ETH zürich

The Roadmap for Mobility Behavior Analysis: From Surveys to Travel Choices and Accessibility

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tmp Transportation and Mobility Planning

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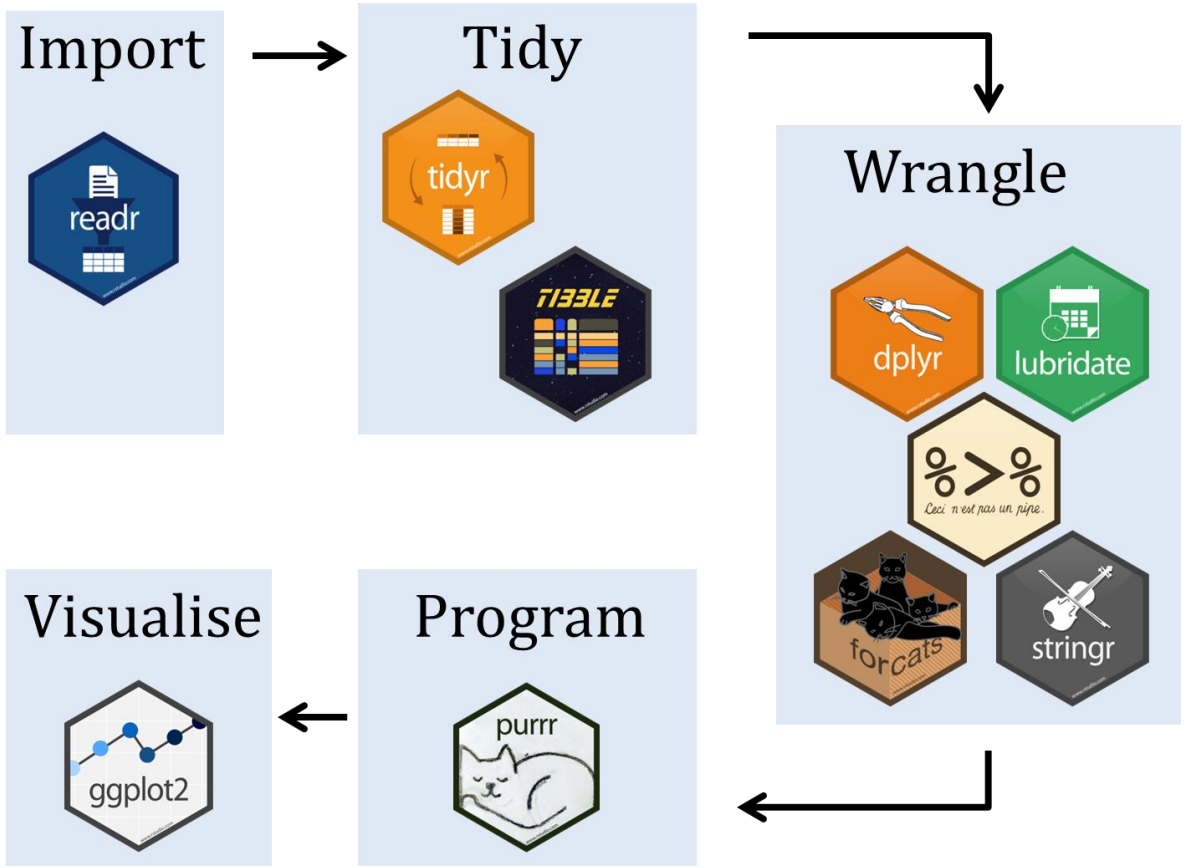
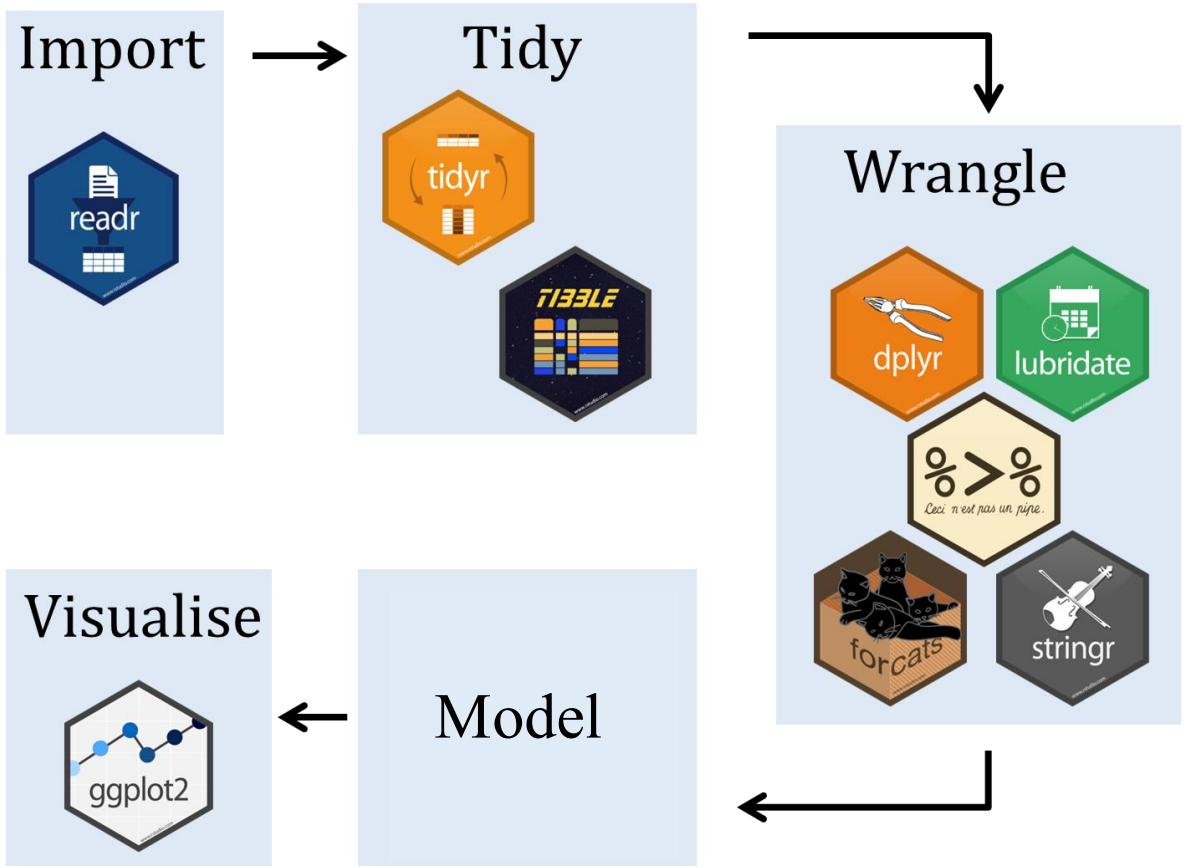
The Basics

