Analysis of mode and walk-route choice in a downtown area considering heterogeneity in trip distance

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Analysis of mode and walk-route choice

- Nested choice structure

in a downtown area considering

- Large number of alternative routes

heterogeneity in trip distance

- Varying effect of difference
  in travel time among alternatives
  on route choice

Introduction (1)

- A critical problem with route choice models, especially in downtown areas, is the formation of the choice set
- Inappropriate choice set results in biased parameter estimation

Frejinger et al. (2009) proposed sampling of alternatives by random walk method

Introduction (2)

- Frejinger et al. (2009) investigated the effect of the random walk parameter on estimation efficiency
  - Using a hypothetical single origin-destination
  - Not clear the method provide efficient estimates with empirical data containing significant variations in trip distance

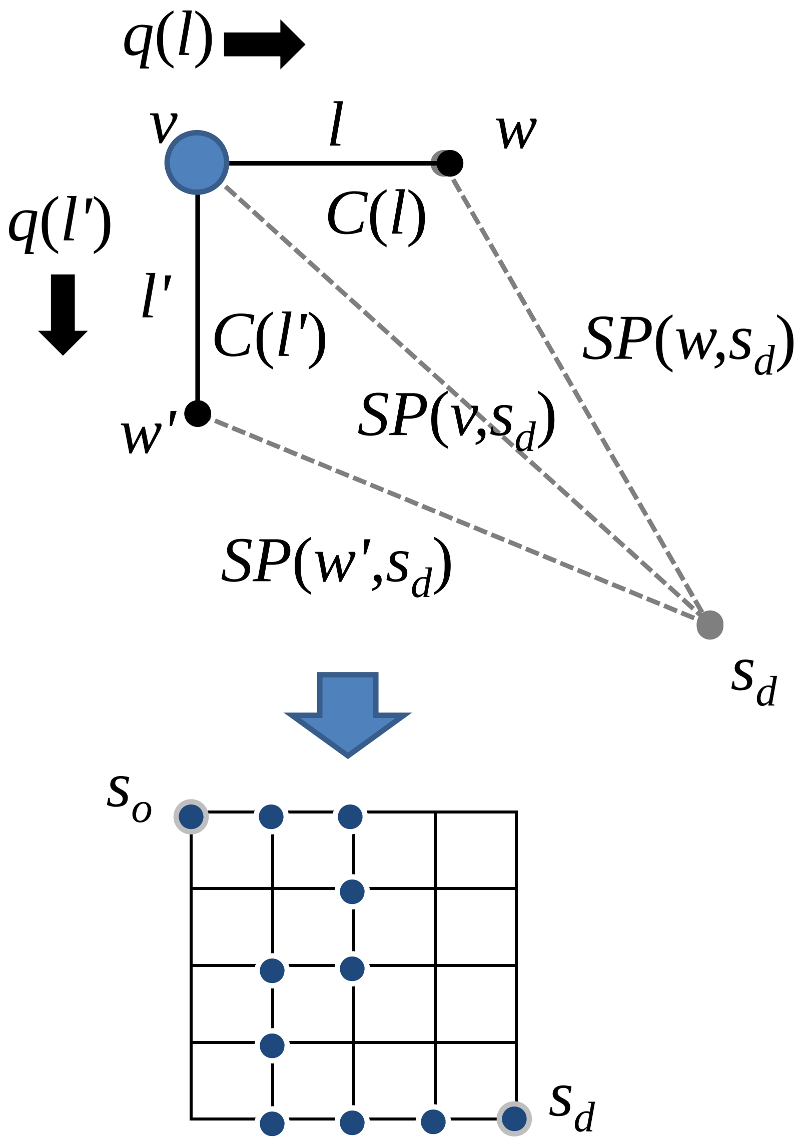
Purpose of the study

- The effect of heterogeneity in trip distance on sampled alternatives is investigated in this study
- A structured random walk parameter according to the trip distance is proposed to improve the efficiency of parameter estimates

Methodology (1)

- Random walk method (Frejinger et al. 2009)
  - At each node, a link is randomly selected based on the distance to the shortest path
  - Randomness is determined by b_1.
  - It includes the shortest path search when $b_1 = \infty$, and a simple random walk when $b_1 = 0$
  - Similar to stochastic assignment algorithm by Dial (1971)

Methodology (2)



Relative distance $x_l = \frac{SP(v, s_d)}{C(l) + SP(w, s_d)}$

$SP(v,w)$: Shortest path from v to w

$C(l)$: Cost of link l

Link weight $\omega(l|b_1) = x_l^{b_1}$

Probability of choosing link l $q(l|E_v, b_1) = \frac{\omega(l|b_1)}{\sum_{l' \in E_v} \omega(l'|b_1)}$

E_v : Set of outgoing links from v

Probability of generating path i

$$q(j) = \prod_{l \in \Gamma_j} q(l|E_v, b_1)$$

Methodology (3)

- Conditional probability of route choice
  - Lower level of nested logit model of mode and walk route choice
  - Identical to multinomial logit model with sampling of alternatives (Frejinger et al. 2009)

$$P(i|C_n) = \frac{\exp\{\mu V_{in} + \ln(k_{in}/q(i))\}}{\sum_{j \in C_n} \exp\{\mu V_{jn} + \ln(k_{jn}/q(j))\}}$$

Correction for sampling

k_{in} : Number of times alternative i is generated

Methodology (4)

- Marginal probability of mode choice
  - Expanded logsum proposed by Lee & Waddell (2010)

$$P(m) = \frac{\exp(\mu' V'_{mn})}{\exp(\mu' V'_{sn}) + \exp(\mu' V'_{wn})} \quad \text{for} \quad m = s, w$$

$$V'_{wn} = (1/\mu)\ln\left\{\sum_{j \in C'_n}\left[\{k_{jn}/q(j)\}\exp(\mu V_{jn})\right]\right\}$$

Expansion of logsum

Methodology (5)

- Correlation among routes
  - Expanded path-size (Frejinger et al. 2009)

$$EPS_{in} = \sum_{a \in \Gamma_i} \frac{L_a}{L_i} \frac{1}{\sum_{j \in C_n} \delta_{aj} \Phi_{jn}}, \quad \Phi_{jn} = \begin{cases} 1 & \text{if } \delta_{jc} = 1 \text{ or } q(j)R_n \geq 1 \\ \dfrac{1}{q(j)R_n} & \text{otherwise.} \end{cases}$$

