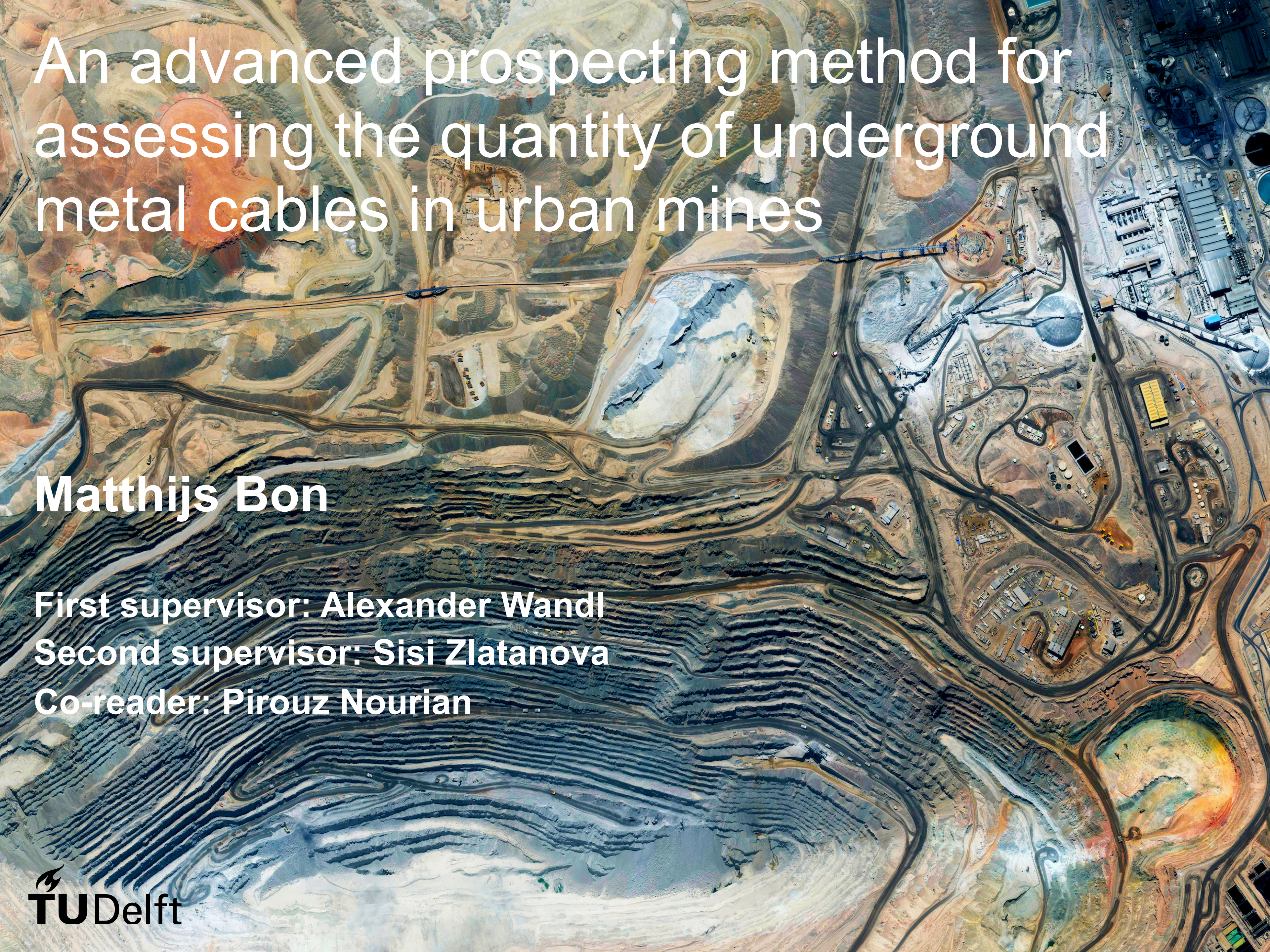


An advanced prospecting method for assessing the quantity of underground metal cables in urban mines

Matthijs Bon

First supervisor: Alexander Wandl
Second supervisor: Sisi Zlatanova
Co-reader: Pirouz Nourian

TU Delft

Outline

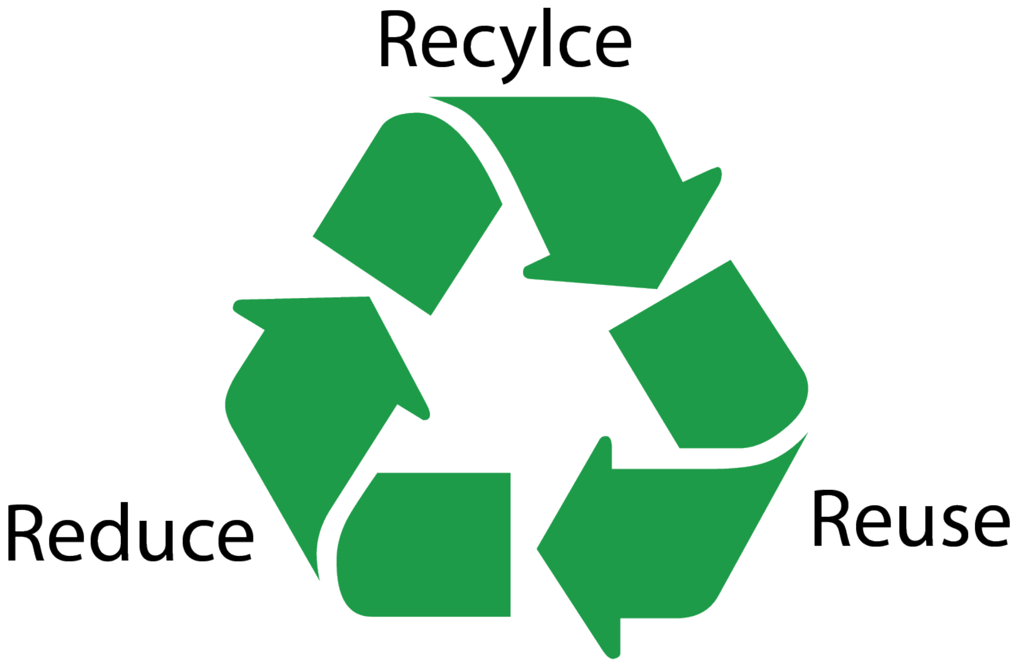
- Introduction
- Research approach
- Process
- Results
- Conclusions and Recommendations

INTRODUCTION

Circular Economy

Circular Economy

Circular Economy



Circular Economy

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- The Netherlands aims to have a circular Economy by 2050 (1)

(1) *Nederland circulair in 2050, Rijksoverheid, 2016*

Circular Economy

- The Netherlands aims to have a circular Economy by 2050 (1)
- Amsterdam municipality promotes local circular economies (2)

(1) *Nederland circulair in 2050, Rijksoverheid, 2016*
(2) *Amsterdam circulair, visie en routekaart, 2015*

Urban Mining

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- Reusing or recycling resources dispersed among the urban environment

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- Urban mining challenge
  - Prospecting: how many resources and where?

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- Urban mining challenge
  - Prospecting: how many resources and where?

- Prospected urban mine as a motive for actual mining

Underground Infrastructure

- Many underground resources, seemingly invisible

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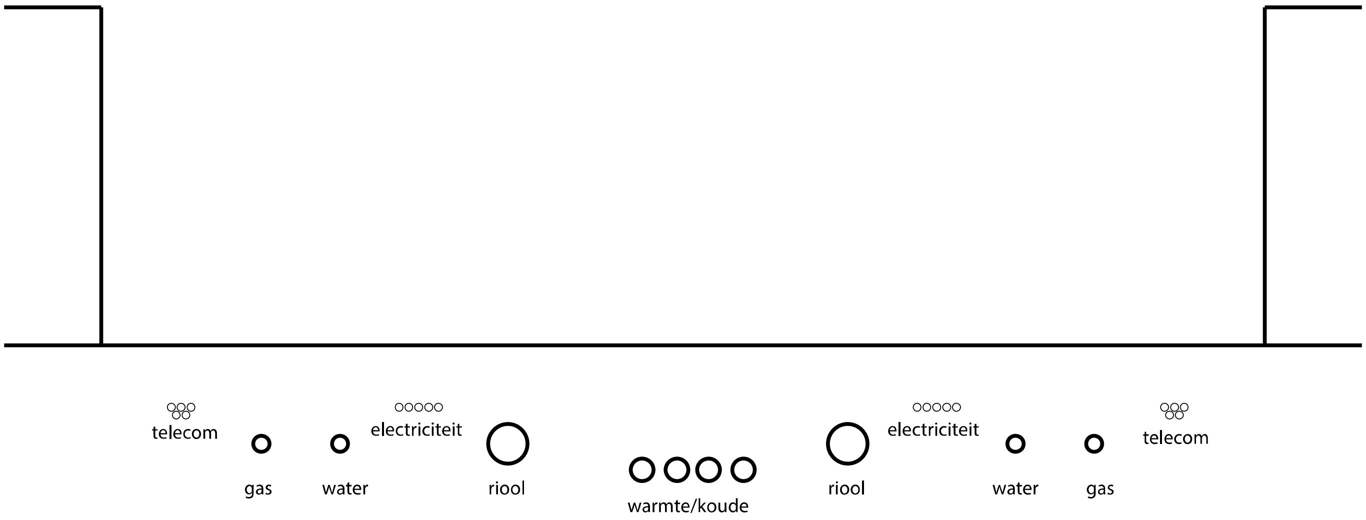

