A Downtown On-Street Parking Model with Urban Truck Delivery Effects

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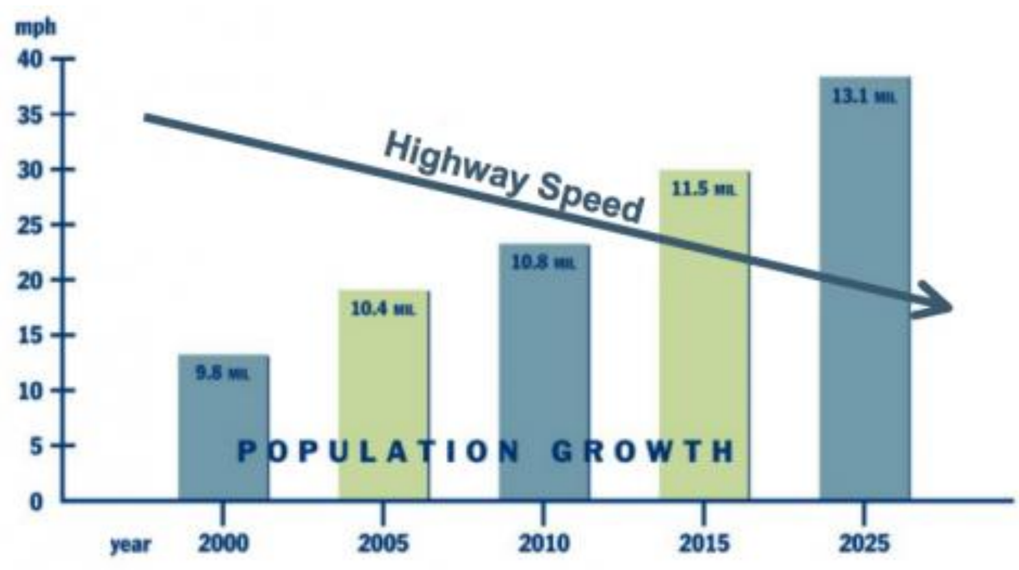
Outline

- ❑ Background
- ❑ The role of parking in fighting congestion
- ❑ A problem never solved, trucks double-park
- ❑ Proposed model
- ❑ Case study
- ❑ Summary

Urban population is growing

Urban population is growing and so is our travel times!



Los Angeles County population growth compared to highway speed (Source: The Planning Report, 2014)

What should we do?

Build bigger roads?

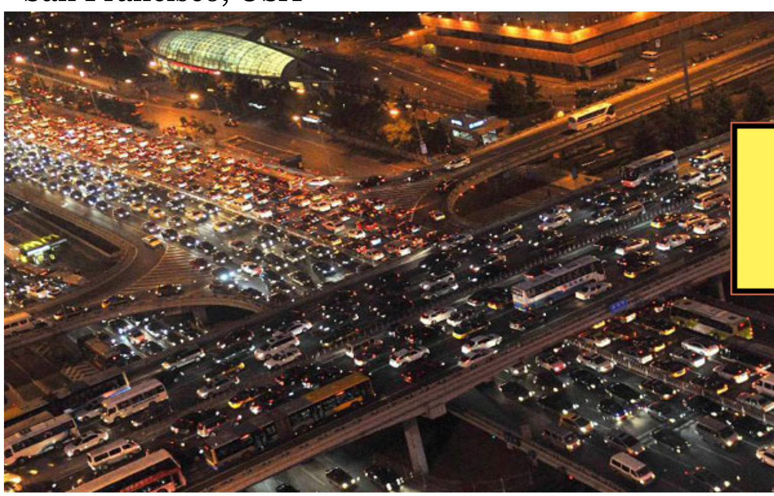
Building Big Asphalt to Fight Congestion, a Myth?
Roads are getting bigger and so does the congestion!

CONGESTION AHEAD

NEXT 20 YEARS

San Francisco, USA

Toronto, Canada



Beijing, China

Sao Paulo, Brazil

Seeking Efficiency in Transportation

The fact is that paving promotes more driving, which in turn raises the demand for paving!

The car which was once seen as an instrument of freedom, is increasingly becoming time wasting.

Transportation planners started to change their long-held practices of creating more capacity for car-oriented infrastructure.

Today, transportation demand management (TDM) approach is taking priority in many cities around world.

