

# *Visualizing accessibility measures (Dissemination area level)*

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## *Introduction*

This Rmarkdown file is part of the **CommuteCA** package. This package was created in conjunction with the office of the *Research Data Center at McMaster University*, the *Sherman Centre for Digital Scholarship* and the *Mobilizing Justice*<sup>1</sup>.

The **CommuteCA** R package was created to develop standardized methods for transport analysis in research, particularly for analysis using the *2021 Census of Population* from Statistics Canada. We focused our efforts on the *Commuting Reference Guide*, which provides valuable variables and information on commuting for the Canadian population aged 15 and older living in private households.

After obtaining the accessibility measures for our study area, in this R Markdown we will visualize the measure in form of maps.

## *Suggested Readings*

- Soukhov, Anastasia, Antonio Paez, Christopher D Higgins, and Moataz Mohamed. 2023."Introducing Spatial Availability, a Singly-Constrained Measure of Competitive Accessibility." *Plos One* 18 (1): e0278468.
- Soukhov, A., Páez, A. (2024). Accessibility analysis for planning applications (Report No. MJ-A2-0002). Mobilizing Justice. <https://github.com/soukhova/MJ-Accessibility-Blogs>
- Pereira, Rafael H. M.; Herszenhut, Daniel. Introduction to urban accessibility: a practical guide with R. Rio de Janeiro: Ipea, 2023. 152 p. ISBN: 978-65-5635-065-3. DOI: <http://dx.doi.org/9786556350653>.
- Soukhov A, Tarriño-Ortiz J, Soria-Lara JA, Páez A (2024) Multi-modal spatial availability: A singly-constrained measure of accessibility considering multiple modes. *PLoS ONE* 19(2): e0299077. <https://doi.org/10.1371/journal.pone.0299077>

## *Data*

The data used in this R markdown is the output of the previous R markdown, in which we calculated accessibility and spatial availability for our study area. The methodology described here is applicable to the results obtained through the synthetic or original census sur-

<sup>1</sup> The Mobilizing Justice project is a multidisciplinary and multi-sector collaboration with the objective of understand and address transportation poverty in Canada and to improve the well-being of Canadians at risk of transport poverty. The Social Sciences and Humanities Research Council (SSHRC) has provided funding for the project, which was created by an unprecedented alliance of academics from various Canadian provinces and institutions, transportation firms, and nonprofit organizations

vey. Additionally, we will use the dissemination areas (DA) geometry, available in this package, to plot maps of the study area.

*Let's code!*

Load the packages:

```
library(CommuteCA)
library(dplyr) # A Grammar of Data Manipulation
library(ggplot2) # Create Elegant Data Visualizations Using the Grammar of Graphics
library(RColorBrewer) # color schemes for maps (and other graphics) designed
library(scales) # for scaling data
library(sf) # support for simple features, a standardized way to encode spatial vector data
library(tmap) # thematic maps
library(tidyr) # tidying data
library(here)
```

Setting the folder with the accessibility measures:

```
code <- "PCD3520"
measures_folder <- paste0(here::here(),"/data-raw/output/", code, "/DA/accessibility-measures/")

HT_mode <- read.csv(paste0(measures_folder, "HT_mode_original.csv"))
HT <- read.csv(paste0(measures_folder, "HT_general_original.csv"))
SA_mode <- read.csv(paste0(measures_folder, "SA_mode_original.csv"))
SA <- read.csv(paste0(measures_folder, "SA_general_original.csv"), fileEncoding = "UTF-8-BOM")
land_use_mode <- read.csv(paste0(measures_folder, "land_use_mode_original_DA.csv"))
land_use_general <- read.csv(paste0(measures_folder, "land_use_general_original_DA.csv"))
```

Reading the DA geometries:

```
directory_spatial_files <- paste0(here(), "/data-raw/output/PCD3520/spatial-files/") # Update this address
dissemination_areas <- st_read(paste0(directory_spatial_files, "dissemination_areas.shp"))

## Reading layer `dissemination_areas' from data source
##   `C:\Bruno\CommuteCA\data-raw\output\PCD3520\spatial-files\dissemination_areas.shp'
##   using driver 'ESRI Shapefile'
## Simple feature collection with 3743 features and 6 fields
## Geometry type: MULTIPOLYGON
## Dimension:      XY
## Bounding box:  xmin: -79.63931 ymin: 43.58095 xmax: -79.11542 ymax: 43.85547
## Geodetic CRS:  WGS 84
```