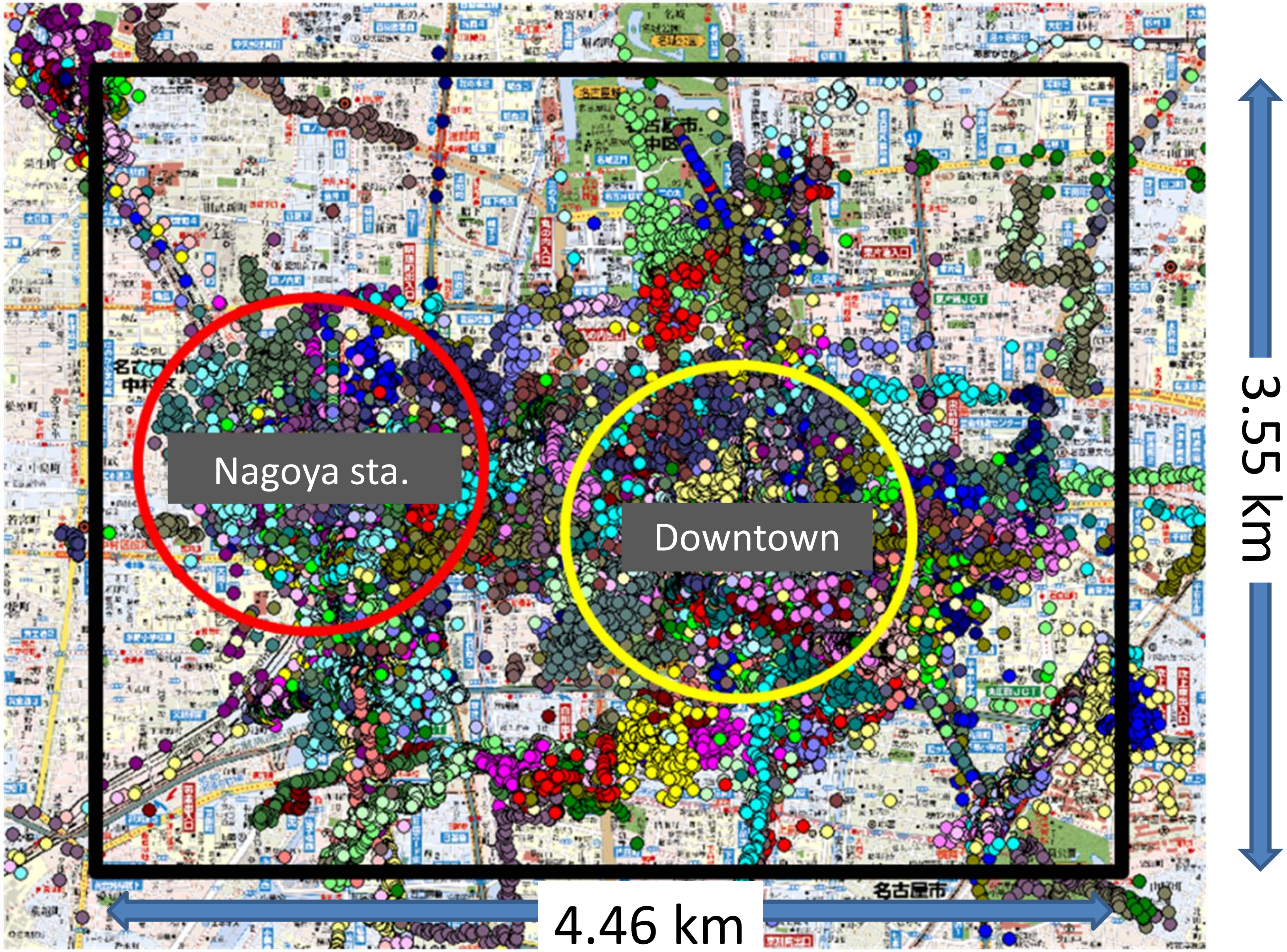
- Heteroscedasticity in route choice
  - Heteroscedasticity based on trip distance (e.g. Gliebe et al. 1999, Morikawa & Miwa 2006)