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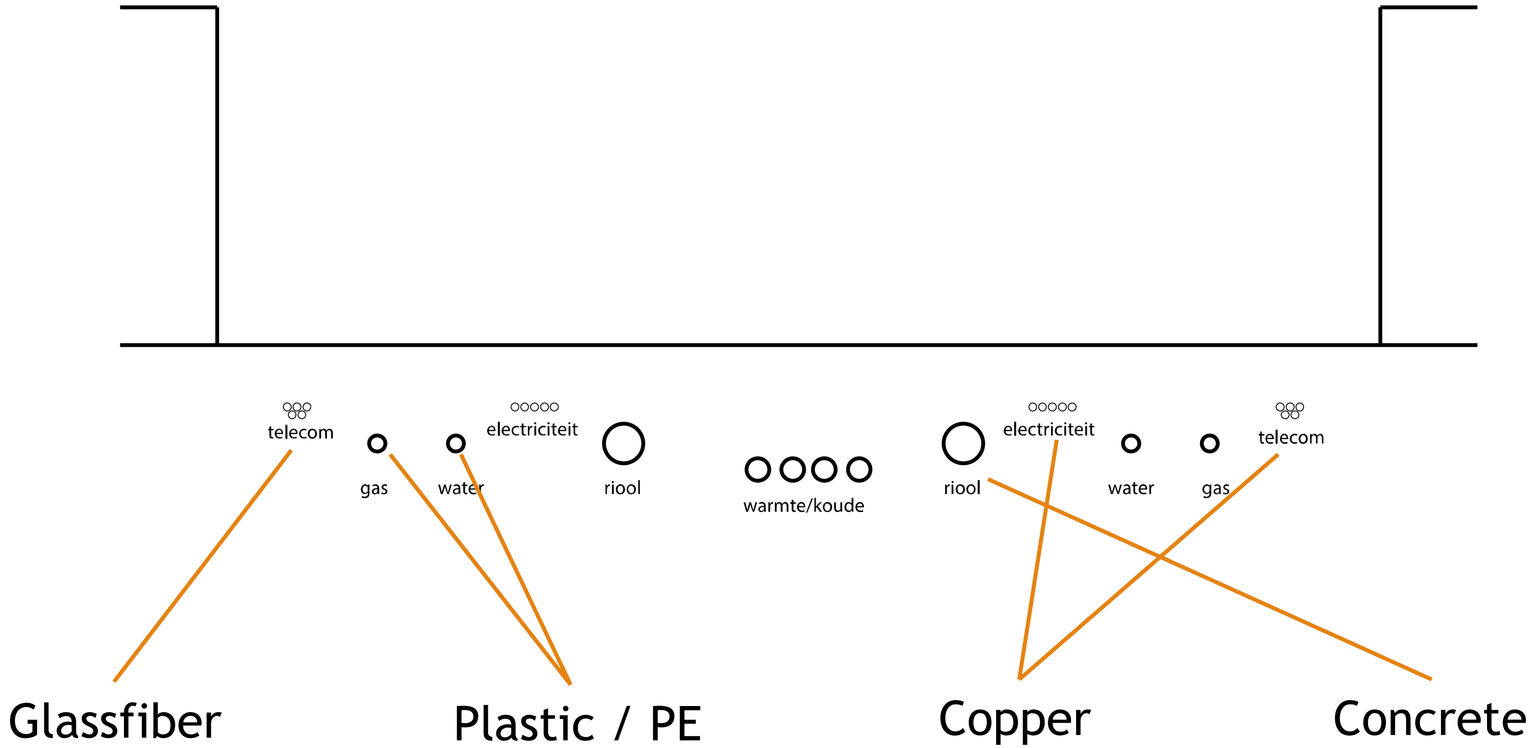

Electrical Networks

- Hierarchical nature
  - Low Voltage distribution network consists of many branches

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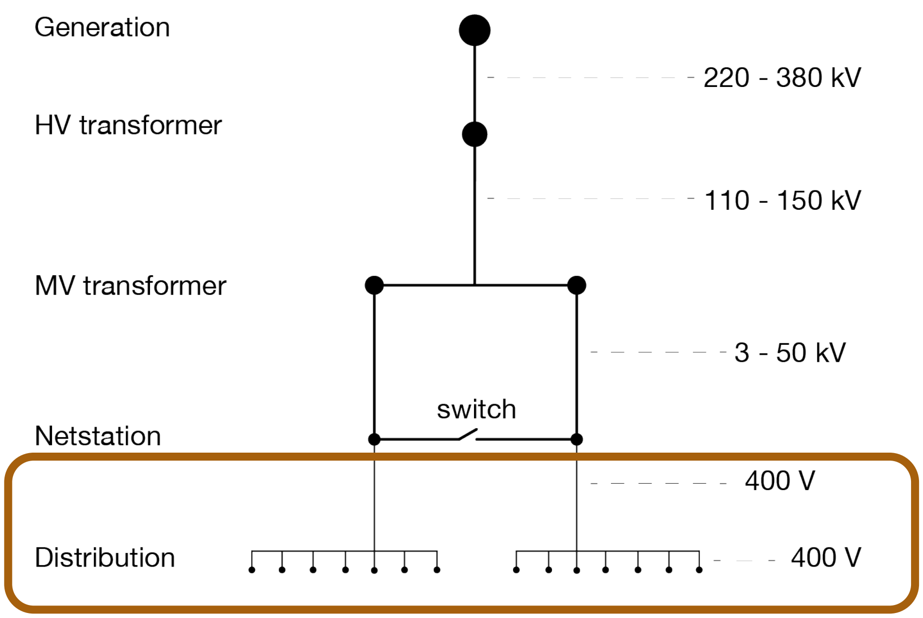

Topology

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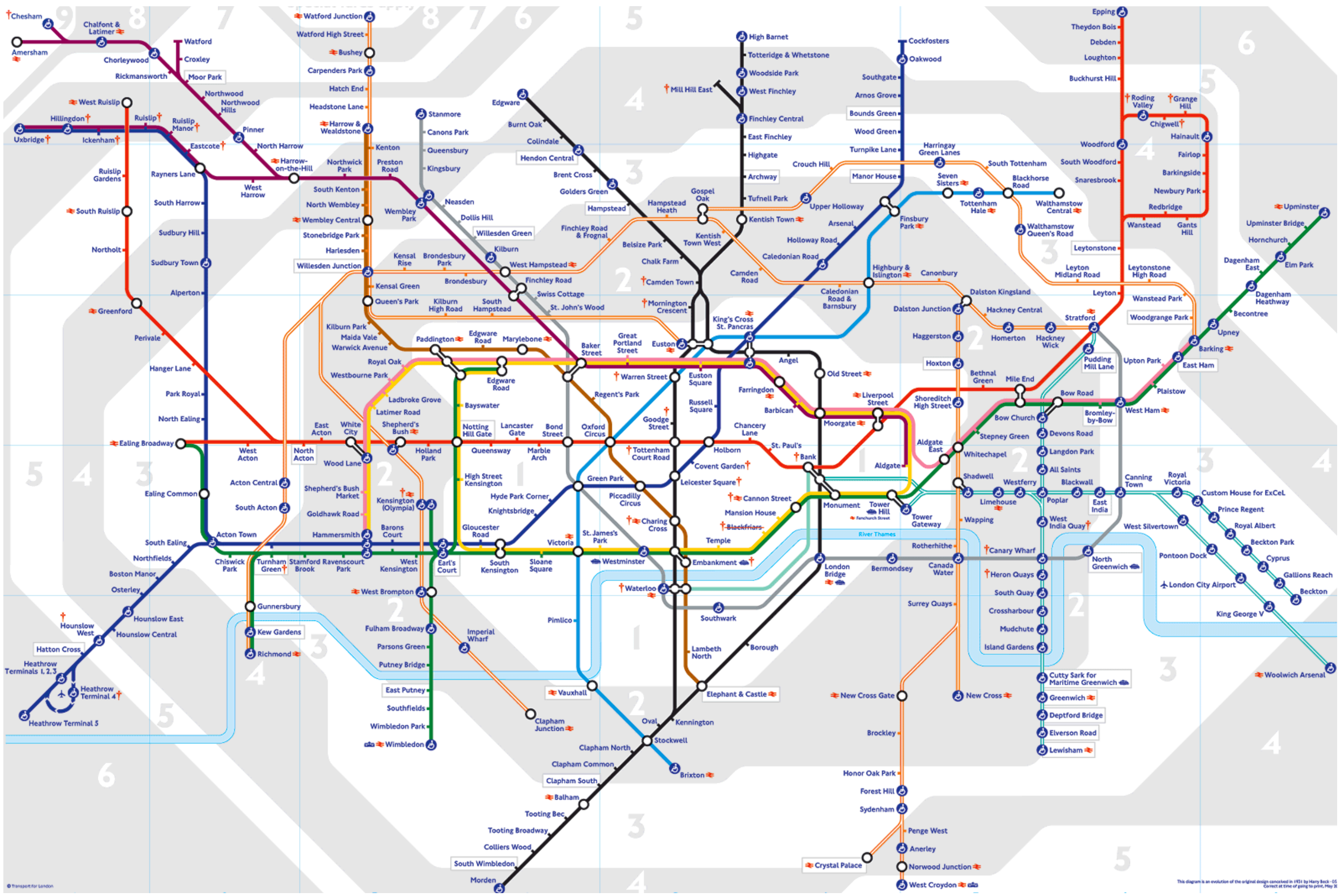

