

**Research and Design:  
Innovative Digital Tools to Enable Greener Travel**

# **Journey Sustainability Analysis Report**

12.6.3 Report

**February 2017**

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## **Centre for Complexity Planning & Urbanism**

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# Aim

This report contains an analysis of the transport emissions and occupancy for the transport network within Manchester. The study aims to identify the differences in travel distance, travel time and CO<sub>2</sub> emissions per occupant for different journeys in Manchester using methods in emissions estimation described in the report 12.6.2 Occupancy/Emissions Sustainability Metric Matrix.

## Objectives

A GIS model was compiled with the road and the public transport network of Manchester to identify 1) Routes with the lowest and highest travel time, 2) Routes with the lowest and highest travel distance and 3) Routes with the lowest and highest CO<sub>2</sub> emission

1. The difference in A) travel time, B) travel distance and C) CO<sub>2</sub> emissions crossing the Manchester District
2. The difference in A) travel time, B) travel distance and C) CO<sub>2</sub> emissions from the Manchester City Centre

The methods of the study are: -

1. Comparison of routes through the Manchester District at a 500m interval across South to North and West to East.
2. Comparison of CO<sub>2</sub> emission and travel time between private car and public transport for a defined distance (5km) travelling from a given location in the Manchester City Centre, using Manchester Central Library as an example.

### Assumptions to note:

Roads speed used are based on speed limits. Emission estimation factors are identified as 1) travel distance 2) average speed and 3) fuel consumption in the report 12.6.2 Occupancy/Emissions Sustainability Metric Matrix

An average occupancy rate from the UK Department of Transport is used.

Journey start time at 9:00am on a Monday for public transport and the routes are calculated based on time schedules from data.gov.uk last updated in January 2017.

### Abbreviations

GIS            Geographic Information System  
CO<sub>2</sub>          Carbon dioxide

# "What is the most sustainable mode of urban transport?"

Our study demonstrates public transport journeys particularly taken using trams are the most sustainable.

Private car journeys are the least sustainable mode of transport.

Note: On some routes, bus journeys can be marginally quicker than tram routes. However, this produce substantially higher emissions.

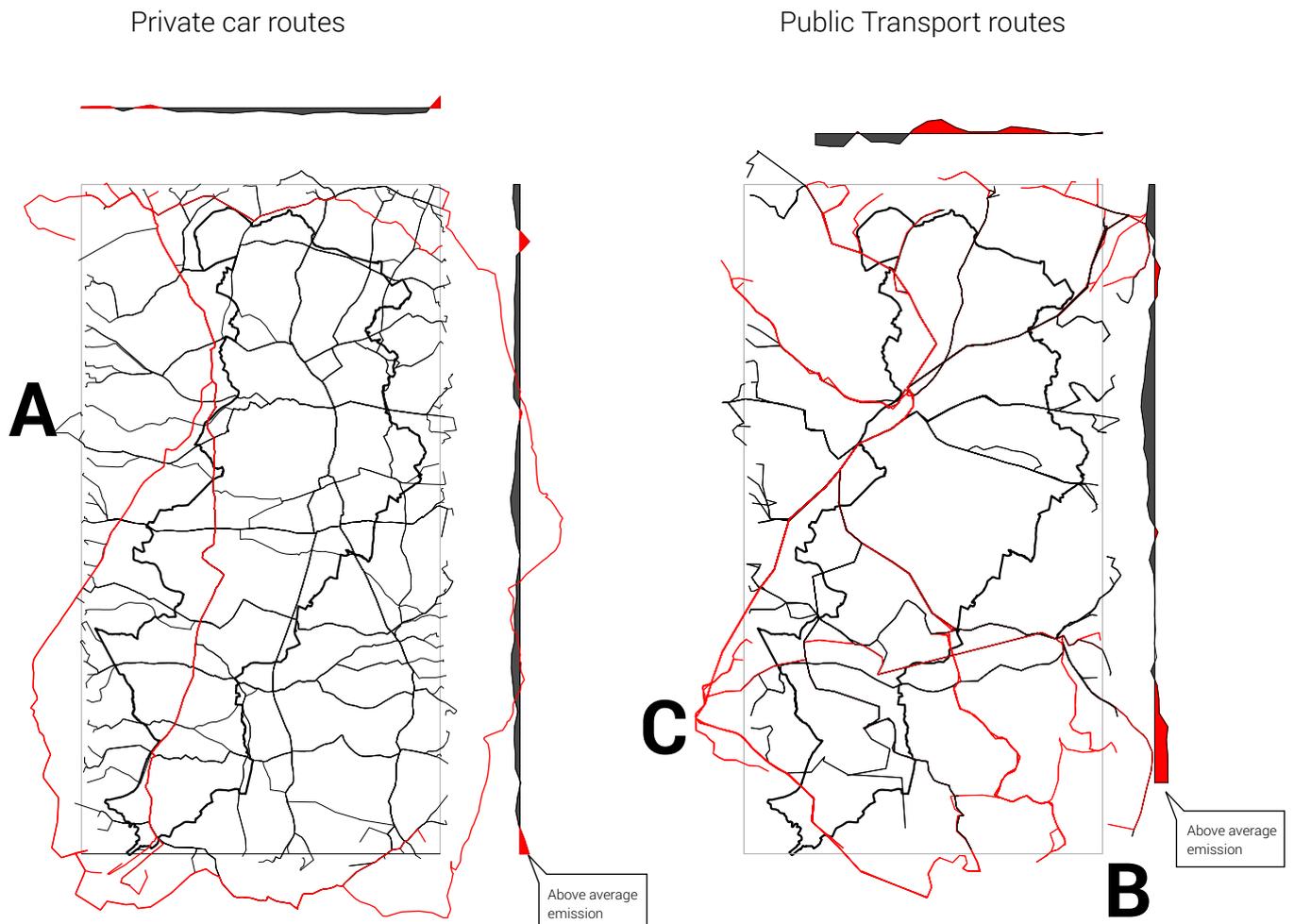
# "Is a journey in North Manchester greener than one in South Manchester?"

Comparison of emissions between different routes for journeys across Manchester from West to East suggests:

- A. Private car journeys with above average emissions are in the South to North direction
- B. Public transport journeys from South East to North East produce the highest emissions in the South to North direction.
- C. Public transport journeys to the South West to South East of Manchester produce highest emissions in the West to East direction.

# “Is a journey in North Manchester greener than one in South Manchester?”

Routes with highest emission in red



Note:  
Based on routes with lowest emissions  
Please find method in page 9

# Executive summary

This report examined a sample set of routes within Manchester District and compared the total emissions produced per journey by private car and public transportation.

## 1. Manchester District - The difference in travel distance, travel time and CO<sub>2</sub> emissions

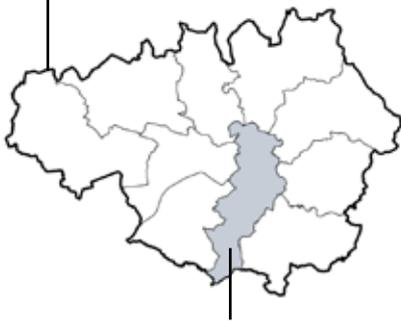
- The lowest emission route is through the City Centre travelling West to East across the Manchester District.
- The worst emission route is through the East of Manchester district travelling South to North across the Manchester District.
- The shortest route can be found through the City Centre across the Manchester District.
- The longest route can be found through the East of Manchester district travelling South to North across the Manchester District.
- The route taking the shortest time is through the North of the Manchester District travelling from West to East on private car across the Manchester District.
- The route taking the longest time is through the East of the Manchester District travelling from South to North via the City Centre.

## 2. The difference in travel distance, travel time and CO<sub>2</sub> emission from Manchester City Centre

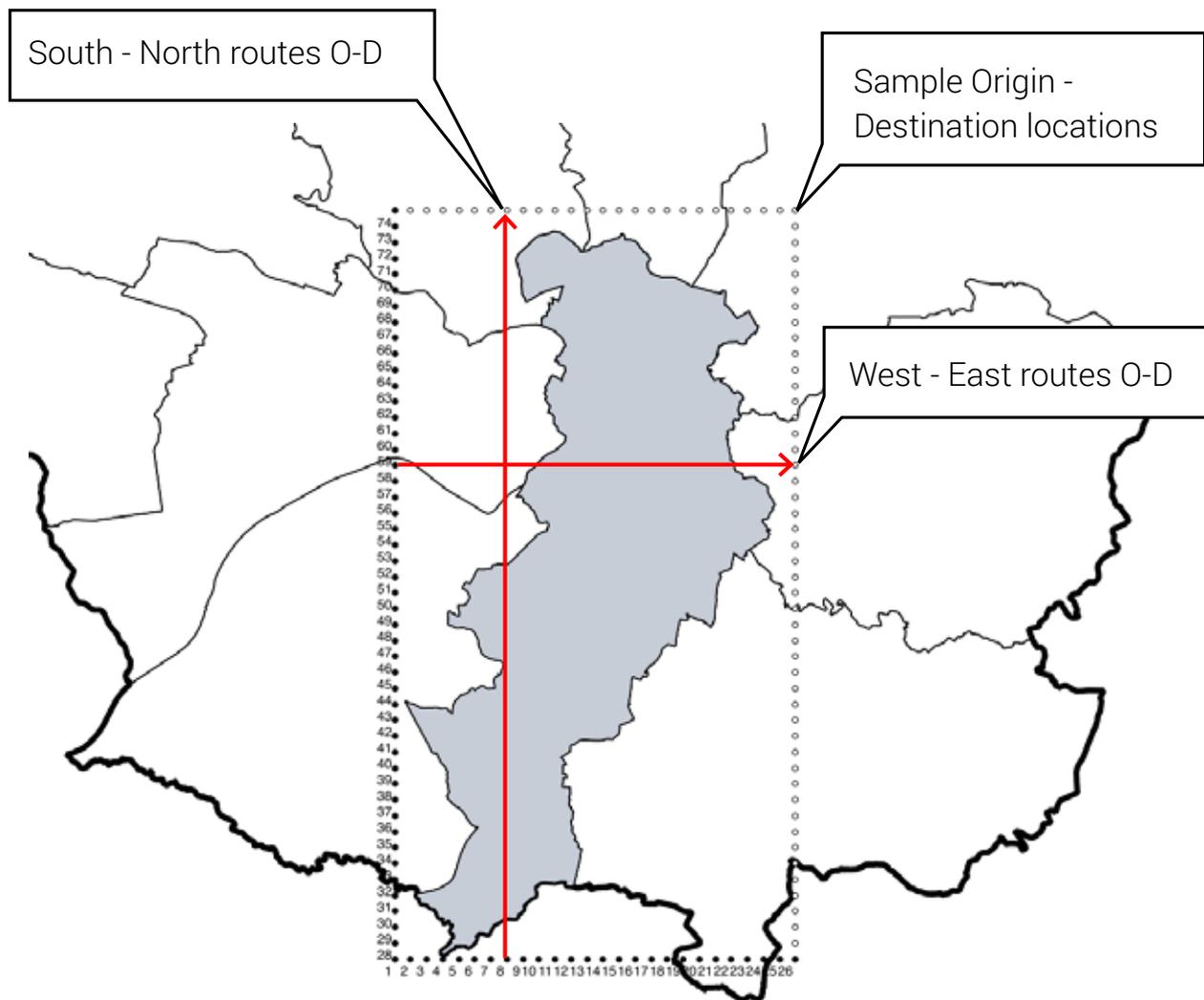
- The lowest emission route is to the East of Manchester on public transport with high proportion of journey on tram from the Manchester City Centre.
- The worst emission route is via private car travelling to the South East of Manchester from the Manchester City Centre.
- The shortest route can be found on public transport travelling in the North-East direction from the Manchester City centre.
- The longest route can be found in a car route towards South East of Manchester District from the Manchester City centre.
- The route taking the shortest time is by car towards North by North East from the Manchester City centre.
- The route taking the longest time is by bus towards South West towards Trafford from the Manchester City centre.

# Journey analysis: Across Manchester District

Greater Manchester



Manchester District



## Method

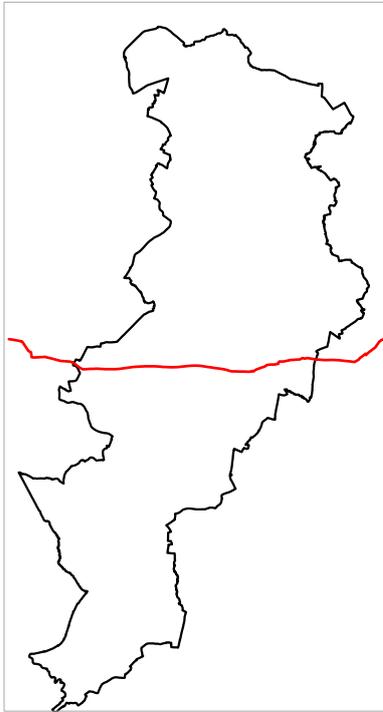
74 points are taken as origin and destination with 26 from South to North and 48 from West to East

Three separate sets of routes are calculated based on shortest distance, quickest route and lowest emission. Results are normalised.

# Route with shortest and longest travel distance

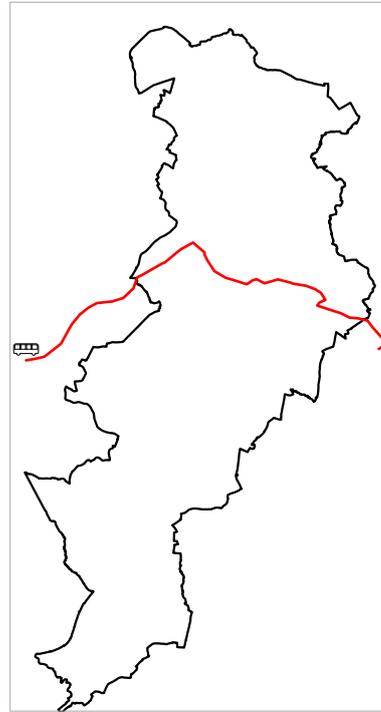
Shortest route by  
private car

ID: 52, Distance: 13639m, Time: 799s, Emission:1496g



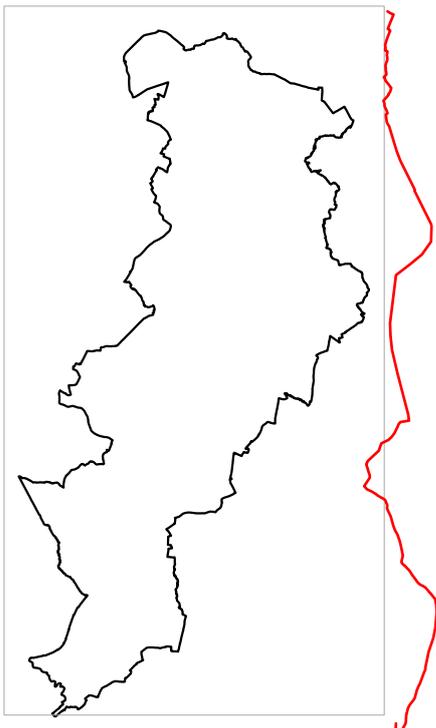
Shortest route by  
public transport

ID: 50, Distance: 12441m, Time: 7620s, Emission:1290g



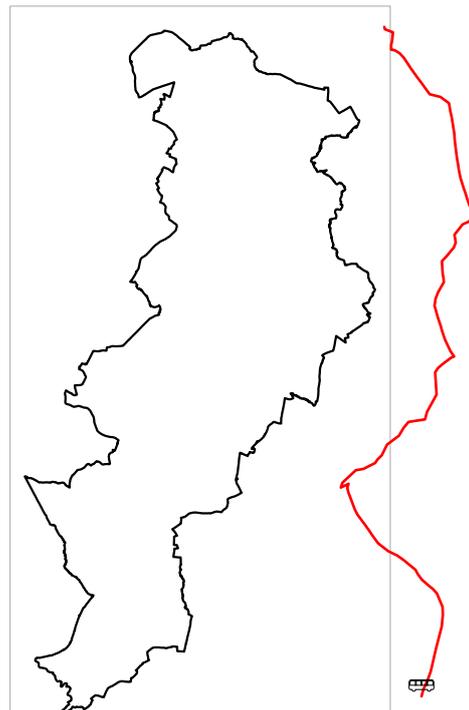
Longest route by  
private car

ID: 26, Distance: 28428m, Time: 1558s, Emission:3274g



Longest route by  
public transport

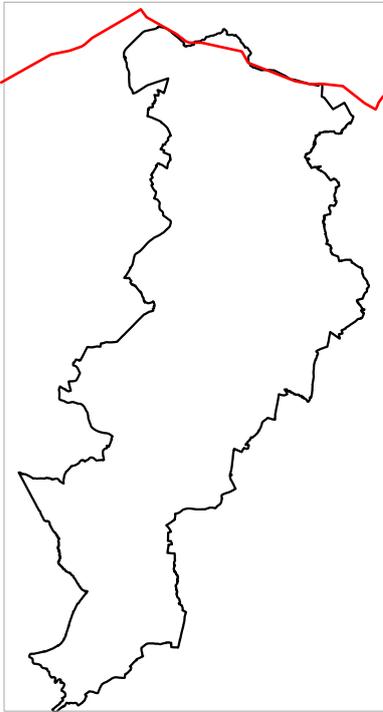
ID: 26, Distance: 28471m, Time: 9080s, Emission:2714g



# Route with lowest and highest travel time

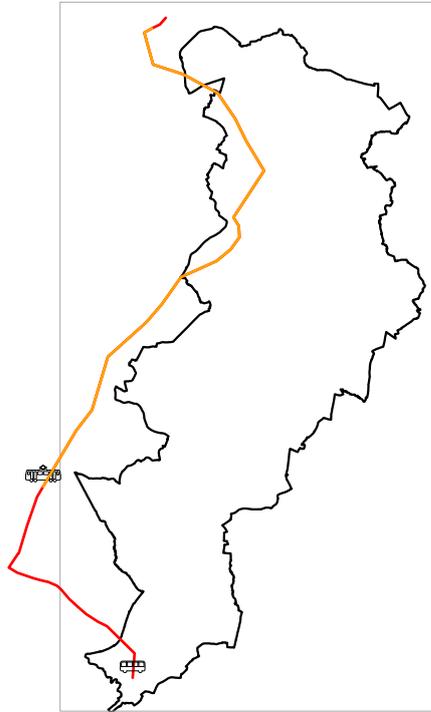
Lowest travel time  
by private car

ID: 69, Distance: 15392m, Time: 476s, Emission:1865g



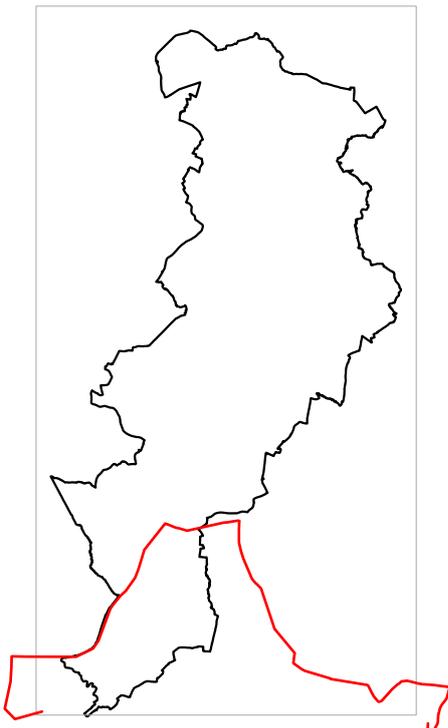
Lowest travel time  
by public transport

