

Institute for Transport Studies

FACULTY OF ENVIRONMENT



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# PARKING LOCATION CHOICE MODELLING IN SATURN

Dr Chandra Balijepalli

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SATURN USER GROUP MEETING, LEEDS



- Car Parks in City Centre

- Short stay (e.g. on street)
- Long stay (e.g. off street)



- Choice of car park depends on

- Activity type and duration
- Distance of car park to ultimate destination
- Parking charges (if any)
- Car park size and its occupancy
- Unobservable preference

- Assignment models usually do not model car parks



- **Disaggregate Choice Modelling**

- Considers the behavioural aspects of drivers, but ignores the effects on re-routing

- **Equilibrium Approach**

- Focuses on routing of drivers through a composite generalised cost function



- **Multiple User Classes**
  - Depending on activity type, e.g. Commuter and Non-commuter
  - Activity duration
- **Multiple Time Periods**
  - to include the car park occupancy effects in time
  - to include the multiple commodities defined by the combinations of activity type and duration

# Generalised Time Function



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All drivers are assumed to minimise their generalised cost/time

$$C_r^{kt} = \tau_r^t + \theta_s^k S_p^{kt} + \theta_z^k Z_p^{kt} + \theta_w^k W_p^{kt} + \eta_p$$

Route travel time on route r for commodity k during departure period t

Search time delay at car park p on route r during departure period t

Parking charges at a car park on route r for the o-d pair j at the time of entry to the car park

In-vehicle travel time on route r at time t

Walking time from the car park to ultimate destination for commodity i

# Search Time Function



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$$S_p^{kt} = s_p^t + \beta \left( \frac{x_p^t}{Y_p} \right)^\gamma$$

Where,

$s_p^t$  = minimum search time in the car park p

$x_p^t$  = net flow into car park p during departure period t

$Y_p$  = Capacity of the car park p

$\beta, \gamma$  are the parameters.

# Parking Location Choice Equilibrium



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Complementarity condition can be stated as below:

$$\begin{aligned} & [C_r^{kt} - C^{*kt}] f_r^{kt} \geq 0 \\ & C_r^{kt} \geq C^{*kt} \\ & f_r^{kt} \geq 0 \end{aligned}$$

Where,

$C^{*kt}$  = minimum cost of travel for the commodity k in departure period t

$f_r^{kt}$  = route flow on route r for the commodity k in departure period t

- **Method 1: Reducing Car Park Capacity Method**

- A car park is modelled as a link
- At the end of each departure period, available car park capacity is derived
- Minimum search time of the car park is increased taking in to account the vehicles already parked

$$S_p^{kt} = S_p^{k(t-1)} + \beta \left( \frac{x_p^t}{\left( Y_p - \sum_{i=1}^{t-1} x_p^i \right)} \right)^\gamma$$

- **Method 2: Cumulative Occupancy Method**

- A car park is modelled as a combination of a link and a zone rather than a link alone
- At the beginning of each departure period, vehicles already in the car park are re-loaded from a special origin zone
- OD matrix needs to be updated at the end of each departure period

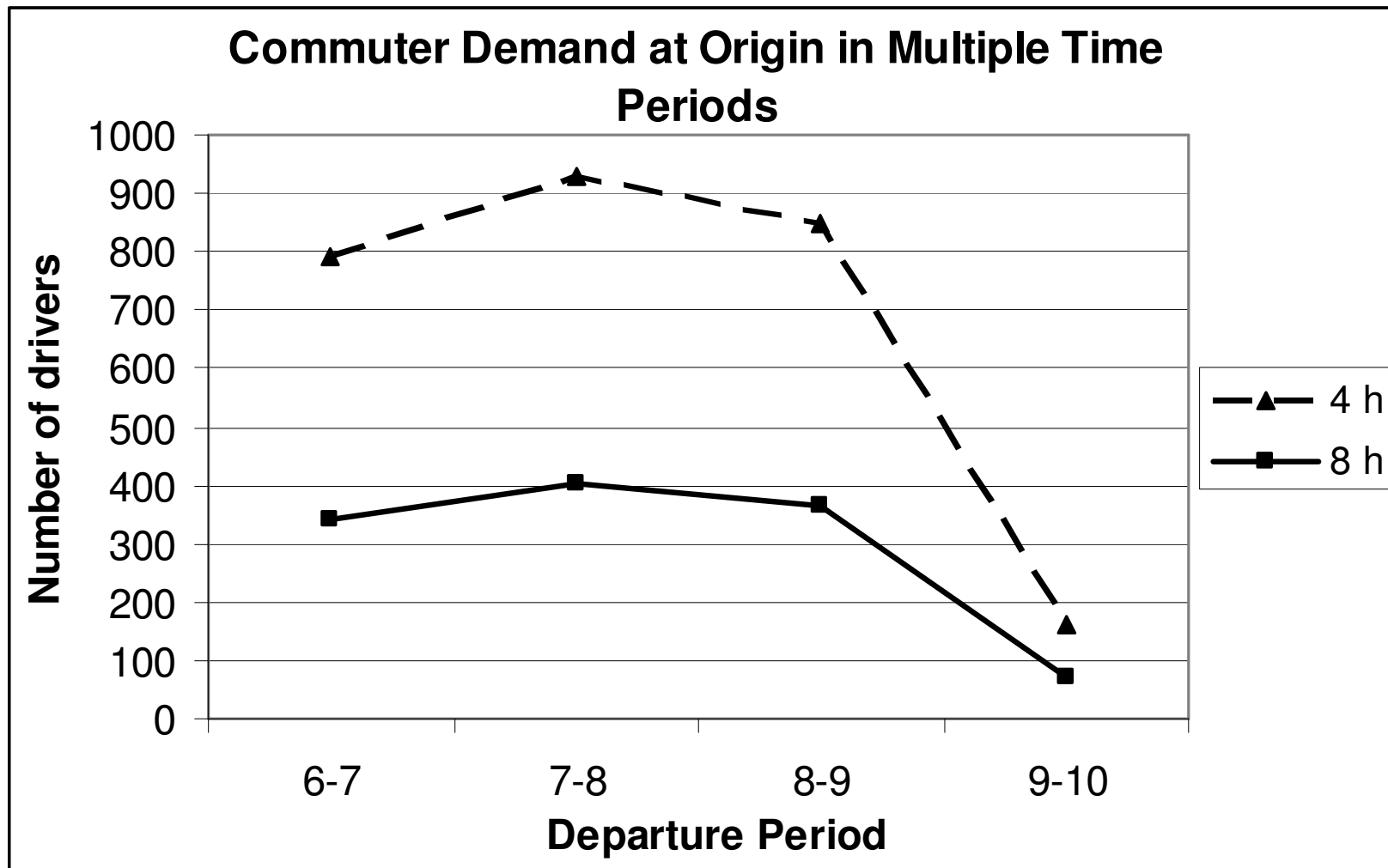
$$S_p^{kt} = s_p^t + \beta \left( \frac{\sum_{i=1}^t x_p^i}{Y_p} \right)^\gamma$$

