Hierarchical system of road networks
with inward, outward, and through traffic

Masashi Miyagawa
University of Yamanashi
Japan

For efficient road networks, an appropriate
hierarchical system must be established

Chiyoda
$S_2/S_1 = 2.5$
$S_1$: Minor arterial (Width: 5.5[m])
$S_2$: Major arterial (Width: 5.5[m])

Setagaya
$S_2/S_1 = 0.3$

The ratio is high in the central part of the city

Ratio of road areas in Nagoya

$S_2/S_1$
$S_1$: Minor arterial
$S_2$: Major arterial

The ratio is high in the central part of the city

Purpose
To find the hierarchical system that
minimizes travel time
Traffic composition
Inner, inward, outward, and through traffic

Contents
1. Grid network model
2. Optimal ratio of road areas
3. Numerical example
Grid network model

Assumptions

1. Origins and destinations are uniformly and independently distributed
2. Every traveller uses both minor and major arterial roads
3. Transfers to different level roads are only allowed at intersections

Nearest intersection routing

Travel time on road networks

Nearest intersection routing is a good approximation for the minimum travel time routing

Traffic in the city

Average travel time

Rectilinear distance in a square
### Accuracy of continuous approximation

The approximation becomes better as the road lengths at each level increase.

### Total travel time

<table>
<thead>
<tr>
<th>Total traffic volume: $q$</th>
<th>Inner</th>
<th>Inward/Outward</th>
<th>Through</th>
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</table>

<table>
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<tr>
<th>Proportion</th>
<th>$\alpha$</th>
<th>$\beta$</th>
<th>$\gamma$</th>
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</thead>
</table>

**Average travel time**

- $2T_0 + 2T_1 + T_2$
- $T_0 + T_1 + T_2$
- $T_2$

### Travel speed on major arterial roads

Travel speed is proportional to the road area and inversely proportional to the traffic volume.

### Formulation

**Optimal ratio of road areas**

- $\frac{S_1^*}{S_2^*} = \frac{w_1\lambda_1}{w_2\lambda_2} \left( 1 + \frac{(4\alpha + 3\beta + 6\gamma)q\lambda_1}{6w_2^2} \right)$

**Optimal ratio increases with the total traffic volume**

### Optimal ratio of road areas

- The optimal ratio increases with the proportions of inward/outward and through traffic.

### Numerical example

1. Origins and destinations are uniformly and independently distributed.
2. Travellers of inter-city traffic minimize the number of turns.
3. If there exist two shortest routes, the traffic volume is divided equally.

Region of $N^2$ cities with grid road networks.
Proportions of inner, inward/outward, and through traffic

Optimal ratio of road areas

The optimal ratio has a maximum at the centre and decreases with the distance from the centre

Conclusion

- The optimal ratio of major arterial roads increases with inward, outward and through traffic
- If origins and destinations are uniformly distributed, the optimal ratio of major arterial roads has a maximum at the centre

For details...