Distributions of Road Spaces in Tokyo Ward Area While Focusing on Pedestrian Spaces
—Toward a Description of Necessary Levels of Roadway Spaces in a Compact City —

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Background

Growing needs for compact city

- Increasing needs to counteract such as global warming, decreases in human population, aging society and the need to conserve resources
- The compact city is most discussed concept in contemporary urban policy.
  - Reducing the environmental loads by transportation, revitalizing downtown, reducing infrastructure maintenance expenses

GHG emissions by region, 1990-2050
Source: OECD(2012), Compact City Policies

Closing shop in downtown (Japan)
Walking and cycling emerges as a viable element for the socio-economically and environmentally sustainable city form.

- Walking is the cleanest and most natural transportation mode.
- Pedestrian space provides more participation and social communication (Jou, 2011).

Many local government authorities have emphasized the concept of walkable town planning.

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**THE DEATH AND LIFE OF GREAT AMERICAN CITIES**

JANE JACOBS

“Perhaps the most influential single work in the history of town planning...a work of literature.”

— The New York Times Book Review

Greenwich village, New York
Background

Shortage of pedestrian space quantity and effective utilization

- Current urban structure has a high dependence on automobiles.
- Current pedestrian spaces are not utilized wisely.
- Pedestrian spaces have been installed according to road class based on automobile flow and not clear standard.

Guideline for walkway width in Japan (Road Structure Ordinance)

<table>
<thead>
<tr>
<th>Class of road</th>
<th>Year</th>
<th>1970</th>
<th>1982</th>
<th>1993</th>
<th>2001</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class 1・2</td>
<td></td>
<td>Over 3m</td>
<td>Over 3m</td>
<td>Over 3.5m</td>
<td>Over 3.5m</td>
</tr>
<tr>
<td>Class 3</td>
<td></td>
<td>Over 1.5m</td>
<td>Over 1.5m</td>
<td>Over 2m</td>
<td>Other roads</td>
</tr>
<tr>
<td>Class 4</td>
<td></td>
<td>Over 1m</td>
<td>Over 1.5m</td>
<td>Over 2m</td>
<td></td>
</tr>
</tbody>
</table>

Source: Tsuda (2002), Minus Design
Purpose of study

Focused on several wards in Tokyo, where pedestrian spaces quite closely resemble the compact city that are envisaged.

Ascertaining the distributional characteristics of roadway spaces

Contributing to describing our vision for roadway spaces in a compact city

1. Classifying land uses including off ground level spaces

2. Analyzing distributional characteristics of roadway spaces
   - Total area of roads, distribution analysis by mesh

3. Deriving relations for the pedestrian space with railway stations and building density
   - Kernel density estimation
Land use classification

- Necessary spaces were created in the third dimension (pedestrian bridge, viaduct).
- Land use, including off-ground level (OGL) roadway spaces, was classified and areas of roadway categories were calculated.

<Land use classification>

- Viaducts (regular streets, expressways)
- Pedestrian bridges, decks
- Underground spaces
- Tunnels (regular streets, expressways)

Target area (14 wards in Tokyo)

02. Definitions of road spaces

- Ground surface
  - Open Space area
    - Ground level walkways
    - OGL walkways
  - All streets (Automobile)
    - Ground level streets
    - OGL streets
- OGL space
  - All walkways (Pedestrian)
○ All roadway spaces were constructed as polygonal data in ArcGIS.
  - 30% of the total underground area is accounted as pedestrian spaces.
○ Ratio of OGL roadway among all roadway: street-3.5%, walkway-8.8%
  - OGL spaces are used much more for pedestrians than for vehicles.

Example of constructed data
(West entrance, Shinjuku Station)

Data : Zenrin Zmap-TOWN II(GL roadways, OGL walkways)
MAPPLE Digital Map Data 10000(OGL streets)
Distribution of road spaces by mesh

Distribution of walkway ratios (GL+OGL)

- High values are observed in the vicinity of railway stations.
- The highest roadway ratio, 63.3% (Marunouchi Central Entrance of Tokyo Station)
- The highest walkway ratio, 23.4% (The west entrance of Shinjuku Station)
Distribution of road spaces by mesh

Ratios of OGL walkways among all walkways

- High values are distributed around railway stations.
- Pedestrian spaces were greatly enhanced by OGL structures.
- Pedestrian spaces have been pursued off the ground surface due to the automobile-centered space.
Surrounding area of stations

- Surrounding area of stations are analyzed to observe composition and road ratio change.
- Mean roadway ratio of within a 500 m radius of railway stations, 25.1% (266 stations)
- OGL walkways are concentrated within 200 m of stations.
- As the number of rider increases, higher walkway ratio was showed.