The Basics



Source: AJ Smit, Amieroh Abrahams & Robert W Schlegel **Intro R Workshop: Data Manipulation, Analysis, and Visualisation** (https://ajsmit.github.io/Intro_R_Official/index.html)

The Basics



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The Basics

Household travel survey data

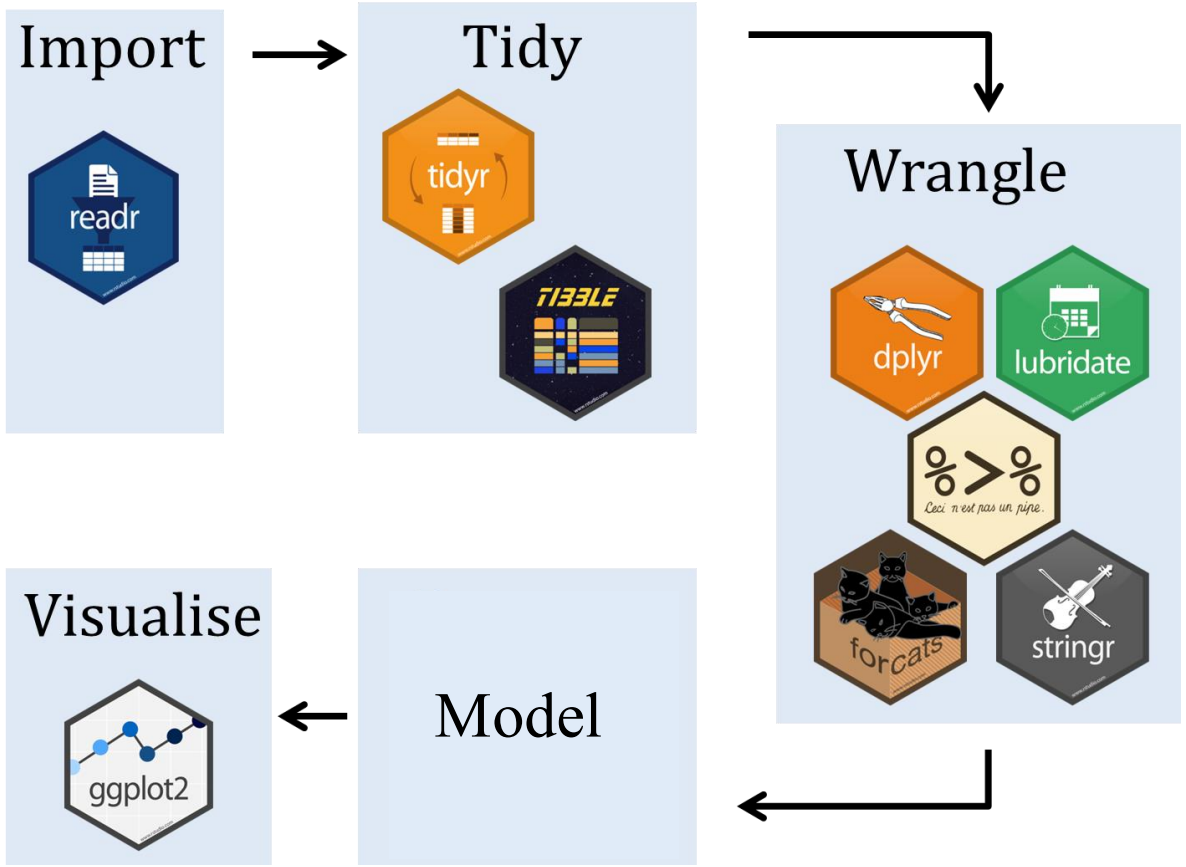
Household data
- household size
- Number of children
- Household income
- Number of cars
…