ID: 8, Distance: 31188m, Time: 5820s, Emission:1582g



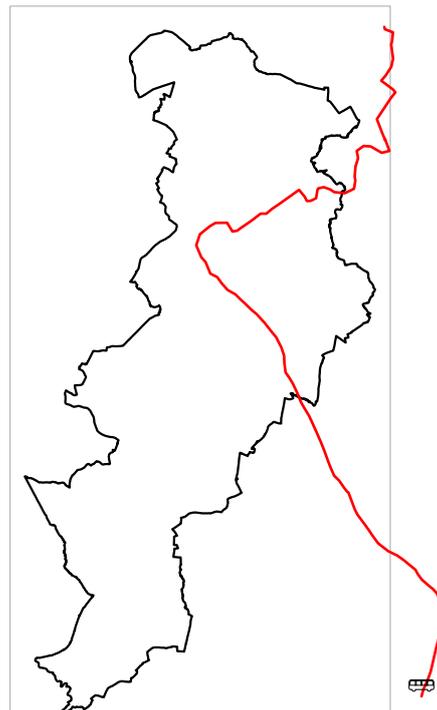
Highest travel time  
by private car

ID: 27, Distance: 27527m, Time: 1669s, Emission:3217g



Highest travel time  
by public transport

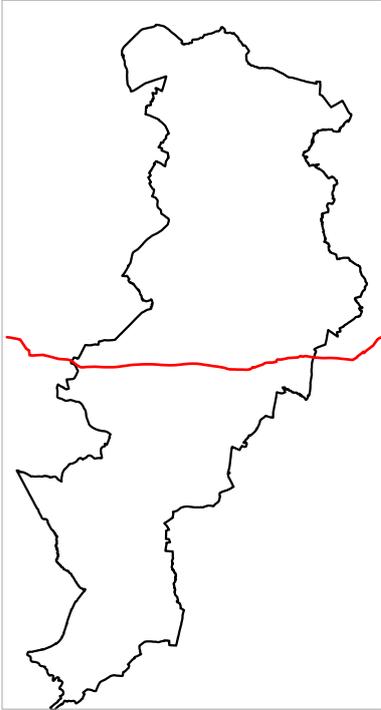
ID: 26, Distance: 33164m, Time: 9720s, Emission:3262g



# Route with lowest and highest emission

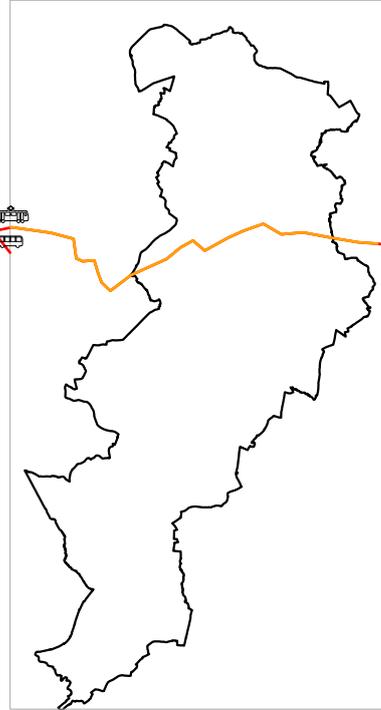
Lowest emission route  
by private car

ID: 52, Distance: 13639m, Time: 799s, Emission:1496g



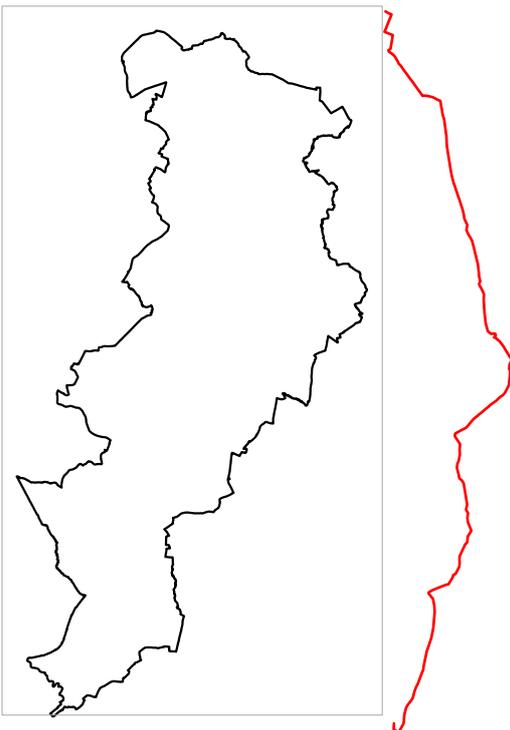
Lowest emission route  
by public transport

ID: 58, Distance: 16667m, Time: 6730s, Emission:703g



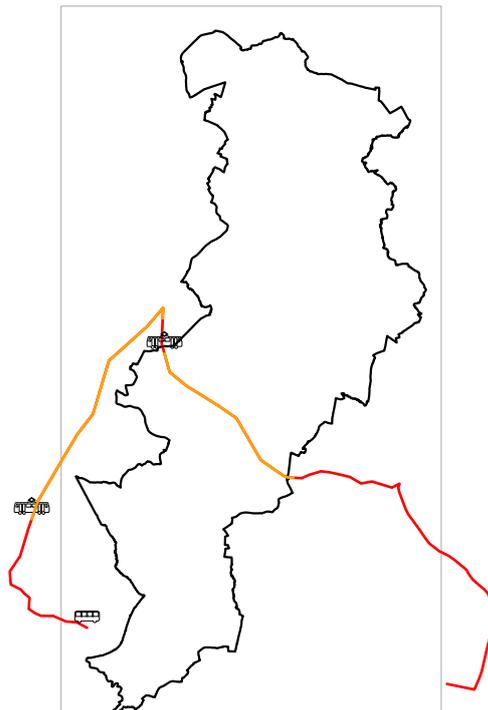
Highest emission route  
by private car

ID: 26, Distance: 28762m, Time: 1675s, Emission:3098g



Highest emission route  
by public transport

ID: 31, Distance: 34735m, Time: 8210s, Emission:2184g



## Public transport routes comparison between quickest route and lowest emission

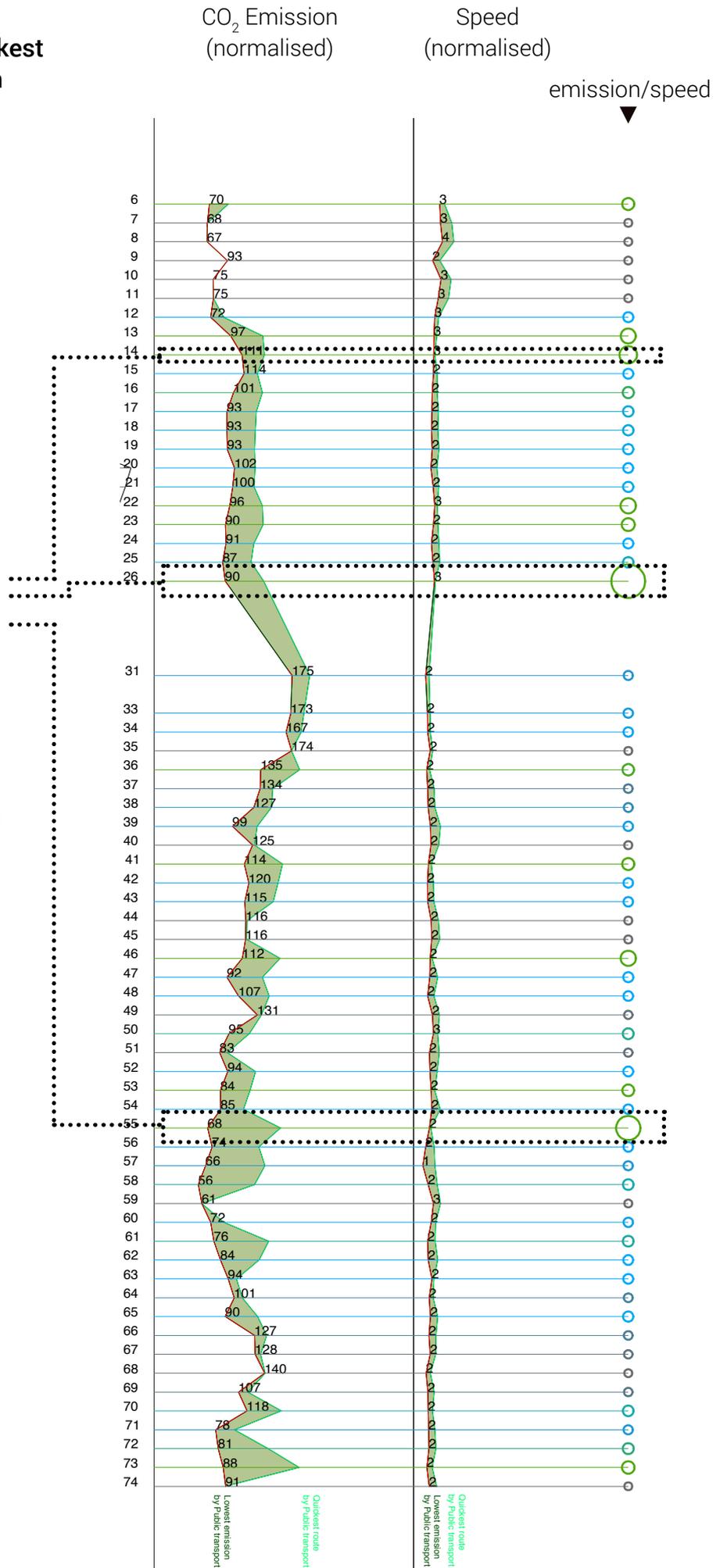
Is it worth the extra travel time on an alternative route for lower carbon emission?

The ratio between the emission and time difference between the quickest route and the route with the lowest emission. The higher the result value indicates a higher benefit in lower emission for the extra time cost.

The results of public transport routes sampled indicates 3 routes with over 1 g/s, therotically a saving of over 600g for a journey that takes and extra 10 minutes (600 seconds).

This can be visually identified in the diagram on the right where there is a the wider section in the CO<sub>2</sub> emission column versus the speed column.

This in addition to the actual time difference can be used as criteria in evaluating the emission benefit between two routes.



## Private car routes comparison between quickest route and lowest emission

The results of public transport routes sampled indicates 60 out of 74 routes with saving of over 1 g/s.

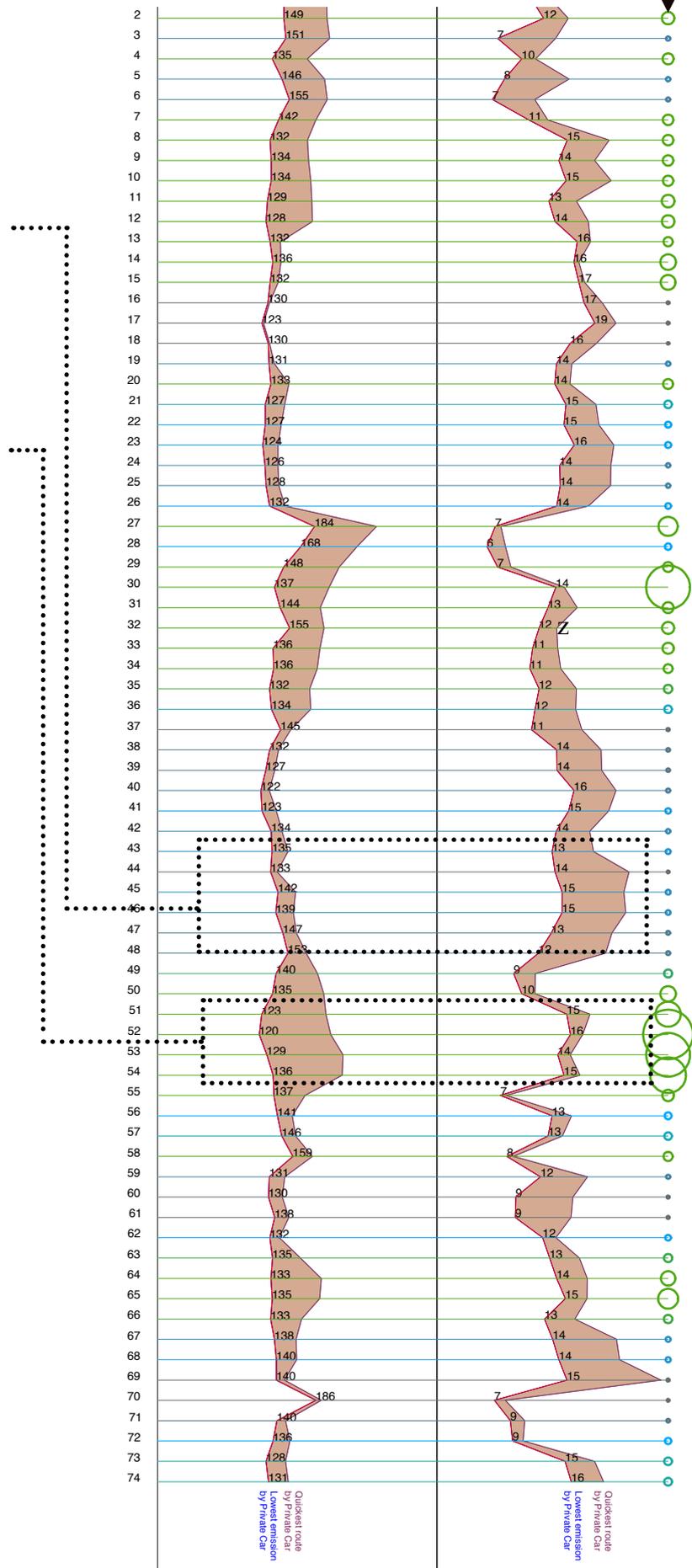
There are routes where the difference in emission saving comparing to journey time increase is significantly low.

However, there are also routes where the difference in emission saving comparing to journey time increase is significantly high.

CO<sub>2</sub> Emission (normalised)

Speed (normalised)

emission/speed



## Public transport and private car routes comparison

CO<sub>2</sub> Emission (normalised)

Speed (normalised)

Private cars achieve quicker journeys in all routes sampled. However, it is important to note that this model assumed movement at speed limits for road network. Public transport times are based on time schedules. Road-based transportations can be affected by traffic conditions.

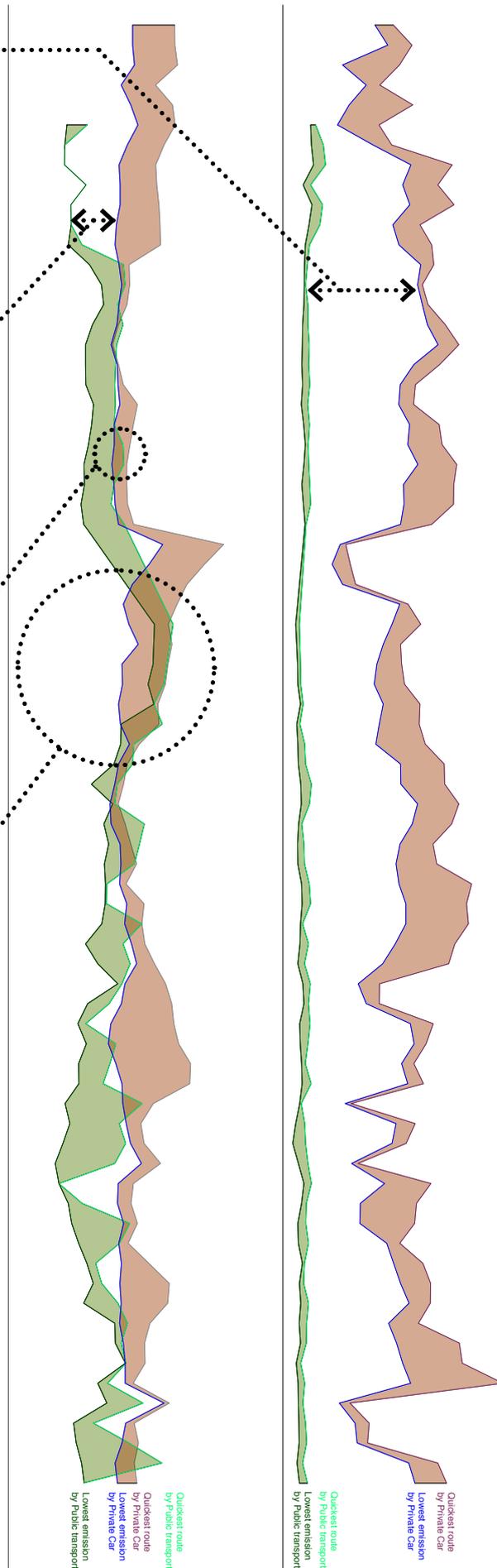
Public transport performs better than car transport in emission for most routes sampled.

Public transport performs worst than car in emission when comparing the quickest route against lowest emission on the corresponding equivalent car journey.

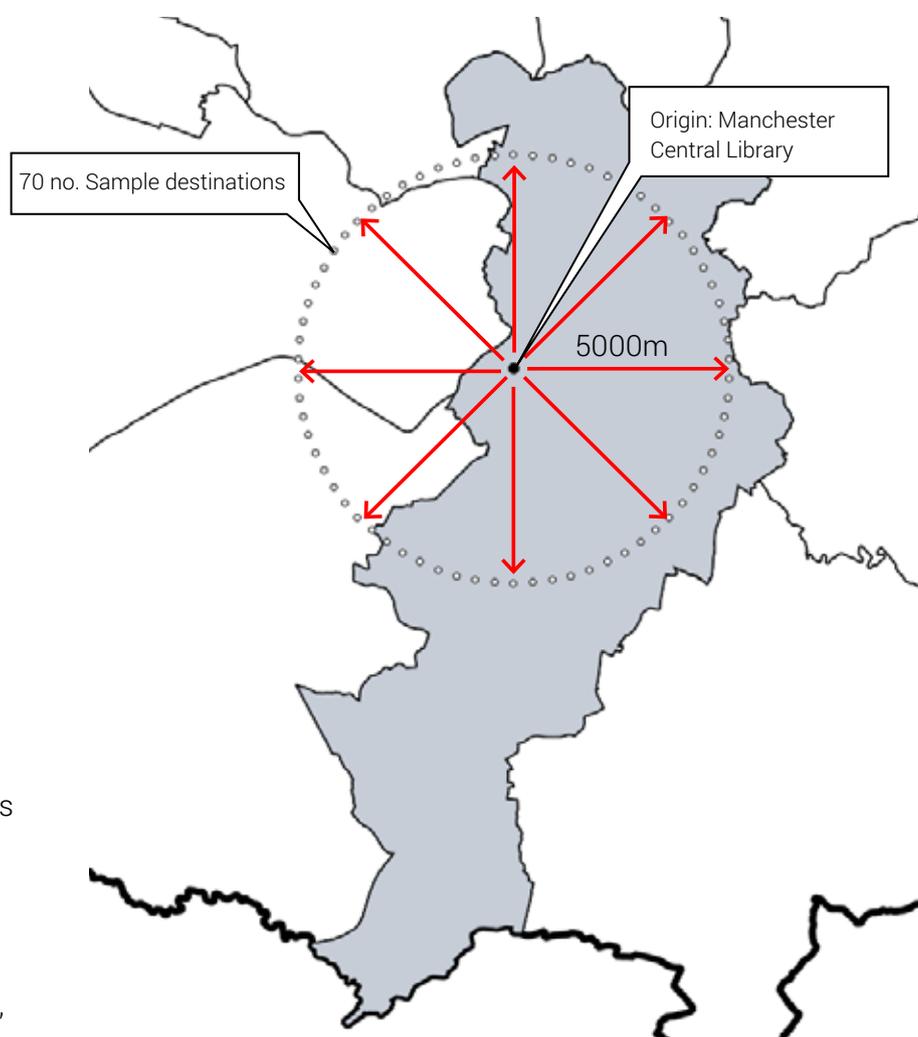
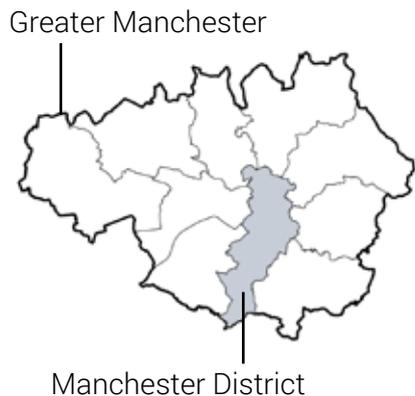
Road - private car journey performs better than public transport in terms of emission for certain routes. This is due to a combination of longer distance - where public transport has a less direct route and a high proportion of the journey taken by bus.