> *"Adding roadway capacity to serve commuter vehicle mobility will not be a priority. The focus of improvements for commuter vehicle traffic will be on optimizing the existing roadway operations."*
>
> *Edmonton Transportation Master Plan, 2009*

The Role of on-street Parking

The Metropolitan Transportation Commission in the San Francisco Bay Area has done a study which concluded that 60% of traffic in downtown Berkeley, CA is cruising for parking.

Percentage of Cruising Motorists by Time of Day for Allston Way, Downtown Berkeley

Time Period	Parking Occurrence	Cars Passing	Cars Passing + Parking	% Cruising
10:00AM - 11:30AM	32	484	516	6.20%
11:30AM - 1:00PM	35	103	138	25.36%
1:00PM - 2:30PM	44	287	331	13.29%
2:30PM - 4:00PM	40	317	357	11.20%
4:00PM - 5:30PM	42	250	292	14.38%
5:30PM - 7:00PM	30	19	49	61.22%
TOTAL	223	1,460	1,683	13.25%

Source: William Hurrell and Andre Chandra, DRAFT Cruising Technical Memorandum , Wilbur Smith Associates, March 28, 200

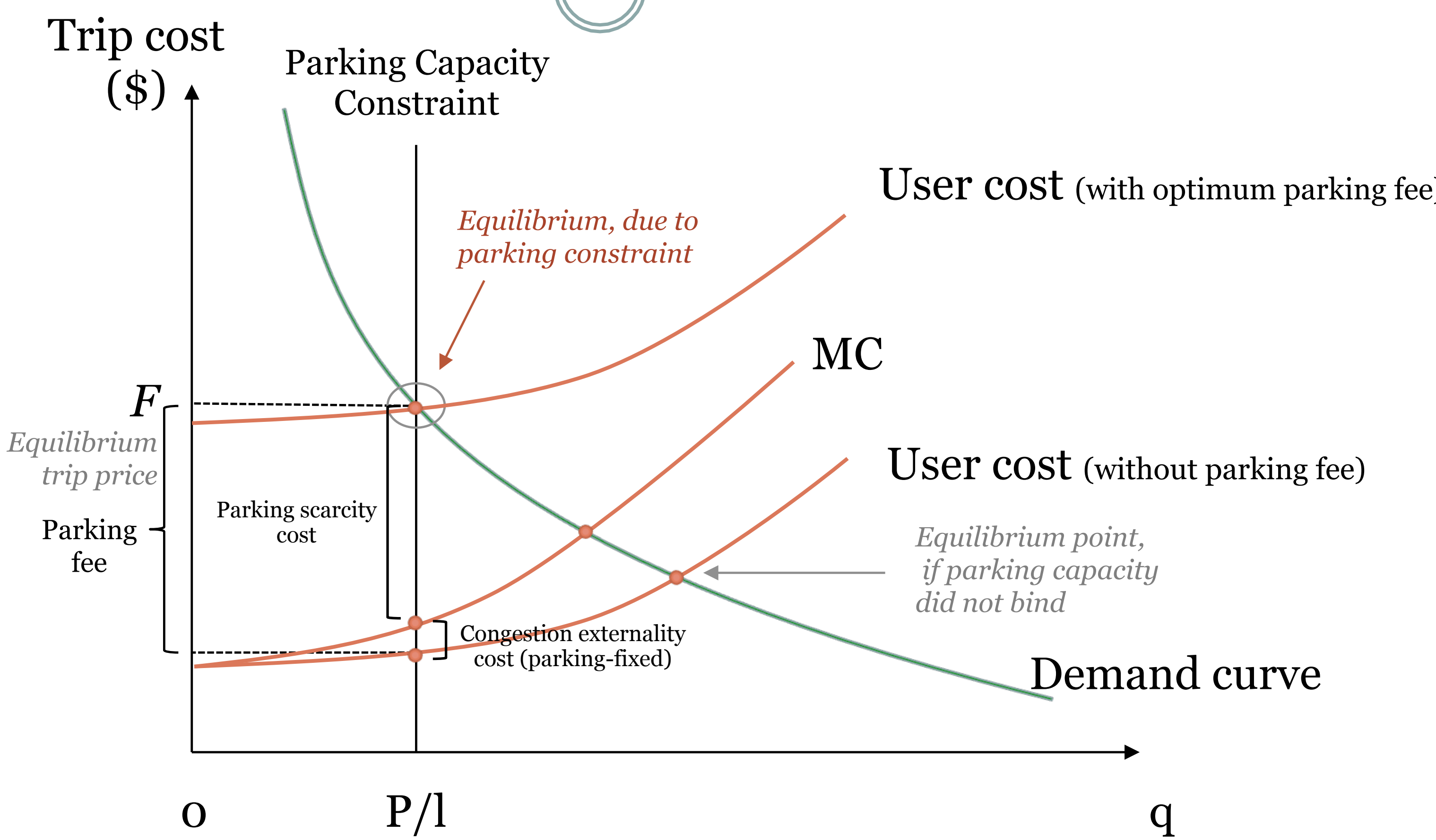
"Because curb parking is underpriced and overcrowded in the busiest parts of most of the world's big cities, the sun never sets on cruising."

