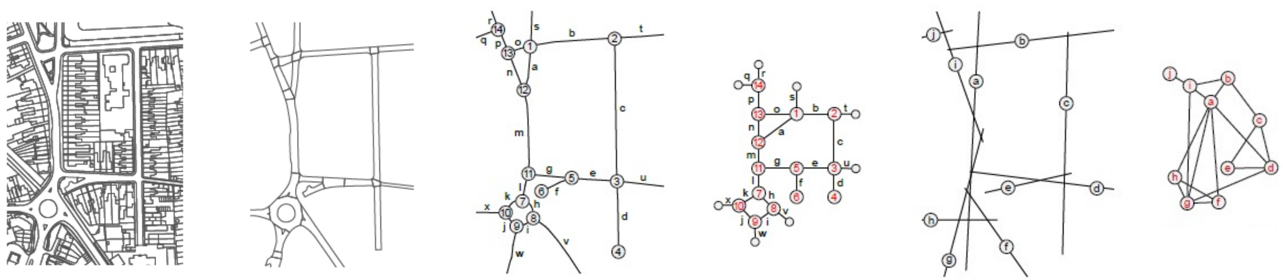
Street Networks

Alternative models, measures & their merits



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AESOP Annual Congress: Göteborg, 11 July 2018

Today's Presentation

1. The Context
2. The Challenge
3. Creating a comparable set of models
4. Results
5. Discussion
6. Next Steps

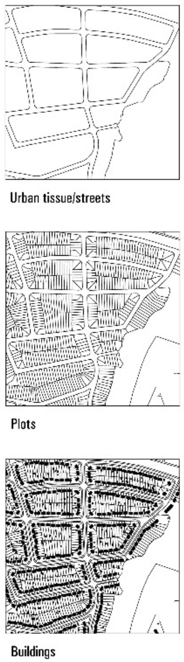
The Context

"To represent an empirical phenomenon as a network is a theoretical act… the appropriate choice of representation is key to getting the correct result." – Butts (2009)

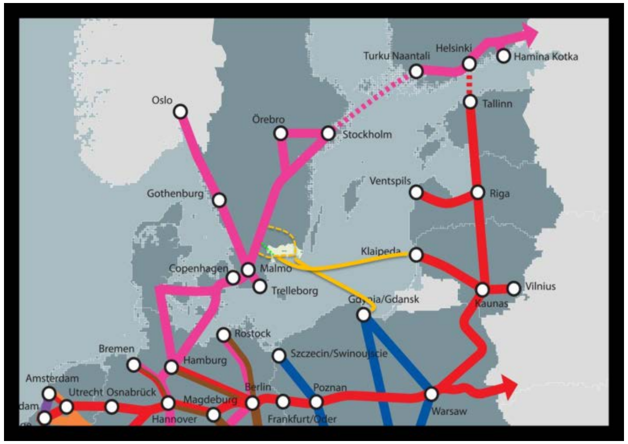
Butts CT (2009) Revisiting the foundations of network analysis. science 325(5939):414–416

The Context

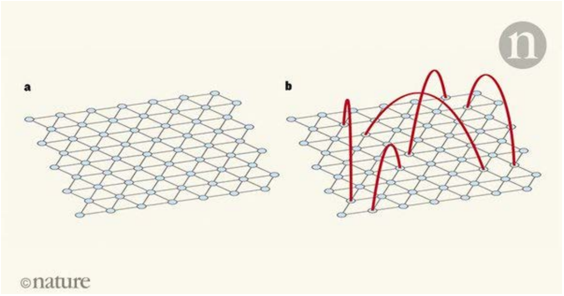
Street layout &
Urban morphology



Transport planning &
transport geography



Network science



'20 years of network science'
Nature, 19th June 2018

'Street network studies'

Distinctive aspects of *street* networks

- Settings for general human behaviour not just traffic movement
- Multi-modal
- Activity in three dimensions not just linear through movement
- Destinations in their own right
- Link significantly to fronting buildings (networks extend inside buildings)
- Hierarchical distinctions between main streets and side streets (not directly captured if broken into discrete links)

