Conducting experiments, recording output and analysing results of agent-based modelling for social scientists

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UK Data Service

13 February 2020

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ABM for social scientists – webinar series

- ABM: An Intro
  - – Jan 16, 2020, recording available
- ABM: Adding Data
  - – Jan 30, 2020
- **ABM: Experiments and Output**
  - – **Feb 13, 2020**

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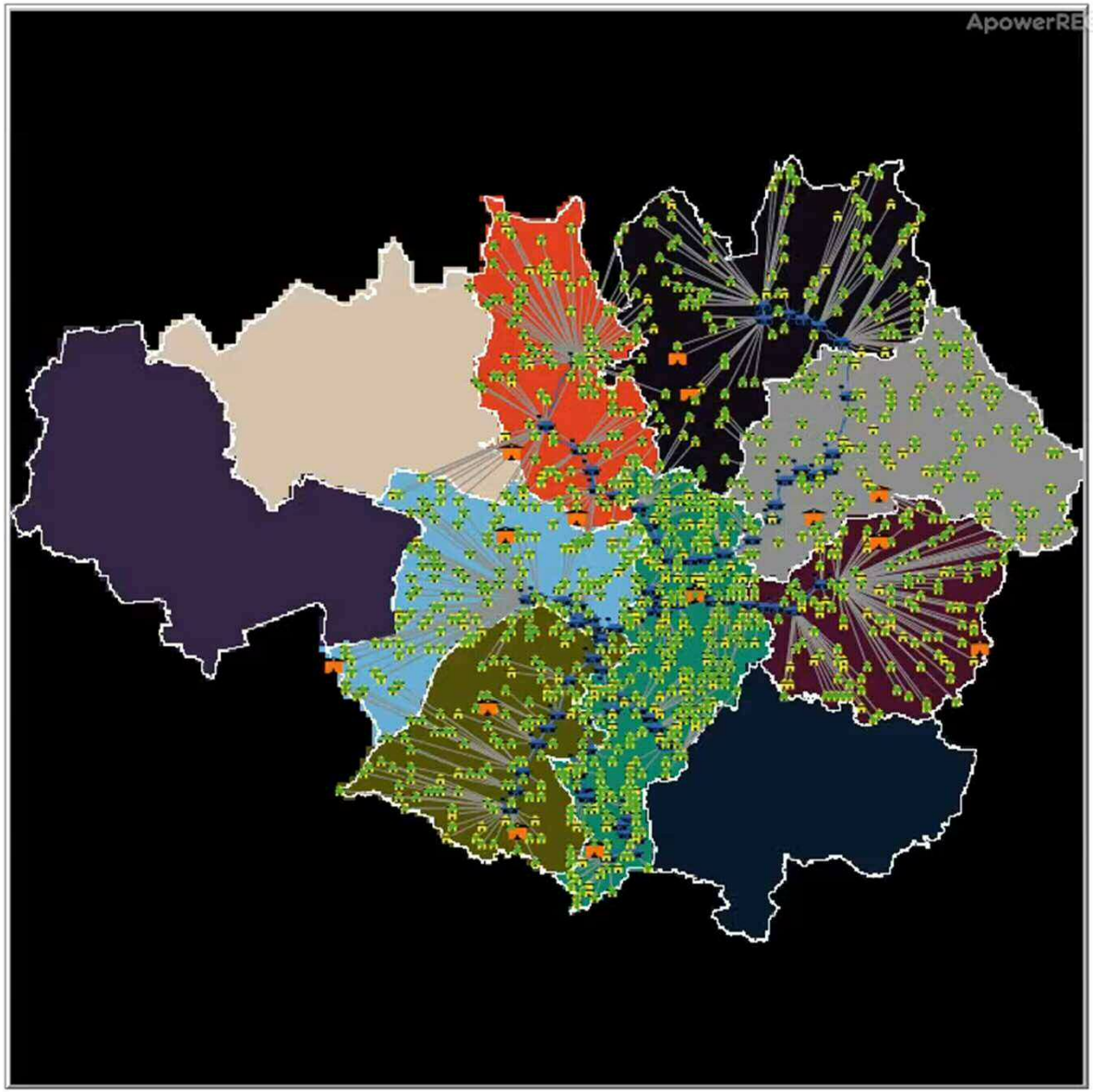
A moment to revisit the "Tram commute" model



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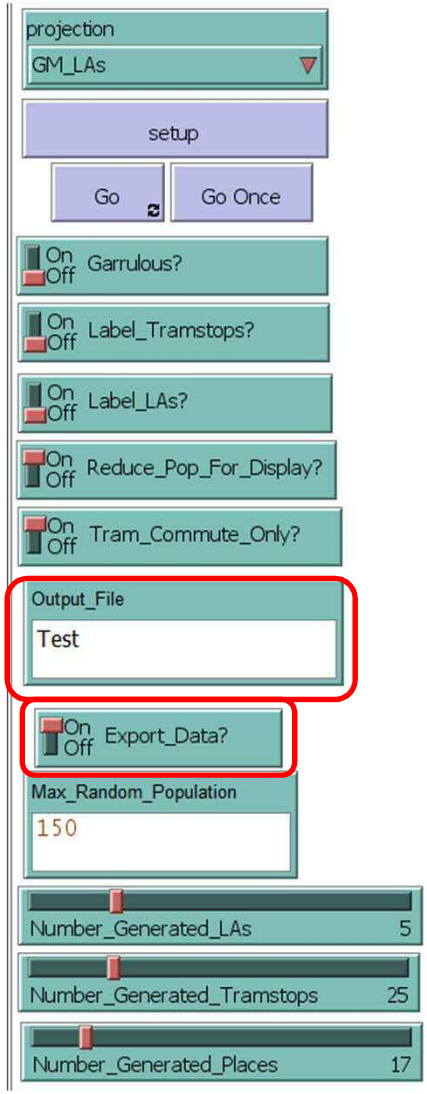
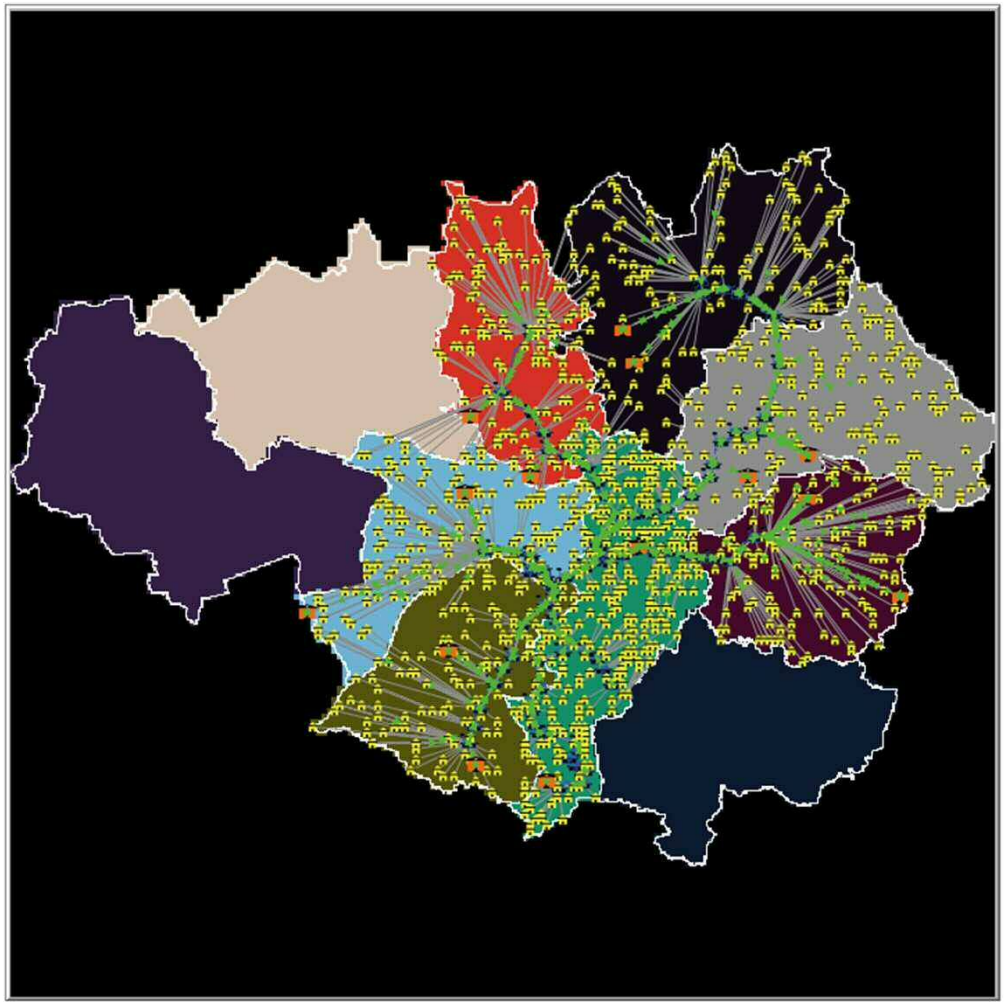
Revisit the "Tram commute model“