Reading the census\_divisions geometries:

```
census_divisions <- st_read(paste0(directory_spatial_files, "census_divisions.shp"))
```

```

## Reading layer `census_divisions` from data source
##   `C:\Bruno\CommuteCA\data-raw\output\PCD3520\spatial-files\census_divisions.shp'
##   using driver `ESRI Shapefile'
## Simple feature collection with 1 feature and 4 fields
## Geometry type: MULTIPOLYGON
## Dimension:      XY
## Bounding box:  xmin: -79.63931 ymin: 43.58095 xmax: -79.11543 ymax: 43.85547
## Geodetic CRS:  WGS 84

Merging the dissemination_areas with the accessibility measures
tables:

names(dissemination_areas)[1] <- "PRCDDA"

mode_metrics_da <-
  expand.grid(PRCDDA = unique(dissemination_areas$PRCDDA), PwMode = unique(HT_mode$PwMode)) %>%
  full_join(dissemination_areas, by = "PRCDDA") %>%
  mutate(PRCDDA = as.numeric(PRCDDA)) %>%
  full_join(HT_mode, by = c("PRCDDA", "PwMode")) %>%
  full_join(SA_mode, by = c("PRCDDA", "PwMode")) %>%
  full_join(land_use_mode[,c("PRCDDA", "PwMode", "labour_force")], by = c("PRCDDA", "PwMode"))

mode_metrics_da <- mode_metrics_da %>%
  mutate(
    HT_im = ifelse(is.na(HT_im), 0, HT_im),
    SA_im = ifelse(is.na(SA_im), 0, SA_im),
    labour_force = ifelse(is.na(labour_force), 0, labour_force)
  )

mode_metrics_da_sf <- st_as_sf(mode_metrics_da, crs = st_crs(dissemination_areas))

Preparing the tables to plot the maps:

# Hansen
HT_metrics_da <- dissemination_areas %>%
  mutate(PRCDDA = as.numeric(PRCDDA)) %>%
  full_join(HT, by = "PRCDDA") %>%
  full_join(land_use_general, by ="PRCDDA")

HT_metrics_da <- HT_metrics_da %>%
  mutate(
    HT_i = ifelse(is.na(HT_i), 0, HT_i),
    labour_force = ifelse(is.na(labour_force), 0, labour_force),
    jobs = ifelse(is.na(jobs), 0, jobs)
  )

```

```
# Spatial Availability
SA_metrics_da <- dissemination_areas %>%
  mutate(PRCDDA = as.numeric(PRCDDA)) %>%
  full_join(SA, by = "PRCDDA") %>%
  full_join(land_use_general, by ="PRCDDA")

SA_metrics_da <- SA_metrics_da %>%
  mutate(
    SA_i = ifelse(is.na(SA_i), 0, SA_i),
    labour_force = ifelse(is.na(labour_force), 0, labour_force),
    jobs = ifelse(is.na(jobs), 0, jobs)
  )
```

### *Visualizing the accessibility measures with maps*

Creating a directory to export the figures:

```
diretorio_export_figures <- paste0(here(),"/data-raw/output/PCD3520/DA/accessibility-figures/") # Updat

if(!dir.exists(diretorio_export_figures)){
  dir.create(diretorio_export_figures, recursive = TRUE)}
```

