PTV USER GROUP MEETING -2016

11/26/2016

CALIBRATION OF VEHICLE FOLLOWING MODELS USING TRAJECTORY DATA UNDER HETEROGENEOUS TRAFFIC CONDITIONS

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Outline of the Talk

- Introduction and Challenges
- Past studies
- Objectives of the study
- Methodology
- Wiedemann theoretical plots
- Study area, Data collection and Data extraction
- Calibration of Wiedemann models and their validation
- Bottleneck analysis
- Conclusions
- References

Introduction and Challenges

- Traffic simulation is an imitation of flow behavior, characteristics, and distinct elements of a transportation system.
- Simulation may not be a true representation of a system or a process, rather a simplification.
- Due to their flexibility and feasibility in testing different alternatives that do not currently exist in the real-world
- Different simulation tools are used in planning and designing of system components along with testing their performance at different scenarios.
- There is a need for demand of robust models in order to increase the confidence on results from the simulation models.
- Modelling such kind of models, which are better replicating field conditions is a hard task, which leaves a gap in this aspect.

Past studies

s.no 4.	Authors	Title	Findings
1.	**Ranjithkar (2005)**	Car Following Models :An Experiment Based Benchmarking.	• car following experiment is conducted on a test track with ten cars each employed with RTK GPS. • responses of the followers were observed and compared with eight car following models. Statistics were applied among the followers' behavior • concluded that linear models were giving better results because of closed constrained conditions.
2.	**Sandeep Menneni, Carlos Sun, Peter Vortisch. (2008).**	Microsimulation Calibration Using Speed Flow Relationships.	• calibrated WIEDEMANN 99 model at different flow levels on a road section and compared macroscopic plots through simulation. • found that the calibrated parameters are almost representing same fundamental characteristics.
3.	**Yu Gao (2008)**	Calibration And Comparison Of The VISSIM And INTEGRATION Microscopic Traffic Simulation Models	• calibrated different car-following models that is based on macroscopic traffic stream data. • compared VISSIM and INTEGRATION software that highlights some of the differences/similarities in modeling traffic, and compares the various measures of effectiveness derived from the models.

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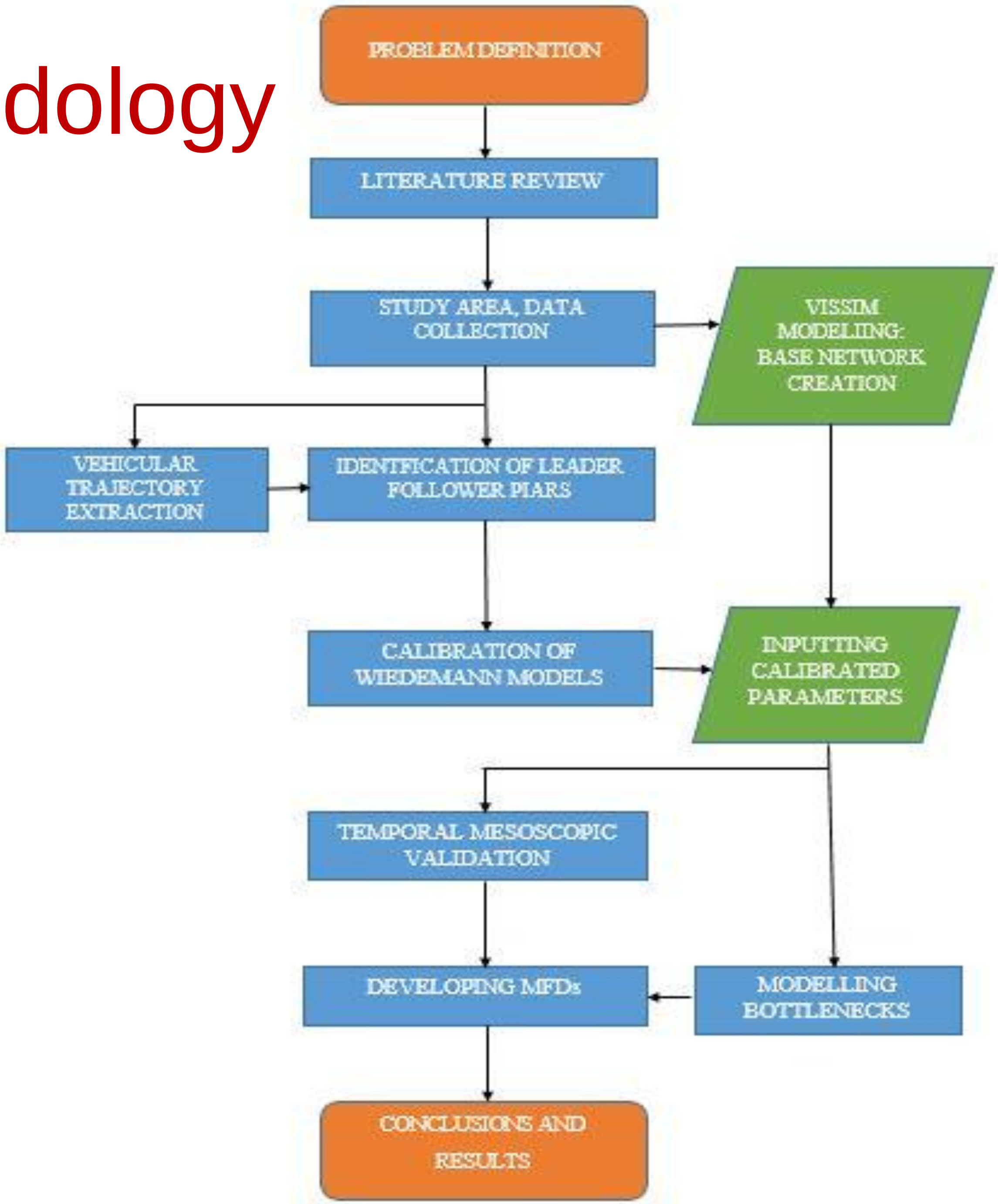
s.no.	Authors	Title	Findings
4.	**Tom V Mathew, Padmakumar Radhakrishnan. (2010).**	Calibration of Microsimulation Models for Nonlane-Based Heterogeneous Traffic at Signalized Intersections	• they simulated three signalized road intersections, they calibrated WIEDMANN 74 and WIEDEMANN 99 car following parameters • based on considering delay as a validating variable using genetic algorithm. it was found that The multi parameter sensitivity analysis was found to be an effective way of finding the significant parameters and the interactions between the vehicles
5.	**Pruthvi Manjunatha, Peter Vortisch and Tom V Mathew (2012)**	Methodology for the Calibration of VISSIM in Mixed Traffic.	• simulated two intersections in mixed traffic environment. They have calibrated VISSIM wiedemann 99 car following model with the help of genetic algorithm and compared observed delays and field delays of the sections considered.
6.	**Umair duranni (2015)**	Calibrating the Wiedemann's vehicle-following model using mixed vehicle-pair interactions	• calibrated WIEDEMANN 99 car following model based on each leader and follower combination wise • simulated the road section in VISSIM software and validated the section based on speed and acceleration over the stretch and compared with default parameters.

Challenges Dealt in this study

- Identification of true leader-following pairs in heterogeneous traffic environment.
- Calibration of WIEDEMANN 74 model and developing simulation models for checking the effectiveness.
- Calibration of advanced WIEDEMANN 99 model and developing simulation model to check the effectiveness.
- Macroscopic validation of calibrated WIEDEMANN 74 and WIEDEMANN 99 models.
- Understanding the effect of bottlenecks in the system and their spatial influence over the road segment on their upstream side as well down stream.

Methodology



Study area, data collection and data extraction

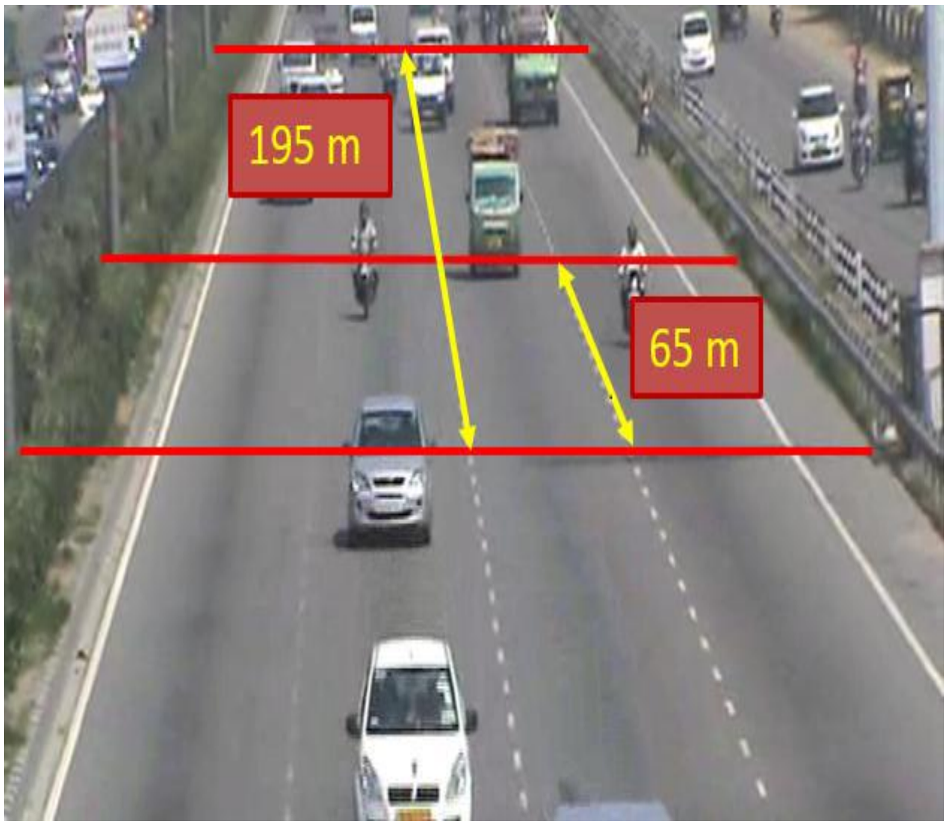
- Based on the need of the study, the study areas were selected to record traffic video on Delhi Gurgaon expressway and an arterial road in Chennai (Saidapet).
- The study stretches were selected after conducting a reconnaissance survey to satisfy the following conditions:

  (1) The stretch should be fairly straight and pavement conditions were similar over the study stretch

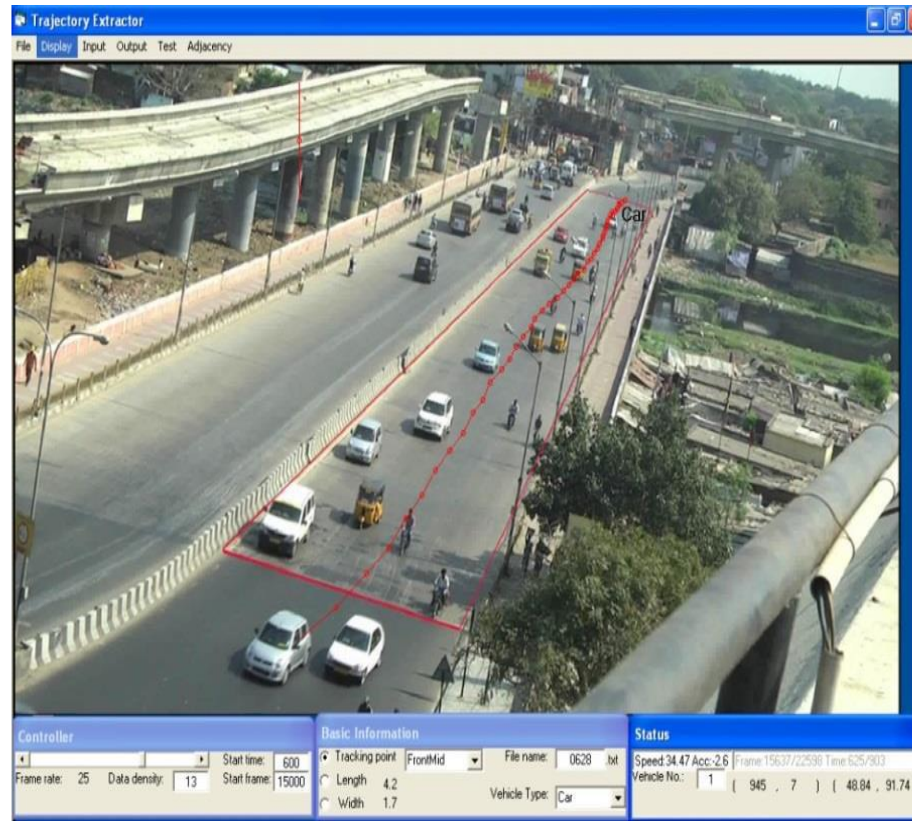
  (2) Width of Roadway should be uniform, and

  (3) There should not be any direct access from the adjoining land uses (i.e., the flow should be conserved)

Study sections



Delhi study section



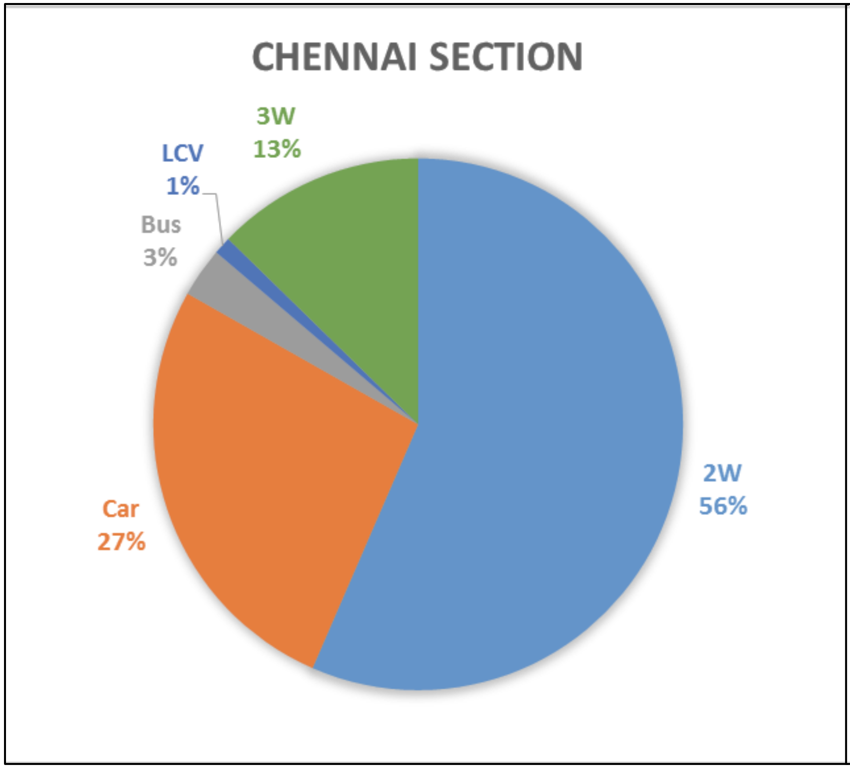
Chennai study section

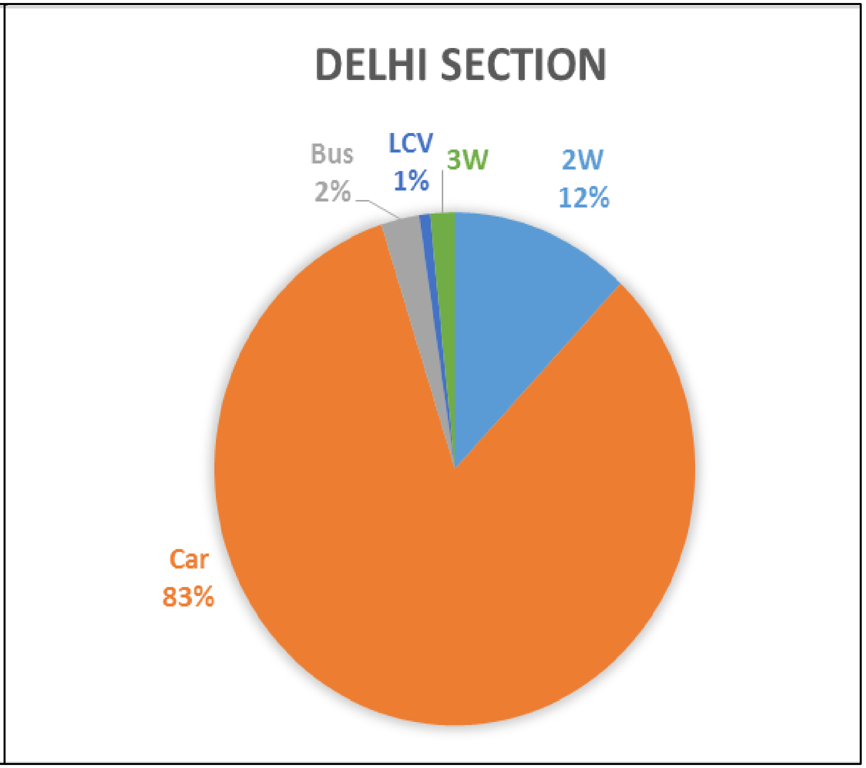
Study area characteristics

S.No.	Section	Road way type	Trap Length	Width
1.	Chennai road section	Urban arterial	250m	11.2m
2.	Delhi Gurgaon section	multi-lane high speed urban corridor	195m	14m