Topology

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Topology

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- Spatial relations in electrical networks
  - Building – Low Voltage Network
  - Low Voltage Network – Transformer – Medium Voltage Network

Case study areas

- Case study areas

Case study areas

- Case study areas
  - Slotervaart

Case study areas

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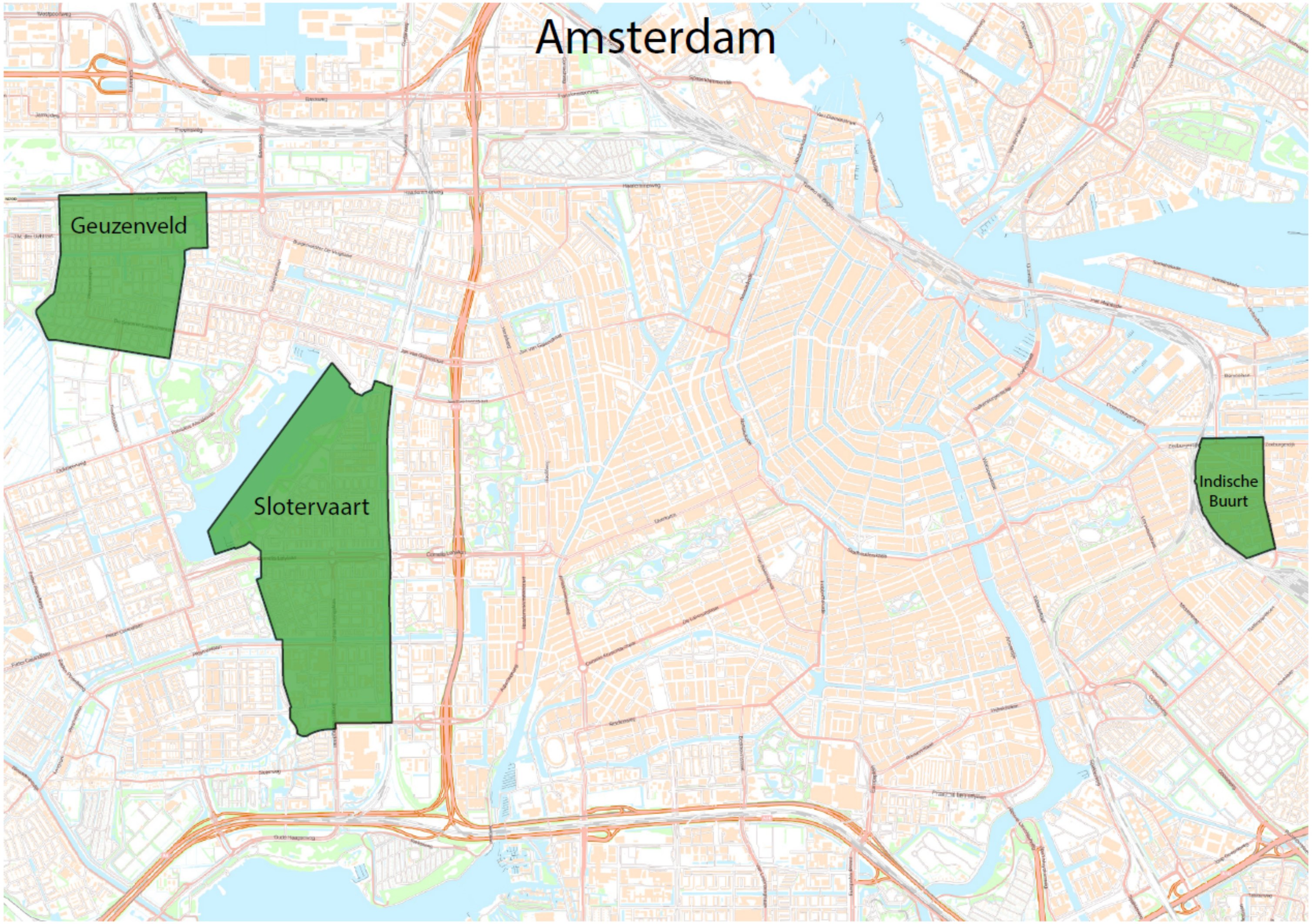

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- Chosen based on similarities

Case study areas

- Case study areas
  - Slotervaart
  - Geuzenveld
  - Indische Buurt
- Chosen based on similarities
  - Building age (built ±1950)
    - Might soon be redeveloped or demolished and provide urban mining opportunities

RESEARCH APPROACH

Research approach

- Research Question:

To what extent can topological networks be used for localization of underground metal cables in order to assess the quantity of an underground urban mine?

Research approach

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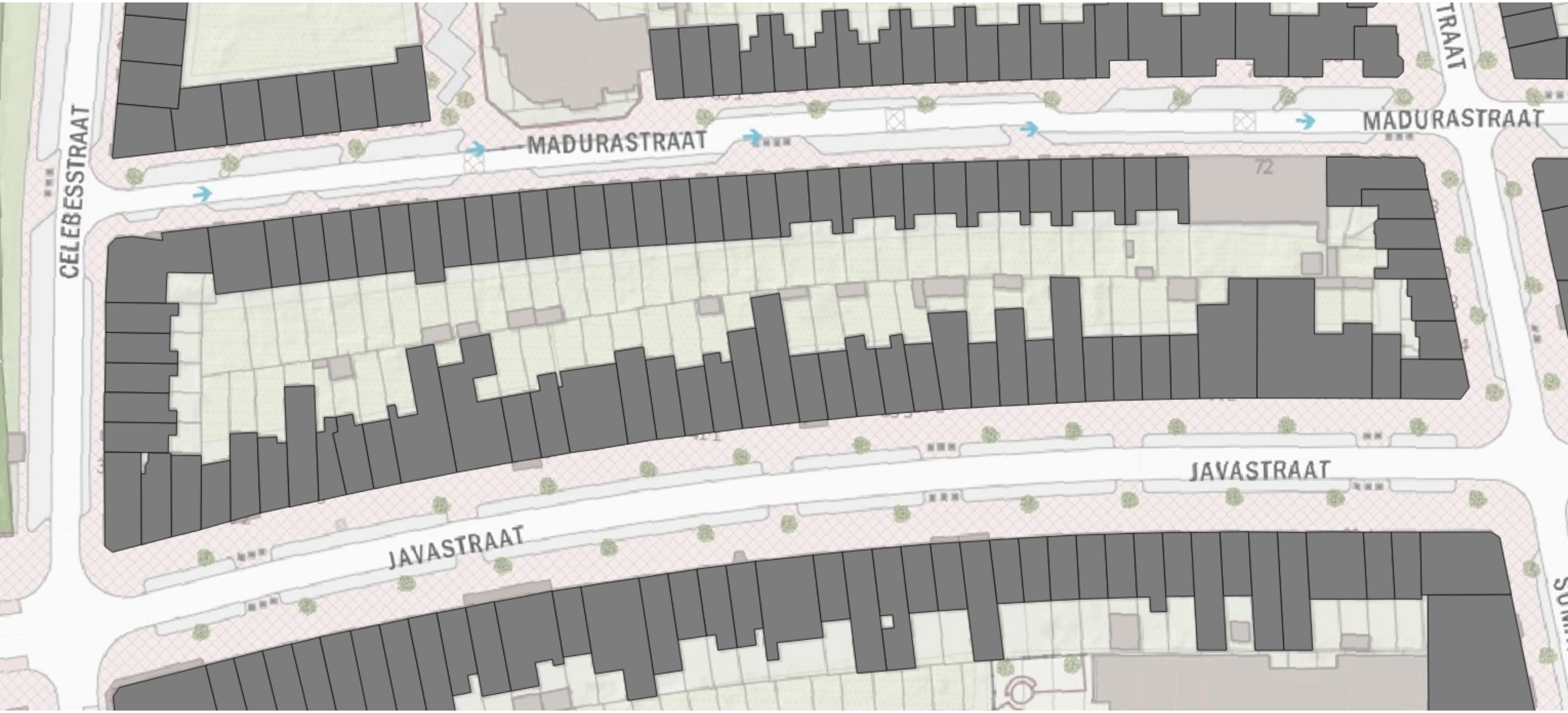
To what extent can topological networks be used for localization of underground metal cables in order to assess the quantity of an underground urban mine?