$$\mu_n = \mu_0 {d_n}^{\gamma}$$

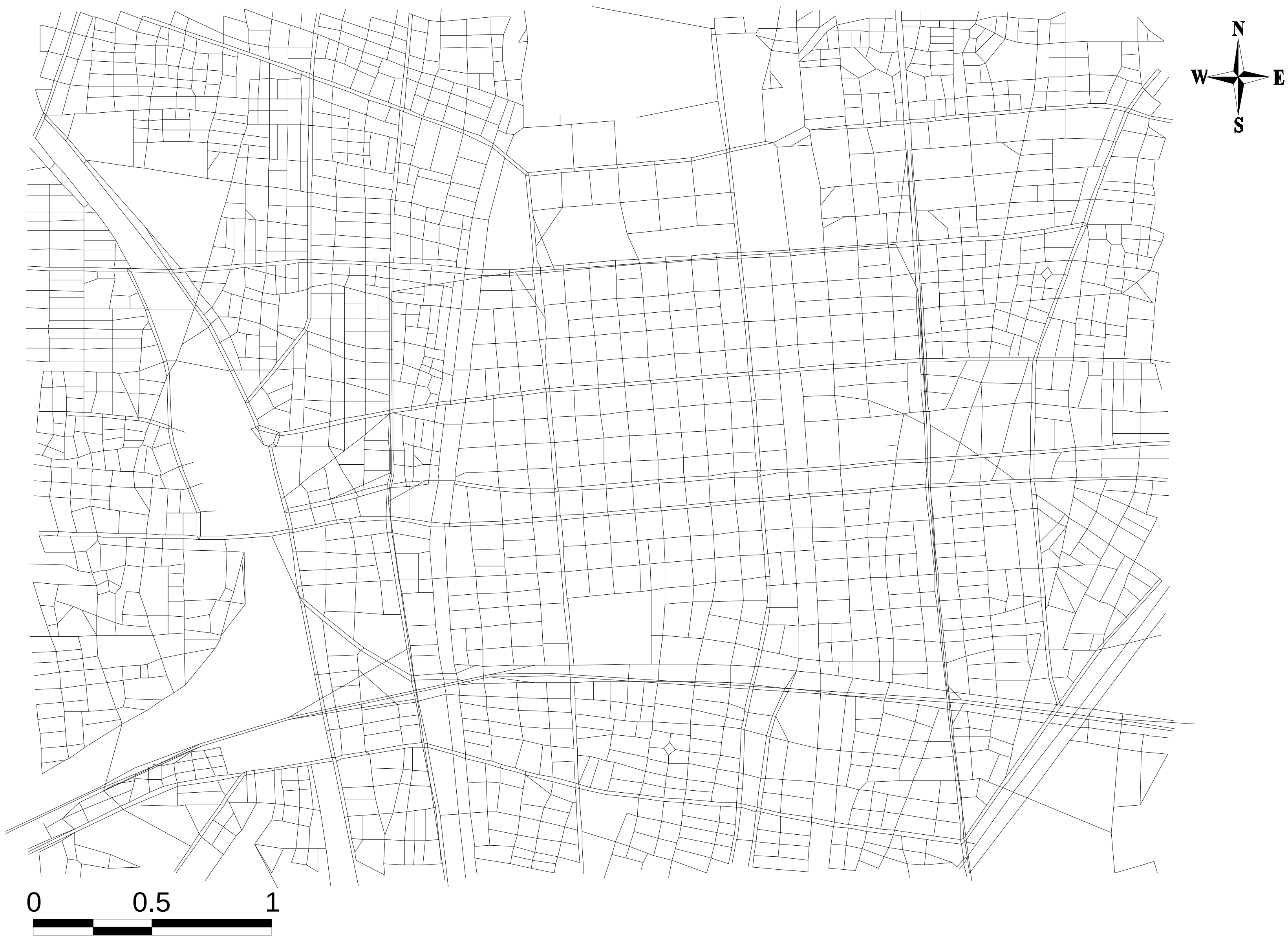
Data

- Person trip survey data at Nagoya, Japan in 2008
- Mobile phone with GPS functions to track trajectories traveling within the city
- 76 subjects and 4 weeks of travel data