Shaded region shows the difference between quickest route and route with lowest emission

- Public transport
- Road - Private car journey



# Journey analysis: From Manchester city centre



## Method

The closest station or road within 100m of the public transport or road network is selected from the sample origin and destination.

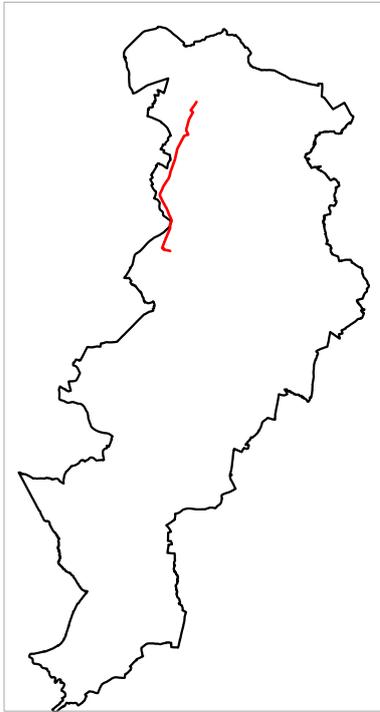
Three separate sets of routes are calculated based on shortest distance, quickest route and lowest emission.

The results are then indexed, drawn with emission and time normalised by the corresponding direct distance of 5000m for comparisons.

# Route with shortest and longest travel distance

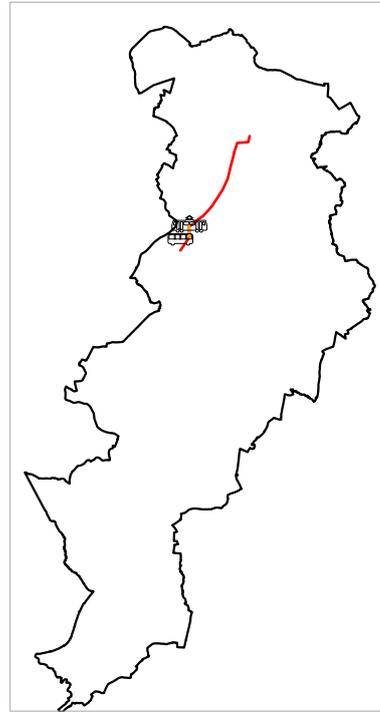
Shortest route by  
private car

ID: 3, Distance: 5804m, Time: 373s, Emission:639g



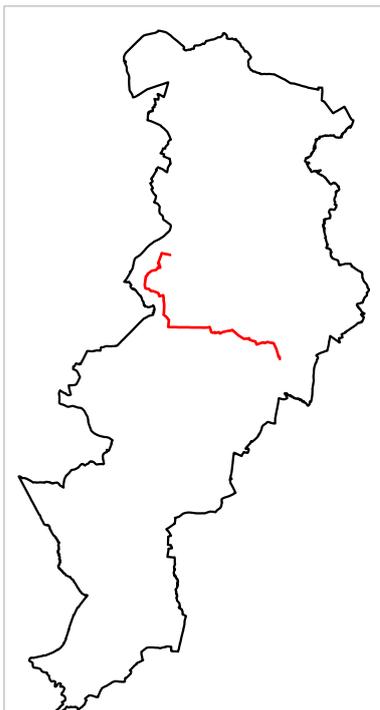
Shortest route by  
public transport

ID: 7, Distance: 4930m, Time: 2580s, Emission:450g



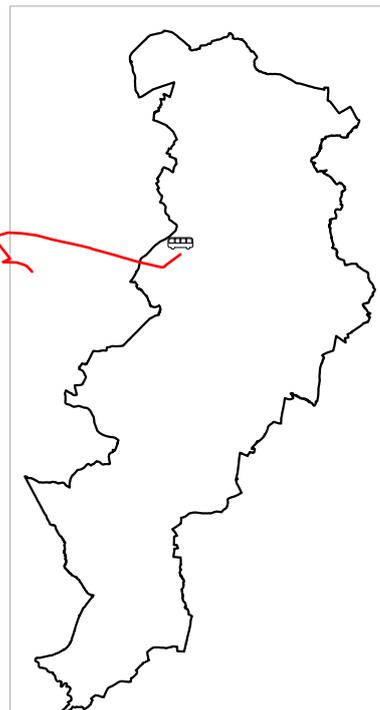
Longest route by  
private car

ID: 27, Distance: 8577m, Time: 756s, Emission:993g



Longest route by  
public transport

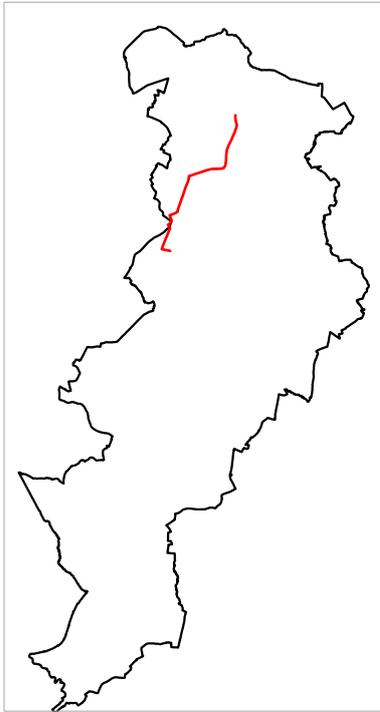
ID: 52, Distance: 8625m, Time: 4310s, Emission:854g



# Route with lowest and highest travel time

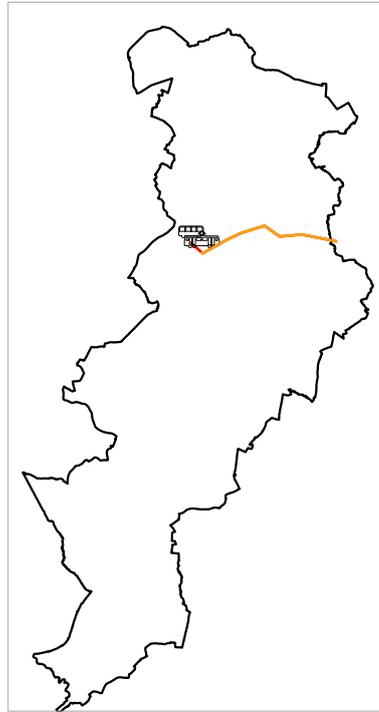
Lowest travel time  
by private car

ID: 6, Distance: 6170m, Time: 303s, Emission:664g



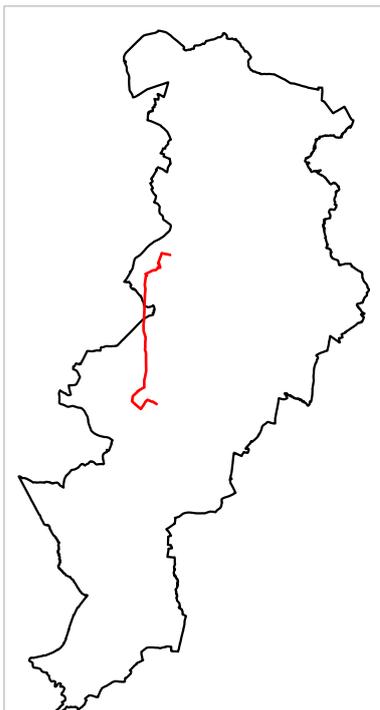
Lowest travel time  
by public transport

ID: 18, Distance: 5974m, Time: 1600s, Emission:228g



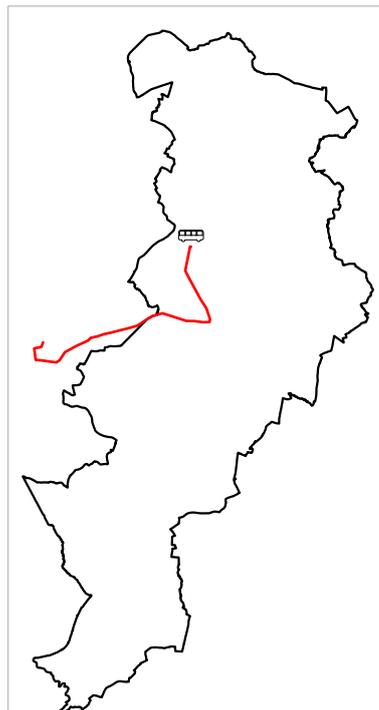
Highest travel time  
by private car

ID: 37, Distance: 7179m, Time: 646s, Emission:820g



Highest travel time  
by public transport

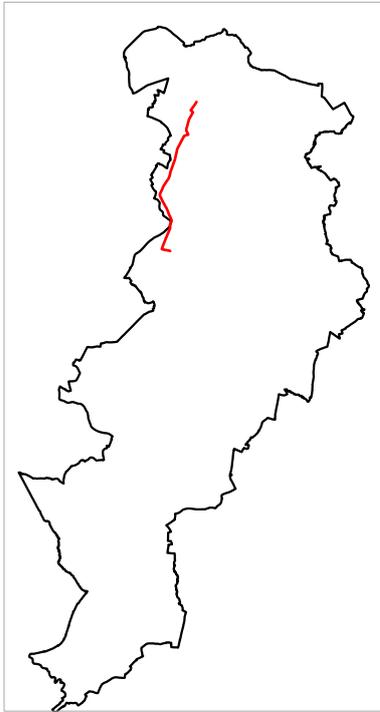
ID: 47, Distance: 10254m, Time: 3920s, Emission:1036g



# Route with lowest and highest emission

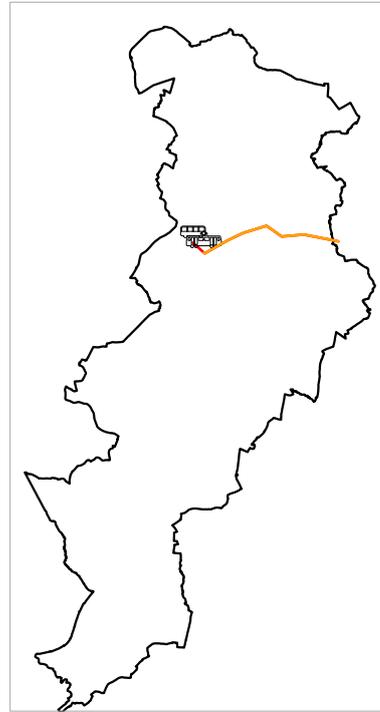
Lowest emission route  
by private car

ID: 3, Distance: 5809m, Time: 370s, Emission:638g



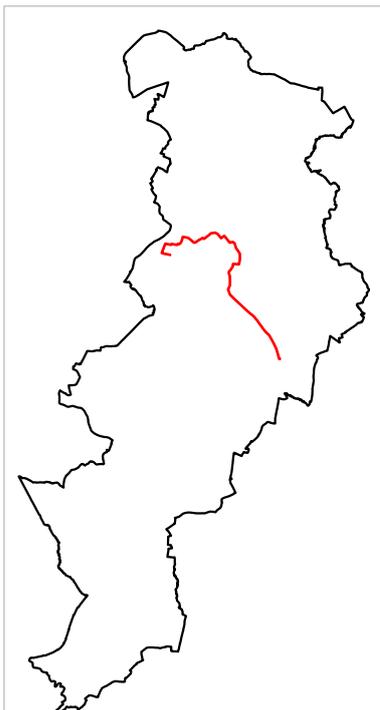
Lowest emission route  
by public transport

ID: 18, Distance: 5974m, Time: 1600s, Emission:228g



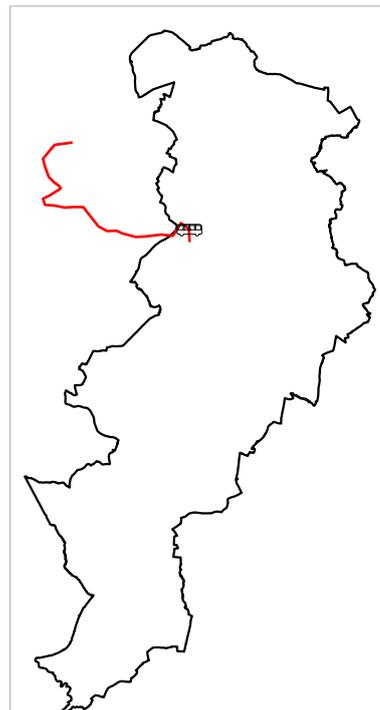
Highest emission route  
by private car

ID: 27, Distance: 8677m, Time: 630s, Emission:967g

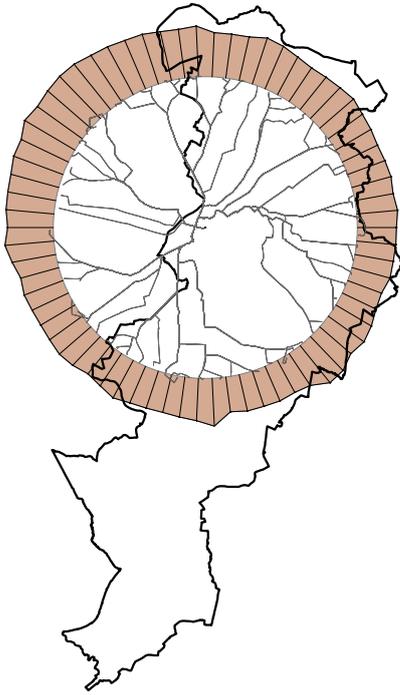


Highest emission route  
by public transport

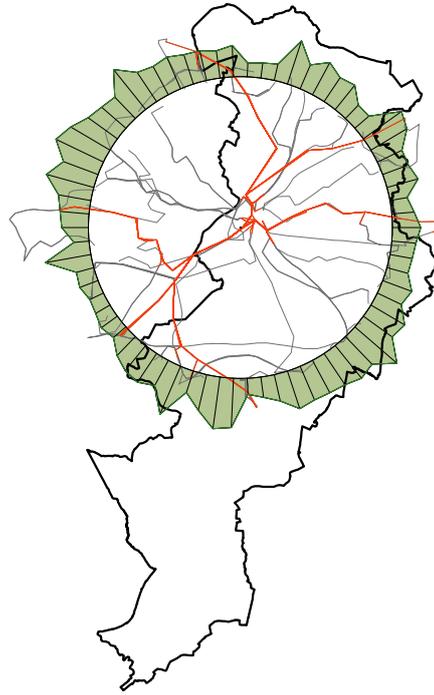
ID: 63, Distance: 9764m, Time: 3350s, Emission:919g



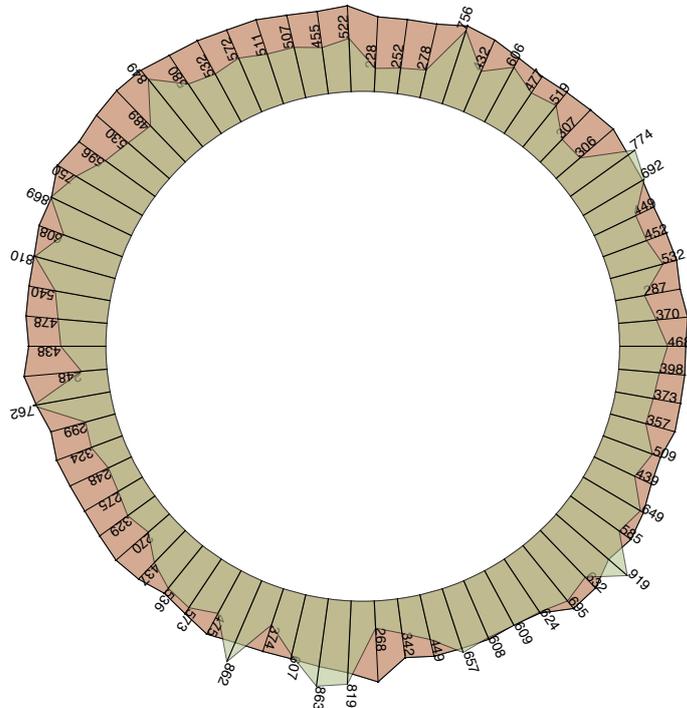
# Public transport and private car routes comparison



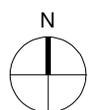
Road routes & CO<sub>2</sub> emission (g)



Public transport routes & CO<sub>2</sub> emission (g)



Road routes versus Public transport routes  
Lowest emission plotted against each sampled destination

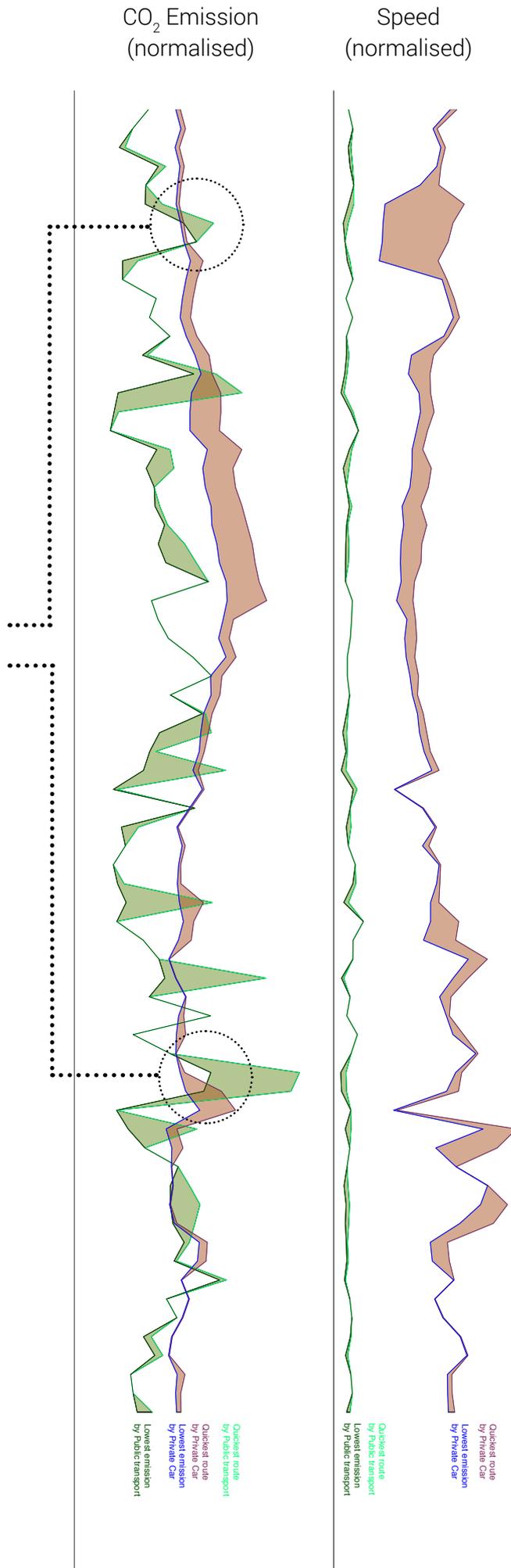


## Public transport and private car routes comparison

1. Private cars achieve quicker journeys in all routes sampled. However, it is important to note that this model assumed best speed for road network and public transport times based on time schedules. The speed for road-based transportations are subject to traffic conditions.
2. Public transport performs better than car transport in emission for most directions.
3. Public transport performs worst than car in emission on the corresponding equivalent car journey towards certain directions.
4. Road - private car journey performs better than public transport in terms of emission for certain routes. This is due to a combination of longer distance - where public transport has a less direct route and a high proportion of the journey taken by bus.