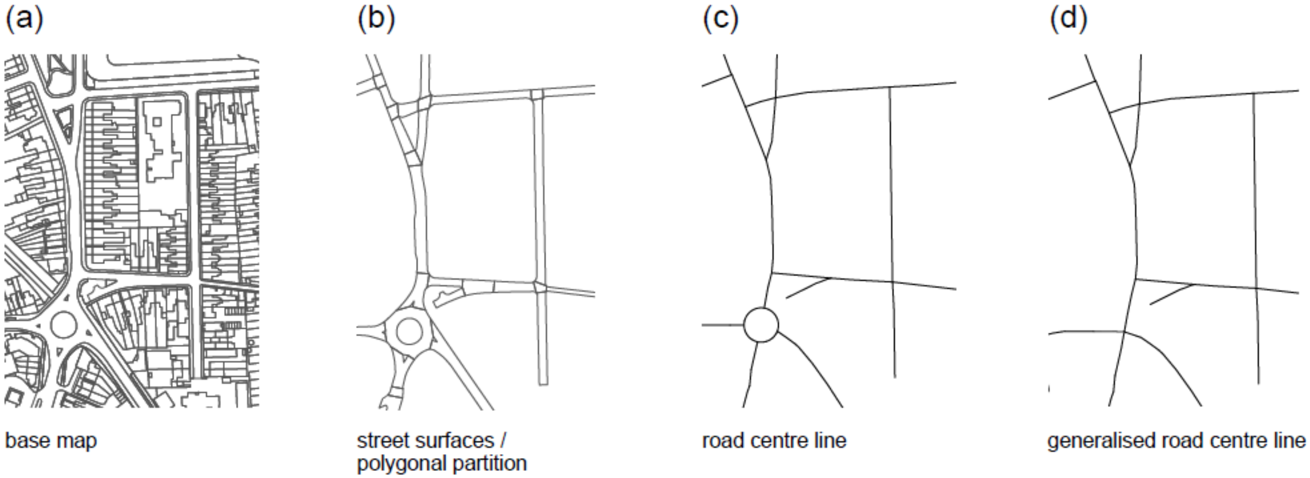
The Challenge

- There are multiple ways of representing and analysing *street* networks
- These tend to (implicitly) use different assumptions and be applied in different ways
- … and tend to be published in different journals, without consistently relating to one another

The Challenge

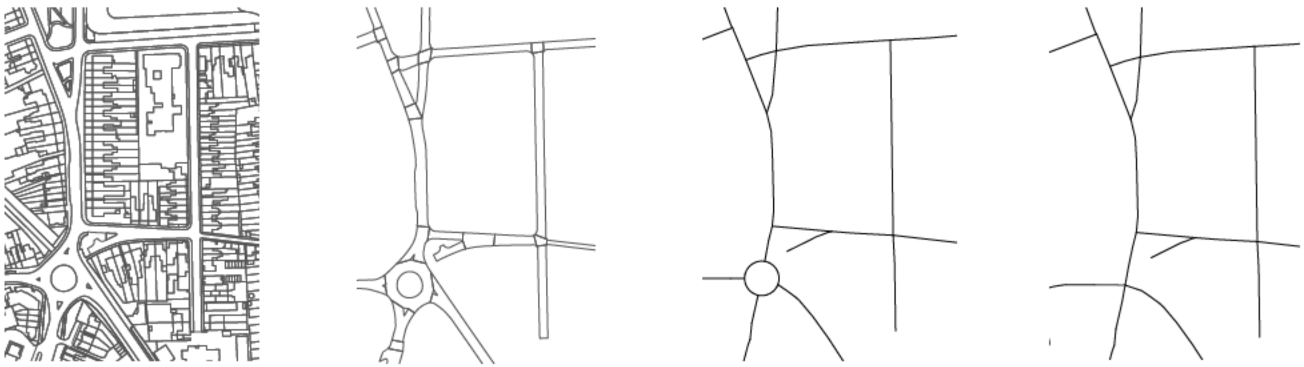
- Divergence between ‘conventional’ approaches from geography, transport planning and physics; and ‘alternative’ approaches from urban morphological traditions
- There is a lack of knowledge about the relative merits of these different models and measures for specific purposes…
- Hence our study….

From networks to models and their representations



Street environment data sets used to create network models

From networks to models and their representations



(a) base map

(b) street surfaces / polygonal partition

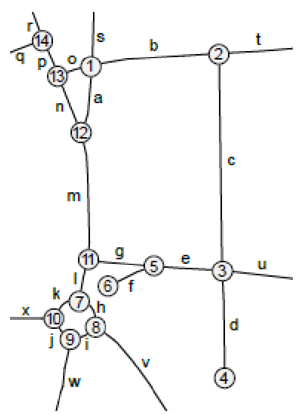
(c) road centre line

(d) generalised road centre line

Street environment data sets used to create network models

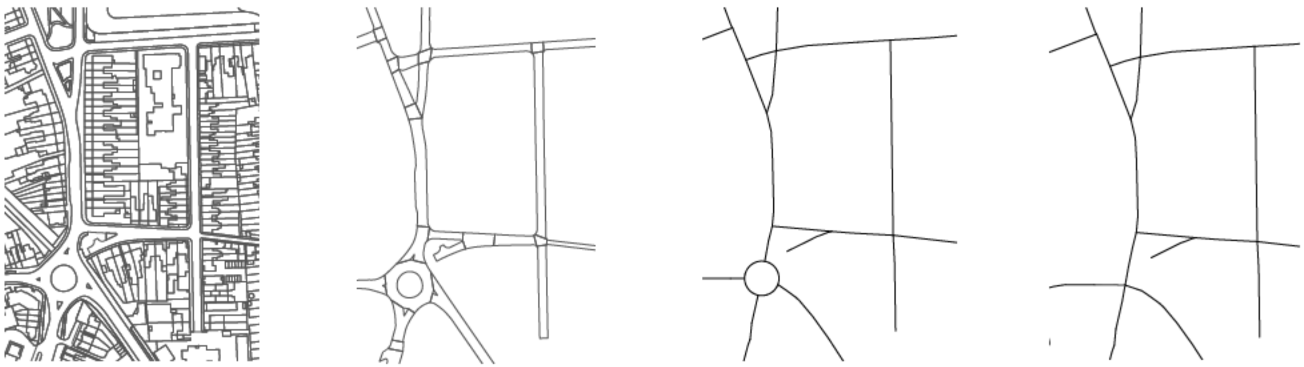
Network model

(e)