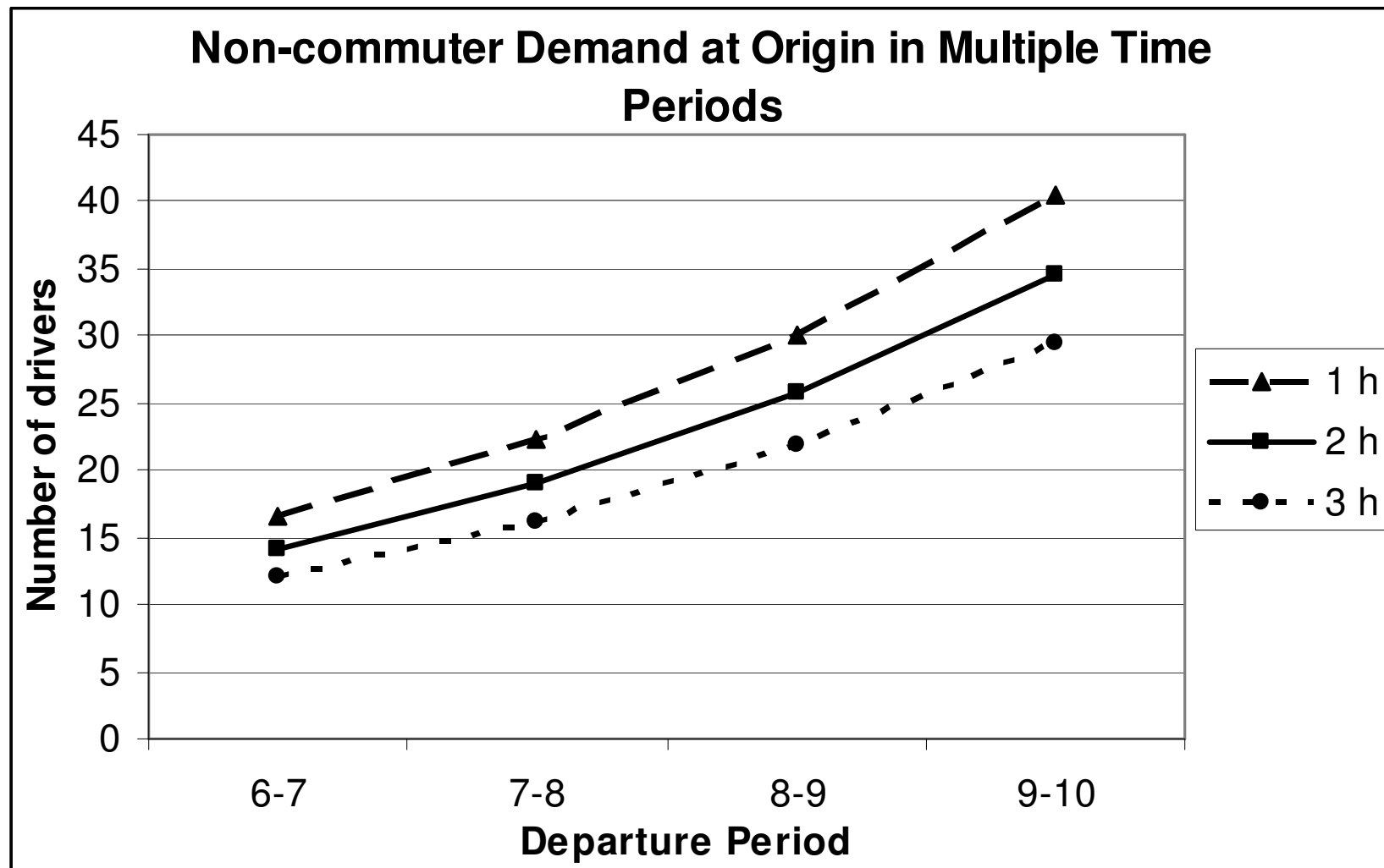
# Numerical Example



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- Five commodities (Commuter 4 hr and 8hr, Non-commuter 1hr, 2hr and 3hr activity duration)
- Four departure periods of an hour each in the morning peak (6-10 AM)
- A single OD pair served by a six link network
- Three car parks A (2000 vehicles), B (2000 vehicles) and C (350 