- Research Objectives
  1. Explore most suitable datasets
  2. Develop automated quantification method
  3. Exemplify method on case study areas

PROCESS

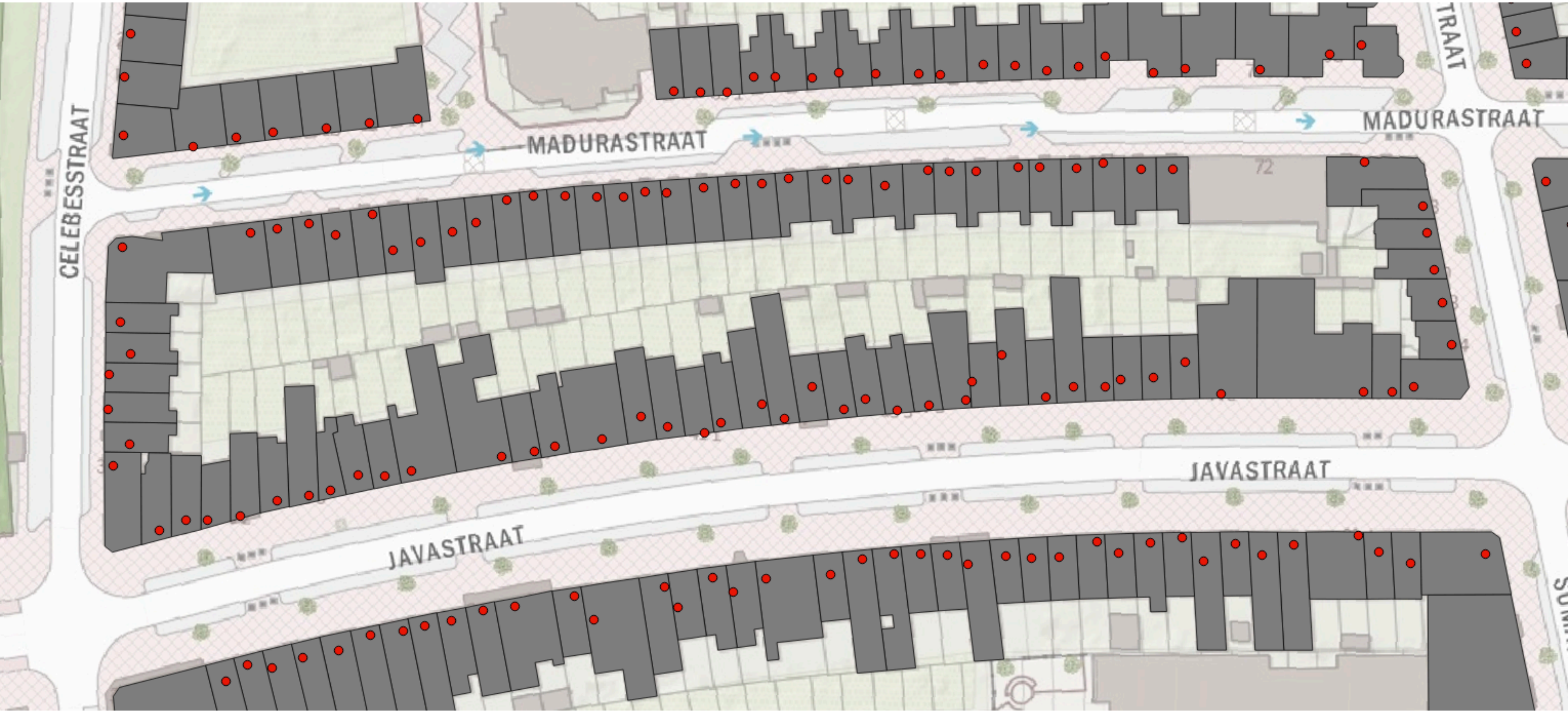
Datasets

Datasets



MADURASTRAAT
MADURASTRAAT
CELEBESSTRAAT
JAVASTRAAT
JAVASTRAAT
72

Datasets



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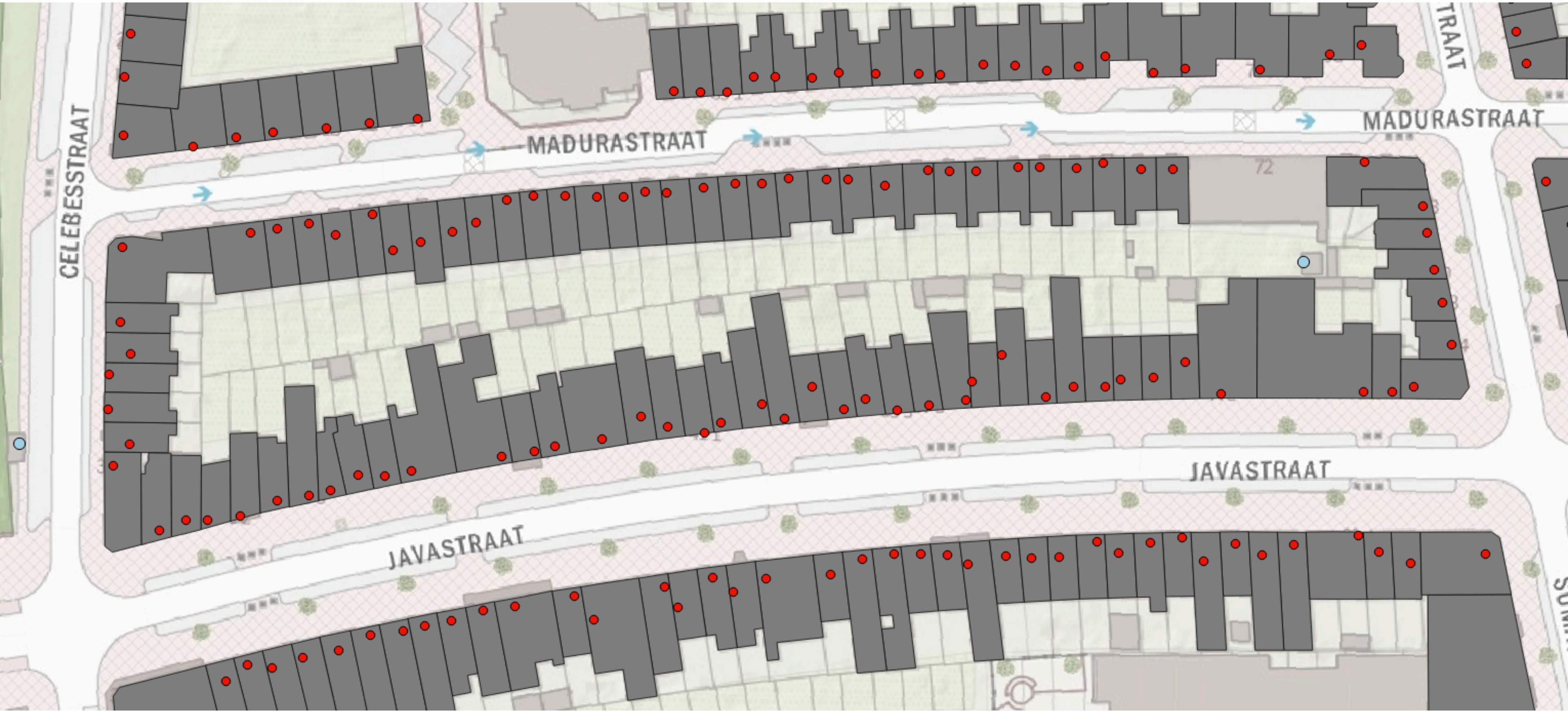

CELEBESSTRAAT
MADURASTRAAT
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72
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Datasets

Connecting points to the network

- NWB is only a collection of lines

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  - Geometrically connect buildings and transformers

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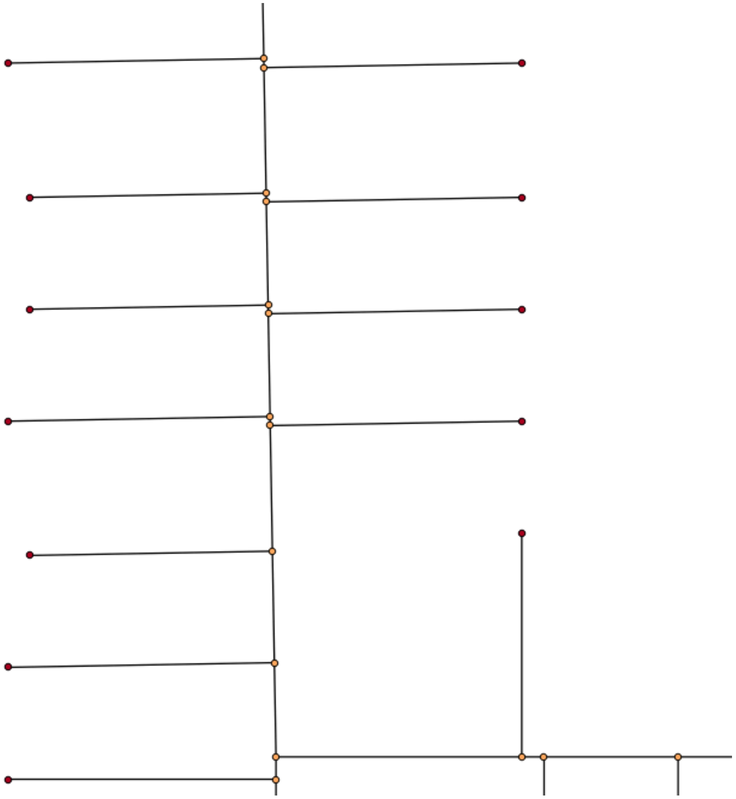

