Preferred citation style for this presentation

Elvarsson, A. B.(2017) Modelling Urban Driving and Parking Behavior for Automated Vehicles, Seminar, Zürich, June 2017.

Modelling Urban Driving and Parking Behavior for Automated Vehicles

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June 2017

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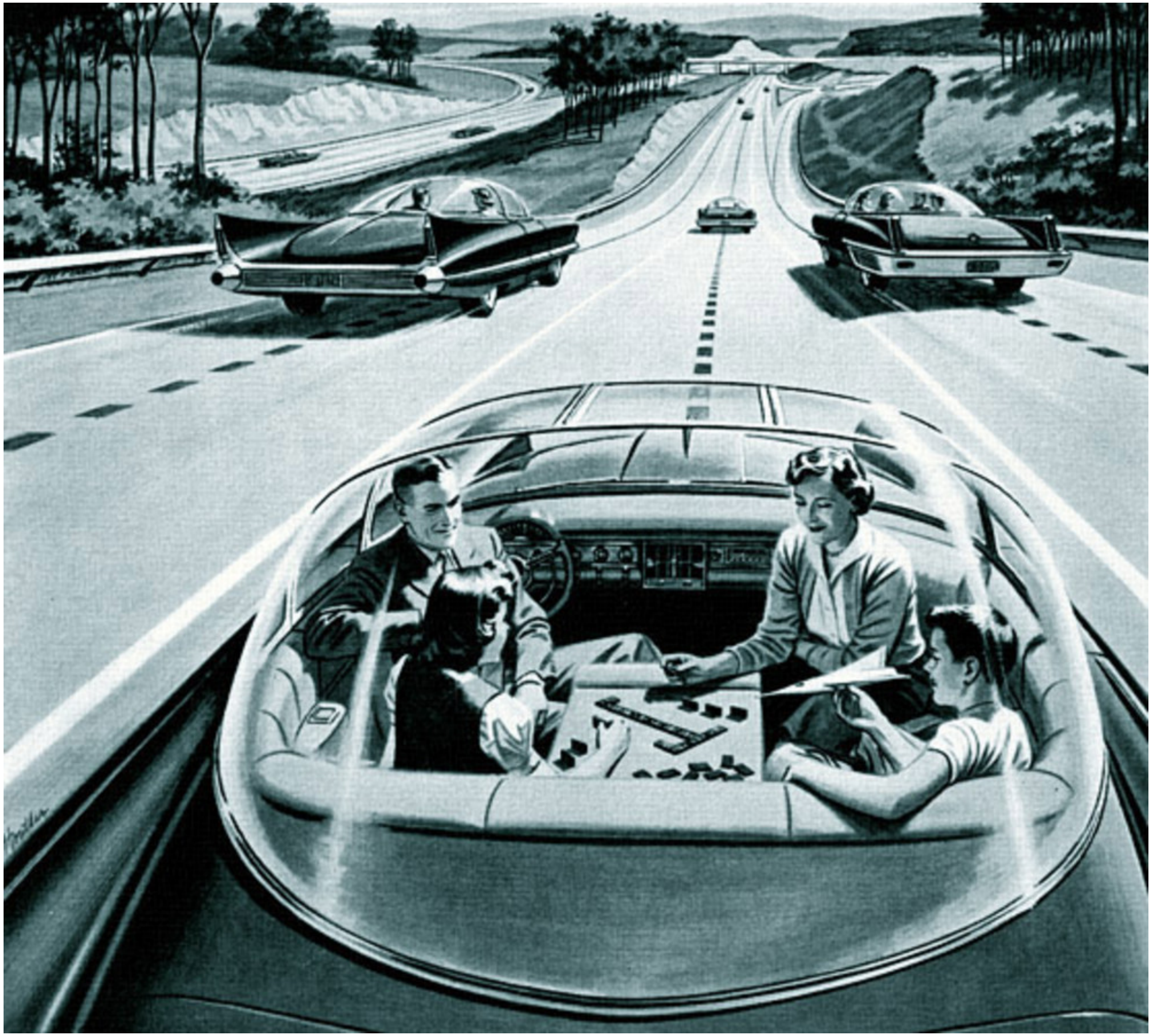
Automated vehicles



Source: Jenn, 2016

TNCs and SAVs

Transportation Network Carriers

Shared Automated Vehicles

- TNCs are already replacing Public Transport
- New York, San Francisco and others are resisting TNCs (SFMTA, 2016; Schaller, 2017)
- Changing behavior calls for change in infrastructure

Aim of Research

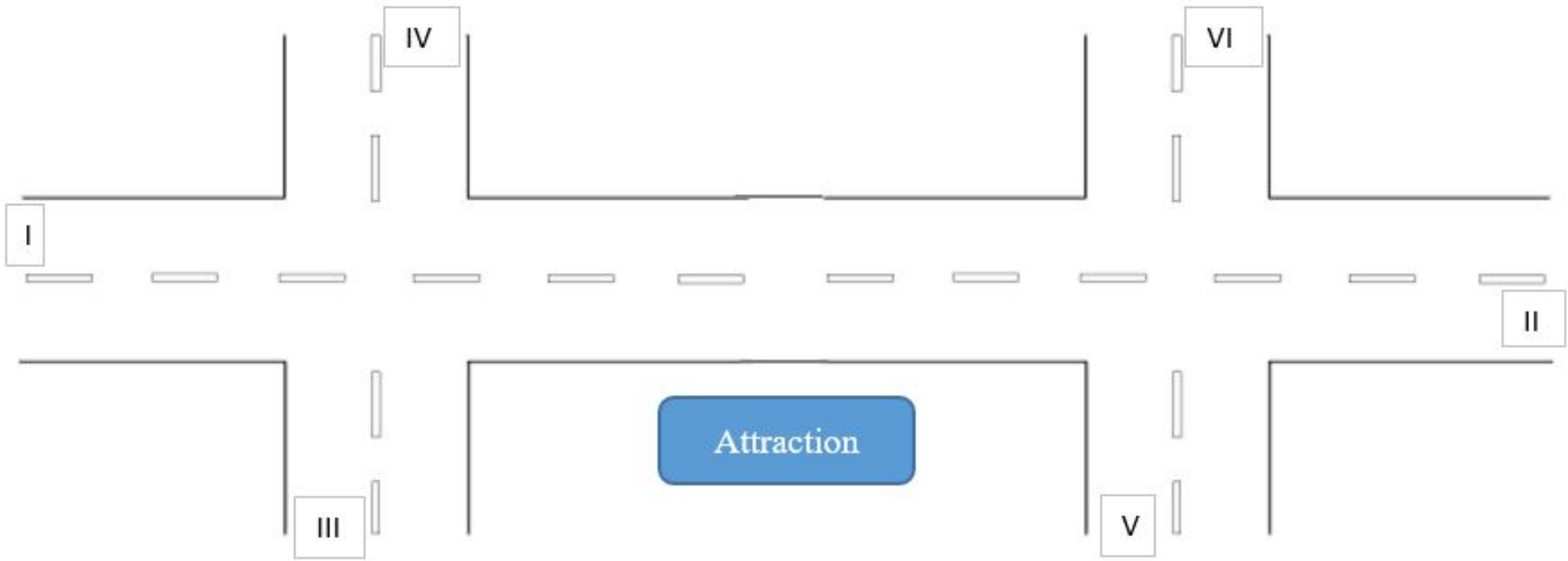
1. model traffic flow of automated vehicles within urban network, and
2. model parking behavior of vehicles for different parking configurations.

Source: Arnd Bätzner, private collection

Agenda

1. Abstract model set up
2. Abstract model results
3. Case Study and Results
4. Discussion
5. Conclusion
6. Further Research

An abstract model



- Simple network in VISSIM
- Only passenger cars
- Modelling automated vehicles is a challenge
- Effects of AV penetration rate
- Effects of parking configurations

Driving behavior

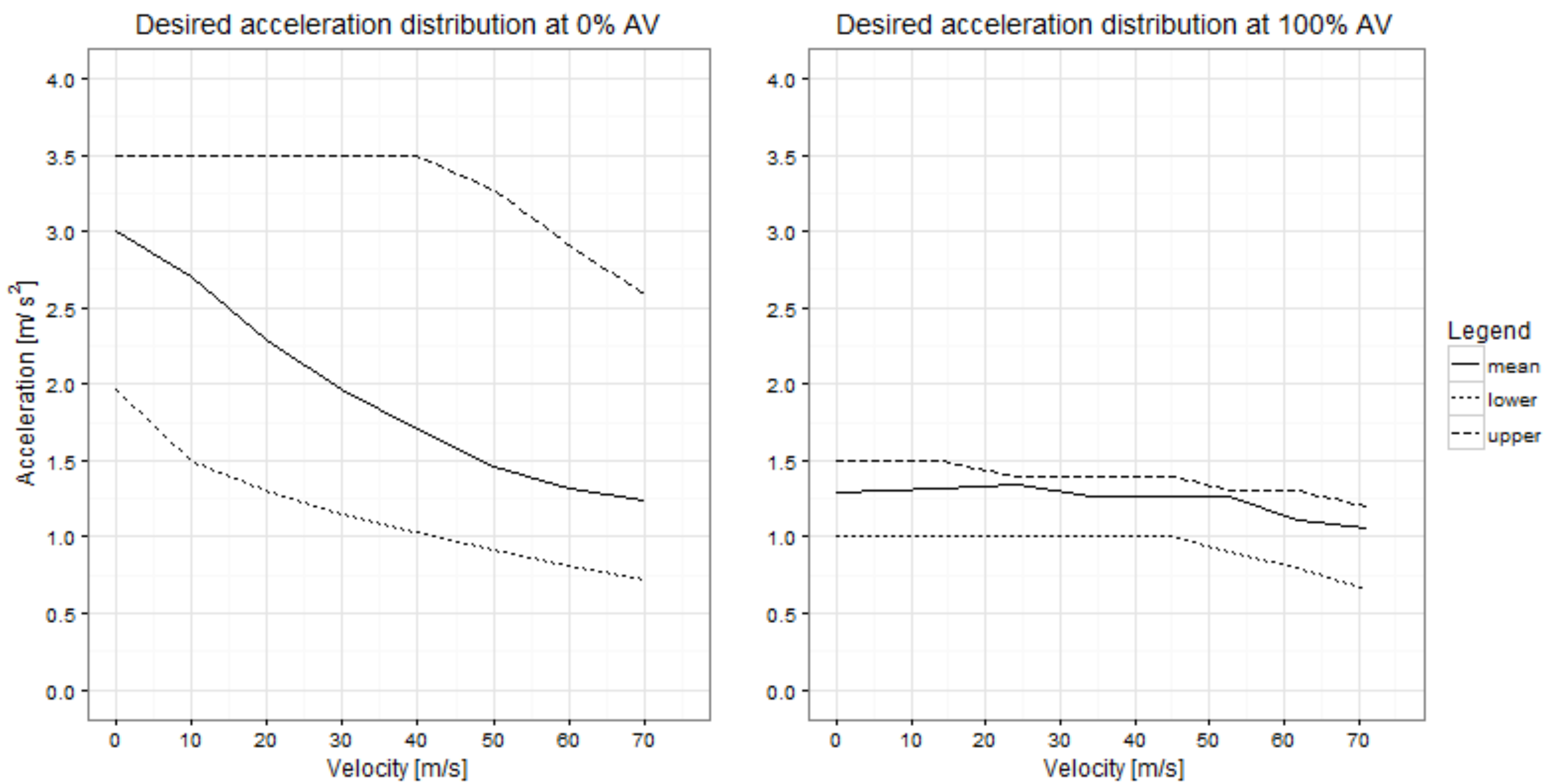
- Homogeneity of traffic behavior on link
- Parameters for Wiedemann Car-following model (1974)
- Flatter speed distribution (PTV Group, 2017)
- Defaults as per Manual (PTV Group, 2015)
- Acceleration distributions as per Le Vine et al. (2015)

