# R Markdown: 04\_accessibility\_measures\_DA.Rmd

**Description:** To obtain the job accessibilities at the level of the dissemination area, calculated according to Hansen's measure (1956) and Soukhov et al. (2023).

In transportation research, accessibility is a spatial measure that refers to the potential of a population to reach spatially distributed opportunities. These often include destinations that are important to ensure that all members of society can lead plentiful, meaningful lives, such as jobs, parks, cultural activities, health services, education, and, in our case, jobs.

The result of the accessibility model is a value assigned to each spatial unit - usually at the origin, and in this case, the dissemination areas. Areas with high accessibility values have more connections and are closer to more opportunities, while areas with low values have the opposite.

Two measures are used to calculate accessibility: the measure of Hansen (1959) and the measure of Soukhov et al. (2023). The measure of Hansen (1959) considers that the sum of opportunities in each destination is gradually discounted as the travel cost increases. In this case, opportunities that area easier to access counts more for the measure. The measure is calculated according to the equation:

Where:

* *i* and *j*: set of spatial units in a region.
* : number of opportunities O at destinations j.
* f(cij): travel cost function, also called decay-function or impedance function.
* : accessibility score at the origin i being represented by the weighted sum of opportunities considering all destinations Oj.

The measure of Soukhov et al. (2023), named Spatial Availability (SA) is calculated with the following equation:

Where:

* is the number of spatially available opportunities from the perspective of the residents that live in the dissemination area i.
* is the number of opportunities O at the destination j.
* is a balancing factor that depends on the population and cost of travel in the system.

Being f(cij) the impedance function and Pi is the population at origin i, the balancing factor Fij consists of two components:

* , a population-based balancing factor that allocates opportunities to i in proportion to the size of the population of the different competing centers. With:
* and , an impedance-based balancing factor that represents the cost of reaching opportunities. With:
* We can obtain by:

## Files to be released:

* **Release file:** “HT\_mode\_release.csv”
* **Support file:** “HT\_mode\_support.csv”
* **Objective:** To investigate the levels of job accessibility Hansen type of each transportation mode for the chosen city at the level of the dissemination areas.
* **Variables:**
  + **PRCDDA:** Identification of the Dissemination area.
  + **PwMode:** Transportation mode.
  + **HT\_i:** Score of job accessibility that the residents from this DA have using the transportation mode mentioned in PwMode, using the Hansen measure.
  + **Respondents\_mode:** Number of respondents in this DA who commute by transportation mode.
  + **Population\_DA:** Total population of the DA.
* **Release file:** “HT\_general\_release.csv”
* **Support file:** “HT\_general\_support.csv”
* **Objective:** To investigate the levels of job accessibility Hansen type for the chosen city at the level of the dissemination areas.
* **Variables:**
  + **PRCDDA:** Identification of the Dissemination area.
  + **PwMode:** Transportation mode.
  + **SA\_i:** Score of job accessibility that the residents from this DA have, using the Hansen measure.
  + **Population\_DA:** Total population of the DA.
* **Release file:** “SA\_mode\_release.csv”
* **Support file:** “SA\_mode\_support.csv”
* **Objective:** To investigate the levels of job accessibility (spatial availability type) for the chosen city at the level of the dissemination areas.
* **Variables:**
  + **PRCDDA:** Identification of the Dissemination area.
  + **PwMode:** Transportation mode.
  + **SA\_im:** Score of job accessibility that the residents from this DA have using the transportation mode mentioned in PwMode, using the spatial availability measure.
  + **Respondents\_mode:** Number of respondents in this DA who commute by transportation mode.
  + **Population\_DA:** Total population of the DA.
* **Release file:** “SA\_general\_release.csv”
* **Support file:** “SA\_general\_support.csv”
* **Objective:** To investigate the levels of job accessibility (spatial availability type) for the chosen city at the level of the dissemination areas.
* **Variables:**
  + **PRCDDA:** Identification of the Dissemination area.
  + **PwMode:** Transportation mode.
  + **SA\_im:** Score of job accessibility that the residents from this DA have, using the spatial availability measure.
  + **Population\_DA:** Total population of the DA.

