

An aerial photograph of an urban mine site. The image shows a complex network of roads, tracks, and industrial structures. In the foreground, there are several large, circular processing tanks, some of which are filled with a blueish-grey slurry. The background features a dense area of buildings and infrastructure, including a large industrial complex with multiple buildings and pipes. The overall scene is a mix of natural and man-made elements, illustrating the scale and complexity of urban mining operations.

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

Outline

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



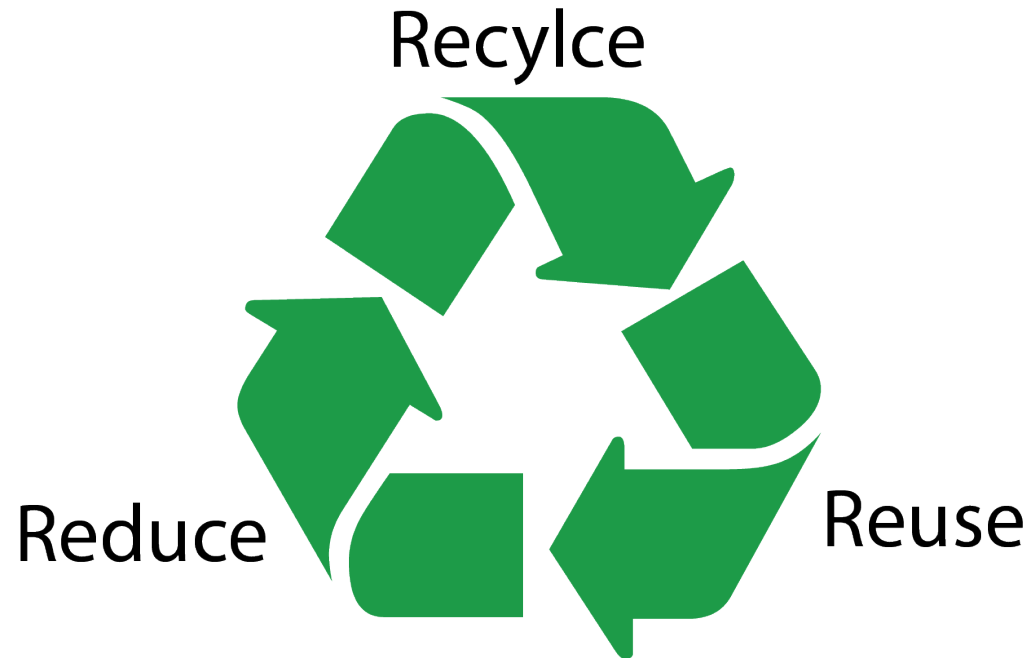
INTRODUCTION

Circular Economy

Circular Economy



Circular Economy



Circular Economy

Circular Economy

- 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

Urban Mining

- Reusing or recycling resources dispersed among the urban environment
- Urban mining challenge
 - Prospecting: how many resources and where?

Urban Mining

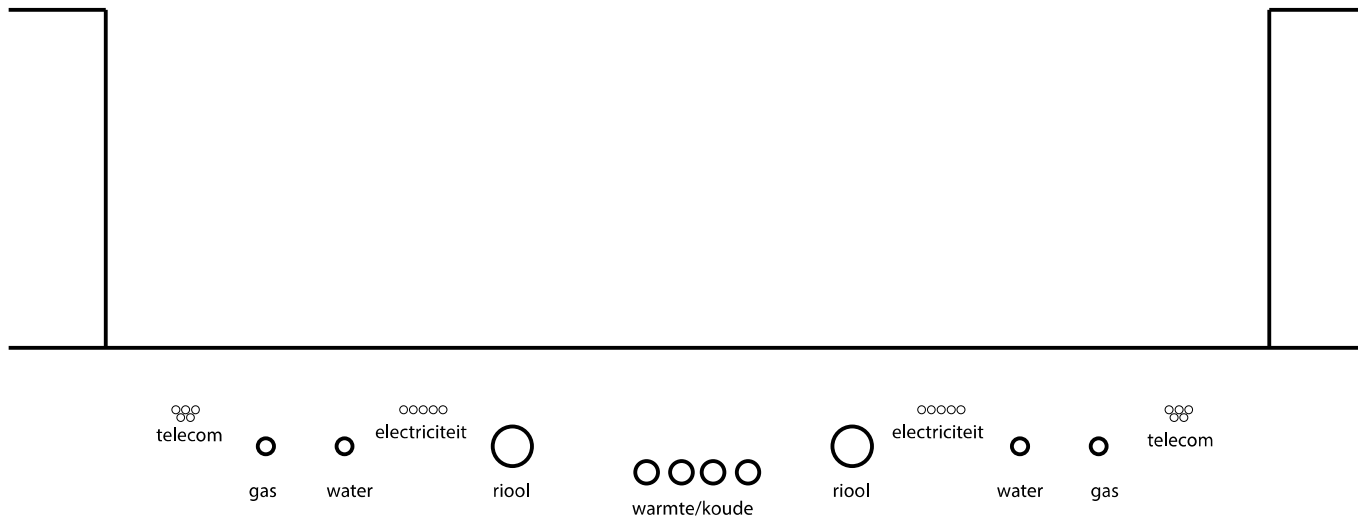
- Reusing or recycling resources dispersed among the urban environment
- Urban mining challenge
 - Prospecting: how many resources and where?
- Prospected urban mine as a motive for actual mining