Shaded region shows the difference between quickest route and route with lowest emission

- Public transport
- Road - Private car journey



# Conclusion

This journey sustainability analysis report was undertaken using a custom tool and the data published in the previous two reports 12.6.2 titled "Occupancy/Emissions Sustainability Metric Matrix". What our analysis demonstrates is that the current private and public transport options within Manchester District and Centre provide variable outcomes for journey times, actual distance and CO2 emissions.

This report use a sample of 70 journeys, from West to East Manchester and South to North Manchester. The outcomes based on this analytical method (which does not incorporate problems such as traffic jams, road works or break down) suggests:

Journeys undertaken with private car tend to be faster than those undertaken by public transport. This is a clear area for improvements if public transport is to become a viable choice for everyone.

Journeys involving trams are the most environmentally friendly. However, the tram network is limited and multi-modal journeys demonstrates that other forms of public transport can be quicker while being less sustainable.

The highest emissions by private car based on routes are typically in East Manchester travelling in a South to North direction. The lowest emission by private car is from West to East directly across the City Centre.

The highest emissions by public transport based on routes are in the South of Manchester while the lowest emission are through the North of Manchester. These values are also indicative of the location of tram lines and the distance involved in travelling by public transport.

# Appendix

## Normalise variable by straight line distance

In theory, a straight-line route is the shortest route. All sampled routes have a greater distance to the direct straight line route. As road vehicles are road bound and cannot travel in a straight line through buildings, the actual travel distance varies depending on the routes chosen to navigate between two locations. As the estimated emission is calculated from travel distance, the longer the journey the higher the emission.

A different route results in a different distance, a straight-line distance is used to normalize the emission and time for comparison between a quickest route, a route with lowest emission and between different modes of transportation for the same origin and destination.

In order to compare between the results, the travel distance, travel time and emission are normalized by the straight-line distance between the defined origin and destination.

## Link between emission and time in user choice

It is possible for a route with lower emission but the time cost can be exceedingly high comparing to the equivalent quickest route. While the figures can be viewed separately in order to select a route based on the time difference alone, or the emission difference alone, it can be useful to quantify how much emission is saved over the time cost as an additional metric to identify best alternative routes.

For a car journey, the best CO<sub>2</sub> emission savings for additional travel time on an alternative route ranges from 24.2 g/s at a cost of 1 minute (67 seconds) – saving 1634.4g CO<sub>2</sub> versus the worst at 0.23 g/s at a cost of 4 minutes (247 seconds).

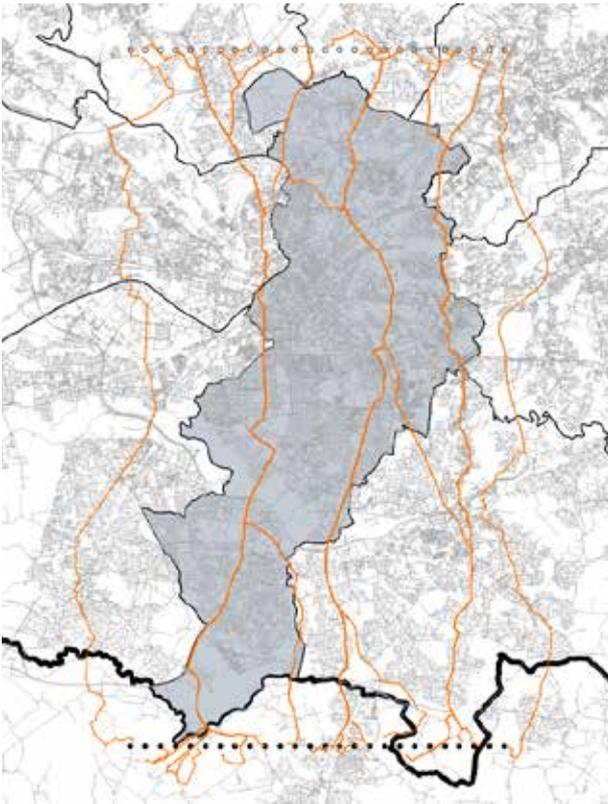
For a multimodal public transport journey, the CO<sub>2</sub> emission savings for additional travel time on an alternative route ranges from 3.25 g/s at a cost of under 6 minutes (350 seconds) – saving 1139.8g CO<sub>2</sub> versus the worst at 0 g/s at a cost of over 30 minutes (1990 seconds).

## Assumptions

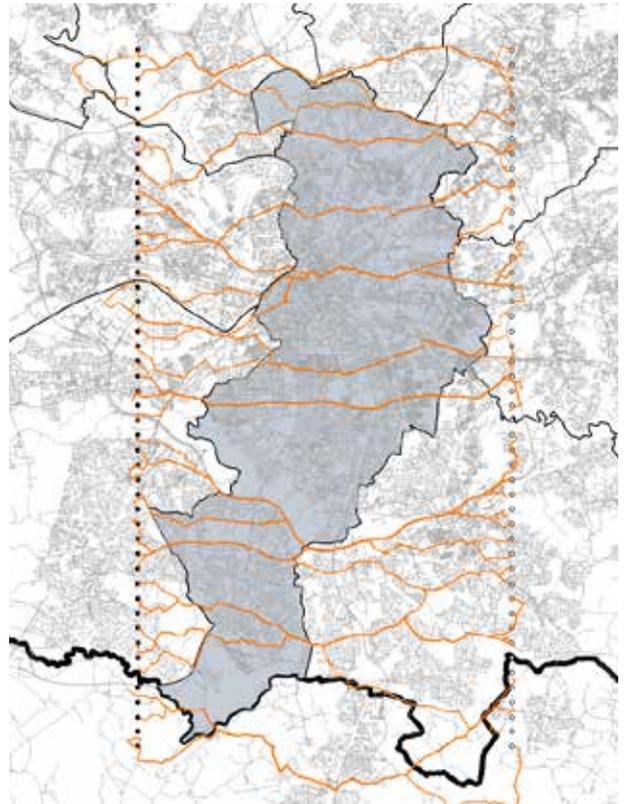
Private car journey takes shorter time compared to public transport based on the best possible speed on roads and time schedules on public transport. In reality, car journey and public transport journeys involving bus will be influenced by traffic conditions and it is likely to lower. It is important to note that decrease in average speed has an influence on emission estimation by average speed that can increase or decrease the estimate.

The emission estimations are based on average occupancy of 1.56 occupant for car journeys, 12 for bus, and 31 for tram. Data of actual occupancy of public transport aggregated for different time of day can improve the estimation.

# Road network: shortest distance



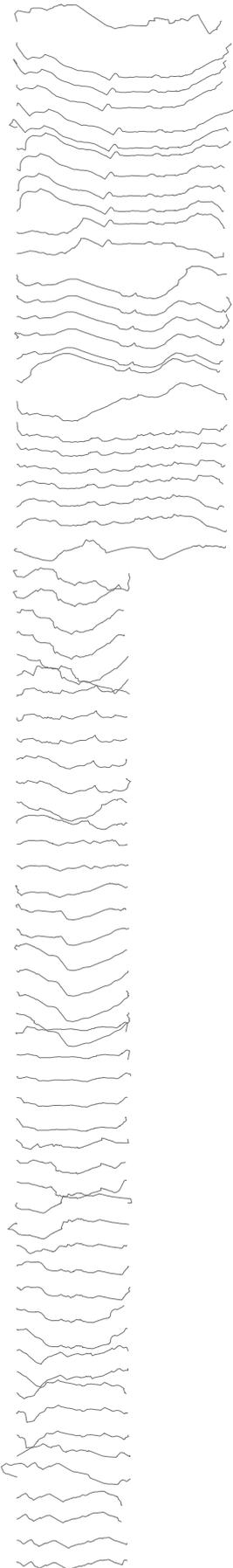
North-South routes



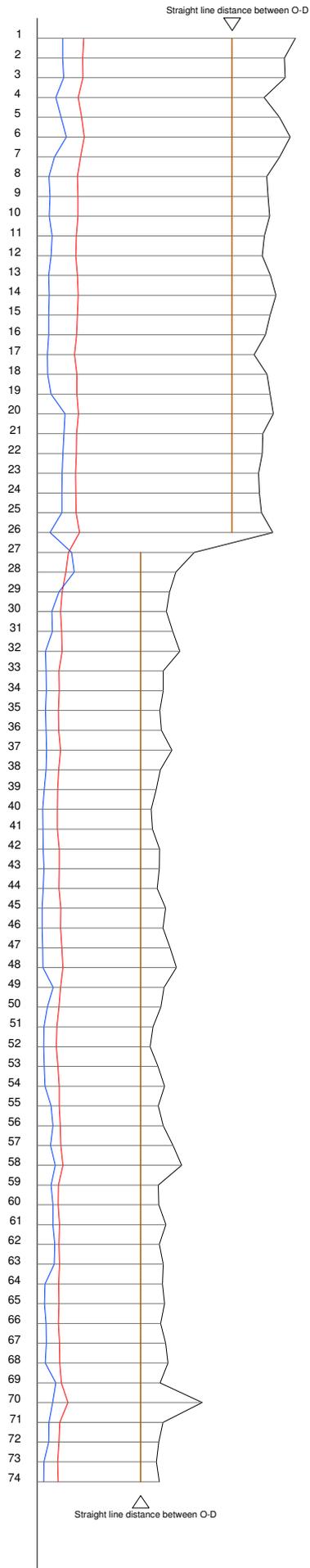
East-West routes

# Road network : shortest distance

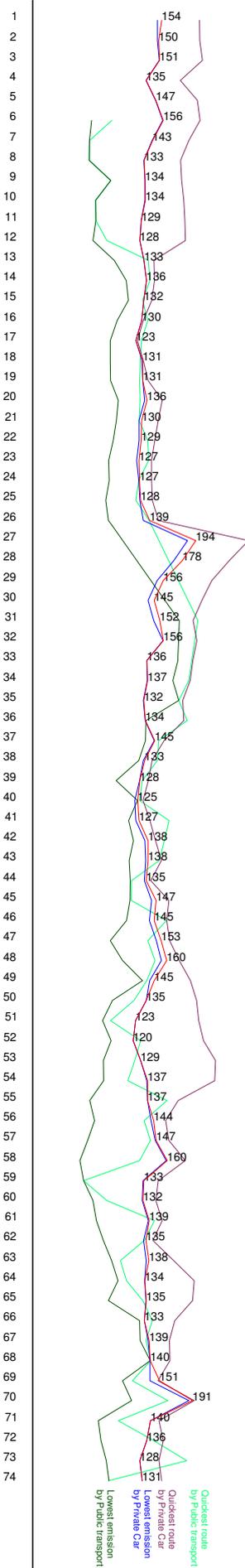
Indexed routes (Geographical)



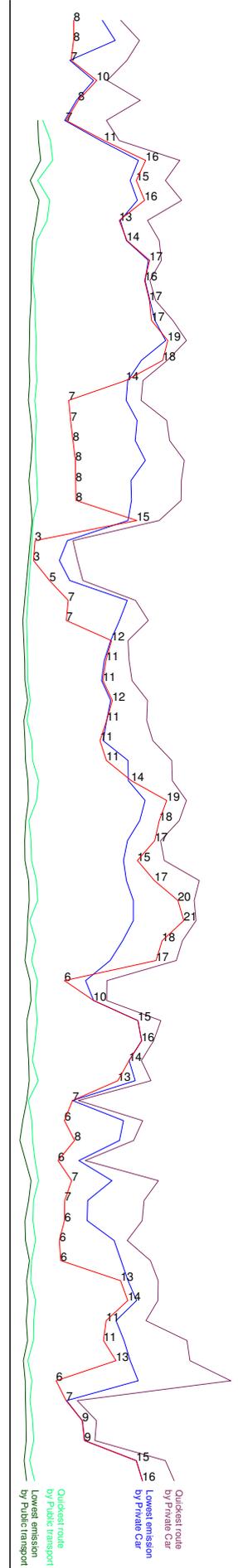
Indexed routes



Emission and Distance to distance between O-D  
g / m

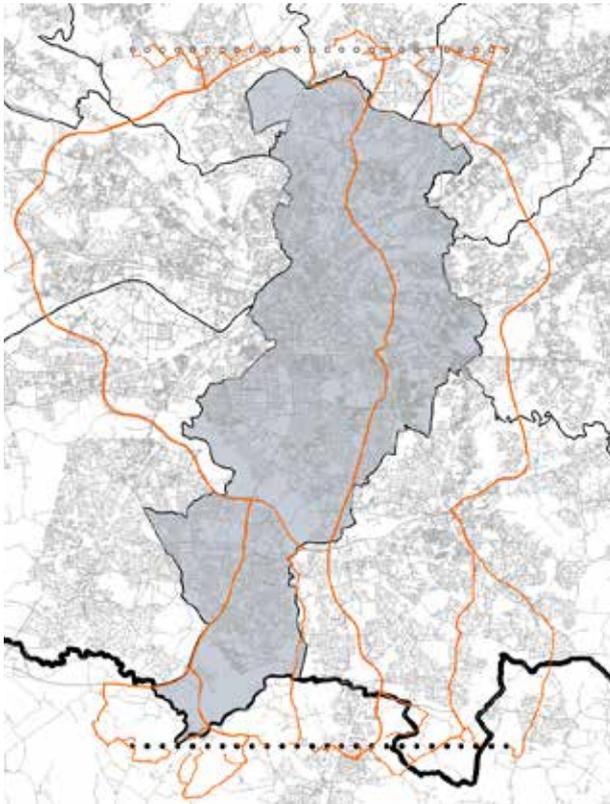


Speed and Distance to distance between O-D  
m / s

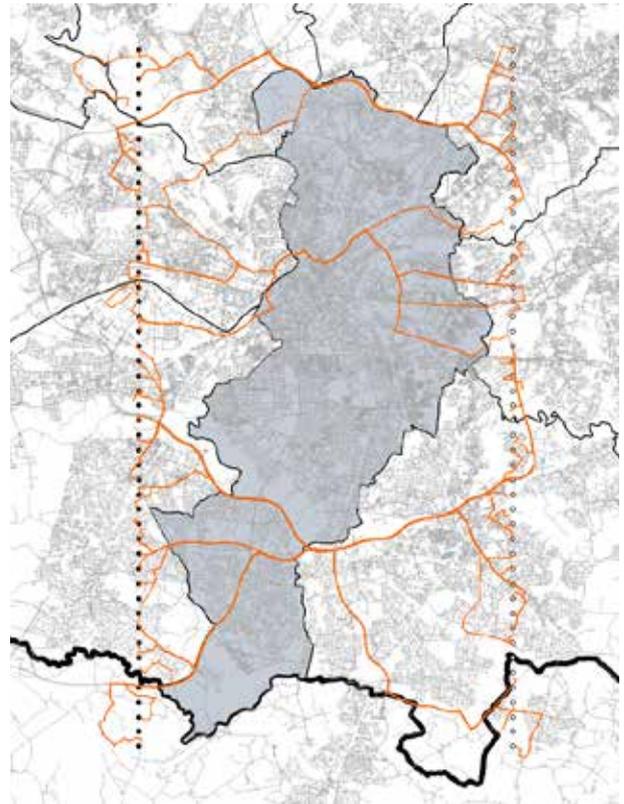


Lowest emission by Public transport  
 Lowest emission by Private Car  
 Lowest emission by Private Car  
 Lowest emission by Public transport  
 Quickest route by Public transport  
 Quickest route by Private Car  
 Quickest route by Private Car  
 Quickest route by Public transport