vehicles). C is a non-commuter only car park, A and B are multi-use car parks

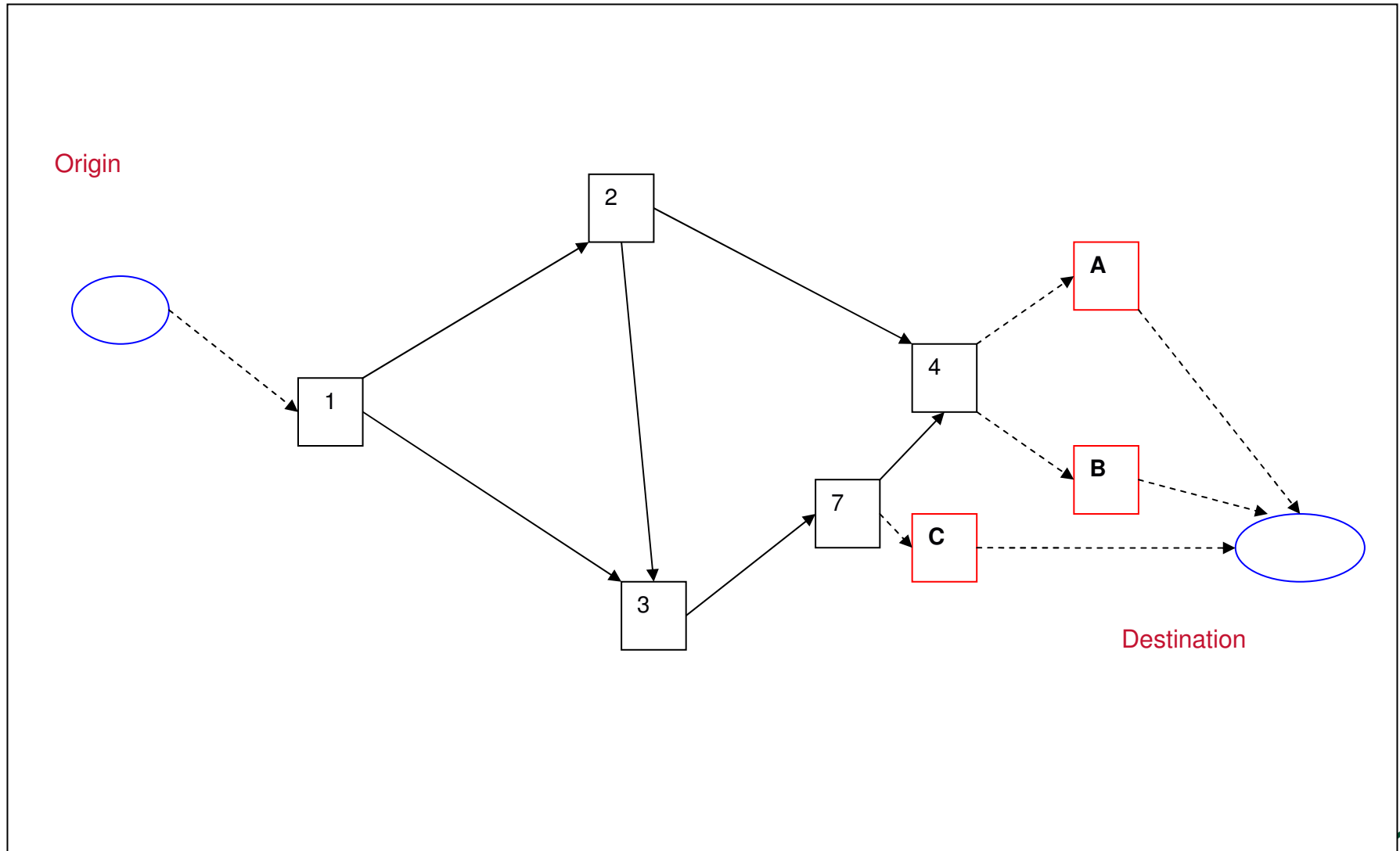




# Schematic Network



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# Network Link Attributes



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Link	Free flow time, hours	Capacity, veh/hr
1-2	0.30	800
1-3	0.45	800
2-3	0.15	500
2-4	0.50	800
3-7	0.20	800
7-4	0.10	700