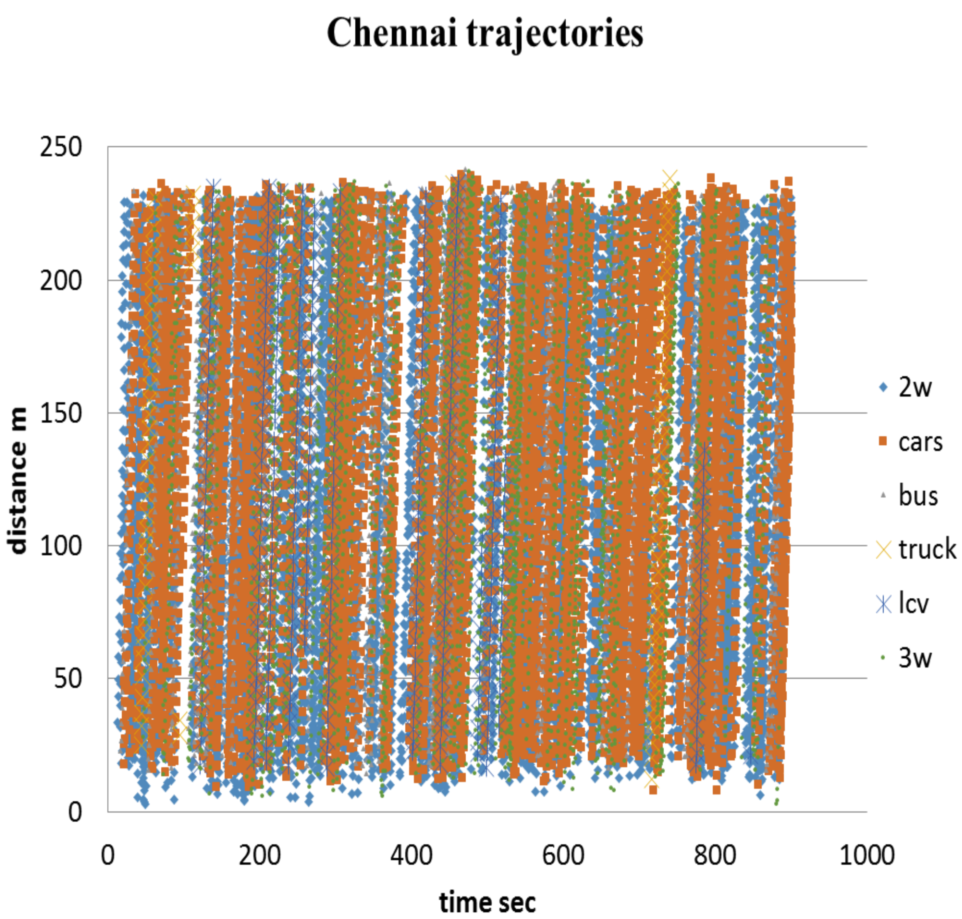
S.No.	Section	Duration of data for micro level analysis	Duration of data for macro level analysis	No of vehicles tracked for trajectories	Dominant vehicle category	Software used for extraction
1.	Chennai road section	15 minutes	-	1504	2w, cars	Trajectory data extractor
2.	Delhi-Gurgaon section	20 minutes	12 hours	2506	cars	Traffic data extractor powered by IIT Bombay, Avidemux

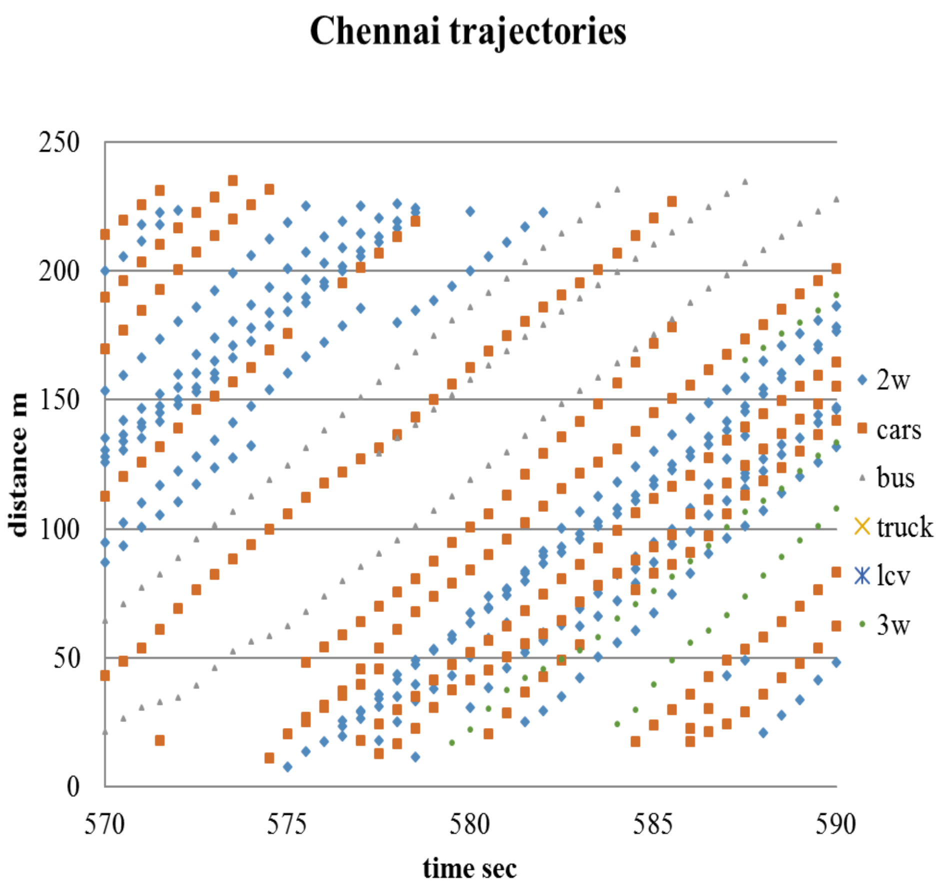
Vehicle composition of study stretches





Trajectory data





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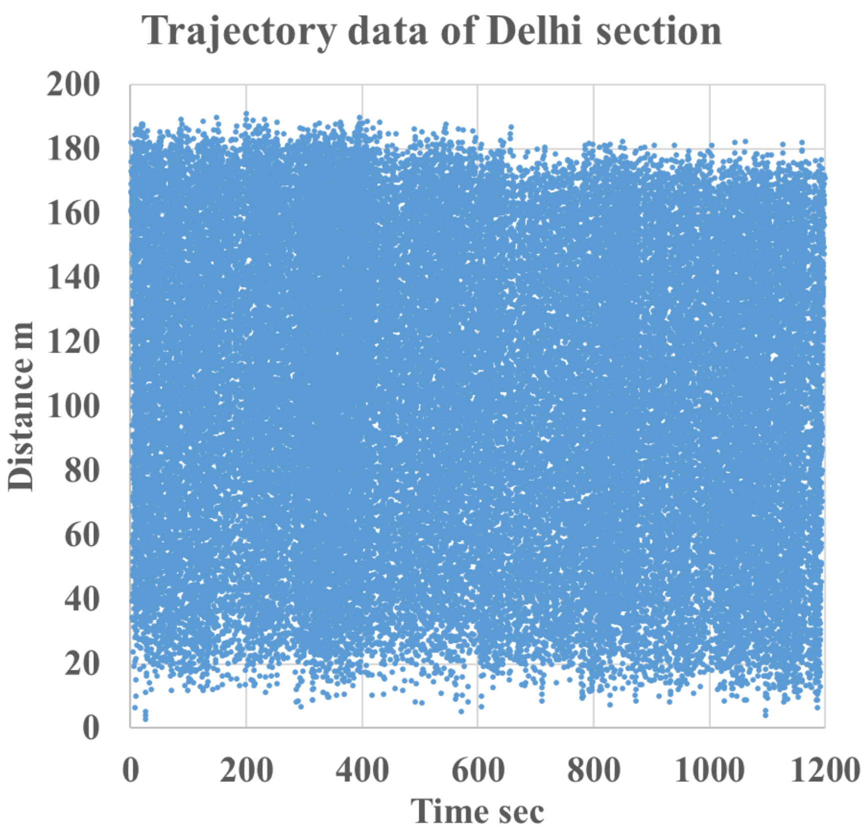
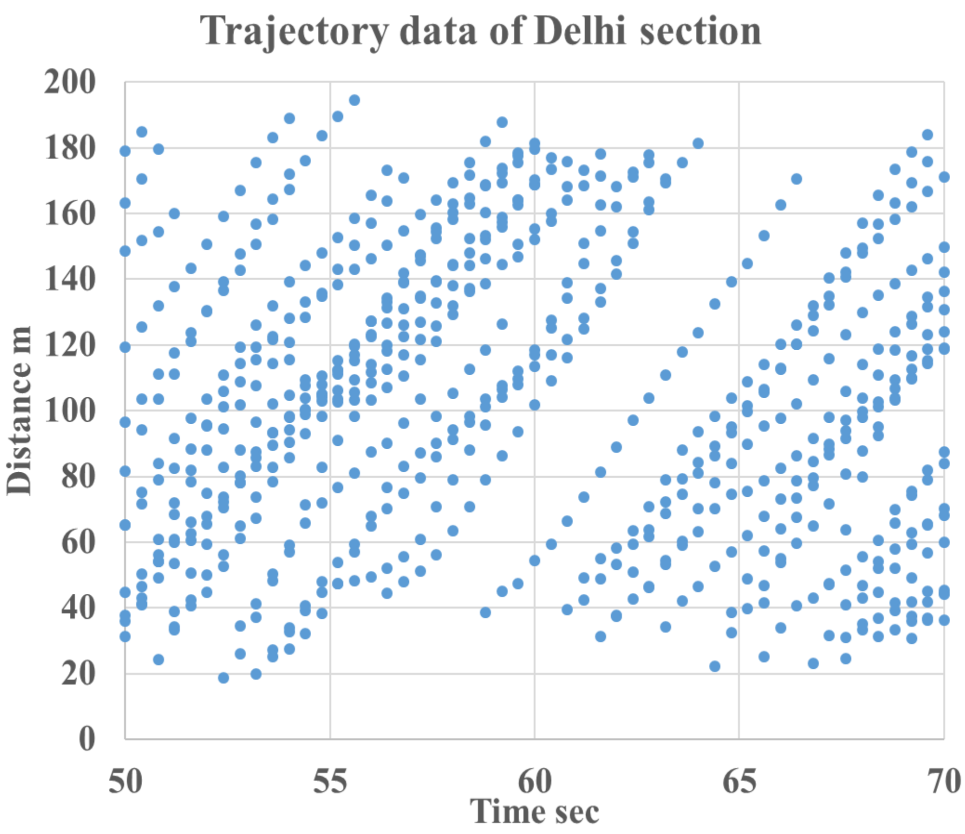
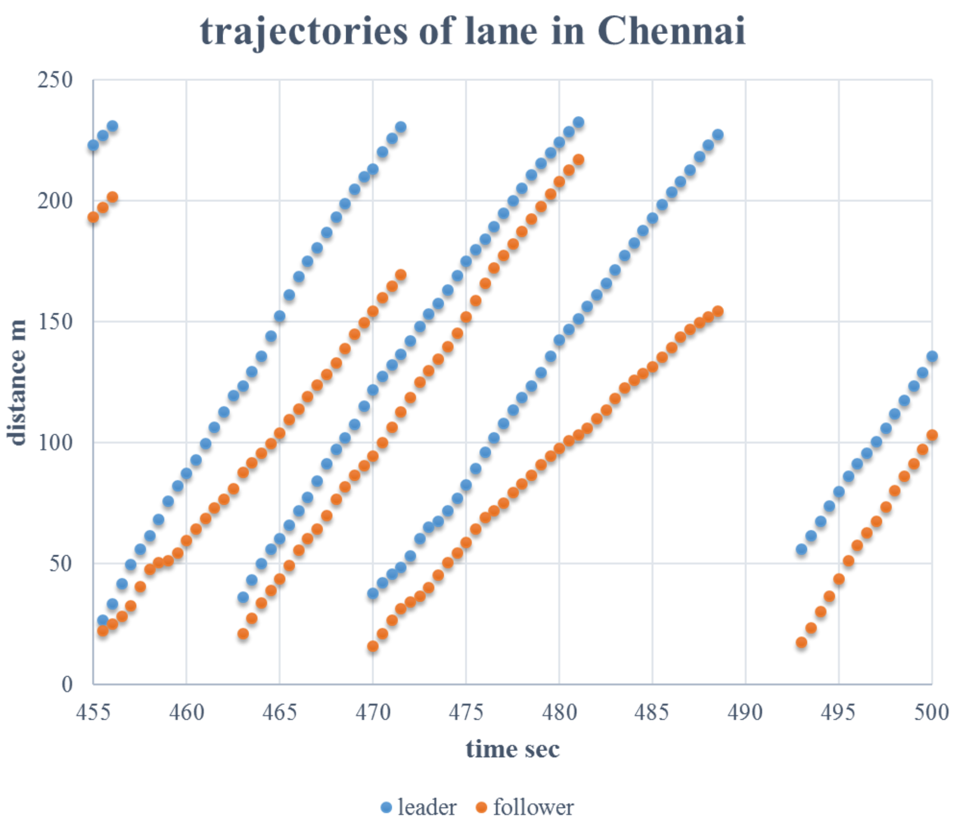
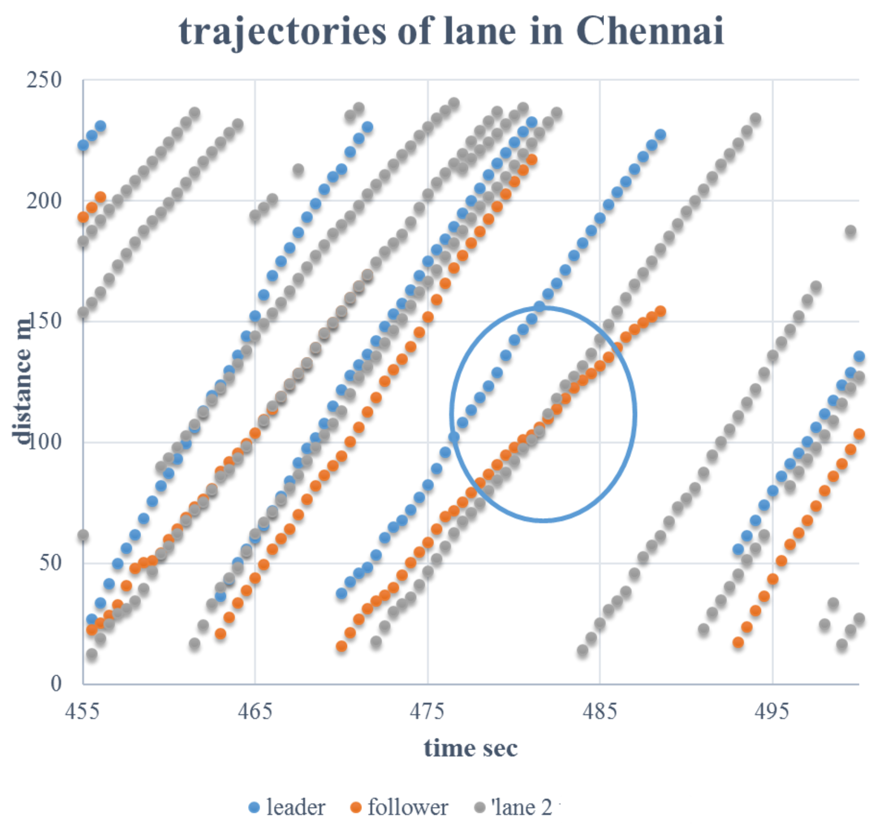

Trajectory data of Delhi section
Distance m
200
180
160
140
120
100
80
60
40
20
0
0
200
400
600
800
1000
1200
Time sec


Trajectory data of Delhi section
Distance m
200
180
160
140
120
100
80
60
40
20
0
50
55
60
65
70
Time sec

Identification of leader following pair





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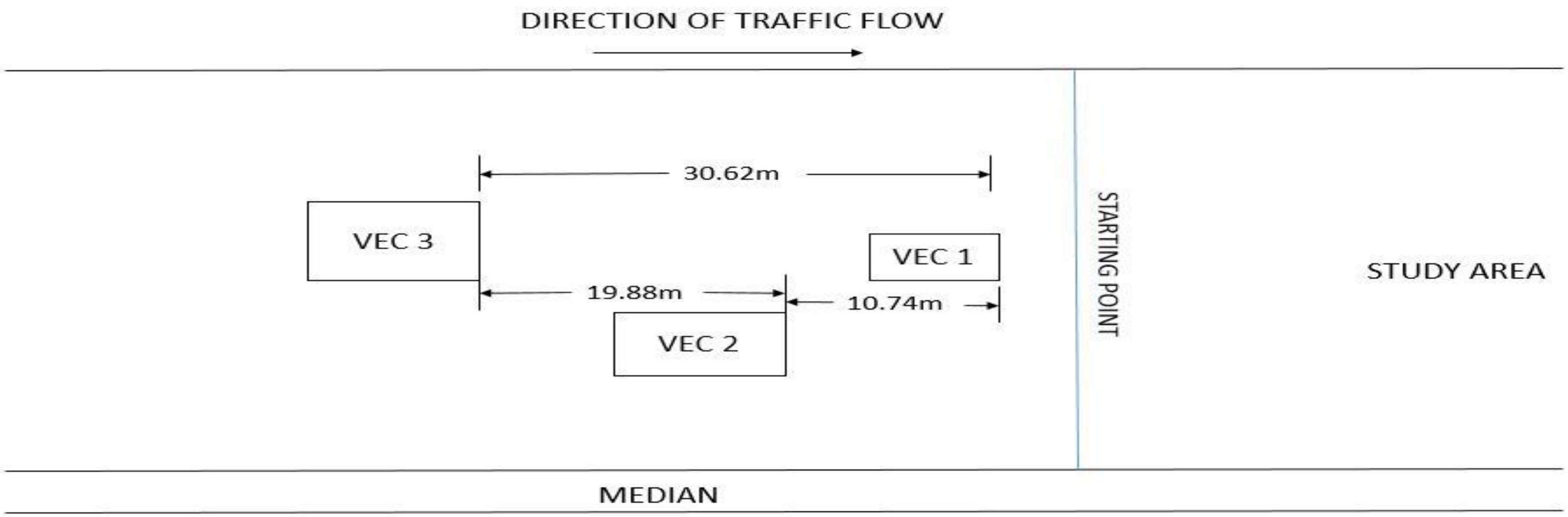
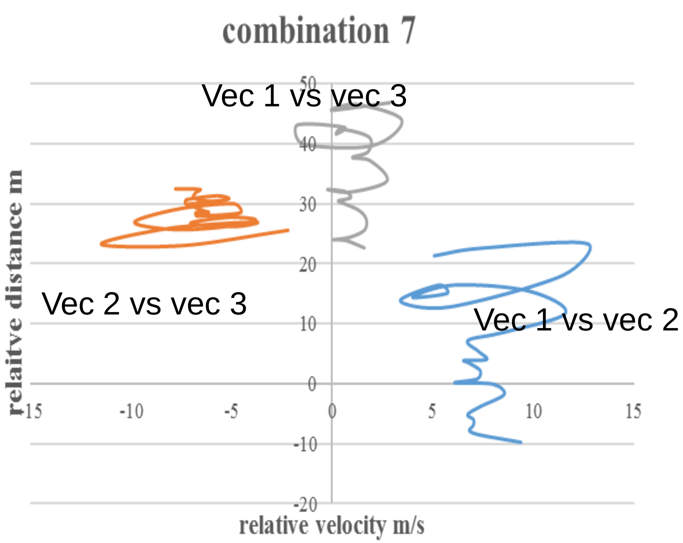
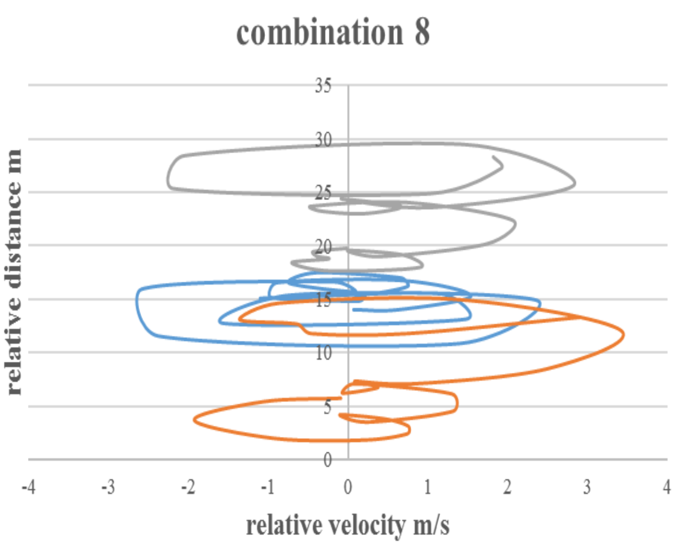