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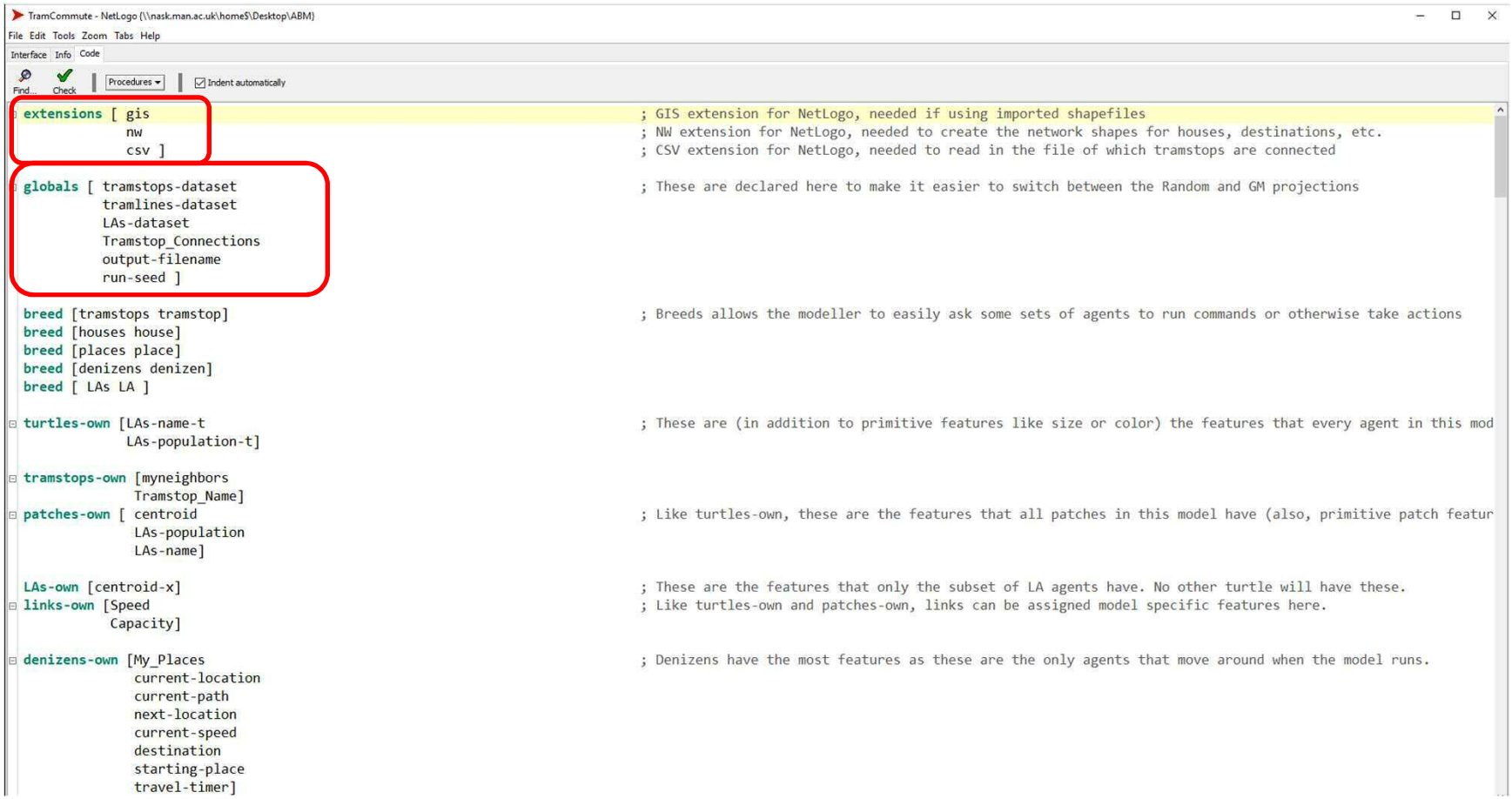
A couple of changes …



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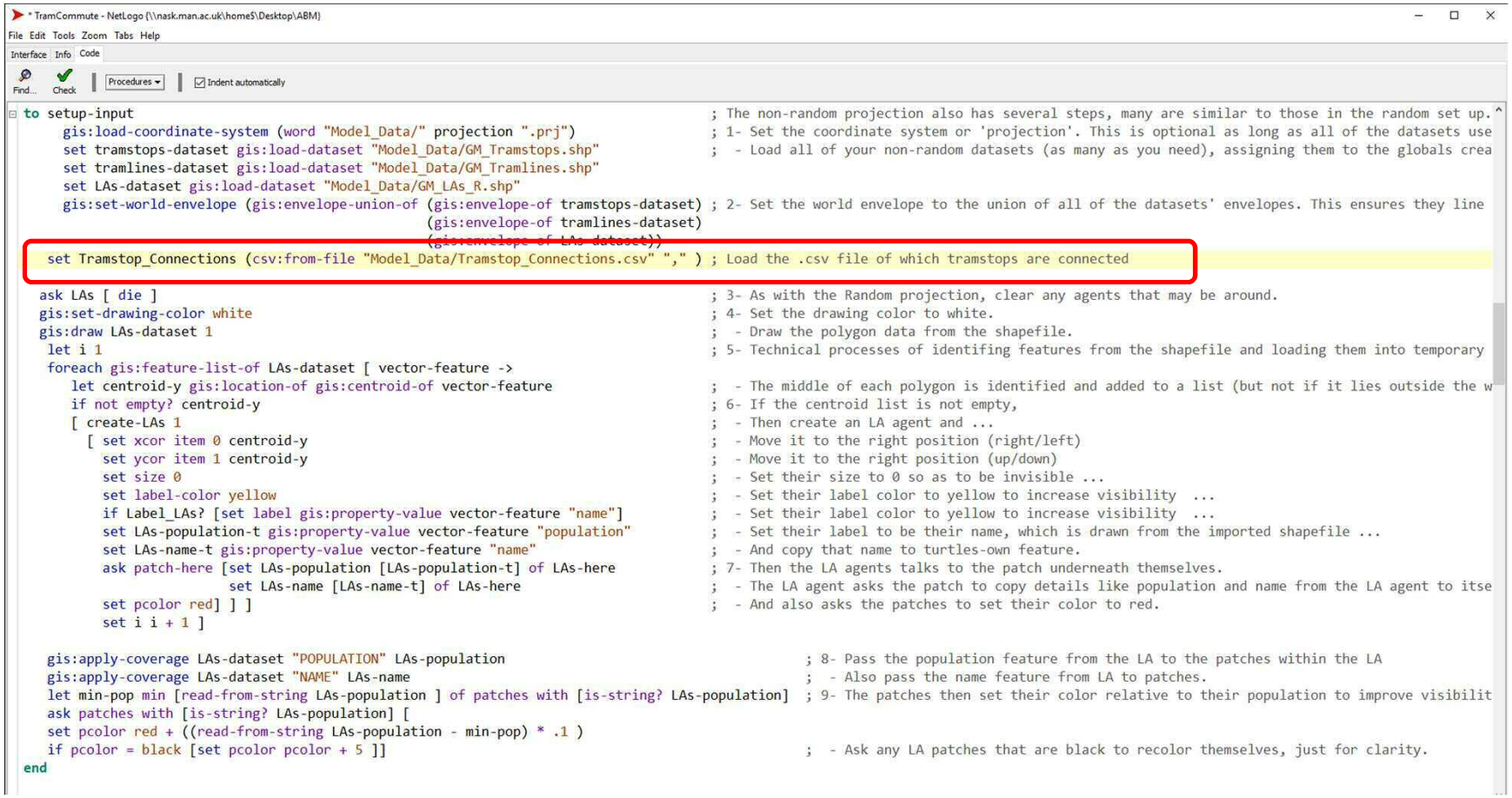
Import a .csv file …




```
to setup-input                                                    ; The non-random projection also has several steps, many are similar to those in the random set up.
    gis:load-coordinate-system (word "Model_Data/" projection ".prj")   ; 1- Set the coordinate system or 'projection'. This is optional as long as all of the datasets use
    set tramstops-dataset gis:load-dataset "Model_Data/GM_Tramstops.shp"  ;  - Load all of your non-random datasets (as many as you need), assigning them to the globals crea
    set tramlines-dataset gis:load-dataset "Model_Data/GM_Tramlines.shp"
    set LAs-dataset gis:load-dataset "Model_Data/GM_LAs_R.shp"
    gis:set-world-envelope (gis:envelope-union-of (gis:envelope-of tramstops-dataset) ; 2- Set the world envelope to the union of all of the datasets' envelopes. This ensures they line
                                                  (gis:envelope-of tramlines-dataset)
                                                  (gis:envelope-of LAs-dataset))
    set Tramstop_Connections (csv:from-file "Model_Data/Tramstop_Connections.csv" "," ) ; Load the .csv file of which tramstops are connected

  ask LAs [ die ]                                                 ; 3- As with the Random projection, clear any agents that may be around.
  gis:set-drawing-color white                                     ; 4- Set the drawing color to white.
  gis:draw LAs-dataset 1                                          ;  - Draw the polygon data from the shapefile.
   let i 1                                                        ; 5- Technical processes of identifing features from the shapefile and loading them into temporary
   foreach gis:feature-list-of LAs-dataset [ vector-feature ->
      let centroid-y gis:location-of gis:centroid-of vector-feature ;  - The middle of each polygon is identified and added to a list (but not if it lies outside the w
      if not empty? centroid-y                                    ; 6- If the centroid list is not empty,
      [ create-LAs 1                                              ;  - Then create an LA agent and ...
        [ set xcor item 0 centroid-y                              ;  - Move it to the right position (right/left)
          set ycor item 1 centroid-y                              ;  - Move it to the right position (up/down)
          set size 0                                              ;  - Set their size to 0 so as to be invisible ...
          set label-color yellow                                  ;  - Set their label color to yellow to increase visibility  ...
          if Label_LAs? [set label gis:property-value vector-feature "name"]  ;  - Set their label color to yellow to increase visibility  ...
          set LAs-population-t gis:property-value vector-feature "population"  ;  - Set their label to be their name, which is drawn from the imported shapefile ...
          set LAs-name-t gis:property-value vector-feature "name"  ;  - And copy that name to turtles-own feature.
          ask patch-here [set LAs-population [LAs-population-t] of LAs-here  ; 7- Then the LA agents talks to the patch underneath themselves.
                          set LAs-name [LAs-name-t] of LAs-here   ;  - The LA agent asks the patch to copy details like population and name from the LA agent to itse
          set pcolor red] ] ]                                     ;  - And also asks the patches to set their color to red.
          set i i + 1 ]

   gis:apply-coverage LAs-dataset "POPULATION" LAs-population                          ; 8- Pass the population feature from the LA to the patches within the LA
   gis:apply-coverage LAs-dataset "NAME" LAs-name                                      ;  - Also pass the name feature from LA to patches.
   let min-pop min [read-from-string LAs-population ] of patches with [is-string? LAs-population]  ; 9- The patches then set their color relative to their population to improve visibilit
   ask patches with [is-string? LAs-population] [
   set pcolor red + ((read-from-string LAs-population - min-pop) * .1 )
   if pcolor = black [set pcolor pcolor + 5 ]]                                         ;  - Ask any LA patches that are black to recolor themselves, just for clarity.
end
```

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With a list of tram stops and their next stops…