# Other Modelling Parameters



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- Minimum search times,  $s_A$  ,  $s_B = 0.1$  hr and  $s_C = 0.05$  hr
- $\beta = 0.31$  and  $\gamma = 4.03$
- $\theta_s = 1.4$  for both commuters and non-commuters
- $\theta_w = 1.8$  for commuters
- $\theta_w = 2.0$  for non-commuters
- Walking distance from car park,  $A = 1.0$ km,  $B = 0.75$ km and  $C = 0.5$  km
- Walking speed = 5kmph

# Method 1: Comparison of Results with Lam et al (2006)



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Departure Time	Model	Commuter Flows				Non-Commuter Flows					
		Parking for 4hr		Parking for 8hr		Parking for 1 hr		Parking for 2 hr		Parking for 3 hr	
		A	B	A	B	B	C	B	C	B	C
06:00-07:00	SATURN	0	790	0	341	0	17	0	14	0	12
	Lam et al	0	790	0	341	0	17	0	14	0	12
07:00-08:00	SATURN	553	376	240	163	0	21	0	12	0	12
	Lam et al	684	245	295	106	0	22	0	19	0	16
08:00-09:00	SATURN	693	159	294	68	0	26	0	26	0	26
	Lam et al	561	289	242	124	0	30	0	26	0	22
09:00-10:00	SATURN	109	53	48	23	0	40	0	34	0	30
	Lam et al	88	75	38	32	0	40	0	35	0	29

## Method 2: Comparison of Results with Lam et al (2006)



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Departure Time	Model	Commuter Flows				Non-Commuter Flows					
		Parking for 4hr		Parking for 8hr		Parking for 1 hr		Parking for 2 hr		Parking for 3 hr	
		A	B	A	B	B	C	B	C	B	C
06:00-07:00	SATURN	0	790	0	341	0	17	0	14	0	12
	Lam et al	0	790	0	341	0	17	0	14	0	12
07:00-08:00	SATURN	705	224	304	97	0	19	0	16	0	14
	Lam et al	684	245	295	106	0	22	0	19	0	16
08:00-09:00	SATURN	529	319	228	138	0	30	0	26	0	22
	Lam et al	561	289	242	124	0	30	0	26	0	22
09:00-10:00	SATURN	85	78	36	34	0	40	0	35	0	29
	Lam et al	88	75	38	32	0	40	0	35	0	29