Parameter		0%	20%	40%	60%	80%	100%
Vehicle acceleration							
- Mean at v=0 m/s	[m/s²]	3.0	2.8	2.5	2.2	1.7	1.3
Vehicle deceleration							
- Mean at v=0 m/s	[m/s²]	2.7	2.4	1.8	1.7	1.5	1.2
Desired speed distribution							
- Minimum	[km/h]	48	48	49	49	49	50
- Maximum	[km/h]	58	57	57	57	55	54
Standstill distance	[m]	2.0	1.8	1.6	1.4	1.2	1.0
Safety distance							
- Additive part	[-]	3.0	2.6	2.2	1.8	1.65	1.5
- Multiplicative part	[-]	4.0	3.6	3.2	2.8	2.65	2.5

$$d = ax + bx$$

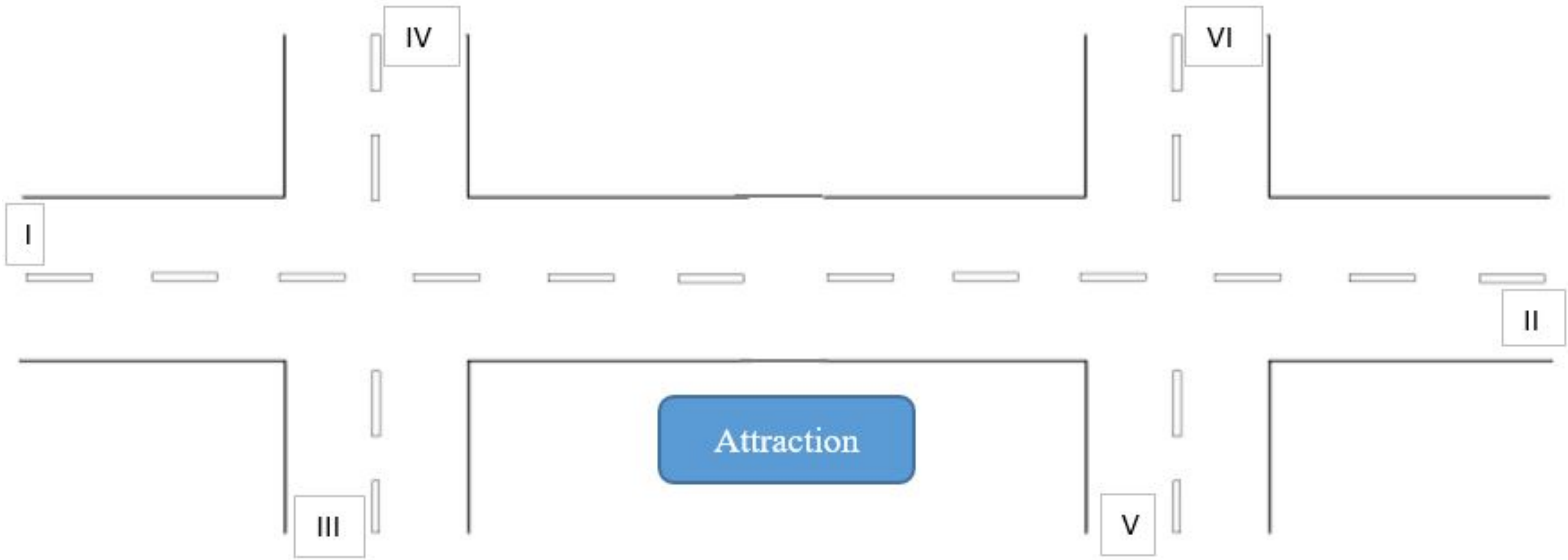
$$bx = (bx_{add} + bx_{mult} \cdot z) \cdot \sqrt{v}$$

Passenger comfort, Le Vine et al (2015)

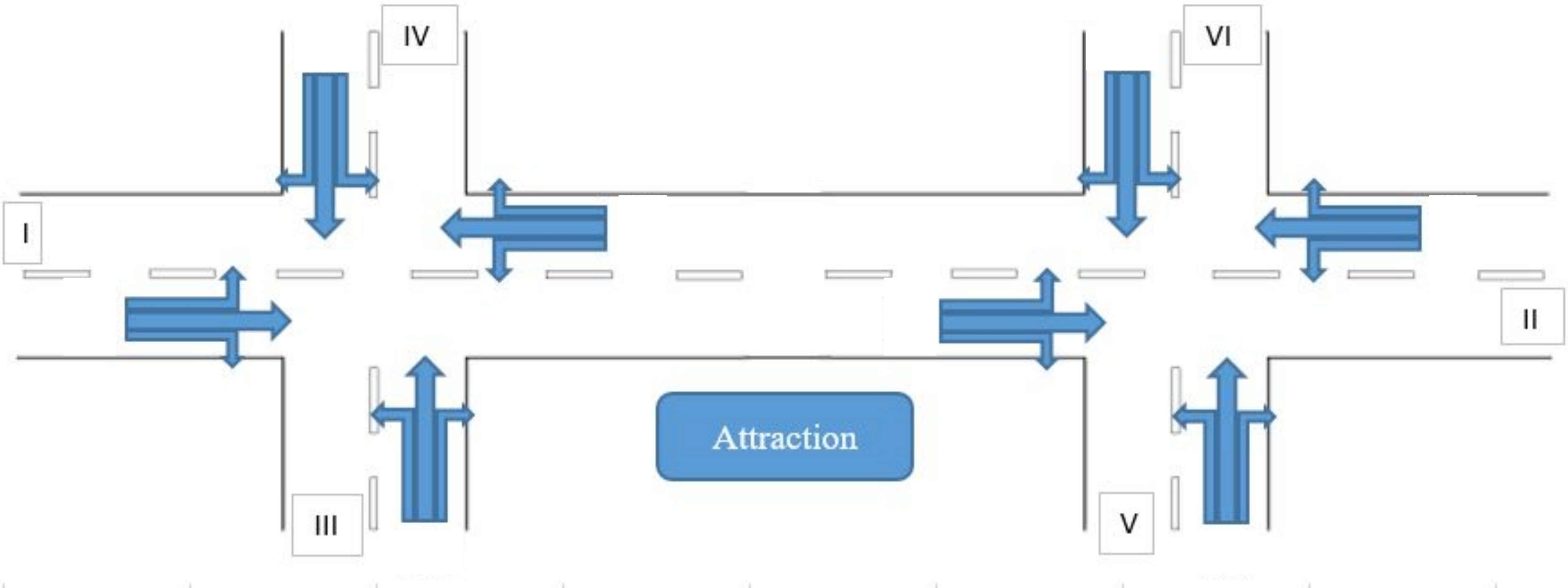


Urban flow capacity and model demand

- Capacity set at 850 pc/ln/hr



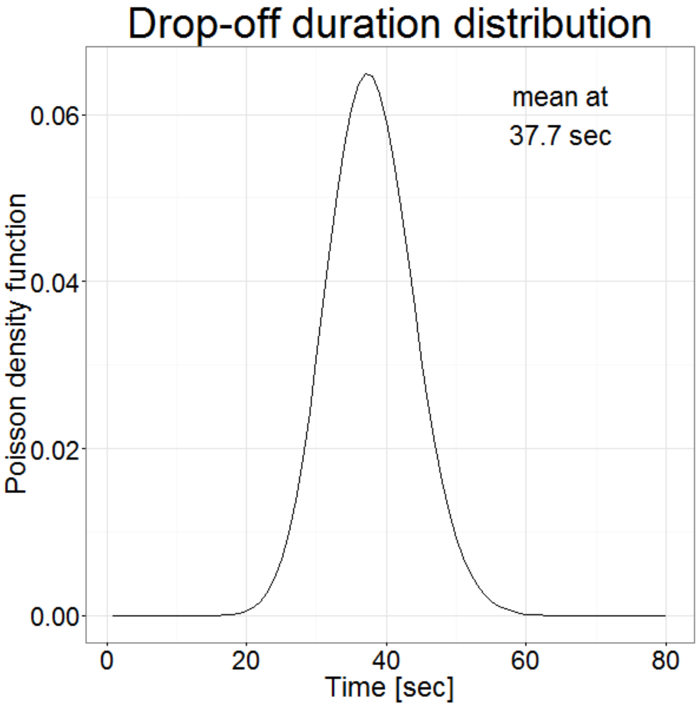
% Capacity	2 Lane	3 Lane
60%	1020	1530
80%	1360	2040
100%	1700	2550