Donald Shoup- Urban planning professor University of California

The objective is that cities manage their parking assets to maximize public benefits.

Parking Economics

Trip cost-Demand Diagram



Trip price = In-transit travel cost + Cruising for parking cost + Visit time costs

Modified from Arnott and Inci, 2006

But trucks double-park!

(Daily news, 2014)

(CNBC, 2015)

Parcel Shipping Facts

UPS
- 18 million packages/day (UPS Annual Report,2014)

FedEx
- 10.8 million packages/day (FedEx Annual Report, 2014)

In Canada
- 713 million packages/ year (Statistics Canada, 2008)
- i.e. 2.75 million /day

Understanding CVs Parking Behaviour

Why CVs do not cruise for parking?

If parking near destination is occupied, CVs double-park.

According to UPS published report (UPS Investor Relations, Sep 2015):

- 1 extra mile is worth $50M
- 1 extra minute is worth $14.6M
- The average driver makes about 120 deliveries/day

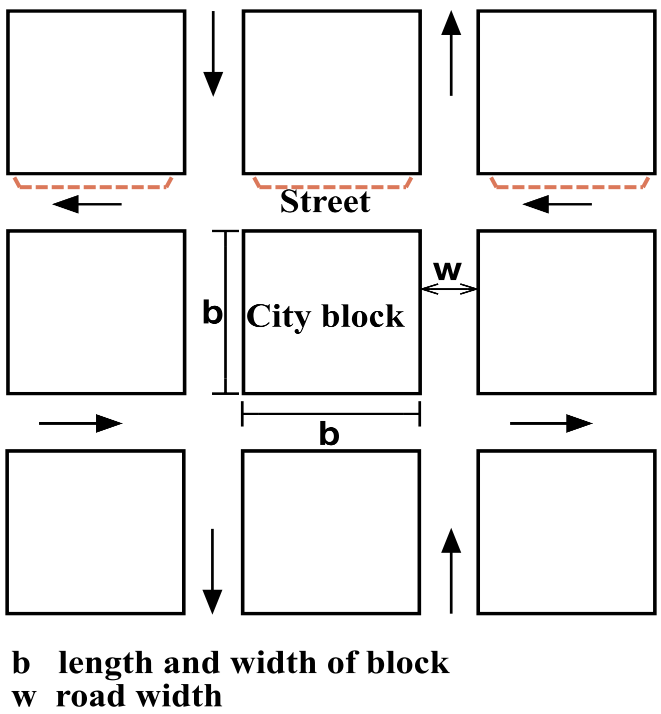
Boston, 2009 Source: www.cluelessinboston.com

(Toronto, 2015)

Current state of research

- Shoup, (2006) modeled travellers cruising for parking in the presence of off-street parking.
- Calthrop and Proost, (2005) formulated a model to regulate on-street parking in the presence of off-street market, however, the model did not include congestion effects.
- Arnott and Inci, (2006) was first to introduce a parking equilibrium model with traffic flow behavior to measure cruising effects.
- Few studies exist on truck parking, (Nourinejad et al., 2014) developed a simulation-based parking-choice model for truck parking in urban areas.
- Tipagornwong and Figliozzi, (2015) investigated the impact of truck parking availability on service costs and parking behavior. Truck deliveries are not elastic with regards to traffic costs, the trucking companies are more likely to transfer the additional cost to the receiver.
- Haider, (2009) and Jaller et al, (2013) confirm that parking policies often overlook urban freight.