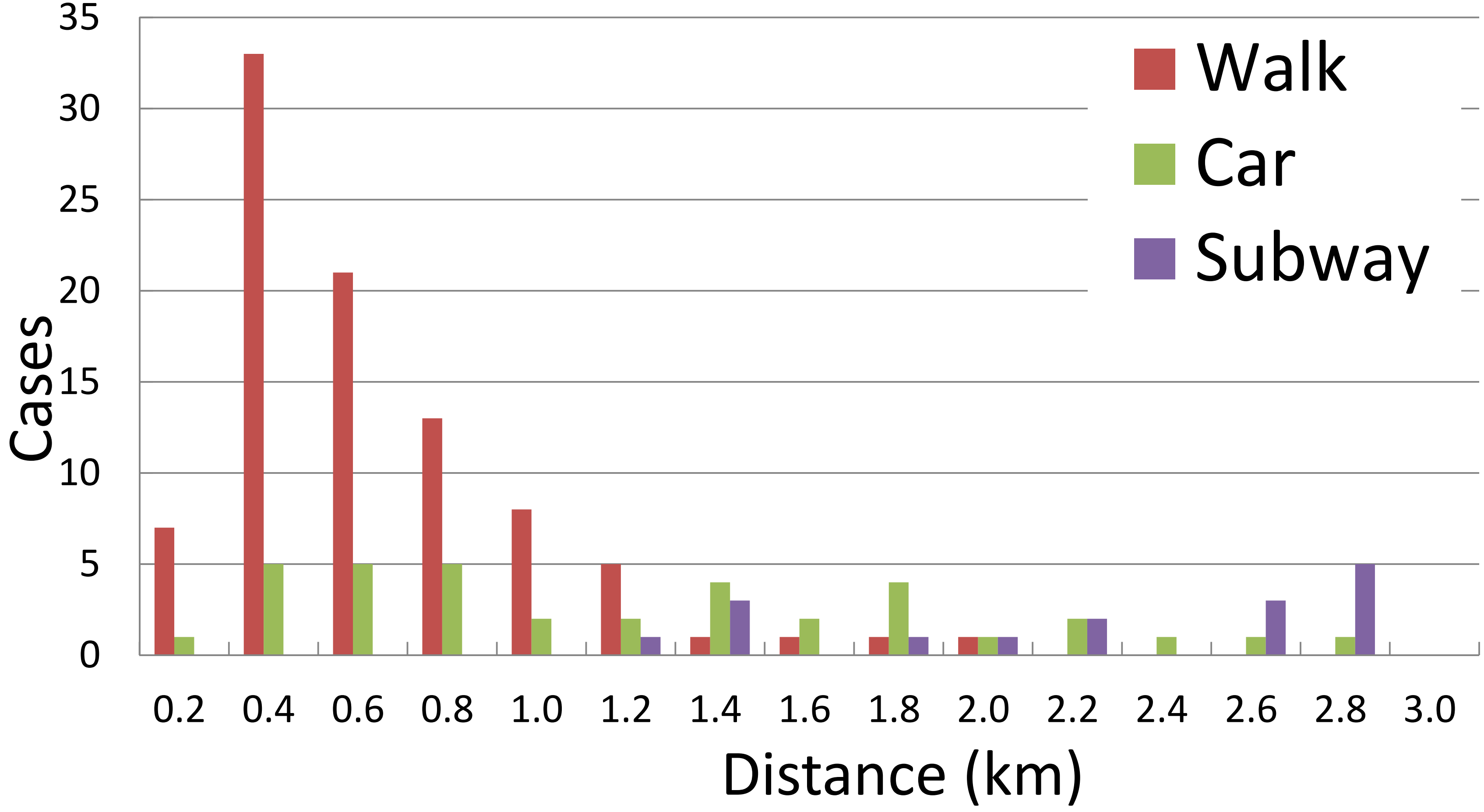
Survey area



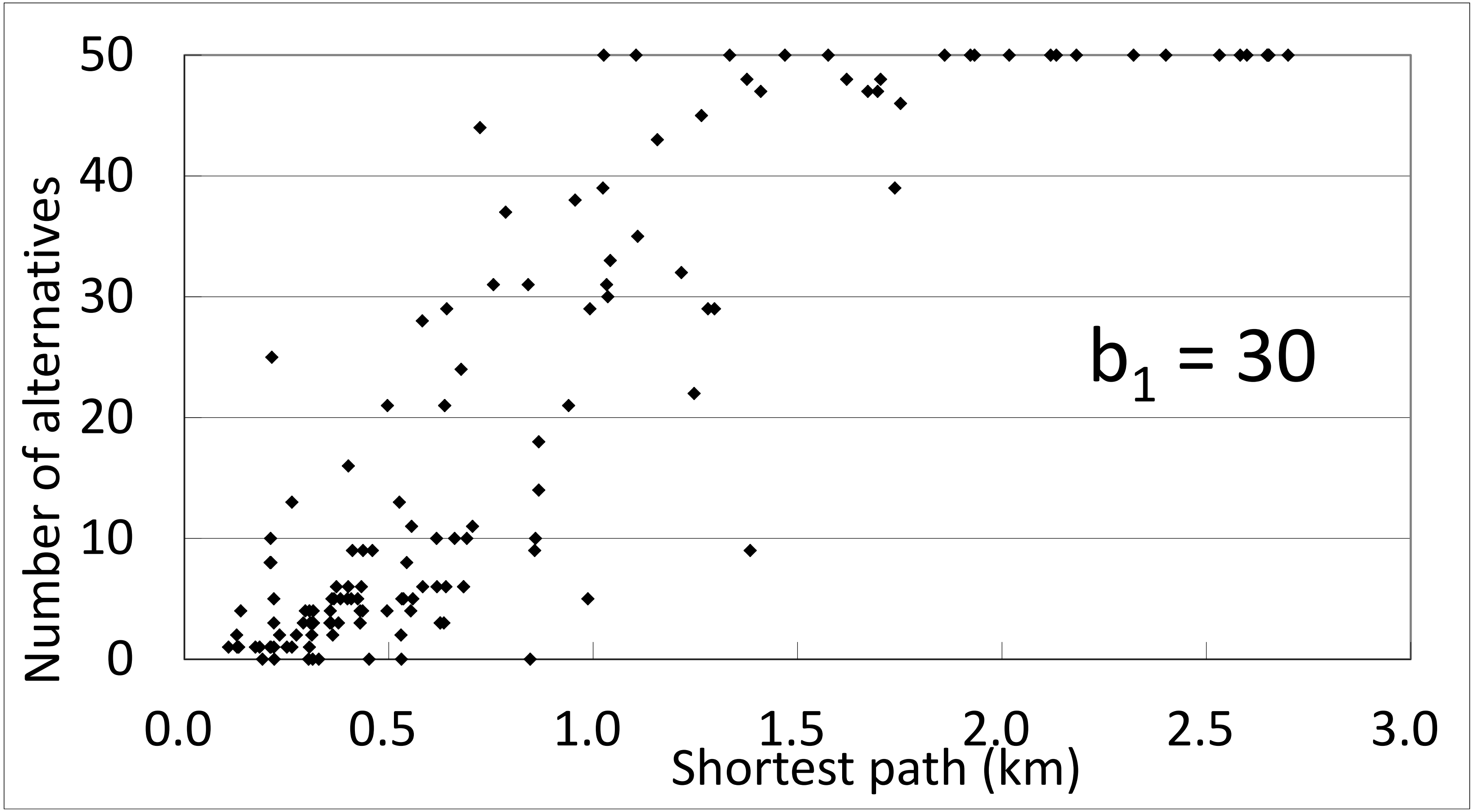
Road network



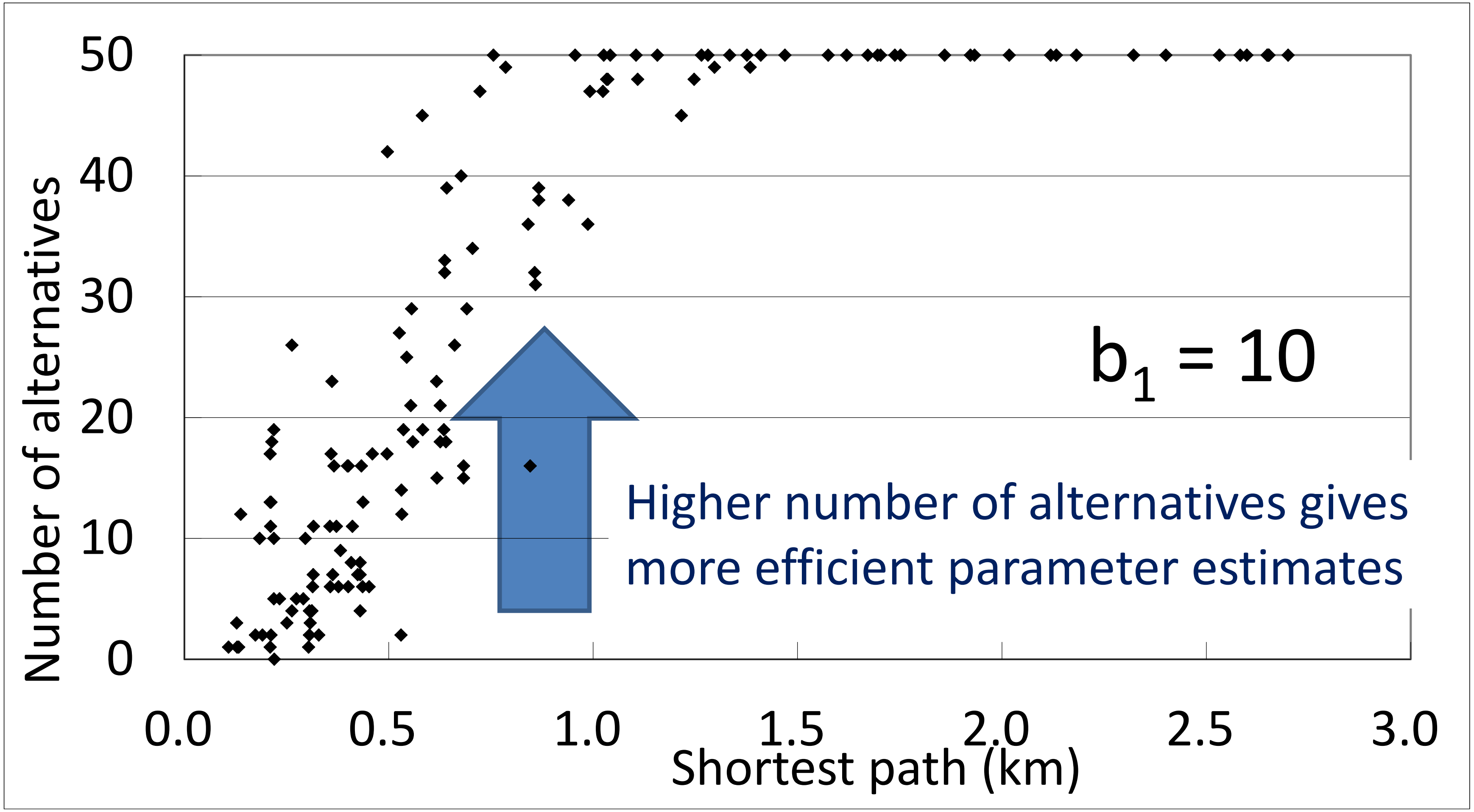
Sample distribution of trip distance



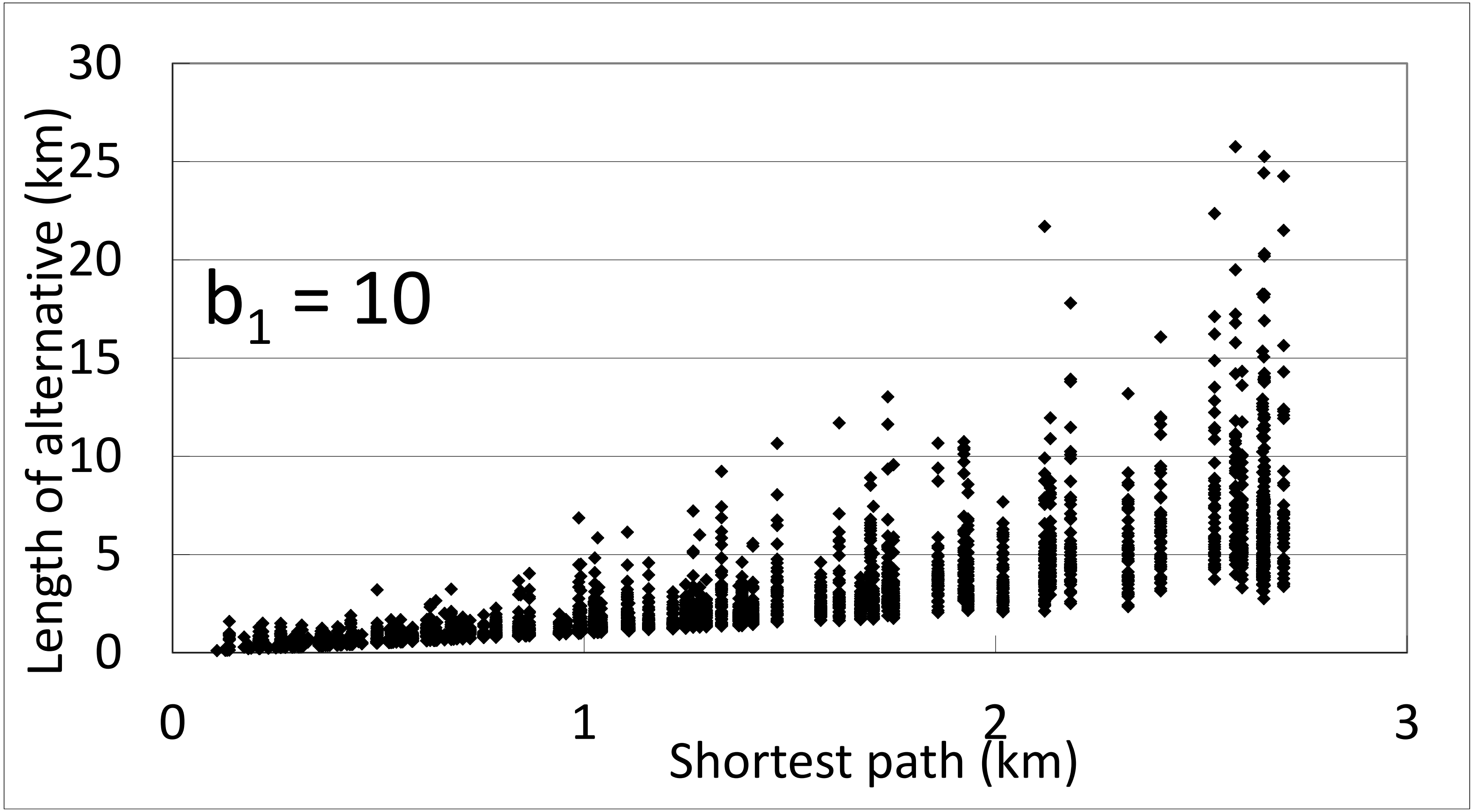