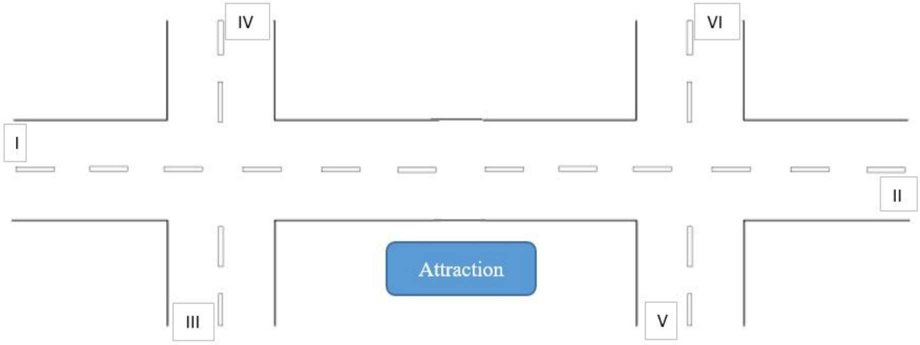


% Capacity	2 Lane	3 Lane
60%	1020	1530
80%	1360	2040
100%	1700	2550

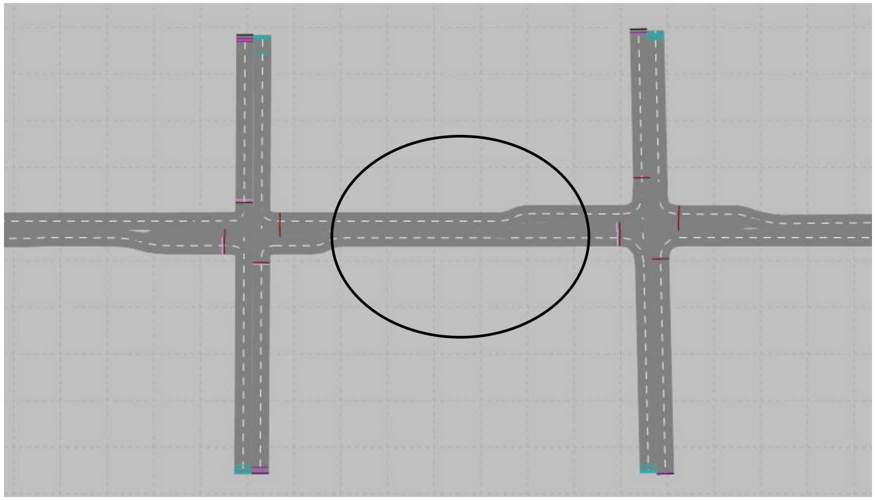
Parking

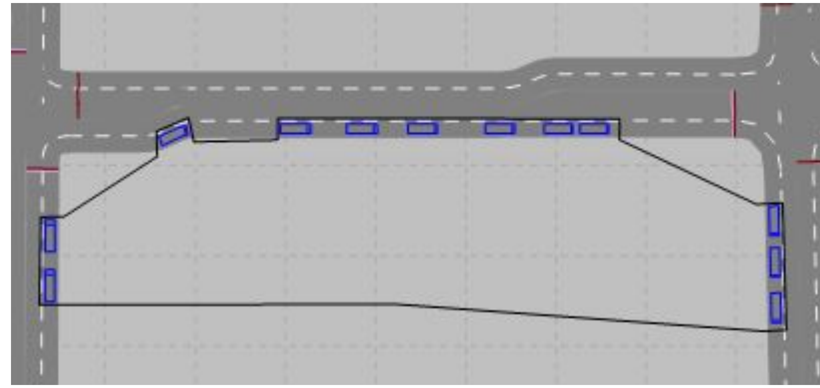
- Drop-off behavior of vehicles, 30 seconds per vehicle
- 12 parking spaces
- Set parking demand as 20% of total demand from I, III and IV
- 4 parking configurations



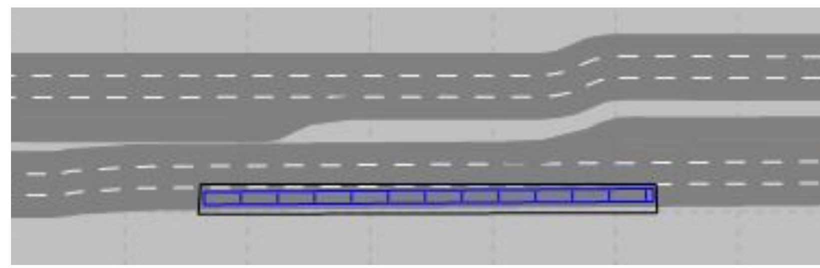


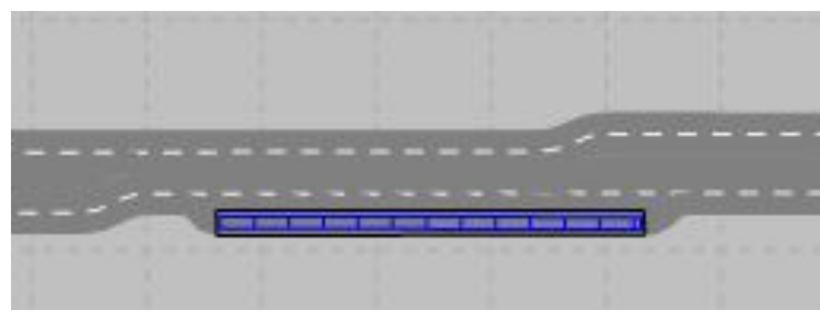
Parking configurations





- No parking
- Sporadic
- Curbside
- Bus drop-off





Other parameters

- Dynamics of urban environment
  - Pedestrians
  - Cyclists
  - Traffic composition
  - Public Transport
- Simulating parking around only one location.

- 1 hour simulations
- 10 time steps per second
- Random seed 42 with increment of 1
- Results are based on averages of 10 simulations

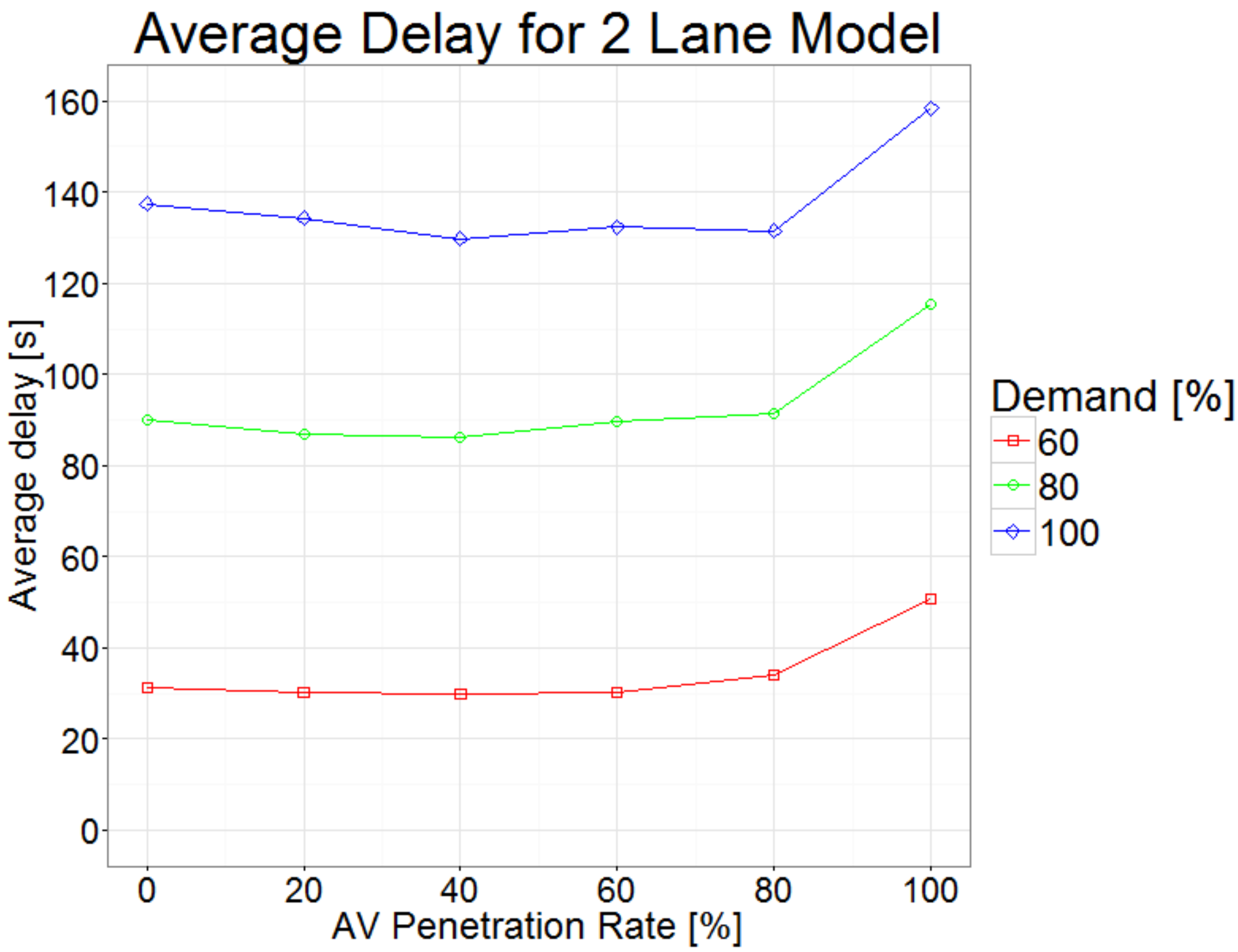
Model parameters and results

- Model parameters are summarised as follows:

Lane number	Parking configuration	AV penetration rate	Demand
2 lanes	Sporadic curbside parking	0%	60% of capacity
3 lanes	Curbside drop-off zone	20%	80% of capacity
	Bus-stop lay-over	40%	100% of capacity
	No parking	60%	
		80%	
		100%	