Proposed Model
Objectives

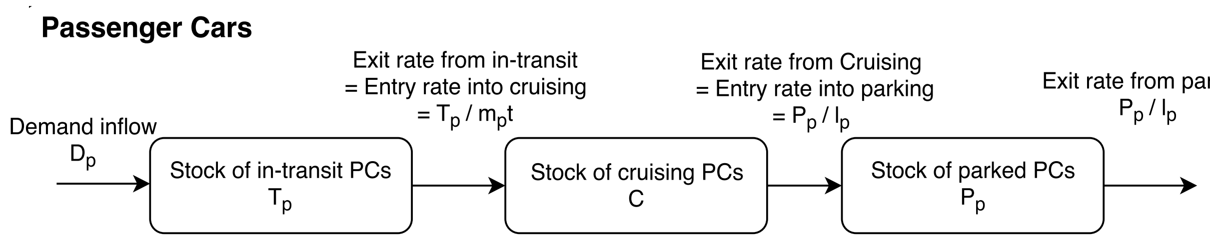


Objectives

- Reflect the interaction between traffic congestion and parking.
- Accommodate the effect of all road users on the downtown streets
- Distinguish between parking behavior of passenger cars and CVs
- Reflect the trade-off between parking space and travelling space
- Optimize parking fee, road space, and minimize road congestion

Proposed Model
Basis from Arnott and Inci, 2006

Saturated parking in a steady state flow



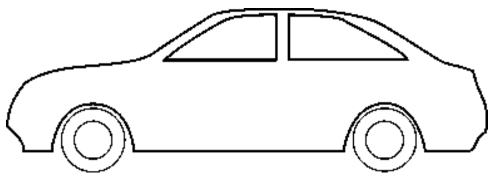
$$D_p = \frac{T_p}{m_p t(T_p, T_c, C, P_p, P_c, H)}$$

$$\frac{T_p}{m_p t(T_p, T_c, C, P_p, P_c, H)} = \frac{P_p}{l_p}$$

D_p	Passenger car trip demand (veh/hr-mi²)
T_p	Stock of in-transit passenger cars (veh/mi²)
C	Stock of cruising passenger cars (veh/mi²)
P_p	Parking spaces allocated to passenger cars (space/mi²)
m_p	Distance travelled by passenger cars in downtown before arriving to destination (mi)
l_p	Parking duration of passenger cars (hr)
ρ_p	Value of time of passenger cars ($/hr)

Proposed Model
Cars and CVs are different

Passenger Car



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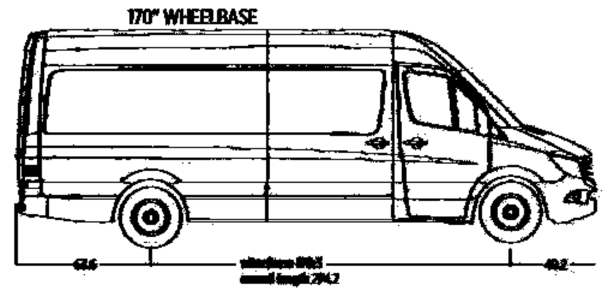
Commercial Vehicle



D_c	Commercial vehicles trip demand (veh/hr-mi²)
T_c	Stock of in-transit CVs (veh/mi²)
H	Stock of double-parking CVs (veh/mi²)
P_c	Parking spaces allocated to CVs (space/mi²)
θ	Ratio of a CVs parking space to that of a passenger car parking space.
m_c	Distance travelled by CVs in downtown before arriving to destination (mi)
l_c	Parking duration of CVs (hr)
ρ_c	Value of time of CVs ($/hr)