DIRECTION OF TRAFFIC FLOW
30.62m
VEC 3
VEC 1
19.88m
10.74m
VEC 2
STARTING POINT
STUDY AREA
MEDIAN


combination 7
Vec 1 vs vec 3
Vec 2 vs vec 3
Vec 1 vs vec 2
relaitve distance m
relative velocity m/s


combination 8
relative distance m
relative velocity m/s

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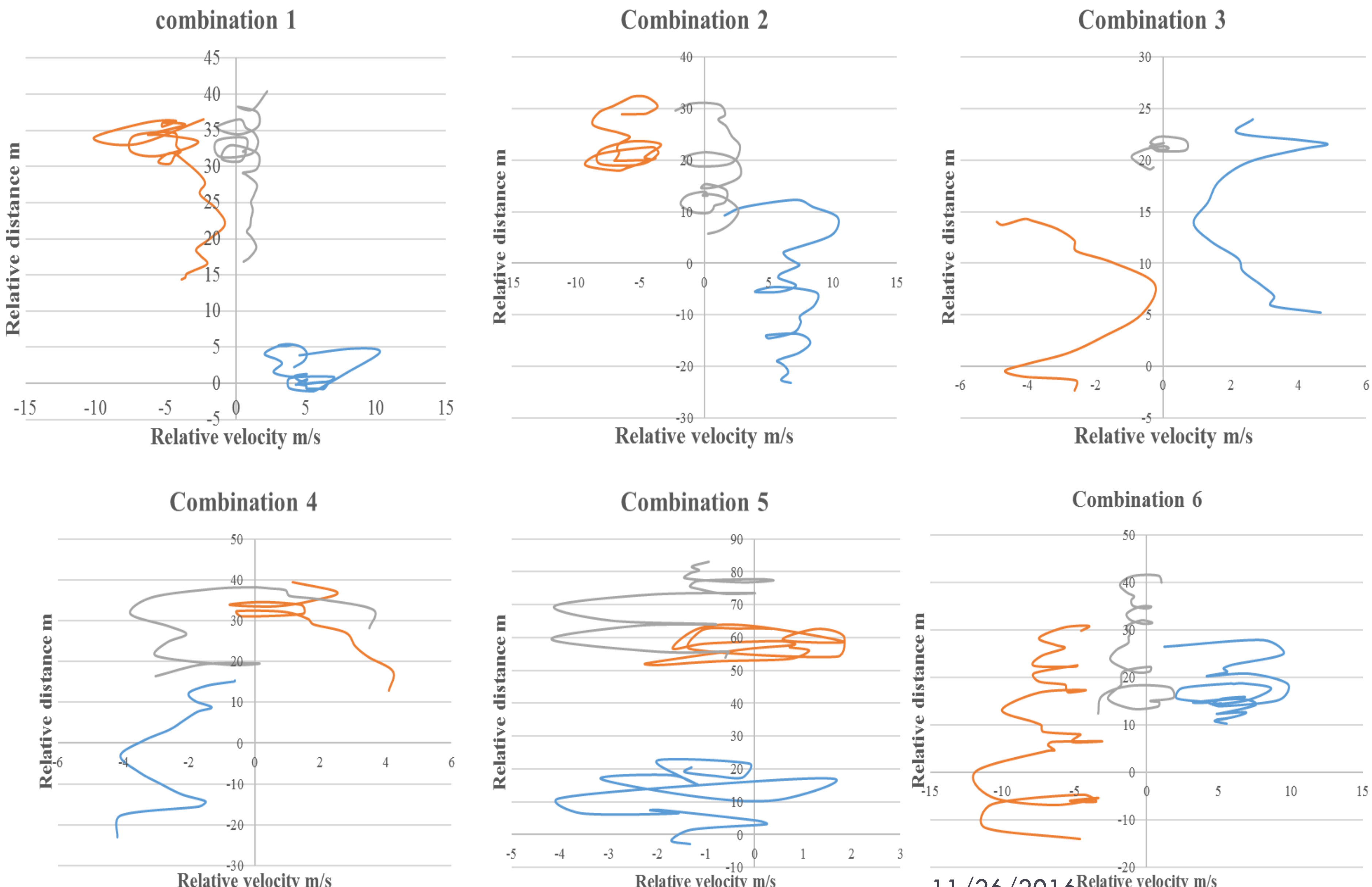
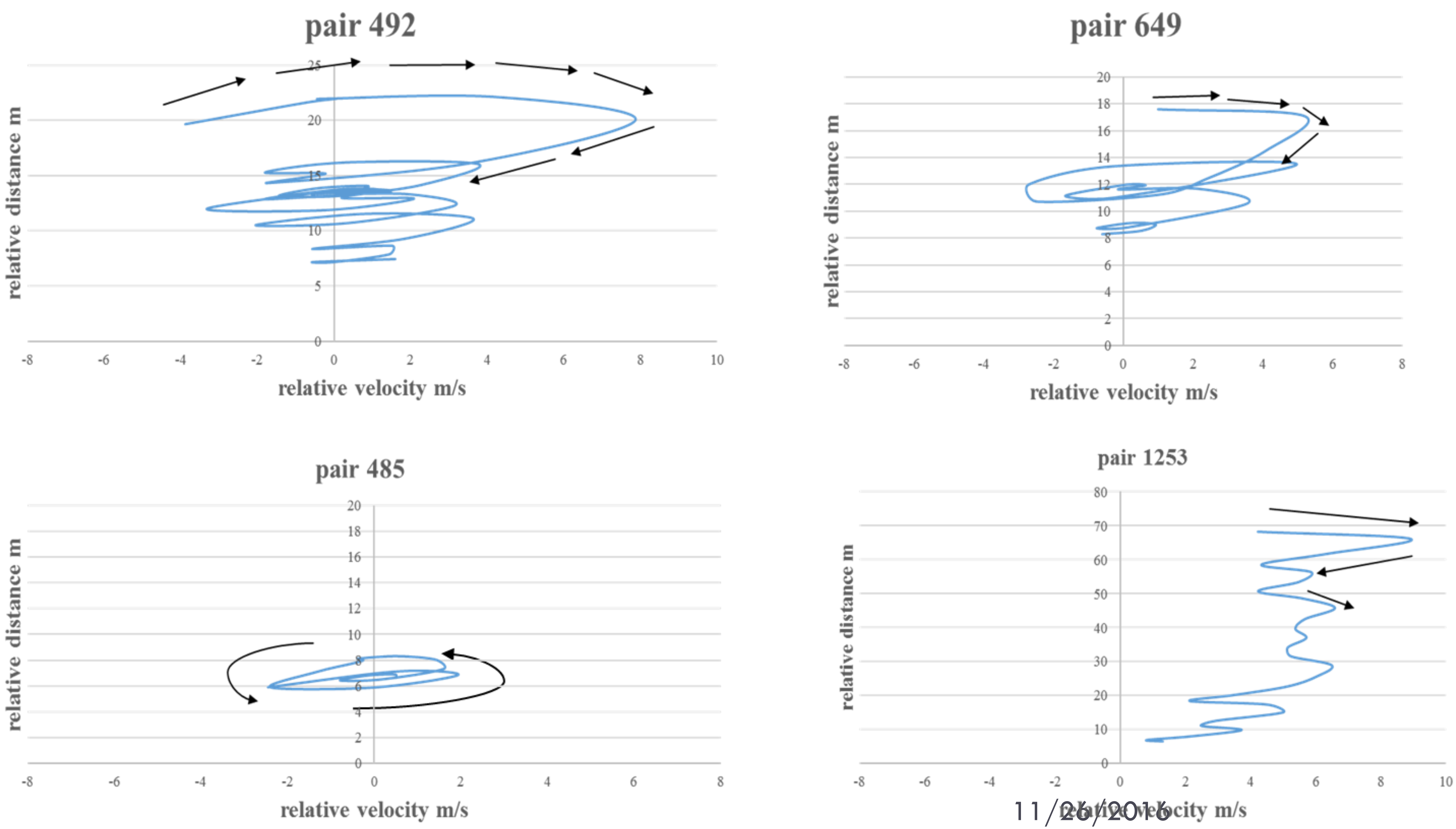
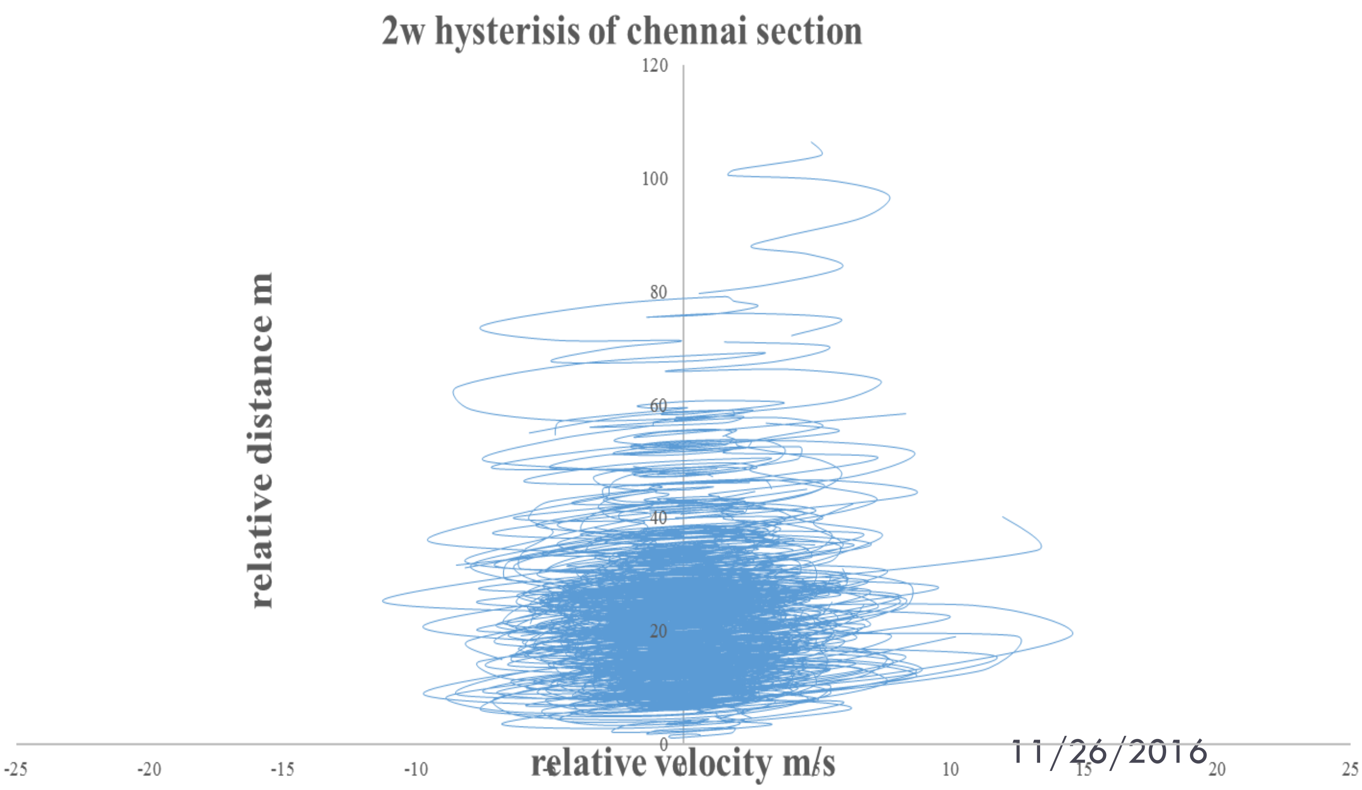

combination 1
Relative distance m
Relative velocity m/s
Combination 2
Relative distance m
Relative velocity m/s
Combination 3
Relative distance m
Relative velocity m/s
Combination 4
Relative distance m
Relative velocity m/s
Combination 5
Relative distance m
Relative velocity m/s
Combination 6
Relative distance m
Relative velocity m/s

Pair-wise hysteresis



Hysteresis plots

- After identifying the true leader and follower from the hysteresis, based on this data was segregated as following vehicle category for further analysis.



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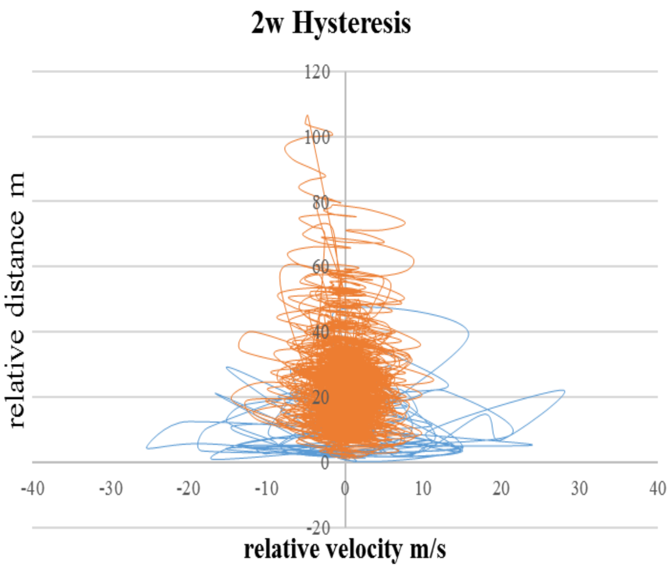
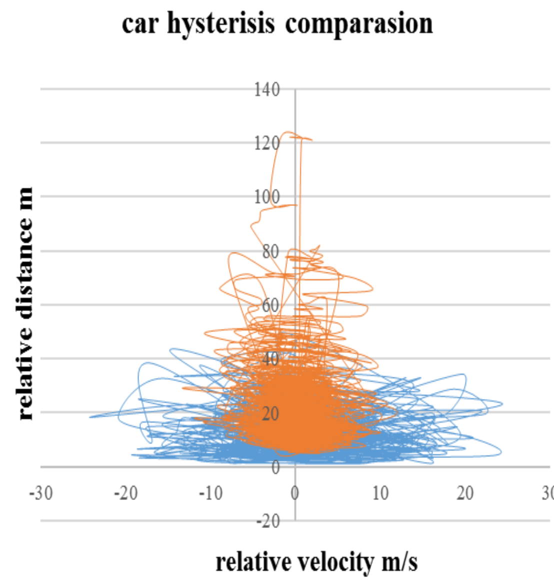
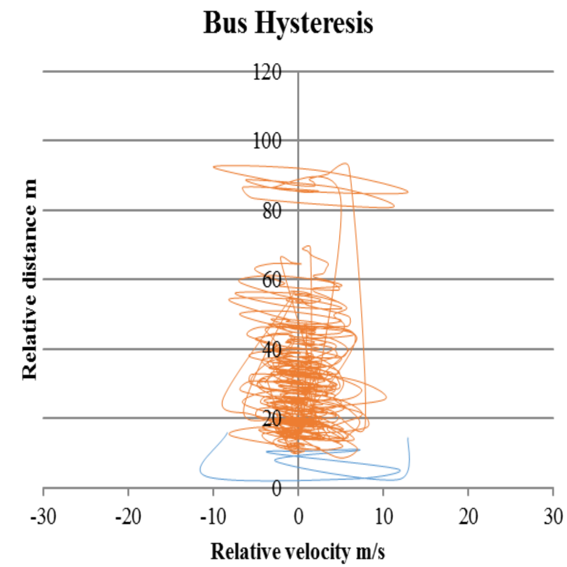


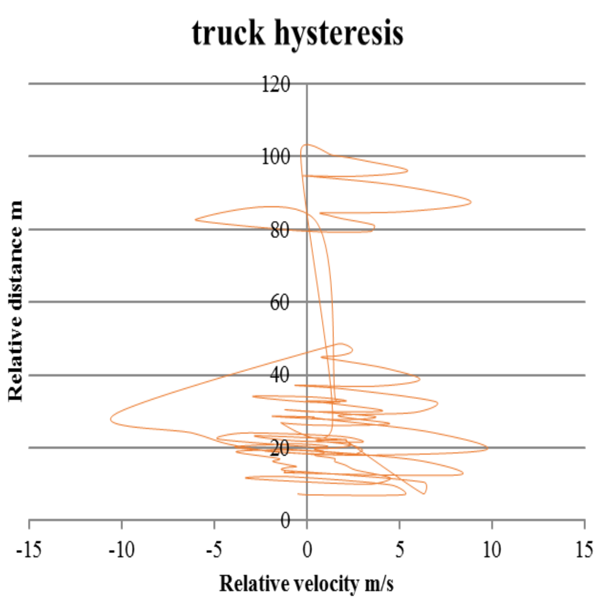
2w Hysteresis
relative distance m
relative velocity m/s
120
100
80
60
40
20
0
-20
-40 -30 -20 -10 0 10 20 30 40



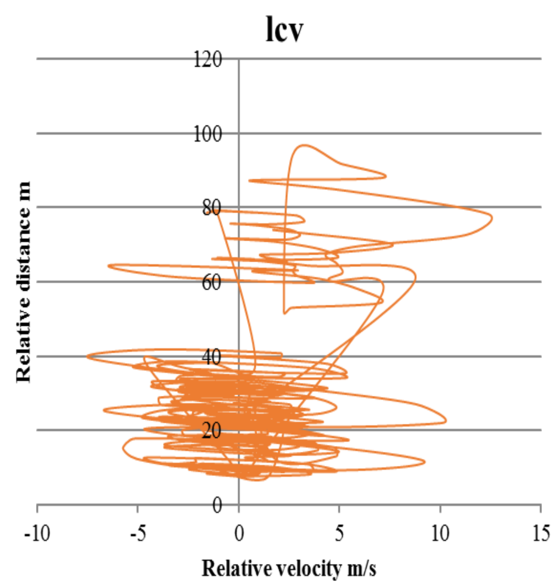
car hysterisis comparasion
relative distance m
relative velocity m/s
140
120
100
80
60
40
20
0
-20
-30 -20 -10 0 10 20 30