# R Markdown: 05\_visualizing\_accessibility\_measures\_DA.Rmd

**Description:** After obtaining the accessibility measures for the selected study area, this rmarkdown display how to visualize the measures in form of maps.

In transportation research, accessibility is a spatial measure that refers to the potential of a population to reach spatially distributed opportunities. These often include destinations that are important to ensure that all members of society can lead plentiful, meaningful lives, such as jobs, parks, cultural activities, health services, education, and, in our case, jobs.

The result of the accessibility model is a value assigned to each spatial unit - usually at the origin, and in this case, the dissemination areas. Areas with high accessibility values have more connections and are closer to more opportunities, while areas with low values have the opposite.

Two measures are used to calculate accessibility: the measure of Hansen (1959) and the measure of Soukhov et al. (2023). After calculating the job accessibility using both measures, we plotted maps to visualize the spatial indicators. All the outputs to be released from this rmarkdown are figures with accessibility indicators.

## Files to be released:

* **Release file:** “HT\_by\_mode\_DA.jpg”
* **Objective:** To visualize job accessibility levels (Hansen type) for each mode of transport for the chosen city at the level of the dissemination areas. Accessibility is represented on a continuous scale ranging from the minimum score (light purple) to the maximum score (dark purple).
* **Release file:** “SA\_by\_mode\_DA.jpg”
* **Objective:** To visualize job accessibility levels (spatial availability type) for each mode of transport for the chosen city at the level of the dissemination areas. Accessibility is represented on a continuous scale ranging from the minimum score (light orange) to the maximum score (dark orange).
* **Release file:** “HT\_SA\_DA.jpg”
* **Objective:** To visualize the total job accessibility level (Hansen and spatial availability types) for the chosen city at the level of the dissemination areas. Accessibility is represented on a continuous scale ranging from the minimum score (light purple to Hansen and light orange for spatial availability) to the maximum score (dark purple to Hansen and dark orange for spatial availability).
* **Release file:** “jobs\_SA\_per\_lf\_DA.jpg”
* **Objective:** To visualize the rate of count of jobs per person in labour force and the accessibility indicator per person in labour force in the chosen city at the level of the dissemination areas. The rates is represented on a continuous scales ranging from the minimum score (orange) to the maximum score (grey). Low scores indicate low number of jobs or job accessibility by person, while high scores indicate a high number of jobs or job accessibility by person.
* **Release file:** “lf\_jobs\_DA.jpg”
* **Objective:** To visualize the total number of people in labour force and total number of jobs in the chosen city at the level of the dissemination areas. The counts are represented on a continuous scales ranging from the minimum score (light red for labour force and light blue for jobs) to the maximum score (dark red for labour force and dark blue for jobs). Low scores indicate low number of labour force or jobs in the dissemination area, while high scores indicate a high number of labour force or jobs in the dissemination area.
* **Release file:** “Pop\_SA\_by\_DA.jpg”
* **Objective:** To visualize the share of the population (estimated) and accessibility in each mode of transport for the chosen city. The figure presents two vertical bar graphs, showing both shares. The purpose of this figure is to show how the level of accessibility is not necessarily uniform among the population and how car users tend to have more accessibility than other users.
* **Release file:** “total\_pop\_by\_mode\_DA.jpg”
* **Objective:** To visualize the estimative of total population who commute in each mode of transport for the chosen city at the level of the dissemination areas. The total estimated population is represented on a continuous scale ranging from the minimum score (light red) to the maximum score (dark red).

Observation about the estimated number of labour force.

In accessibility analyses, it is important not only to know the number of people in the labour force and the number of available jobs, but also the modes of transport people use to access these jobs. However, considering that the labour force includes unemployed people and even those working remotely, we need to estimate how many people would potentially use each mode of transport.

Thus, specifically for the mode analysis, the labour force variable is an estimate. This estimate is derived by calculating the proportion of trips made by each mode of transport in each dissemination area, then distributing non-commuters (people who either don't work or work from home) among these transport modes.