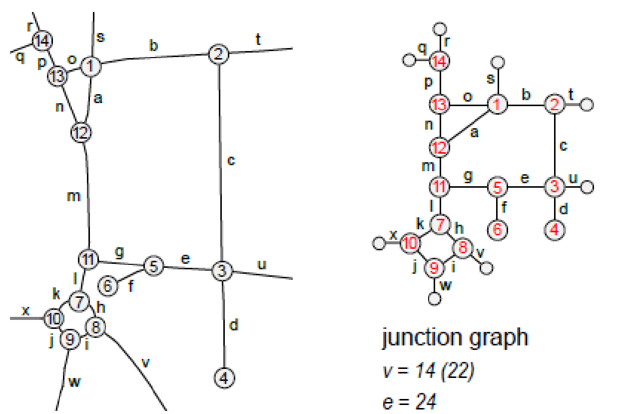
labelled nodes and links

From networks to models and their representations



Street environment data sets used to create network models

Network model

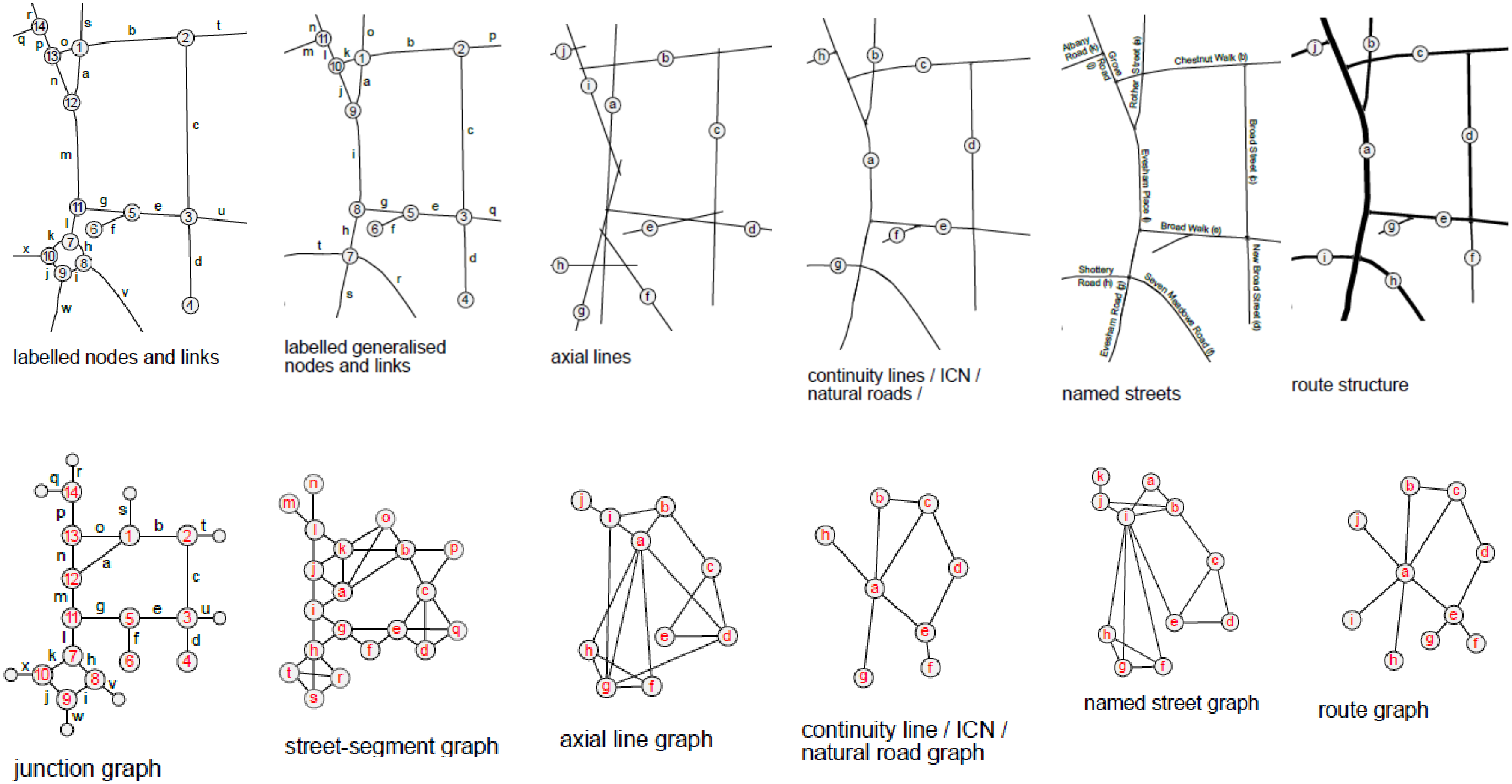


Graph representation

Alternative models and their graph representations

Network model

Graph representation



‘Conventional’ approaches

Space syntax (Hillier *et al*)

Figueiredo , Porta *et al*, Jiang *et al*

Tomko, etc.

Marshall, Kropf, etc.

Marshall, Gil, Kropf, Tomko & Figueiredo (forthcoming)

Table 1 Attributes of graphs associated with different network models.