Proposed Model

Travel congestion and Travel demand

- Traffic Density

$$k = T_p + \propto C + \beta T_c + \gamma H$$

- Jam Density

$$k_j = \Omega \left[1 - \frac{P_p + \theta P_c}{P_{max}} \right]$$

- Travel Time

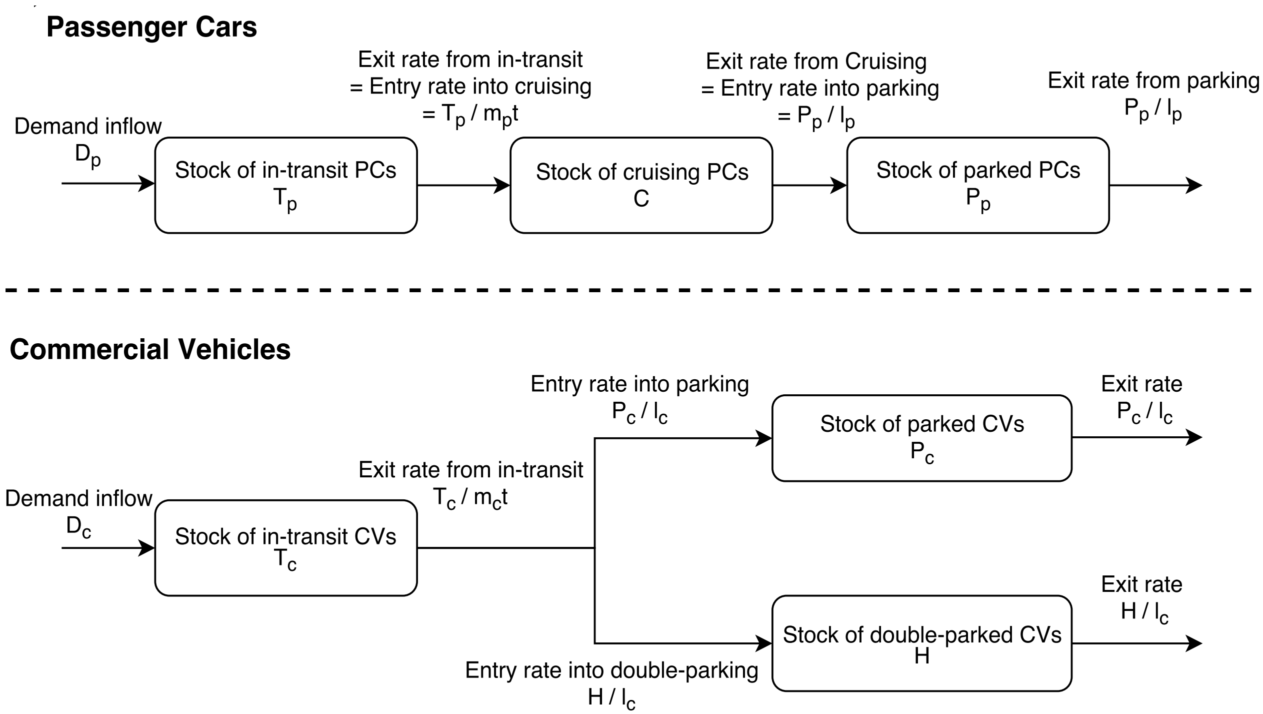
$$t = \frac{t_o}{1 - \frac{k}{k_j}}$$

- Travel Demand Function

$$D_p = D_o \left[\rho_p m_p t + \rho_p C \left(\frac{l_p}{P_p} \right) + f l_p \right]^e$$

Proposed Model

Saturated parking in a steady state flow



$$D_p = \frac{T_p}{m_p t(T_p, T_c, C, P_p, P_c, H)}$$

$$\frac{T_p}{m_p t(T_p, T_c, C, P_p, P_c, H)} = \frac{P_p}{l_p}$$

$$D_c = \frac{T_c}{m_c t(T_p, T_c, C, P_p, P_c, H)}$$

$$\frac{T_c}{m_c t(T_p, T_c, C, P_p, P_c, H)} = \frac{P_c}{l_c} + \frac{H}{l_c}$$

$$t = \frac{t_o}{1 - \frac{k}{k_j}}$$

$$D_p = D_o \left[\rho_p m_p t + \rho_p C \left(\frac{l_p}{P_p} \right) + f l_p \right]^e$$

Comparing
Base Model vs. Proposed Model

	Arnott &Inci Model	Proposed Model		
	Base Scenario	Base Scenario	Scenario 1	Scenario 2
	No commercial vehicles (CVs) considered	No commercial vehicles (CVs) considered	CVs considered, but no parking assigned	CVs considered, and parking assigned to it
Inputs				
m_p (mi)	2			
l_p (hr)	2			
ρ_p (\$/hr)	20			
t_0 (hr/mi)	0.05			
D_0 (constant)	3190.04			
P_{max} (space/mi^2)	11136	*same*	*same*	*same*
Ω (veh/mi^2)	2667.2			
K_j (veh/mi^2)	1778.2			
e (unitless)	-0.2			
f (\$/hr)	1			
α (uniless)	1.5			
β (unitless)	n/a	1.8	1.8	1.8
γ (uniless)	n/a	5.07	5.07	5.07
m_c (mi)	n/a	0.181	0.181	0.181
l_c (hr)	n/a	0.15	0.15	0.15
P_p (space/mi^2)	3712	3712	3712	3692
P_c (space/mi^2)	n/a	0	0	20
D_c (veh/hr/mi^2)	n/a	0	250	250
Resulting Equilibrium				
D_p (veh/hr/mi^2)	1856	1856	1856	1846
t (hr/mi)	0.2275	0.2275	0.2948	0.2768
T_p (veh/mi^2)	844.5	844.5	1094.34	1022.03
C (veh/mi^2)	361.89	361.89	112.05	215.77
T_c (veh/mi^2)	n/a	0	13.34	12.53
H (veh/mi^2)	n/a	0	37.5	17.5