# Road network: quickest route



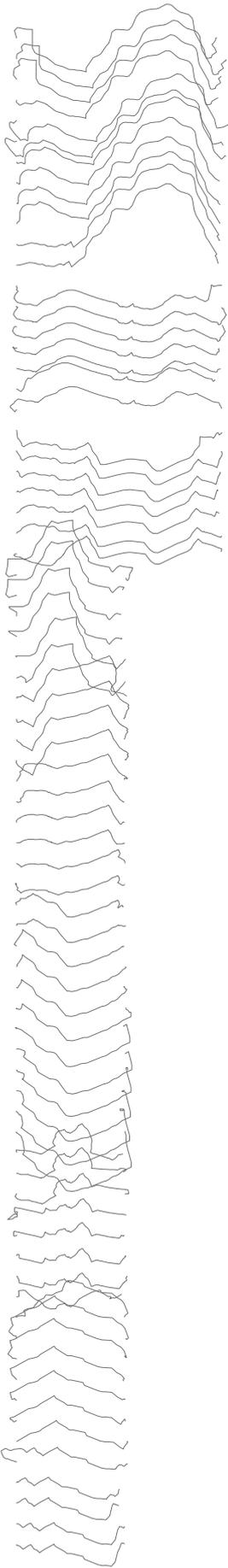
North-South routes



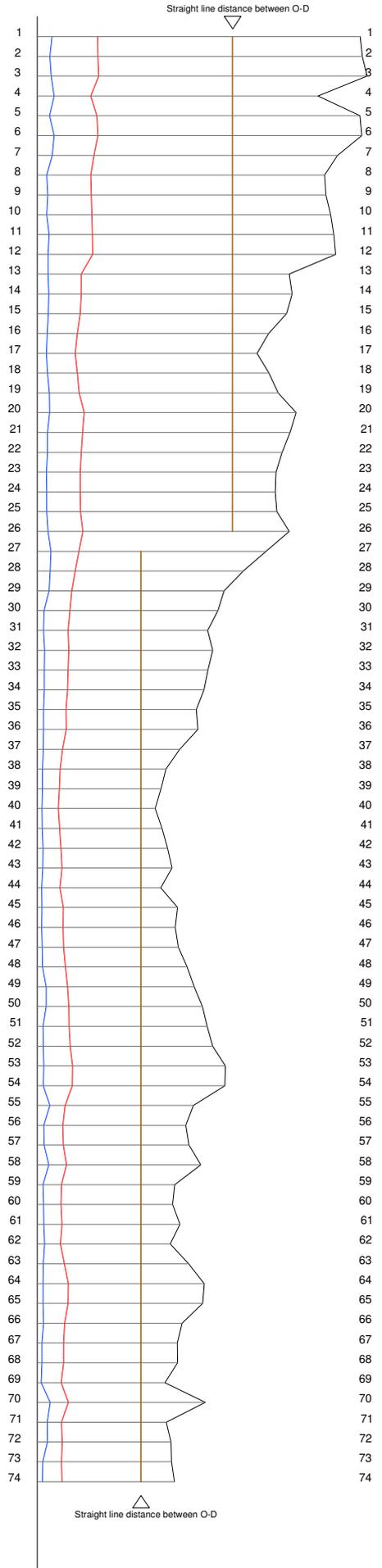
East-West routes

# Road network : quickest route

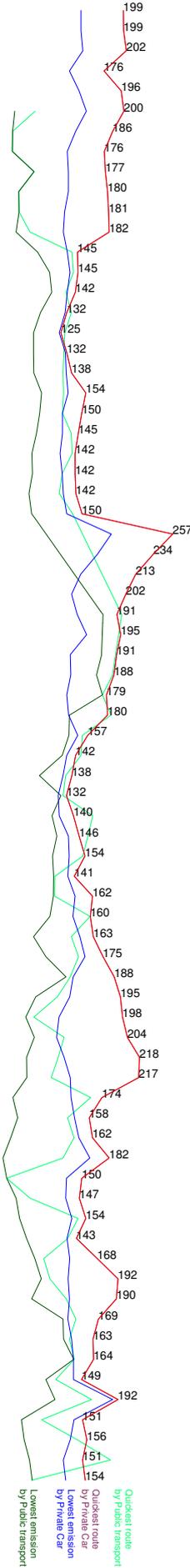
Indexed routes (Geographical)



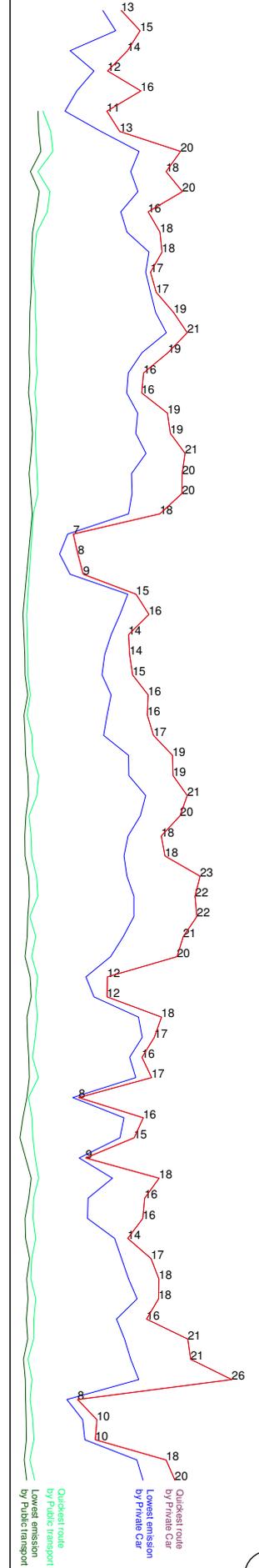
Indexed routes



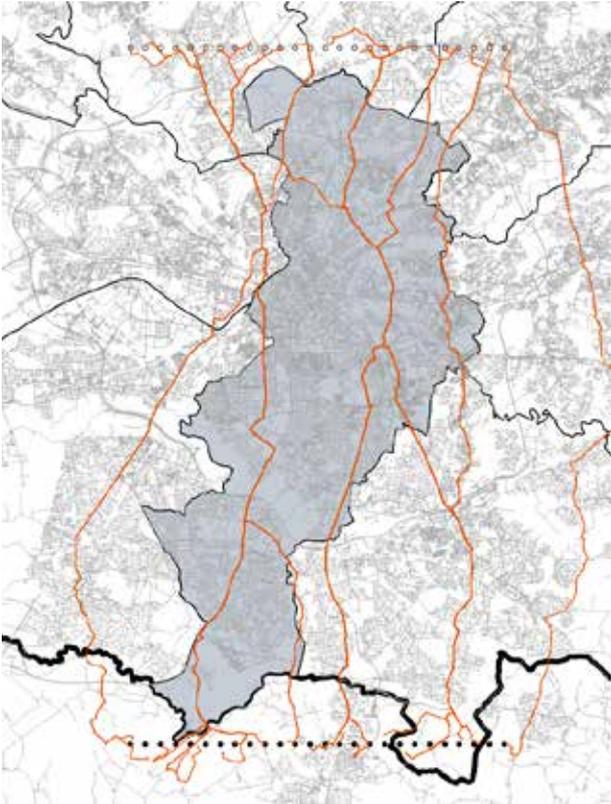
Emission rate to distance between O-D  
g / m



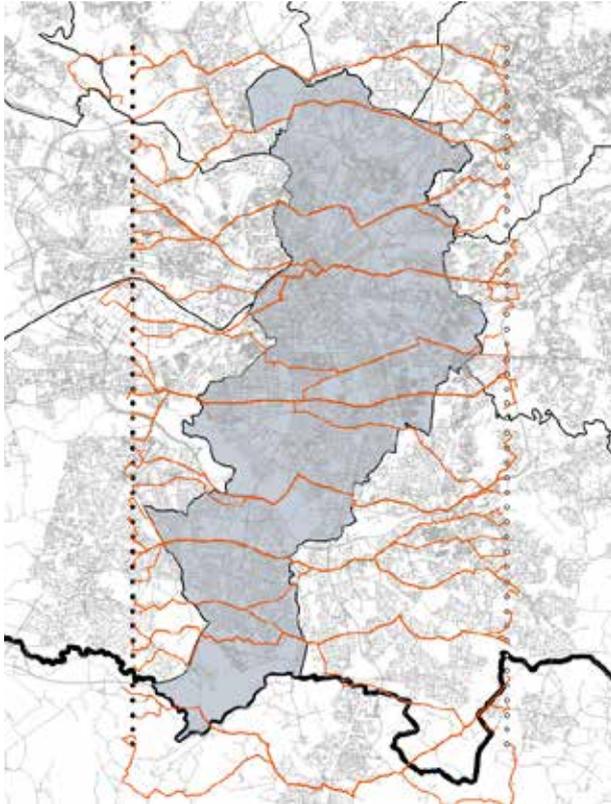
Speed to distance between O-D  
m / s



# Road network: lowest CO<sub>2</sub> emission



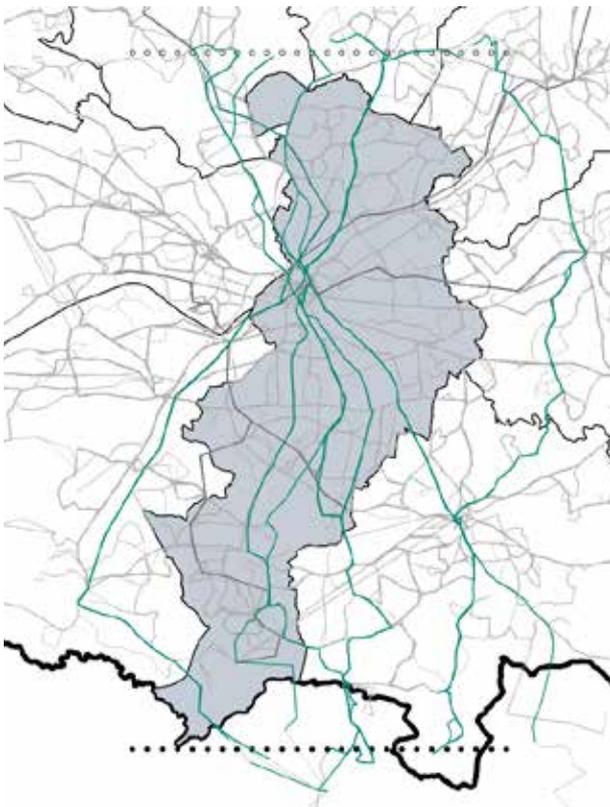
North-South routes



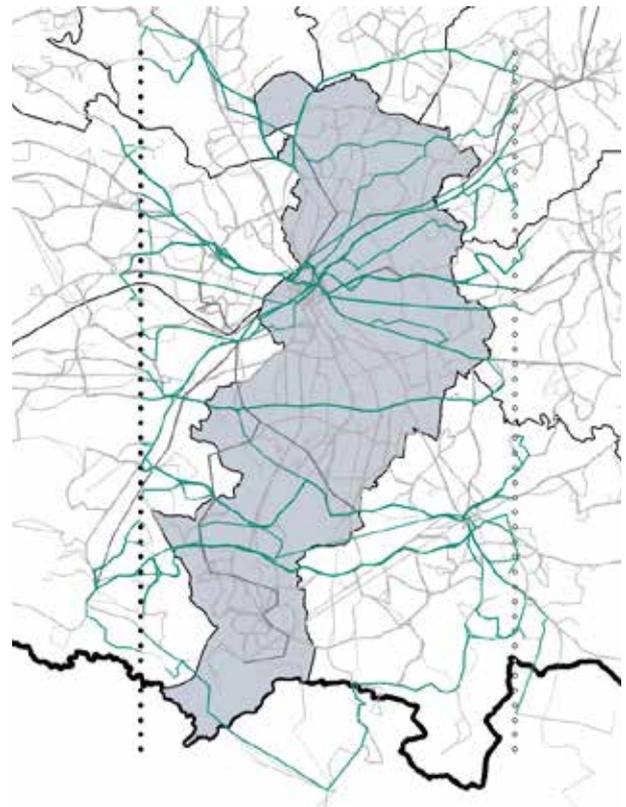
East-West routes



# Public transport: shortest distance



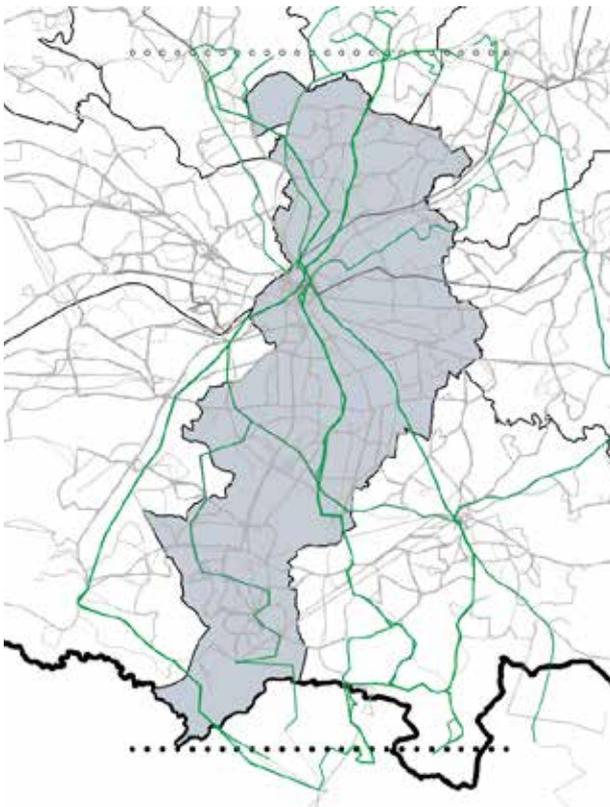
North-South routes



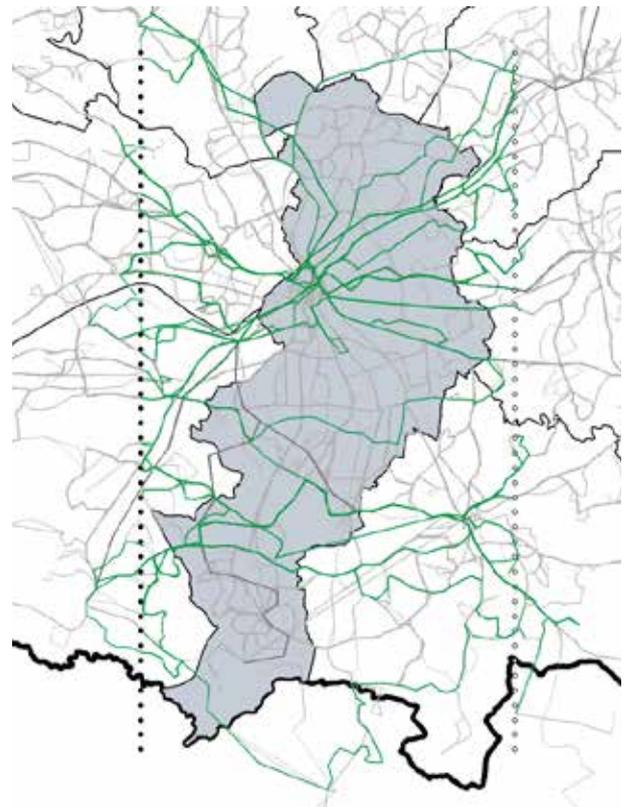
East-West routes



# Public transport: quickest route



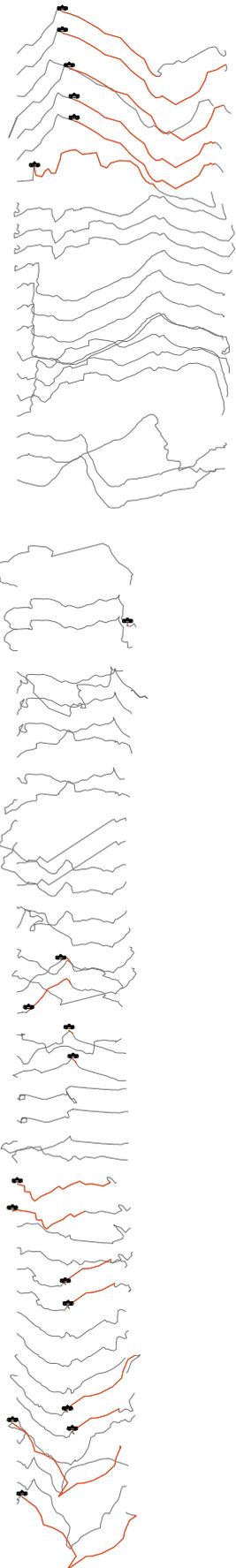
North-South routes



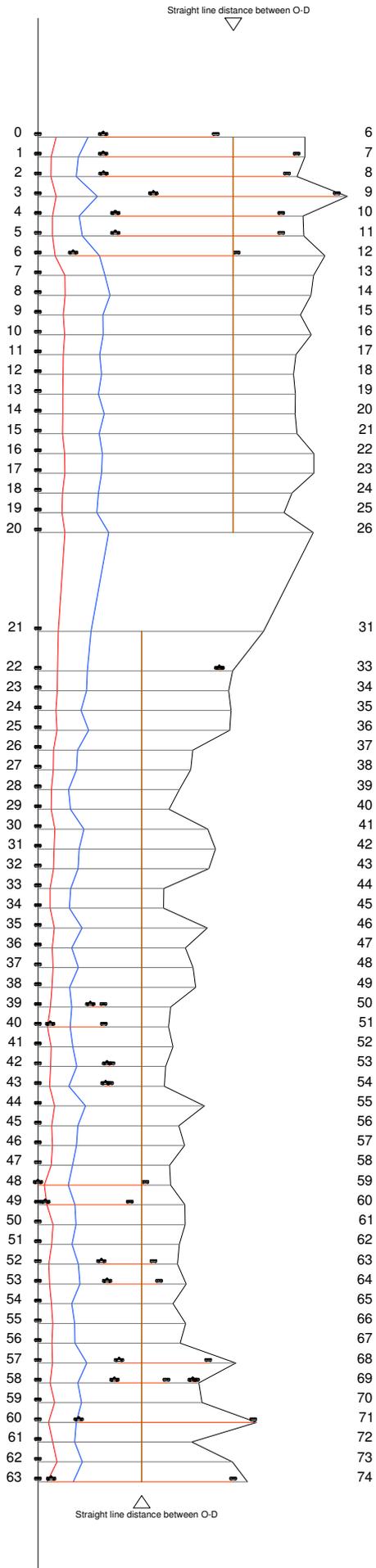
East-West routes

# Public transport : quickest route

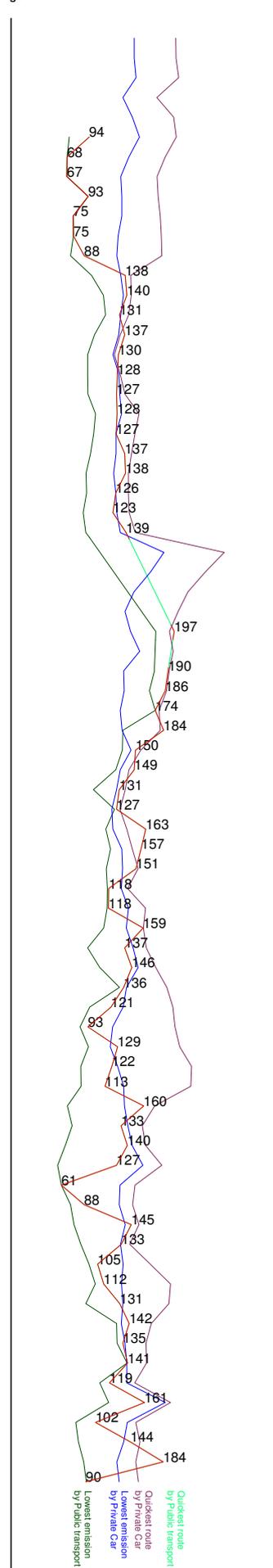
Indexed routes (Geographical)



