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Are there too many bus stops in Stockholm?

Zifei Yan, Maria Börjesson, Chau Man Fung, Stef Proost

October 18, 2016

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Outline

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Introduction

Method

Model calibration

Results

Introduction

- What's the optimal number of bus stops for Stockholm?
- How much externality does bus user & biker create?
- Welfare distribution among user groups.

Introduction

Figure: One bus stop at Odengatan

Introduction

- Put the bike lane go around the bus stops.

Figure: Bike lane design in Bromma. (Pic from Google street view)

Outline

Model

- Three modes: b - bus, c - car, v - bike
- 7 user groups:
  - trip distance $j = s,\ l$
  - income groups: $k = p,\ m,\ r$
  - one no-bike group, distance>15km

Model-utility

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Utility function

$$U(m,\ q_v^{j,k},\ q_b^{j,k},\ q_c^{j,k}) = m + B(q_v^{j,k},\ q_b^{j,k},\ q_c^{j,k})$$

m is the utility from other goods than transportation, and the quadratic sub-utility function has the form

$$B(q_v^{j,k},\ q_b^{j,k},\ q_c^{j,k}) = \sum_k^{p,m,r} \sum_j^{l,s} \sum_h^{v,b,c} \Big[a_h^{j,k} q_h^{j,k} - 0.5 b_h^{j,k} \left(q_h^{j,k}\right)^2 - \sum_{g \neq h}^{v,b,c} i_{hg}^{j,k} q_h^{j,k} q_g^{j,k} \Big]$$

where i is the interaction term between modes.

Model-user cost

- User cost:

$$
\begin{aligned}
uc_c^{j,k} &= dis^j c_c + dis^j VOT_c^{inv,j,k} TT_c \\
uc_b^{j,k} &= c_b + VOT_b^w \frac{60}{2f} + VOT_b^{ac} \frac{L}{2 n_s v_w} \\
&\quad + dis^j VOT_b^{inv} \cdot TT_b^{inv} \cdot DisCom \\
uc_v^{j,k} &= dis^j c_v + dis^j VOT_v TT_v
\end{aligned}
$$

- Crowding in bus

$$
DisCom = 1 + dc_b \cdot (n_{on} - V_b) \cdot \theta (n_{on} - V_b)
$$

Model-trip time

- Trip times:

$$
\begin{aligned}
TT_c &= \alpha_c + \beta_c \left(\frac{q_c^l + \lambda q_c^s}{n_h cap_c} + \frac{out}{cap_c} \right) + \gamma_c n_s P_b P_v \\
TT_b &= \alpha_b + \beta_b \frac{\sigma(s_b) f}{cap_b} + \gamma_{b,v} n_s P_v + TS_b \\
TT_v &= \alpha_v + \beta_v \frac{q_v^l + \lambda q_v^s}{n_h cap_v} + \gamma_v n_s P_b P_c \\
TS_b &= n_s \cdot \left(t_s + \gamma_{b,p} (q_b^l + q_b^s) / f n_h n_s \right)
\end{aligned}
$$

At bus stops

- Probability that a bus/car/bike shows up at one bus stop is:

$$
\begin{aligned}
P_b &= \max\left[TS_b \cdot f/60,\ 1\right] \\
P_c &= \max\left[TS_c \cdot \left(q_c^l + \lambda q_c^s + out\right)/(60 \cdot n_h)\ 1\right] \\
P_v &= \max\left[TS_v \cdot \left(q_v^l + \lambda q_v^s\right)/(60 \cdot n_h),\ 1\right]
\end{aligned}
$$

where TS refers to the average time the vehicle spend at the bus stop.

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Calibration

- Set marginal utility equal to marginal cost

$$\frac{dB}{dq_h^{j,k}} = uc_h^{j,k}$$

- Will give us:

$$B(q_v^{j,k},\ q_b^{j,k},\ q_c^{j,k}) = \sum_{k}^{p,m,r} \sum_{j}^{l,s} \sum_{h}^{v,b,c} \left[a_h^{j,k} q_h^{j,k} - 0.5 b_h^{j,k} \left(q_h^{j,k} \right)^2 - \sum_{g \neq h}^{v,b,c} i_{hg}^{j,k} q_h^{j,k} q_g^{j,k} \right]$$

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DATA

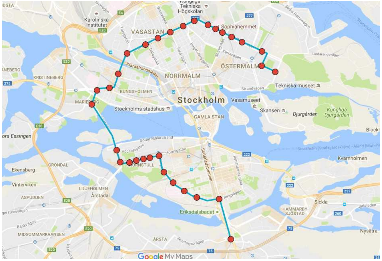

Figure: Bus No. 4 in Stockholm

- 31 stops, 12 km, 65,000 passenger per day, departure every 5 min

DATA

- 7114 samples, then normalized to the route of bus No.4
- validation: compare with real traffic counts along bus No. 4

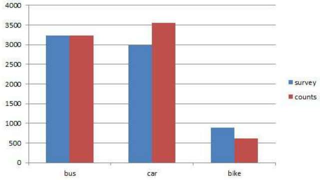

Figure: Compare with real traffic counts.

Outline

Optimal pricing

Scenario	n_s	τ_b	τ_c	τ_v	f	$Occup$	$\Delta Welfare$
Base line	31	0	1.8	0	12	0.81	0
Bus stop	**17**	0	1.8	0	12	0.81	4332
Bus fare	31	**7.58**	1.8	0	12	0.67	28516
Car toll	31	0	**0.93**	0	12	0.80	322
Bike toll	31	0	1.8	**-0.79**	12	0.80	454
Bus frequency	31	0	1.8	0	**17.87**	0.61	61713
All charge	31	**7.93**	**2.93**	**0.56**	12	0.67	29123
All above	**20**	**-0.68**	**2.81**	**0.34**	**18.33**	0.61	64909
Sep. bike lane	31	0	1.8	0	12	0.81	2136

Table: Optimal charge for each mode

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Question

Thank you!