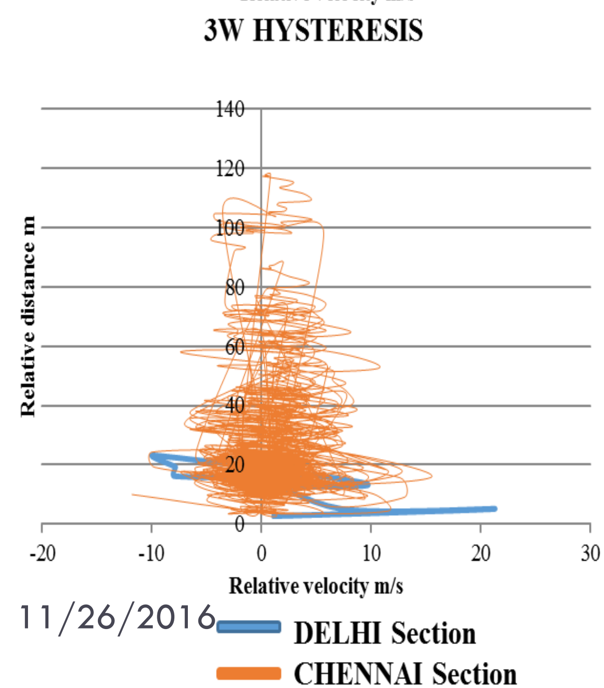
Bus Hysteresis
Relative distance m
Relative velocity m/s
120
100
80
60
40
20
0
-30 -20 -10 0 10 20 30



truck hysteresis
Relative distance m
Relative velocity m/s
120
100
80
60
40
20
0
-15 -10 -5 0 5 10 15



lcv
Relative distance m
Relative velocity m/s
120
100
80
60
40
20
0
-10 -5 0 5 10 15



3W HYSTERESIS
Relative distance m
Relative velocity m/s
140
120
100
80
60
40
20
0
-20 -10 0 10 20 30
DELHI Section
CHENNAI Section

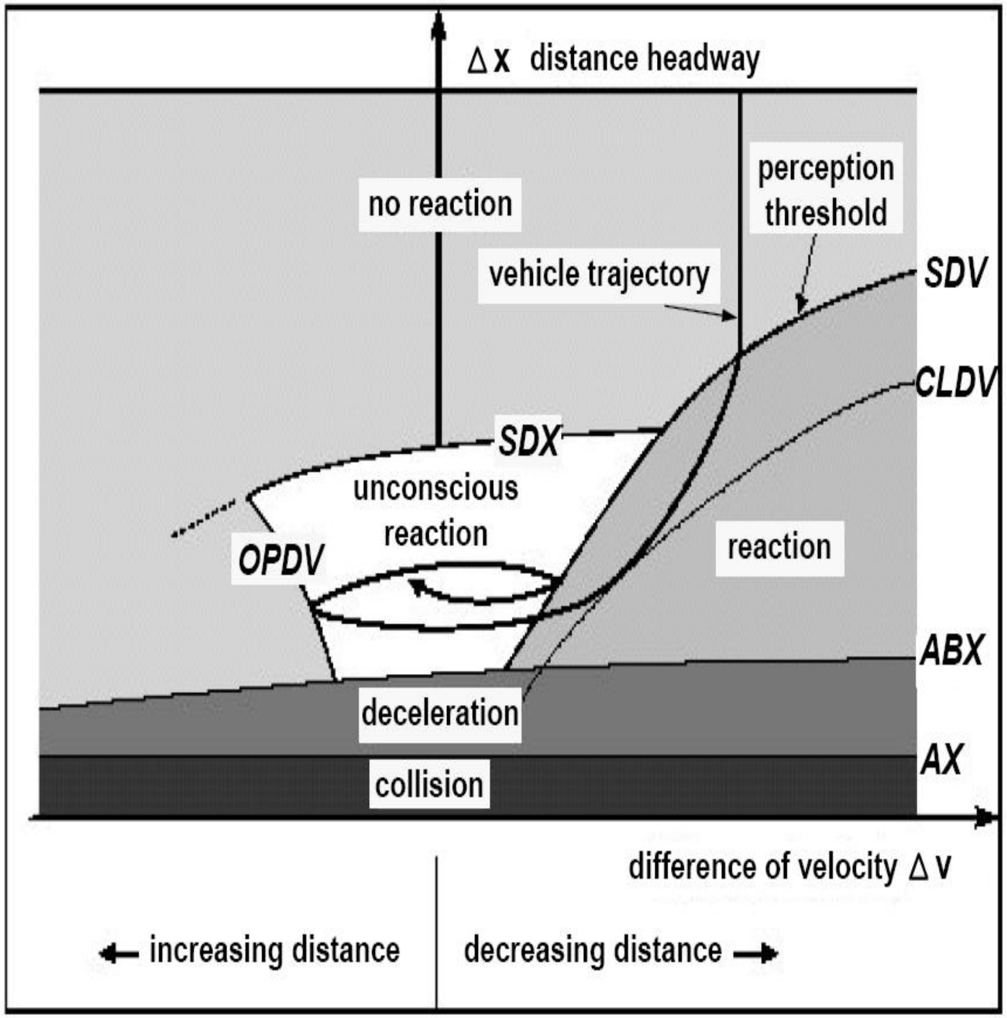
Wiedemann following models

- In this study, wiedemann’s psycho physical models are used to calibrate the following nature of vehicles
- The basic concept of this model is that the driver of a faster moving vehicle starts to decelerate as he reaches his perception threshold to a slower moving vehicle.
- Since he cannot exactly determine the speed of that vehicle, his speed will fall below that vehicle’s speed until he starts to slightly accelerate again after reaching another perception threshold. This results in an iterative process of acceleration and deceleration.
- The VISSIM microsimulation software has two different implementations of the car following models, The basic idea of the WIEDEMANN model is the assumption that a driver can be in one of four driving modes:

1. **Free driving**
2. **Approaching**
3. **Following**
4. **Braking**

Continued…

1. **AX:** is the minimum distance headway (front-bumper to front-bumper distance) in a standstill condition
2. **ABX:** is the minimum desired following distance
3. **SDX:** is the maximum desired following distance
4. **SDV:** the threshold at which driver recognizes that he is approaching a slower vehicle
5. **OPDV:** is the threshold for speed difference in an opening process during a following condition



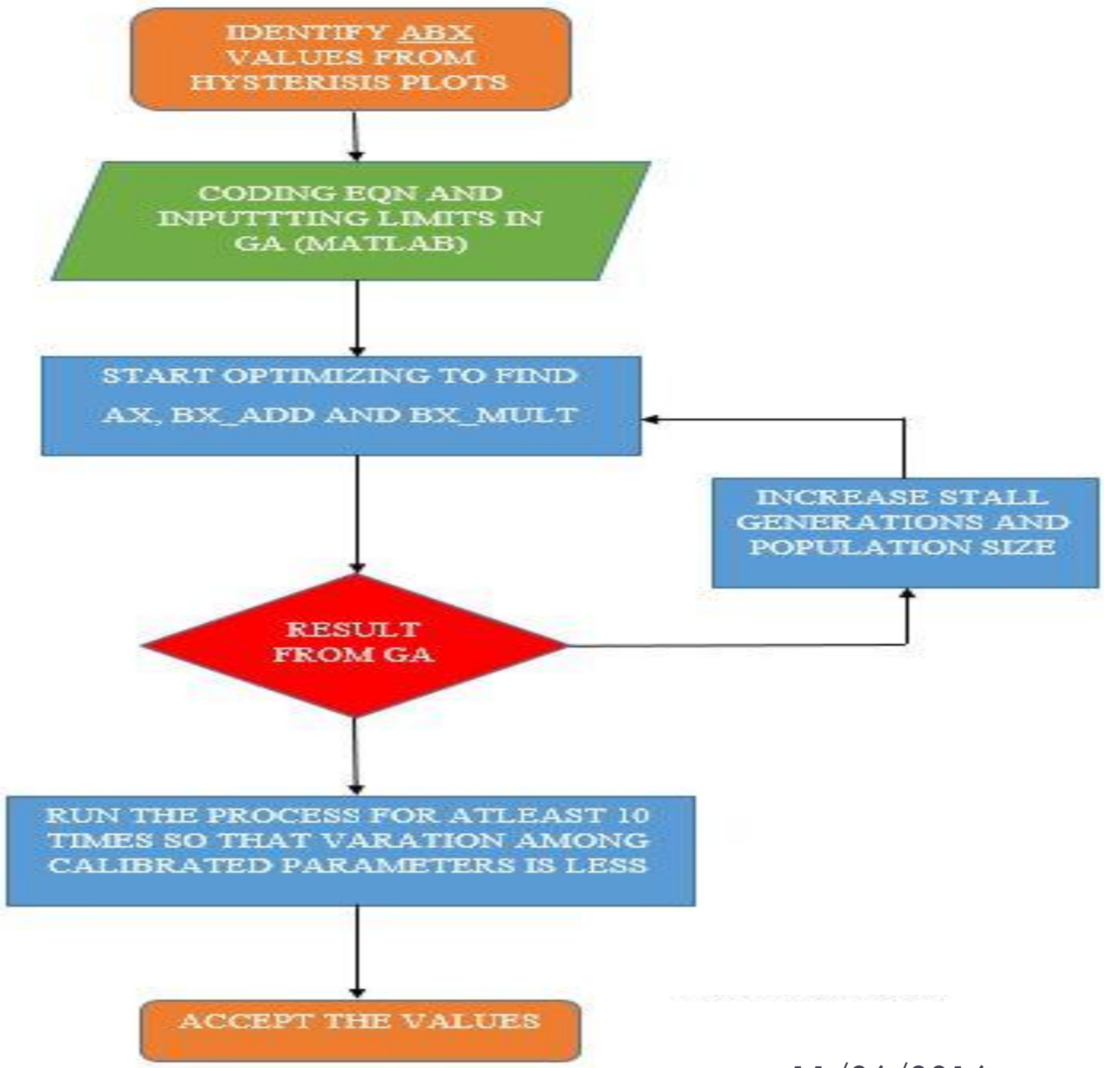
Source: Menneni (2008)

Wiedemann74 model

- The WIEDEMANN 74 car following model is one of the two implementations of car following models available in VISSIM.
- This model is suggested for use in urban traffic. The driver behavior modeling in car following is based on perception thresholds.
- The formulation is best explained using a relative velocity vs. relative distance graphs.

$$ABX = AX + (bx\_add + bx\_mult * N[0.5, 0.15]) * \sqrt{v_{slower}}$$

Calibration of wiedemann74



WIEDEMANN 74 calibrated parameters

SNo.	Following vehicle category	ABX of Chennai study section (m)	ABX of Delhi study section (m)
1.	Motorized Two wheeler	1.06	0.77
2.	Car	4.825	2.184
3.	Bus	8.76	2.399
4.	Heavy vehicle	7.21	2.344
5.	Light commercial vehicle	7.5	5.425
6.	Motorized three wheelers	2.99	2.59

SNo.	Following vehicle category	Wiedemann 74 parameters of Chennai			Wiedemann 74 parameters of Delhi		
		AX	bx_add	bx_mult	AX	bx_add	bx_mult
1.	Motorized Two wheeler	0.25	0.119	0.254	0.2	0.064	0.182
2.	Car	1.10	0.347	1.54	0.55	0.239	0.355
3.	Bus	1.8	1.305	1.67	0.6	0.313	0.463
4.	Heavy vehicle	1.8	0.780	1.669	0.6	0.227	0.322
5.	Light commercial vehicle	1.1	1.154	1.531	1.35	0.693	0.715
6.	Motorized three wheelers	0.75	0.203	1.046	0.65	0.298	0.534

Simulation of midblock sections

- In order to check the effectiveness of calibrated following behavior, simulation models were modeled using VISSIM 8.0. for Chennai section
- vehicular volume, vehicular composition was given for every 5-minutes for 15 minutes, similarly desired speed distributions were given as an inputs for each vehicle category, which are calculated from the vehicular trajectory data.

S.No	Vehicle category	Average dimensions of vehicles		Projected Area m^2
		Length m	Width m	
1.	Two wheeler	1.87	0.64	1.2
2.	Car	3.72	1.44	5.39
3.	Bus	10.1	2.43	24.74
4.	Truck	7.5	2.35	17.62
5.	LCV	6.1	2.1	12.81
6.	Three wheeler	3.2	1.4	4.48

(S Chandra 2003)

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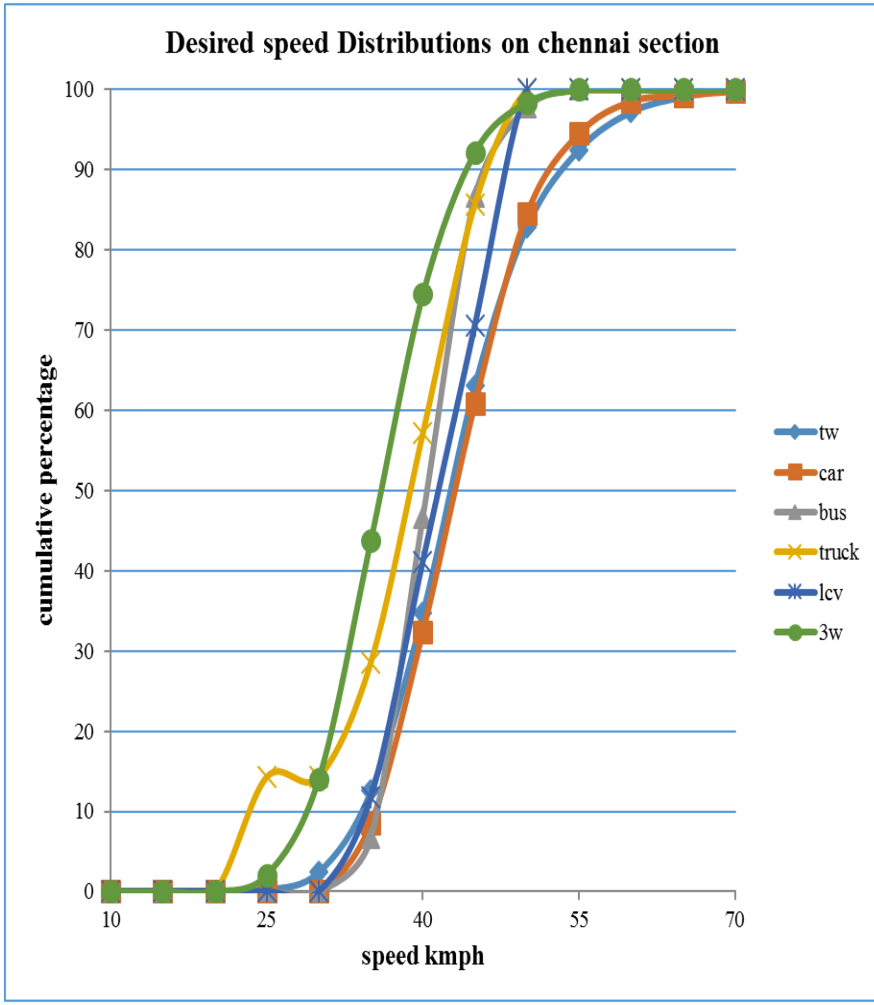
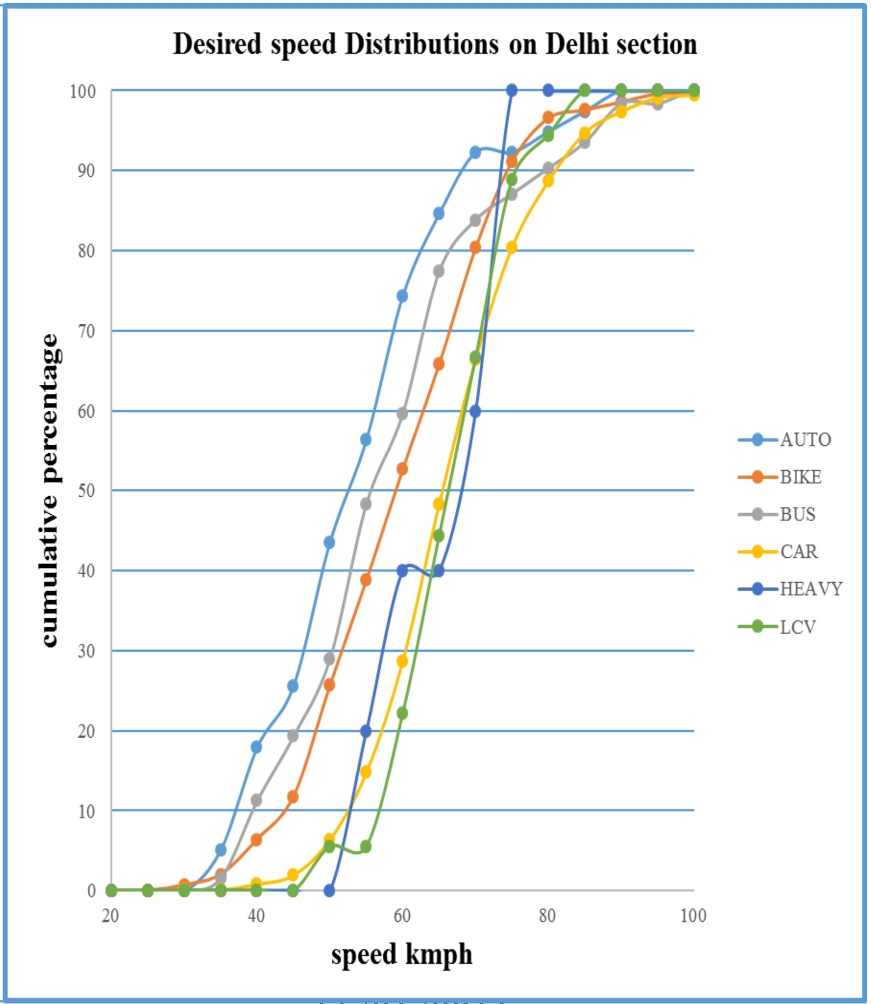
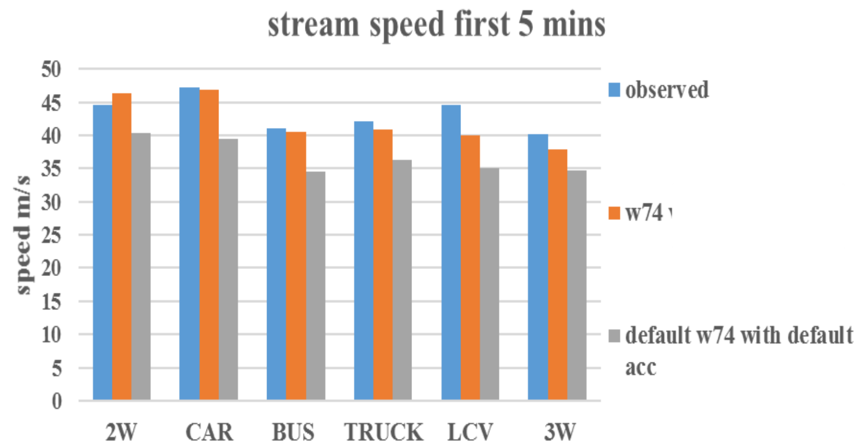
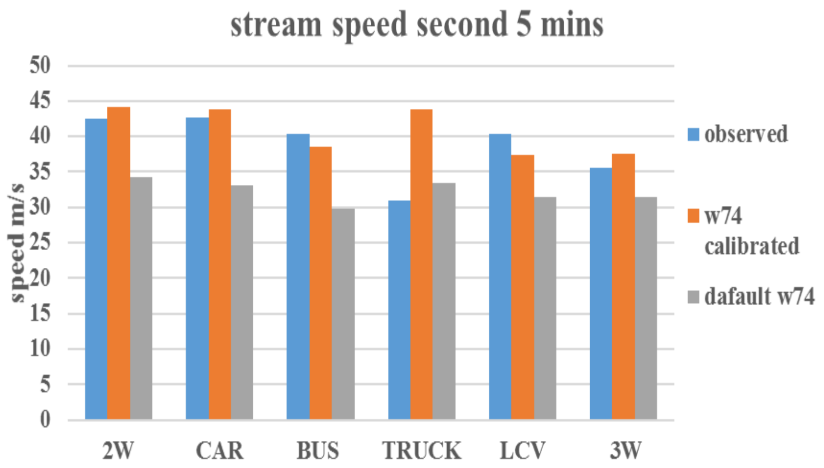
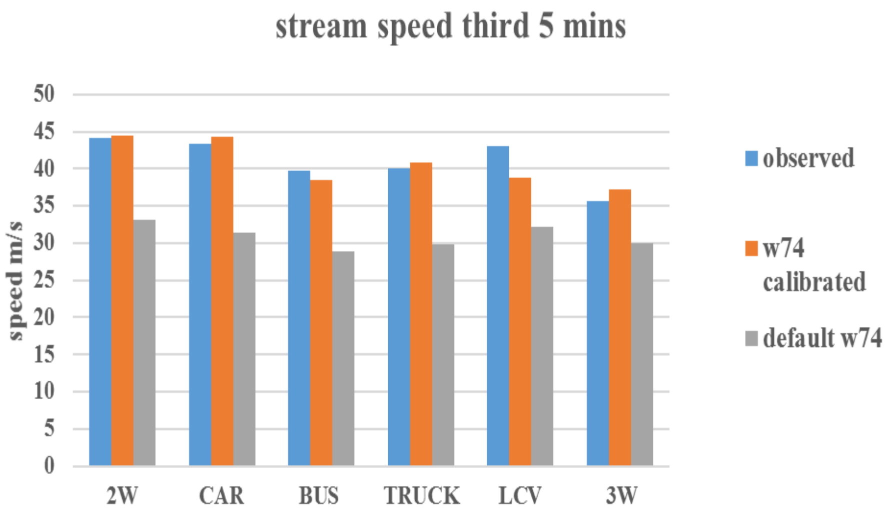