<Mean ratios of roadways with distance from railway stations>

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<Mean ratios of roadways with distance from railway stations>
Characteristics of roadway distribution

Relation between Pedestrian space and stations

- Walkway ratio is especially high in the vicinity of stations.
- Degree of relation by location and number of riders

Other factor of Walkway concentrations

- Concentrations of walkway are observed in other meshes.
- Finding out other factor of walkway concentrations

By using Kernel density estimation,
1. Degree of relation between pedestrian space and stations considering the number of riders
2. Relation with high building density area where a lot of people can be gathered
Kernel density distribution estimation

- Kernel density distribution is used to analyze relative concentration of pedestrian space considering surrounding area.
- **Pedestrian space peaks**: The points of highest density compared to their surroundings
- **Distributions of pedestrian space peaks** is compared with the distribution of railway station and building density peak

- The pedestrian spaces were rasterized to cell sizes of 1 m, converted to point data.

Source: left-http://www.csun.edu/~sg4002/courses/Forensic/Lab_Kernal_density_smoothing.pdf
right-http://jratcliffe.net/ware/spam1.htm
Peaks and stations within bandwidth from boundary were excluded from analysis.

When bandwidth was set at 400m, 250 pedestrian peaks are extracted.

Bandwidth which the number of stations and peaks are similar to figure out whether stations are primary facility of pedestrian space concentration.

<table>
<thead>
<tr>
<th>Bandwidth (m)</th>
<th>Peaks</th>
<th>Railway stations</th>
</tr>
</thead>
<tbody>
<tr>
<td>300</td>
<td>250</td>
<td>418</td>
</tr>
<tr>
<td>400</td>
<td>238</td>
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<td>500</td>
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<td>600</td>
<td>227</td>
<td></td>
</tr>
<tr>
<td>700</td>
<td>222</td>
<td></td>
</tr>
</tbody>
</table>

250 pedestrian space peaks

Pedestrian space density

Railway

Pedestrian space peak
Distribution of pedestrian space peaks

Relationship with railway stations

- 107 (42.8%) of the 250 pedestrian space peaks were found to be within 200 m of railway stations.
- Most of pedestrian peaks in the center of target area have relation to station
Distribution of pedestrian space peaks

Degree of Relationship by number of rider

- 110 (46.2%) of the 238 stations had a pedestrian space peak within 200m.
- This relationship strengthens with higher rider numbers at stations.
- Some stations in outer area cannot have pedestrian space peaks.

![Graph showing distribution of pedestrian space peaks](image)

- Railway stations: 238 (100.0%)
  - Nearby peak: 110 (46.2%)
  - No peak: 128 (53.8%)

![Map showing distribution of pedestrian space peaks](image)
Distribution of pedestrian space peaks

Relationship with building density peak

- 219 building density peaks are extracted
- 85 (34.0%) of the pedestrian space peaks had building density peaks within 200 m
- Pedestrian peaks within 200m from building density peaks tend to distribute outer side of target area.

Pedestrian space peak 250(100%)
- Nearby building peak and station 41(16.4%)
- Nearby building peak 44(17.6%)
- Others 165(66.0%)
Classification of pedestrian space peak

Pedestrian space peaks

- 60.4% of pedestrian peaks are related with stations or building density peaks
- Railway station is primary facility of pedestrian space concentration

- Railway station, 66, 26.4%
- Building peak, 44, 17.6%
- Both station and building peak, 41, 16.4%
- Other, 99, 39.6%
歩行者空間の集積要因と関係分析

関係分析の手順

○ 変数の設定
○ 回帰分析の実行（500mメッシュ単位）
  - 全体データを用い、相関・回帰分析を行い、異常値を除外（標準化された残差基準）
  - 異常値を除外してから、回帰分析を実行
  - 回帰分析による個別予測区間（90%信頼区間）を計算
○ 実際値と信頼区間の上限・下限を比較し、十分な地域・足りない地域区分
歩行者空間の集積要因と関係分析

歩行者空間の集積要因

○駅の立地、乗降者数、建物の集積などが歩行者空間の集積に影響があると分析された。
○それに加え、歩行者空間の形成に影響があると考えられる変数を追加した。

■目的変数: 歩道率（％）

■説明変数

<table>
<thead>
<tr>
<th>区分</th>
<th>データ</th>
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<tbody>
<tr>
<td>容積率（％）</td>
<td>ZmapTown</td>
</tr>
<tr>
<td>駅から距離帯別の面積の比率（％）</td>
<td>200m</td>
</tr>
<tr>
<td>乗降者数（面積により配分）（万人）</td>
<td>200m基準</td>
</tr>
<tr>
<td></td>
<td>国土数値情報 交通流動量 駅別乗降数データ（端末交通手へ徒歩のみ）</td>
</tr>
<tr>
<td>建物棟数</td>
<td>ZmapTown</td>
</tr>
<tr>
<td>平均建築面積（㎡）</td>
<td>ZmapTown</td>
</tr>
</tbody>
</table>
歩行者空間の集積要因と関係分析