Proposed Model
Analysis of Social Optimum

Social benefit

Social cost

$$\max_{D_p, T_p, C, P_p, T_c, H, P_c, f} \int_0^{P_p/l_p} D_P^{-1}(x)dx - \left[\rho_p T_p + \rho_p C + f P_p + \rho_p P_p + \rho_c T_c + f P_c + qH + \rho_c (P_c + H)\right]$$

Subject to

$$D_p = \frac{T_p}{m_p t(T_p, T_c, C, P_p, P_c, H)}$$

$$\frac{T_p}{m_p t(T_p, T_c, C, P_p, P_c, H)} = \frac{P_p}{l_p}$$

$$D_c = \frac{T_c}{m_c t(T_p, T_c, C, P_p, P_c, H)}$$

$$\frac{T_c}{m_c t(T_p, T_c, C, P_p, P_c, H)} = \frac{P_c}{l_c} + \frac{H}{l_c}$$

$$D_p = D_o * \left[\rho_p m_p t + \rho_p C \left(\frac{l_p}{P_p}\right) + f l_p\right]^e$$

$$t = \frac{t_o}{1 - \frac{k}{k_j}}$$

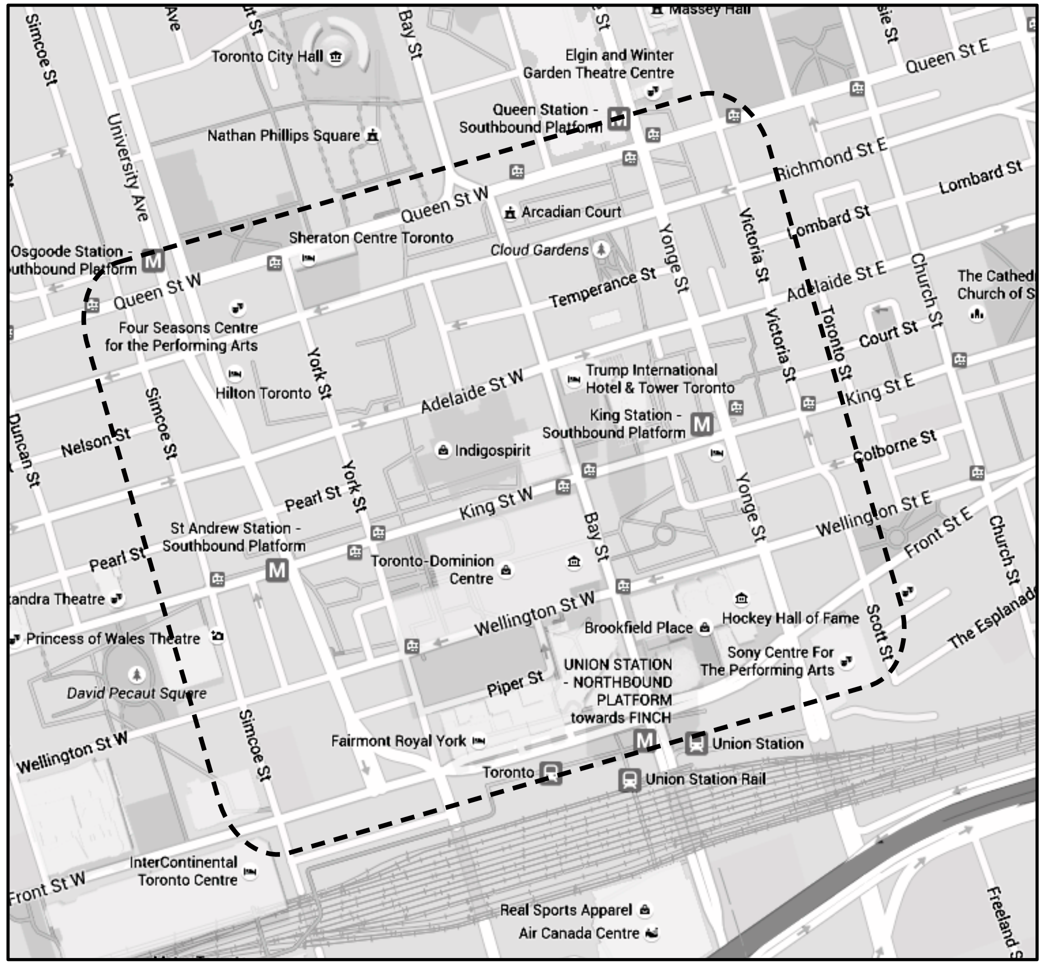