Plotting the count of people within the labour force and count of job opportunities in each dissemination\_areas:

```
labour_force_plot <- tm_shape(HT_metrics_da) +
  tm_polygons("labour_force",
              style = "cont",
              palette = "Reds",
              title = " ",
              border.col = NULL) +
  tm_shape(census_divisions) +
  tm_borders("black", lwd=0.5) +
  tm_scale_bar(position = c("right", "bottom"))+
  tm_compass(position = c("left", "top"), size=1.0) +
  tm_layout(legend.outside = FALSE,
            legend.position = c("left", "bottom"),
            panel.labels = "Labour force")

jobs_plot <- tm_shape(SA_metrics_da) +
  tm_polygons("jobs",
              style = "cont",
              palette = "Blues",
              title = " ",
              border.col = NULL) +
```

```

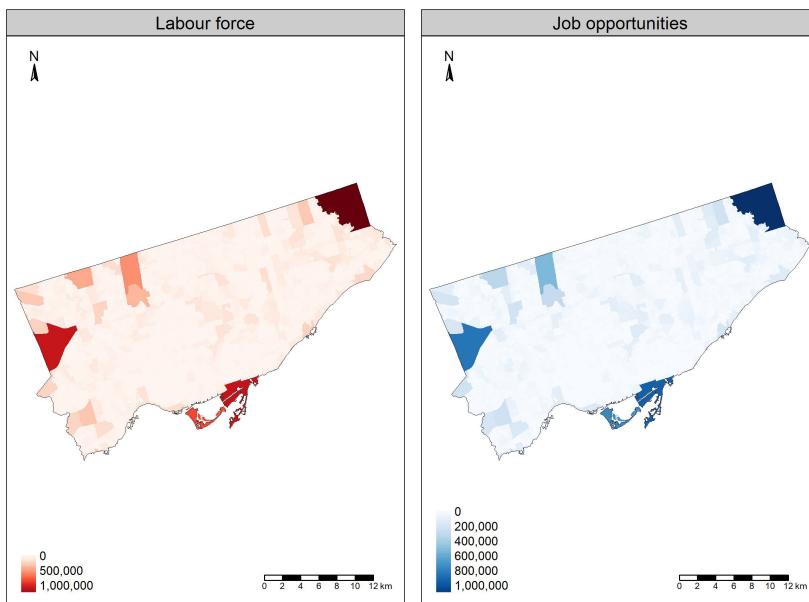
tm_shape(census_divisions) +
  tm_borders("black", lwd=0.5) +
  tm_scale_bar(position = c("right", "bottom"))+
  tm_compass(position = c("left", "top"), size=1.0) +
  tm_layout(legend.outside = FALSE,
            legend.position = c("left", "bottom"),
            panel.labels = "Job opportunities")

lf_jobs_DA <- tmap_arrange(labour_force_plot, jobs_plot, ncol = 2)

tmap_save(lf_jobs_DA,
          paste0(diretorio_export_figures,"lf_jobs_DA.jpg"),
          width = 20,
          height = 15,
          units = "cm",
          dpi = 300)

knitr::include_graphics(paste0(diretorio_export_figures,"/lf_jobs_DA.jpg"))

```



Plotting the accessibility measures:

```

ht_plot <- tm_shape(HT_metrics_da) +
  tm_polygons("HT_i",
              style = "cont",
              palette = "Purples",
              title = " ",
              border.col = NULL) +
  tm_shape(census_divisions) +

```

```

tm_borders("black", lwd=0.5) +
tm_scale_bar(position = c("right", "bottom"))+
tm_compass(position = c("left", "top"), size=1.0) +
tm_layout(legend.outside = FALSE,
          legend.position = c("left", "bottom"),
          panel.labels = "Hansen-type accessibility of jobs")

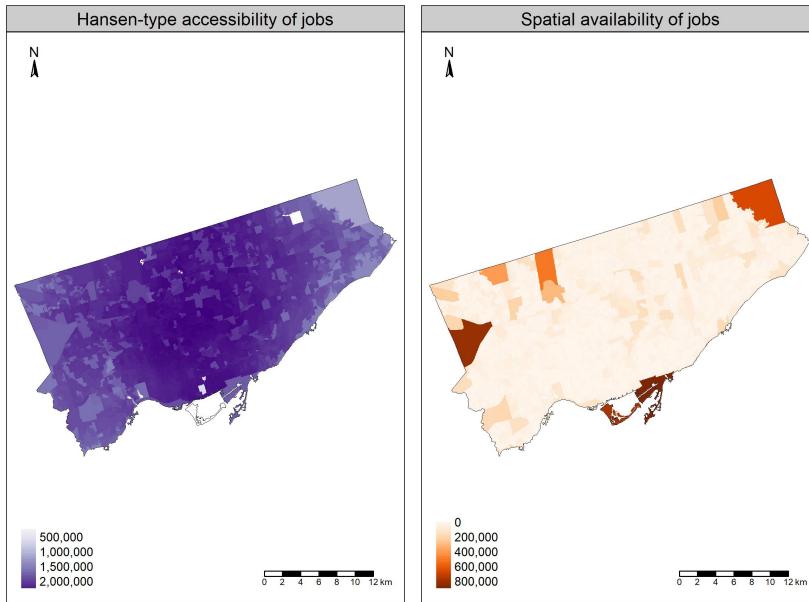
sa_plot <- tm_shape(SA_metrics_da) +
  tm_polygons("SA_i",
              style = "cont",
              palette = "Oranges",
              title = " ",
              border.col = NULL) +
  tm_shape(census_divisions) +
  tm_borders("black", lwd=0.5) +
  tm_scale_bar(position = c("right", "bottom"))+
  tm_compass(position = c("left", "top"), size=1.0) +
  tm_layout(legend.outside = FALSE,
            legend.position = c("left", "bottom"),
            panel.labels = "Spatial availability of jobs")

HT_SA_DA <- tmap_arrange(ht_plot, sa_plot, ncol = 2)

tmap_save(HT_SA_DA,
          paste0(diretorio_export_figures,"HT_SA_DA.jpg"),
          width = 20,
          height = 15,
          units = "cm",
          dpi = 300)

knitr::include_graphics(paste0(diretorio_export_figures,"/HT_SA_DA.jpg"))