Number of alternatives by the trip distance



Number of alternatives by the trip distance



Length of alternative by the shortest path length



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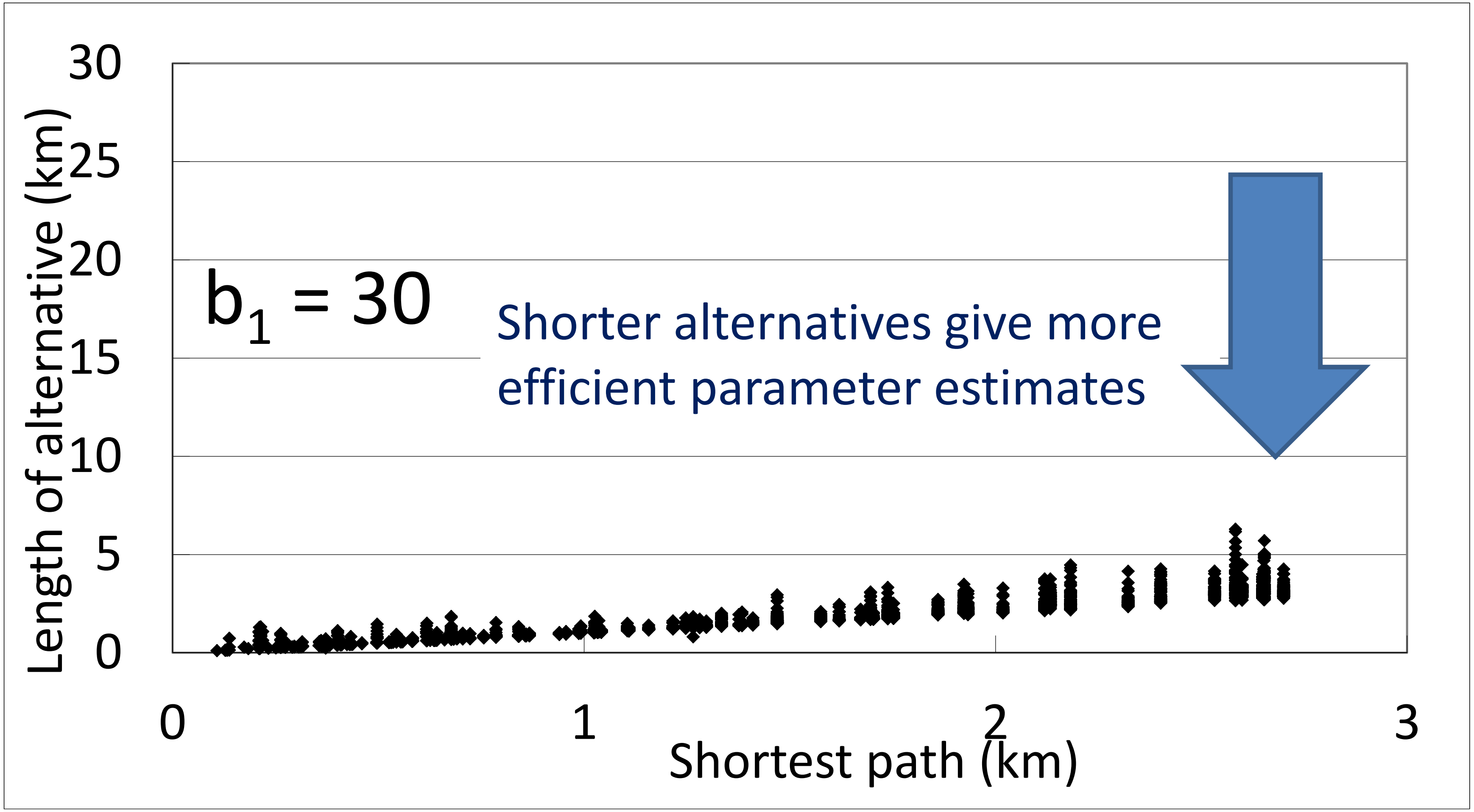