Tramstop_Connections - Notepad

File Edit Format View Help

```
"Abraham Moss","Crumpsall","Queen's Road"
"Manchester Airport","Shadowmoss"
"Altrincham","Navigation Road"
"Ashton Moss","Ashton West","Audenshaw"
"Anchorage","Habour City","Salford Quay"
"Audenshaw","Droylsden","Ashton Moss"
"Ashton-Under-Lyne","Ashton West"
"Ashton West","Ashton Moss","Ashton-Under-Lyne"
"Baguley","Roundthorn","Moor Road"
"Barlow Moor Road","St Werburgh's Road","Sale Water Park"
"Brooklands","Timperley","Sale"
"Benchill","Crossacres","Martinscroft"
"Burton Road","West Didsbury","Withington"
"Besses o'th'Barn","Prestwich","Whitefield"
"Bowker Vale","Crumpsall","Heaton Park"
"Bury","Radcliffe"
"Broadway","Langworthy","MediaCityUK","Harbour City"
"Cemetery Road","Edge Lane","Droylsden"
"Chorlton","St Werburgh's Road","Firswood"
"Clayton Hall","Edge Lane","Velopark"
"Cornbrook","Pomona","Trafford Bar","Deansgate-Castlefield"
"Crumpsall","Bowker Vale","Abraham Moss"
"Crossacres","Wythenshawe Town Centre","Benchill"
"Central Park","Monsall","Newton Heath and Moston"
"Derker","Oldham Mumps","Shaw and Compton"
"Didsbury Village","East Didsbury","West Didsbury"
"Dane Road","Sale","Stretford"
"Droylsden","Cemetery Road","Audenshaw"
"Eccles","Ladywell"
"Etihad Campus","Holt Town","Velopark"
"East Didsbury","Didsbury Village"
"Edge Lane","Cemetery Road","Clayton Hall"
"Exchange Quay","Salford Quays","Pomona"
"Exchange Square","St Peter's Square","Victoria"
"Firswood","Trafford Bar","Chorlton"
"Freehold","South Chadderton","Westwood"
"Failsworth","Hollinwood","Newton Heath and Moston"
"Deansgate - Castlefield","St Peter's Square","Cornbrook"
"Harbour City","Anchorage","MediaCityUK","Broadway"
"Heaton Park","Bowker Vale","Prestwich"
"Hollinwood","Failsworth","South Chadderton"
"Holt Town","New Islington","Etihad Campus"
```

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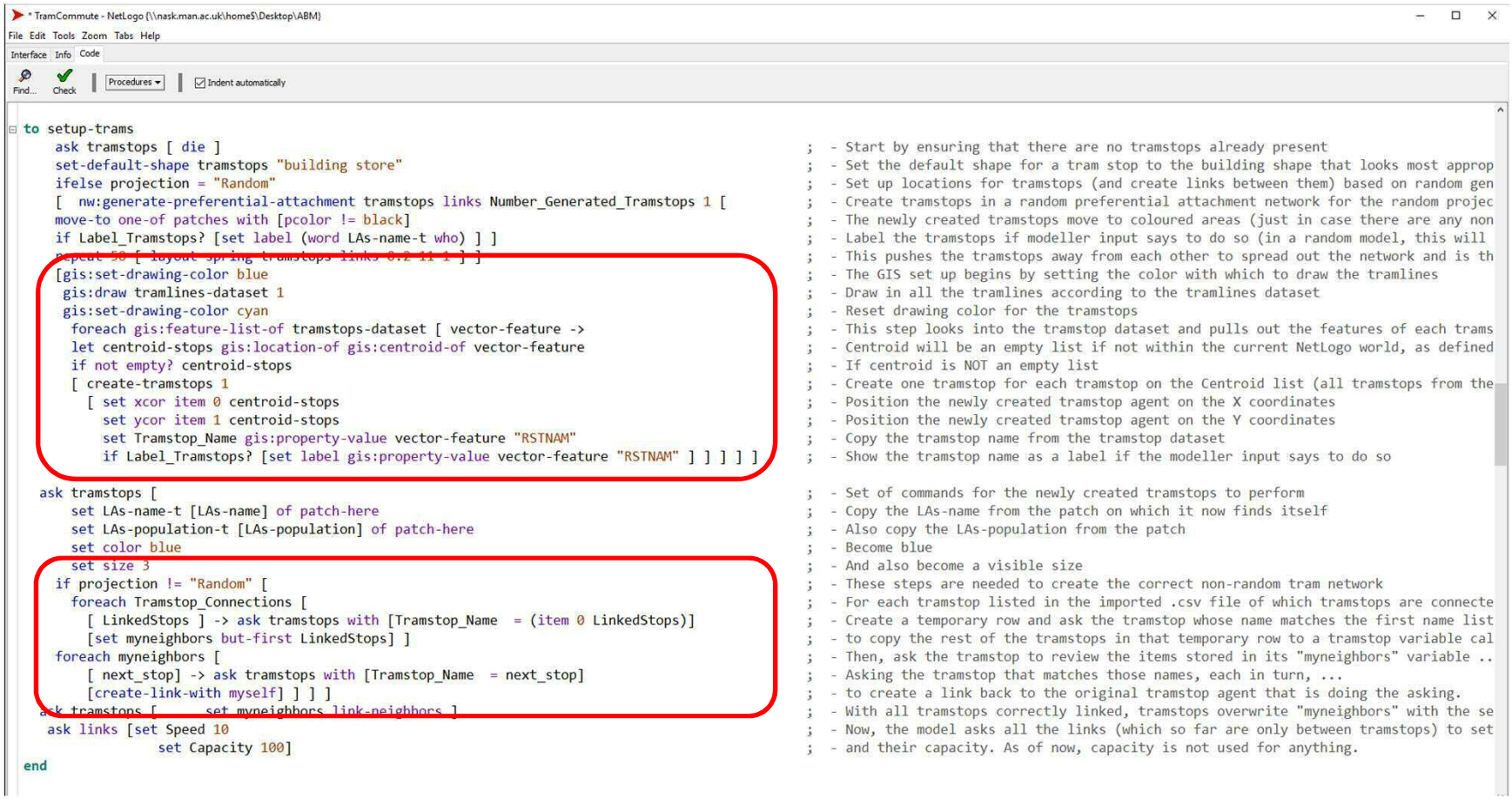
Model now opens .csv to link tram stop-agents



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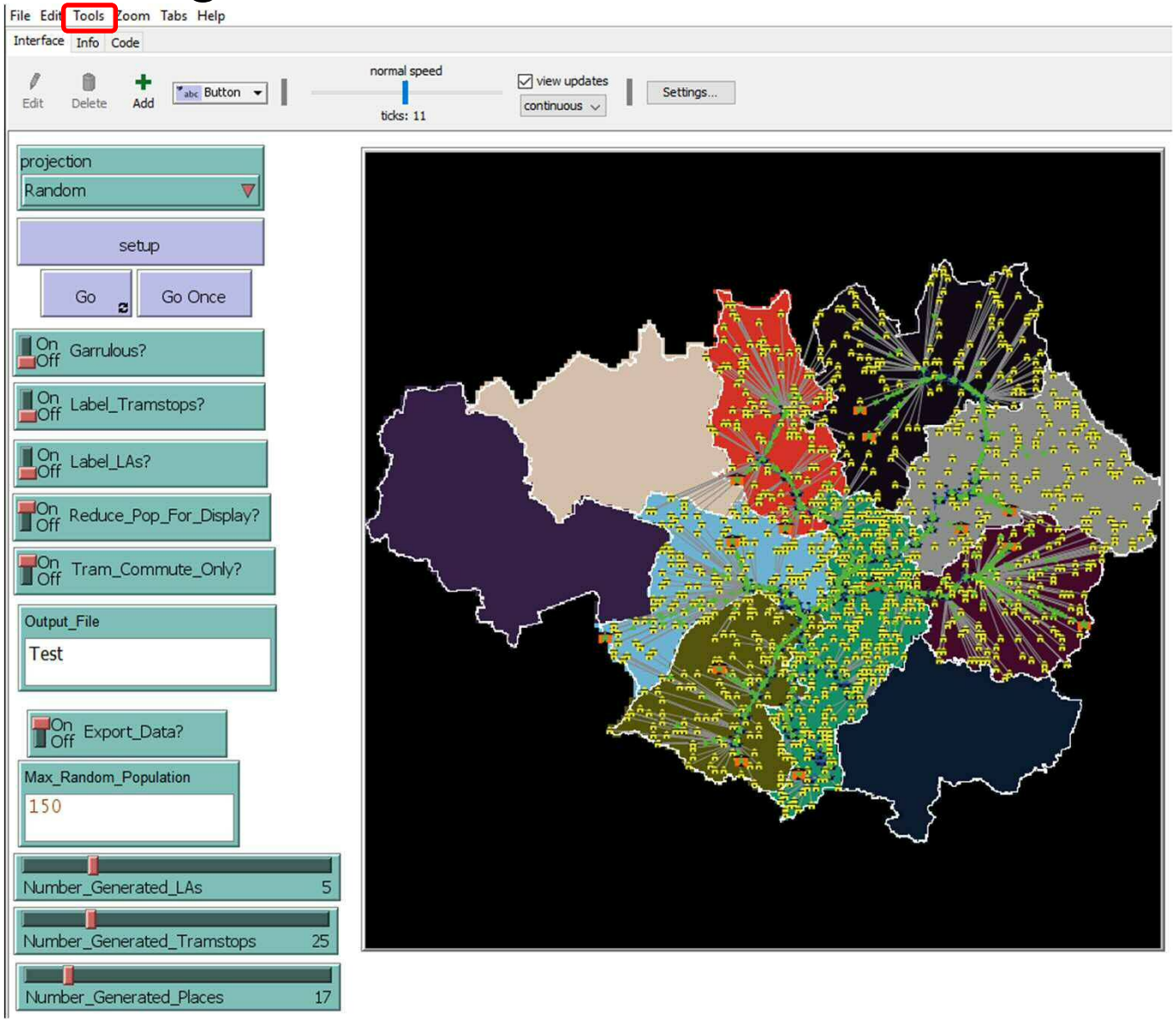
Moving on!