```



Plotting the jobs per labour force, and the spatial availability per labour force:

```
HT_metrics_da$jobs_per_lf <- HT_metrics_da$jobs / HT_metrics_da$labour_force

HT_metrics_da <- HT_metrics_da %>%
  mutate(jobs_per_lf = case_when(
    jobs == 0 & labour_force == 0 ~ 0,
    labour_force == 0 & jobs != 0 ~ jobs,
    TRUE ~ jobs_per_lf))

jobs_per_labour_force <- tm_shape(HT_metrics_da) +
  tm_polygons("jobs_per_lf",
    style = "fixed",
    breaks = c(0, 0.5, 1, 2.5, 5, 10, Inf),
    palette = "RdYlGn",
    title = " ",
    border.col = NULL) +
  tm_shape(census_divisions) +
  tm_borders("black", lwd=0.5) +
  tm_scale_bar(position = c("right", "bottom"))+
  tm_compass(position = c("left", "top"), size=1.0) +
  tm_layout(legend.outside = FALSE,
            legend.position = c("left", "bottom"),
            panel.labels = "Jobs per person in labour fource")

SA_metrics_da$SA_per_lf <- SA_metrics_da$jobs / SA_metrics_da$labour_force
```

```

SA_metrics_da <- SA_metrics_da %>%
  mutate(SA_per_lf = case_when(
    jobs == 0 & labour_force == 0 ~ 0,
    labour_force == 0 & jobs != 0 ~ jobs,
    TRUE ~ SA_per_lf))

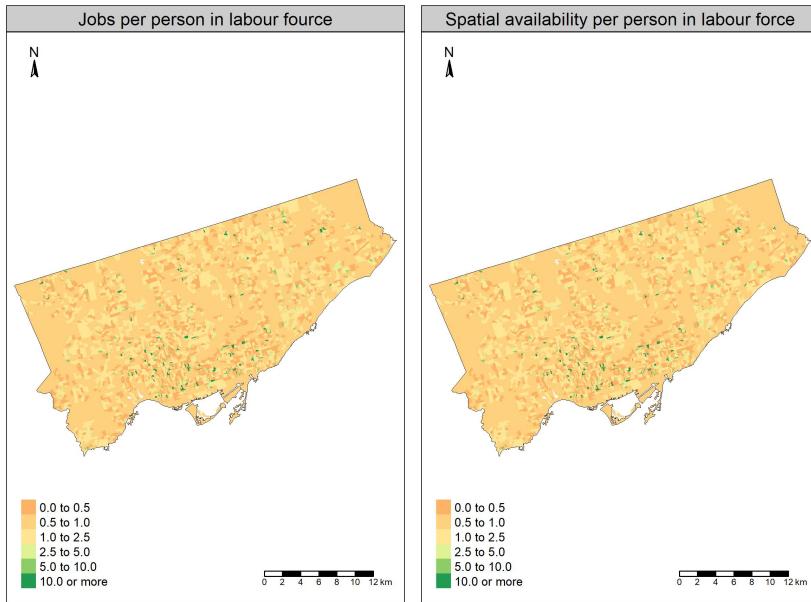
SA_per_labour_force <- tm_shape(SA_metrics_da) +
  tm_polygons("SA_per_lf",
    style = "fixed",
    breaks = c(0, 0.5, 1, 2.5, 5, 10, Inf),
    palette = "RdYlGn",
    title = " ",
    border.col = NULL) +
  tm_shape(census_divisions) +
  tm_borders("black", lwd=0.5) +
  tm_scale_bar(position = c("right", "bottom"))+
  tm_compass(position = c("left", "top"), size=1.0) +
  tm_layout(legend.outside = FALSE,
            legend.position = c("left", "bottom"),
            panel.labels = "Spatial availability per person in labour force")

jobs_SA_per_lf_DA <- tmap_arrange(jobs_per_labour_force, SA_per_labour_force, ncol = 2)

tmap_save(jobs_SA_per_lf_DA,
          paste0(diretorio_export_figures,"jobs_SA_per_lf_DA.jpg"),
          width = 20,
          height = 15,
          units = "cm",
          dpi = 300)

knitr::include_graphics(paste0(diretorio_export_figures,"/jobs_SA_per_lf_DA.jpg"))