Our proposal

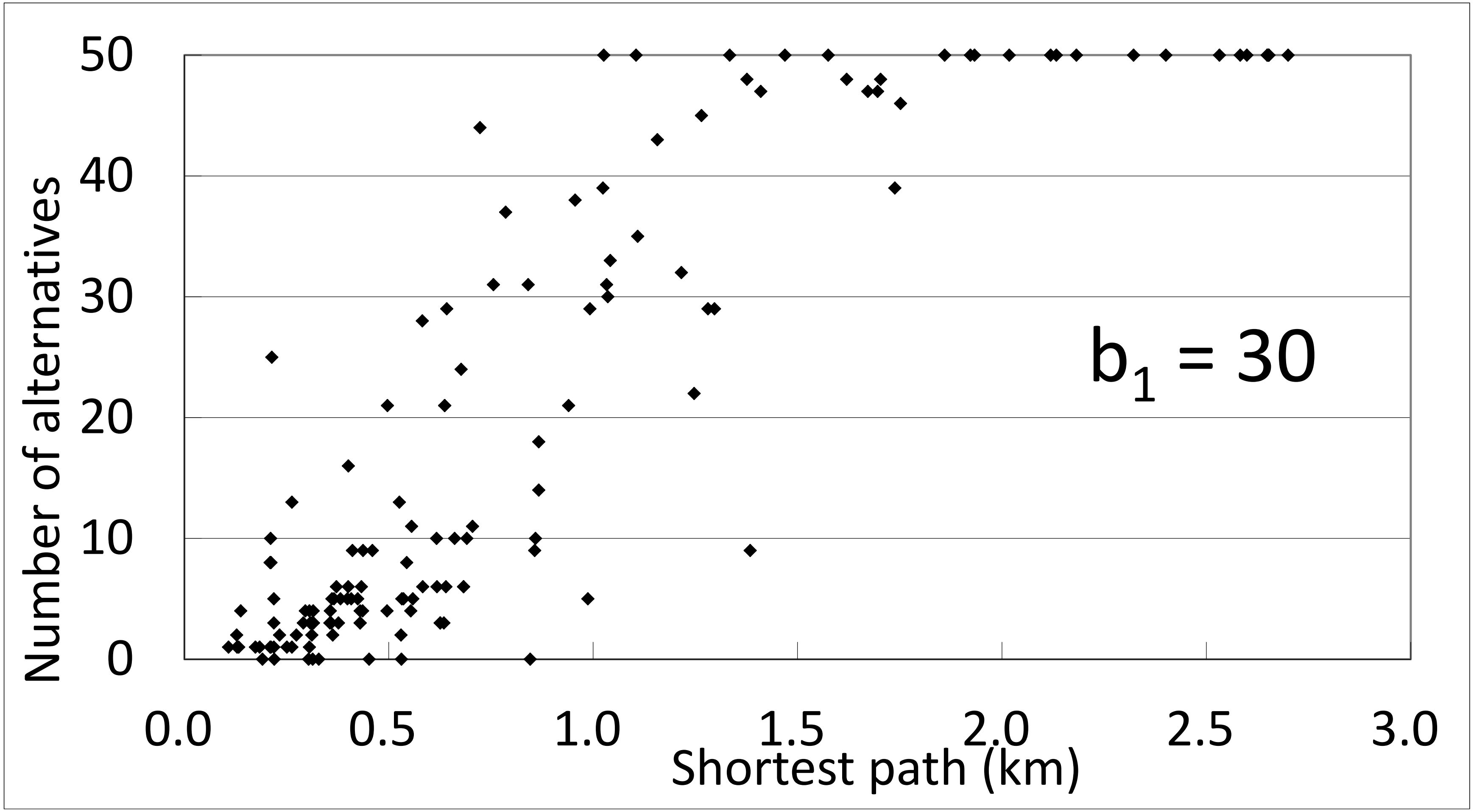
- Structured random walk parameter

$$b_1 = b_3 + b_4 SP(s_o, s_d)$$

Shortest path from s_o to s_d

  - Stronger inclination to shortest path for longer trip distance
  - More randomness for shorter trip distance

