Accessibility and its measures

Prof. Ennio Cascetta
Università degli Studi di Napoli Federico II
Dipartimento di Ingegneria dei Trasporti “L. Tocchetti”
1. The Concept of Accessibility and its uses
2. Terminology and Notations
3. Accessibility Measures
1. The Concept of Accessibility and its uses
2. Terminology and Notations
3. Accessibility Measures
1. the concept of accessibility and its uses

Activities and Transportation

Accessibility is a concept expressing the relationship between the activity system located in a region and the transportation system serving it.

- Accessibility measures are used to translate the concept of accessibility in quantitative indicators that take into account both the socio-economical and the transportation systems.
1. the concept of accessibility and its uses

- Active accessibility
- Passive accessibility

- Level and location of economic activities
- Number and location of households by type
- Space availability by area and type

Accessibility Instruments for Planning Practice in Europe
COSTAction TU1002 - Summer Training School 2012
Naples, June 20th, 2012
1. the concept of accessibility and its uses

Common Definitions of Accessibility

- “the opportunity which an individual or type of person at given location possesses to take part in a particular activity or set of activities” *Hansen* (1959)
- “the accessibility of a point in a system is a function of its location in space with respect to all other points in the system” and “implies relative nearness either in the sense of a direct linkage or a minimum expenditure of travel cost or time” *Hack* (1976) and *de Lannoy* (1978)
- “the average opportunity which the residents of the area possess to take part in a particular activity or set of activities” *Wachs and Kumagai* (1972)
- “the consumer surplus, or net benefit, that people achieve from using the transport and land-use system” *Leonardi* (1978)
- “the ease and convenience of access to spatially distributed opportunities with a choice of travel” *U.S. Department of Environment* (1996)
1. The concept of accessibility and its uses

A Synthetic Definition

The ease in meeting one’s needs in locations distributed over space for a subject located in a given area

It depends on:

➢ The **point** where the subject is located (reference point)

➢ the **spatial distribution** of the activities in the region

➢ the **transportation system** connecting the reference point to the location of the activities
1. The concept of accessibility and its uses

Active and Passive Accessibility

The concept of accessibility can be related to the needs of carrying out activities (to go shopping, to go to cinemas, to go working, etc.) by a subject located in a certain zone (active or origin accessibility) or to the needs of being reached by potential users (clients, workers, providers, etc.) of an activity located in a certain zone (passive or destination accessibility) (Ben-Akiva and Lerman, 1979; Cascetta, 2009)
1. the concept of accessibility and its uses

Active Accessibility

The ease of participating to activities, i.e. the **active (origin) accessibility**, depends on:

- the involved subject: the socio economic characteristics of the subject involved in the activity
- the quantity, the quality and the location and of the opportunities (activities) considered (e.g. shopping, recreational, health care, schooling, workplaces)
- LOS attributes (travel time, access/egress times, direct and indirect costs) and the quality of the travel allowed by the transportation supply system

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td></td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>ZONE 1</td>
<td></td>
<td>+</td>
</tr>
</tbody>
</table>

+ + = Residents

□ = Activity locations

ZONE 1 has a **high** active accessibility (high number of nearby activity locations, e.g. shops)

ZONE 2 has a **low** active accessibility (few number of nearby activity locations, e.g. shops)
1. The concept of accessibility and its uses

Active Accessibility
An example of active accessibility to airports
1. the concept of accessibility and its uses

Passive Accessibility

The ease of being reached by potential users, i.e. the passive (destination) accessibility, depends on:

✓ the involved subject: the socio economic characteristics of the subject involved in the activity (e.g. a hospital or a mall)
✓ the nature, the quantity, the location of the potential users (e.g. residents, firms, etc.)
✓ LOS attributes (travel time, access/egress times, direct and indirect costs) and the quality of the travel allowed by the transportation supply system

<table>
<thead>
<tr>
<th>ZONE 1</th>
<th>ZONE 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>□ □ □</td>
<td>+ +</td>
</tr>
<tr>
<td>□ □ □</td>
<td>+ +</td>
</tr>
<tr>
<td>□ □ □</td>
<td>+ +</td>
</tr>
<tr>
<td>□ □ □</td>
<td>+ +</td>
</tr>
<tr>
<td>□ □ □</td>
<td>+ +</td>
</tr>
</tbody>
</table>