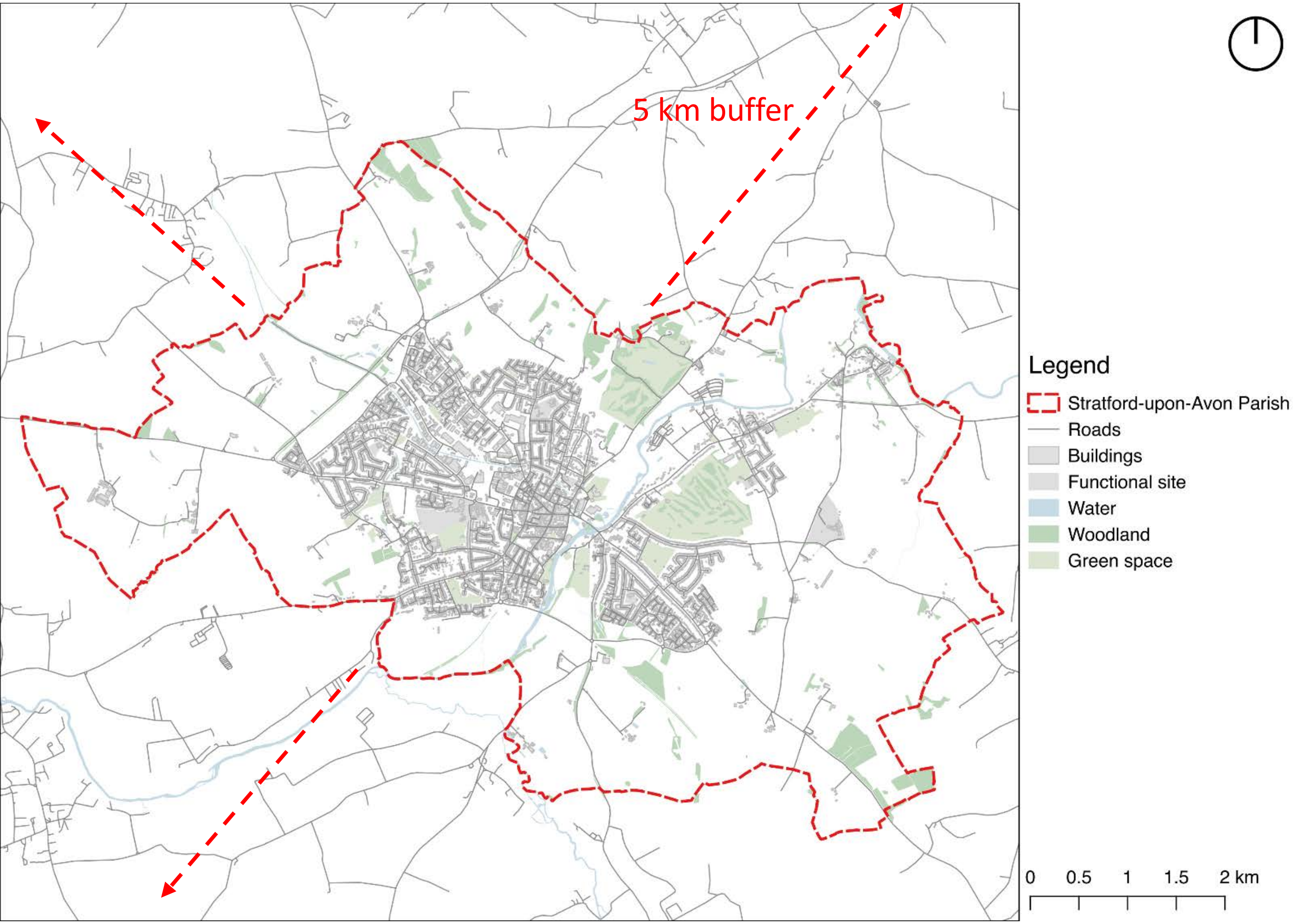
Representation (Figure 1 reference)	Planar	Vertices	Edges	Weights	Directed	Data source
Junction graph (f)	No*	Junctions	Segments	Metric, other	Possible	RCL
Street-segment graph (h)	No*	Segments	Junctions	Metric, angular, other	Possible	RCL
Axial line graph (j)	No	Axial line	Intersection	Topological	No	Custom
Continuity graph (l)†	No	Continuity line	Intersection	Topological	No	Custom or RCL
Natural road or ICN graph (l)†	No	Continuous angle road	Intersection	Topological	No	RCL
Named street graph (n)	No	Continuous named road	Intersection	Topological	No	RCL or Named Streets
Route graph (p)	No*	Routes	Junctions	Labels	No	RCL

Notes: * potentially planar, the existence of bridges, tunnels, under/over passes breaks the planarity of the graph; † Although derived differently, these cases typically end up represented by the same graph, as in Figure 1 (l).

How to reconcile this diversity of network models and representations?
What are the merits of these different models and the measures?

Marshall, Gil, Kropf, Tomko & Figueiredo (forthcoming)

Creating a comparable set of models



Typical operations:

- (Filter features)
- (Generalise geometry)
- (Simplify representation)
- Split geometry
- Aggregate features
- Calculate weights
- Label features
- Clean topology
- Snap junctions

Data sources: Ordnance Survey (OS) Open Data (OS Open Roads, OS Open Map Local, OS Open Greenspace)
https://www.ordnancesurvey.co.uk/business-and-government/products/opendata.html

Junction model

Steps:

1. Calculate length
2. Convert links to edges list (source/target) attributes

Software: QGIS, PostGIS

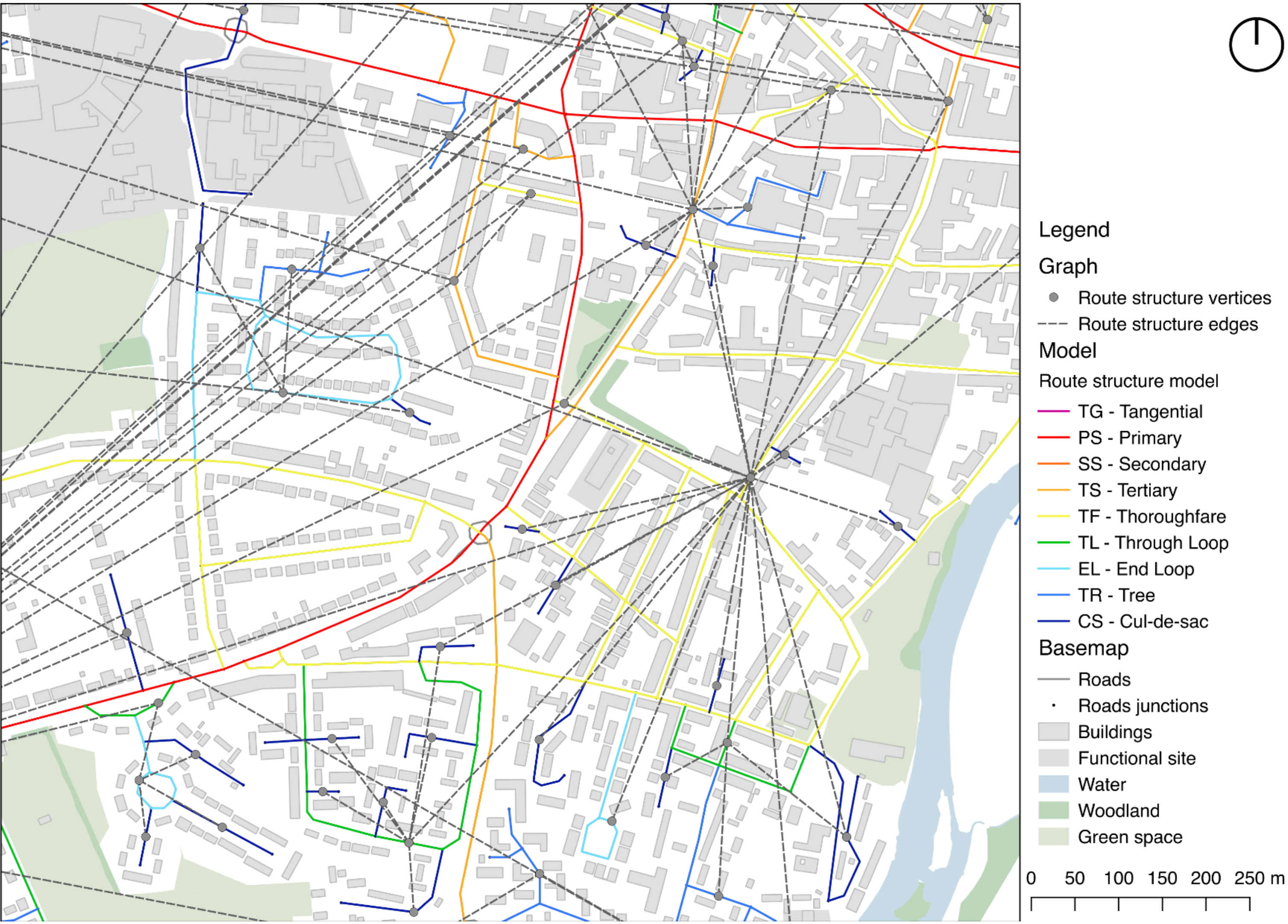
Street-segment model

Steps:

1. Calculate length
2. Generate edges list from intersecting street segments
3. Calculate length edge weight

Software: QGIS, PostGIS

Route structure model



Steps:

1. Analyse street network and urban context
2. Identify and sort strategic routes
3. Label strategic routes
4. Identify and sort local route sub-systems
5. Label local sub-systems
6. Aggregate intersecting routes of same type as one feature
7. Create vertex as centroid of grouped features
8. Create edges list from intersecting features

Software: QGIS, PostGIS

Natural Roads/Continuity model

Steps:

1. Split segments into straight sub-segments
2. Calculate azimuth
3. Aggregate sub-segments into natural roads: connection angle (35 degrees) and cumulative angle (70 degrees)
4. Clean topology
5. Create vertices as centroid of natural roads
6. Create edges list from intersecting features

Software: Mindwalk, QGIS, PostGIS

Intersection Continuity Negotiation (ICN) model

Steps:

1. Calculate azimuth
2. Aggregate sub-segments into features: connection angle (35 degrees)
3. Clean topology
4. Create vertices as centroid of features
5. Create edges list from intersecting features

Software: Mindwalk, QGIS, PostGIS

RCL segment model

Steps:

1. Split segments into straight sub-segments
2. Snap connections
3. Clean topology
4. Calculate length
5. Calculate azimuth
6. Create vertices as centroid of natural roads
7. Create edges list from intersecting features
8. Calculate length edge weight
9. Calculate angle edge weight

Software: FME, PST, QGIS, PostGIS

Axial model

Steps:

1. Draw axial lines
2. Create vertices as centroid of features
3. Create edges list from intersecting features

For context:

1. Split segments into straight sub-segments
2. Aggregate segments: connection angle (5 degrees) and cumulative angle (15 degrees)
3. Generalise (10 m)
4. Extend endpoints (10%)

Software: CAD, QGIS, PST, PostGIS

Axial segment model

Steps:

1. Split axial lines into line segments at intersection
2. Remove dangling line ends
3. Clean topology
4. Calculate length
5. Calculate azimuth
6. Create vertices as centroid of natural roads
7. Create edges list from intersecting features
8. Calculate length edge weight
9. Calculate angle edge weight