Desired speed Distributions on chennai section
cumulative percentage
speed kmph
0
10
20
30
40
50
60
70
80
90
100
10
25
40
55
70
tw
car
bus
truck
lcv
3w


Desired speed Distributions on Delhi section
cumulative percentage
speed kmph
0
10
20
30
40
50
60
70
80
90
100
20
40
60
80
100
AUTO
BIKE
BUS
CAR
HEAVY
LCV

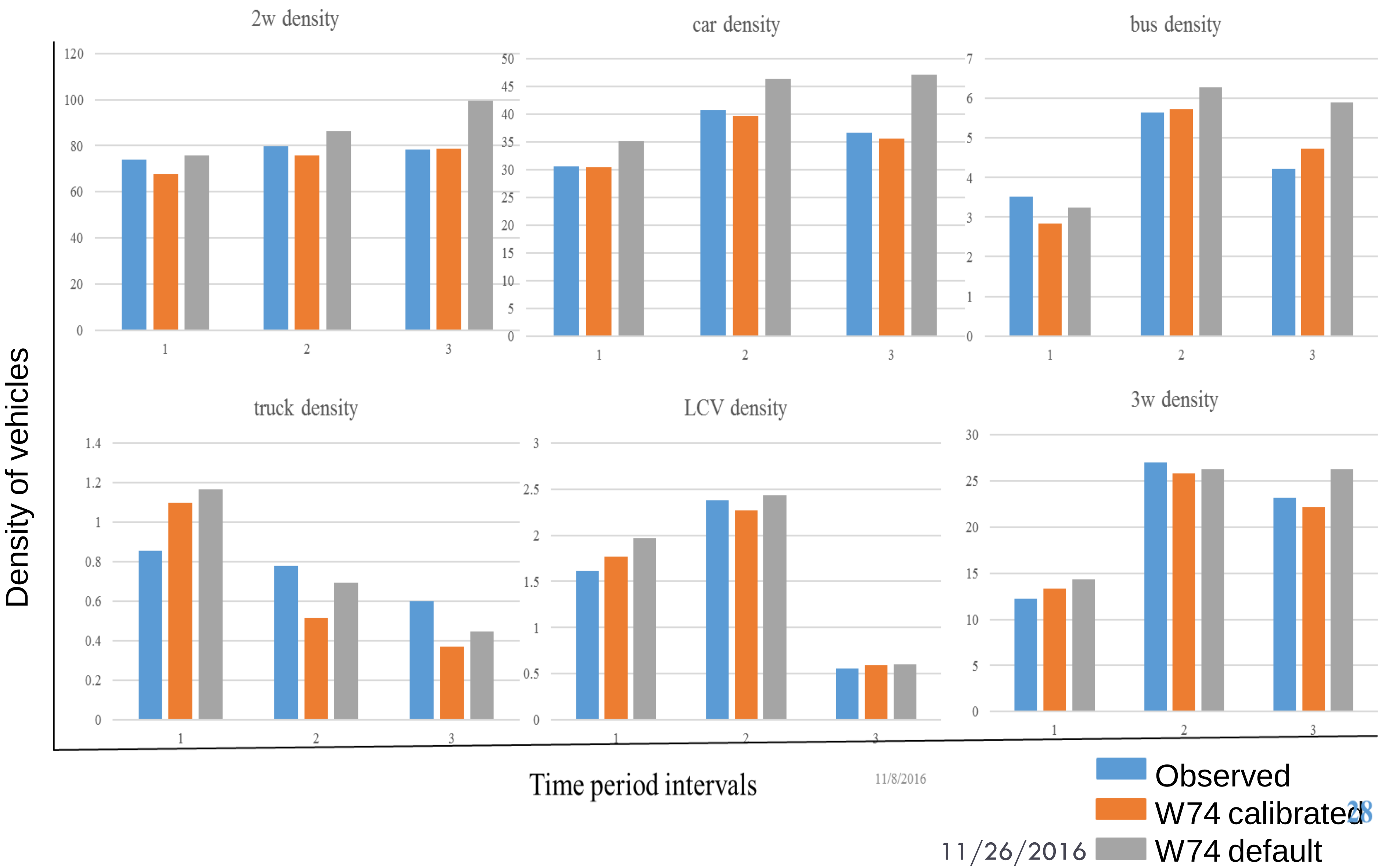
Microscopic analysis of wiedemann74 with out acceleration inputs on Chennai section







Microscopic analysis of wiedemann74 with out acceleration inputs on Chennai section

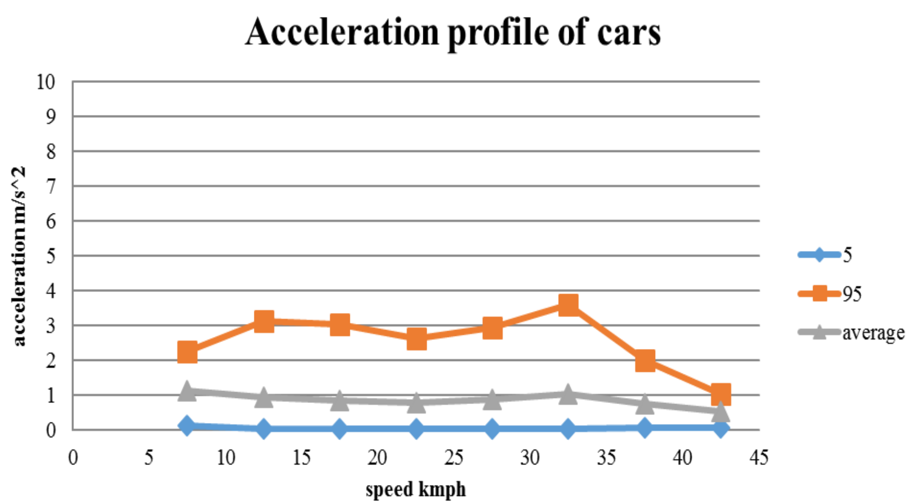


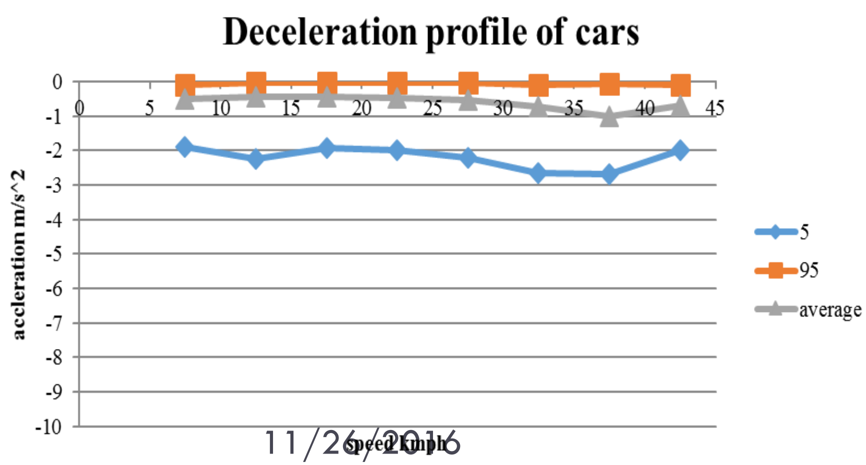
Microscopic analysis of wiedemann74 with out acceleration inputs on Chennai section

CRITERIA OF CHECKING ERROR	CAHARACTERISTICS	MODEL	2W	CAR	BUS	TRUCK	LCV	3W
MAPE %	speed	calibrated w74	2.92	1.79	3.10	15.46	9.06	5.06
		default w74	17.92	22.21	22.99	15.89	22.82	13.61
avg of absolute difference	density	calibrated w74	3.63	0.76	0.42	0.24	0.10	1.11
		default w74	9.93	6.92	0.86	0.18	0.15	1.96
avg of absolue difference	volume	calibrated w74	6.74	1.22	1.43	0.49	0.36	0.65
		default w74	22.90	10.52	2.08	0.46	0.73	5.04

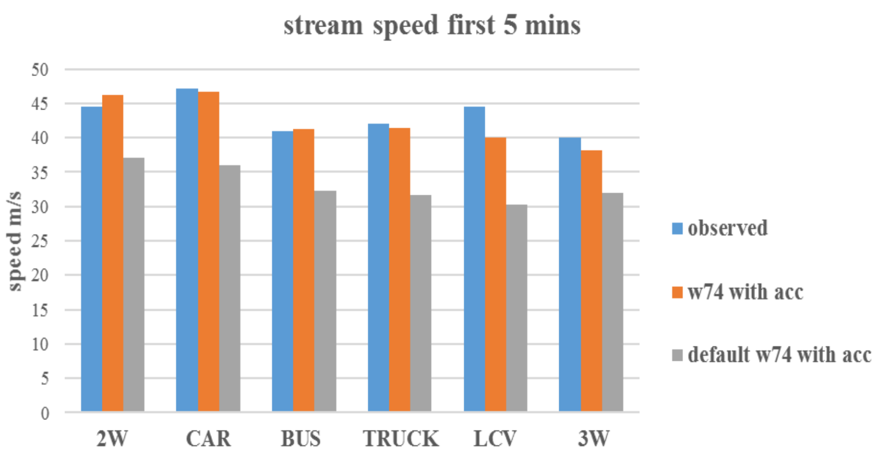
Wiedemann74 validation with acceleration inputs

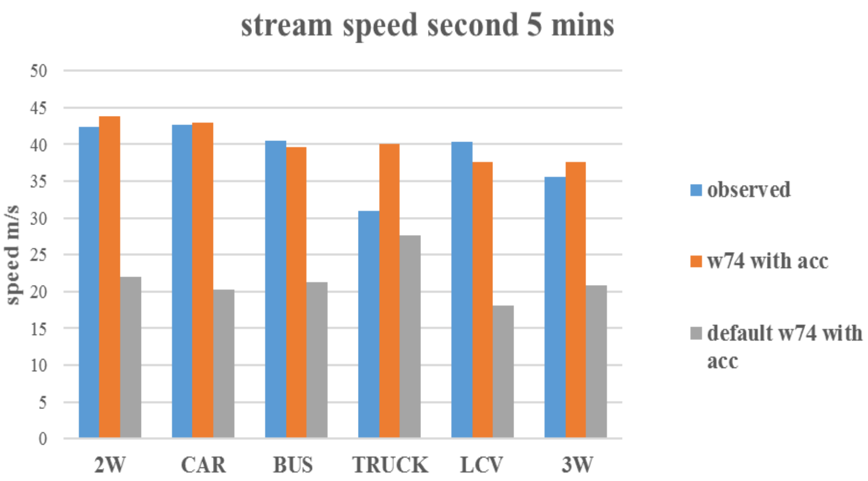
- in order to increase the degree of effectiveness of simulation desired acceleration and desired deceleration values were calculated from the vehicular trajectories based on the speed of the vehicles at that instant of time for each vehicle category,
- acceleration values are calculated in such way that at first based on speed acceleration values were segregated for every 5kmph interval. After segregation 5th percentile, average and 95th percentile were calculated from the clusters based on this acceleration and deceleration plots were plotted.

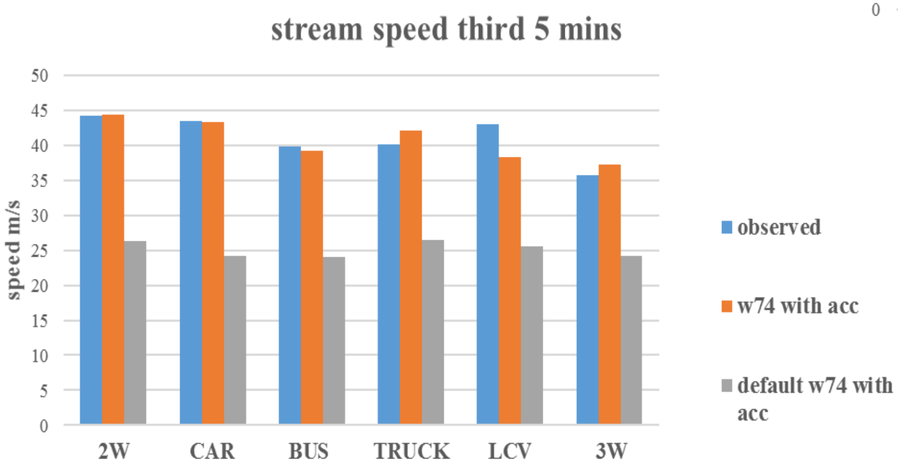




Microscopic analysis of wiedemann74 with acceleration inputs on Chennai section







Microscopic analysis of wiedemann74 with acceleration inputs on Chennai section

CRITERIA OF CHECKING ERROR	CAHARACTERISTICS	MODEL	2W	CAR	BUS	TRUCK	LCV	3W
MAPE %	Speed	calibrated w74	2.42	0.57	1.23	12.02	9.27	4.96
		default w74	35.19	40.19	36.05	23.11	42.53	31.27
Avg of absolute difference	Density	calibrated w74	3.50	0.18	0.41	0.23	0.11	1.12
		default w74	16.65	12.00	0.61	0.24	0.57	2.63
Avg of absolute difference	Volume	calibrated w74	6.96	1.04	1.41	0.51	0.37	0.58
		default w74	65.97	31.16	4.64	0.54	1.67	15.63

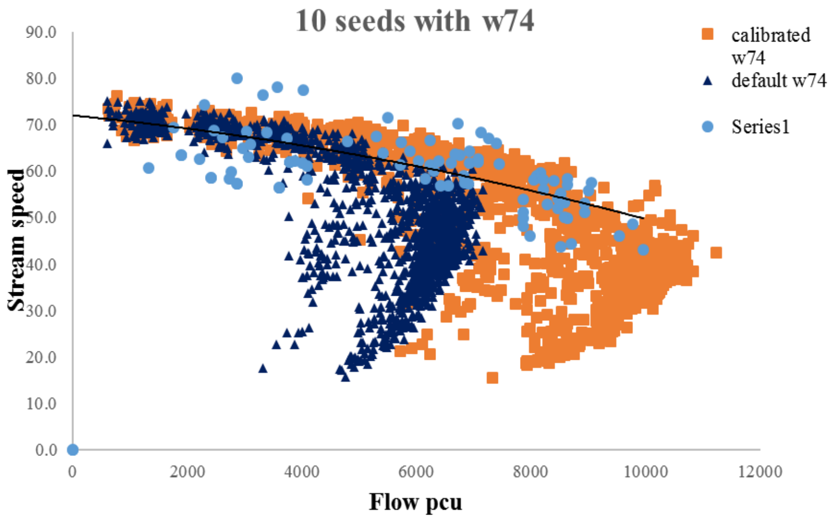
SIMULATION ON DELHI SECTION

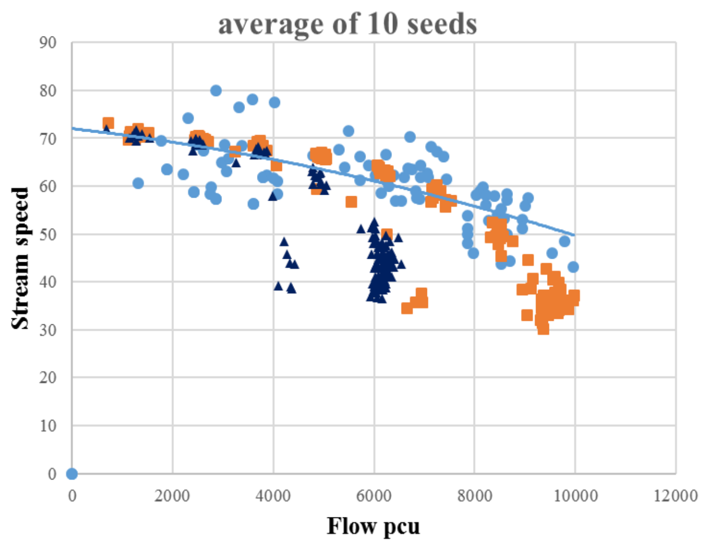
- The Delhi simulation models were developed for one-hour duration. Similar to Chennai section desired speed distributions, desired acceleration and desired deceleration distributions were given as an inputs to simulation model.
- Similarly, calibrated following behavior parameters were given as input to simulation model.
- Lateral clearance share were given as input because of there influence on macroscopic characteristics
- Based on this simulation model is run for different volume levels for one hour each for 10 random seeds to develop the complete macroscopic fundamental