```



*Visualizing the accessibility measures by transportation modes with maps*

Visualizing the total labour force by transportation mode:

```
total_pop_by_mode_DA <- tm_shape(mode_metrics_da_sf) +
  tm_polygons("labour_force",
    style = "cont",
    palette = "Reds",
    title = " ",
    border.col = NULL) +
  tm_facets(by = "PwMode") +
  tm_scale_bar(position = c("right", "bottom")) +
  tm_compass(position = c("left", "top"), size = 1.0) +
  tm_shape(census_divisions) +
  tm_borders("black", lwd=0.5)

tmap_save(total_pop_by_mode_DA,
  paste0(diretorio_export_figures,"total_pop_by_mode_DA.jpg"),
  width = 20,
  height = 20,
  units = "cm",
  dpi = 300)

knitr::include_graphics(paste0(diretorio_export_figures,"/total_pop_by_mode_DA.jpg"))
```

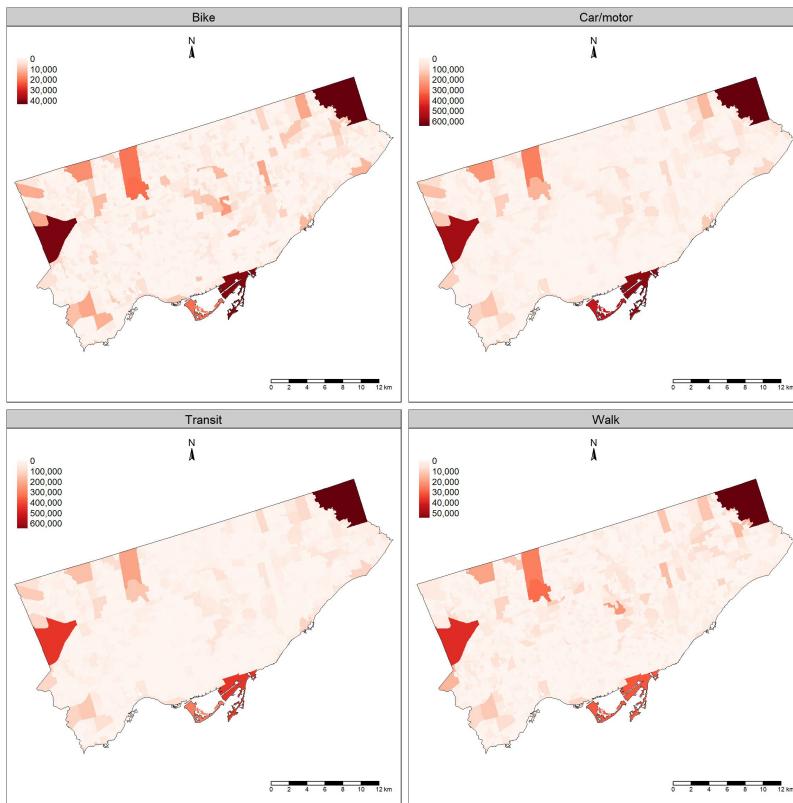


Visualizing the total labour force by transportation mode (with independent legends for each facet):

```
total_pop_by_mode_DA_2 <- tm_shape(mode_metrics_da_sf) +
  tm_polygons("labour_force",
    style = "cont",
    palette = "Reds",
    title = " ",
    border.col = NULL) +
  tm_facets(by = "PwMode", free.scales = TRUE) +
  tm_scale_bar(position = c("right", "bottom")) +
  tm_compass(position = c("left", "top"), size = 1.0) +
  tm_shape(census_divisions) +
  tm_borders("black", lwd=0.5)

tmap_save(total_pop_by_mode_DA_2,
  paste0(diretorio_export_figures,"total_pop_by_mode_DA_2.jpg"),
  width = 20,
  height = 20,
  units = "cm",
  dpi = 300)

knitr::include_graphics(paste0(diretorio_export_figures,"/total_pop_by_mode_DA_2.jpg))
```



Visualizing the Hansen-type accessibility by transportation mode:

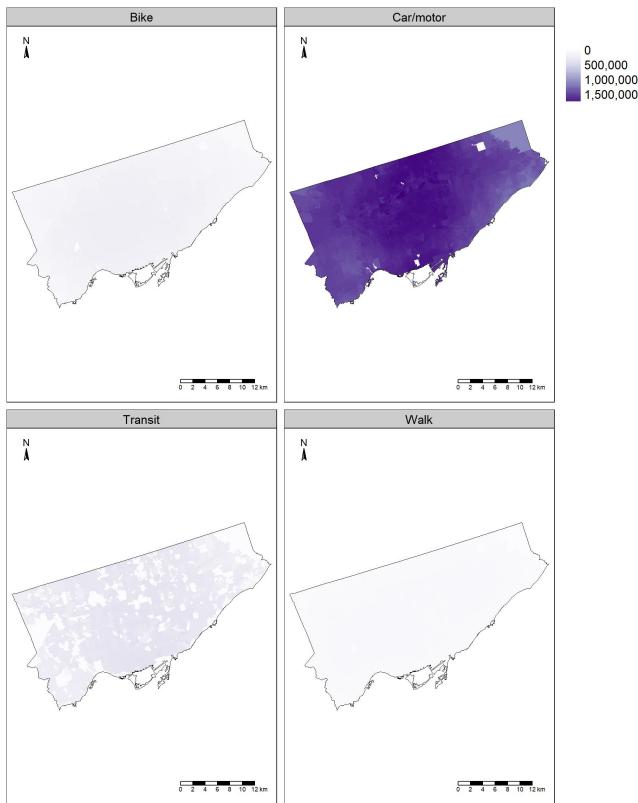
```

HT_by_mode_DA <- tm_shape(mode_metrics_da_sf) +
  tm_polygons("HT_im",
    style = "cont",
    palette = "Purples",
    title = " ",
    border.col = NULL) +
  tm_scale_bar(position = c("right", "bottom"))+
  tm_compass(position = c("left", "top"), size=1.0) +
  tm_facets(by="PwMode") +
  tm_shape(census_divisions) +
  tm_borders("black", lwd=0.5)

tmap_save(HT_by_mode_DA,
  paste0(diretorio_export_figures,"HT_by_mode_DA.jpg"),
  width = 20,
  height = 20,
  units = "cm",
  dpi = 300)

knitr::include_graphics(paste0(diretorio_export_figures,"/HT_by_mode_DA.jpg"))

```

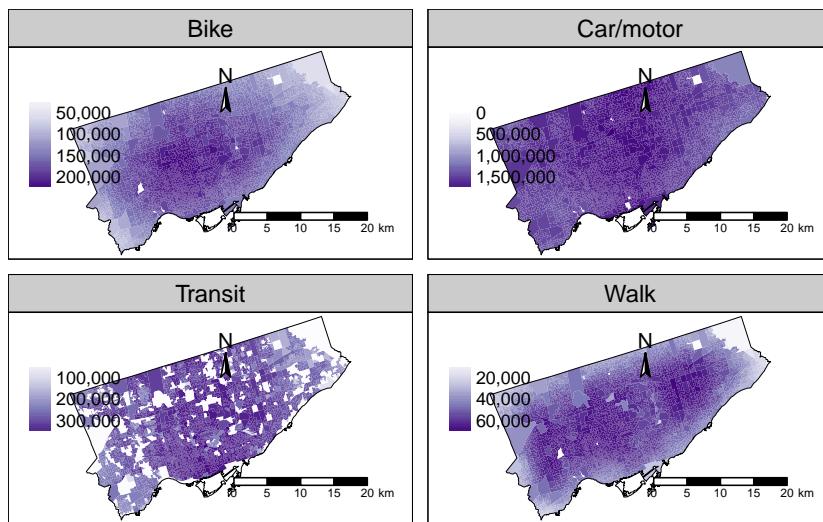


Visualizing the Hansen-type accessibility by transportation mode  
(with independent legends for each facet):