回帰分析の結果

残差の分布

地域の区分

図中、地域は以下の水準に区分されています：
- 十分な地域
- 少ない地域

鉄道駅の位置も示されています。
歩行者空間の集積要因と関係分析

回帰分析の結果

○740個のメッシュの中で、異常値を除外した698個を用いた結果である。

モデル要約

<table>
<thead>
<tr>
<th>モデル</th>
<th>R</th>
<th>R2 乗</th>
<th>調整済みR2 乗</th>
<th>推定値の標準誤差</th>
<th>Durbin-Watson</th>
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<tbody>
<tr>
<td>1</td>
<td>.819a</td>
<td>.671</td>
<td>.668</td>
<td>1.205</td>
<td>1.554</td>
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</tbody>
</table>

a. 予測値：（定数）・駅200割合、建物棟数、容積率、平均建築面積、乗降者配分。
b. 従属変数：歩道率

係数

<table>
<thead>
<tr>
<th>モデル</th>
<th>標準化されていない係数</th>
<th>標準化係数</th>
<th>有意確率</th>
<th>共線性的統計量</th>
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</thead>
<tbody>
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<td></td>
<td>B</td>
<td>標準誤差</td>
<td>ベータ</td>
<td>t 値</td>
</tr>
<tr>
<td>1 （定数）</td>
<td>.602</td>
<td>.170</td>
<td>3.536</td>
<td>.000</td>
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<td>容積率</td>
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<td>.001</td>
<td>23.346</td>
<td>.000</td>
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<td>建物棟数</td>
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<td>.000</td>
<td>-.179</td>
<td>-6.456</td>
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<tr>
<td>平均建築面積</td>
<td>.001</td>
<td>.000</td>
<td>.082</td>
<td>2.980</td>
</tr>
<tr>
<td>乗降者配分</td>
<td>.049</td>
<td>.007</td>
<td>.214</td>
<td>7.216</td>
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<tr>
<td>駅200割合</td>
<td>.011</td>
<td>.003</td>
<td>.096</td>
<td>3.527</td>
</tr>
</tbody>
</table>

a. 従属変数：歩道率

○容積率が100%増加すると歩道率は1.5%増加する
○地域内の建物の棟数が1000棟増えることにより歩道率は1%減少する一方で、一棟当りの平均建築面積が1000㎡増加することによる歩道率が1%減少すると分析された。
→大規模の面的開発の方がもっと多い歩行者空間を確保することを表す結果だと考えられる。
Discussion and conclusion

Required quantity of pedestrian space

- Roadway space distributions for both vehicles and pedestrians (including OGL roadway spaces) in 14 of the wards of Tokyo were analyzed.

- The result clarified that walkway ratio is especially high in the vicinity of stations.
  - Over 40% of pedestrian space peaks are linked with railway stations, and this relationship strengthens with higher rider numbers at stations.
  - Some Stations located in outer side or used by a few people can not have peaks.

- Results of this study cannot explain required quantity of pedestrian spaces.
- It can be deal with considering the demand of pedestrian space based on traffic volume or building density.
Discussion and conclusion

Quality of pedestrian space

- This study focused on quantity of road spaces and figured out that OGL spaces are used at a high ratio in pedestrian spaces.
  - Ratio of OGL roadway among all roadway: street-3.5%, walkway-8.8%
  - Pedestrian spaces were greatly enhanced by OGL structures.

- Even though there are satisfactory amount of pedestrian space, it cannot be said as friendly space for pedestrian
  - Pedestrian spaces have been pursued off the ground surface due to the automobile-centered space.
  - OGL pedestrian spaces can be inconvenience because people have to move up and down and can separate people from ground level shops

- Convenience of movement, network, accessibility to other facilities should be considered together.
Discussion and conclusion

For further study...

- Considering various vehicles
  - Bicycles and the vehicles that are anticipated to be common in the future, such as electric motorbikes and vehicles for elderly people.
  - It is needed to consider a difference of necessary space for each vehicle.

- Changing demands of roadway space by mixed land use
  - Most parts of present-day Tokyo, land use is functionally separated, in accordance with regulations.
  - Mixed land use moderates the traffic load in compact city.
Reference


Thank you