 Residents

 Activity locations

ZONE 1 has a **high** active accessibility (high number of nearby activity locations, e.g. shops)

ZONE 2 has a **low** active accessibility (few number of nearby activity locations, e.g. shops)
1. The concept of accessibility and its uses

Passive Accessibility
An example of passive accessibility

Estimated minimum travel time to the nearest city of 50,000 or more people in year 2000

HIGH passive accessibility (high number of nearby residents)

LOW passive accessibility (low number of nearby residents)

Travel Time to major cities (in hours and days) and shipping lane density

1. The concept of accessibility and its uses

Accessibility and its Uses

- Understanding and modeling Transportation – Land-use interactions
- Understanding and modeling travel demand (activity participation and travel levels)
- Measure of Effectiveness of transportation plans and projects (equity, territorial development)
- Optimal location of Public Utilities and Services
1. The Concept of Accessibility and its uses
2. Terminology and Notations
3. Accessibility Measures
3. terminology and notations

Active Accessibility

Relative accessibility between two zones: \( a_{od} \)
The ease of participating in an activity located in “d”, for a user located in “o”.
It depends on:

i) the *average perceived generalized cost* to overcome the spatial separation between “o” and “d”, and

ii) the *number of perceived activities* located in “d”

Integral accessibility: \( AA_o = \sum_d a_{od} \)
The ease of participating in an activity wherever located, for a user located in “o”
3. terminology and notations

Active Accessibility Matrix

<table>
<thead>
<tr>
<th>Regional Poles</th>
<th>1</th>
<th>2</th>
<th>...</th>
<th>d</th>
<th>d+1</th>
<th>...</th>
<th>n_d</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>a_{11}</td>
<td>a_{12}</td>
<td>...</td>
<td>a_{2d}</td>
<td>a_{1d+1}</td>
<td>...</td>
<td>a_{1n_d}</td>
</tr>
<tr>
<td>2</td>
<td>a_{21}</td>
<td>a_{22}</td>
<td>...</td>
<td>a_{2d}</td>
<td>a_{2d+1}</td>
<td>...</td>
<td>a_{2n_d}</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>o</td>
<td>a_{o1}</td>
<td>a_{o2}</td>
<td>...</td>
<td>a_{od}</td>
<td>a_{od+1}</td>
<td>...</td>
<td>a_{on_d}</td>
</tr>
<tr>
<td>o+1</td>
<td>a_{o+11}</td>
<td>a_{o+12}</td>
<td>...</td>
<td>a_{o+1d}</td>
<td>a_{o+1d+1}</td>
<td>...</td>
<td>a_{o+1n_d}</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>n_o</td>
<td>a_{no1}</td>
<td>a_{no2}</td>
<td>...</td>
<td>a_{nod}</td>
<td>a_{nod+1}</td>
<td>...</td>
<td>a_{nom_d}</td>
</tr>
</tbody>
</table>

\[ AA_o = \sum_{d=1}^{nd} a_{od} \]
Passive Accessibility

Relative accessibility between two zones: $a_{o}^{d}$
The ease of being reached by all potential users located in “o”, for an activity located in “d”

It depends on:

i) the *average perceived generalized cost* to overcome the spatial separation between “o” and “d”, and

ii) the *total number of potential users* located in “o”

**Integral accessibility:** $PA_{d} = \sum_{o} a_{o}^{d}$
The ease of reaching an activity located in “d” by all possible users wherever located
### 3. terminology and notations