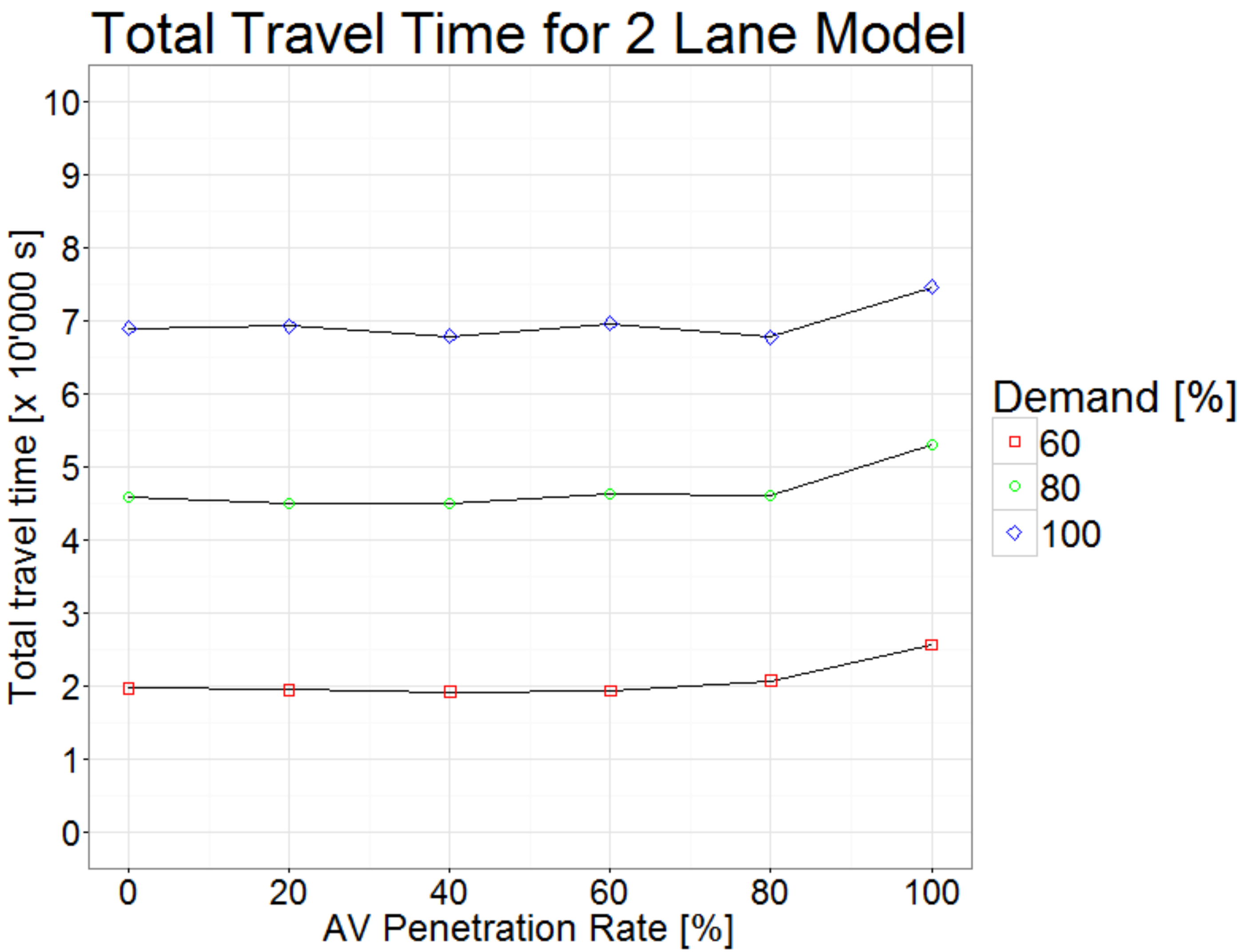
- Results collected were in the form of
  - Average delay
  - Average stops
  - Total Travel Time
  - Average speed
  - (Queue Counts)

Results (1.1)



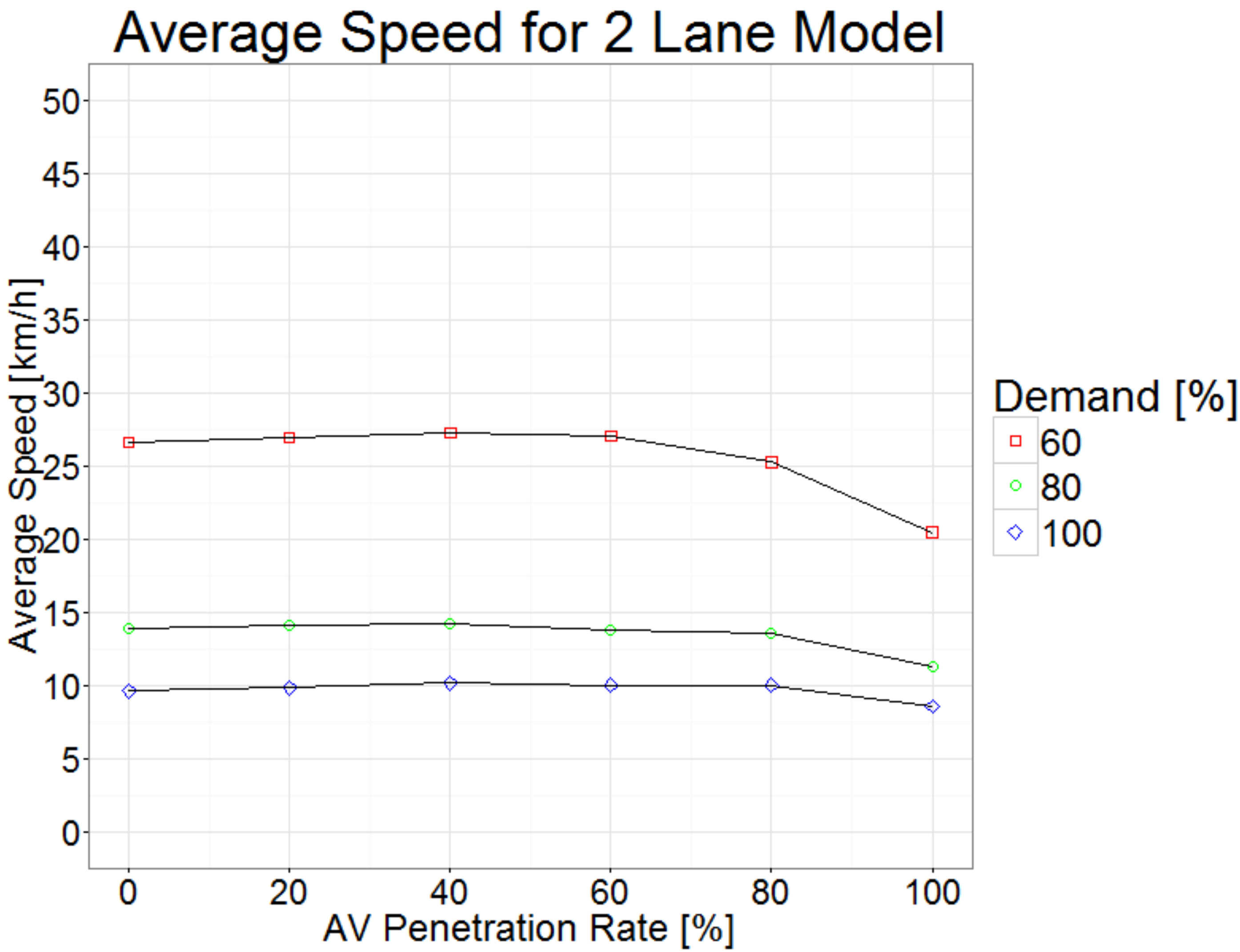
Average Delay for 2 Lane Model
Average delay [s]
0
20
40
60
80
100
120
140
160
AV Penetration Rate [%]
0
20
40
60
80
100
Demand [%]
60
80
100

Results (1.2)



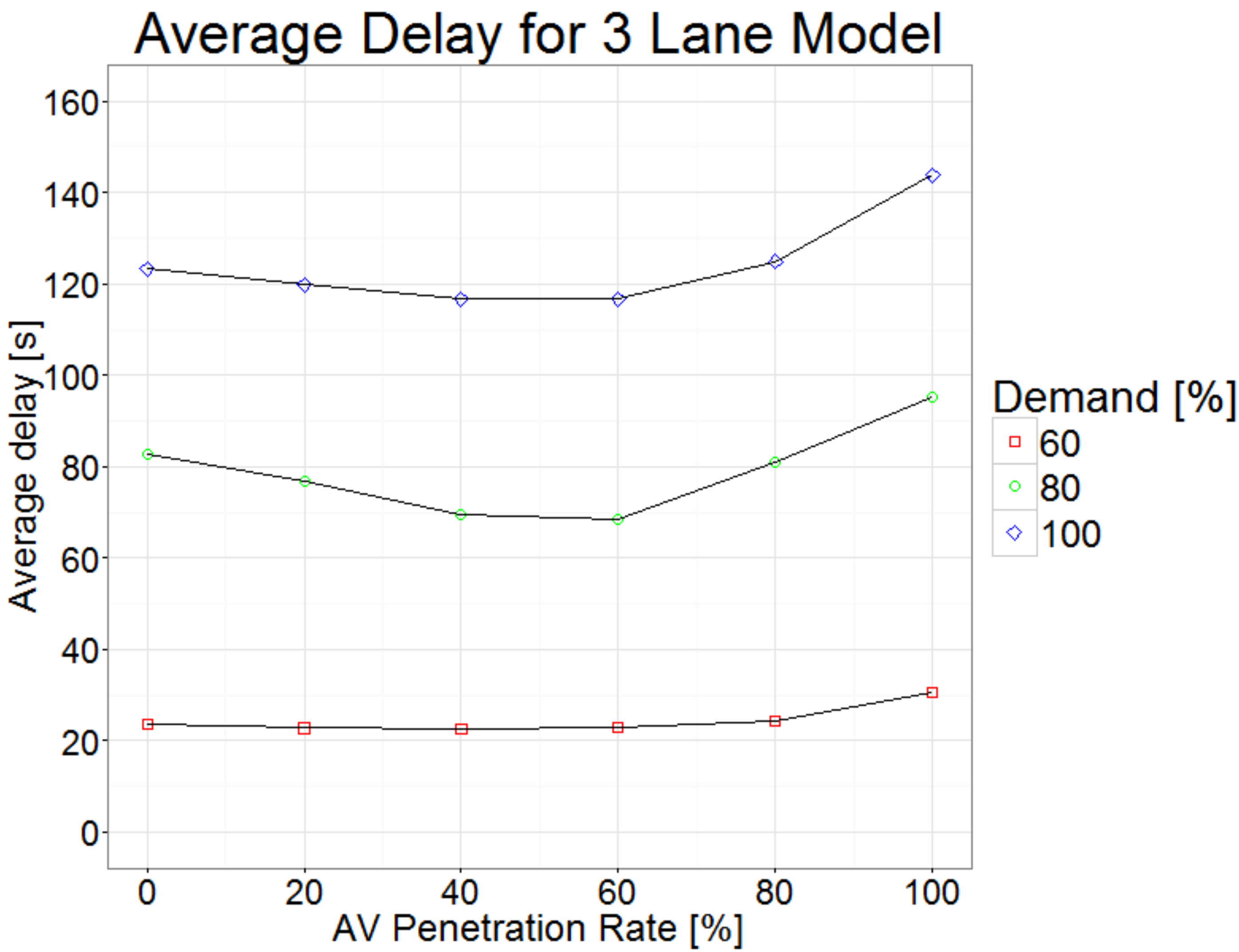
Total Travel Time for 2 Lane Model
Total travel time [x 10'000 s]
10
9
8
7
6
5
4
3
2
1
0
0
20
40
60
80
100
AV Penetration Rate [%]
Demand [%]
60
80
100

Results (1.3)



Average Speed for 2 Lane Model
Average Speed [km/h]
50
45
40
35
30
25
20
15
10
5
0
0
20
40
60
80
100
AV Penetration Rate [%]
Demand [%]
60
80
100

Results (1.4)



Average Delay for 3 Lane Model
Average delay [s]
AV Penetration Rate [%]
0
20
40
60
80
100
120
140
160
Demand [%]
60
80
100

What have we found out so far?