Case Study – Toronto Downtown

Known to be the most densely built-up area of Toronto. Home to numerous corporate headquarters and key legal and accounting firms.

- *Area is approx. 0.3 mi^2*
- *Total lane length= 18.845 mi*
- *Total street area= 0.04 mi^2 (102,890 m^2)*

- *Among the establishments in the area:*
  - *Toronto Stock Exchange*
  - *Toronto Board of Trade*
  - *Royal Bank of Canada*
  - *Trump International Hotel*

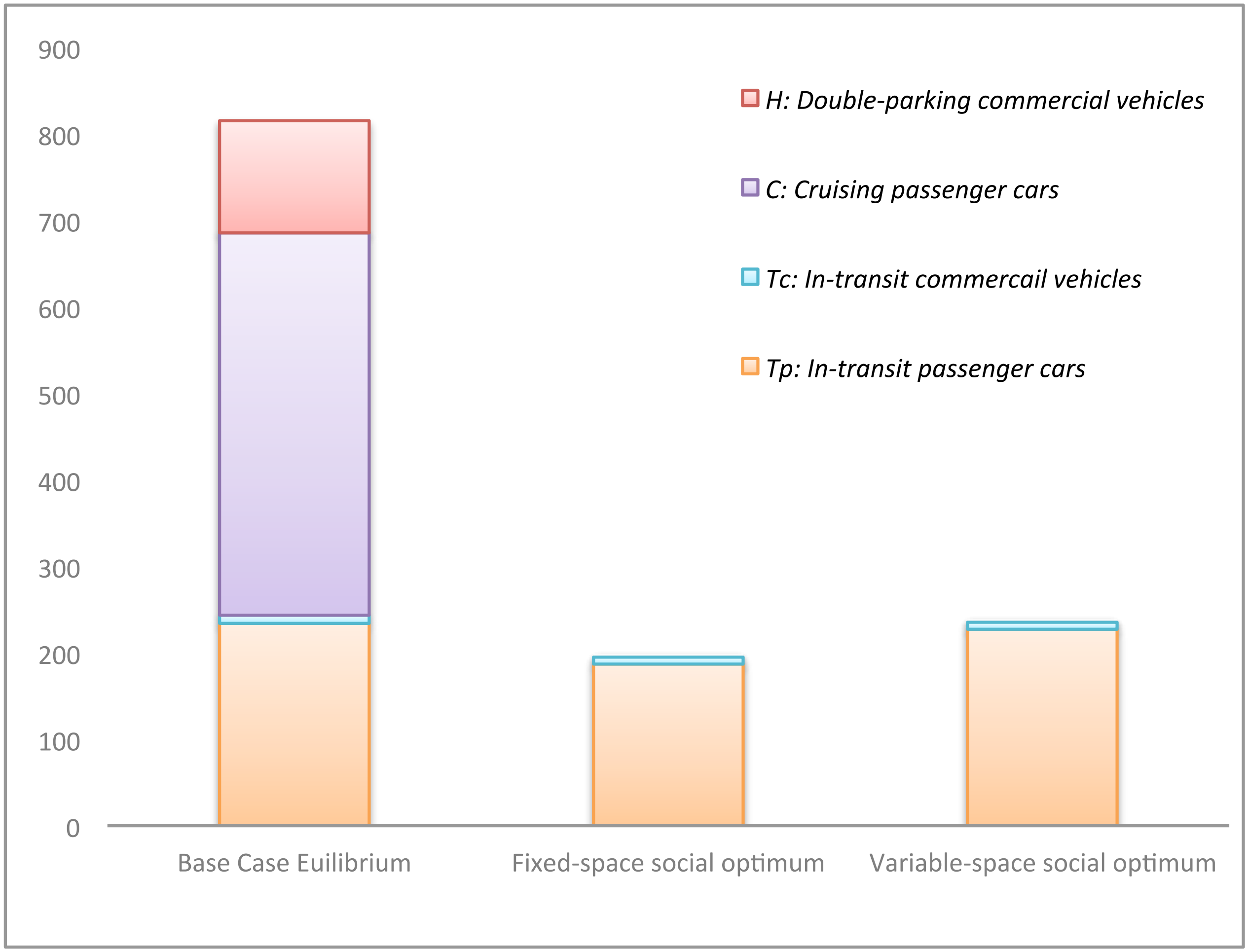
- *Data Sources:*
  - Field surveys
  - City by-law no. 569-2013
  - Toronto Parking Authority (TPA,2015)
  - Cordon Count Data Retrieval System (CCDRS) (DMG, 2015)
  - Transportation Tomorrow Survey (TTS) (DMG,2015)