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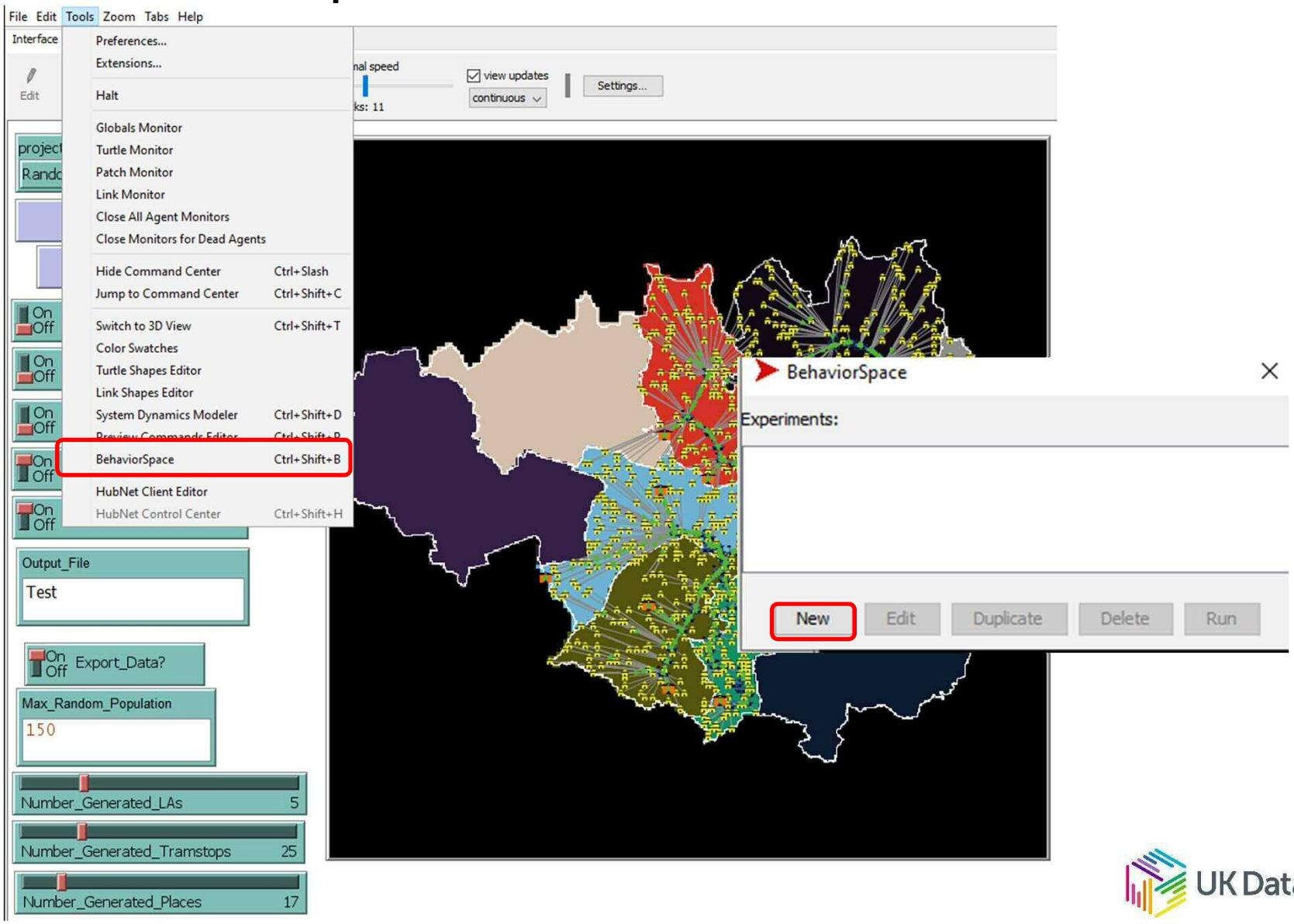
Behaviour Space



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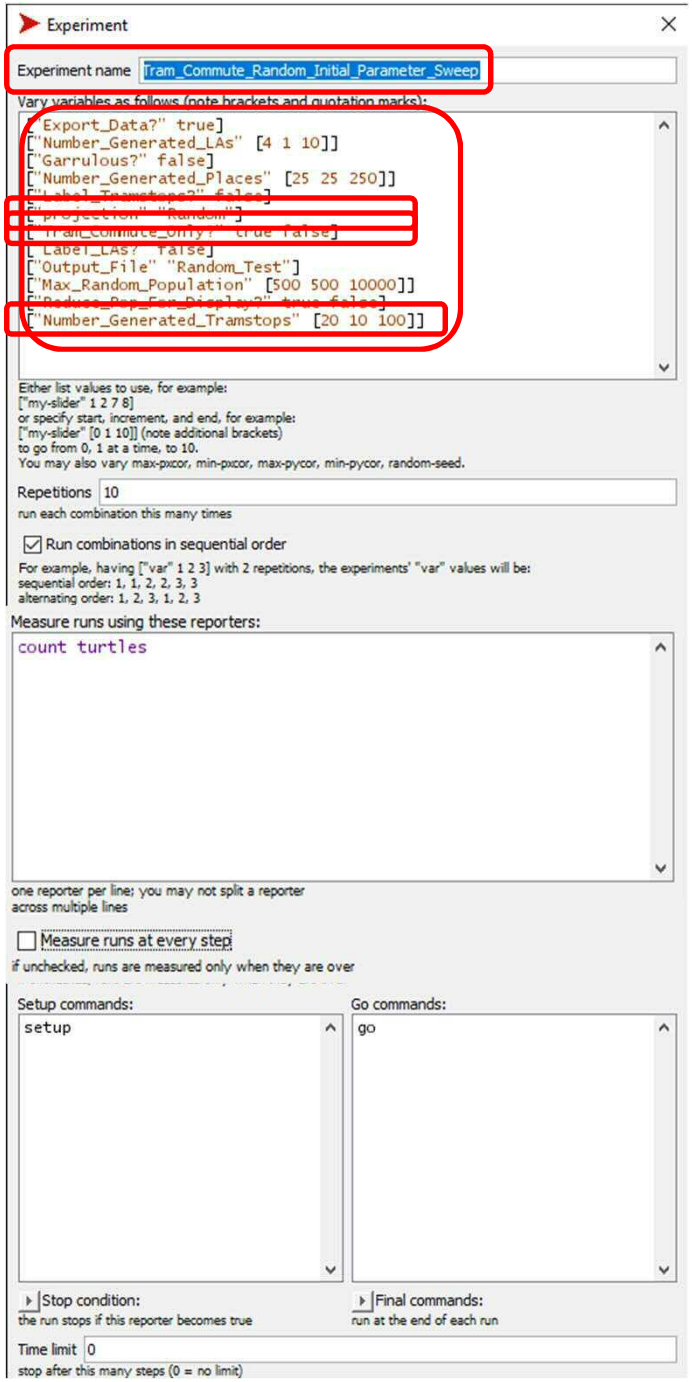
Behaviour Space



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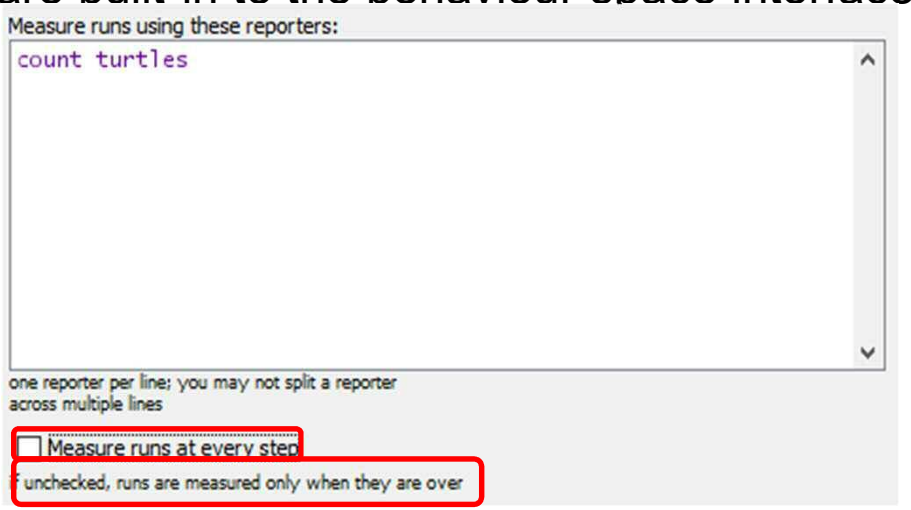
Basic Behaviour Space output

- Output options are built-in to the behaviour space interface.



- BUT!
  - Choice to measure selected commands at every step or
  - Measure selected commands at end of run.
  - Swap out the above “if” command for a very basic “count tramstop-agents”

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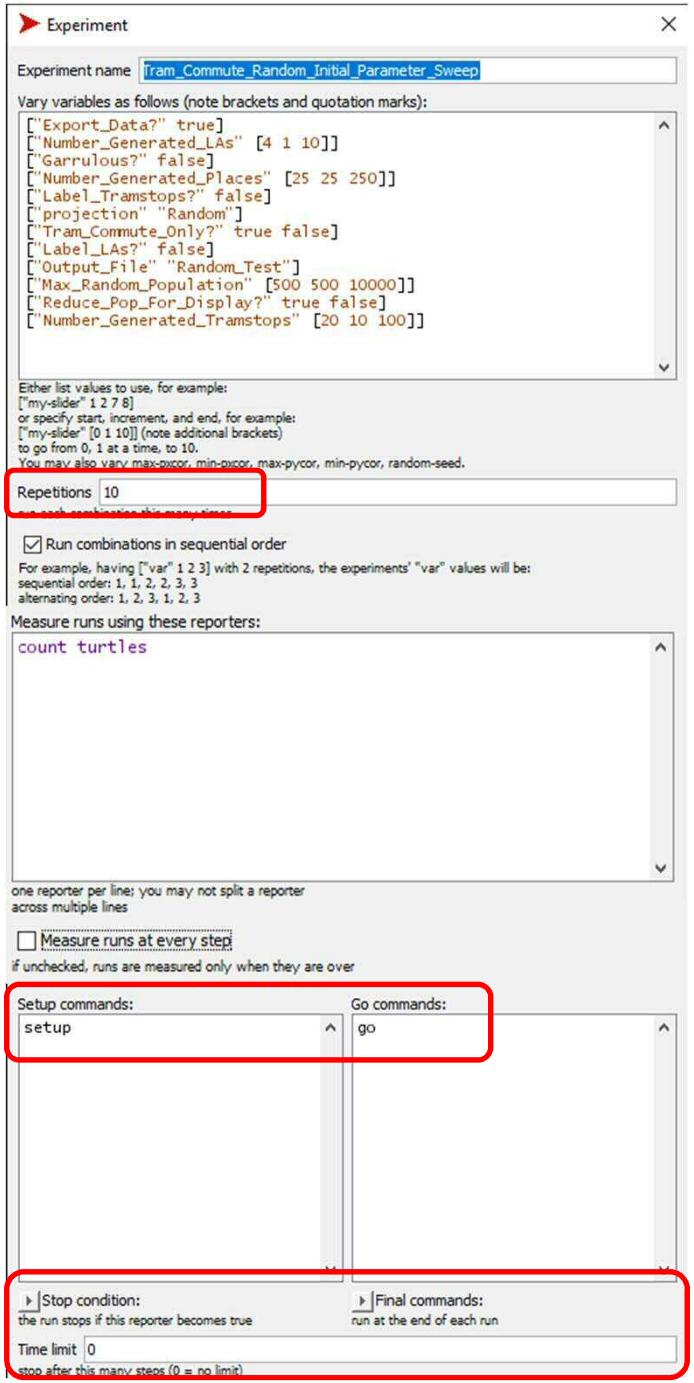
Behaviour Space