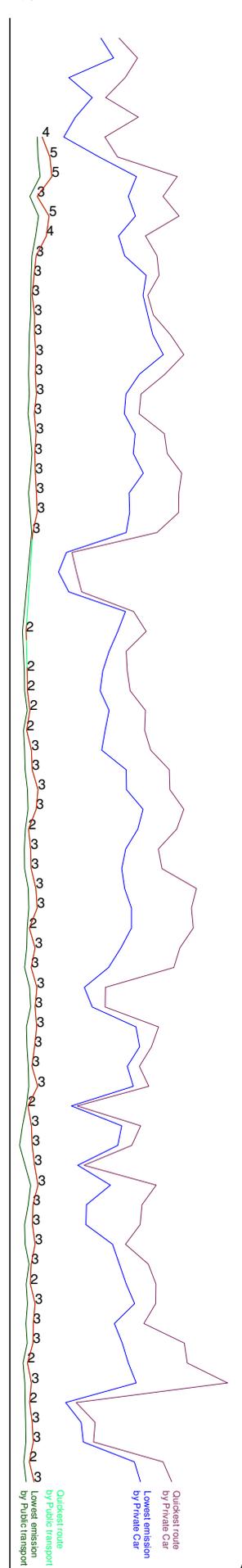
Indexed routes



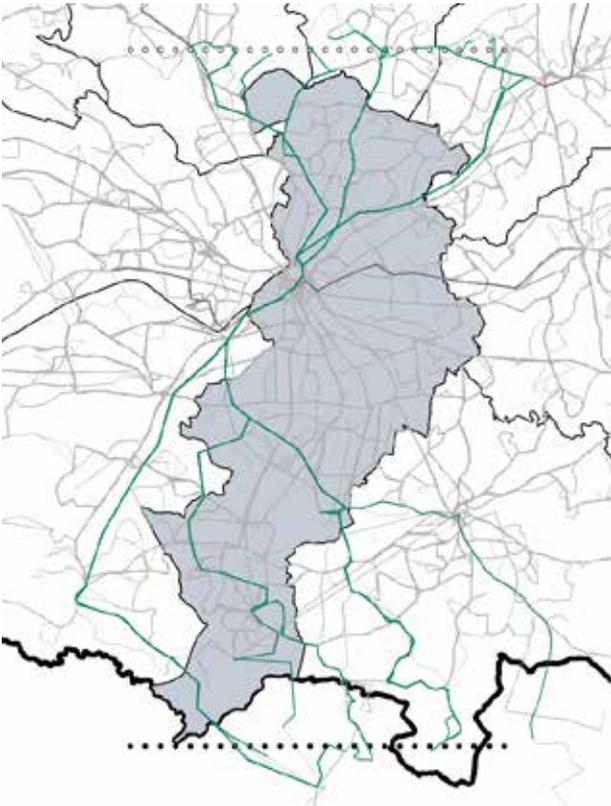
Emission and Distance to distance between O-D g / m



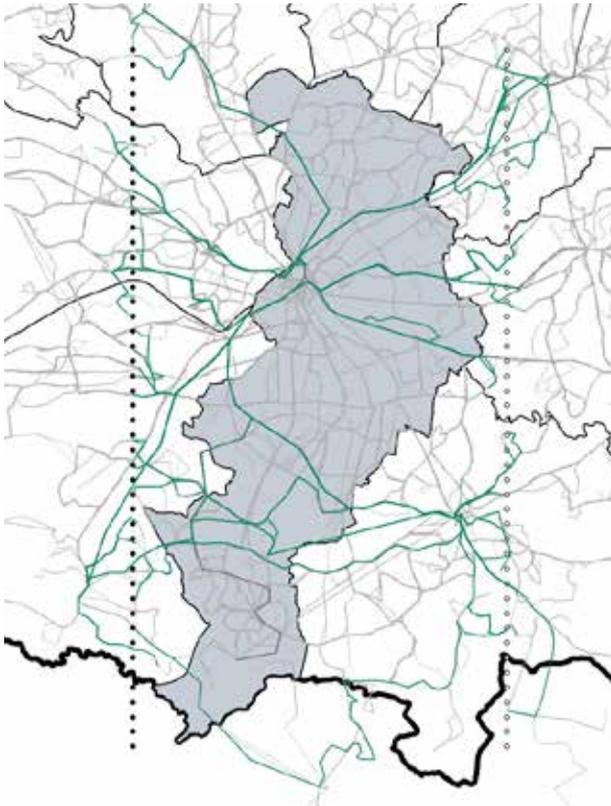
Speed and Distance to distance between O-D m / s



# Public transport: lowest CO<sub>2</sub> emission



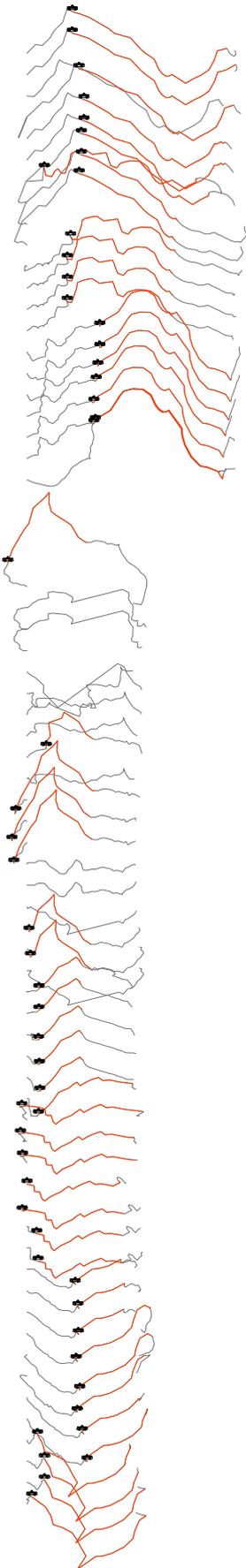
North-South routes



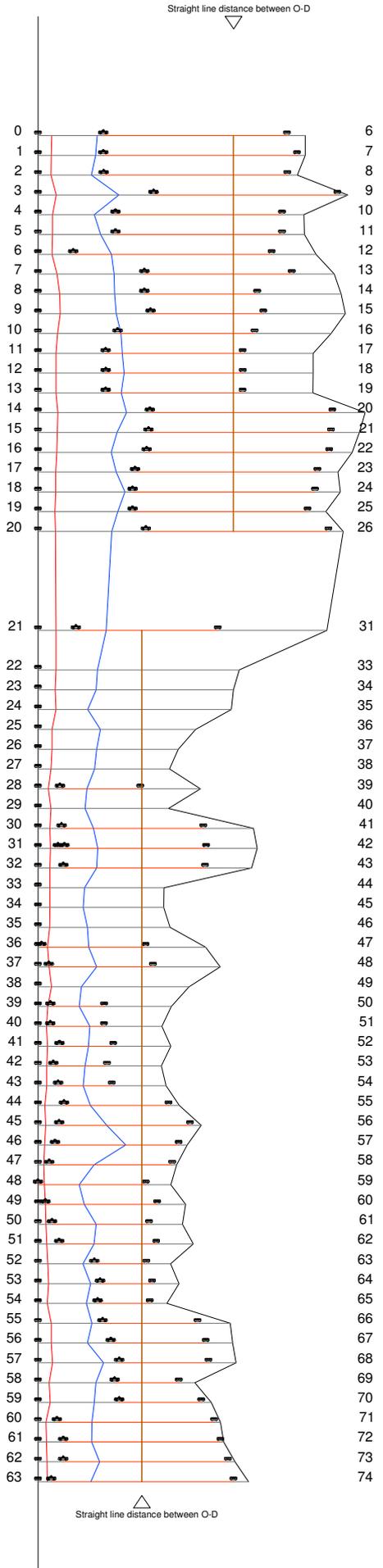
East-West routes

# Public transport : lowest CO<sub>2</sub> emission

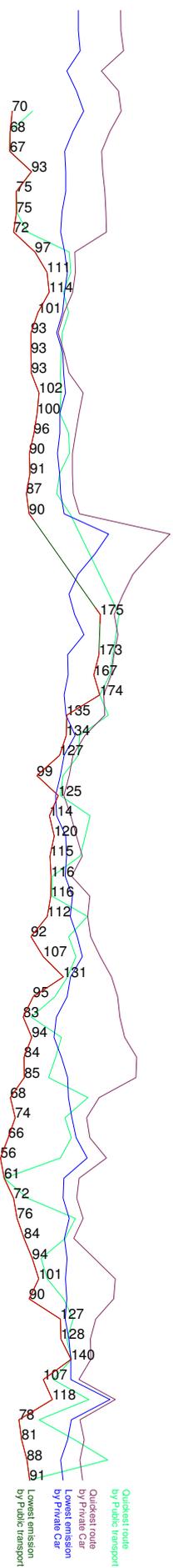
Indexed routes (Geographical)



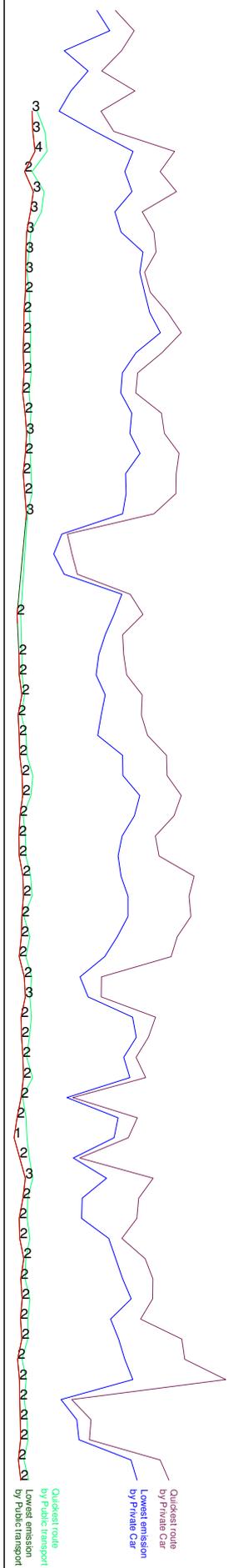
Indexed routes



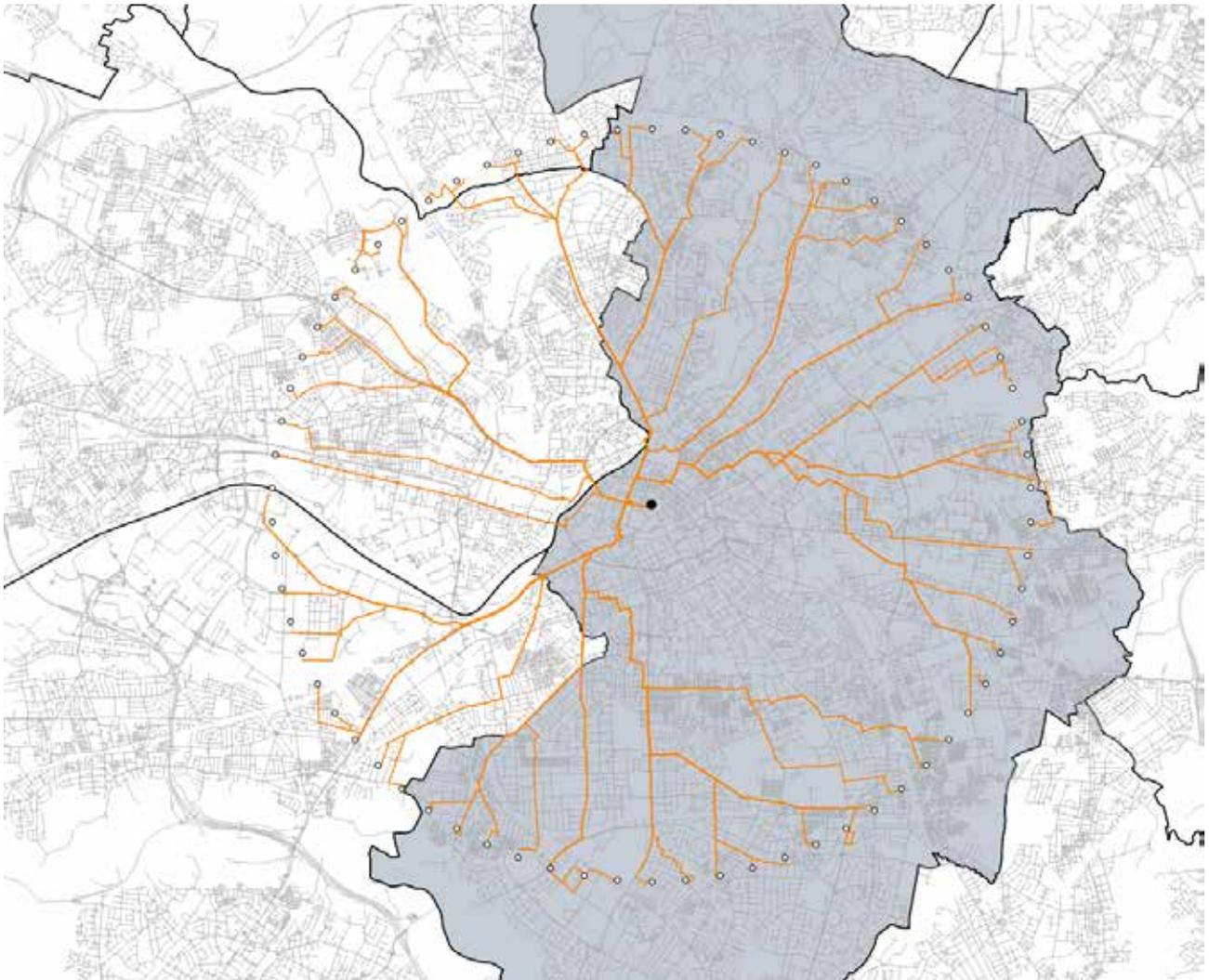
Emission and Distance to distance between O-D  
g / m



Speed to distance between O-D  
m / s

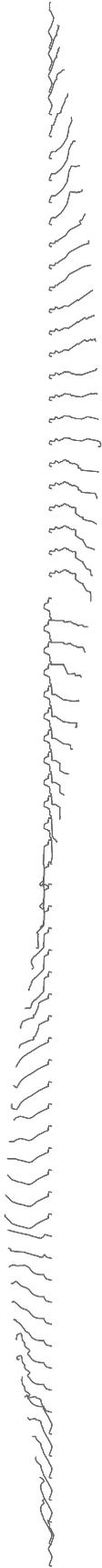


# Road network: shortest distance



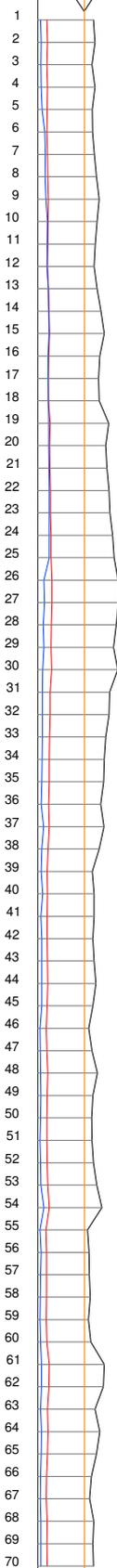
# Road network : shortest distance

Indexed routes (Geographical)

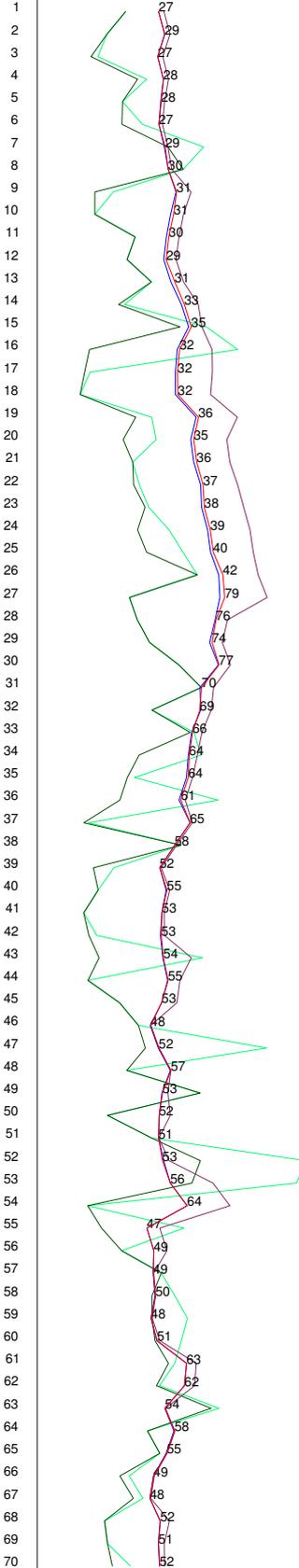


Indexed routes

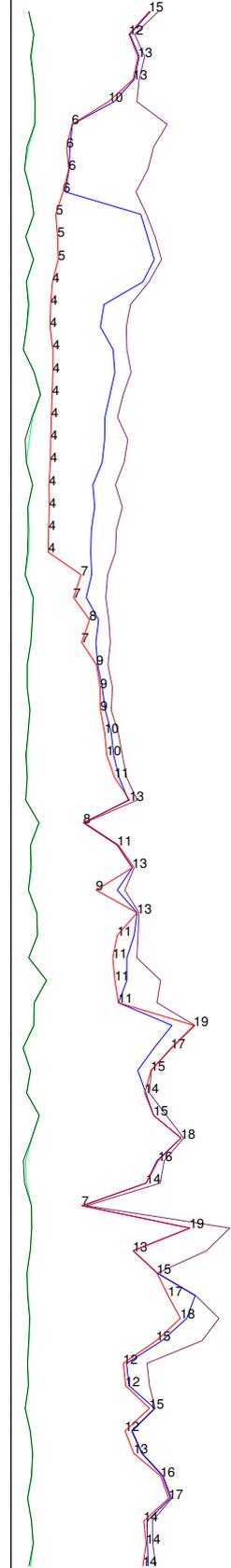
Straight line distance between O-D



Emission / Distance  
g / m

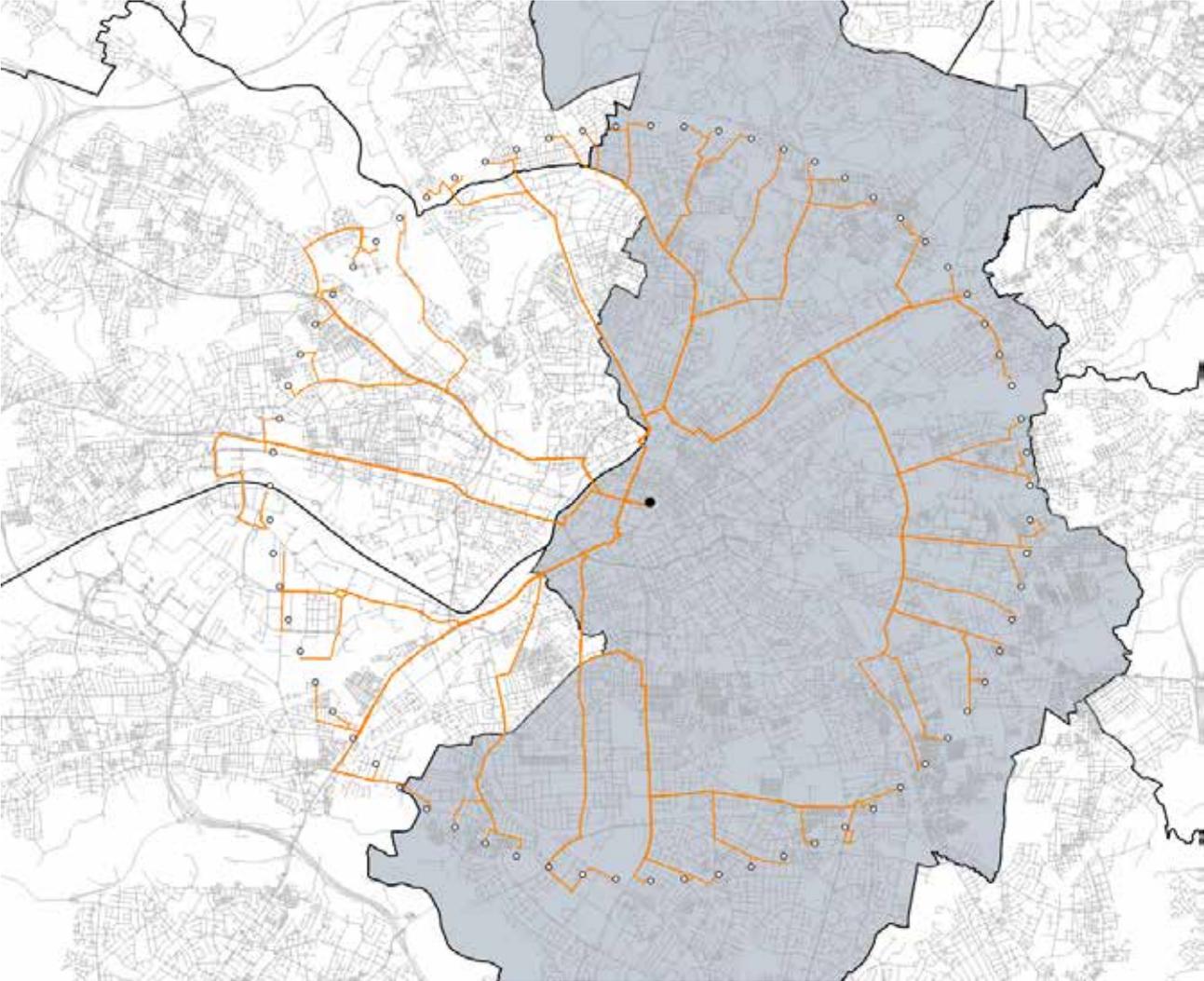


Overall Speed  
m / s



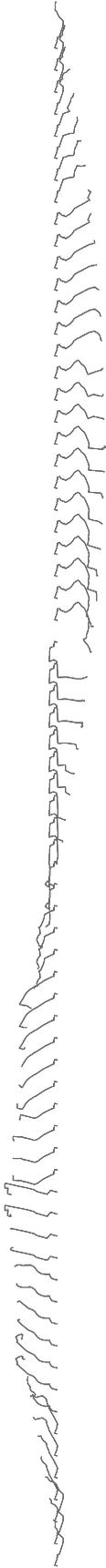
Quickest route by Public transport  
 Quickest route by Private Car  
 Lowest emission by Private Car  
 Lowest emission by Public transport