#### Passive Accessibility Matrix

<table>
<thead>
<tr>
<th>Regional Poles</th>
<th>1</th>
<th>2</th>
<th>...</th>
<th>d</th>
<th>d+1</th>
<th>...</th>
<th>n&lt;sub&gt;d&lt;/sub&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>a'&lt;sub&gt;11&lt;/sub&gt;</td>
<td>a'&lt;sub&gt;12&lt;/sub&gt;</td>
<td>...</td>
<td>a'&lt;sub&gt;2d&lt;/sub&gt;</td>
<td>a'&lt;sub&gt;1d+1&lt;/sub&gt;</td>
<td>...</td>
<td>a'&lt;sub&gt;1n_d&lt;/sub&gt;</td>
</tr>
<tr>
<td>2</td>
<td>a'&lt;sub&gt;21&lt;/sub&gt;</td>
<td>a'&lt;sub&gt;22&lt;/sub&gt;</td>
<td>...</td>
<td>a'&lt;sub&gt;2d&lt;/sub&gt;</td>
<td>a'&lt;sub&gt;2d+1&lt;/sub&gt;</td>
<td>...</td>
<td>a'&lt;sub&gt;2n_d&lt;/sub&gt;</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>o</td>
<td>a'&lt;sub&gt;_o1&lt;/sub&gt;</td>
<td>a'&lt;sub&gt;_o2&lt;/sub&gt;</td>
<td>...</td>
<td>a'&lt;sub&gt;_od&lt;/sub&gt;</td>
<td>a'&lt;sub&gt;_o_d+1&lt;/sub&gt;</td>
<td>...</td>
<td>a'&lt;sub&gt;_on_d&lt;/sub&gt;</td>
</tr>
<tr>
<td>o+1</td>
<td>a'&lt;sub&gt;_o+1 1&lt;/sub&gt;</td>
<td>a'&lt;sub&gt;_o+1 2&lt;/sub&gt;</td>
<td>...</td>
<td>a'&lt;sub&gt;_o+1 d&lt;/sub&gt;</td>
<td>a'&lt;sub&gt;_o+1 d+1&lt;/sub&gt;</td>
<td>...</td>
<td>a'&lt;sub&gt;_o+1 n_d&lt;/sub&gt;</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>n&lt;sub&gt;_o&lt;/sub&gt;</td>
<td>a'&lt;sub&gt;_no 1&lt;/sub&gt;</td>
<td>a'&lt;sub&gt;_no 2&lt;/sub&gt;</td>
<td>...</td>
<td>a'&lt;sub&gt;_no d&lt;/sub&gt;</td>
<td>a'&lt;sub&gt;_no d+1&lt;/sub&gt;</td>
<td>...</td>
<td>a'&lt;sub&gt;_no n_d&lt;/sub&gt;</td>
</tr>
</tbody>
</table>

\[
PA_d = \sum_{o=1}^{n_o} a'_{o_d}
\]

<table>
<thead>
<tr>
<th></th>
<th>PA&lt;sub&gt;1&lt;/sub&gt;</th>
<th>PA&lt;sub&gt;2&lt;/sub&gt;</th>
<th>...</th>
<th>PA&lt;sub&gt;d&lt;/sub&gt;</th>
<th>PA&lt;sub&gt;d+1&lt;/sub&gt;</th>
<th>...</th>
<th>PA&lt;sub&gt;n_d&lt;/sub&gt;</th>
</tr>
</thead>
</table>

**Accessibility Instruments for Planning Practice in Europe**

**COSTAction TU1002 - Summer Training School 2012**

**Naples, June 20th, 2012**
1. The Concept of Accessibility and its uses
2. Terminology and Notations
3. Accessibility Measures
4. accessibility measures

Classification

1. Utility-based measures
   a. *Non Behavioral approach*: Gravity models
   b. *Behavioral approach*: Random Utility models
      - Trip-based measure
      - Activity-based measure

2. Opportunity-based measures
   a. *Non Behavioral approach*: Isochrones models
   b. *Behavioral approach*: Perceived Opportunity models
4. accessibility measures

Classification

1. Utility-based measures
   a. Non Behavioral approach: Gravity models
   b. Behavioral approach: Random Utility models
      - Trip-based measure
      - Activity-based measure

 Measures trying to capture the
 Net Utility = Utility from activities – Travel Cost
 received by a subject in a given location

2. Opportunity-based measures
   a. Non Behavioral approach: Isochrones models
   b. Behavioral approach: Perceived Opportunity models
4. accessibility measures

Utility-based measures

Gravity models (Hansen, 1959; Huff, 1963; Wilson, 1971; Geertman et al., 1995)