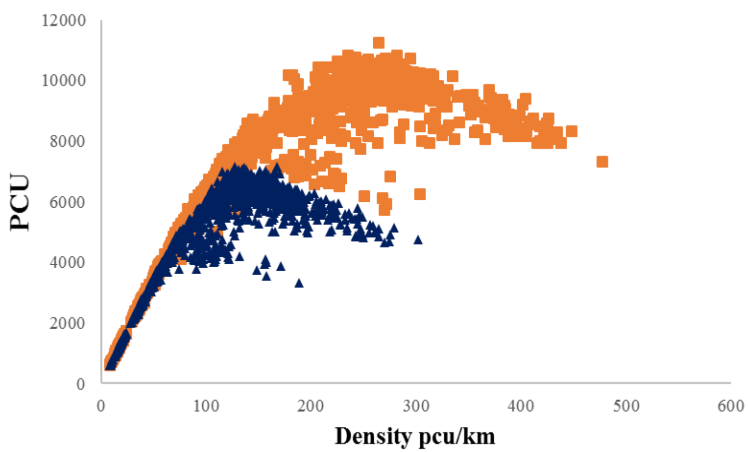
S.No.	Vehicle Category	Lateral clearance share (m)	
		@ Stand still conditions	Moving @ 50 KMPH
1.	Two wheeler	0.25	0.3
2.	Car	0.3	0.5
3.	Bus	0.4	0.7
4.	Truck	0.4	0.7
5.	LCV	0.3	0.5
6.	Three wheeler	0.25	0.3

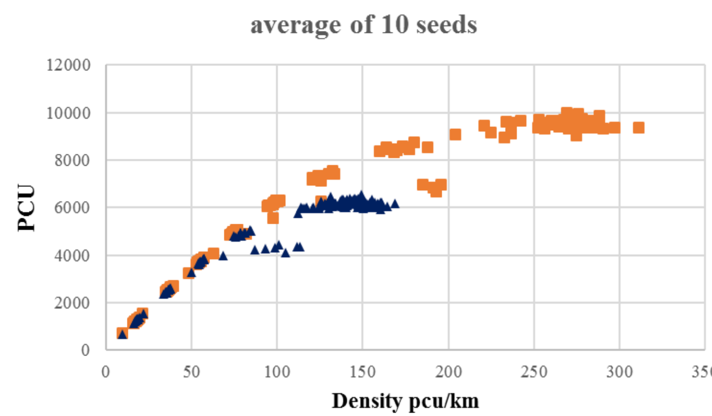
(Arasan and Arkatkar 2010)

Macro level analysis on Delhi section









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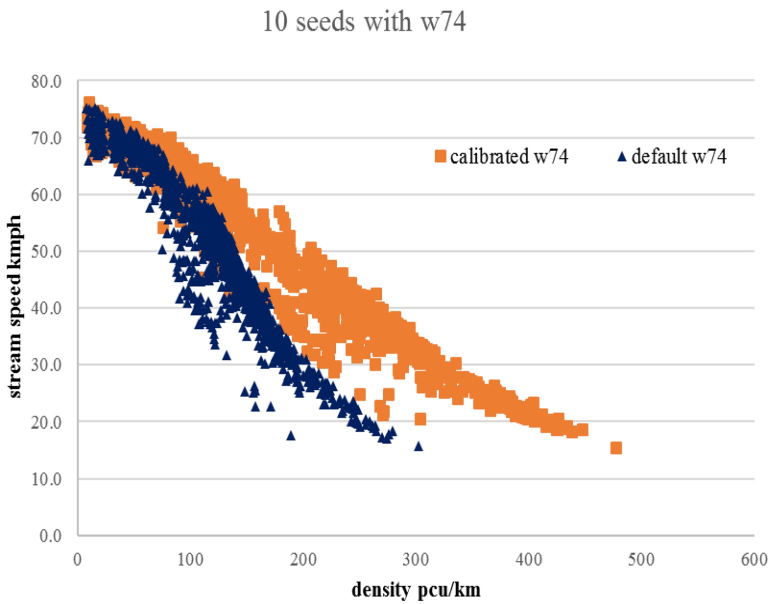
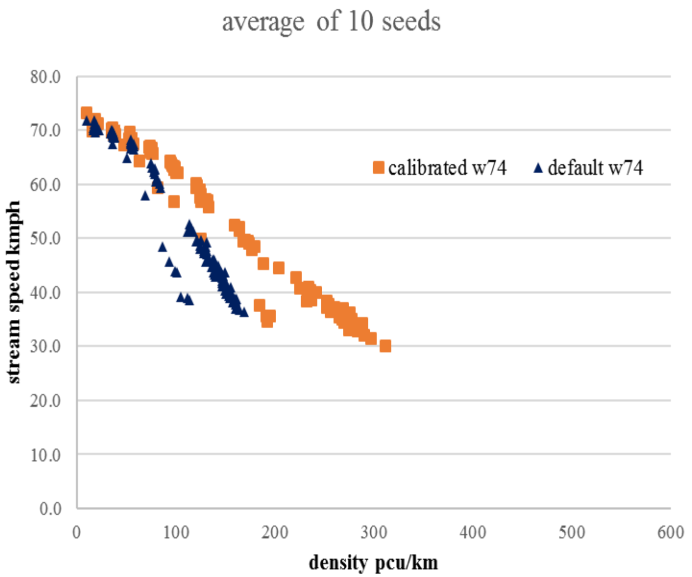




S.No.	Parameter	Observed	Calibrated w74	Default w74
1.	Capacity (pcu)	9960	9956	6534
2.	Free flow speed (kmph)	75	73	73

Wiedemann 99 model

- CC0: defines the desired front bumper-to-front bumper distance between stopped cars. This parameter has no variation.

  $AX = CC0$

- CC1: defines the time (in seconds) the following driver wishes to keep.

  $ABX = L_{n-1} + CC0 + CC1 * v_{slower}$

- CC2: defines, rather restricts the longitudinal oscillation during following condition. In other words, it defines how much more distance than the desired safety distance (ABX) before the driver intentionally moves closer.

  $SDX = ABX + CC2$

- CC3: defines the start (in seconds) of the deceleration process; i.e., the time in seconds, when the driver recognizes a slower moving preceding vehicle, and starts to decelerate.

  $SDV = CC3$

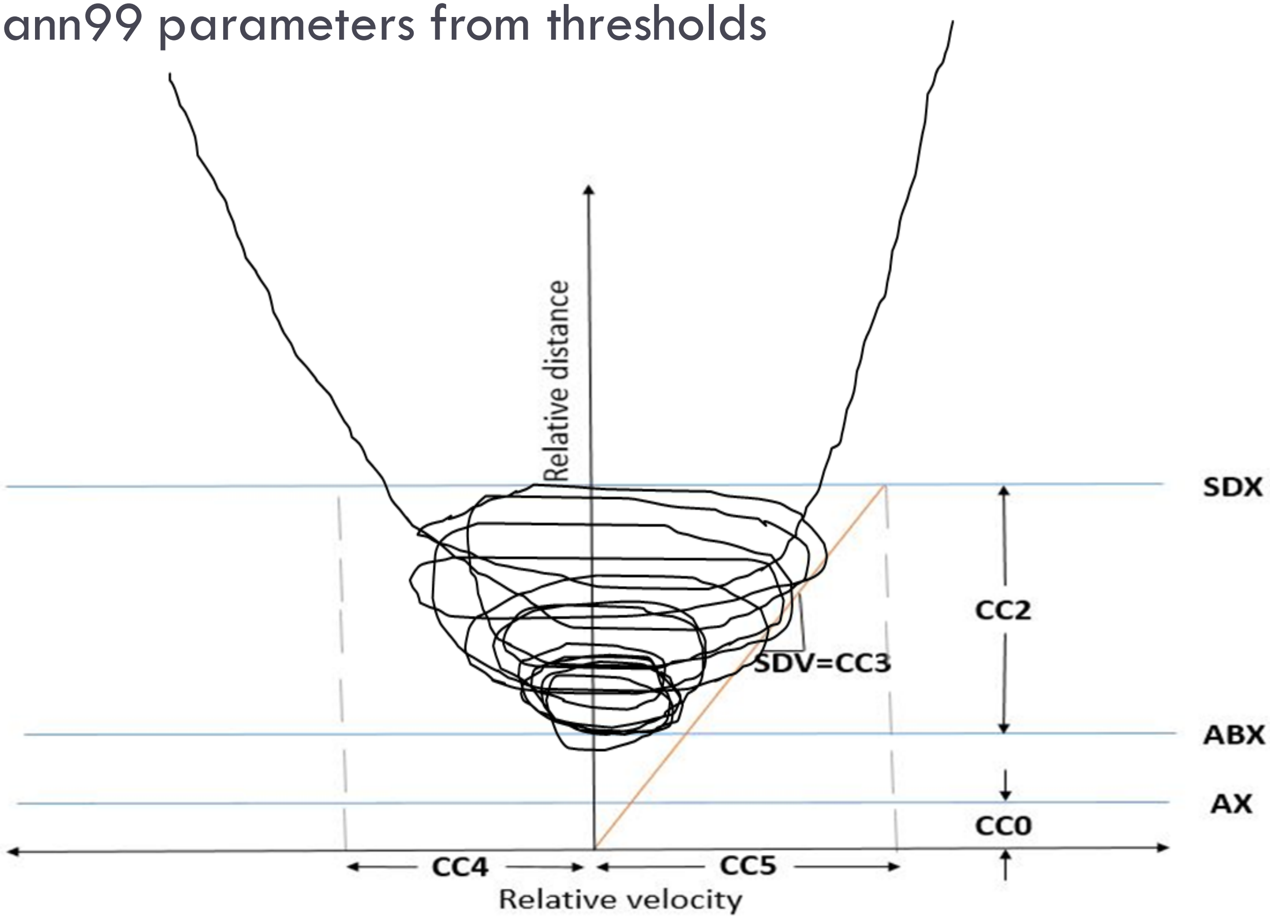
- CC4 and CC5: define the speed difference (in m/s) during the following process. CC4 controls speed differences during closing process, and CC5 controls speed differences in an opening process.
- CC6: defines the influence of distance on speed oscillation during following condition.
- CC7: defines actual acceleration during oscillation in a following process.
- CC8: defines the desired acceleration when starting from a standstill.
- CC9: defines the desired acceleration when at 80km/hr. However, it is limited by maximum acceleration for the vehicle type.

Parameters of wiedemann99

s.no.	Parameter	Evaluation in present study
1.	CC0	Taken from calibrated wiedemann74
2.	CC1	Based on optimization
3.	CC2	From 25th percentile value of relative distances
4.	CC3	Taken as a slope
5.	CC4	50th percentile of speeds on –ve side
6.	CC5	50th percentile of speeds on +ve side
7.	CC6	Default value is adopted
8.	CC7	Calculated as acceleration in following process
9.	CC8	Default value is adopted
10.	CC9	Default value is adopted

Continued…

Wiedemann99 parameters from thresholds

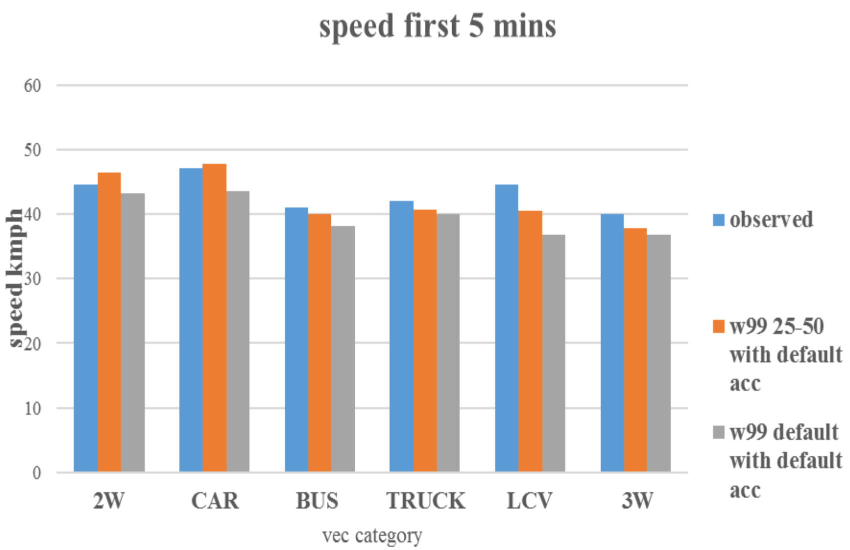


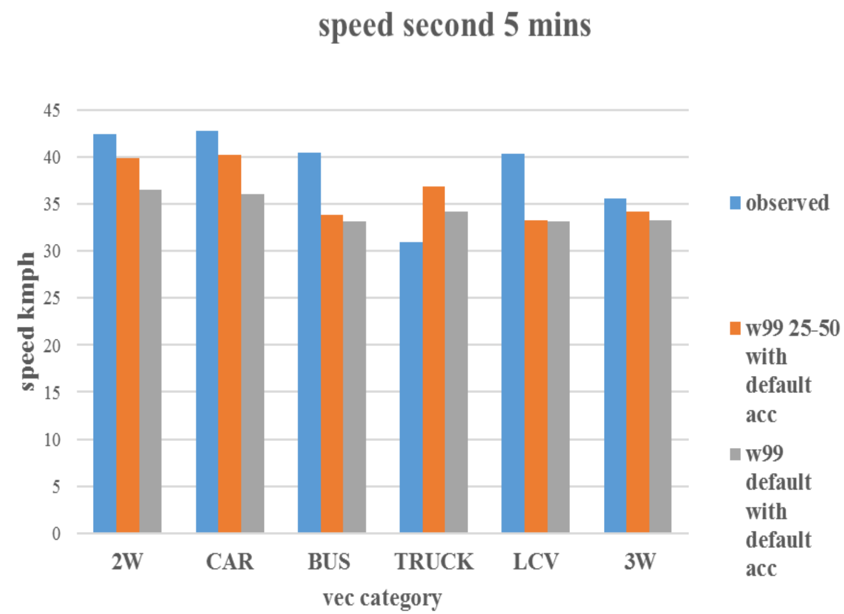
WIEDEMANN 99 calibrated parameters

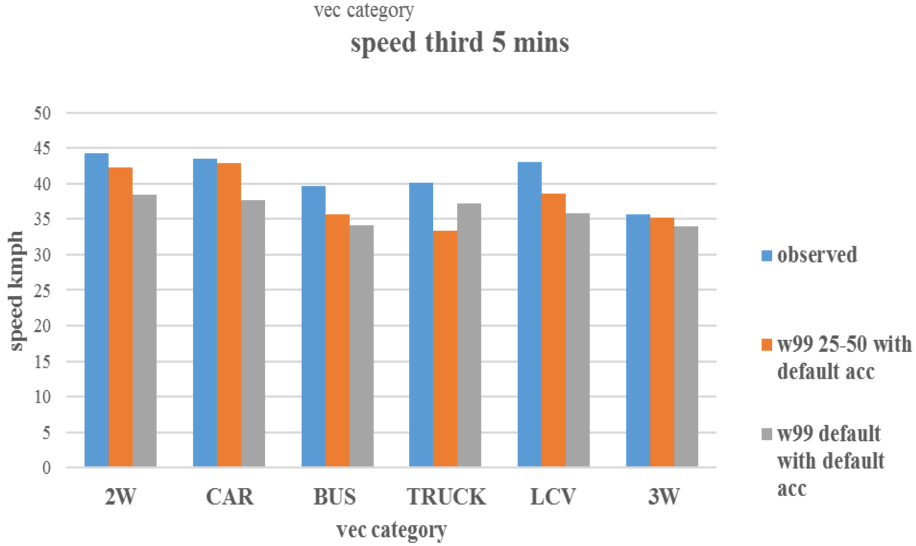
PARAMETER	DEFAULT VALUE	2w	CAR	bus	TRUCK	LCV	3w
CC0	1.5	0.25	1.1	1.8	1.8	1.1	0.75
CC1	0.9	0.16	0.14	0.51	0.27	0.29	0.14
CC2	4	9.64	5.46	8.26	10.99	9.82	11.48
CC3	-8	-6.09	-3.78	-5.30	-5.28	-5.76	-6.24
CC4	-0.35	-1.42	-1.29	-1.34	-1.07	-1.29	-1.23
CC5	0.35	1.58	1.44	1.55	2.07	1.70	1.83
CC6	11.44	11.44	11.44	11.44	11.44	11.44	11.44
CC7	0.25	0.49	0.80	0.36	0.67	0.47	0.58
CC8	3.5	3.5	3.5	3.5	3.5	3.5	3.5
CC9	1.5	1.5	1.5	1.5	1.5	1.5	1.5

Wiedemann 99 parameters of Chennai section

Microscopic analysis of wiedemann99 with out acceleration inputs on Chennai section