Connecting points to the network

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  - 3 methods:
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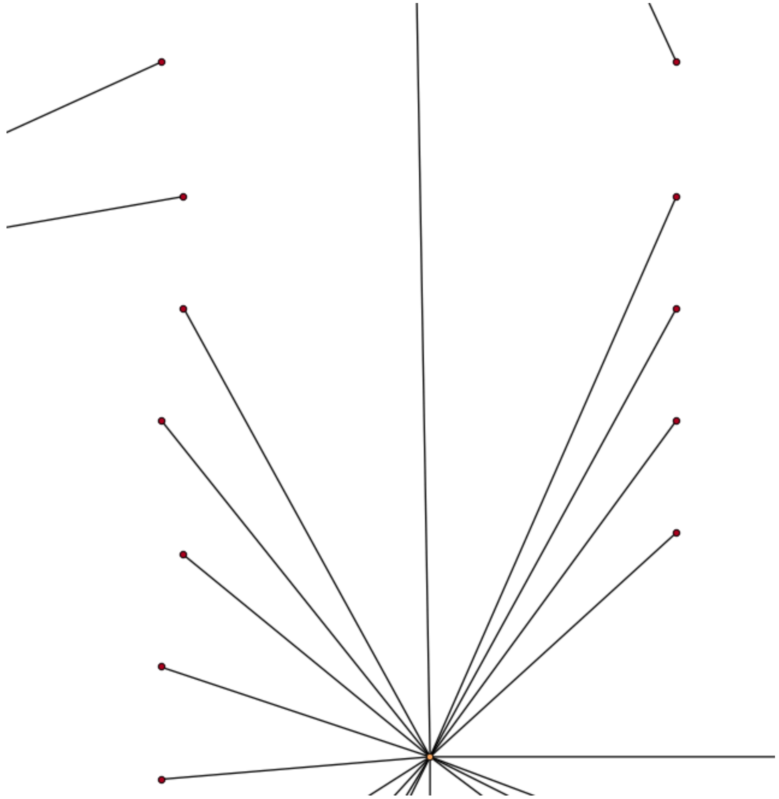
- Closest Junction



Connecting points to the network

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  - 3 methods:
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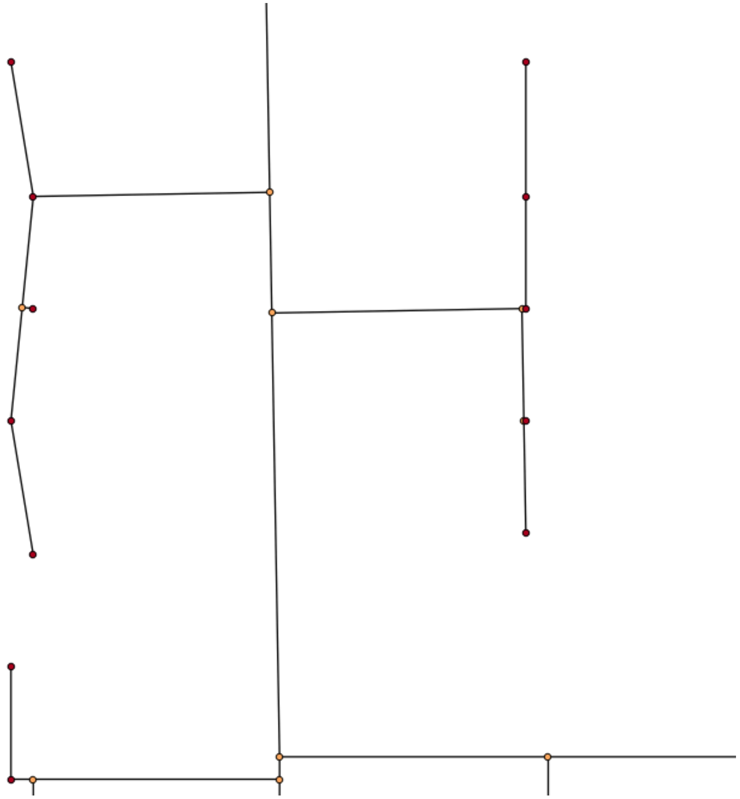
- Closest Junction
- Iterative Closest Junctio



Three topological networks

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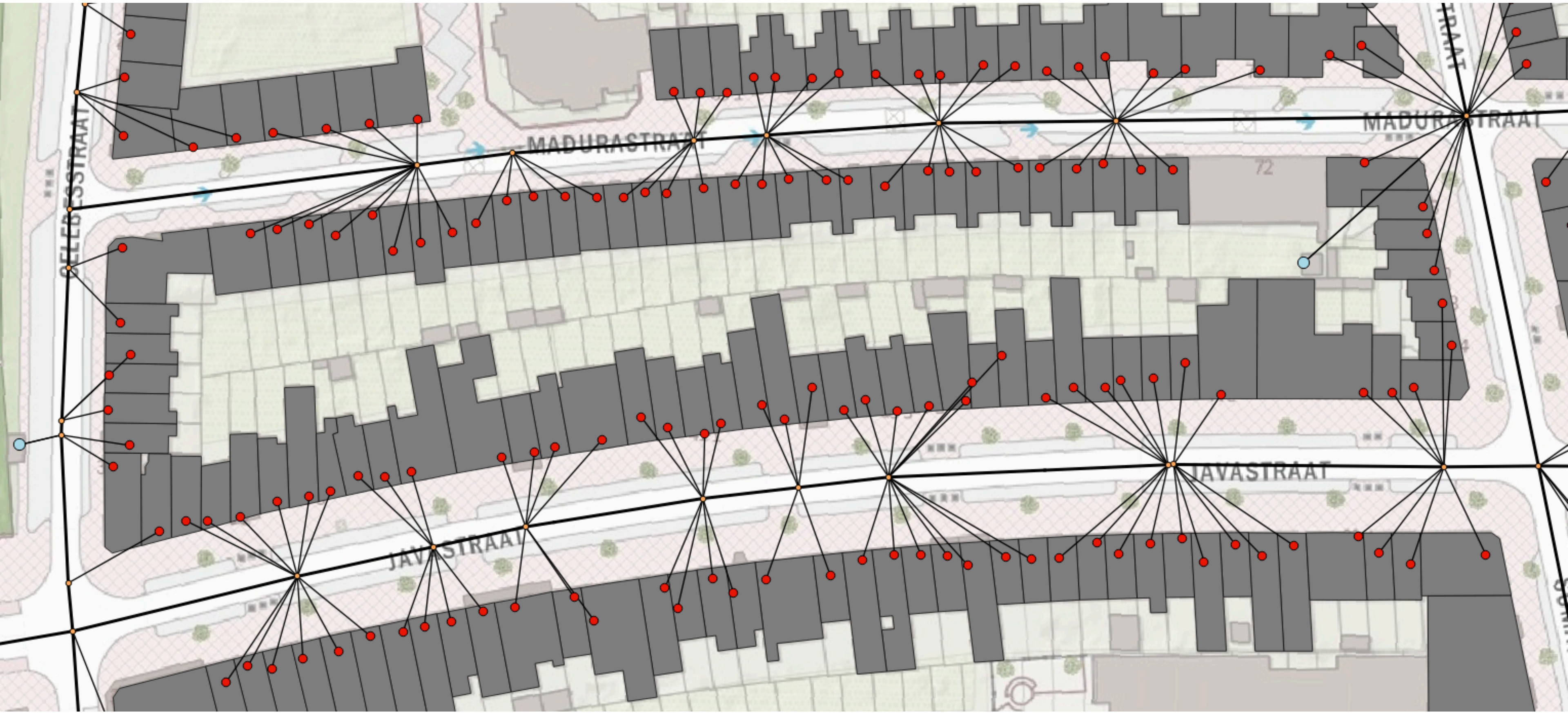