The estimation is performed using the following formula:

Labour\_force\_estimated = commuters + (transport mode percentage \* non-commuters)

For example: If dissemination area A has 100 people in the labour force, and only 50 of them commute to work using different modes of transport. Out of these 50:

* 25 commute by car (50% of commuters)
* 5 commute by walking (10%)
* 15 commute by public transit (30%)
* 10 commute by bicycle (20%)

The remaining 50 non-commuters in the labour force will be distributed as potential commuters across the transport modes based on these proportions. Thus:

* labour\_force\_estimated\_car = people who commute by car (25) + (car ratio) 0.5 \* total non-commuters (50) = 50
* labour\_force\_estimated\_walking = people who commute by walking (5) + (walking ratio) 0.1 \* total non-commuters (50) = 10
* labour\_force\_estimated\_cycling = people who commute by cycling (10) + (cycling ratio) 0.2 \* total non-commuters (50) = 20
* labour\_force\_estimated\_transit = people who commute by transit (15) + (transit ratio) 0.3 \* total non-commuters (50) = 30

Since this is an estimate, it is not possible to obtain an unweighted value for this variable.

# R Markdown: 06\_disadvantaged\_populations.Rmd

**Description:** After calculating job accessibility, in this R markdown we will identify disadvantaged population groups with lower job accessibility levels. Considering only on the labor force population, the median level of job accessibility (spatial availability) for youth (15 to 24 years old), women, low-income individuals, unemployed, people with disabilities, single-parent households, refugees, new immigrants, and racialized populations will be measured separately. For each group, the Mann-Whitney U test is applied to compare accessibility levels between the disadvantaged group and the corresponding non-disadvantaged group (for instance, comparing the accessibility levels of youth aged 15 to 24 years with adults older than 24 years). The Mann-Whitney U test is a non-parametric statistical test that compares two independent distributions to determine if they come from the same population. The result of a Mann-Whitney U test indicates whether two samples have the same median.

## Files to be released:

* **Release file:** “medians\_by\_pop\_group.jpg”
* **Objective:** To visualize differences in job accessibility medians (spatial availability) between disadvantaged and non-disadvantaged groups, considering different aspects of socioeconomic/demographic population groups. The figure displays horizontal bar plots with the median accessibility values by groups. Medians of accessibility are represented as bar plots differing by colour (light orange for non-disadvantaged and dark orange for disadvantaged population).
* **Release file:** “boxplot\_by\_pop\_group.jpg”
* **Objective:** To visualize distribution in job accessibility (spatial availability) between disadvantaged and non-disadvantaged groups, considering different aspects of socioeconomic/demographic population groups. The figure displays horizontal box plots of accessibility values by groups. Accessibility values are represented as bar plots differing by colour (green for non-disadvantaged and purple for disadvantaged population).
* **Release file:** “ratio\_medians\_by\_pop\_group.jpg”
* **Objective:** This figure compares median job‐accessibility (spatial availability) between disadvantaged and non‐disadvantaged socioeconomic groups. It uses horizontal bar plots to show the ratio of each group’s median accessibility relative to the other group. Light-blue bars represent non-disadvantaged populations; dark-blue bars represent disadvantaged populations. For each group, we calculate a “rate” by dividing its median accessibility by the median accessibility of the opposite group (e.g., the disadvantaged group’s rate = disadvantaged median / non-disadvantaged median, and vice-versa). Ratios above or below 1 highlight inequities, with values above 1 indicating higher accessibility for the group in question relative to its counterpart.
* **Release file:** “medians\_by\_racial\_group.jpg”
* **Objective:** To visualize differences in median job accessibility (spatial availability) between disadvantaged and non-disadvantaged populations, focusing exclusively on visible minority groups. According to the census codebook, visible minority refers to whether a person is considered part of a visible minority group as defined by the Employment Equity Act, which defines visible minorities as: “Persons, other than Aboriginal peoples, who are non-Caucasian in race or non-white in colour.” The visible minority population primarily includes the following groups: South Asian, Chinese, Black, Filipino, Arab, Latin American, Southeast Asian, West Asian, Korean, and Japanese. The figure displays horizontal bar plots showing the median job accessibility values by visible minority group. Bar colours indicate group status: Orange for non-disadvantaged populations; Green for disadvantaged populations.
* **Release file:** “ratio\_medians\_by\_racial\_group.jpg”
* **Objective:** To illustrate the relative differences in median job accessibility (spatial availability) between disadvantaged and non-disadvantaged populations within visible minority groups. This figure presents horizontal bar plots showing ratios of median accessibility values. For each visible minority group, two ratios are calculated:
  + Disadvantaged group ratio: median accessibility of the disadvantaged group divided by that of the non-disadvantaged group.
  + Non-disadvantaged group ratio: median accessibility of the non-disadvantaged group divided by that of the disadvantaged group.