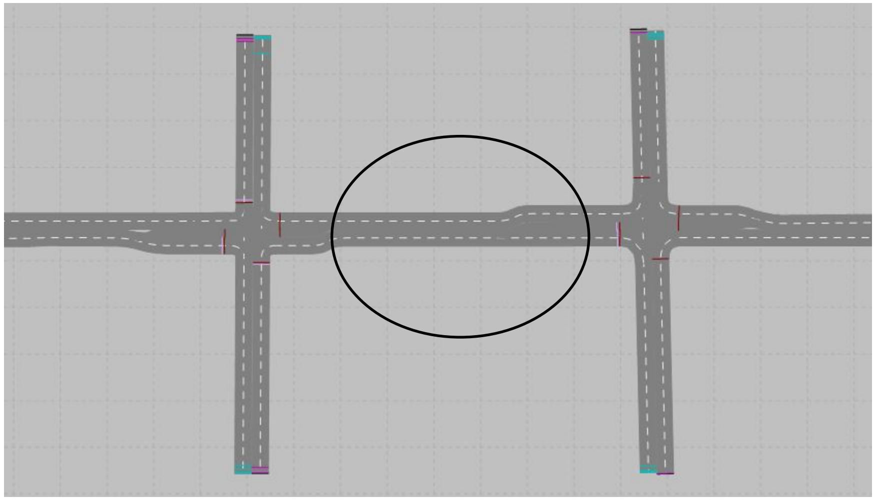
1. model traffic flow of automated vehicles within urban network, and
2. model parking behavior of vehicles for different parking configurations.

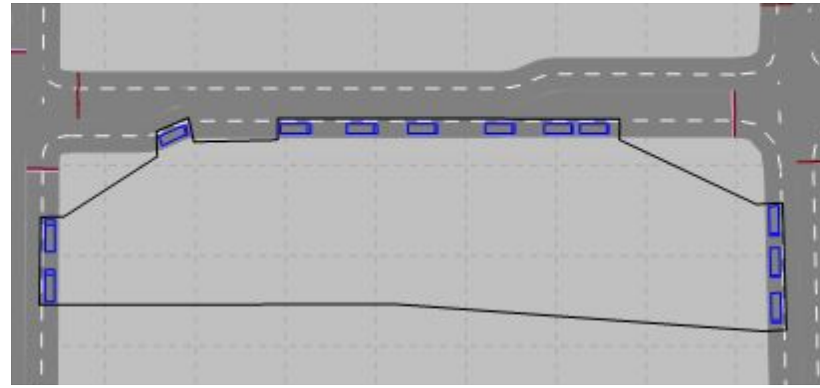
- Modelling AVs in VISSIM is challenging
- Slow improvement in network performance until 40% AV penetration rate.
- Reduction in network performance after 60% AV penetration rate
- Possibilities of model improvement

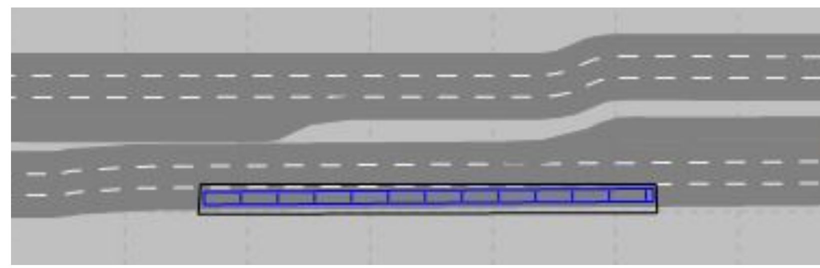
Now what?

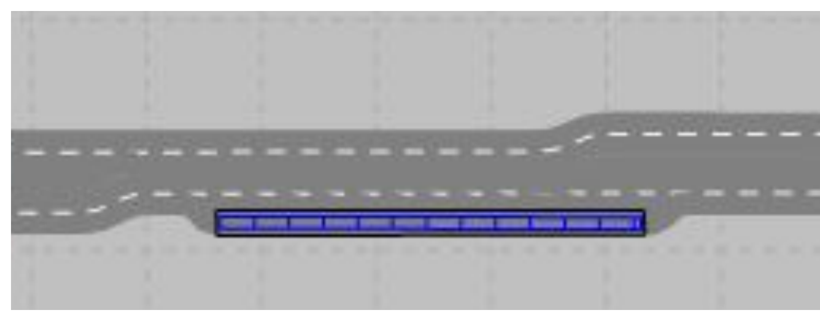
- Based on modelled driving behavior, how do cars behave when they also drop passengers off?
- Consider cars to currently stop sporadically
- Can improvements be made?