Match by household-id

Person data
- Age
- Gender
- Employment
- Mobility tools
…

Match by person-id

Trip data
- Start & End (coord.)
- Start & End (time)
- Mode
…



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The Interdisciplinarity of Transport Research

The Interdisciplinarity of Transport Research

- Transport is an inherently interdisciplinary field

- We borrow methods from various other disciplines, including geography and geosciences, environmental sciences, sociology, physics & computer science.

The Interdisciplinarity of Transport Research

Example: Impact of Extreme Heat on Intra-Person Changes in Walking and Cycling Behavior

- **Data**
  - Travel Behavior: Longitudinal GPS-based travel diary (TimeUse+) beginning 17 July 2022.
  - Temperature: Spatial temperature distribution through kriging.
- **Exposures**
  - Tropical night: daily minimum temperature ≥ 20 °C
  - Heat stress: maximum daily temperature ≥ 35 °C
- **Outcomes**
  - Number of walking and cycling trips
  - Distance (km per day) traveled for walking and cycling

The Interdisciplinarity of Transport Research

Example: Impact of Extreme Heat on Intra-Person Changes in Walking and Cycling Behavior

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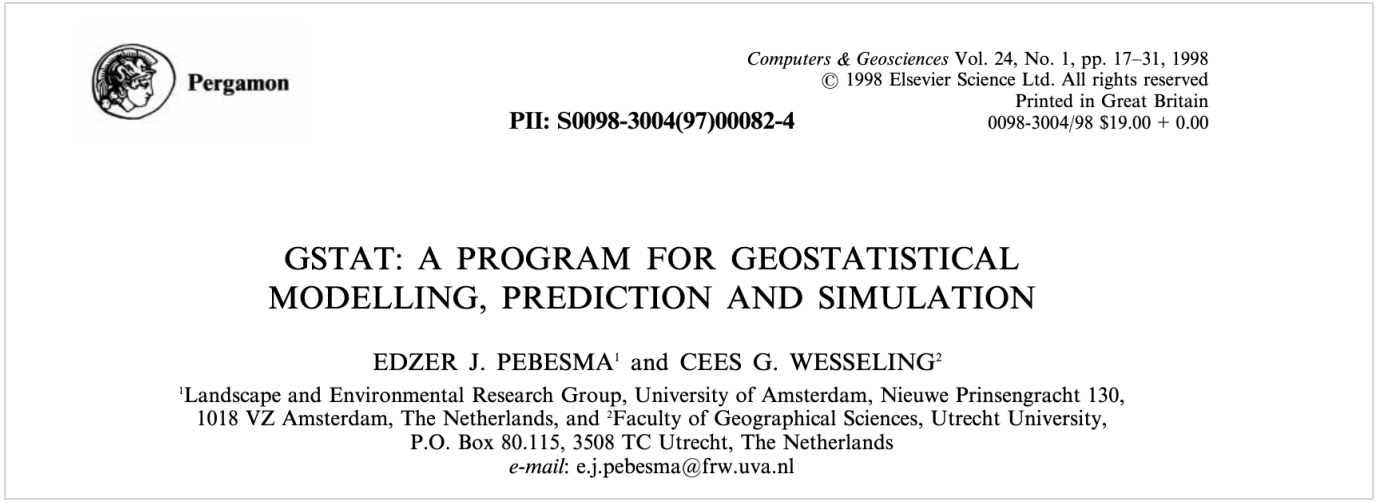