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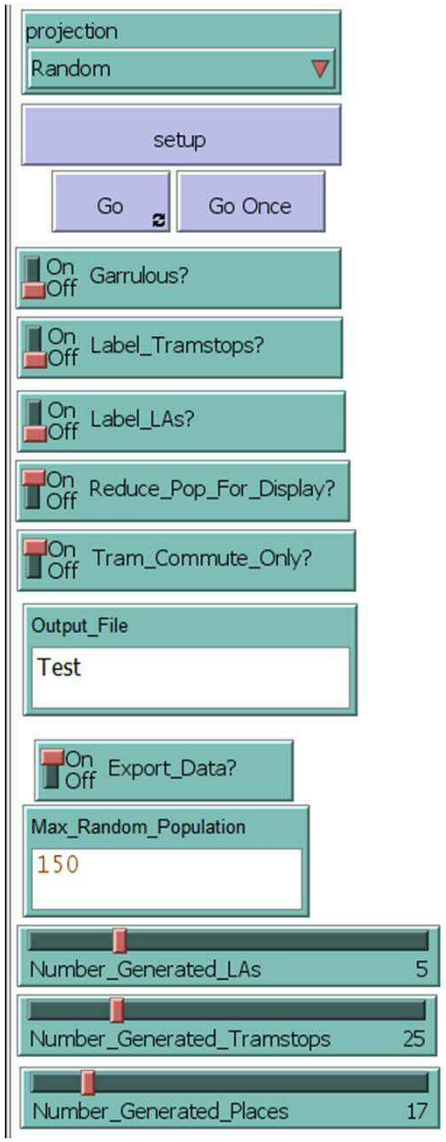
Experiments on random projection



First experiments will be parameter sweeps:

- All parameters vary
- Wide ranges, big increments
- Fewer repetitions

Then, use the results to run targeted sweeps with:

- Maybe not all parameters
- Narrower ranges and/or smaller increments
- More repetitions

Or experiments

- MANY repetitions on single/few settings
- Changes to model code
  - Generate more tram stops, houses, or places
  - Generate more commuters
  - After some trigger or at a fixed point in time
- Etc.

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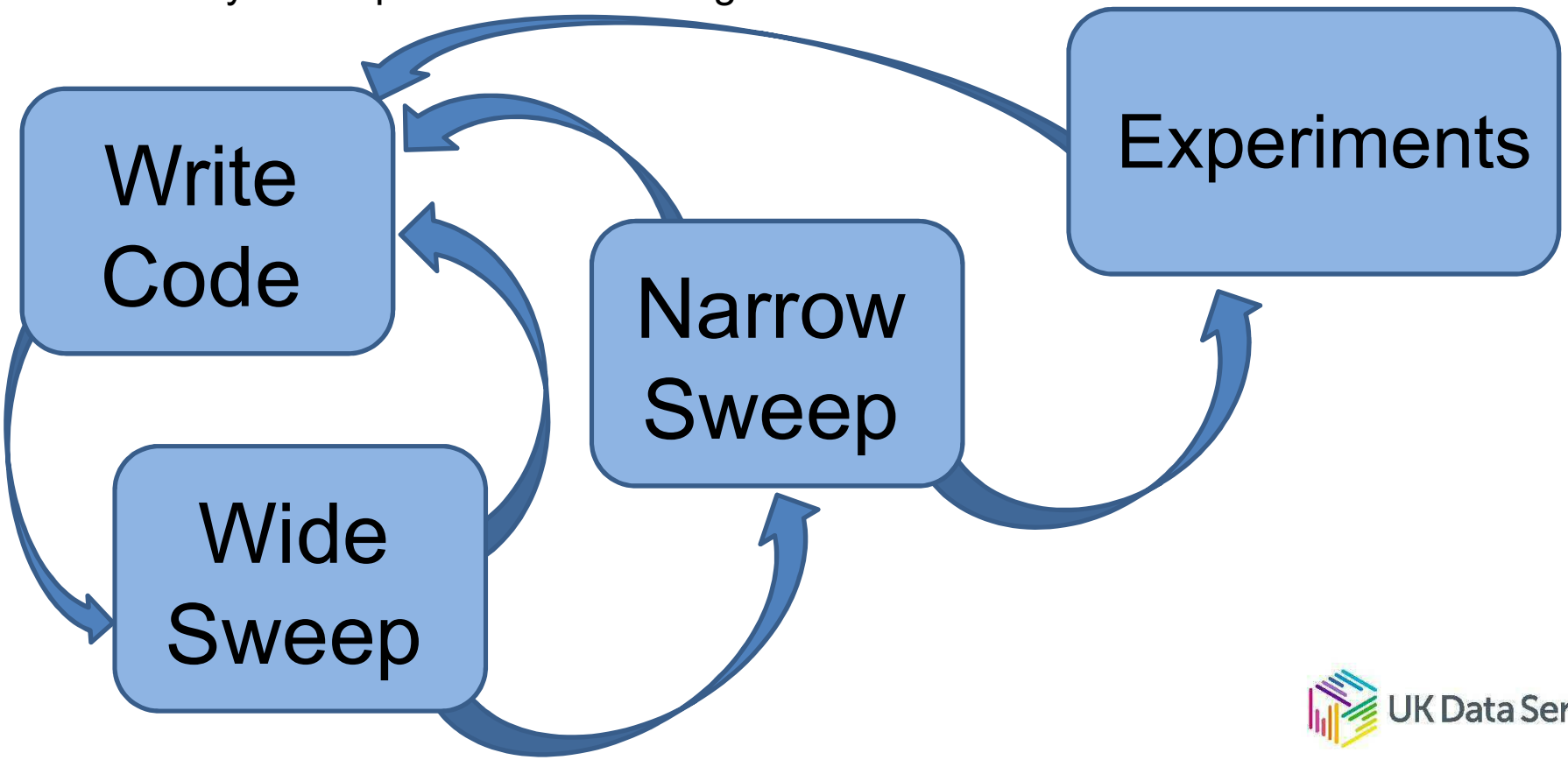
Random projection experiments needed to:

- Verify model logic
- Test model changes
- Identify interactions of various parameters
- Identify break points / critical ranges



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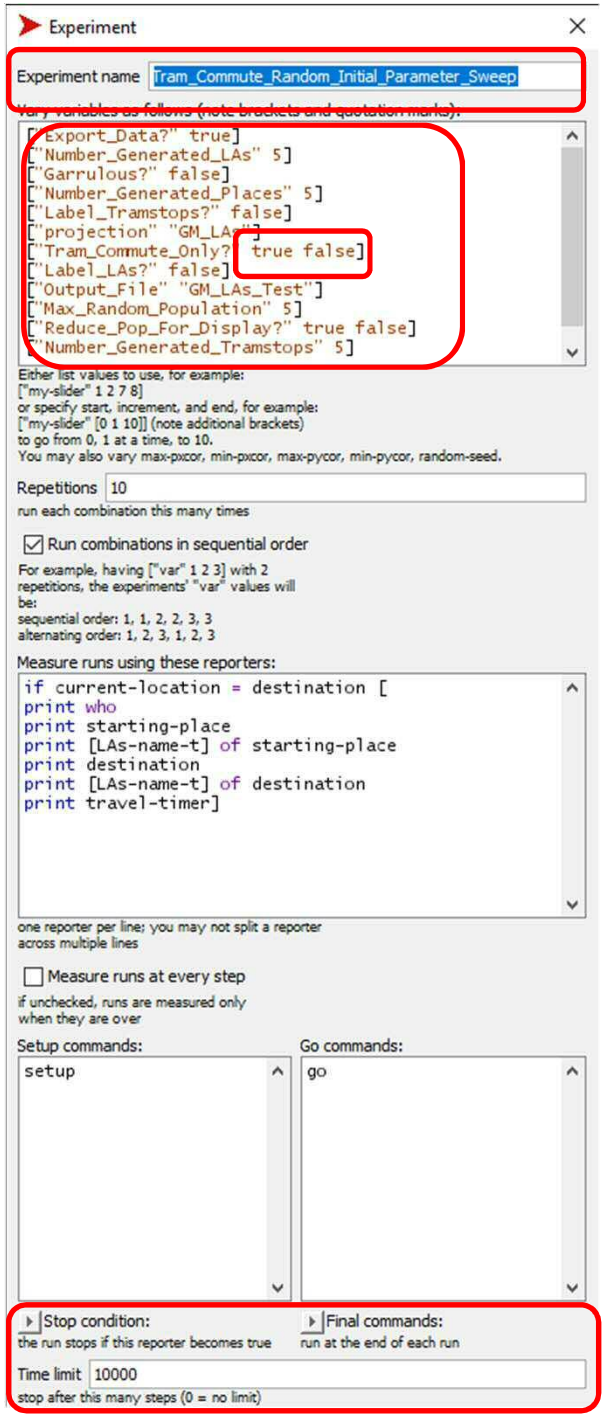
Behaviour Space



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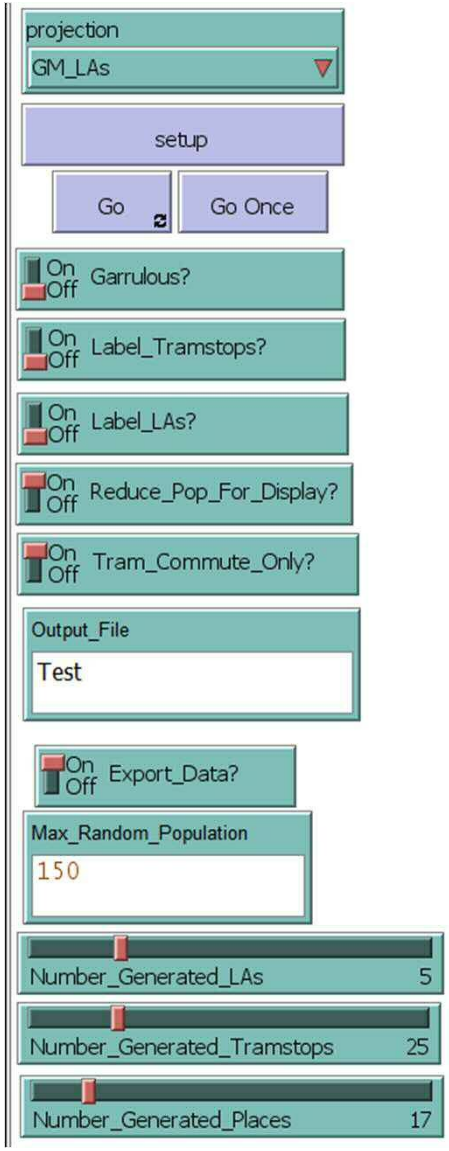
Experiments on GM_LAs projection



First experiments are still parameter sweeps:

- Still important to check model function
- May not need as many rounds

Experiments

- Can still repeat on large scale
- Can change projection and/or model code
  - Start with oldest tramlines and add extensions at specified points in model run
  - Include currently agreed extensions (from beginning or at specified point in model run)
  - Include currently considered lines, rejected lines, totally imaginary lines, etc.
- Others?