Parking configurations



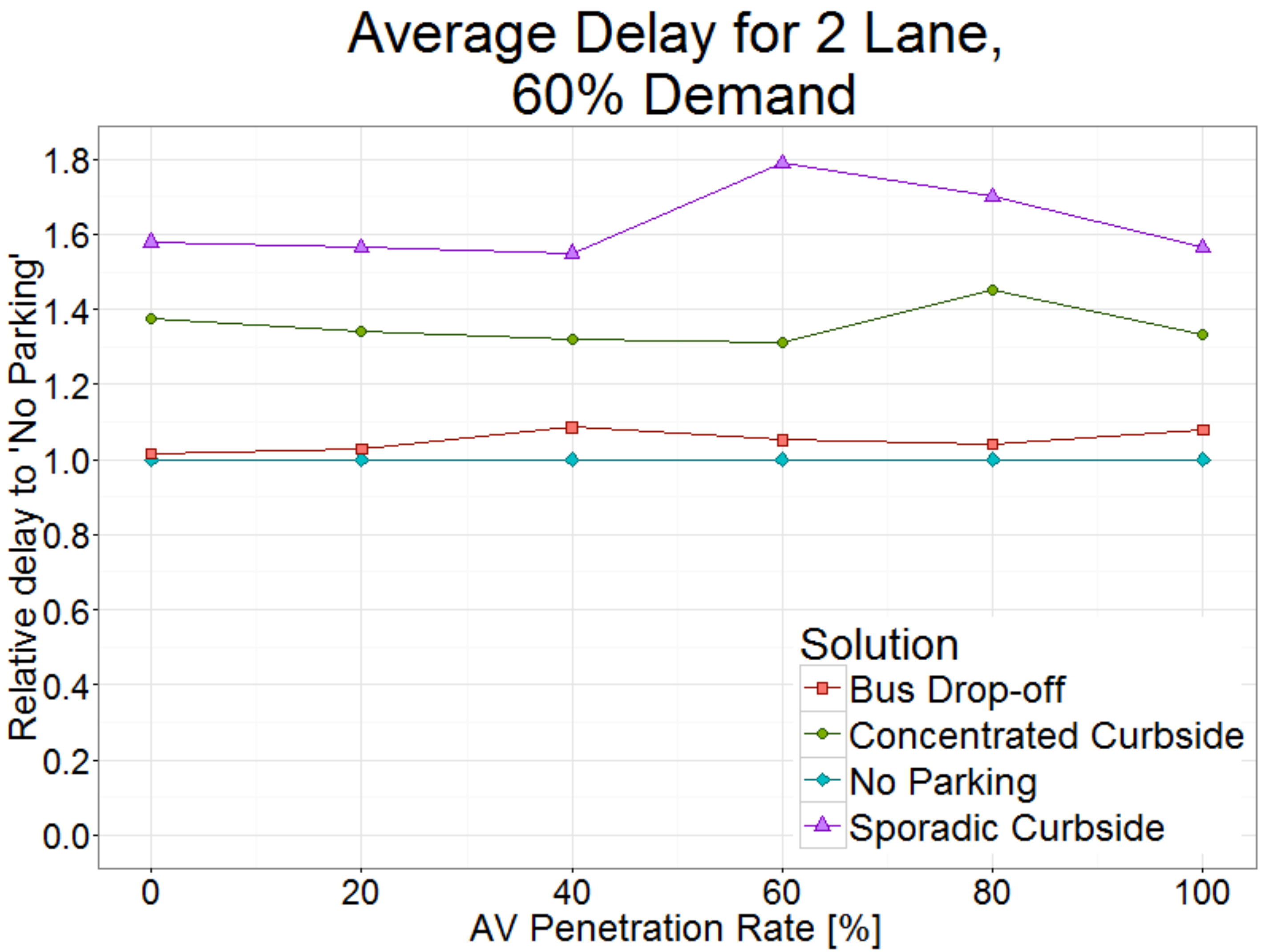






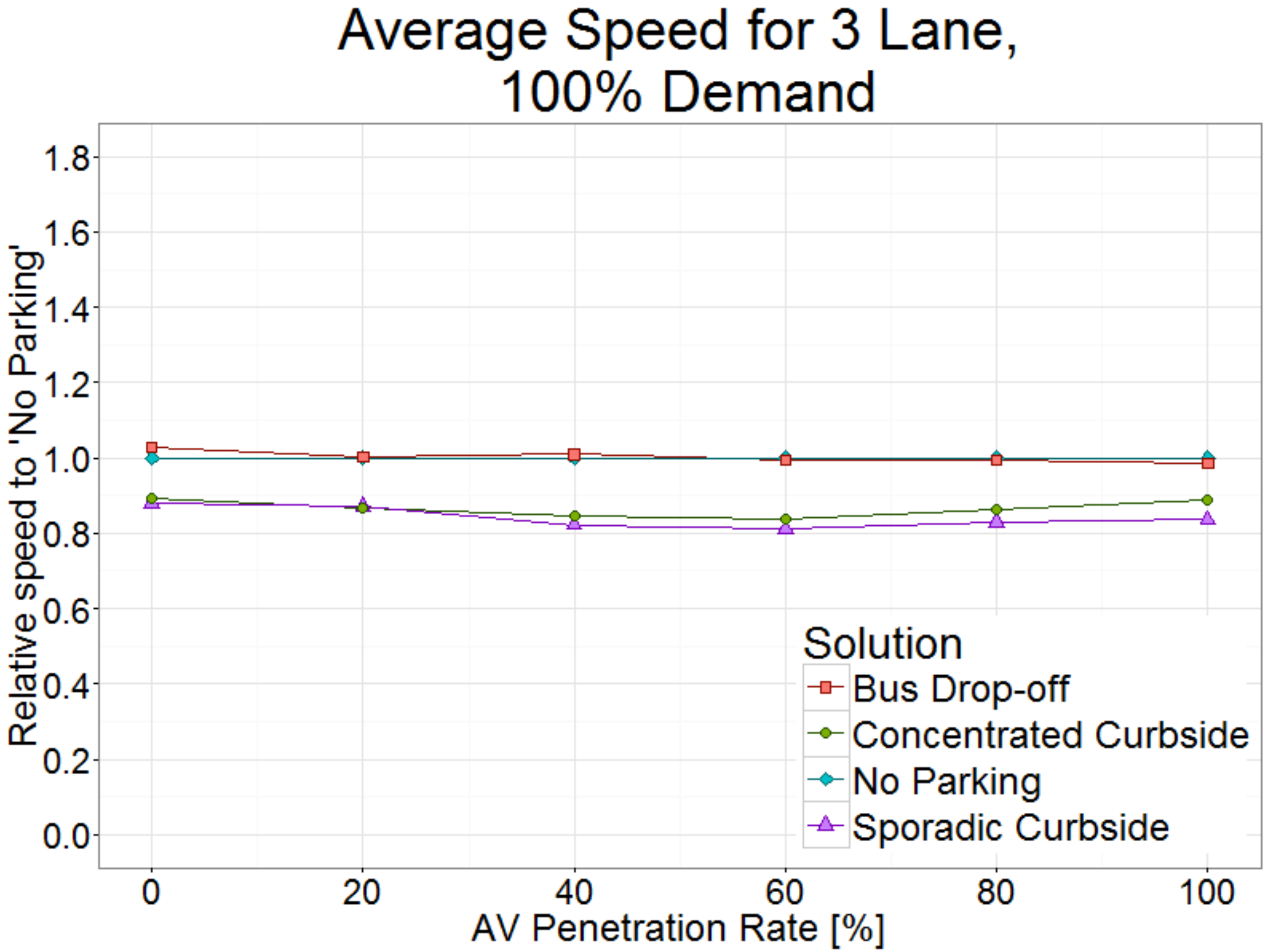
- No parking
- Sporadic
- Curbside
- Bus drop-off

Results (2.1)



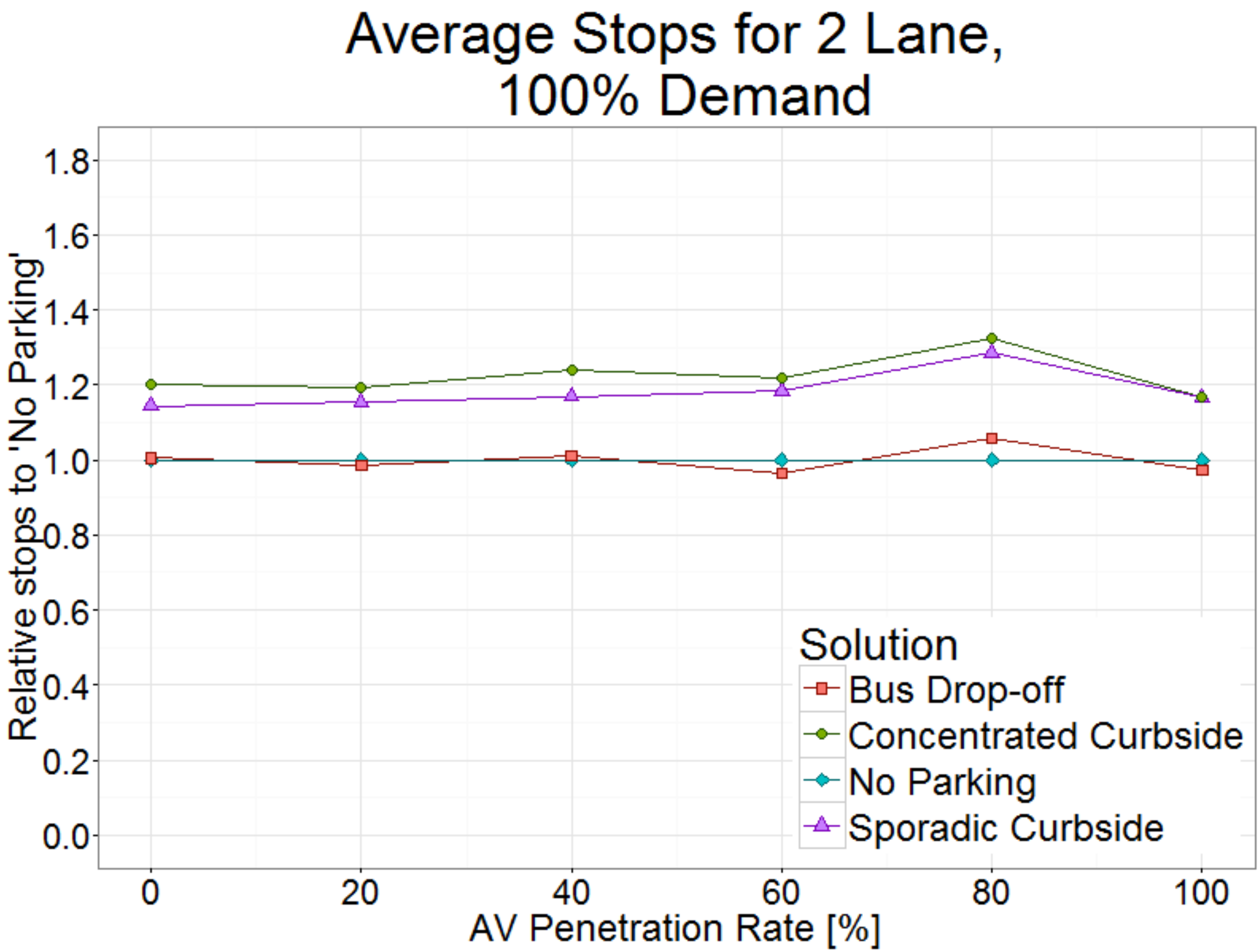
Average Delay for 2 Lane,
60% Demand
Relative delay to 'No Parking'
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
20
40
60
80
100
AV Penetration Rate [%]
Solution
Bus Drop-off
Concentrated Curbside
No Parking
Sporadic Curbside

Results (2.2)

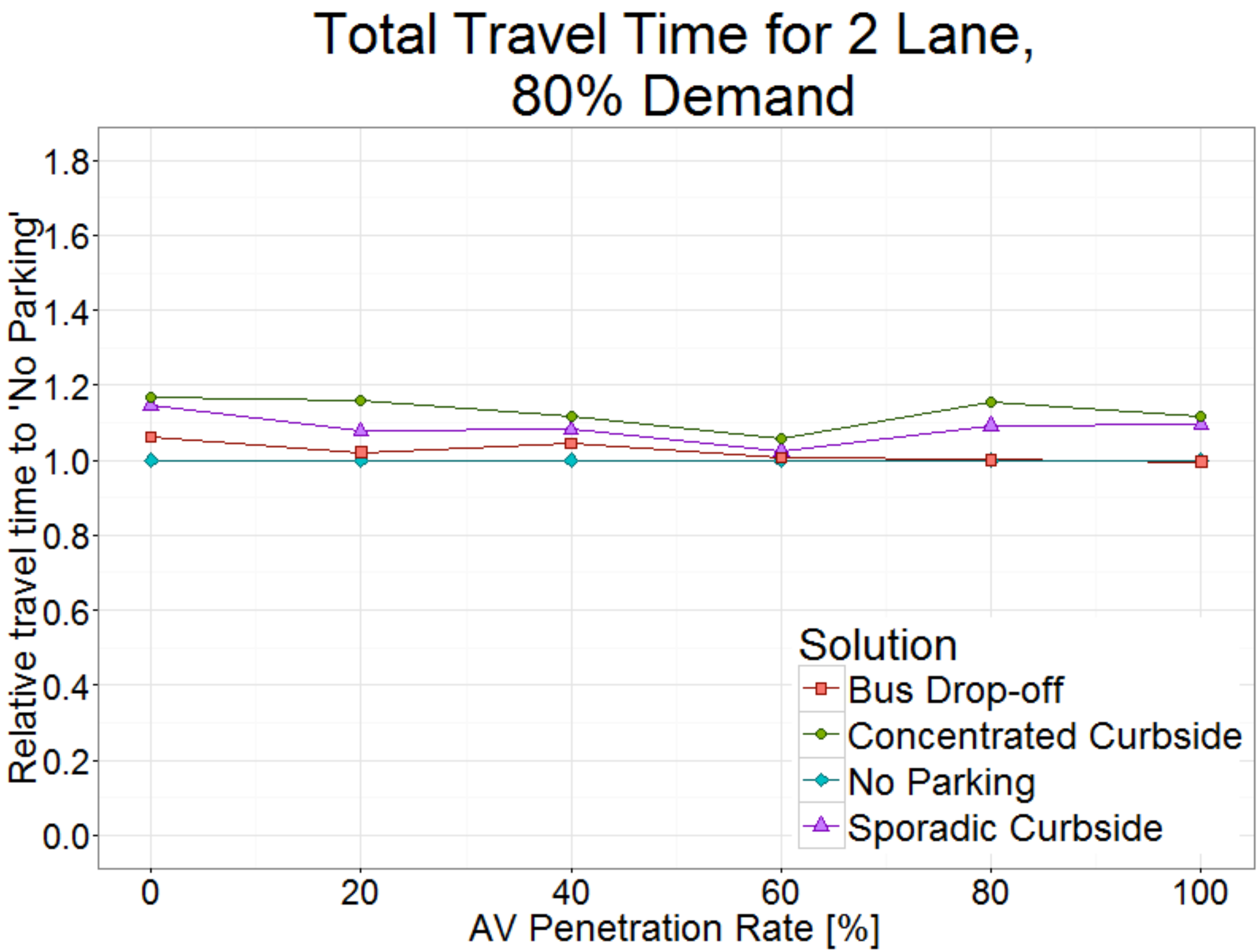


Average Speed for 3 Lane,
100% Demand
Relative speed to 'No Parking'
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
20
40
60
80
100
AV Penetration Rate [%]
Solution
Bus Drop-off
Concentrated Curbside
No Parking
Sporadic Curbside

Results (2.3)


Average Stops for 2 Lane,
100% Demand
Relative stops to 'No Parking'
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
20
40
60
80
100
AV Penetration Rate [%]
Solution
Bus Drop-off
Concentrated Curbside
No Parking
Sporadic Curbside