Bar colours distinguish group status: Green represents the disadvantaged population; Orange represents the non-disadvantaged population. A ratio equal to 1 indicates parity in median accessibility between the groups. Ratios above or below 1 highlight inequities, with values above 1 indicating higher accessibility for the group in question relative to its counterpart. This visualization provides a comparative view of accessibility disparities across different visible minority populations, as defined by the Employment Equity Act.

* **Release file:** “means\_by\_pop\_group.jpg”
* **Objective:** To visualize differences in mean values of job accessibility (spatial availability) between disadvantaged and non-disadvantaged groups, considering different aspects of socioeconomic/demographic population groups. The figure displays horizontal bar plots with the mean accessibility values by groups. Means of accessibility are represented as bar plots differing by colour (light orange for non-disadvantaged and dark orange for disadvantaged population).
* **Release file:** “ratio\_means\_by\_pop\_group.jpg”
* **Objective:** This figure compares mean job‐accessibility (spatial availability) between disadvantaged and non‐disadvantaged socioeconomic groups. It uses horizontal bar plots to show the ratio of each group’s mean accessibility relative to the other group. Light-blue bars represent non-disadvantaged populations; dark-blue bars represent disadvantaged populations. For each group, we calculate a “rate” by dividing its mean accessibility by the mean accessibility of the opposite group (e.g., the disadvantaged group’s rate = disadvantaged mean / non-disadvantaged mean, and vice-versa). Ratios above or below 1 highlight inequities, with values above 1 indicating higher accessibility for the group in question relative to its counterpart.
* **Release file:** “means\_by\_racial\_group.jpg”
* **Objective:** To visualize differences in mean job accessibility (spatial availability) between disadvantaged and non-disadvantaged populations, focusing exclusively on visible minority groups. According to the census codebook, visible minority refers to whether a person is considered part of a visible minority group as defined by the Employment Equity Act, which defines visible minorities as: “Persons, other than Aboriginal peoples, who are non-Caucasian in race or non-white in colour.” The visible minority population primarily includes the following groups: South Asian, Chinese, Black, Filipino, Arab, Latin American, Southeast Asian, West Asian, Korean, and Japanese. The figure displays horizontal bar plots showing the mean job accessibility values by visible minority group. Bar colours indicate group status: Orange for non-disadvantaged populations; Green for disadvantaged populations.
* **Release file:** “ratio\_means\_by\_racial\_group.jpg”
* **Objective:** To illustrate the relative differences in mean job accessibility (spatial availability) between disadvantaged and non-disadvantaged populations within visible minority groups. This figure presents horizontal bar plots showing ratios of mean accessibility values. For each visible minority group, two ratios are calculated:
  + Disadvantaged group ratio: mean accessibility of the disadvantaged group divided by that of the non-disadvantaged group.
  + Non-disadvantaged group ratio: mean accessibility of the non-disadvantaged group divided by that of the disadvantaged group.

Bar colours distinguish group status: Green represents the disadvantaged population; Orange represents the non-disadvantaged population. A ratio equal to 1 indicates parity in mean accessibility between the groups. Ratios above or below 1 highlight inequities, with values above 1 indicating higher accessibility for the group in question relative to its counterpart. This visualization provides a comparative view of accessibility disparities across different visible minority populations, as defined by the Employment Equity Act.