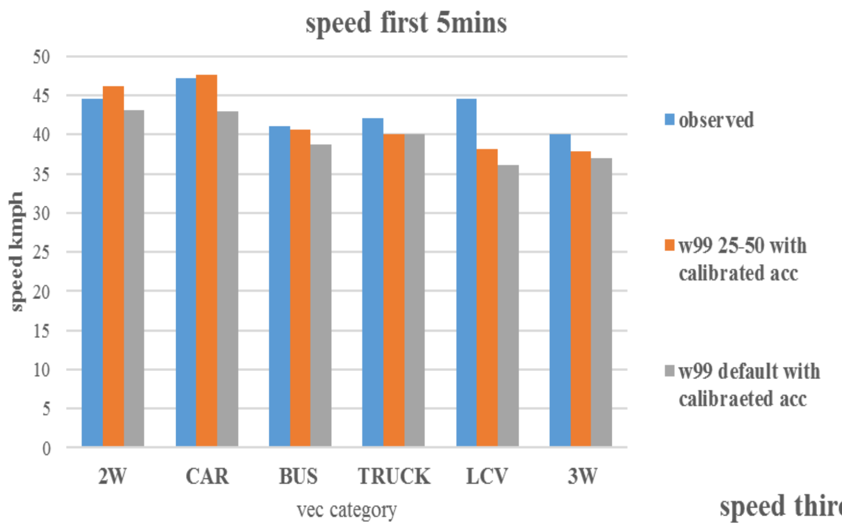


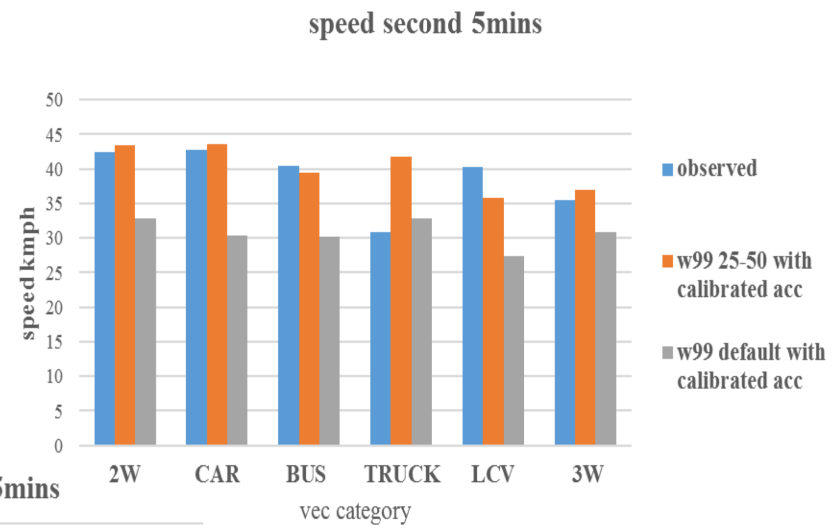


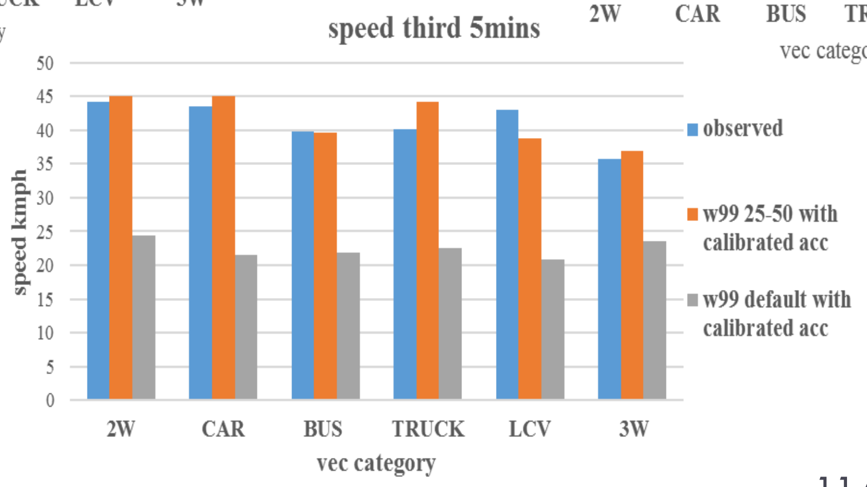
Microscopic analysis of wiedemann99 with out acceleration inputs on Chennai section

criteria of checking error	caharacteristics	model	2W	CAR	BUS	TRUCK	LCV	3W
MAPE %	speed	Calibrated w99	4.90	2.83	9.59	13.11	12.24	3.61
		default w99	9.89	12.17	13.03	7.59	17.22	6.44
avg of absolue difference	density	calibrated w99	5.15	1.22	0.83	0.19	0.13	0.81
		default w99	8.98	4.95	0.87	0.18	0.18	1.43
avg of absolue difference	volume	calibrated w99	9.02	1.11	1.71	0.51	0.40	1.28
		default w99	10.39	1.77	1.74	0.51	0.40	1.31

Microscopic analysis of wiedemann99 with acceleration inputs on Chennai section







Microscopic analysis of wiedemann99 with acceleration inputs on Chennai section

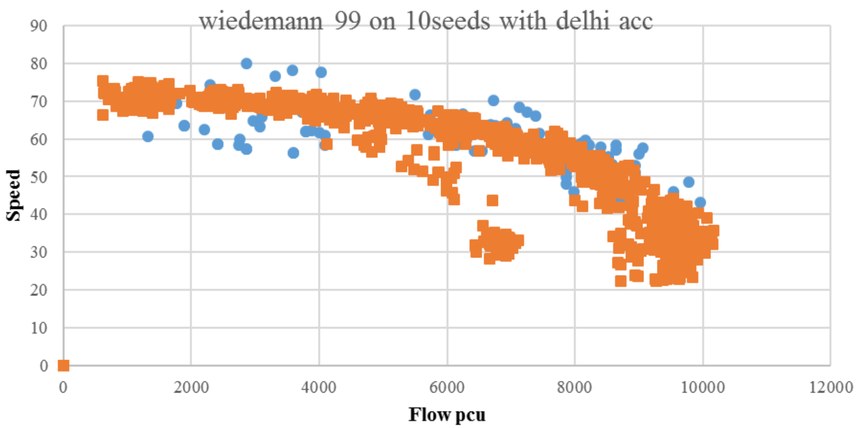
criteria of checking error	Characteristics	Model	2w	car	bus	truck	lcv	3w
MAPE	speed	calibrated w99	2.64	2.32	1.33	16.78	11.72	4.41
		default w99	23.50	29.41	25.20	18.32	34.17	18.42
avg of absolute difference	density	calibrated w99	3.02	1.00	0.36	0.25	0.10	0.93
		default w99	20.99	14.44	1.79	0.13	0.57	4.52
avg of absolute difference	volume	calibrated w99	6.72	1.08	1.41	0.51	0.36	0.61
		default w99	23.82	10.88	1.36	0.63	0.49	3.81

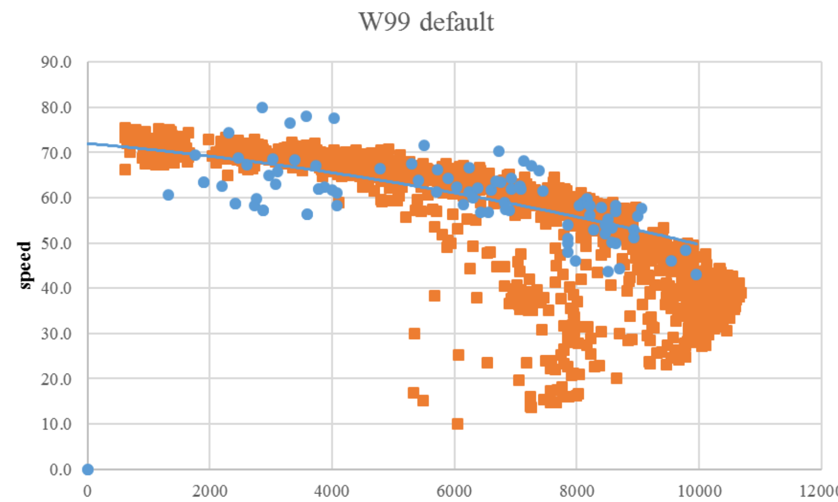
Continued…

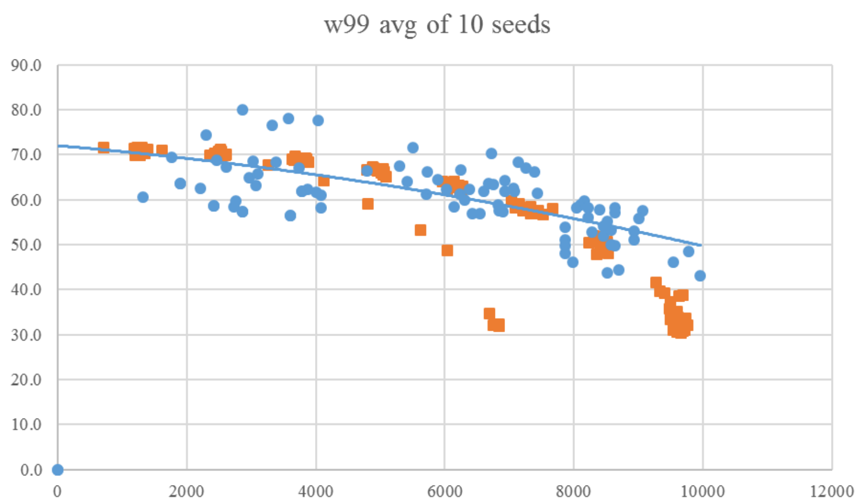
Wiedemann 99 parameters of Delhi section

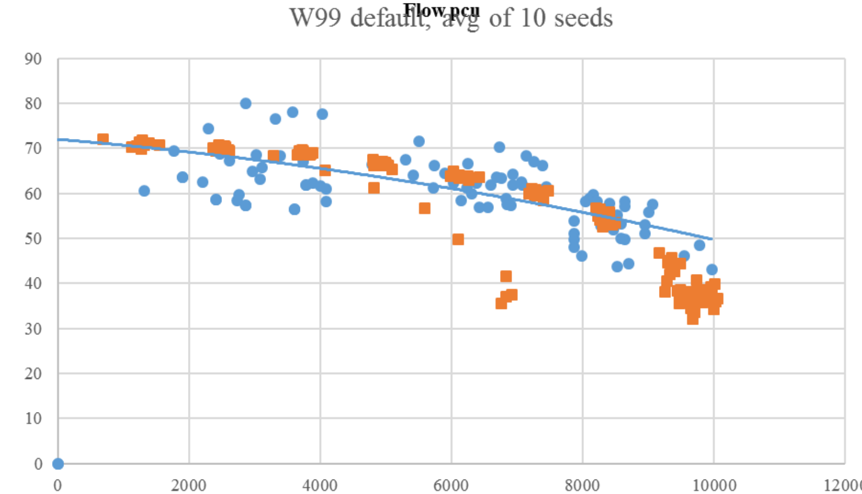
parameter	default value	auto	bike	bus	car	heavy	lcv
cc0	1.5	0.65	0.2	0.6	0.55	0.6	1.35
cc1	0.9	0.9	0.9	0.9	0.9	0.9	0.9
cc2	4	4.39	3.13	1.41	4.62	2.35	9.52
cc3	-8	-0.55	-0.48	-0.24	-0.96	-0.80	-2.08
cc4	-0.35	-3.43	-7.02	-9.47	-5.24	-1.61	-4.19
cc5	0.35	7.98	6.52	5.83	4.79	2.90	4.68
cc6	11.44	11.44	11.44	11.44	11.44	11.44	11.44
cc7	0.25	0.25	0.25	0.25	0.25	0.25	0.25
cc8	3.5	3.5	3.5	3.5	3.5	3.5	3.5
cc9	1.5	1.5	1.5	1.5	1.5	1.5	1.5

Macro level comparison on Delhi section









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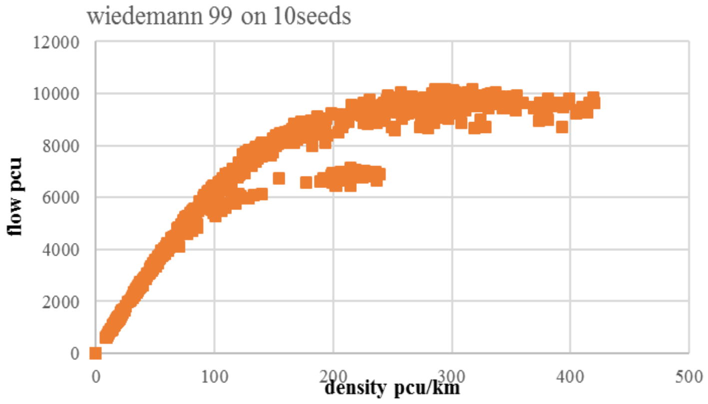
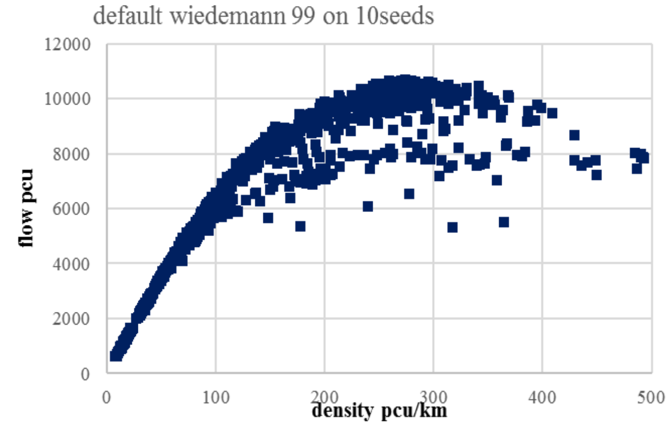
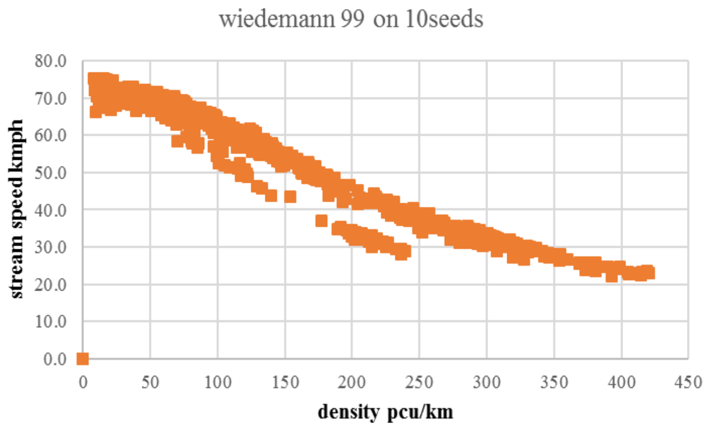
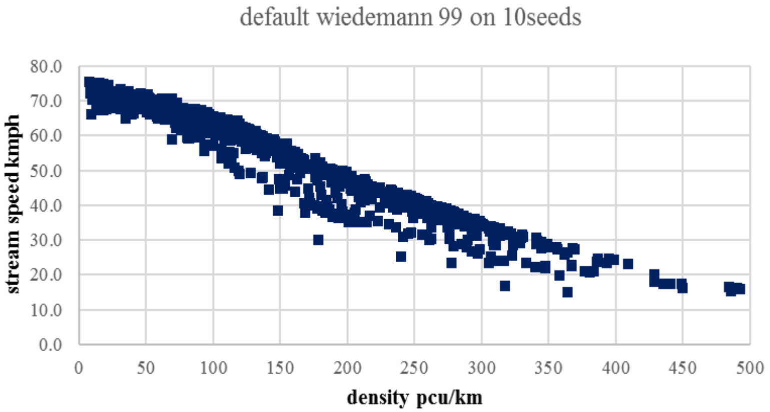








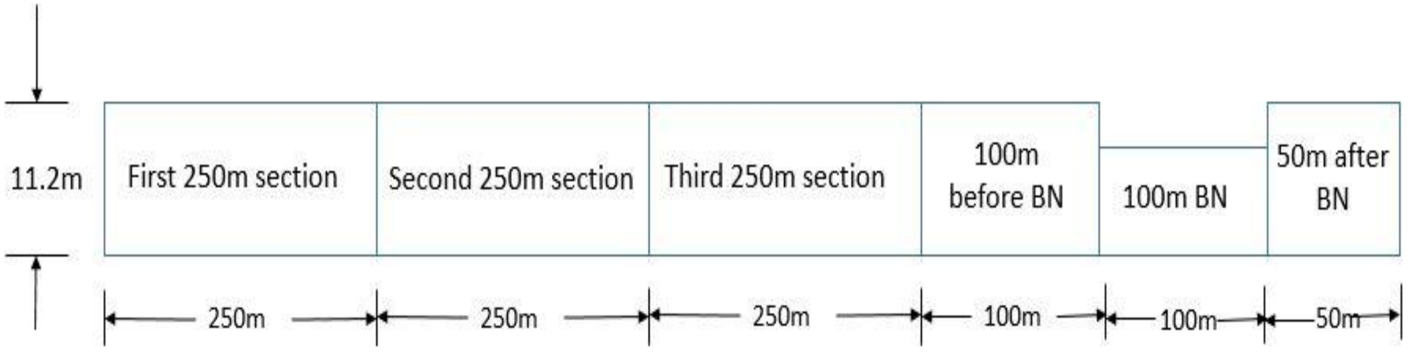
S.No.	Characteristics	Observed	Calibrated w99	Default w99
1.	Capacity (pcu)	9960	9761	10049
2.	Free flow speed (kmph)	75	72	72

Observations from calibration

- Delhi section, when compared to Chennai section vehicle tends to maintain relative spacing at high relative velocities.
- It was found that calibrated wiedemann-74 and wiedemann-99 models are performing better in replicating the observed field conditions with and without accelerations.
- Whereas in case of default wiedemann-74 model, there is a significant variation is observed among observed data set.
- On the other hand default wiedemann99 is giving a better output. Based on the analysis results were quantified.
- With the input in calibrated acceleration values, the results of default models were not yielding good results.