Results (2.4)



Total Travel Time for 2 Lane,
80% Demand
Relative travel time to 'No Parking'
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
20
40
60
80
100
AV Penetration Rate [%]
Solution
Bus Drop-off
Concentrated Curbside
No Parking
Sporadic Curbside

Cost-Benefit Analysis

- Cost of delay
  - Value of travel time savings (USDOT, 2014)
- Cost of increased fuel consumption
  - Fuel costs from (Energy Information Administration, 2017)
  - Fuel consumption (Kwak et al., 2012)
- Social cost of emissions
  - Hill et al. (2008)
- Cost of land use
  - Buildable land prices in Manhattan (Hughes, 2015)
- Benefit of parking fees
  - Fee assumed 0.5 USD

$$C_i = C_{i,D} + C_{i,FC} + C_{i,SE} + C_{i,LU}$$

$$B_i = B_{i,P}$$

$$NV_i = (B_i - B_{sporadic}) - (C_i - C_{sporadic})$$

$$MS = \Delta NV / \Delta C$$

CBA Results for 2-lane model

		Parking configuration				
		Concentrated		*Bus drop-off*		
AV %	Demand	B-C Ratio	B-C Ratio without fee	B-C Ratio	B-C Ratio without fee	Marginal Savings of Bus drop-off
0%	60%	0.30	0.13	0.65	0.44	9.6
	80%	0.05	-0.03	0.17	0.09	13.5
	100%	0.04	-0.02	0.16	0.09	20.8
20%	60%	0.33	0.15	0.63	0.41	7.9
	80%	-0.01	-0.09	0.15	0.06	17.0
	100%	0.06	0.00	0.18	0.11	21.0
40%	60%	0.33	0.15	0.55	0.33	5.7
	80%	0.04	-0.04	0.12	0.03	8.2
	100%	0.03	-0.04	0.17	0.10	25.6
60%	60%	0.50	0.31	0.77	0.56	6.5
	80%	0.05	-0.04	0.10	0.01	5.2
	100%	0.04	-0.02	0.23	0.16	32.0
80%	60%	0.30	0.15	0.70	0.51	12.2
	80%	0.01	-0.06	0.19	0.10	19.2
	100%	0.05	-0.01	0.22	0.15	30.1
100%	60%	0.25	0.14	0.47	0.34	10.0
	80%	0.05	-0.01	0.19	0.12	17.3
	100%	0.04	-0.01	0.20	0.13	28.2

CBA Results for 3-lane model

		Parking configuration				
		Concentrated		*Bus drop-off*		
AV %	Demand	B-C Ratio	B-C Ratio without fee	B-C Ratio	B-C Ratio without fee	Marginal Savings of Bus drop-off
0%	60%	0.18	-0.05	0.36	0.09	6.4
	80%	0.11	0.03	0.23	0.14	17.9
	100%	0.08	0.01	0.27	0.19	41.8
20%	60%	0.18	-0.06	0.35	0.07	5.8
	80%	0.10	0.01	0.26	0.16	22.6
	100%	0.05	-0.02	0.25	0.17	45.0
40%	60%	0.19	-0.06	0.37	0.09	6.2
	80%	0.10	0.01	0.24	0.14	18.9
	100%	0.08	0.02	0.33	0.25	53.5
60%	60%	0.20	-0.05	0.37	0.09	5.7
	80%	0.15	0.05	0.25	0.14	13.0
	100%	0.08	0.01	0.32	0.25	55.0
80%	60%	0.19	-0.04	0.36	0.10	6.3
	80%	0.20	0.11	0.29	0.20	12.2
	100%	0.08	0.02	0.30	0.23	51.1
100%	60%	0.15	-0.02	0.25	0.06	5.0
	80%	0.12	0.04	0.15	0.07	5.2
	100%	0.10	0.04	0.28	0.21	47.0

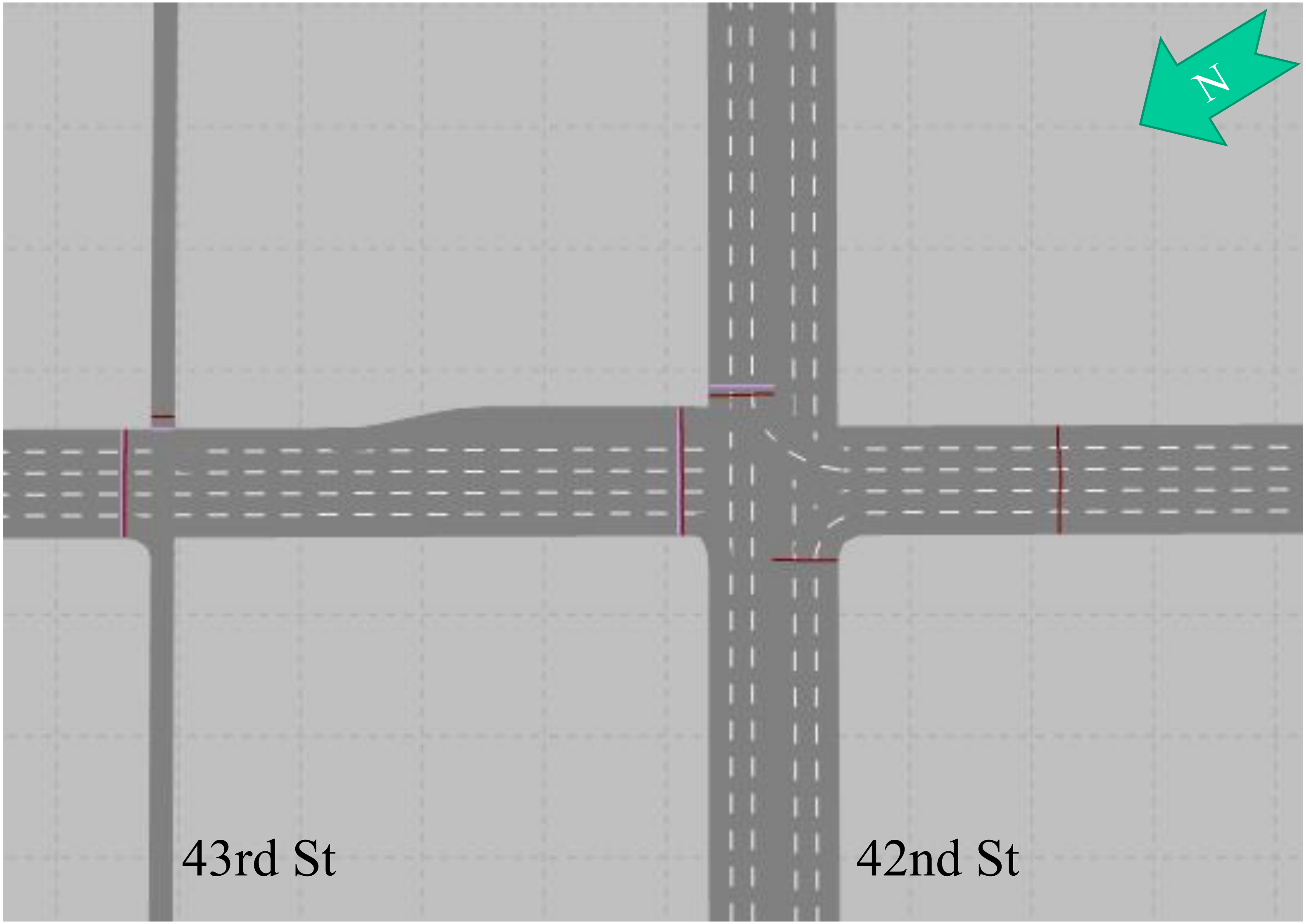
What have we found out so far?

1. model traffic flow of automated vehicles within urban network, and
2. model parking behavior of vehicles for different parking configurations.

- Concentrated Curbside and Sporadic cluster. Bus-drop off clusters with no parking.
- Travel time in the system is 5-15% higher if vehicles are left to park sporadically over the network
- This difference reduces to 0-5% if a bus drop-off is used for parking purposes.
- CBA shows high Marginal savings for bus drop-off compared to concentrating parking