# GEH Statistics for Method 2



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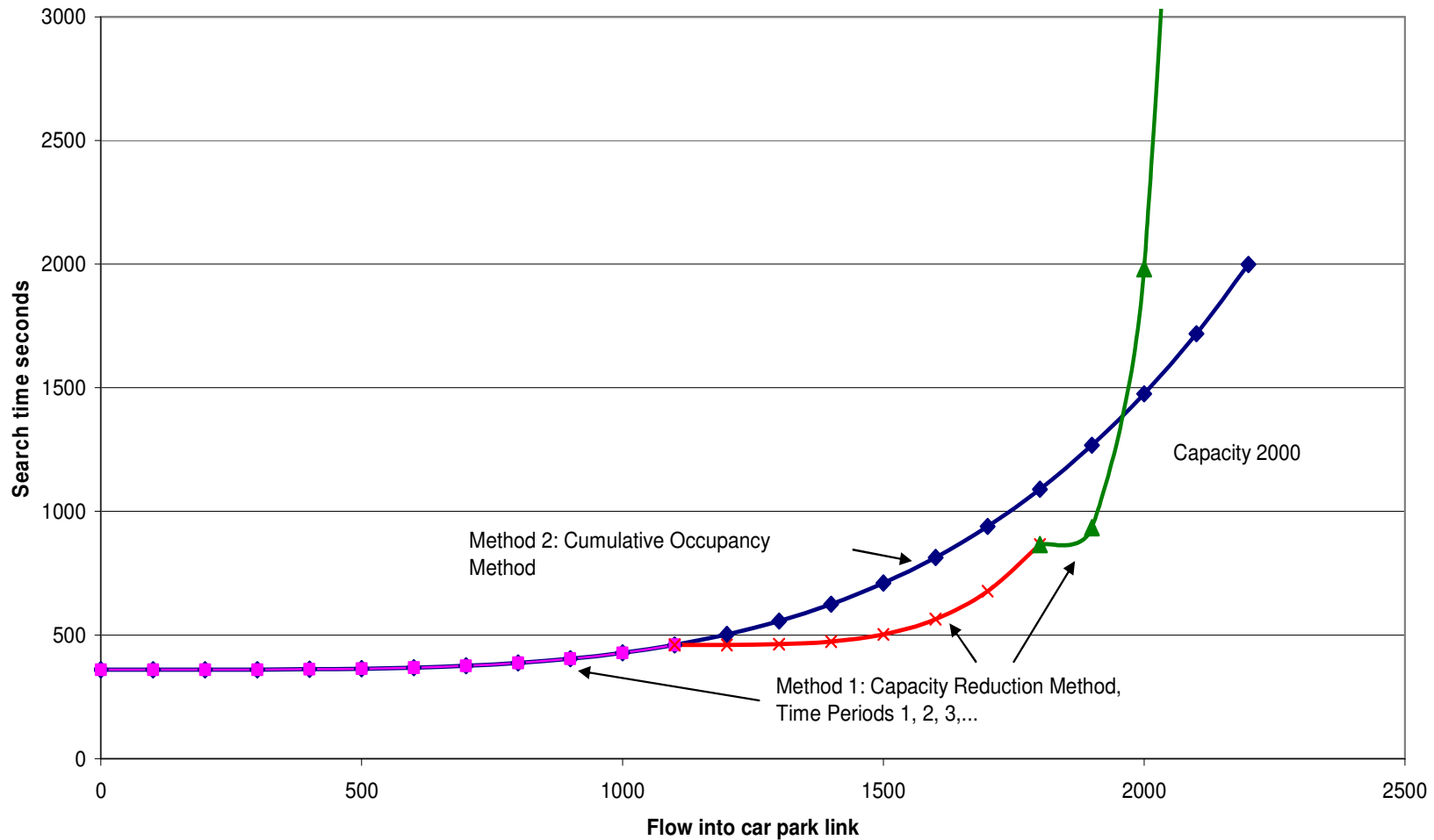
Departure Period	Car Park	Lam et al Flows	SATURN Flows	Capacity	Difference	% difference	GEH
07:00-08:00	A	979	1017	2000	38	3.86	<b>1.2</b>
07:00-08:00	B	351	321	2000	-29	-8.54	<b>1.64</b>
07:00-08:00	C	57	49	350	-7	-13.64	<b>1.07</b>
Cumulative	A	979	1017	2000	38	3.86	<b>1.2</b>
Cumulative	B	1482	1452	2000	-29	-2.02	<b>0.78</b>
Cumulative	C	100	92	350	-7	-7.78	<b>0.79</b>
08:00-09:00	A	803	757	2000	-45	-5.75	<b>1.65</b>
08:00-09:00	B	413	457	2000	44	10.7	<b>2.12</b>
08:00-09:00	C	78	78	350	0	0	<b>0</b>
Cumulative	A	1782	1774	2000	-7	-0.46	<b>0.19</b>
Cumulative	B	1895	1909	2000	14	0.75	<b>0.33</b>
Cumulative	C	178	170	350	-7	-4.49	<b>0.61</b>
09:00-10:00	A	126	121	2000	-4	-4.06	<b>0.46</b>
09:00-10:00	B	107	112	2000	5	4.78	<b>0.49</b>
09:00-10:00	C	104	104	350	0	0	<b>0</b>
Cumulative	A	1908	1895	2000	-12	-0.69	<b>0.3</b>
Cumulative	B	2002	2021	2000	19	0.95	<b>0.43</b>
Cumulative	C	282	274	350	-7	-2.84	<b>0.48</b>



# Profile of Search Time Function



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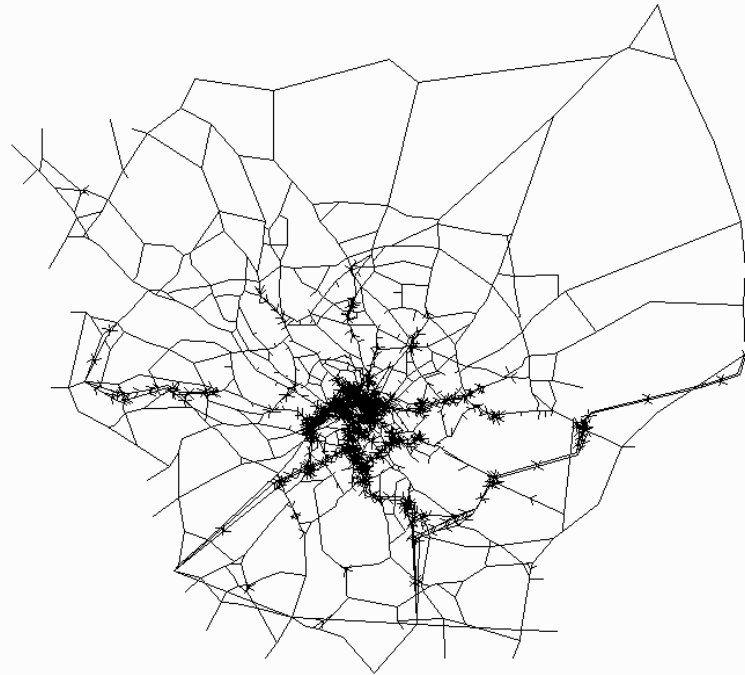
- Method 1 changes the profile of the search time function
- Method 2 converges closer to Lam et al's results
- We assume that Lam's method has converged well
- Lam et al might have used more sophisticated dynamic network loading methods to calculate the travel times
- Given the differences in approaches, Method 2 involving passing of car park occupancy worked well