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GSTAT: A PROGRAM FOR GEOSTATISTICAL MODELLING, PREDICTION AND SIMULATION

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The Interdisciplinarity of Transport Research

Example: Impact of Extreme Heat on Intra-Person Changes in Walking and Cycling Behavior

- **Data**
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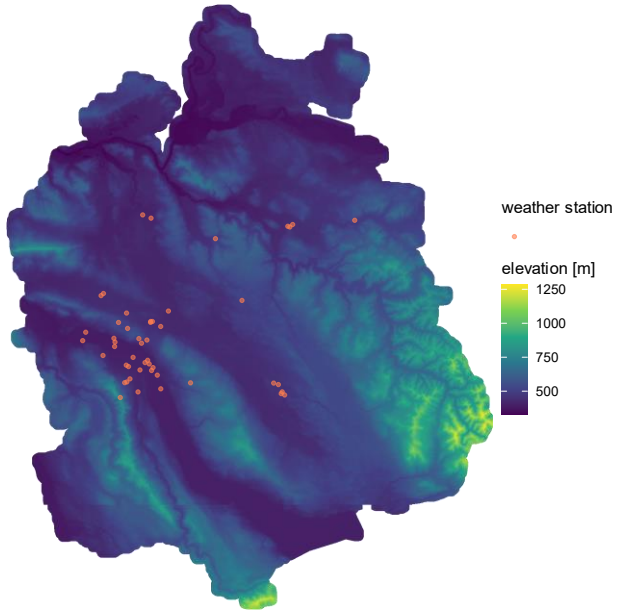
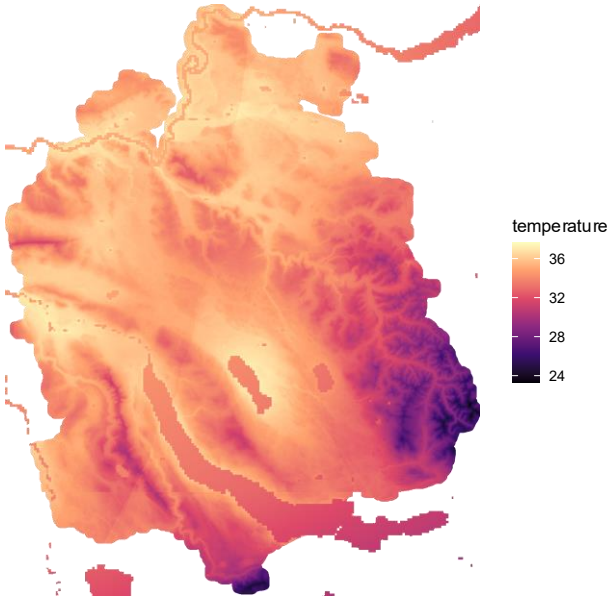
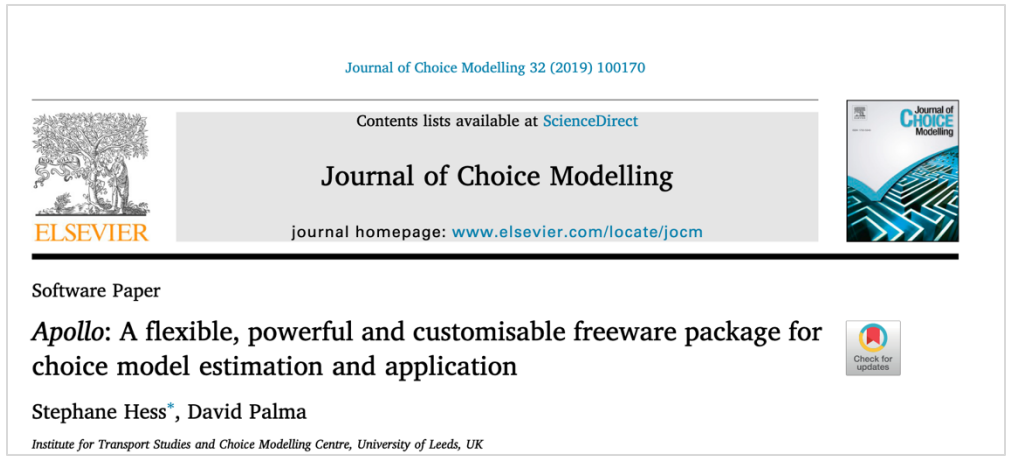