Number of alternatives by the trip distance



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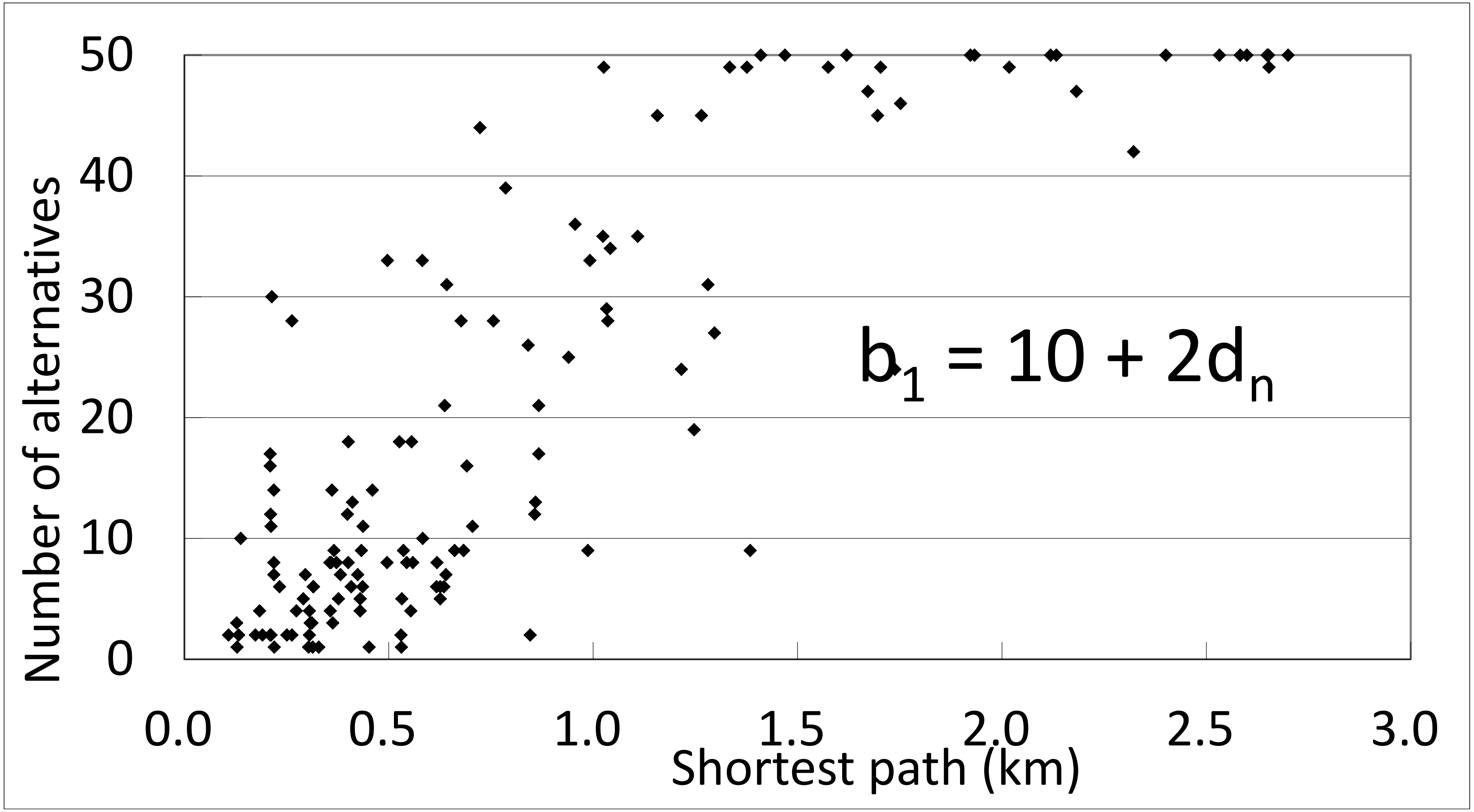
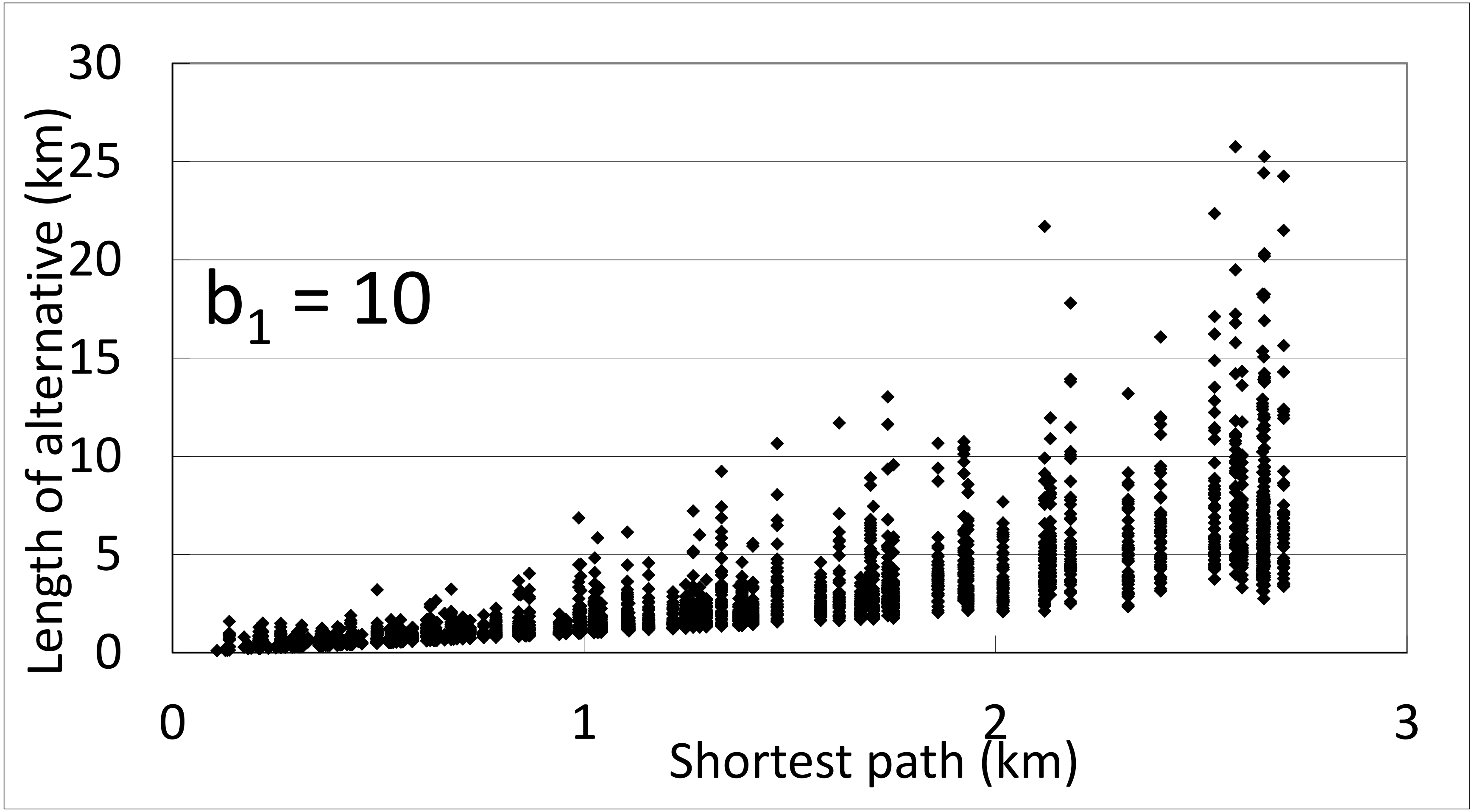
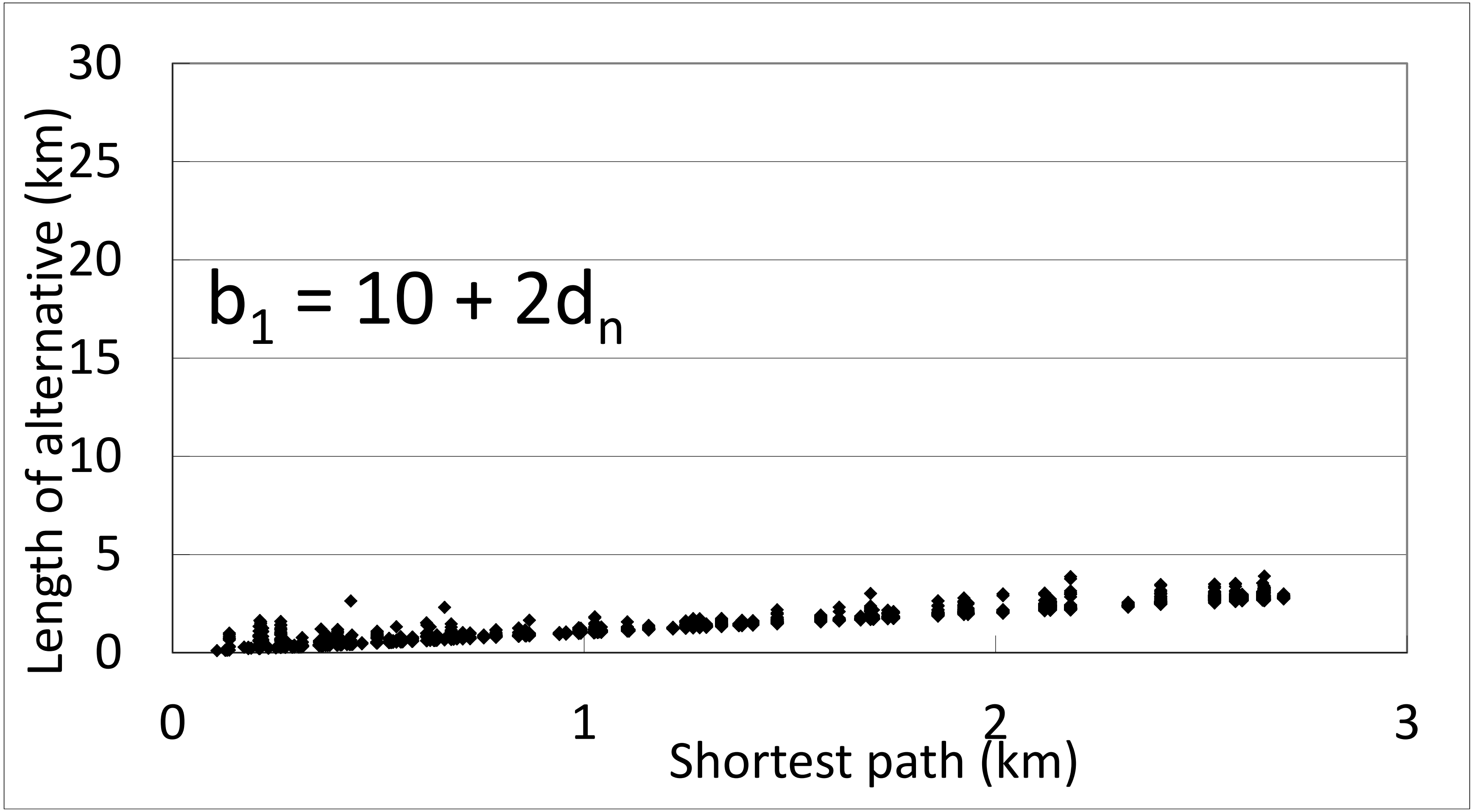