The original measure of accessibility without any theoretical derivation

Zonal accessibility is proportional to the number of activities/users, located in “d”/”o”, and inversely proportional to travel cost attributes

\[ a_{od} = K_d^{\beta_1} \cdot f(c_{od}) \quad a'_{od} = P_o^{\beta_1} \cdot f(c_{od}) \]

\[ AA_o = \sum_{d=1}^{n} K_d^{\beta_1} \cdot f(c_{od}) \quad PA_d = \sum_{o=1}^{n} P_o^{\beta_1} \cdot f(c_{od}) \]

where:
- \( K_d \) is a measure of the activities and services located in the destination zone “d”
- \( P_o \) is a measure of the potential users located in the origin zone “o”
- \( \beta \) are model parameters (to be calibrated)
- \( f(c_{od}) \) is the impedance function that quantify the disutility of the travel,
  e.g. \( f(c_{od}) = \exp(-\beta_2 \cdot c_{od}) \) \quad \( f(c_{od}) = c_{od}^{-\beta_2} \)
4. accessibility measures

Utility-based measures

Gravity models

Example of active accessibility towards commercial activities, with private transportation

Model specification

\[ a_{od/m} = K_d^{\beta_1} \cdot \exp(-\beta_2 \cdot t_{od/m}) \]
\[ AA_{o/m} = \sum_{d=1}^{n} K_d^{\beta_1} \cdot \exp(-\beta_2 \cdot t_{od/m}) \]

where:
- \( K_d \) is the number of commercial activities located in the destination zone “d”
- \( t_{od} \) is the minimum travel time between “o” and “d”, given mode \( m \)
- \( \beta_1, \beta_2 \) are model parameters

<table>
<thead>
<tr>
<th>( \beta_1 )</th>
<th>( \beta_2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.5</td>
<td>-2</td>
</tr>
</tbody>
</table>
4. accessibility measures

Utility-based measures

Gravity models
Example of active relative accessibility levels from the origin point towards commercial activities, with private transportation
4. accessibility measures

Utility-based measures

Gravity models
Example of active integral accessibility levels towards commercial activities, with private transportation

• commercial centre
4. accessibility measures

Utility-based measures

The average net utility of participating to an activity is derived from an explicit behavioral model.

Random Utility models: Trip-based measure

Zonal accessibility is proportional to the utility obtained from the choice of carrying out an activity in the different territorial areas:

- Expected utility of carrying out an activity (active accessibility) for a subject located in “o”
- Expected utility of carrying out an activity located in “d” (passive accessibility)
4. accessibility measures

Utility-based measures

Random Utility models: Trip-based measure

Trip-based choice alternatives for participating in an activity
4. accessibility measures

Utility-based measures

Random Utility models: Trip-based measure

Utilities $U_i^j$ perceived by the user class $i$, located in $o$, wishing to participate in an activity $s$ with the alternative choice sequence $s(x, o, d, m, k)$, are random variables expressed by:

$$U_j^i = V_j^i(X_j) + \varepsilon_j^i = \sum \beta_k X_{kj}^i + \varepsilon_j^i$$

where $j$ stands for the trip alternative sequence $s(x, o, d, m, k)$ chosen by the user category $i$

$V_j^i$ are the mean values of the utilities for the alternative $j$ (systematic utility)

$X_j$ are the attributes of the systematic utility; some are “utility” attributes ($\beta_k > 0$), others are “cost” attributes ($\beta_k < 0$)
4. accessibility measures

Utility-based measures

Random Utility models: Trip-based measure

The user $i$ chooses the alternative $j$ that maximizes his/her utility.

The relative accessibility is the average net utility of choosing to carry out an activity in zone “d” from “o” with mode $m$.

$$a_{od/m}^i = E[U_{od/m}^i] = V_{od/m}^i$$

The relative accessibility with all the modes is:

$$a_{od}^i = E[\max_m U_{odm}^i] = V_{od}^i + E[\max_m U_{od/m}^i]$$
4. accessibility measures

Utility-based measures

Random Utility models: Trip-based measure

The integral accessibility is the mean surplus expected by decision makers belonging to the same user group.