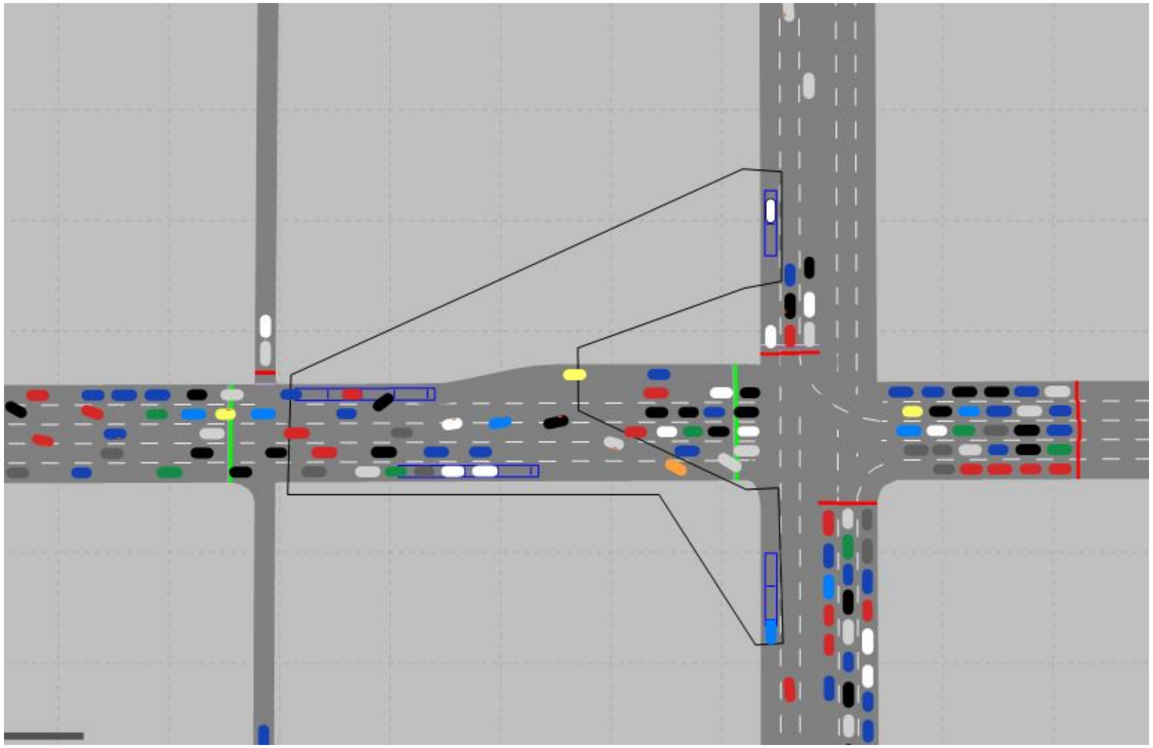
Case Study

2nd Avenue, between 42nd and 43rd Street in Manhattan, NY

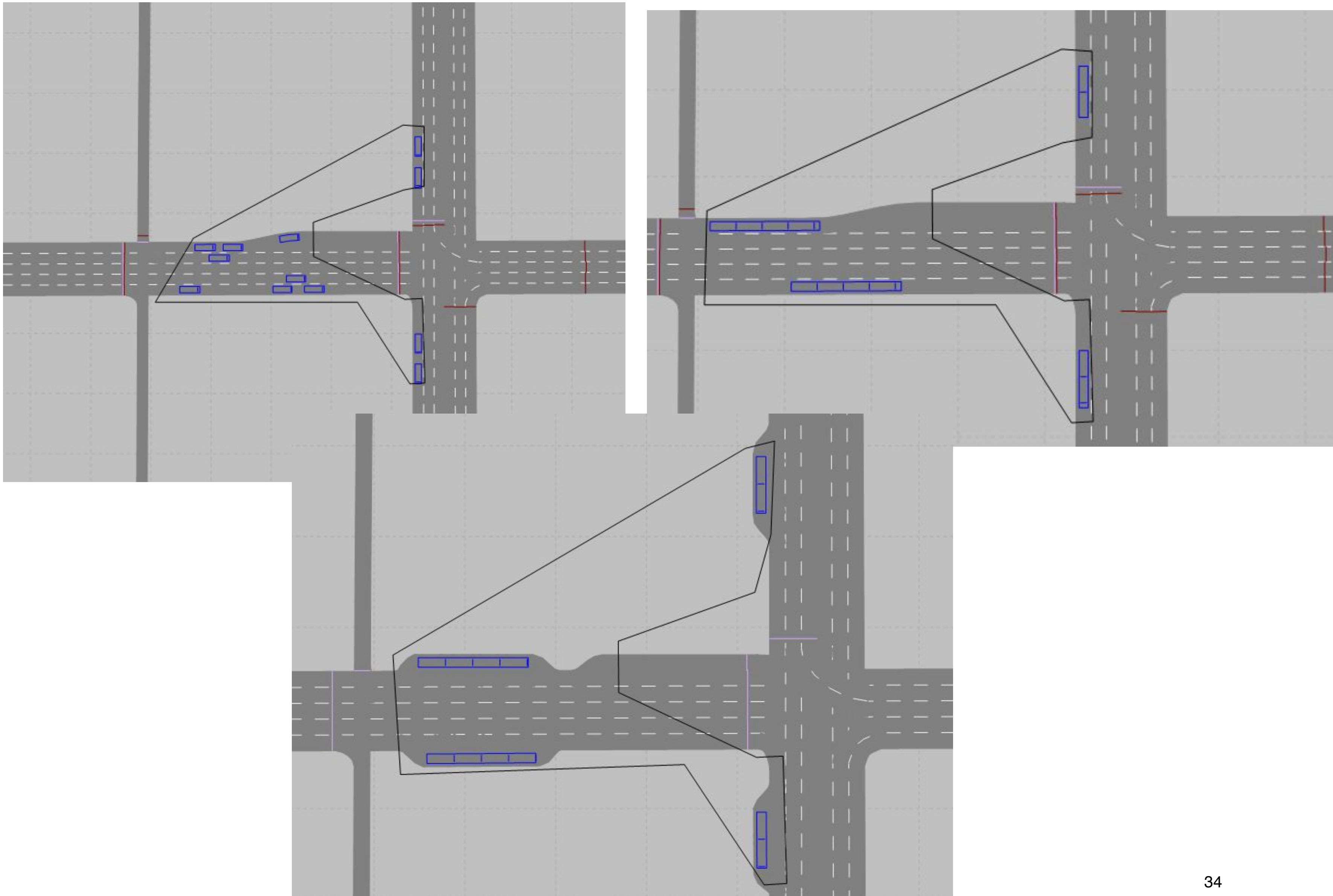

N
43rd St
42nd St

Actual Demand for Case Study

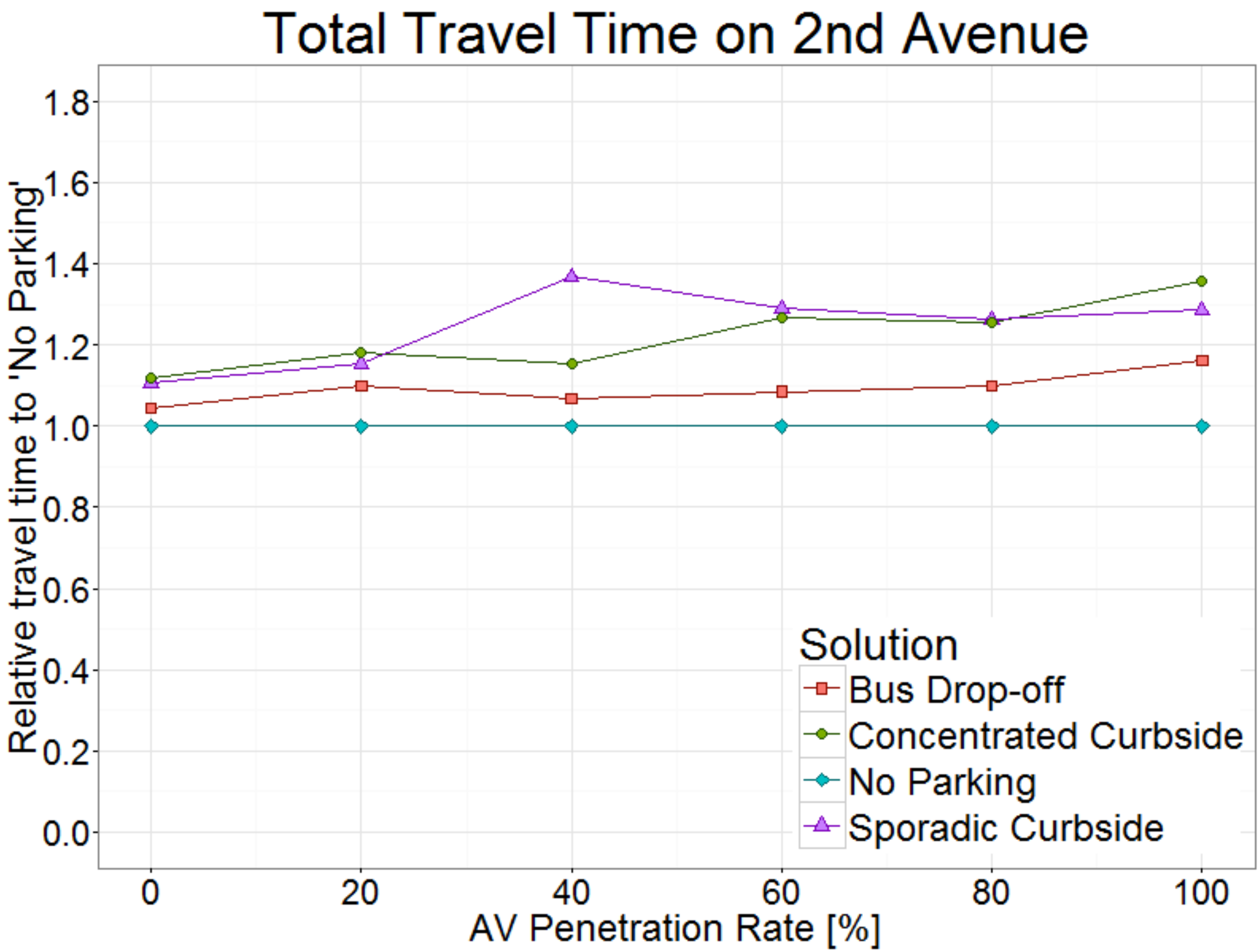
Road section	Peak hour	Section	Year
2nd Avenue	2597	From 59th Street to 42nd Street	2014
42nd Street westb.	752	From 5th Avenue to Franklin D Roosevelt Drive	2011
42nd Street eastb.	842	From 5th Avenue to Franklin D Roosevelt Drive	2011
43rd Street	220	From 5th Avenue to 1st Avenue	2009



Parking configurations



Results of Case Study



Cost Benefit Analysis of Case Study

- Performed in same way as before, but VTTS set at 24.10 USD
- Bus drop-off increased in total area

	Parking configuration				
	Concentrated		*Bus drop-off*		
AV %	B-C Ratio	B-C Ratio without fee	B-C Ratio	B-C Ratio without fee	Marginal Cost of Bus drop-off
0%	0.05	-0.01	0.13	0.07	21.4
20%	0.04	-0.03	0.13	0.06	19.6
40%	0.33	0.25	0.46	0.38	19.0
60%	0.12	0.02	0.38	0.26	33.2
80%	0.10	0.01	0.32	0.21	28.1
100%	0.00	-0.07	0.23	0.14	40.2

Summary

- Modelling AVs in VISSIM is challenging
- Reduction in network performance after 60% AV penetration rate

- Concentrated Curbside and Sporadic cluster. Bus-drop off clusters with no parking.
- Travel time in the system is 5-15% higher if vehicles are left to park sporadically over the network
- This difference reduces to 0-5% if a bus drop-off is used for parking purposes.
- CBA shows high Marginal savings for bus drop-off compared to concentrating parking

- Application to Case Study in New York based on assumptions

Discussion

- Low acceleration rates increase importance of effective intersections
- Wiedemann car-following behavior will not be applicable with platooning / simultaneous accelerating
- Acceleration seems to have a strong impact, the assumption should be verified
- Bus drop-off consistently shows to improve network performance
- Net Value for 2nd Avenue in peak hour:
  - concentrating parking ranges between 3 - 1‘105 USD/hr, and
  - bus drop-off pocket 454-1‘407 USD/hr

Conclusion

This research aimed to:

1. model traffic flow of automated vehicles within urban network, and
2. model parking behavior of vehicles for different parking configurations.

Further research

- Verification of acceleration distribution by Le Vine et al. (2015)
- Search for a more fitting car-following model
- Integration of C2C or C2X will allow modelling of PT and more
- Further parking configurations with respect to urban dynamics
- Cost Benefit Analysis
- Sensitivity of input parameters

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