# Application to Leeds Network



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- SATURN network of Leeds



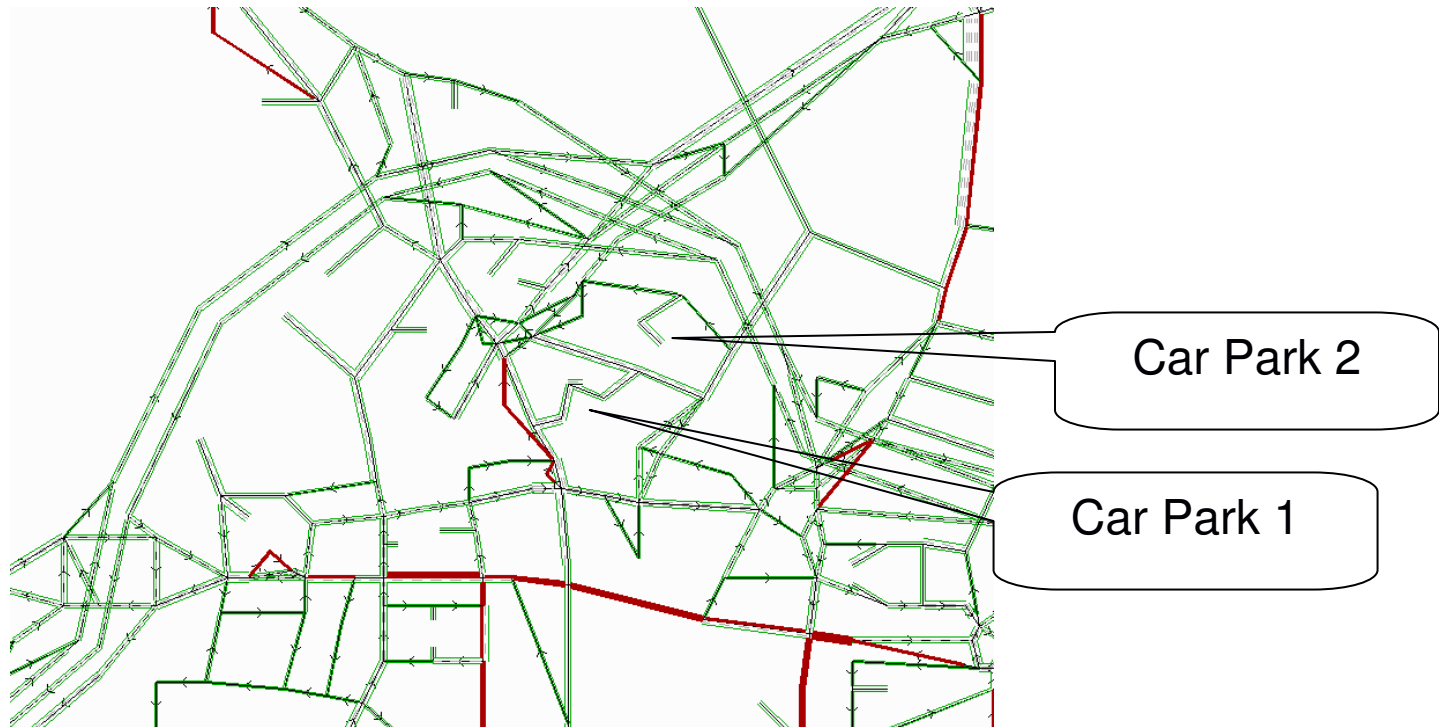
- AM peak with over 100,000 pcus
- Zoning system with about 478 traffic zones