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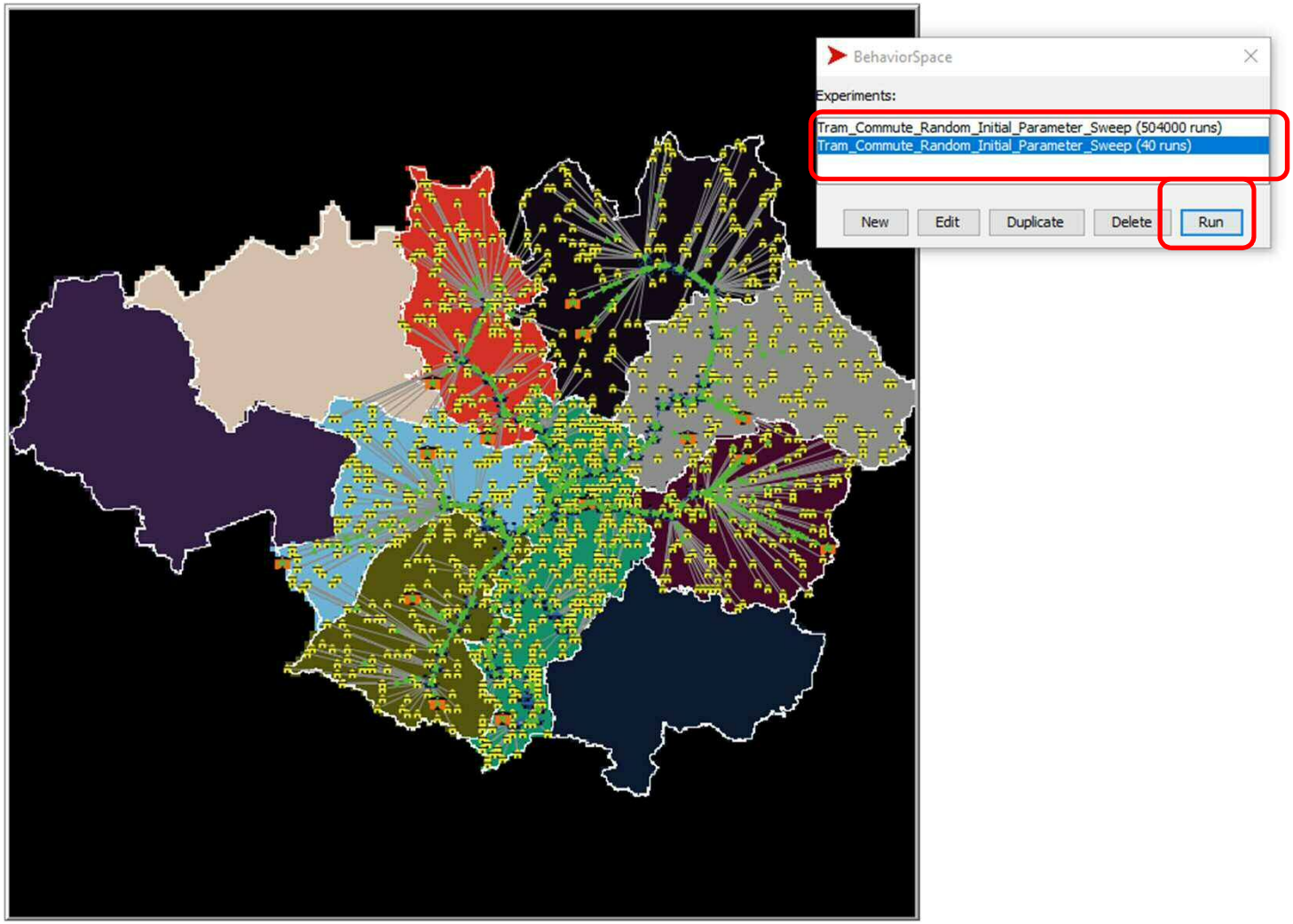
GM_LAs projection experiments needed to:

- Compare model behaviour to real-world observations
- Test projection-specific model changes
- Identify interactions of various parameters under realistic layout
- Identify break points / critical ranges
- Model possible outcomes of making changes
- Answer specific research questions

Parameter sweeps are part of model testing



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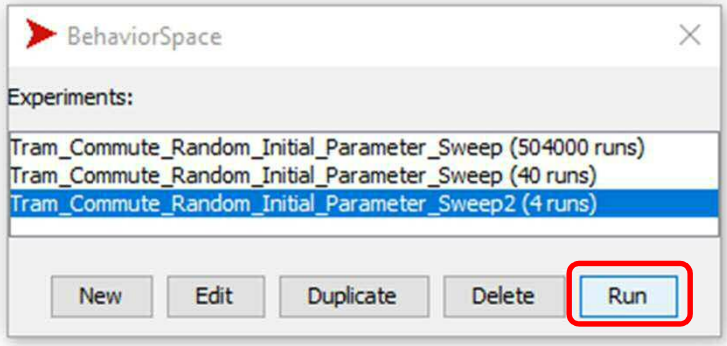
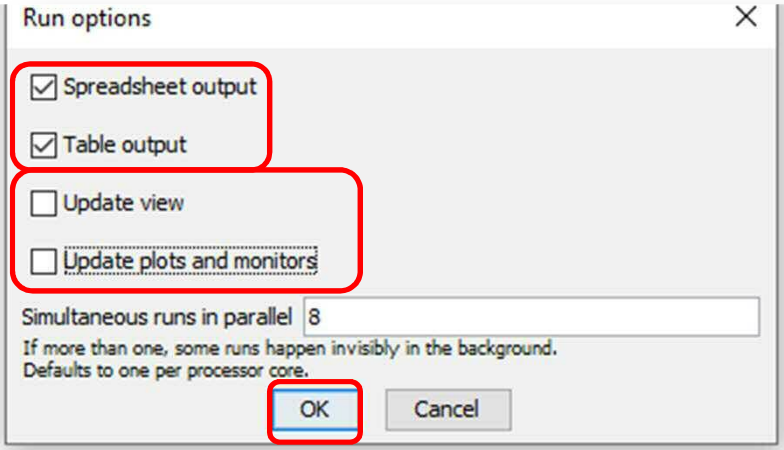
But first…

- Ideal output is well-motivated by:
  - Research questions
  - Model design
  - Iterative developments
- In this model, as it stands, I decided to look at output related to:
  - How long does it take to travel between one LA and another?
  - How common are trips within each LA and between Las?
- With fairly minor changes we could also get output related to:
  - Most popular places to visit
  - Most used tram stops
  - More?

Hitting the Run button





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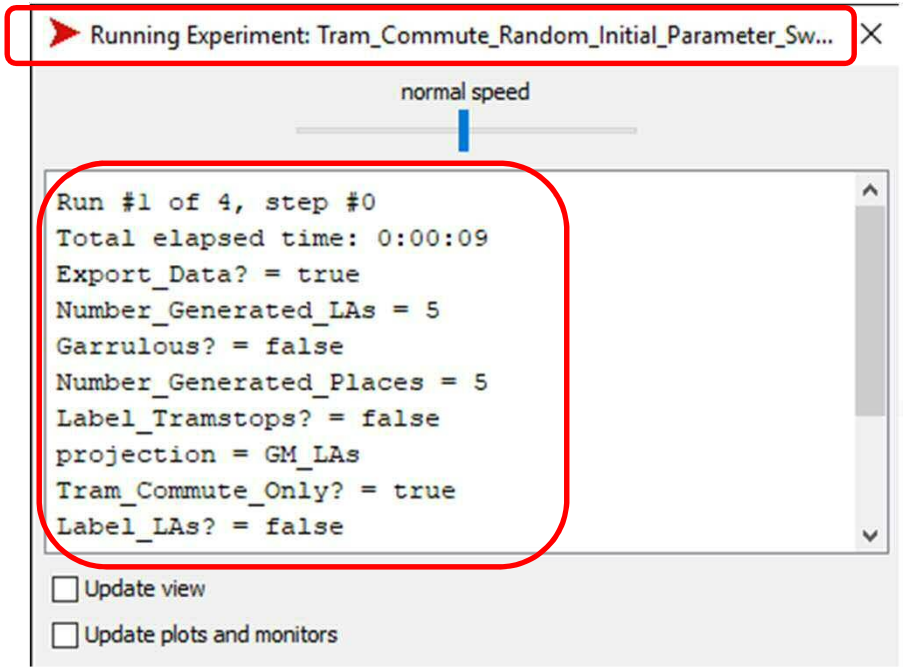
Experiments need output!



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Behaviour Space standard output - spreadsheet

BehaviorSpace results (NetLogo 6.1.1)			
TramCommute.nlogo			
Tram_Commute_Initial_Parameter_Sweep			
02/11/2020 17:05:56:445 +0000			
min-pxcor	max-pxcor	min-pycor	max-pycor
-90	90	-90	90
[run number]	1	2	
Export_Data?	TRUE	TRUE	
Number_Generated_LAs	5	5	
Garrulous?	FALSE	FALSE	
Number_Generated_Places	17	17	
Label_Tramstops?	FALSE	FALSE	
projection	GM_LAs	GM_LAs	
Tram_Commute_Only?	TRUE	FALSE	
Label_LAs?	FALSE	FALSE	
Output_File	Test	Test	
Max_Random_Population	150	150	
Reduce_Pop_For_Display?	TRUE	TRUE	
Number_Generated_Tramstops	25	25	
[steps]	1000	1000	
[initial & final values]	count tramstops	count tramstops	
	93	93	

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Behaviour Space standard output - table

BehaviorSpace results (NetLogo 6.1.1)														
TramCommute.nlogo														
Tram_Commute_Initial_Parameter_Sweep														
02/11/2020 17:05:26:223 +0000														
min-pxcor	max-pxcor	min-pycor	max-pycor											
-90	90	-90	90											
[run number]	Export_Data?	Number_Generated_LAs	Garrulous?	Number_Generated_Places	Label_Tramstops?	projection	Tram_Commute_Only?	Label_LAs?	Output_File	Max_Random_Population	Reduce_Pop_For_Display?	Number_Generated_Tramstops	[step]	count tramstops
1	TRUE	5	FALSE	17	FALSE	GM_LAs	TRUE	FALSE	Test	150	TRUE	25	1000	93
2	TRUE	5	FALSE	17	FALSE	GM_LAs	FALSE	FALSE	Test	150	TRUE	25	1000	93

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Alternate output

- Output options are built-in to the behaviour space interface.
  - Choice to measure selected commands at every step or
  - Measure selected commands at end of run.
  - Spreadsheet or table options
- Other output options can be built directly into the model code.