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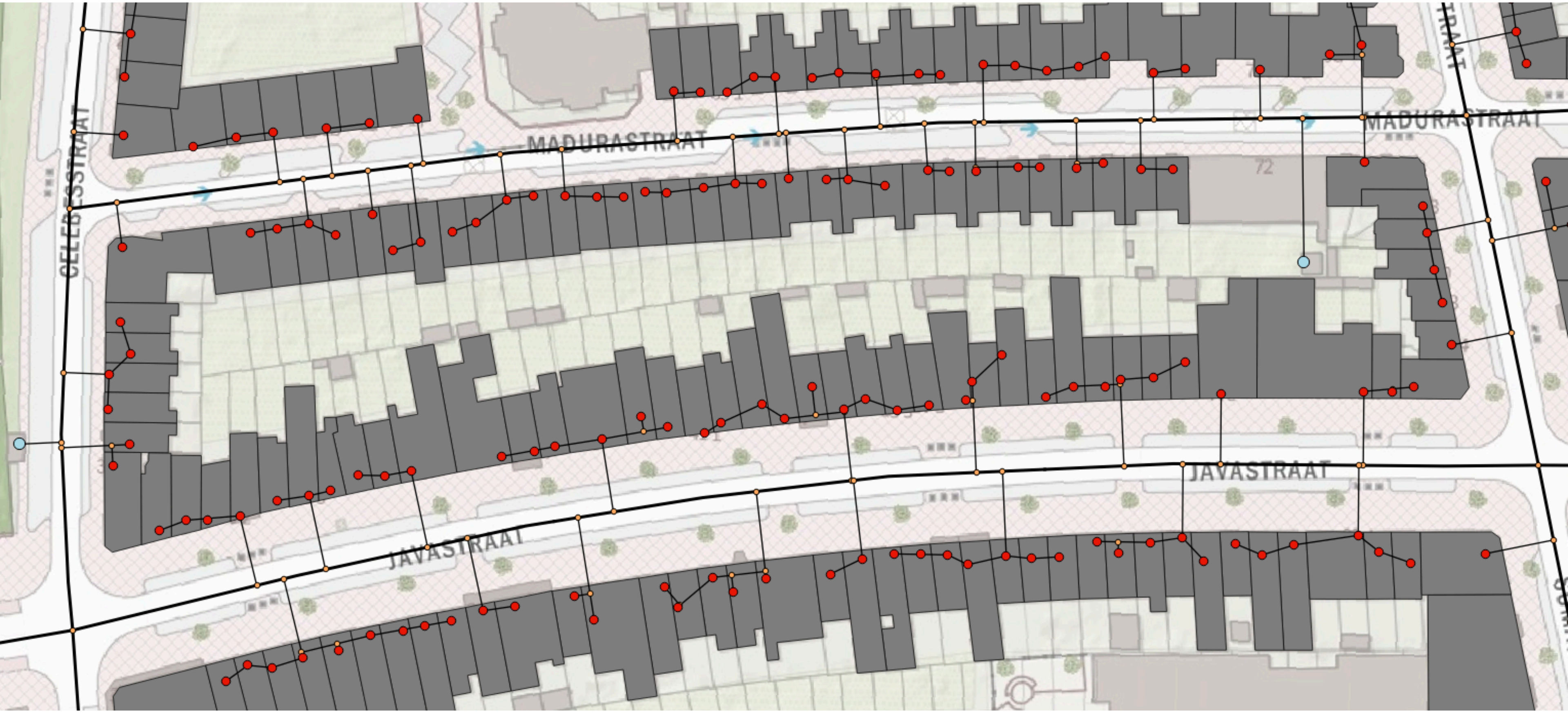

Topological networks

Closest Point	*vertices*	*Total edge length (m)*	*Average edge length (m)*
Geuzenveld	4409	59165.47	12.79
Slotervaart	5278	81960.25	14.58
Indische buurt	2415	26016.75	10.43
Closest Junction	***vertices***	***Total edge length (m)***	***Average edge length (m)***
Geuzenveld	2774	72247.88	24.95
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Iterative Closest Junction	***vertices***	***Total edge length (m)***	***Average edge length (m)***
Geuzenveld	3634	46936.02	10.25
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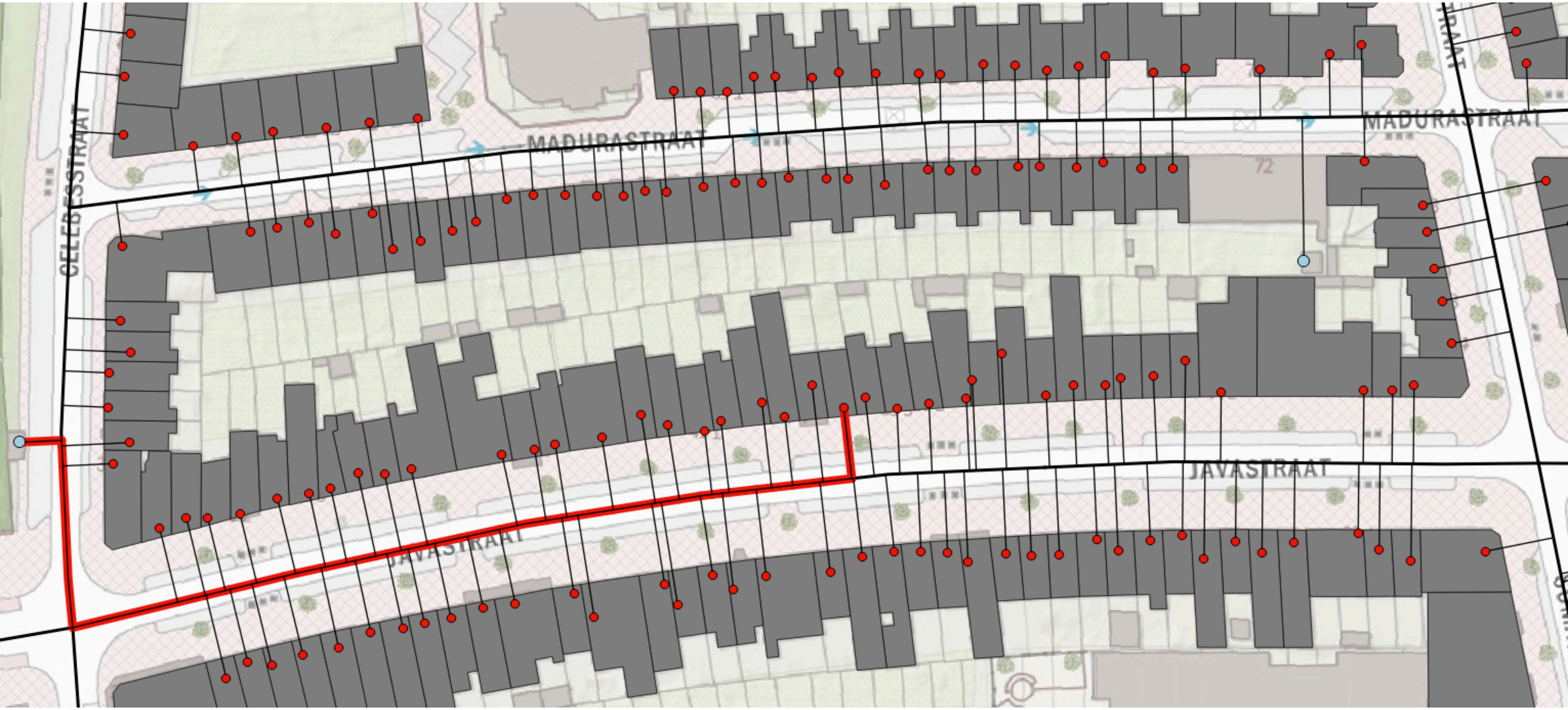
Shortest Paths

- Finding closest transformer
  - Shortest path from building to all transformers

Shortest Paths



Edge ‘betweenness’

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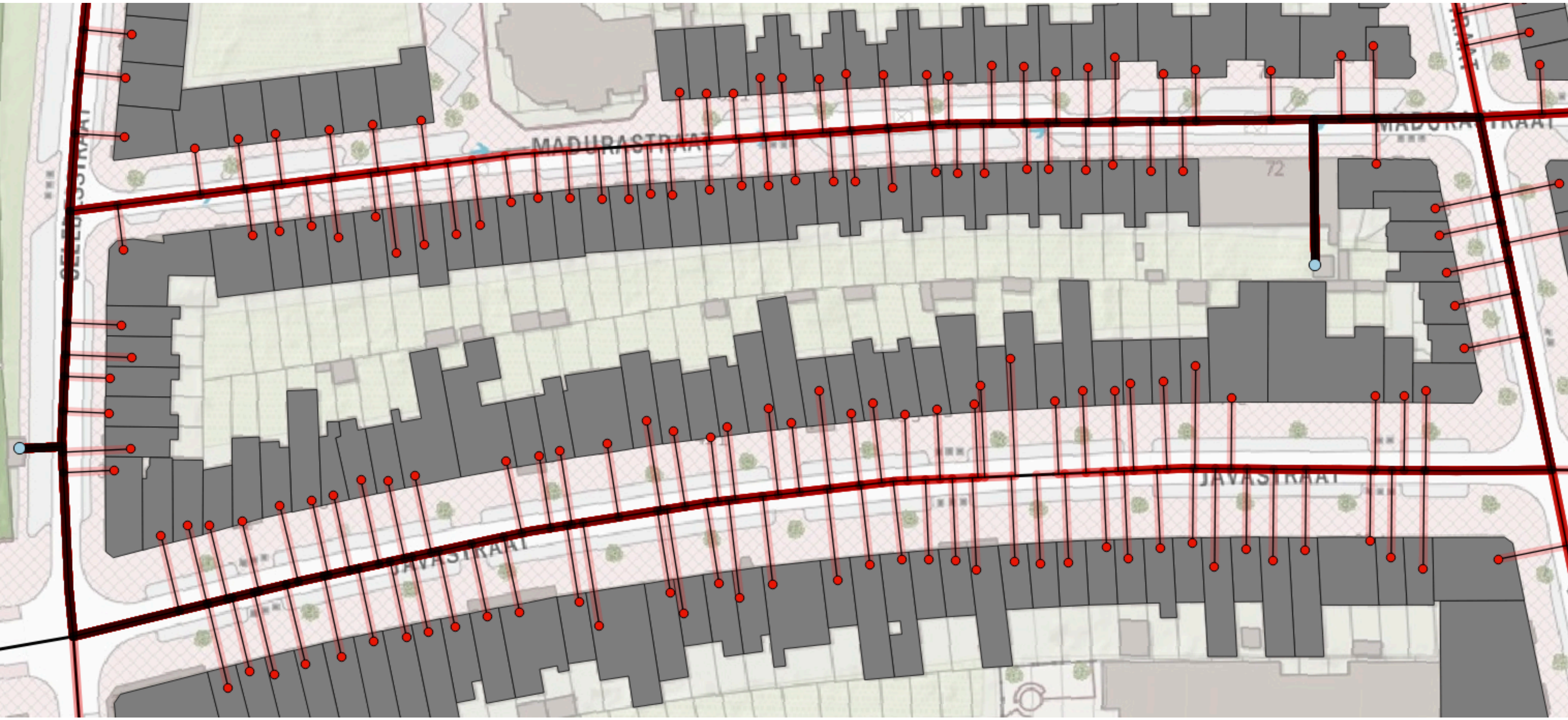