Choice Modeling

Choice Modeling



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Software Paper

Apollo: A flexible, powerful and customisable freeware package for choice model estimation and application

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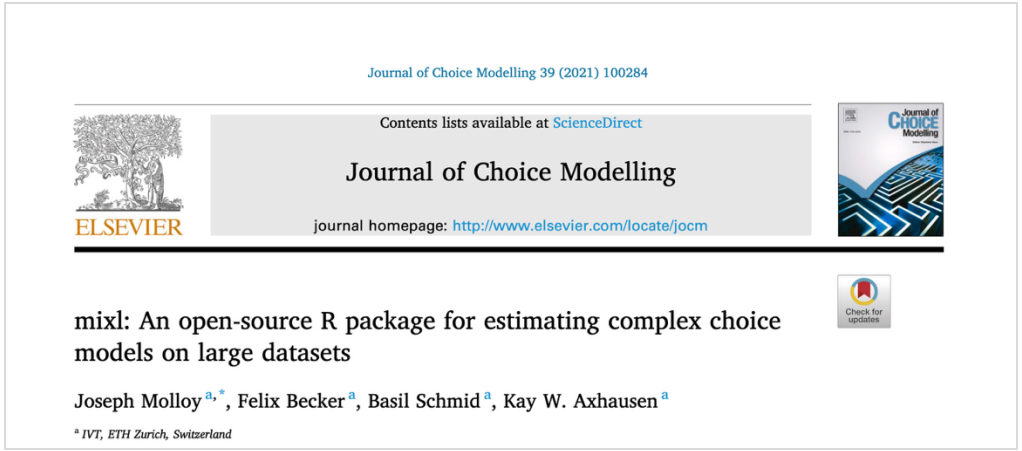

Journal of Choice Modelling 39 (2021) 100284

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journal homepage: http://www.elsevier.com/locate/jocm

mixl: An open-source R package for estimating complex choice models on large datasets

Joseph Molloy[a,*], Felix Becker[a], Basil Schmid[a], Kay W. Axhausen[a]

[a] *IVT, ETH Zurich, Switzerland*

Choice Modeling using Apollo

More info on the package here: https://apollochoicemodelling.com/

- Given their own and mode characteristics, which mode will individuals choose?

	ID	av_car	av_bus	av_air	av_rail	time_car	cost_car	time_bus	cost_bus	access_bus	time_air	cost_air	access_air	service_air	time_rail	cost_rail	access_rail	female	income	choice
1	1	0	0	1	1	0	0	0	0	0	50	80	55	0	140	55	5	0	46705	4
2	1	0	0	1	1	0	0	0	0	0	70	80	45	0	170	45	20	0	46705	4
17	2	1	1	0	1	345	40	345	30	15	0	0	0	0	130	55	20	1	50123	2
18	2	1	1	0	1	345	45	345	25	20	0	0	0	0	130	45	10	1	50123	2
33	3	0	0	1	1	0	0	0	0	0	90	65	40	0	130	35	20	1	67589	4
34	3	0	0	1	1	0	0	0	0	0	60	110	40	0	170	35	15	1	67589	4

Choice Modeling using Apollo

More info on the package here: https://apollochoicemodelling.com/

- Given their own and mode characteristics, which mode will individuals choose?

```r
library(apollo)
# ################################################################# #
#### LOAD LIBRARY AND DEFINE CORE SETTINGS                       ####
# ################################################################# #

### Initialise code
apollo_initialise()

### Set core controls
apollo_control = list(
  modelDescr      = "Simple MNL model on mode choice RP data",
  indivID         = "ID",
  outputDirectory = "output"
)

# ################################################################# #
#### LOAD DATA AND APPLY ANY TRANSFORMATIONS                     ####
# ################################################################# #

### Loading data from package
### if data is to be loaded from a file (e.g. called data.csv),
### the code would be: database = read.csv("data.csv",header=TRUE)
database = apollo_modeChoiceData
### for data dictionary, use ?apollo_modeChoiceData

### Use only RP data
database = subset(database,database$RP==1)
```