# Road network: quickest route



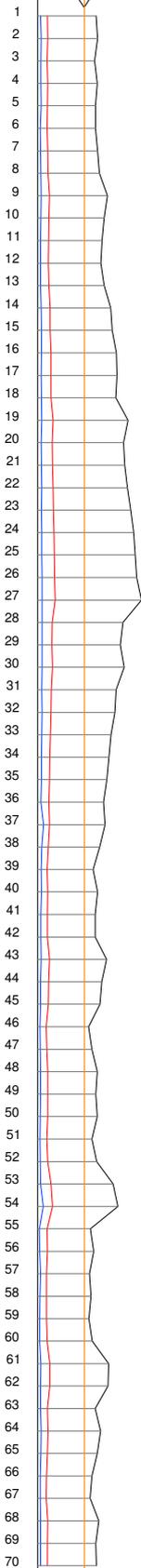
# Road network : quickest route

Indexed routes (Geographical)

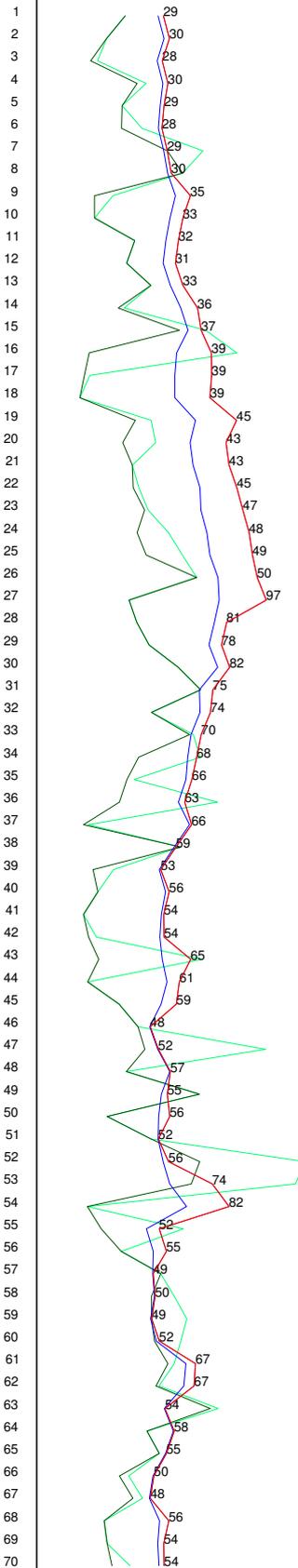


Indexed routes

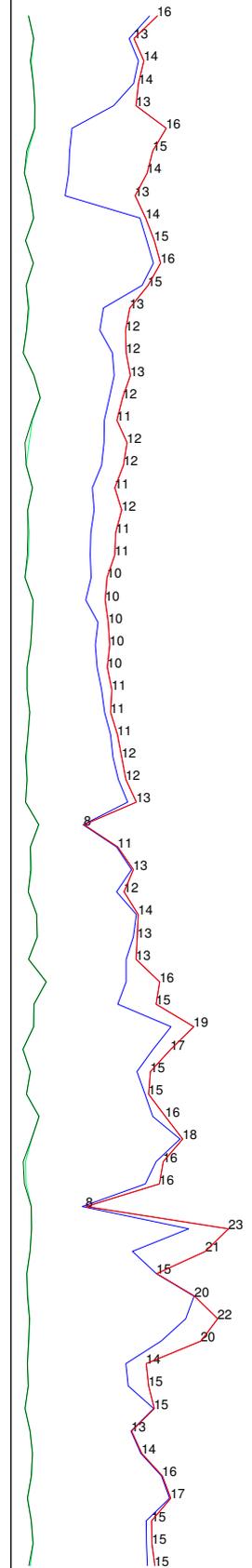
Straight line distance between O-D



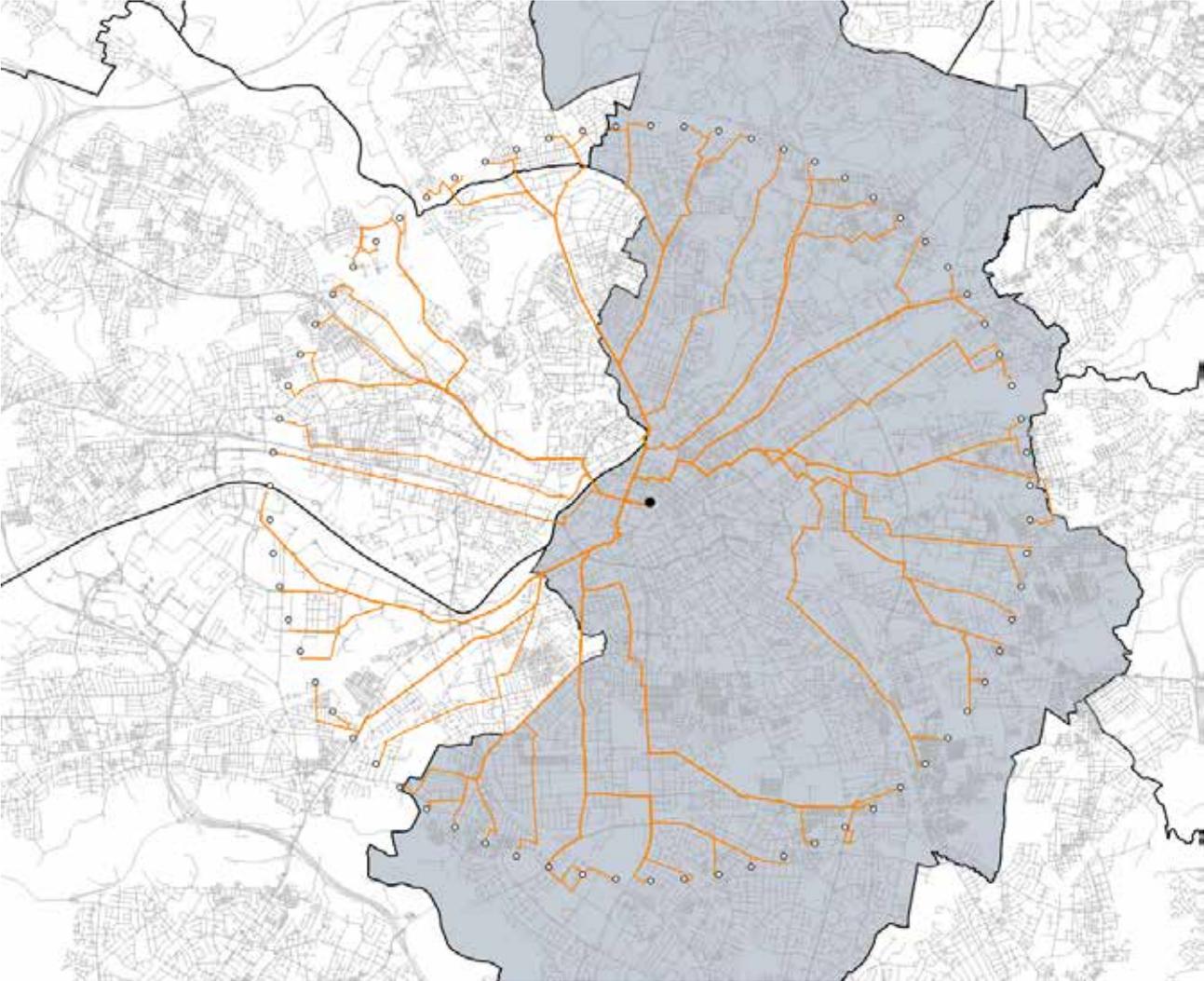
Emission / Distance  
g / m



Overall Speed  
m / s

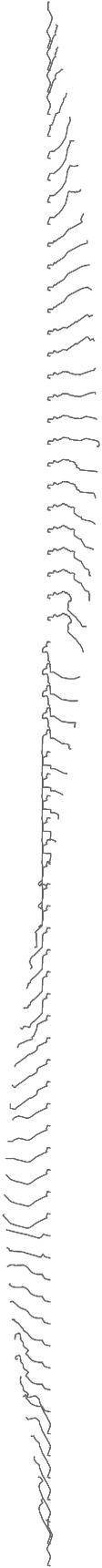


# Road network: lowest CO<sub>2</sub> emission



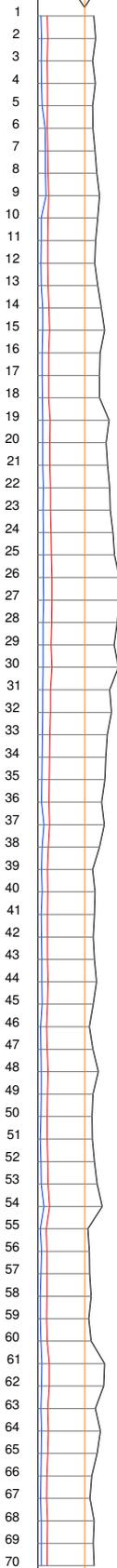
# Road network : lowest CO<sub>2</sub> emission

Indexed routes (Geographical)

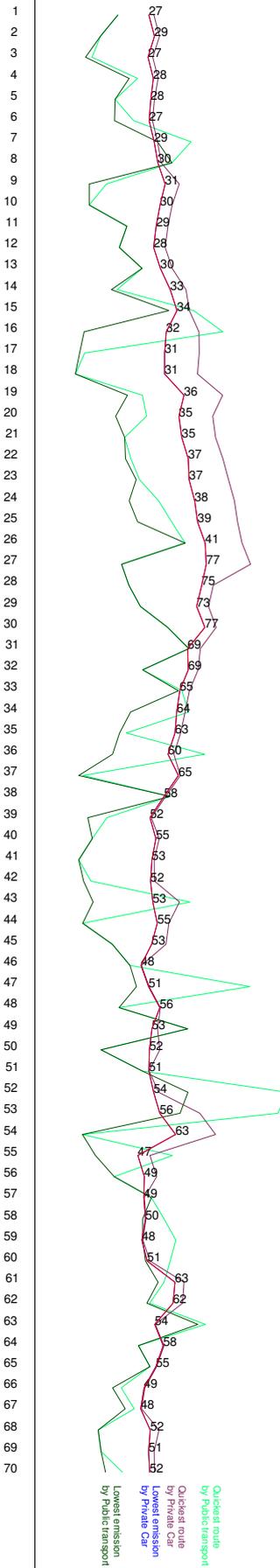


Indexed routes

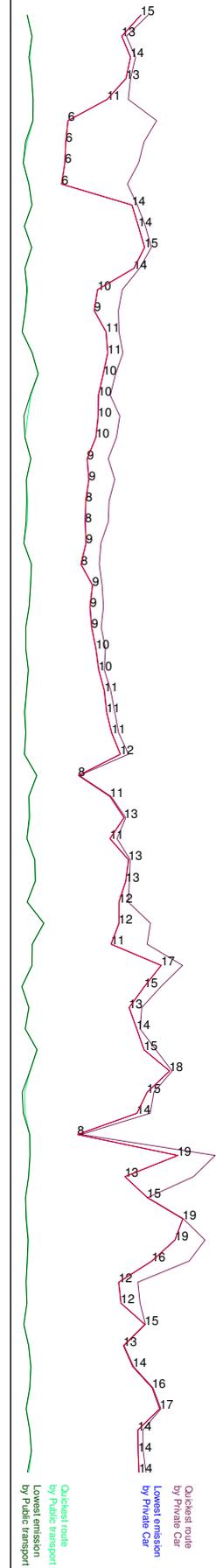
Straight line distance between O-D



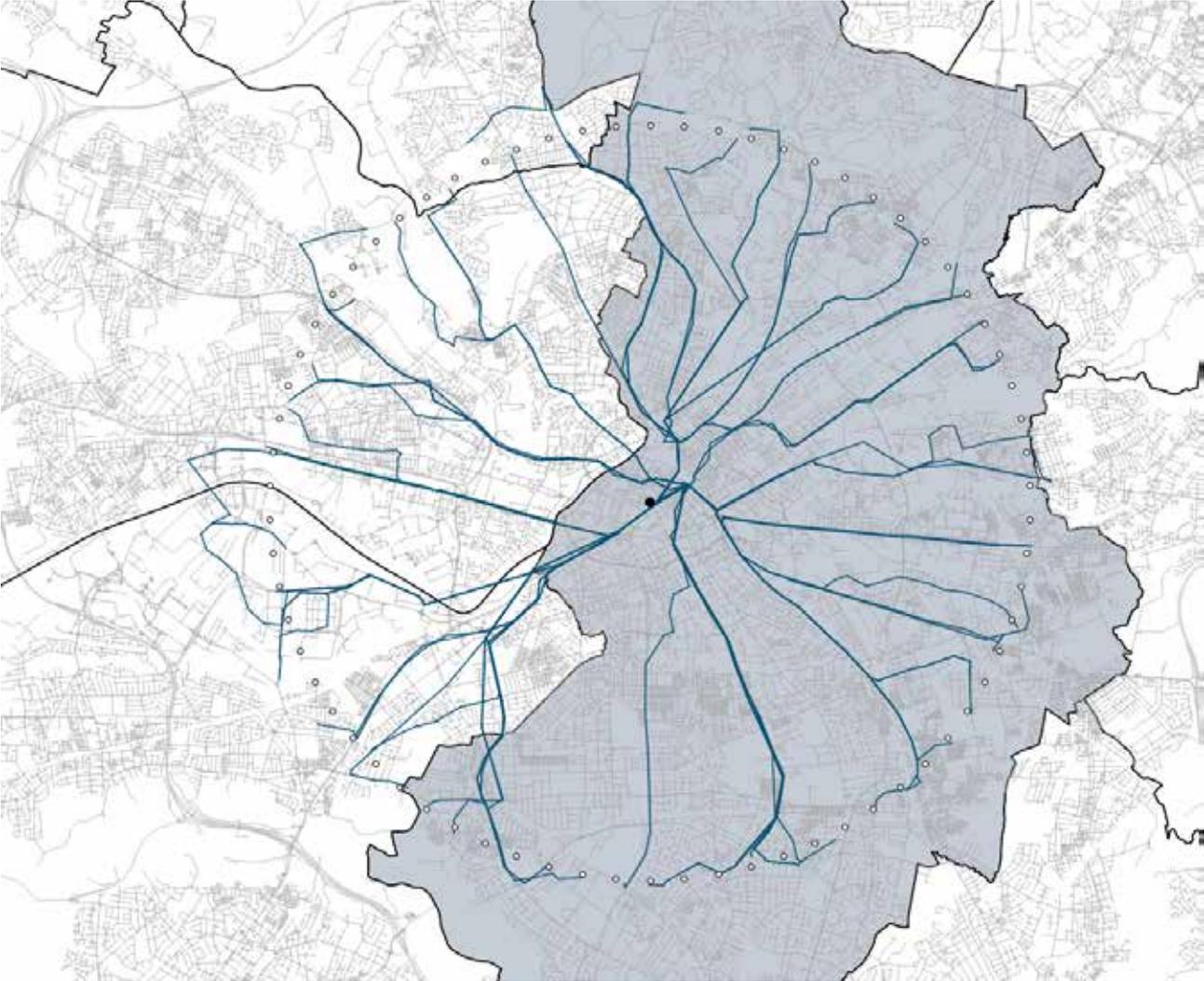
Emission / Distance  
g / m



Overall Speed  
m / s

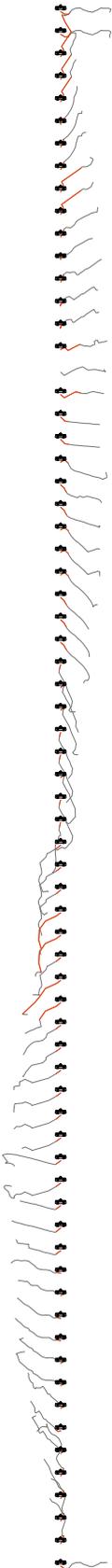


# Public transport: shortest distance



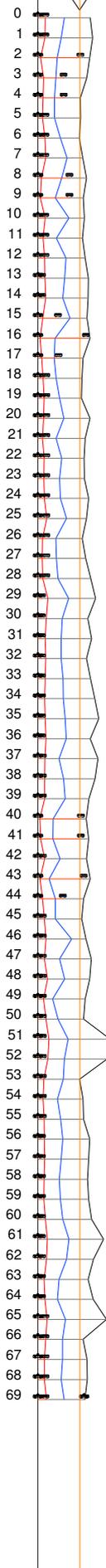
# Public transport : shortest distance

Indexed routes (Geographical)