Exports in setup

```
extensions [ gis                    ; GIS extension for NetLogo, needed if using imported shapefiles
             nw                     ; NW extension for NetLogo, needed to create the network shapes for houses, destinations, etc.
             csv ]                  ; CSV extension for NetLogo, needed to read in the file of which tramstops are connected
```

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Exports in setup

```
to setup
  clear-all                                                    ; Always start by clearing everything.
  set run-seed new-seed                                        ; Creates a "seed" to use as a unique identifier for the run (also, allows the run to be re-run e
  random-seed run-seed                                         ; Initiates this run using the just created seed
  set output-filename (word projection "_" Output_File "_" run-seed )  ; Creates an output file to record the model run based on the projection selected, a user input v
  ifelse projection = "Random"                                 ; The model diverges significantly depending on whether you want to use randomly generated or imp
    [ setup-random ]                                           ; This initiates the procedures to set up a random world, drawing on the various "Random_Generate
    [ setup-input  ]                                           ; This initiates the procedures to set up a world based on imported shapefiles. This too draws or
  setup-trams                                                  ; the Random projection models, such as "Random_Generated_Tramstops".
  if Garrulous? [ask links [print end1]]
  setup-houses-and-places
  setup-denizens
  check-speed
  initial-exports
  reset-ticks
end

to initial-exports
    if Export_Data?
       [file-open (word output-filename ".csv" )                 ; Creates a file named with the output-filename created earlier. Wrapping it
        file-print (word "Commuter,Origen,Origin_LA,Destination,Destination_LA,Travel_time")  ; Set up the headers that should appear in the output file
 ;      file-print (word " , , , , , ,")                         ; Currently not needed - but you could use row (or more like it) to write ou
        file-close]                                            ; Closes the file - necessary to save the input just added and also prepare
end

to when-at-destination
    set current-location next-location                         ;  They copy over their next proximal destination to their current location
    set travel-timer travel-timer + 1                          ;  They add one to their travel time
    if Export_Data?                                            ;  Check to see if the modeller wants data exports
    [file-open (word output-filename ".csv" )                  ;  If so, they open the appropriate file. The "," enables it to be formatted for .
    file-print                                                 ;  Adds their who number, origen, origen LA, destination, destination LA, and trav
    (word who "," starting-place "," [LAs-name-t] of starting-place "," destination "," [LAs-name-t] of starting-place "," travel-timer)
    file-close]                                                ;  And closes the file - still important.
    set starting-place destination                             ;  They copy over their current destination to be the starting-place for the next
    set destination one-of My_Places                           ;  Pick a  new destination is head to...
    set travel-timer 0                                         ;  Reset the counter that tracks time elapsed for travel back to zero
    if any? places-here                                        ;  Checks to see if they are currently at a Place and...
       [create-link-with one-of places-here]                   ;  If so, creates a link with that place.
     if any? houses-here                                       ;  f they are currently at a House and...
       [create-link-with one-of houses-here]                   ;  a link with that house.
     set current-path []                                       ;  ent-path to their new destination back to an empty list
     set current-path nw:turtles-on-path-to destination        ;  identifies the path to that new destination and fills in the recently reset cur
     set next-location first current-path                      ;  Sets next proximal destination
     face next-location                                        ;  Turns to face that proximal destination
     set current-path but-first current-path                   ;  And removes the proximal destination from the current-path
end
```

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One file per run

GM_LAs_Test_-85998618 - Notepad

File Edit Format View Help

```
Commuter,Origen,Origin_LA,Destination,Destination_LA,Travel_time
2867,(house 177),Trafford,(place 1238),Trafford,3
2838,(house 205),Trafford,(place 1238),Trafford,3
3136,(house 1047),Tameside,(place 1234),Tameside,4
3029,(house 205),Trafford,(place 1238),Trafford,4
3313,(house 1085),Tameside,(place 1234),Tameside,4
3355,(house 1047),Tameside,(place 1234),Tameside,4
3033,(house 234),Trafford,(place 1238),Trafford,4
2481,(house 630),Bury,(place 1232),Bury,4
3093,(house 103),Trafford,(place 1237),Trafford,4
1370,(house 716),Rochdale,(place 1232),Rochdale,4
3359,(house 962),Tameside,(place 1233),Tameside,4
3145,(house 1063),Tameside,(place 1233),Tameside,4
2455,(house 572),Bury,(place 1231),Bury,4
2304,(house 678),Bury,(place 1231),Bury,4
3066,(house 169),Trafford,(place 1238),Trafford,4
2588,(house 1196),Oldham,(place 1236),Oldham,4
3367,(house 1030),Tameside,(place 1234),Tameside,4
2552,(house 1171),Oldham,(place 1236),Oldham,4
2532,(house 576),Bury,(place 1232),Bury,4
2724,(house 1201),Oldham,(place 1236),Oldham,4
3388,(house 1085),Tameside,(place 1234),Tameside,4
2838,(place 1238),Trafford,(place 1238),Trafford,2
2857,(house 104),Trafford,(place 1227),Trafford,5
3136,(place 1234),Tameside,(place 1234),Tameside,2
2534,(house 665),Bury,(place 1232),Bury,5
2309,(house 610),Bury,(place 1231),Bury,5
3405,(house 992),Tameside,(place 1234),Tameside,5
2854,(house 237),Trafford,(place 1238),Trafford,5
3029,(place 1238),Trafford,(place 1238),Trafford,2
2471,(house 598),Bury,(place 1231),Bury,5
3367,(place 1234),Tameside,(place 1234),Tameside,2
2685,(house 1112),Oldham,(place 1233),Oldham,5
1370,(place 1232),Bury,(place 1232),Bury,2
3375,(house 959),Tameside,(place 1233),Tameside,5
3321,(house 1011),Tameside,(place 1233),Tameside,5
1287,(house 768),Rochdale,(place 1229),Rochdale,5
3156,(house 959),Tameside,(place 1234),Tameside,5
2234,(house 427),Manchester,(place 1236),Manchester,5
2727,(house 1112),Oldham,(place 1233),Oldham,5
3354,(house 1011),Tameside,(place 1233),Tameside,5
3134,(house 959),Tameside,(place 1234),Tameside,5
3258,(house 988),Tameside,(place 1233),Tameside,5
3026,(house 127),Trafford,(place 1237),Trafford,5
2992,(house 232),Trafford,(place 1237),Trafford,5
2231,(house 494),Manchester,(place 1234),Manchester,5
2814,(house 1217),Oldham,(place 1235),Oldham,5
3207,(house 993),Tameside,(place 1234),Tameside,5
3319,(house 975),Tameside,(place 1233),Tameside,5
2433,(house 671),Bury,(place 1232),Bury,5
3388,(place 1234),Tameside,(place 1234),Tameside,2
3030,(house 112),Trafford,(place 1238),Trafford,5
1746,(house 935),Salford,(place 1228),Salford,6
```

	A	B	C	D	E	F
1	Commuter	Origen	Origin_LA	Destination	Destination_LA	Travel_time
2	2381	(house 473)	Manchester	(place 1229)	Manchester	3
3	3305	(house 201)	Trafford	(place 1237)	Trafford	3
4	2491	(house 439)	Manchester	(place 1229)	Manchester	3
5	2218	(house 556)	Manchester	(place 1230)	Manchester	4
6	2345	(house 458)	Manchester	(place 1230)	Manchester	4
7	3361	(house 146)	Trafford	(place 1233)	Trafford	4
8	2451	(house 697)	Manchester	(place 1229)	Manchester	4
9	2788	(house 1195)	Oldham	(place 1235)	Oldham	4
10	3052	(house 931)	Bury	(place 1225)	Bury	4
11	3043	(house 860)	Bury	(place 1225)	Bury	4
12	3234	(house 239)	Trafford	(place 1237)	Trafford	4
13	2092	(house 1017)	Tameside	(place 1227)	Tameside	4
14	2563	(house 458)	Manchester	(place 1230)	Manchester	4
15	2326	(house 614)	Manchester	(place 1230)	Manchester	4
16	1707	(house 371)	Salford	(place 1233)	Salford	4
17	2903	(house 860)	Bury	(place 1225)	Bury	4
18	3340	(house 116)	Trafford	(place 1229)	Trafford	4
19	3385	(house 126)	Trafford	(place 1233)	Trafford	4
20	1841	(house 977)	Tameside	(place 1227)	Tameside	4
21	1794	(house 346)	Salford	(place 1225)	Salford	4
22	1650	(house 248)	Salford	(place 1225)	Salford	4
23	2525	(house 600)	Manchester	(place 1229)	Manchester	4
24	2546	(house 423)	Manchester	(place 1229)	Manchester	4
25	1819	(house 960)	Tameside	(place 1227)	Tameside	4
26	2783	(house 1144)	Oldham	(place 1235)	Oldham	4
27	3301	(house 146)	Trafford	(place 1233)	Trafford	4
28	1945	(house 1036)	Tameside	(place 1227)	Tameside	4
29	1501	(house 835)	Rochdale	(place 1232)	Rochdale	5
30	3259	(house 218)	Trafford	(place 1237)	Trafford	5
31	1891	(house 961)	Tameside	(place 1227)	Tameside	5
32	2169	(house 389)	Manchester	(place 1230)	Manchester	5
33	2396	(house 664)	Manchester	(place 1230)	Manchester	5
34	1916	(house 1073)	Tameside	(place 1227)	Tameside	5
35	2021	(house 1047)	Tameside	(place 1227)	Tameside	5
36	2009	(house 1047)	Tameside	(place 1227)	Tameside	5
37	1925	(house 1086)	Tameside	(place 1227)	Tameside	5
38	3215	(house 109)	Trafford	(place 1238)	Trafford	5