Software: PST, QGIS, PostGIS

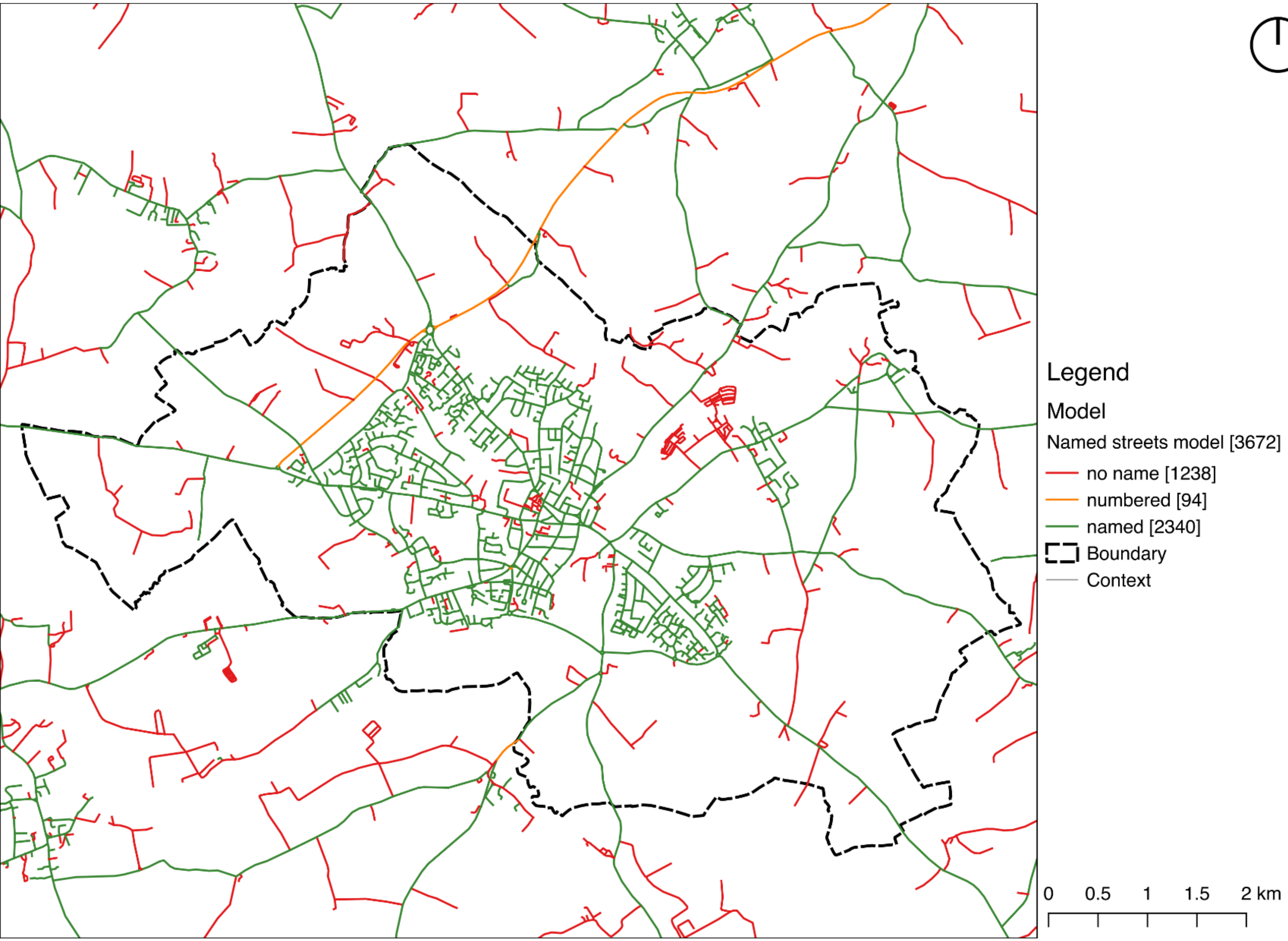
Axial continuity model

Steps:

1. Calculate azimuth
2. Aggregate axial lines into continuity lines: connection angle (35 degrees) and cumulative angle (70 degrees)
3. Trim ends at joined intersections
4. Clean topology
5. Create vertices as centroid of features
6. Create edges list from intersecting features

Software: Mindwalk, QGIS, PostGIS

Named street model



Steps:

1. Not possible due to incomplete and inconsistent naming of the street segments

Software: QGIS, PostGIS

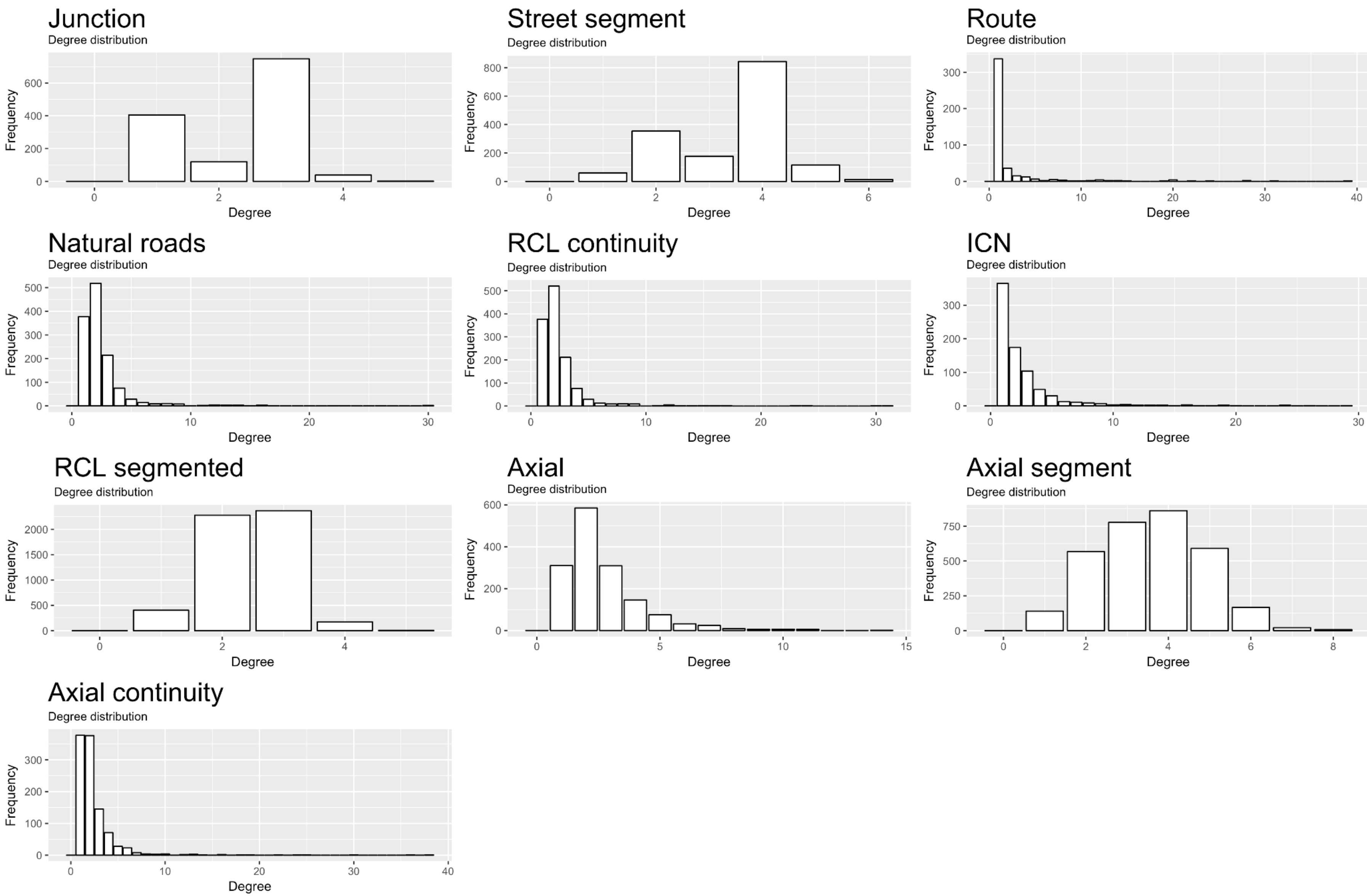
Results

Comparing graph properties

Graph	Vertices	Edges	Diameter	Radius	Avg degree	Avg path length	Assortativity coeff	Avg clustering coeff
Junction	1311	1522	65	36	2.3219	27.47	-0.0763	0.0365
Street segment	1560	2660	64	36	3.4103	26.83	0.1972	0.5051
Route	440	516	9	5	2.3455	4.81	-0.3512	0.0750
Natural roads	1275	1578	28	15	2.4753	10.07	-0.0735	0.0702
RCL continuity	1274	1580	27	15	2.4804	10.00	-0.0761	0.0737
ICN	788	1036	17	9	2.6294	7.79	-0.2052	0.1786
RCL segmented	5224	6387	249	131	2.4453	90.96	0.5266	0.1683
Axial	1507	1986	48	24	2.6357	16.23	0.1800	0.1331
Axial segment	3130	5602	114	57	3.5796	37.28	0.3707	0.4985
Axial continuity	1055	1301	24	12	2.4664	8.13	-0.0687	0.0530

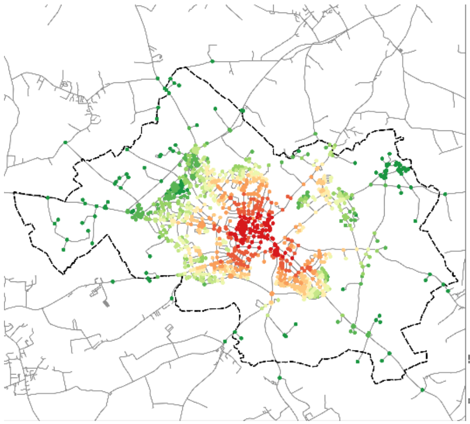
Software: Python, networkx

Results – Degree distribution

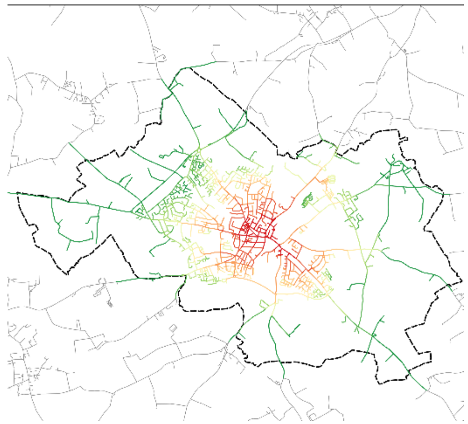


Results – Closeness centrality

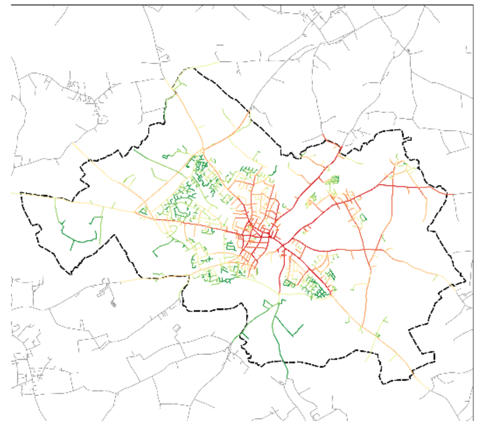
Junction model
(metric)