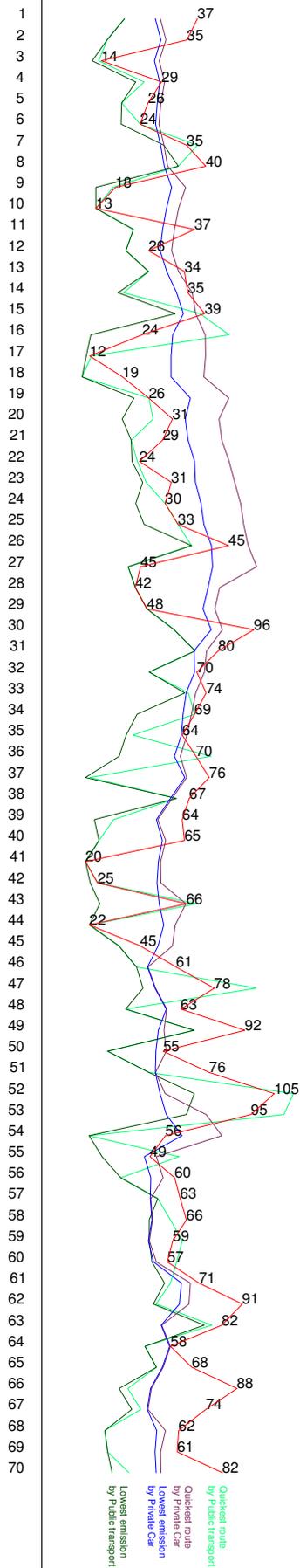


Indexed routes

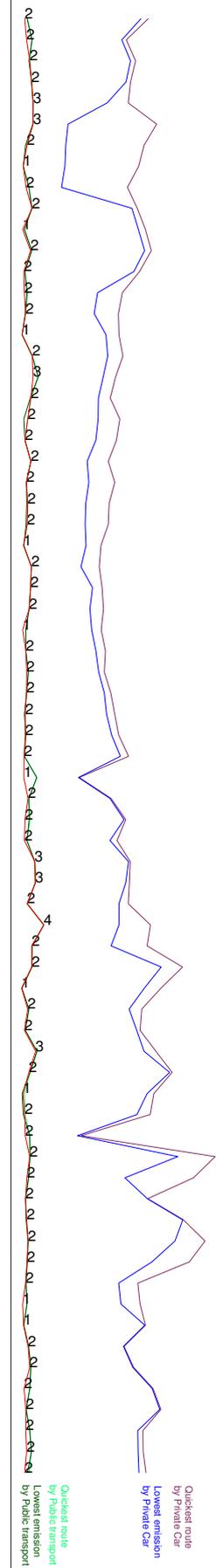
Straight line distance between O-D



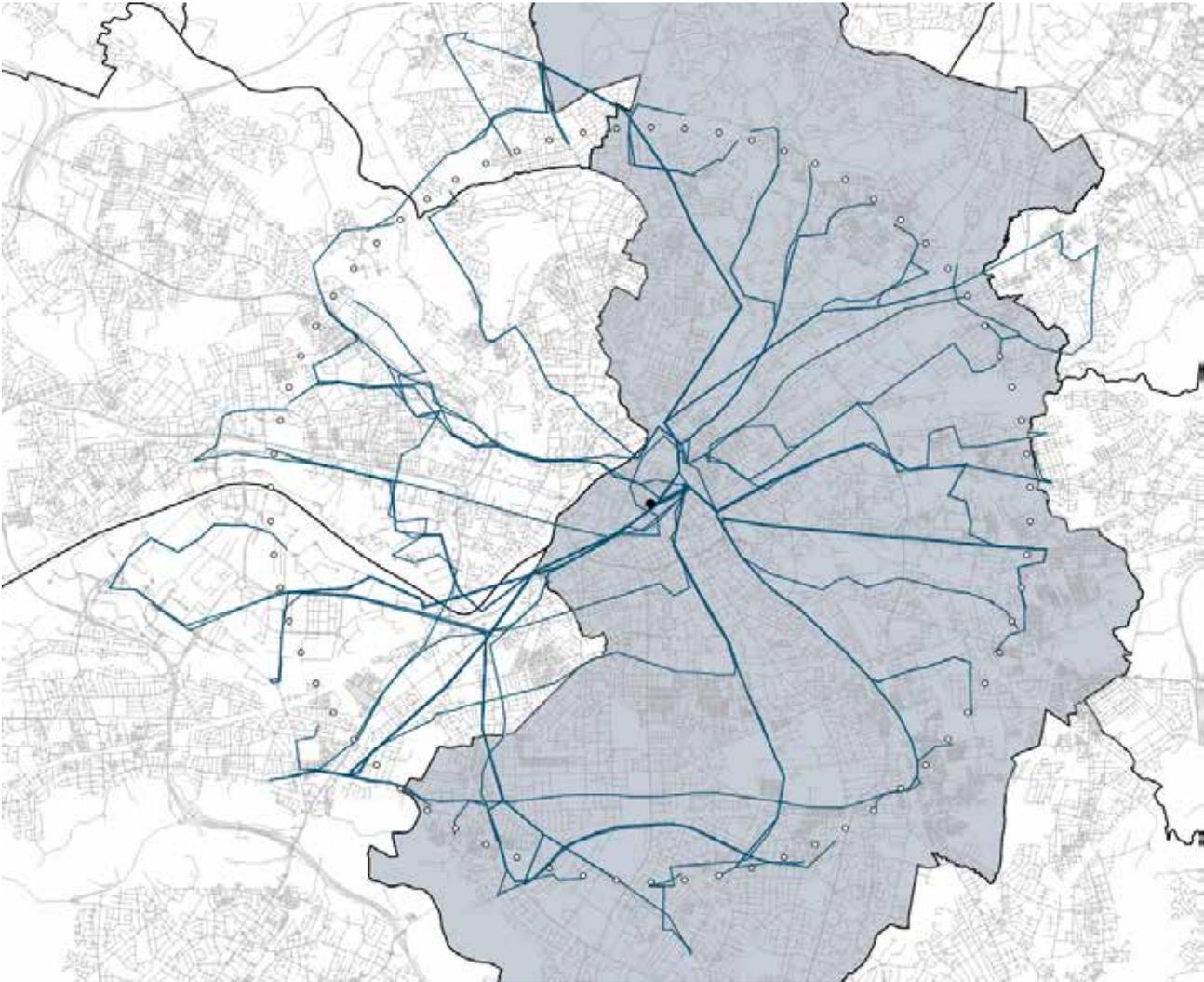
Emission / Distance  
g / m



Overall Speed  
m / s

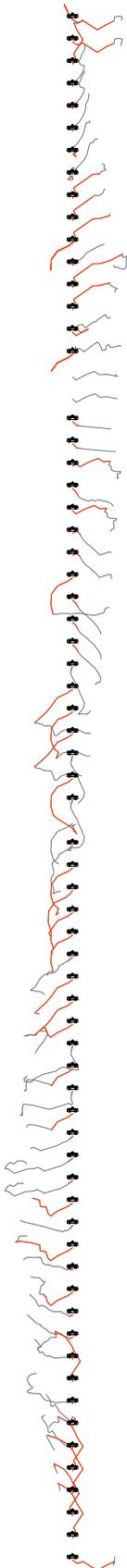


# Public transport: quickest route

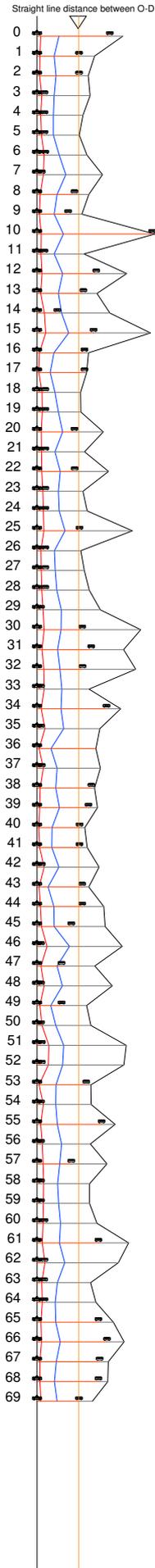


# Public transport : quickest route

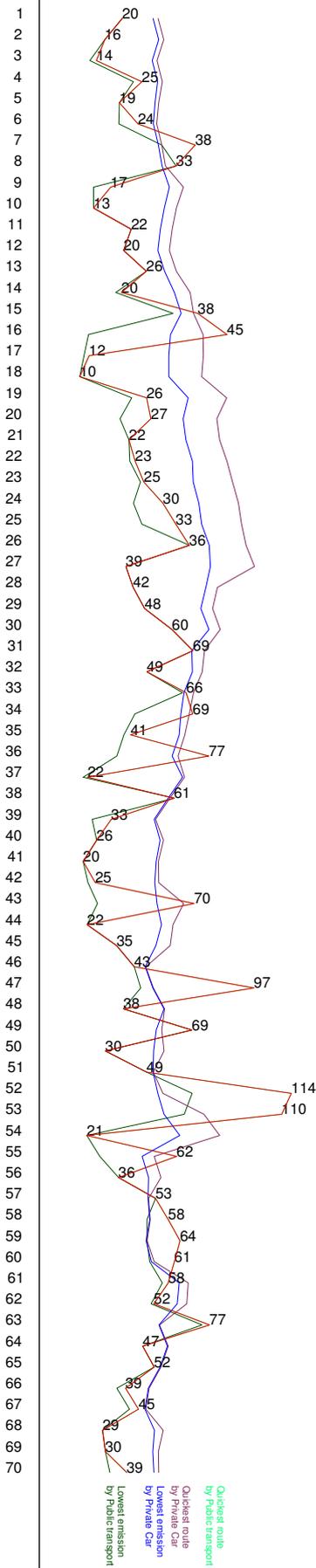
Indexed routes (Geographical)



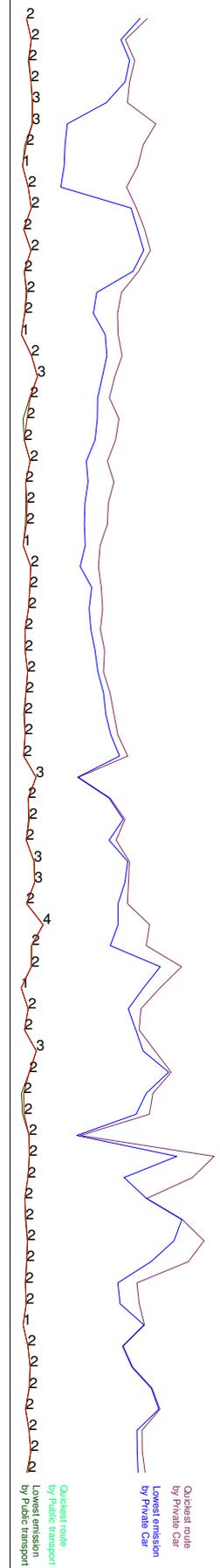
Indexed routes



Emission / Distance  
g / m

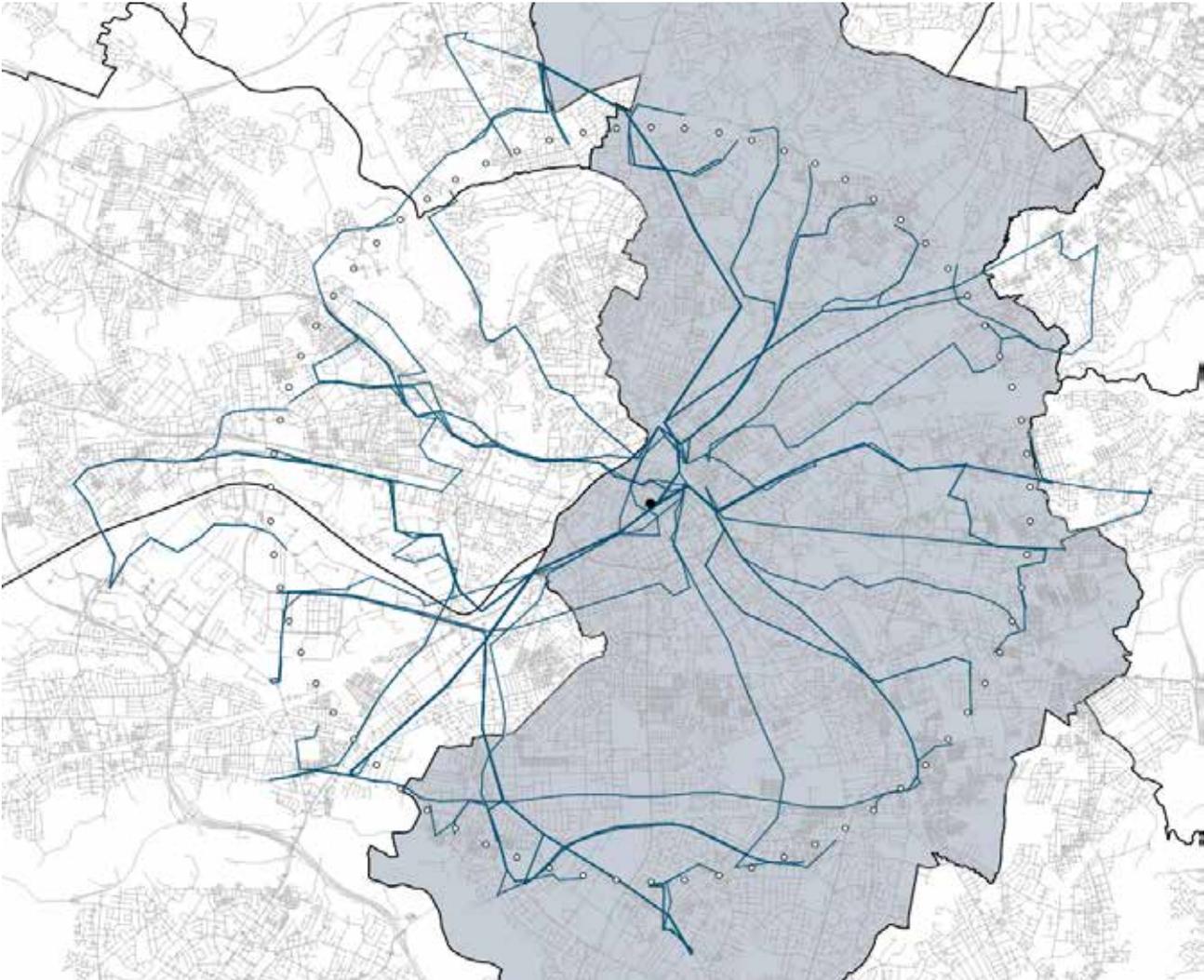


Overall Speed  
m / s



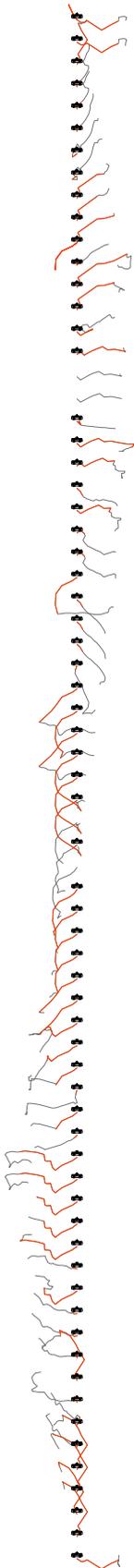
■ Quickest route by Public transport  
■ Quickest route by Private car  
■ Lowest emission by Private car  
■ Lowest emission by Public transport  
■ Quickest route by Public transport  
■ Lowest emission by Private car  
■ Lowest emission by Public transport

# Public transport: lowest CO<sub>2</sub> emission

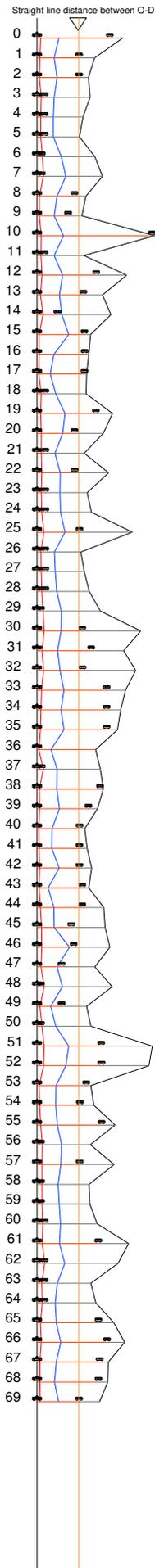


# Public transport : lowest CO<sub>2</sub> emission

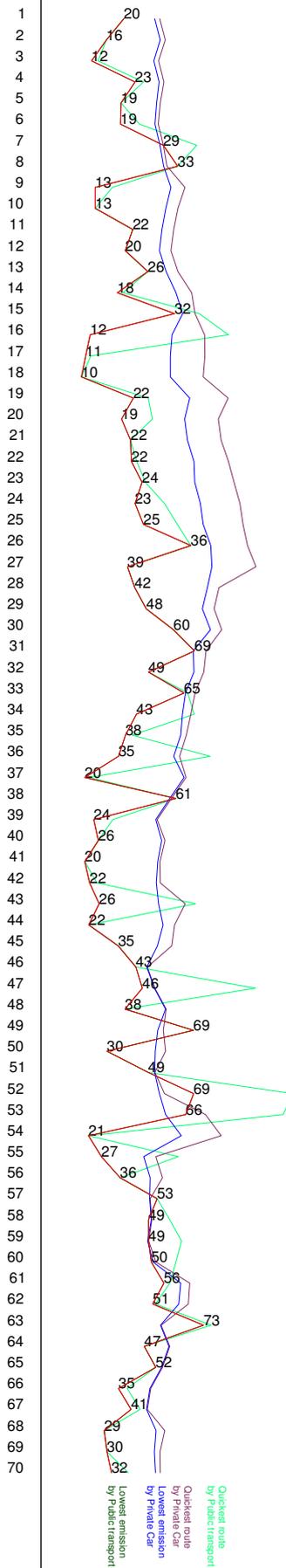
Indexed routes (Geographical)



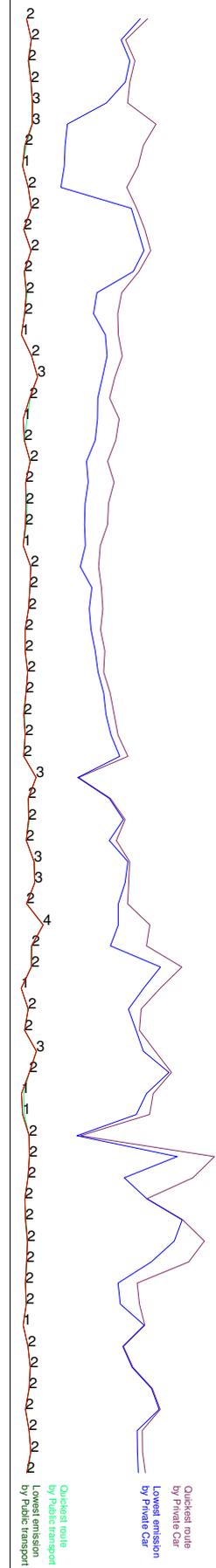
Indexed routes



Emission / Distance  
g / m



Overall Speed  
m / s



# Data sources

- Ordnance Survey via Digimap
- Ordnance Survey Boundary-Line
- TfGM – GTFS public transport schedules via [data.gov.uk](http://data.gov.uk)
- Openstreetmap

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