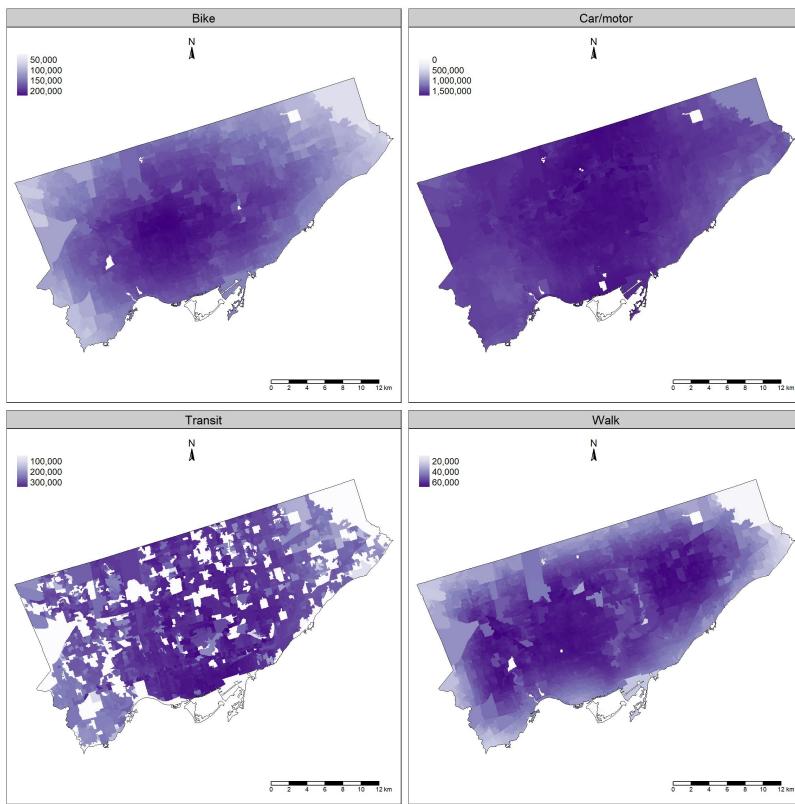
```
HT_by_mode_DA_2 <- tm_shape(mode_metrics_da_sf) +
  tm_polygons("HT_im",
    style = "cont",
    palette = "Purples",
    title = " ",
    border.col = NULL) +
  tm_scale_bar(position = c("right", "bottom"))+
  tm_compass(position = c("left", "top"), size=1.0) +
  tm_facets(by = "PwMode", free.scales = TRUE) +
  tm_shape(census_divisions) +
  tm_borders("black", lwd=0.5)

tmap_save(HT_by_mode_DA_2,
  paste0(diretorio_export_figures,"HT_by_mode_DA_2.jpg"),
  width = 20,
  height = 20,
  units = "cm",
  dpi = 300)
```

HT\_by\_mode\_DA\_2



```
knitr::include_graphics(paste0(diretorio_export_figures,"/HT_by_mode_DA_2.jpg"))
```



Visualizing the Spatial Availability by transportation mode:

```
SA_by_mode_DA <- tm_shape(mode_metrics_da_sf) +
  tm_polygons("SA_im",
```

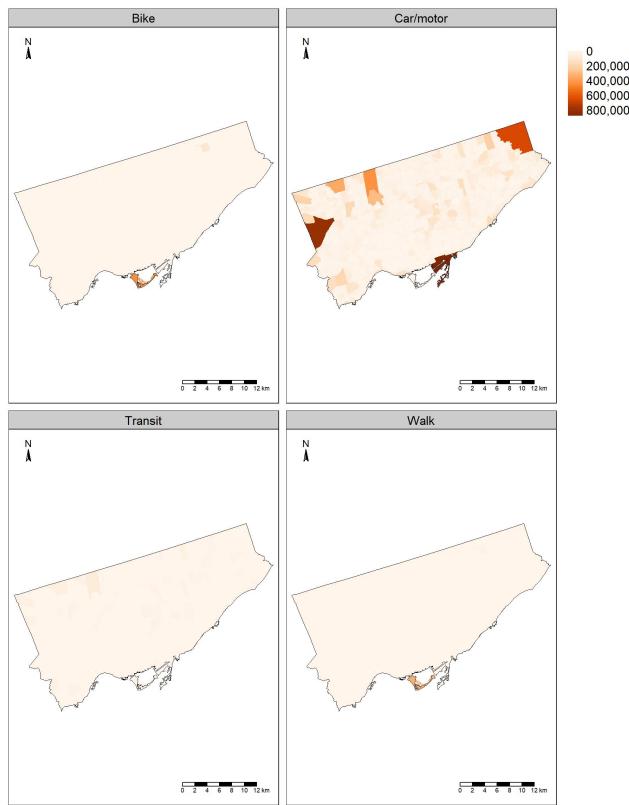
```

style = "cont",
palette = "Oranges",
title = " ",
border.col = NULL) +
tm_scale_bar(position = c("right", "bottom"))+
tm_compass(position = c("left", "top"), size=1.0) +
tm_facets(by="PwMode") +
tm_shape(census_divisions) +
tm_borders("black", lwd=0.5)

tmap_save(SA_by_mode_DA,
          paste0(diretorio_export_figures,"SA_by_mode_DA.jpg"),
          width = 20,
          height = 20,
          units = "cm",
          dpi = 300)

knitr::include_graphics(paste0(diretorio_export_figures,"/SA_by_mode_DA.jpg"))

```



Visualizing the Spatial Availability by transportation mode (with independent legends for each facet):

```
SA_by_mode_DA_2 <- tm_shape(mode_metrics_da_sf) +
```