Study on bottleneck

- Study on bottleneck were carried out using the validated simulated models, by increasing the length of the segments.
- Bottleneck is created by reducing the width of the section, over a selected location in such way that macroscopic fundamental diagrams



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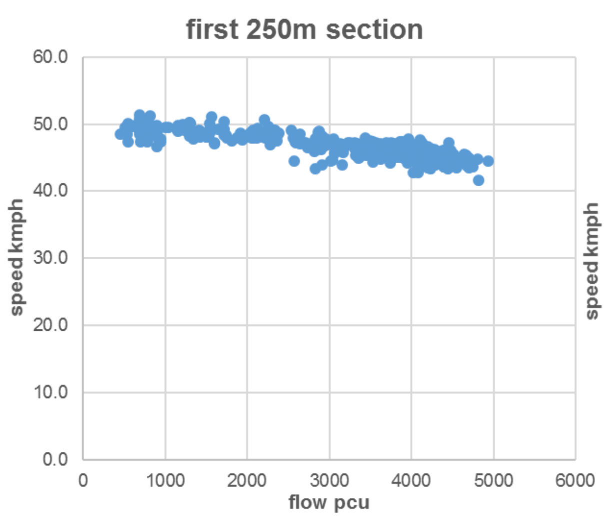
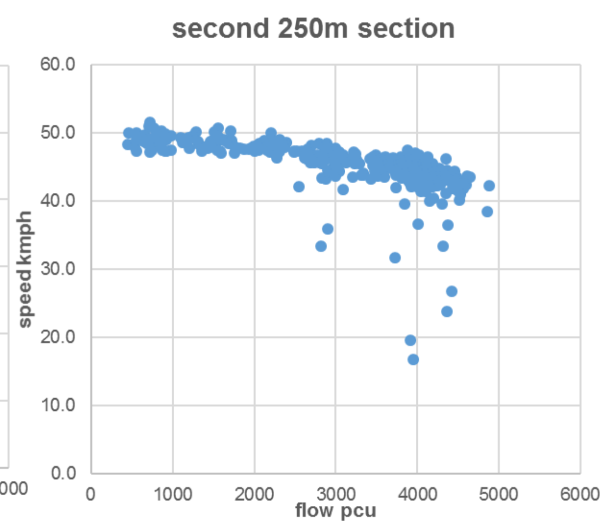
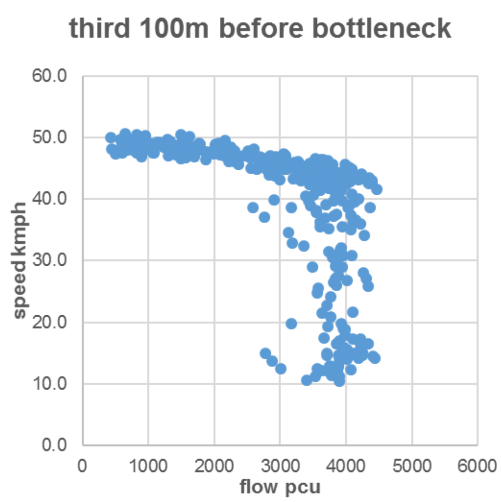
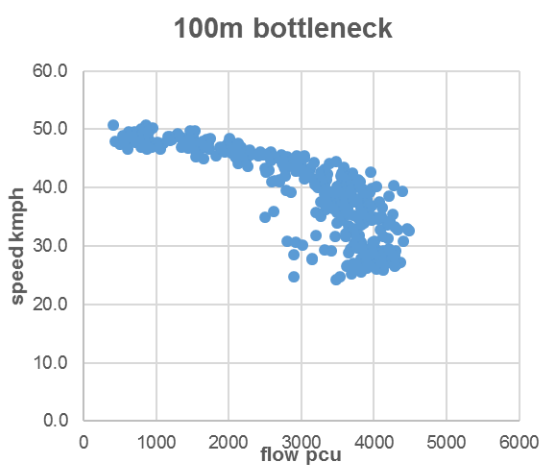
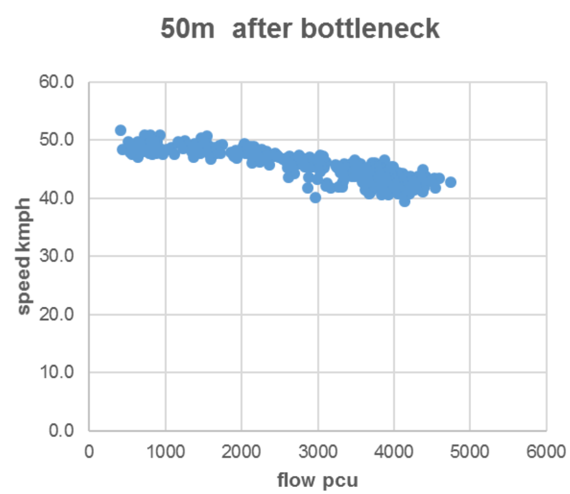

first 250m section
60.0
50.0
40.0
30.0
20.0
10.0
0.0
speed kmph
0
1000
2000
3000
4000
5000
6000
flow pcu


second 250m section
60.0
50.0
40.0
30.0
20.0
10.0
0.0
speed kmph
0
1000
2000
3000
4000
5000
6000
flow pcu

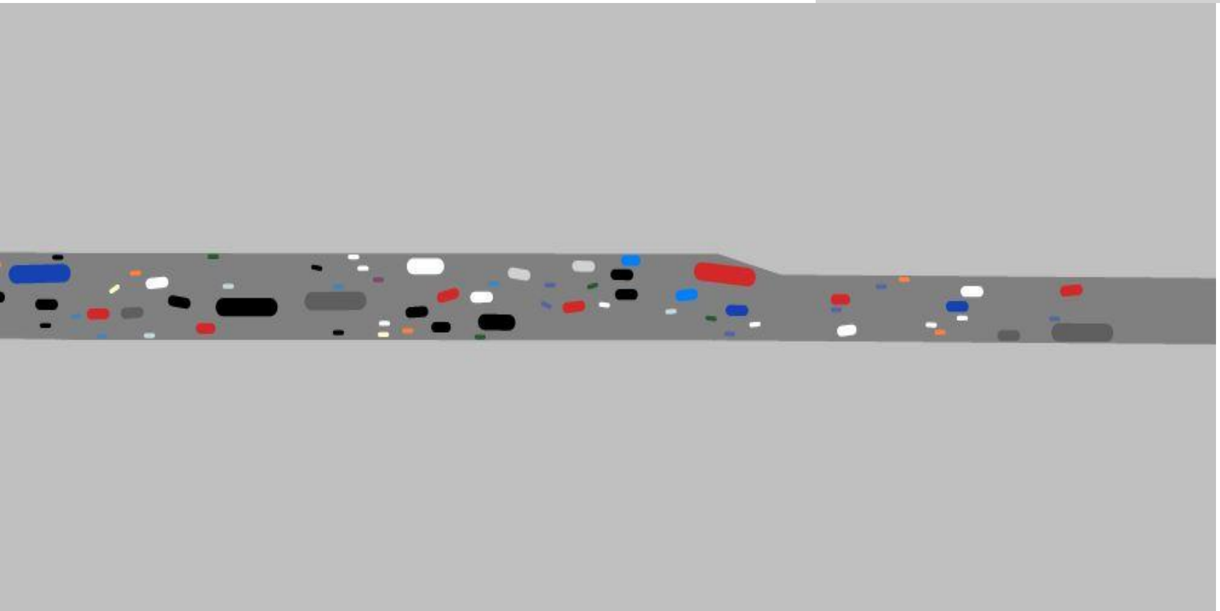

third 100m before bottleneck
60.0
50.0
40.0
30.0
20.0
10.0
0.0
speed kmph
0
1000
2000
3000
4000
5000
6000
flow pcu


100m bottleneck
60.0
50.0
40.0
30.0
20.0
10.0
0.0
speed kmph
0
1000
2000
3000
4000
5000
6000
flow pcu


50m after bottleneck
60.0
50.0
40.0
30.0
20.0
10.0
0.0
speed kmph
0
1000
2000
3000
4000
5000
6000
flow pcu

Continued…

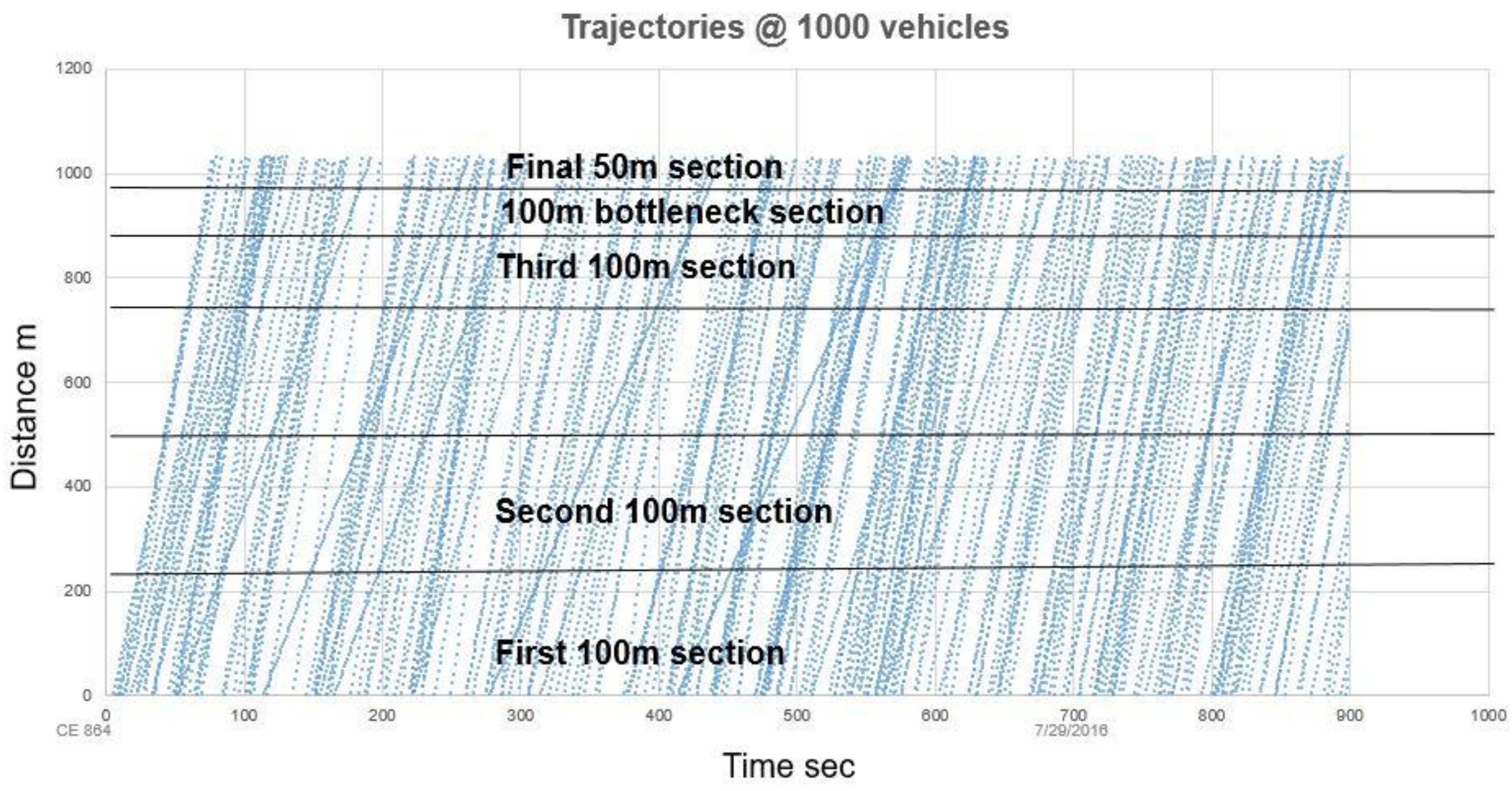
Jamming conditions in the simulation models



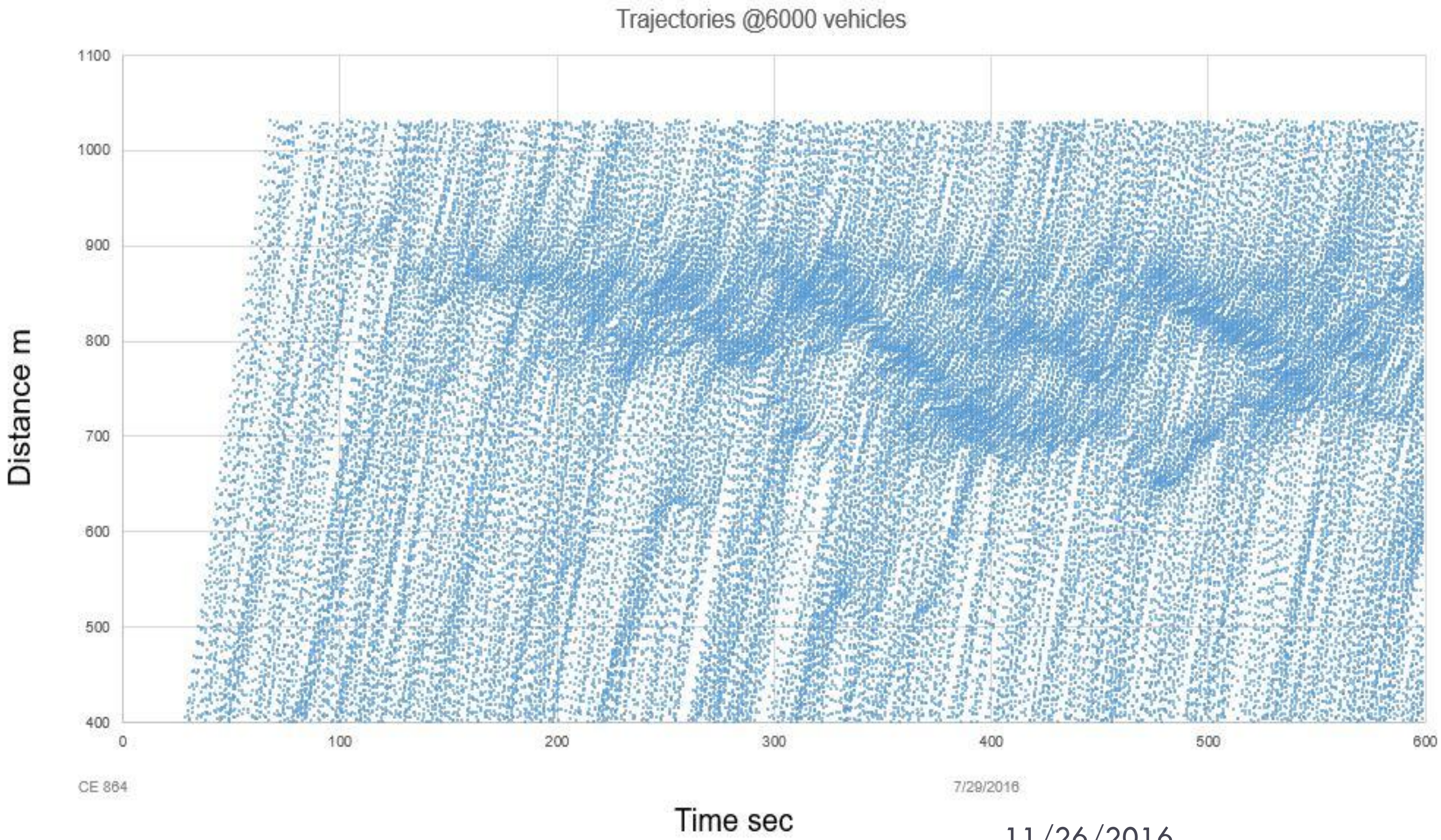
Observation from bottleneck study

- It was observed that in first 250m section is less affected section.
- second 250m section is slightly congested, bottleneck effect is clearly observed.
- Whereas the third 100m section which is on just up-stream of bottleneck is experiencing congestion on the segment.
- Bottleneck section is serving up to its capacity, but reduced due to lane-drop
- Finally,100m section on down-stream bottleneck is always at free regime condition and it is not all serving up to its potential

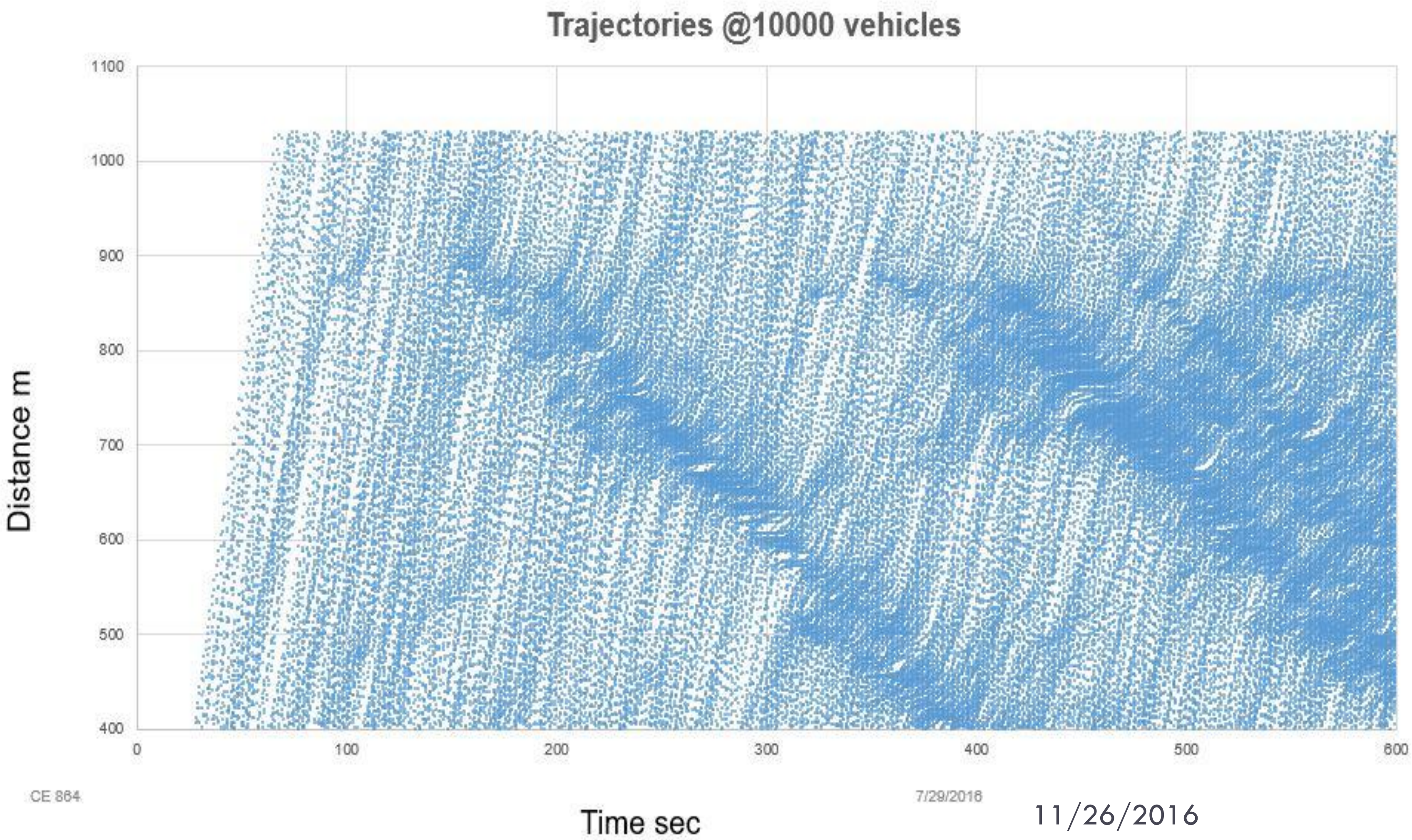
Vehicular trajectories at low traffic volume



Vehicular trajectories at medium traffic volume



Vehicular trajectories at high traffic volume



Conclusions of the study

- Under heterogeneous traffic conditions perfect leader-follower interactions may not happen one-to-one but there may be effect of vehicles in surrounding.
- Variation in driving behavior among vehicular categories in same road segments.
- There is a variation in driving behavior among over different road segments.
- With calibrated wiedemann-74 and wiedemann-99 models, the simulated models are performing good in replicating the field conditions.
- From the analysis on Delhi section, It was observed that lateral behavior of the vehicles plays its part along with following behavior in driving behavior.
- From bottleneck study, section which is near the upstream side of section is highly effected, the section which is on the downstream of the section is not serving beyond the bottleneck capacity. the section which are on the upstream is effected based on the farness from the bottleneck.

Thanks & Questions!

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