This value can be calculated as the expectation (mean) of the perceived net utility (surplus) for the chosen alternative (i.e. the one that maximizes its perceived utility)

\[ EMPU(o,i) = E[\max_{xodm} U^i_{xodm}] \]
4. accessibility measures

Utility-based measures

Random Utility models: Trip-based measure

<table>
<thead>
<tr>
<th></th>
<th>V</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>$U^1$</td>
<td></td>
<td>4.5</td>
<td>3.8</td>
<td>1.5</td>
<td>3.5</td>
<td><strong>5.7</strong></td>
</tr>
<tr>
<td>$U^2$</td>
<td></td>
<td>3.2</td>
<td>2.5</td>
<td>2.3</td>
<td><strong>4.2</strong></td>
<td>4.1</td>
</tr>
<tr>
<td>$a_{od}$</td>
<td></td>
<td>3.5</td>
<td></td>
<td></td>
<td>3.7</td>
<td></td>
</tr>
<tr>
<td>$AA_o$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3.6</td>
</tr>
</tbody>
</table>

Average
4. accessibility measures

Utility-based measures

Random Utility models: Trip-based measure

The EMPU depends on the attributes $X_k$ and the distribution of the random variables $\varepsilon_j$

- Measures of Attractiveness (e.g. density of activities located in “d”, etc.)
- Socio-economic attributes of the commuter (e.g. income, driving license availability, PT availability, etc.)
- LOS attributes of the transportation system and mode choice (travel times, costs, etc.)
4. accessibility measures

Utility-based measures

Random Utility models: Trip-based measure

Example of model specification for evaluating active accessibility

\[
Pr(odm) = \frac{\exp\left(\frac{V_{odm}}{\theta}\right)}{\sum_{d'=1}^{n} \exp\left(\frac{V_{od'm}}{\theta}\right)}
\]

\[
a_{od} = V_{od} = \beta_1 \cdot \ln(K_d) + \beta_2 \cdot \ln\left(\sum_m V_{od/m}\right)
\]

\[
V_{od/m} = \beta_3 \cdot t_{od/m} + \beta_4 \cdot c_{od/m} + \sum \beta_k \cdot SE_k
\]

\[
AA_o = \ln \sum_d \exp(a_{od})
\]

where \(SE_k\) is a set of dummy variables related to socio-economic attributes that influence the mode choice (e.g. age, auto availability, etc.)
4. accessibility measures

Utility-based measures

Random Utility models: Activity-based measure

Zonal accessibility incorporates the impact of trip chaining and scheduling of activities. It differs from the traditional trip-based measures, which focus on a particular trip purpose without trip chaining (i.e. activity pattern) and without considering the time dimension.

It is derived from Day Activity Schedule (DAS) model system which is an activity-based travel demand model system. Rather than modeling each trip separately or as a part of a tour, the DAS models the whole day’s schedule of multiple activities and trips taken by an individual.
4. accessibility measures

Utility-based measures

Random Utility models: Activity-based measure

Activity-based modeling architecture
4. accessibility measures

Utility-based measures

Random Utility models: Activity-based measure
(Ben-Akiva et al., 1996; Ben-Akiva et al., 2006)

The Activity-Based Accessibility (ABA) measure is defined as the expected (mean) value of an individual’s maximum utility among the available activity schedules, given his/her residential location:

- it reflects the outcome of travel and activity scheduling
- it captures the relative attractiveness of various alternatives for activity participation, trip combination, travel model and timing
- it reflects not only the nature of land-use and properties of the transportation system, but also the socio-economic characteristics of individuals

*Only integral accessibility measures can be calculated*
4. accessibility measures

Additional References on Random Utility models and measures
4. accessibility measures

Classification

1. Utility-based measures
   a. Non Behavioral approach: Gravity models
   b. Behavioral approach: Random Utility models
      ▪ Trip-based measure
      ▪ Activity-based measure

2. Opportunity-based measures
   a. Non Behavioral approach: Isochrones models
   b. Behavioral approach: Perceived Opportunity models
4. accessibility measures

Opportunity-based measures

**Isochrones models** (Wachs and Kumagai, 1973; Vickerman, 1974)

Accessibility is the total number of opportunities (activities or users) located in zones that can be reached within a selected threshold of travel time, distance, cost, etc.

\[ a_{od} = K_d \cdot W_{od} \quad AA_o = \sum_{d=1}^{n} K_d \cdot W_{od} \quad \text{Opportunities} = \text{Activities} \]

\[ a'_{od} = P_o \cdot W_{od} \quad AP_d = \sum_{o=1}^{n} P_o \cdot W_{od} \quad \text{Opportunities} = \text{Users} \]