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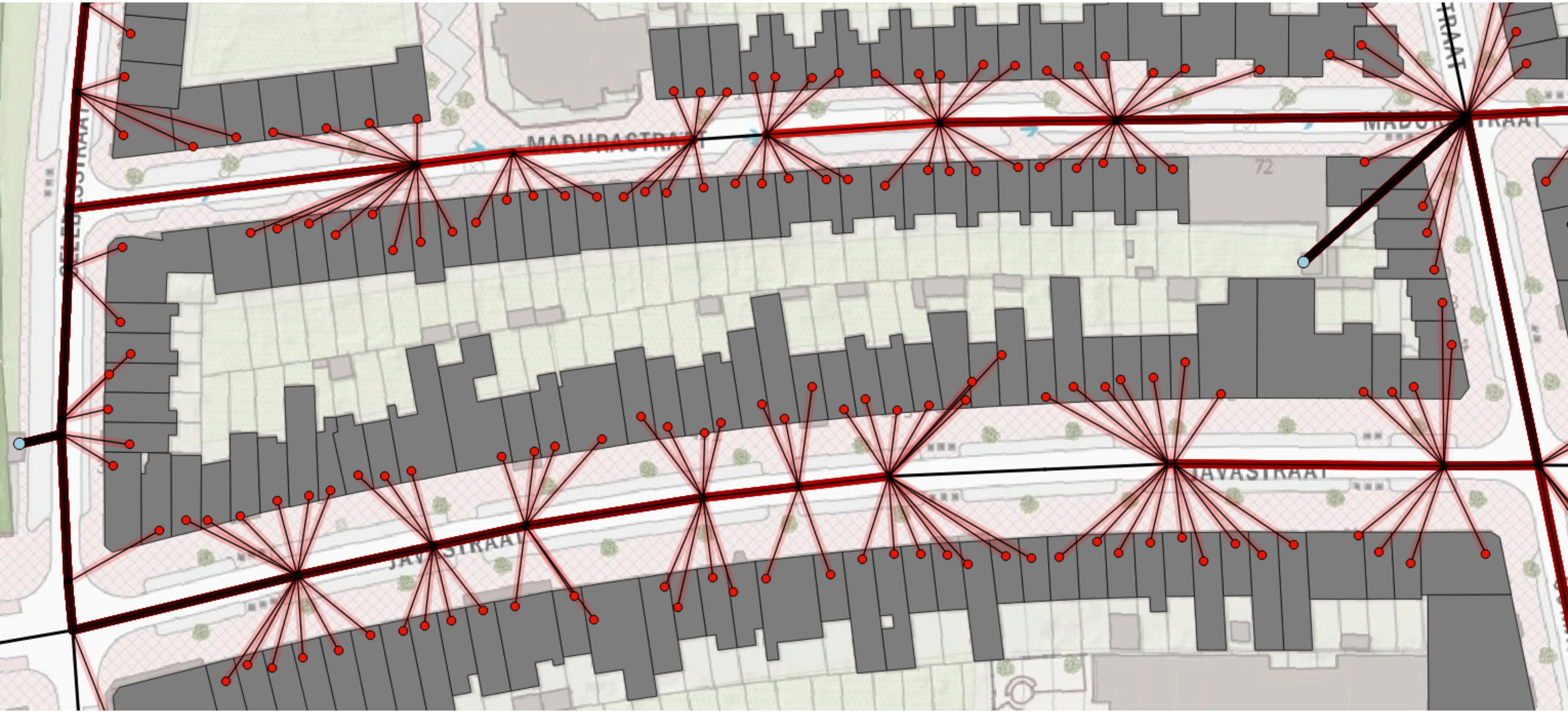

Edge ‘betweenness’

Power consumption

Power consumption

- Amount of households influences maximum power consumption
  - More households -> more power consumed
  - Average household consumes ±2400 - 3300 kWh / year

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  - More households -> more power consumed
  - Average household consumes ±2400 - 3300 kWh / year
- For each edge
  - Calculate maximum power
  - Compute current supposed to be flowing through a cable

Cable types

GPLK 3-ad.

Cu	Al	I (A)
10	16	63
16	25	85
25	35	110
35	50	130
50	70	160
70	95	190
-	120	205
95	150	240
120	185	275
150	240	320
185	-	350
240	-	410
300	400	450

XLPE 3-ad.

Cu	Al	I (A)
-	95	215
-	150	280
-	240	360

XLPE 1-ad.

95	-	335
drie hoek	240	355
	400	450
	630	575
plat	630	645

Quantification

Quantification

- Total metal mass in the network

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$$\sum_{1}^{n} M = \sum_{1}^{n} l_n \cdot A_n \cdot d_n$$

M = Total mass (kg)
l_n = length of edge n (cm)
A_n = cross section area of edge n (cm^2)
d = density of the edge n material (g/cm^3)

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$d =$ density of the edge n material (g/cm^3)

- Unsure whether a cable is made of copper or aluminium
  - Ratio of 70/30 (Cu/Al) is used to quantify metal content

RESULTS

Cable length

Geuzenveld	Computed length	Real length	%
Closest Junction	72.247,9	73.876,7	97,8%
Closest Point	59.165,5	73.876,7	80,1%
Iterative Closest Junction	46.936,0	73.876,7	63,5%
Indische buurt	**Computed length**	**Real length**	**%**
Closest Junction	34.503,0	58.028,2	59,5%
Closest Point	26.016,8	58.028,2	44,8%
Iterative Closest Junction	22.268,0	58.028,2	38,4%
Slotervaart	**Computed length**	**Real length**	**%**
Closest Junction	98.393,2	107.375,7	91,6%
Closest Point	81.960,3	107.375,7	76,3%
Iterative Closest Junction	69.828,3	107.375,7	65,0%

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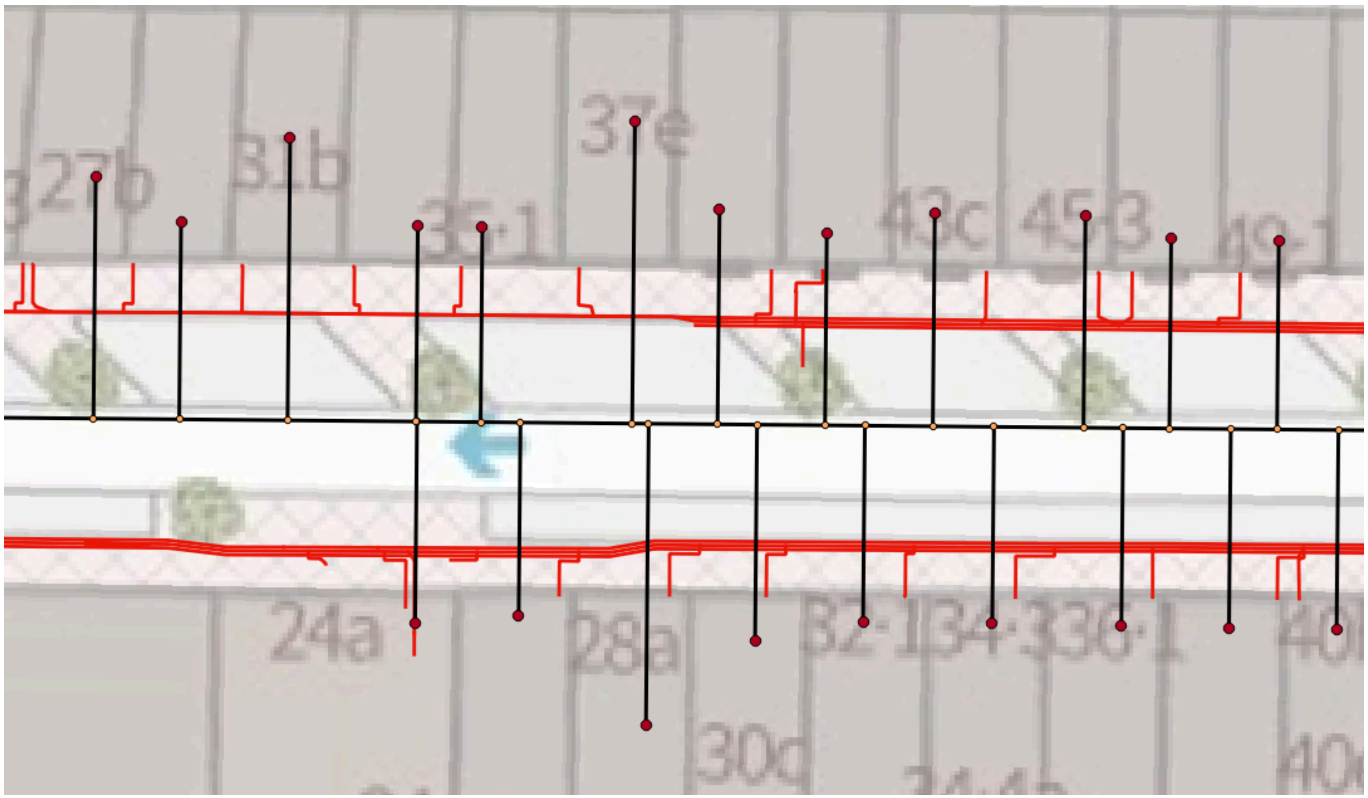