Underground Infrastructure

- Many underground resources, seemingly invisible

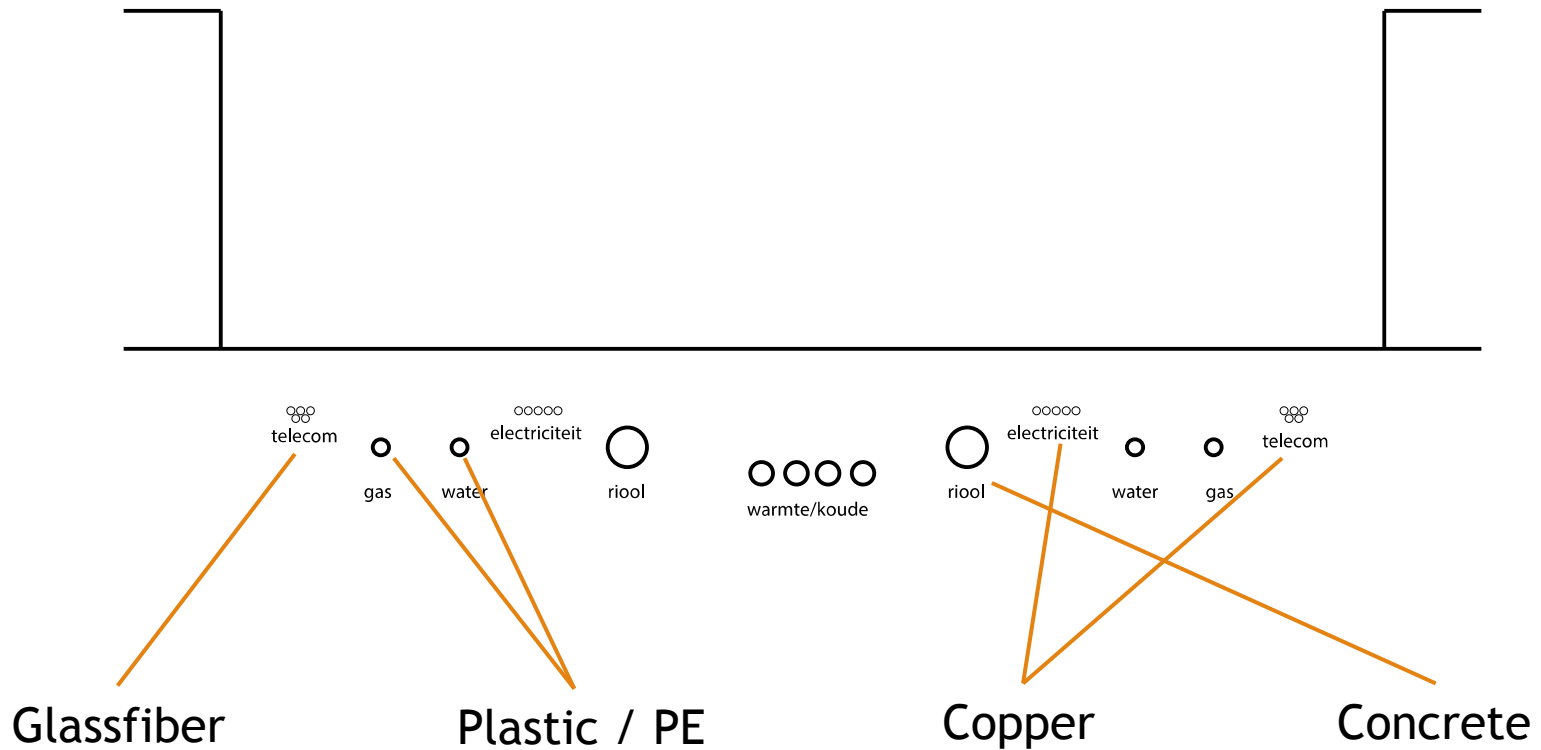
Underground Infrastructure

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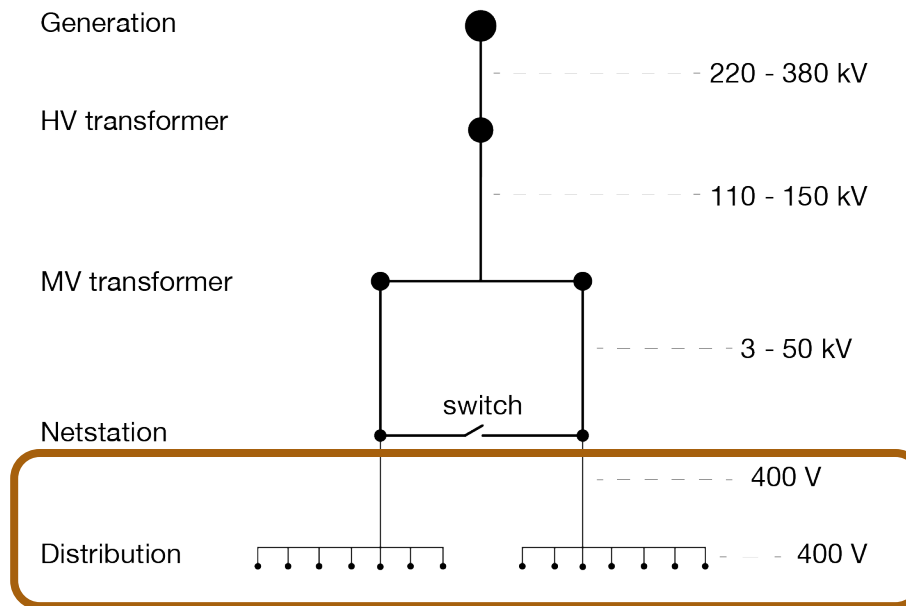


Electrical Networks