- transportation system is a constraint w. r. t. the accessibility
- threshold must be estimated based on the perceived opportunities (e.g. a cinema located 120 minutes away is not perceived as a potential choice alternative)
- different thresholds for different activities (e.g. distribution of the maximum available budget of a commuter to reach work site)
4. accessibility measures

Opportunity-based measures

Isochrones models: How to set time thresholds

- Function of the activities/potential users (i.e. active/passive accessibility) and of the maximum time/cost to access them (e.g. 30’, 60’, 90’, 120’) for each transport mode

- Different threshold for different types of activity

\[ W_{od} = f(t_{od}) \]

\[ f(t_{od}) = \begin{cases} 1 & se \ t_{od} \leq t_{max} \\ 0 & se \ t_{od} > t_{max} \end{cases} \]
4. accessibility measures

Opportunity-based measures

Isochronic lines
City of Berlin: isochrones of 30’, 60’, 90’ and 120’ related to rail mode
4. accessibility measures

Opportunity-based measures

Isochronic lines
City of Berlin: isochrones of 30’, 60’, 90’ and 120’ related to road mode
4. accessibility measures

Opportunity-based measures

Isochronic lines
Passive accessibility for the localization choice of the logistic platform for the distribution. Isochrones are related to TT thresholds of 30’, 60’, 90’, 120’ and >120’, for LDVs.

Accessibility Instruments for Planning Practice in Europe
COSTAction TU1002 - Summer Training School 2012
Naples, June 20th, 2012
4. accessibility measures

Opportunity-based measures

Isochrones models
Passive accessibility for the localization choice of the logistic platform for the distribution. Isochrones are related to TT thresholds of 30’, 60’, 90’, 120’ and >120’, for LDVs

<table>
<thead>
<tr>
<th>Isochrones (min)</th>
<th>Casoria Industry farms and commercial activities</th>
<th>Battipaglia Industry farms and commercial activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>[30-60]</td>
<td>63.605</td>
<td>42.635</td>
</tr>
<tr>
<td>[60-90]</td>
<td>42.904</td>
<td>86.979</td>
</tr>
<tr>
<td>[90-120]</td>
<td>28.417</td>
<td>22.823</td>
</tr>
<tr>
<td>&gt; 120</td>
<td>13.551</td>
<td>5.863</td>
</tr>
</tbody>
</table>

Number of perceived opportunities as a function of time thresholds
4. accessibility measures

Opportunity-based measures

Isochrones models

Example of active accessibility towards commercial activities, with private transportation

Model specification

\[
Class = \begin{cases} 
1 & se \quad t_{od} \leq 5 \text{ min} \\
2 & se \quad 5 \text{ min} < t_{od} \leq 10 \text{ min} \\
3 & se \quad 10 \text{ min} < t_{od} \leq 15 \text{ min} \\
4 & se \quad 15 \text{ min} < t_{od} \leq 20 \text{ min} \\
5 & se \quad t_{od} > 20 \text{ min}
\end{cases}
\]
4. accessibility measures

Opportunity-based measures

Car-based isochronic lines from the origin point ★
4. accessibility measures

Opportunity-based measures

Isochrones models
Example of active relative accessibility levels from the origin point towards commercial activities, with private transportation

\[ t_{od} \leq 18 \text{ min} \]

....but what if we choose a different threshold value?

commercial centre
4. accessibility measures

Opportunity-based measures

Perceived Opportunity models

Integral zonal (origin or destination) accessibility is equal to:

- the average number of spatial distributed activities that are perceived as available by a user located in “o” (origin accessibility)

\[ a_{od} = K_d \cdot p(d / o) \]

- the average number of spatial distributed users that perceive the activity located in “d” as available (destination accessibility)

\[ AA_o = \sum_{d=1}^{n} K_d \cdot p(d / o) \]

\[ a'_{od} = P_o \cdot p( d / o) \]

\[ AP_d = \sum_{o=1}^{n} P_o \cdot p( d \in ChoiceSet(o)) \]

\[ p(d / o) = p( d \in ChoiceSet(o)) \] is the probability that a subject class \(i\) perceives opportunities located in \(d\) as available for satisfying his/her needs.
4. accessibility measures