Final quantification

Geuzenveld	Iterative Closest Junction		Closest Point		Closest Junction	
Calculated cable length	36.078,6	(m)	49.824,8	(m)	60.685,6	(m)
Real cable length	73.813,4	(m)	73.813,4	(m)	73.813,4	(m)
	Cu (kg)	*Al (kg)*	*Cu (kg)*	*Al (kg)*	*Cu (kg)*	*Al (kg)*
Metal mass from algorithm	14.147,0	2.816,6	16.766,9	3.351,5	19.557,6	3.961,4
Metal mass in reality	44.013,1	13.262,9	44.013,1	13.262,9	44.013,1	13.262,9
Adjusted metal mass	28.294,0	5.633,3	33.533,7	6.703,0	39.115,2	7.922,7
Indische Buurt						
Calculated cable length	19.082,2	(m)	23.377,7	(m)	30.253,0	(m)
Real cable length	57.792,4	(m)	57.792,4	(m)	57.792,4	(m)
	Cu (kg)	*Al (kg)*	*Cu (kg)*	*Al (kg)*	*Cu (kg)*	*Al (kg)*
Metal mass from algorithm	9.910,2	1.898,2	10.681,6	2.064,6	13.153,1	2.581,2
Metal mass in reality	44.449,7	13.394,4	44.449,7	13.394,4	44.449,7	13.394,4
Adjusted metal mass	19.820,3	3.796,4	21.363,3	4.129,1	26.306,3	5.162,4
Slotervaart						
Calculated cable length	46.795,2	(m)	60.450,7	(m)	74.060,5	(m)
Real cable length	107.282,4	(m)	107.282,4	(m)	107.282,4	(m)
	Cu (kg)	*Al (kg)*	*Cu (kg)*	*Al (kg)*	*Cu (kg)*	*Al (kg)*
Metal mass from algorithm	15.625,1	3.074,5	18.061,8	3.568,6	21.386,7	4.219,8
Metal mass in reality	84.255,3	25.389,4	84.255,3	25.389,4	84.255,3	25.389,4
Adjusted metal mass	31.250,2	6.149,0	36.123,6	7.137,3	42.773,4	8.439,5

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Method comparison

		Geuzenveld			Indische Buurt			Slotervaart		
		Closest Junction	Closest Point	Iterative Closest Junction	Closest Junction	Closest Point	Iterative Closest Junction	Closest Junction	Closest Point	Iterative Closest Junction
Geuzenveld	Closest Junction		117%	138%	149%	183%	197%	91%	108%	125%
	Closest Point	86%		119%	127%	157%	169%	78%	93%	107%
	Iterative Closest Junction	72%	84%		108%	132%	143%	66%	78%	91%
Indische Buurt	Closest Junction	67%	78%	93%		123%	133%	62%	73%	84%
	Closest Point	55%	64%	76%	81%		108%	50%	59%	68%
	Iterative Closest Junction	51%	59%	70%	75%	93%		46%	55%	63%
Slotervaart	Closest Junction	109%	128%	151%	163%	200%	216%		118%	137%
	Closest Point	92%	108%	128%	137%	169%	182%	84%		116%
	Iterative Closest Junction	80%	93%	110%	119%	146%	158%	73%	87%	

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Accuracy

Geuzenveld	Computed metal mass		Real metal mass		Accuracy	
	Cu (kg)	*Al (kg)*	*Cu (kg)*	*Al (kg)*	*Cu*	*Al*
Closest Junction	39.115,20	7.922,75	44.013,09	13.262,87	88,9%	59,7%
Closest Point	33.533,73	6.702,95	44.013,09	13.262,87	76,2%	50,5%
Iterative Closest Junction	28.294,03	5.633,29	44.013,09	13.262,87	64,3%	42,5%
Indische buurt	*Cu (kg)*	*Al (kg)*	*Cu (kg)*	*Al (kg)*	*Cu*	*Al*
Closest Junction	26.306,27	5.162,36	44.449,66	13.394,43	59,2%	38,5%
Closest Point	21.363,26	4.129,12	44.449,66	13.394,43	48,1%	30,8%
Iterative Closest Junction	19.820,31	3.796,40	44.449,66	13.394,43	44,6%	28,3%
Slotervaart	*Cu (kg)*	*Al (kg)*	*Cu (kg)*	*Al (kg)*	*Cu*	*Al*
Closest Junction	42.773,36	8.439,52	84.255,30	25.389,43	50,8%	33,2%
Closest Point	36.123,55	7.137,28	84.255,30	25.389,43	42,9%	28,1%
Iterative Closest Junction	31.250,22	6.149,05	84.255,30	25.389,43	37,1%	24,2%

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  - Could be caused by investigating residential buildings only.

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- **This methodology *can* find a minimum quantity of underground metals, but is *not suitable* for finding the exact location of these cables**

DISCUSSION & RECOMMENDATIONS

Discussion

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- Data limitations

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  - Building points

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  - Transformers

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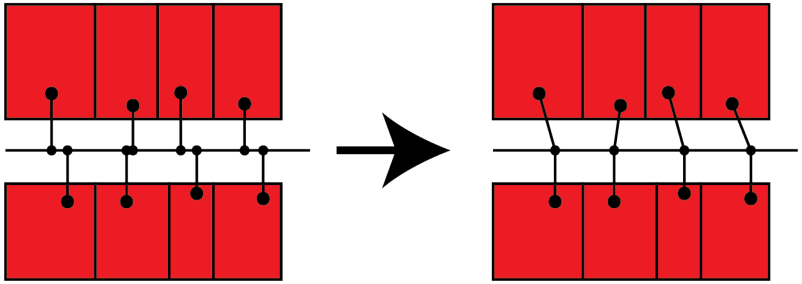

Closest Point

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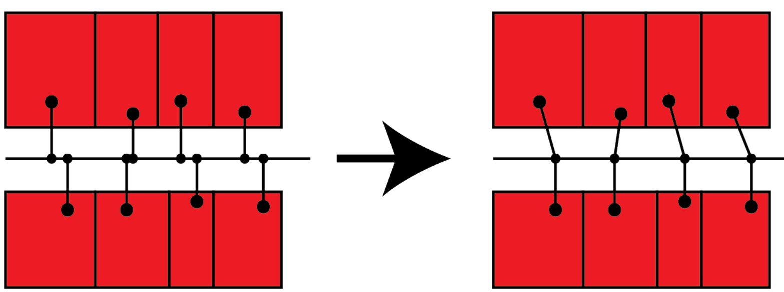

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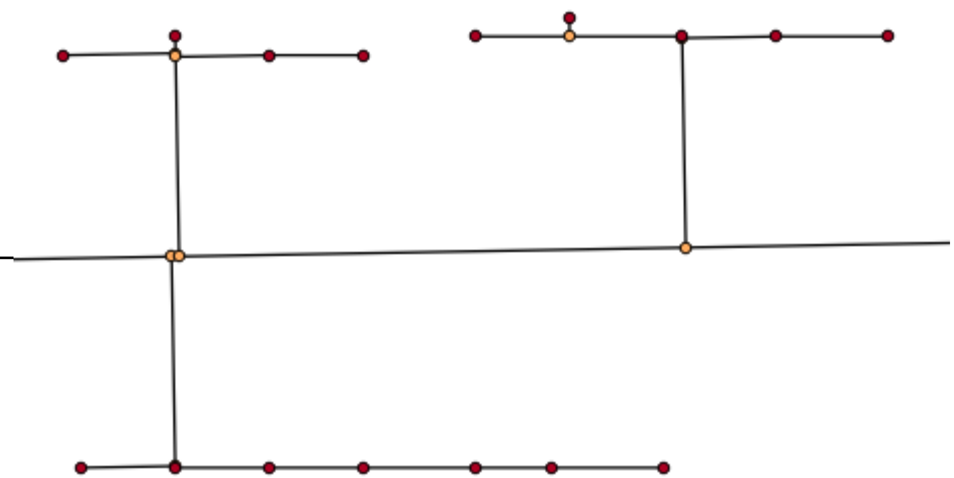

Iterative Closest Junction

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Future work & recommendations

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  - Offset NWB network to both sides
  - Find the centreline of pavements
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- Improve *completeness*
  - Tram lines
  - Public Lighting
  - Other materials (pipes and optical fibres)
- Improve buildings points by cooperation with network operators

THANK YOU FOR YOUR ATTENTION