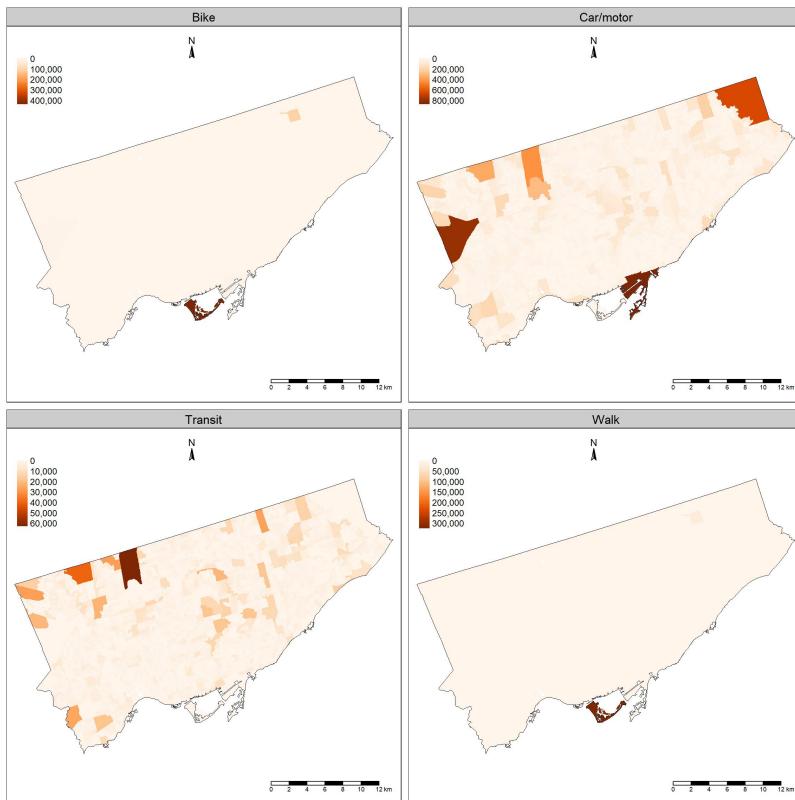
```

tm_polygons("SA_im",
            style = "cont",
            palette = "Oranges",
            title = " ",
            border.col = NULL) +
tm_scale_bar(position = c("right", "bottom"))+
tm_compass(position = c("left", "top"), size=1.0) +
tm_facets(by = "PwMode", free.scales = TRUE) +
tm_shape(census_divisions) +
tm_borders("black", lwd=0.5)

tmap_save(SA_by_mode_DA_2,
          paste0(diretorio_export_figures,"SA_by_mode_DA_2.jpg"),
          width = 20,
          height = 20,
          units = "cm",
          dpi = 300)

knitr::include_graphics(paste0(diretorio_export_figures,"/SA_by_mode_DA_2.jpg"))

```



Computing of the labour force by transportation mode:

```
total_pop <- sum(land_use_mode$labour_force)
```

```

total_SA <- sum(mode_metrics_da$SA_im)

modal_SA_percents <- mode_metrics_da %>%
  group_by(PwMode) %>%
  dplyr::summarize(total_labour_fource = sum(labour_force),
                   SA_mean = mean(SA_im),
                   SA_sum = sum(SA_im),
                   perc_SA = sum(SA_im)/total_SA,
                   perc_pop= sum(labour_force)/total_pop)

modal_SA_long <- modal_SA_percents %>%
  pivot_longer(cols = c(perc_SA, perc_pop), names_to = "perc", values_to = "measure")

```

Visualizing the share of labour force and spatial availability by transportation mode:

```

Pop_SA_by_mode_DA <- ggplot(modal_SA_long,
  aes(x = perc, y = measure, fill = PwMode, label = measure %>% percent(accuracy = 0.1))) +
  scale_x_discrete(labels = c(
    "perc_SA" = paste("Spatial Availability\n by Mode\n(Total: ", formatC(total_SA, format = "f", digits = 0),
    "perc_pop" = paste("Population\n by Mode\n(Total: ", formatC(total_pop, format = "f", digits = 0,
  geom_col(width = 0.5) +
  geom_text(position = position_stack(vjust=0.5), color="black") +
  theme_classic() +
  theme(axis.ticks = element_blank(),
        axis.title = element_blank(),
        axis.line = element_blank(),
        axis.text.y = element_blank(),
        axis.text = element_text(color="black"),
        legend.position = "bottom",
        legend.title = element_blank())

ggsave(file = paste0(diretorio_export_figures,"Pop_SA_by_mode_DA.jpg"),
       plot = Pop_SA_by_mode_DA,
       width = 8,
       height = 10,
       units = "cm",
       dpi = 300)

knitr::include_graphics(paste0(diretorio_export_figures,"/Pop_SA_by_mode_DA.jpg"))

```