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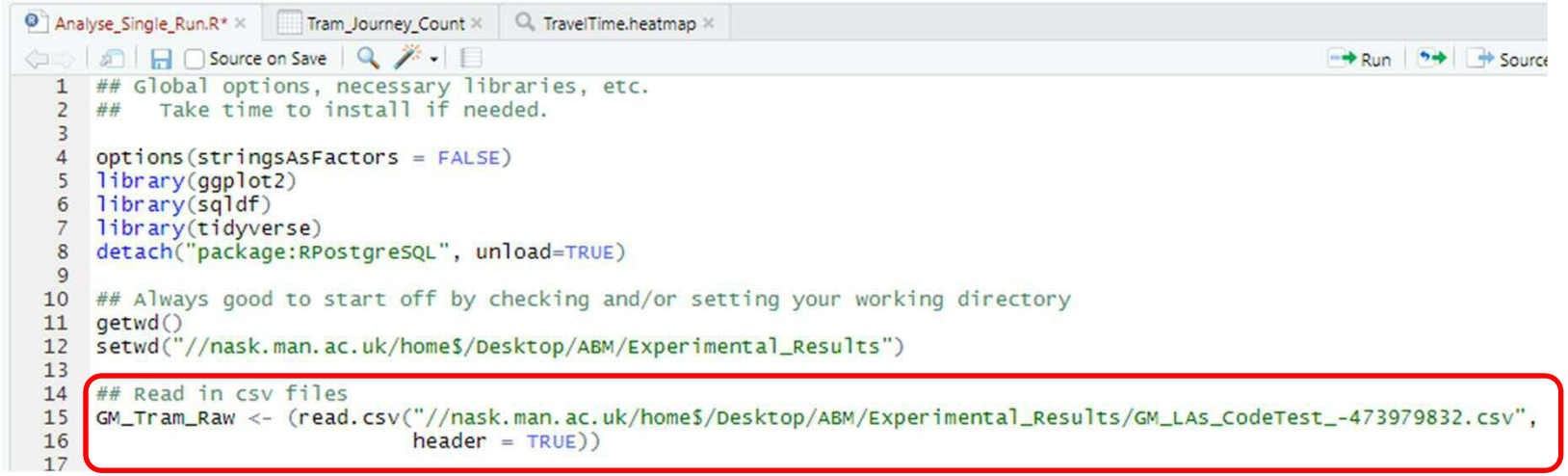
Open in RStudio



UK Data Service

Look at raw file

Analyse_Single_Run.R | GM_Tram_Raw | TravelTime.heatmap | Tram_Journey_Count

Filter

	Commuter	Origen	Origen_LA	Destination	Destination_LA	Travel_time
1	1425	(house 165)	Salford	(place 1235)	Salford	3
2	1609	(house 433)	Manchester	(place 1225)	Manchester	3
3	2679	(house 356)	Trafford	(place 1235)	Salford	3
4	1531	(house 138)	Salford	(place 1235)	Salford	4
5	1508	(house 104)	Salford	(place 1227)	Bury	4
6	1505	(house 122)	Salford	(place 1235)	Salford	4
7	1785	(house 605)	Manchester	(place 1225)	Manchester	4
8	3137	(house 772)	Oldham	(place 1232)	Oldham	4
9	2537	(house 952)	Bury	(place 1228)	Bury	4
10	2515	(house 918)	Bury	(place 1227)	Bury	4
11	1425	(place 1235)	Salford	(place 1235)	Salford	2
12	1537	(house 553)	Manchester	(place 1225)	Manchester	4

Open in RStudio

```
14  ## Read in csv files
15  GM_Tram_Raw <- (read.csv("//nask.man.ac.uk/home$/Desktop/ABM/Experimental_Results/GM_LAs_CodeTest_-473979832.csv",
16                           header = TRUE))
17
18  ## Basic clean up
19  ## Remove parertheses
20  GM_Tram_Raw$Origen  <- (gsub("[()]", "", GM_Tram_Raw$Origen))
21
22  ## Split the Origen column into one that tracks the agent-type and another than has that agent's who number
23  GM_Tram_Adjusted <- GM_Tram_Raw %>%
24    separate(Origen, c("Journey", "OSpecifics"), 6)
25
26  ## Remove unneeded columns
27  GM_Tram_Slim <- GM_Tram_Adjusted[c("Commuter", "Journey","Origen_LA","Destination_LA","Travel_time")]
28
29  ## Rename some columns to streamline interpretation
30  GM_Tram_Slim <- GM_Tram_Slim %>%
31    rename(
32      Origen = Origen_LA,
33      Destination = Destination_LA )
34
35  ## Shockingly basic analysis
36  ## Count the number of journeys taken between each pair of LAs
37  Tram_Journey_Count <- GM_Tram_Slim %>%
38    group_by (Origen, Destination) %>%
39    summarize( GM_Tram_Slim = n())
40
41
42  #Heat map of travel time between Origen LA and destination LA
43  TravelTime.heatmap <- ggplot(data = GM_Tram_Slim, mapping = aes(x = Origen,
44                                                                  y = Destination,
45                                                                  fill = Travel_time)) +
46    geom_tile() +
47    xlab(label = "Heatmap of Travel Time")
48
```

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```
35 ## Shockingly basic analysis
36 ## Count the number of journeys taken between each pair of LAs
37 Tram_Journey_Count <- GM_Tram_Slim %>%
38   group_by (Origen, Destination) %>%
39   summarize( GM_Tram_Slim = n())
40
41
42 #Heat map of travel time between Origen LA and destination LA
43 TravelTime.heatmap <- ggplot(data = GM_Tram_Slim, mapping = aes(x
44                                                              y = Dest
45                                                          fill = Trav
46   geom_tile() +
47   xlab(label = "Heatmap of Travel Time")
```

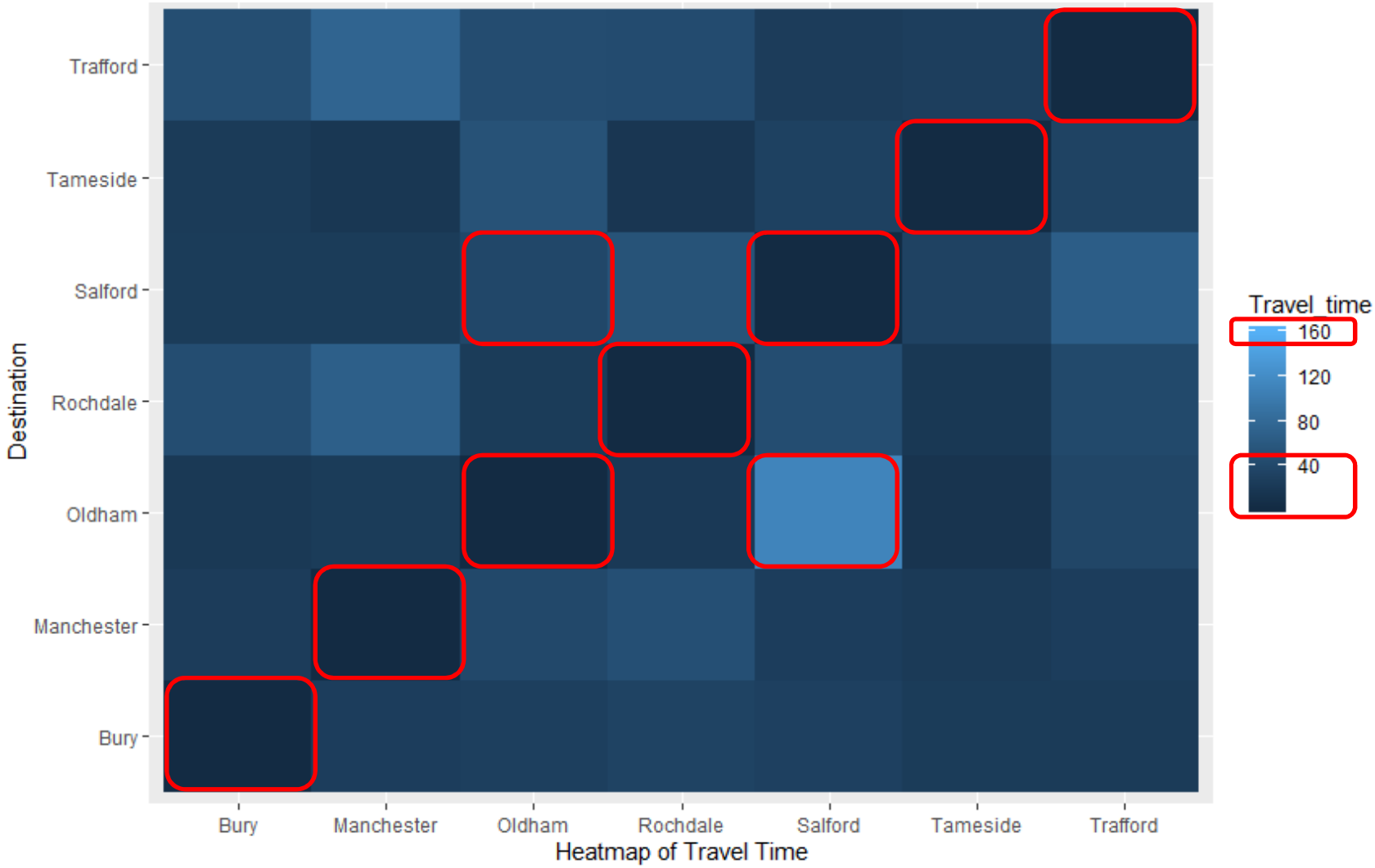
Analyse_Single_Run.R × | Tram_Journey_Count ×

Filter

	Origen	Destination	GM_Tram_Slim
1	Bury	Bury	582
2	Bury	Manchester	197
3	Bury	Oldham	277
4	Bury	Rochdale	234
5	Bury	Salford	257
6	Bury	Tameside	3
7	Bury	Trafford	275
8	Manchester	Bury	223
9	Manchester	Manchester	1684
10	Manchester	Oldham	198
11	Manchester	Rochdale	152
12	Manchester	Salford	189
13	Manchester	Tameside	695
14	Manchester	Trafford	199
15	Oldham	Bury	261
16	Oldham	Manchester	175
17	Oldham	Oldham	628
18	Oldham	Rochdale	315

Showing 1 to 20 of 49 entries, 3 total columns

Open in RStudio



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Summary

- Revisit the "Tram commute model“
- Behaviour Space
- Consider what experiments to run –
  - parameter sweeps
  - targeted research questions
- Building output creation into your model code – an optional extra
- Open output
  - Process
  - Analyze
  - Visualise
- https://www.comses.net/codebases/5ec74433-0536-4343-88fd-8385e7f5066c/releases/1.0.0/
- Or
- https://tinyurl.com/wagewt9

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Questions

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