Opportunity-based measures

Perceived Opportunity models

\[ p( d \in \text{ChoiceSet}(o)) = \frac{1}{1 + \exp(-Z_{od})} \]

where \( Z_{od} \) depends on the characteristics of the transportation systems and on the socio-economic attributes of the user/activity, e.g.

\[ Z_{od} = \beta_0 \cdot SZ + \sum_{i=1}^{I_{LOS}} \beta_i \cdot X_{i,LOS} + \sum_{i=1}^{I_{SE}} \beta_i \cdot X_{i,SE} \]
4. accessibility measures

Opportunity-based measures

Perceived Opportunity models

Example of active accessibility towards commercial activities, with private transportation

\[ Z_{od} = \beta_0 \cdot SZ + \sum_{i=1}^{5} \beta_i \cdot X_i \cdot t_{od} + \beta_6 \cdot SC_d \]

where \( SC_d \) is dummy variable equal to 1 if there is a shopping centre in “d”, 0 otherwise

\[ X_1 = \begin{cases} 
1 & \text{se } t_{od} \leq 5\text{min} \\
0 & \text{otherwise}
\end{cases} \]

\[ X_2 = \begin{cases} 
1 & \text{se } 5\text{min} \leq t_{od} \leq 10\text{min} \\
0 & \text{otherwise}
\end{cases} \]

\[ X_3 = \begin{cases} 
1 & \text{se } 10\text{min} \leq t_{od} \leq 15\text{min} \\
0 & \text{otherwise}
\end{cases} \]

\[ X_4 = \begin{cases} 
1 & \text{se } 15\text{min} < t_{od} \leq 20\text{min} \\
0 & \text{otherwise}
\end{cases} \]

\[ X_5 = \begin{cases} 
1 & \text{se } t_{od} > 20\text{min} \\
0 & \text{otherwise}
\end{cases} \]
4. accessibility measures

Opportunity-based measures

Perceived Opportunity models
Example of active relative accessibility levels from the origin point towards commercial activities, with private transportation

Accessibility Instruments for Planning Practice in Europe COSTAction TU1002 - Summer Training School 2012
Naples, June 20th, 2012
4. accessibility measures

Comparison between Opportunity-based measures

**Isochrones model**
- 2150 shops perceived

**Perceived Opportunity model**
- 175 shops perceived
## 4. Accessibility measures

### Comparison between Opportunity- and Utility-based measures

<table>
<thead>
<tr>
<th>Interpretation of the measure (i.e. unit of measure)</th>
<th>Utility-Based</th>
<th>Opportunity-Based</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gravity</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Random Utility</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Isochrones</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Perceived Opportunity</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Behavioral nature of the measure</th>
<th>Utility-Based</th>
<th>Opportunity-Based</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interpretation of the measure (i.e. unit of measure)</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Gravity</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Random Utility</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Isochrones</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Perceived Opportunity</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Model parameters estimation</th>
<th>Utility-Based</th>
<th>Opportunity-Based</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interpretation of the measure (i.e. unit of measure)</td>
<td>+*</td>
<td>+</td>
</tr>
<tr>
<td>Gravity</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Random Utility</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Isochrones</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Perceived Opportunity</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Independency from the zoning</th>
<th>Utility-Based</th>
<th>Opportunity-Based</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interpretation of the measure (i.e. unit of measure)</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Gravity</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Random Utility</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Isochrones</td>
<td>+*</td>
<td>-</td>
</tr>
<tr>
<td>Perceived Opportunity</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Quantitative comparison between different territorial areas</th>
<th>Utility-Based</th>
<th>Opportunity-Based</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interpretation of the measure (i.e. unit of measure)</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Gravity</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Random Utility</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Isochrones</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Perceived Opportunity</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>

* subject to conditions
basic references

Modeling Transportation and Land-Use Systems interaction

Concept of Accessibility, terminology and notations

Utility-based accessibility measures: Gravity models
basic references

Utility-based accessibility measures: Random Utility models (trip-based)

Utility-based accessibility measures: Random Utility models (activity-based)

Isochones accessibility measures

Perceived Opportunity measures
Cascetta et al. (2012). A behavioral indicator for cumulative accessibility to opportunities: definition and application to a real case. *Submitted to WCTR 2013*