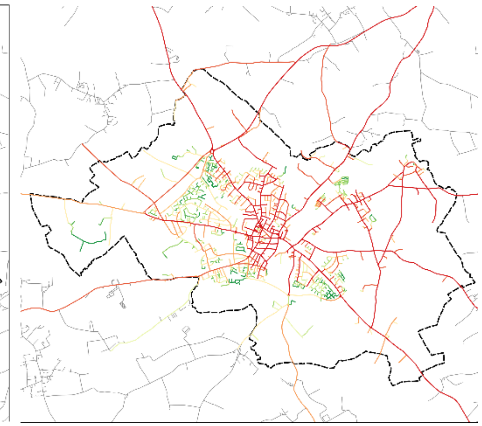
Street-segment model
(metric)



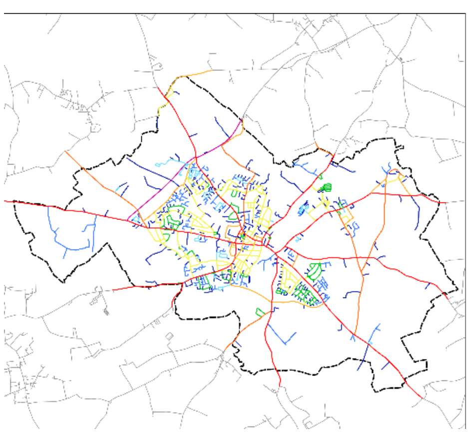
RCL-segment model
(angular)



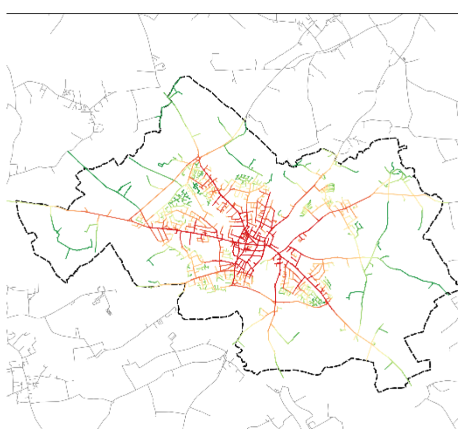
Natural roads/Continuity model
(topological)



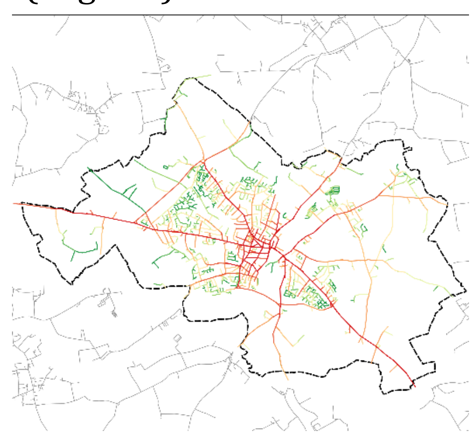
Route structure
(manual classification)



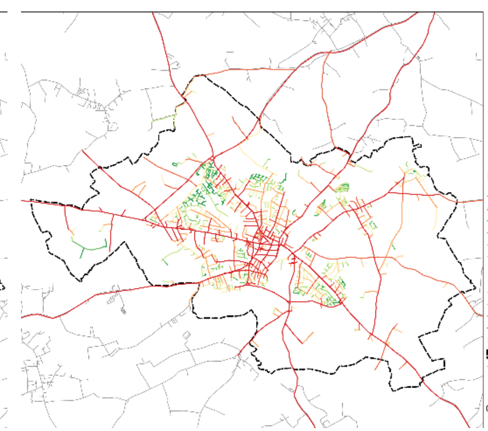
Axial model
(topological)



Axial segment model
(angular)



Axial Continuity model
(topological)



Summary of Results

- All graphs are very different (except natural roads and RCL continuity), hence they are modelling different aspects of the urban environment
- The degree of disaggregate graphs gives a typology of intersections
- The degree of aggregate graphs gives a typology of streets
- The urban hierarchies obtained from aggregate models are similar visually
- Route structure gives a clear classification, difficult to obtain from disaggregate models

Discussion

- All models are interpretations of reality, but just use different selective criteria
- RCL data needs pre-processing, and the model is influenced by assumptions built into the data
- Axial model as a starting point requires time to draw, but provides an appropriate coverage of the pedestrian realm (pedestrian space not linear!).
- Disaggregate models have many steps and analysis parameters, most important to specify explicitly, most flexible for different applications

Next Steps

- Assess analysis with a purpose: fitness of model/analysis pairs
- Apply to more locations
- Apply comparison of metrics
- Explore different approaches to route structure
- Explore relationships between all models

Thank You

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