# Application to Leeds Network



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- City centre car parks

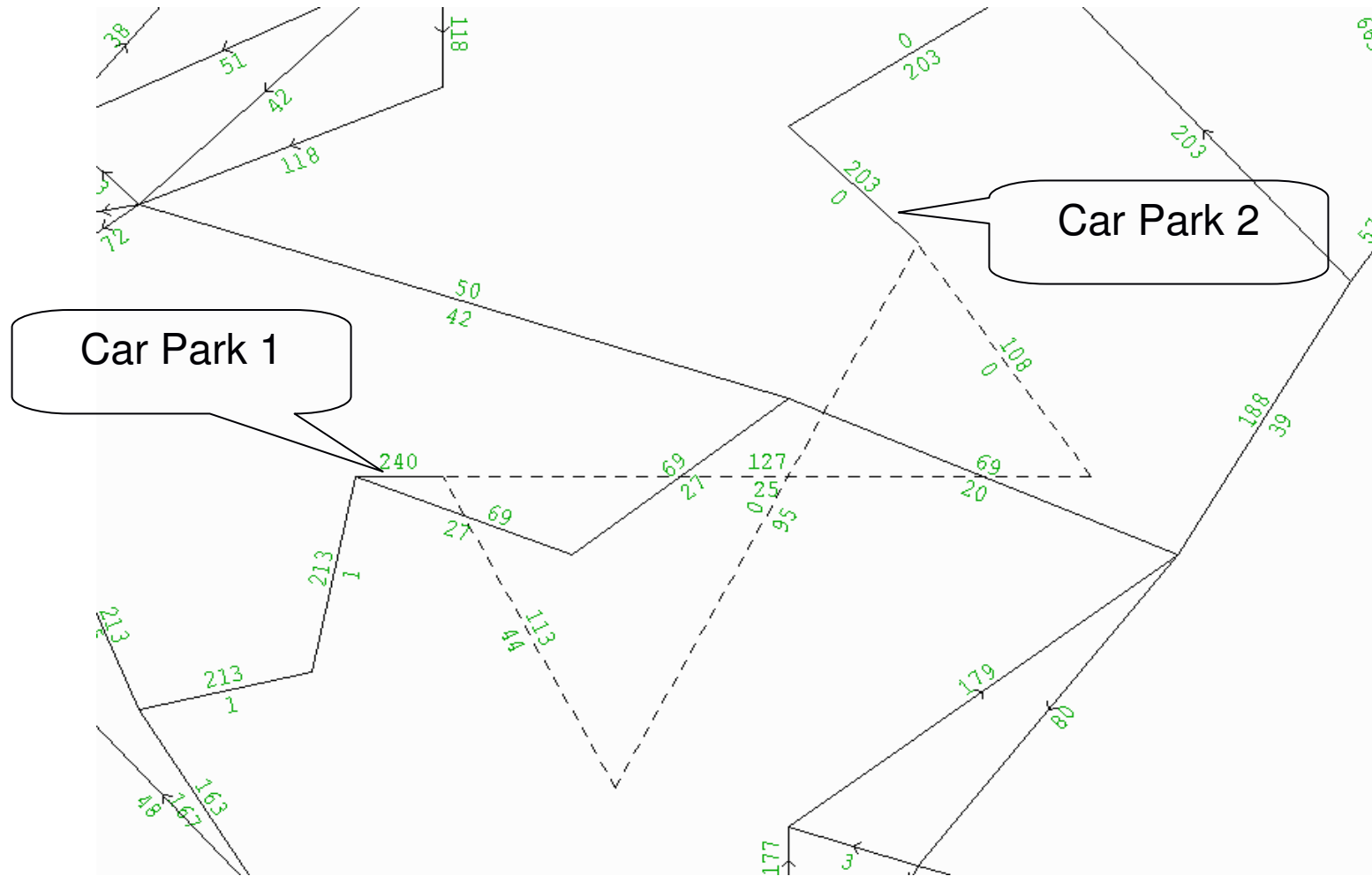


- Car park 1: capacity 350 vehicles (similar to car park C)
- Car park 2: capacity 2000 vehicles (similar to car park B)

# Assigned Flows to Car Parks



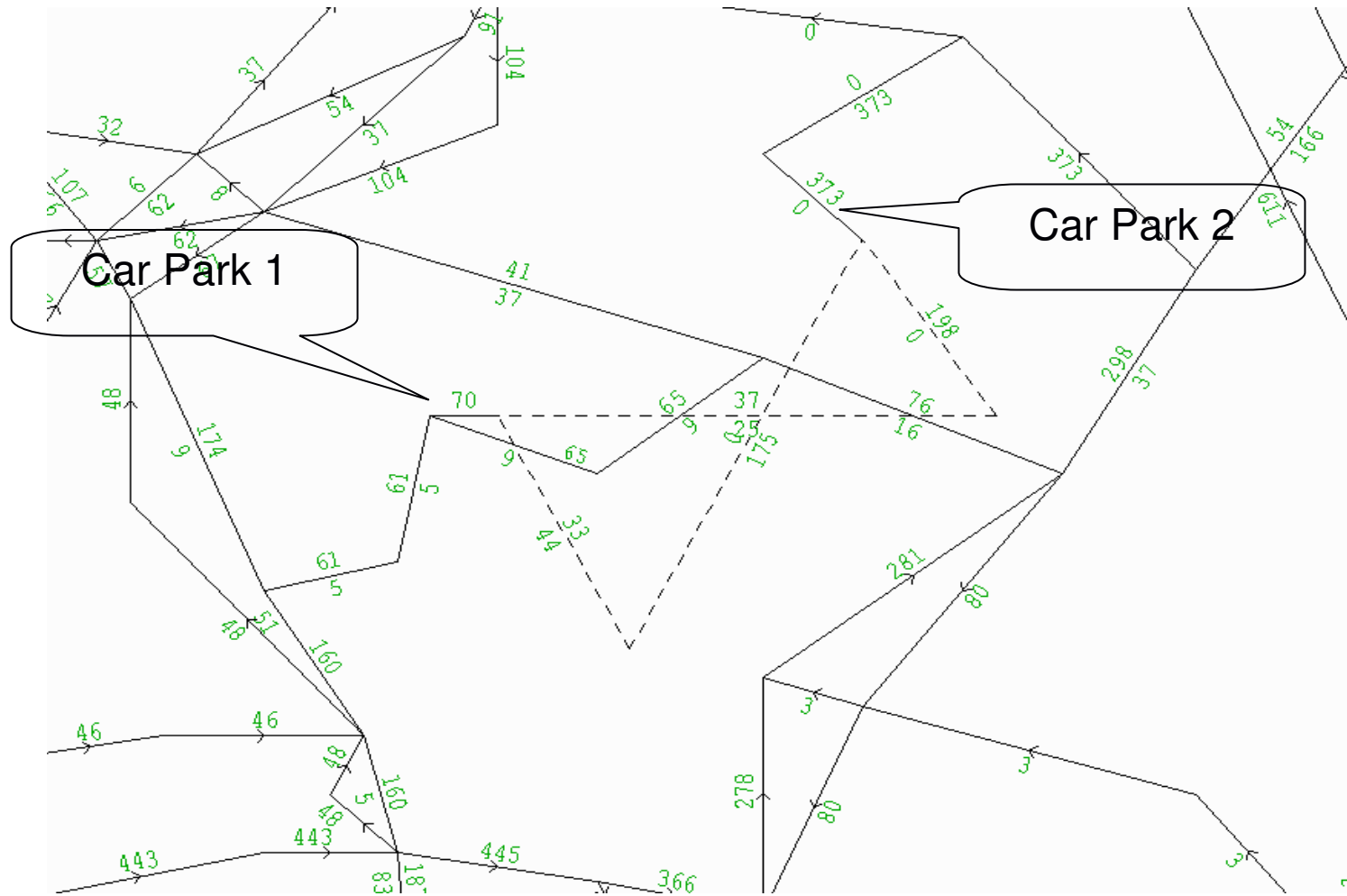
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# Sensitivity to Capacity of Car Park