Choice Modeling using Apollo

More info on the package here: https://apollochoicemodelling.com/

- Given their own and mode characteristics, which mode will individuals choose?

```
29  # ################################################################# #
30  #### DEFINE MODEL PARAMETERS                                     ####
31  # ################################################################# #
32
33  ### Vector of parameters, including any that are kept fixed in estimation
34  apollo_beta=c(asc_car   = 0,
35                asc_bus   = 0,
36                asc_air   = 0,
37                asc_rail  = 0,
38                b_tt_car  = 0,
39                b_tt_bus  = 0,
40                b_tt_air  = 0,
41                b_tt_rail = 0,
42                b_access  = 0,
43                b_cost    = 0)
44
45  ### Vector with names (in quotes) of parameters to be kept fixed at their start
46  apollo_fixed = c("asc_car")
47
48  # ################################################################# #
49  #### GROUP AND VALIDATE INPUTS                                   ####
50  # ################################################################# #
51
52  apollo_inputs = apollo_validateInputs()
```

Choice Modeling using Apollo

More info on the package here: https://apollochoicemodelling.com/

- Given their own and mode characteristics, which mode will individuals choose?

```r
# ################################################################# #
#### DEFINE MODEL AND LIKELIHOOD FUNCTION                        ####
# ################################################################# #

apollo_probabilities=function(apollo_beta, apollo_inputs, functionality="estimate"){

  ### Attach inputs and detach after function exit
  apollo_attach(apollo_beta, apollo_inputs)
  on.exit(apollo_detach(apollo_beta, apollo_inputs))

  ### Create list of probabilities P
  P = list()

  ### List of utilities: these must use the same names as in mnl_settings, order is irrelevant
  V = list()
  V[["car"]]  = asc_car  + b_tt_car  * time_car                          + b_cost * cost_car
  V[["bus"]]  = asc_bus  + b_tt_bus  * time_bus  + b_access * access_bus  + b_cost * cost_bus
  V[["air"]]  = asc_air  + b_tt_air  * time_air  + b_access * access_air  + b_cost * cost_air
  V[["rail"]] = asc_rail + b_tt_rail * time_rail + b_access * access_rail + b_cost * cost_rail

  ### Define settings for MNL model component
  mnl_settings = list(
    alternatives  = c(car=1, bus=2, air=3, rail=4),
    avail         = list(car=av_car, bus=av_bus, air=av_air, rail=av_rail),
    choiceVar     = choice,
    utilities     = V
  )

  ### Compute probabilities using MNL model
  P[["model"]] = apollo_mnl(mnl_settings, functionality)

  ### Take product across observation for same individual
  P = apollo_panelProd(P, apollo_inputs, functionality)

  ### Prepare and return outputs of function
  P = apollo_prepareProb(P, apollo_inputs, functionality)
  return(P)
}

# ################################################################# #
#### MODEL ESTIMATION                                            ####
# ################################################################# #

model = apollo_estimate(apollo_beta, apollo_fixed, apollo_probabilities, apollo_inputs)
```

- Given their own and mode characteristics, which mode will individuals choose?

Model Results:

Estimates:

	Estimate	s.e.	t.rat.(0)	Rob.s.e.	Rob.t.rat.(0)
asc_car	0.000000	NA	NA	NA	NA
asc_bus	0.474676	1.018672	0.4660	0.990600	0.4792
asc_air	1.629072	0.827435	1.9688	0.817513	1.9927
asc_rail	0.944534	0.803551	1.1755	0.795160	1.1879
b_tt_car	-0.003646	0.001555	-2.3455	0.001568	-2.3251
b_tt_bus	-0.008846	0.002624	-3.3711	0.002616	-3.3815
b_tt_air	-0.020685	0.006599	-3.1346	0.006424	-3.2202
b_tt_rail	-0.011239	0.004386	-2.5626	0.004468	-2.5157
b_access	-0.011466	0.006430	-1.7832	0.006297	-1.8210
b_cost	-0.033947	0.003295	-10.3035	0.003180	-10.6755