* **Release file:** “summary\_pop\_table.csv”
* **Support file:** “summary\_pop\_table\_support.csv”
* **Objective:** To investigate the median levels of job accessibility (spatial availability type) for different population groups in the selected city.
* **Variables:**
  + **Variable:** Name of the census variable used to differentiate the population groups.
  + **Description:** Description of the census variable.
  + **Category:** Population group category, obtained from the census variable.
  + **Equity:** If the group is considered as disadvantaged or non-disadvantaged based on the transportation literature.
  + **Total\_pop:** Total population in this group category (Sum of weights (CompW1)).
  + **Total\_pop\_rounded:** Rounded total population in this group category (Sum of weights (CompW1), rounded in multiple of 5).
  + **Respondents:** Number of respondents in this group category (Count of respondents).
  + **Respondent\_PCD: Number of the respondents in the selected city (Count of respondents)**
  + **Median:** Median value of job accessibility for this population group.
  + **Mean:** Average value of job accessibility for this population group.
  + **Median\_rate:** median accessibility of a group category divided by that of the other group category (within same census variable).
  + **Mean\_rate:** mean accessibility of a group category divided by that of the other group category (within same census variable).
  + **PCD:** Census Division Code (City) – same values for all rows.
  + **Population\_PCD:** Total Population in the City/Census Division – same values for all rows.
* **Release file:** “summary\_vmin\_table.csv”
* **Support file:** “summary\_vmin\_table\_support.csv”
* **Objective:** To investigate the median levels of job accessibility (spatial availability type) between disadvantaged and non-disadvantaged populations, focusing exclusively on visible minority groups. According to the census codebook, visible minority refers to whether a person is considered part of a visible minority group as defined by the Employment Equity Act, which defines visible minorities as: “Persons, other than Aboriginal peoples, who are non-Caucasian in race or non-white in colour.” The visible minority population primarily includes the following groups: South Asian, Chinese, Black, Filipino, Arab, Latin American, Southeast Asian, West Asian, Korean, and Japanese.
* **Variables:**
  + **Variable:** Name of the census variable used to differentiate the population groups (in this case, all the same).
  + **Description:** Description of the subgroup analyzed.
  + **Category:** Visible minority group category, obtained from the census variable (DVisMin).
  + **Equity:** If the group is considered as disadvantaged or non-disadvantaged based on the transportation literature.
  + **Total\_pop:** Total population in this group category (Sum of weights (CompW1)).
  + **Total\_pop\_rounded:** Rounded total population in this group category (Sum of weights (CompW1), rounded in multiple of 5).
  + **Respondents:** Number of respondents in this group category (Count of respondents).
  + **Respondent\_PCD: Number of the respondents in the selected city (Count of respondents)**
  + **Median:** Median value of job accessibility for this population group.
  + **Mean:** Average value of job accessibility for this population group.
  + **Median\_rate:** median accessibility of a group category divided by that of the other group category (within same census variable).
  + **Mean\_rate:** mean accessibility of a group category divided by that of the other group category (within same census variable).
  + **PCD:** Census Division Code (City) – same values for all rows.
  + **Population\_PCD:** Total Population in the City/Census Division – same values for all rows.
* **Release file:** “pvalue\_table.csv”
* **Support file:** “pvalue\_table\_support.csv”
* **Objective:** To investigate the median levels of job accessibility (spatial availability type) between disadvantaged and non-disadvantaged populations is statistically significant (p-value < 0.05), applying Mann-Whitney U test.
* **Variables:**
  + **Variable:** Name of the census variable used to differentiate the population groups.
  + **Description:** Description of the census variable.
  + **Disadvantaged:** Disadvantaged population group according to the transportation literature.
  + **Population\_group:** Total population used in the Mann-Whitney U test statistic.
  + **P\_value:** P-value obtained in the Mann-Whitney U test.
  + **Significance:** If the p-value of the Mann-Whitney U test is significant (p-value < 0.5).
  + **PCD:** Census Division Code (City) – same values for all rows.
  + **Population\_PCD:** Total Population in the City/Census Division – same values for all rows.
  + **Respondent\_PCD: Number of the respondents in the selected city (Count of respondents)**