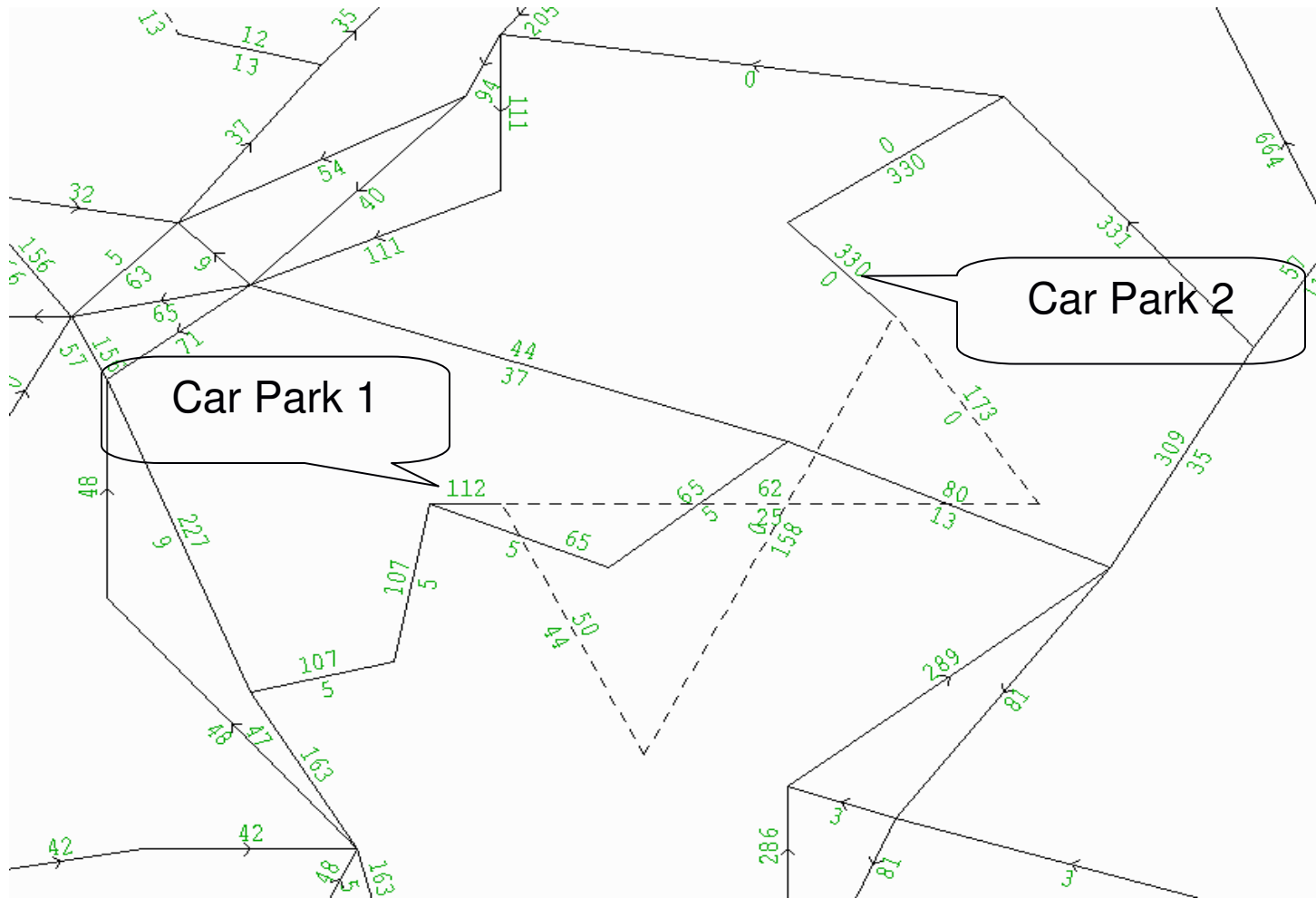
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# Parking Demand Management



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- Specifies a method for modelling the choice of car parks
- Illustrates the concepts with numerical examples
- Reducing capacity method works well at or near capacity, whereas the cumulative occupancy method is good when the car parks are less busier
- Impact of car park pricing structures can be studied
- Can be extended to elastic demand and/or departure time choice models