Length of alternative by the shortest path length



Length of alternative by the shortest path length



Route choice model (N = 91)

Random walk parameter	Structured $b_1 = 10 + 2d_n$	Constant $b_1 = 20$
	Coef.	Coef.
Distance (100 m)	-5.89	-6.14
Street with department stores for the elderly (100 m)	7.34	8.76
Street with restaurants on holidays (100 m)	4.61	3.37
Street without stores (100 m)	1.58	1.55
lnEPS	0.54	0.38
Heteroscedasticity of scale parameter (γ)	-0.56	-0.59

Route choice model (N = 91)

Random walk parameter	Structured $b_1 = 10 + 2d_n$	Constant $b_1 = 20$
	s.e.	s.e.
Distance (100 m)	1.37	3.83
Street with department stores for the elderly (100 m)	1.88	5.42
Street with restaurants on holidays (100 m)	1.78	2.35
Street without stores (100 m)	0.66	1.20
lnEPS	0.14	0.22
Heteroscedasticity of scale parameter (γ)	0.24	0.37

Route choice model (N = 91)

Random walk parameter	Structured $b_1 = 10 + 2d_n$	Constant $b_1 = 20$
	t-stat.	t-stat.
Distance (100 m)	-4.30	-1.60
Street with department stores for the elderly (100 m)	3.91	1.62
Street with restaurants on holidays (100 m)	2.60	1.43
Street without stores (100 m)	2.41	1.29
lnEPS	3.93	1.71
Heteroscedasticity of scale parameter (γ)	-2.37	-1.62

Mode & walk route choice (N = 107)

	Coef.	t-stat.
Travel time (10 min.)	-0.93	-2.63
Waiting time for subway (10 min.)	-3.39	-2.42
Subway constant	-3.98	-3.07
Street with department stores for elderly (km)	1.49	2.50
Street with restaurants on holidays (km)	0.96	2.55
Street without stores (km)	0.35	2.10
lnEPS	1.38	2.90
Scale parameter ($1/\mu_0$)	0.03	2.38
Heteroscedasticity of scale parameter (γ)	-0.49	-2.85

Mode & walk route choice (N = 107)

Trip distance	0.5km	1.0km	1.5km	2.0km	2.5km
$1/\mu$	0.019	0.026	0.032	0.037	0.041

The utility at the route choice level does not have a big effect on the mode choice

Empirical findings

- Shorter routes are preferred
- Older pedestrians prefer main shopping streets with department stores
- Streets with restaurants are preferred on holidays (partly because more trips on weekdays are undertaken after 5 pm)
- Overlapping of paths significantly causes correlation of utility among routes

Conclusion

- Structured random walk parameter improves the efficiency of the parameter estimates with empirical data containing trips of various distance