Choice Modeling using Apollo

More info on the package here: https://apollochoicemodelling.com/

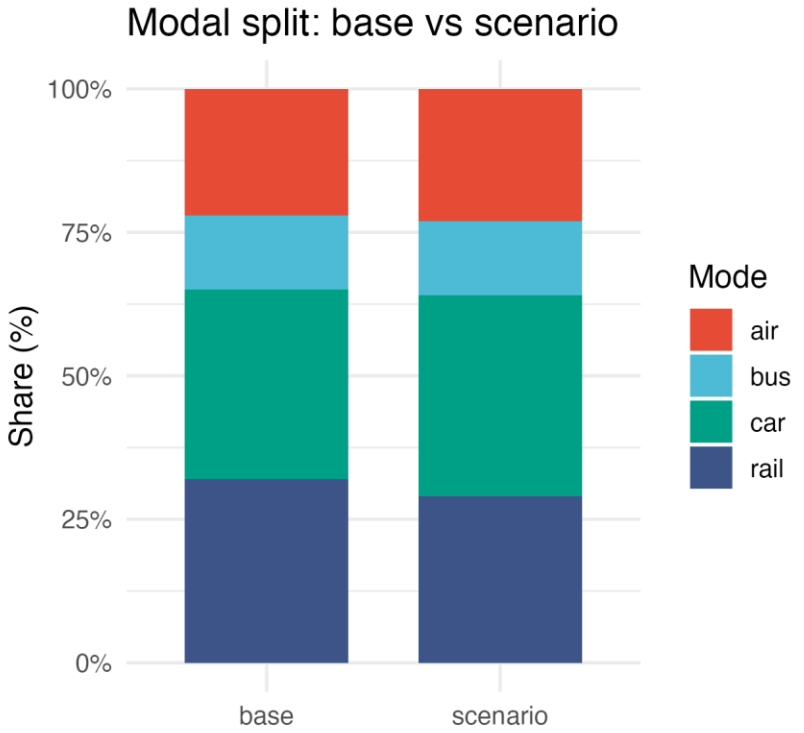
- Model predictions:

```
Running predictions from model using parameter estimates...
Prediction at user provided parameters
             car    bus    air   rail
Aggregate 332.00 126.00 215.00 327.00
Average     0.33   0.13   0.21   0.33
```

- Scenario: Increased rail costs

```
### Now imagine the cost for rail increases by 1%
database$cost_rail = 1.1*database$cost_rail
### Rerun predictions with the new data
apollo_inputs = apollo_validateInputs()
predictions_new = apollo_prediction(model, apollo_probabilities, apollo_inputs)
```

```
> predictions_new = apollo_prediction(model, apollo_probabilities, apollo_inputs)
Running predictions from model using parameter estimates...
Prediction at user provided parameters
             car    bus    air   rail
Aggregate 349.17 133.87 226.19 290.77
Average     0.35   0.13   0.23   0.29
```



OpenStreetMaps and Routing

Downloading OpenStreetMap Data with osmextract

```r
#canton network
zurich_lines = oe_get("Zurich", download_directory = "./data")
#clip network to city boundaries in terminal:
#osmium extract -b 8.47,47.32,8.60,47.42 openstreetmap_fr_zurich-latest.osm.pbf -o zurich_city_clip.osm.pbf

z_lines <- oe_read("./data/zurich_city_clip.osm.pbf")

z_network <- z_lines |>
  filter(highway %in% c("motorway",
                        "primary", "primary_link",
                        "secondary", "secondary_link",
                        "tertiary", "tertiary_link")) |>
  ggplot() +
  annotation_map_tile(type = "cartolight", zoom = 13) +
  geom_sf(color = "navyblue", alpha = .6) +
  theme_void()
```