Case Study – Toronto Downtown

	Base Case Equilibrium	Social Optimum Parking fixed	Social Optimum Parking variable
Inputs			
$P=P_p+\theta P_c$ (space/mi^2)	3863	3863	-
P_p (space/mi^2)	3863	-	-
P_c (space/mi^2)	0	-	-
f ($/hr)	4	-	-
Solution			
P_p^* (space/mi^2)	-	3650	4406
P_c^* (space/mi^2)	-	130	130
f^* ($/hr)	-	8.93	2.86
D_p (veh/hr/mi^2)	1932	1825	2203
T_p (veh/mi^2)	233.99	186.93	227.19
C (veh/mi^2)	442.02	0	0
T_c (veh/mi^2)	9.48	8.02	8.07
H (veh/mi^2)	129.75	0	0
t (hr/mi)	0.0606	0.0512	0.0516
v (mi/hr)	16.5	19.5	19.4
Gain in social surplus ΔSS ($/hr-mi^2)		$13,502	$23,204

Case Study – Toronto Downtown



Summary

- Urban truck deliveries has a big impact on commuter parking because:
  - the inelasticity of freight demand
  - and the need to double-park when no spaces are available due to need for proximity

- The presented model distinguishes four types of travelers that make up the traffic composition of the streets in the downtown

- The model then provides tools for policy makers to optimize the trade-offs in parking spaces, pricing, and network congestion

Opportunities for future research

- Reflecting the effect of off-street parking
- Introducing a heterogeneous population
- Incorporating other parking control measures
- Incorporating truck fleet operating characteristics like fleet size and number of stops

Acknowledgment

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Thank you

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Sets of initial guesses used

(4a) Initial guesses for the second-best allocation policy

Variable	Starting Points									
	Set 1	Set 2	Set 3	Set 4	Set 5	Set 6	Set 7	Set 8	Set 9	Set 10
T_p	10	50	50	0	200	400	200	400	800	900
T_c	10	10	50	0	10	200	200	200	500	800
H	10	10	50	0	0	150	50	150	200	50
C	10	10	50	0	0	200	100	200	200	100
t	0.05	0.05	0.3	0.2	0.06	0.3	0.3	0.3	0.4	0.3
P_p	10	300	700	1000	3800	600	500	600	2000	4000
P_c	10	100	400	500	120	1000	40	80	50	50
f	0	1	3	3	0	5	4	5	6	6
Iterations	43	16	15	13	8	15	14	16	12	13
Runtime (sec)	0.31	0.11	0.10	0.09	0.08	0.10	0.10	0.12	0.09	0.09

(4b) Initial guesses for the first-best allocation policy

Variable	Starting Points									
	Set 1	Set 2	Set 3	Set 4	Set 5	Set 6	Set 7	Set 8	Set 9	Set 10
T_p	10	10	0	10	10	50	50	300	800	0
T_c	10	10	0	10	10	0	50	200	400	0
H	10	10	0	10	10	0	50	0	0	0
C	10	10	0	10	10	0	50	0	0	0
t	0.05	0.05	0.3	0.05	0.05	0.05	0.1	0.3	0.3	0.1
P_p	10	200	500	1000	2000	1000	2000	4000	6000	5000
P_c	10	200	0	1000	2000	0	2000	500	500	2000
f	1	1	0	2	2	0	1	0	0	0
Iterations	175	101	38	25	18	50	19	11	21	14
Runtime (sec)	1.75	0.84	0.28	0.15	0.12	0.39	0.13	0.08	0.12	0.10

Proposed Model

Double-parking creates Bottleneck in Traffic Flow