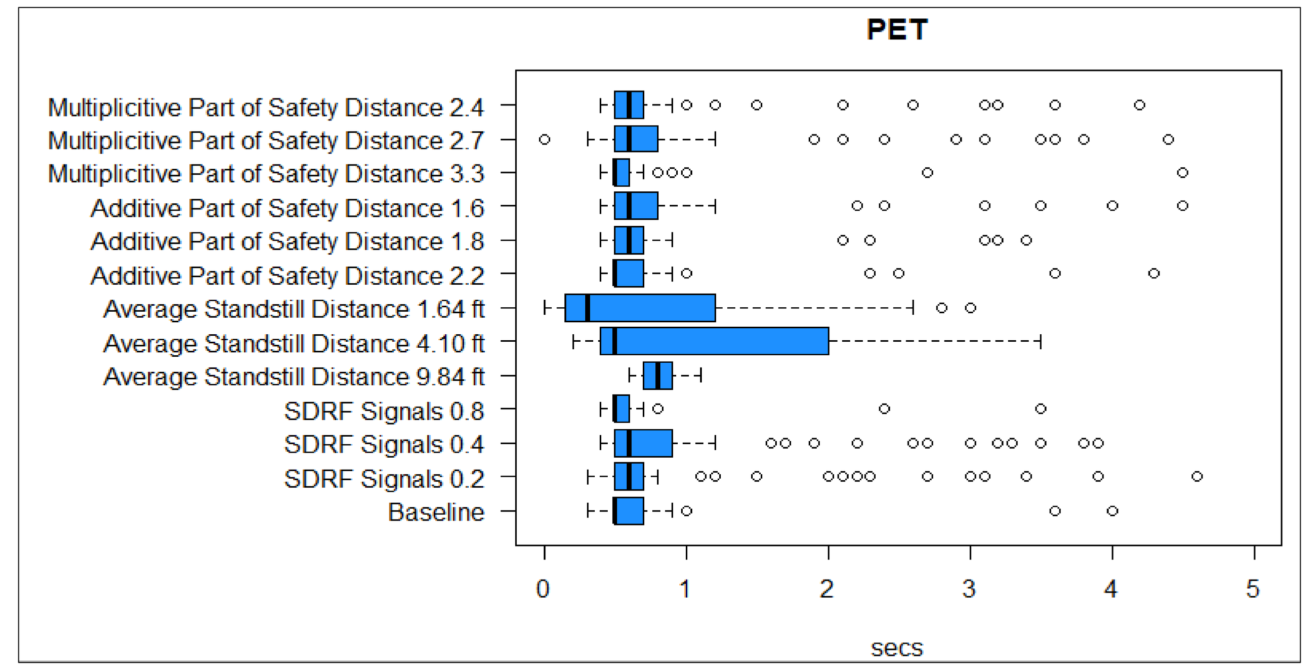

Figure 5: Boxplots of average PET for BV conflicts by parameter tested

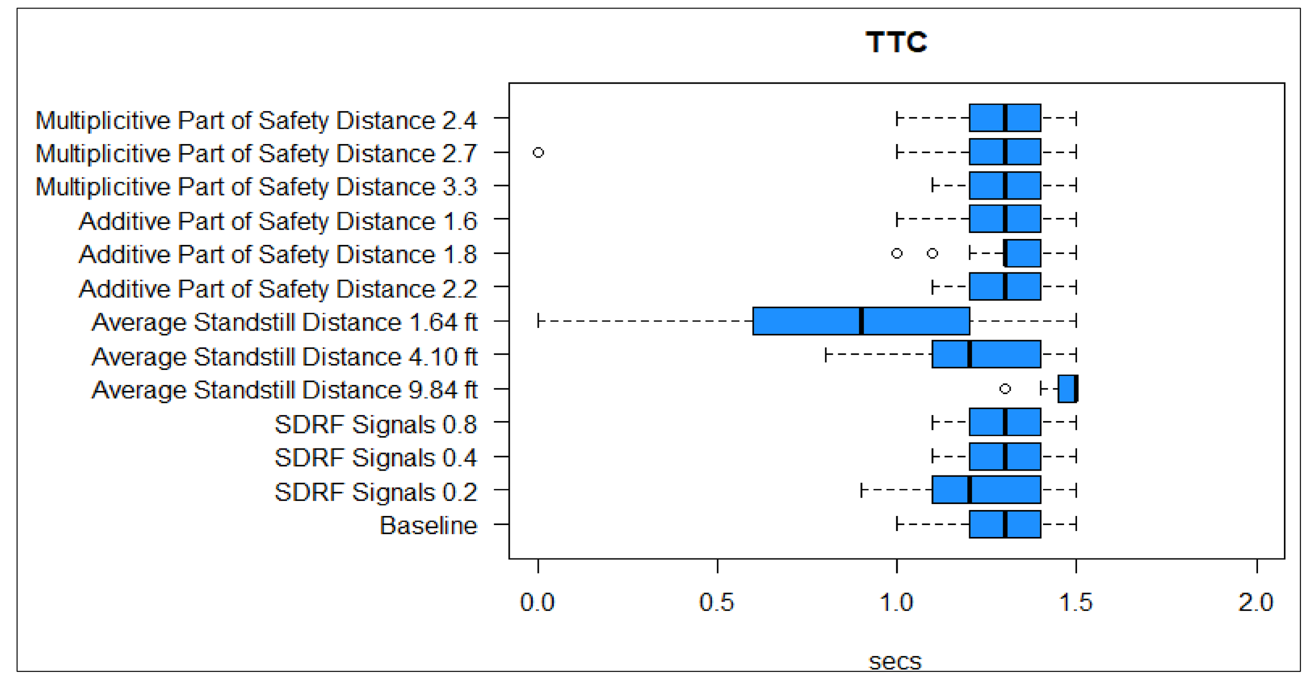

Figure 6 Boxplots of average TTC for BV conflicts by parameter tested

Conclusion

- Max lookback distance, max deceleration of trailing vehicle, safety distance reduction factor (lane change), and min headway had no effect on bicycle-vehicle conflicts in this simulation.
- Safety distance reduction factor (signals), additive part of safety distance, and multiplicative part of safety distance all had an effect on both conflicts and travel times, but the results were not always consistent in terms of increase or decrease in conflicts or travel times.
- Average standstill distance had by far the largest impact on both conflicts and travel times, and the effect was consistent; as average standstill distance decreased, conflicts increased and travel decreased.
- Overall, it is recommended that further experimentation with conflict zone setup, priority rule schemes, and behavioral parameters, both those explored in this study and others, is needed to progress towards the goal of using microsimulation/SSAM to accurately to assess bicyclist safety.