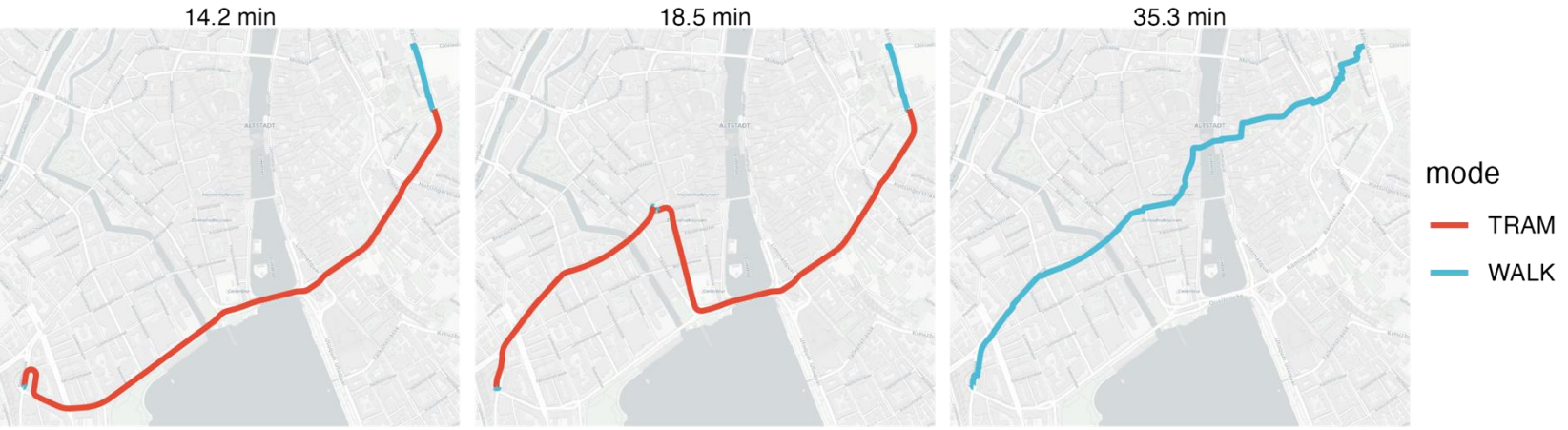
Routing with r5r

- Necessary input:
  - OSM network (.pbf file) → mandatory
  - GTFS data (.zip file) → optional
  - Digital Elevation Model → optional

```r
options(java.parameters = "-Xmx8G")

library(r5r)
library(data.table)


r5r_network <- r5r::build_network(data_path = "./data")

# extract OSM network
street_net <- r5r::street_network_to_sf(r5r_network)

# extract public transport network
transit_net <- r5r::transit_network_to_sf(r5r_network)

poi <- data.frame(
  id = c("UZH", "ETH_poly", "ETH_hoengg", "HB", "BHF_enge"),
  lat = c(47.37472, 47.376174, 47.408259, 47.37753, 47.36422),
  lon = c( 8.54932,  8.546599,  8.507384,  8.54198,  8.53140)
)

# set inputs
origins <- poi[1,]
destinations <- poi[5,]
mode <- c("WALK", "TRANSIT")
max_walk_time <- 60 # minutes
departure_datetime <- as.POSIXct("09-10-2025 21:00:00", format = "%d-%m-%Y %H:%M:%S")

det <- detailed_itineraries(
  r5r_network,
  origins = origins,
  destinations = destinations,
  mode = mode,
  departure_datetime = departure_datetime,
  max_walk_time = max_walk_time,
  shortest_path = FALSE
)
```

- Routing output

```
> det |> st_drop_geometry() |>
+   select(-c(route)) |> print()
   from_id from_lat from_lon    to_id   to_lat to_lon option departure_time total_duration total_distance segment   mode segment_duration  wait distance total_duration_str
    <char>    <num>    <num>   <char>    <num>  <num>  <int>         <char>          <num>          <int>   <int> <char>            <num> <num>    <int>              <char>
1:     UZH 47.37472  8.54932 BHF_enge 47.36422 8.5314      1       21:00:00           35.3           2074       1   WALK             35.3   0.0     2074           35.3 min
2:     UZH 47.37472  8.54932 BHF_enge 47.36422 8.5314      2       21:05:58           14.2           2306       1   WALK              4.3   0.0      250           14.2 min
3:     UZH 47.37472  8.54932 BHF_enge 47.36422 8.5314      2       21:05:58           14.2           2306       2   TRAM              8.3   1.5     2050           14.2 min
4:     UZH 47.37472  8.54932 BHF_enge 47.36422 8.5314      2       21:05:58           14.2           2306       3   WALK              0.1   0.0        6           14.2 min
5:     UZH 47.37472  8.54932 BHF_enge 47.36422 8.5314      3       21:09:44           18.5           2698       1   WALK              4.3   0.0      250           18.5 min
6:     UZH 47.37472  8.54932 BHF_enge 47.36422 8.5314      3       21:09:44           18.5           2698       2   TRAM              7.2   1.6     1525           18.5 min
7:     UZH 47.37472  8.54932 BHF_enge 47.36422 8.5314      3       21:09:44           18.5           2698       3   WALK              0.6   0.0       33           18.5 min
8:     UZH 47.37472  8.54932 BHF_enge 47.36422 8.5314      3       21:09:44           18.5           2698       4   TRAM              3.5   1.1      877           18.5 min
9:     UZH 47.37472  8.54932 BHF_enge 47.36422 8.5314      3       21:09:44           18.5           2698       5   WALK              0.3   0.0       13           18.5 min
```




```
route_plot <- ggplot() +
  annotation_map_tile(type = "cartolight", zoom = 16) +
  geom_sf(data = det, aes(color = mode), linewidth = 1) +
  facet_wrap(. ~ total_duration_str) +
  scale_color_npg() +
  theme_void()
```

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