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

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 - Low Voltage distribution network consists of many branches



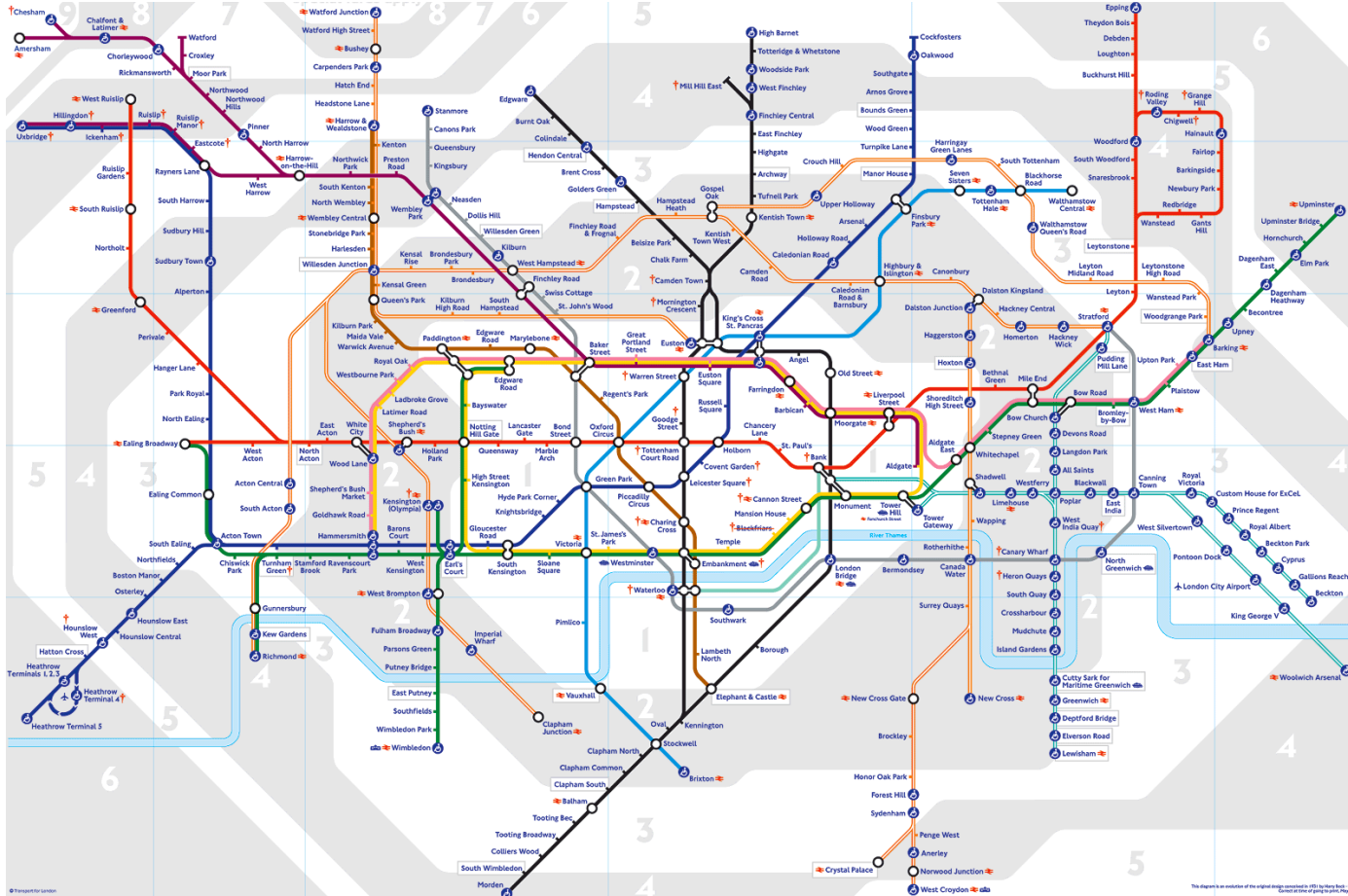
Topology

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

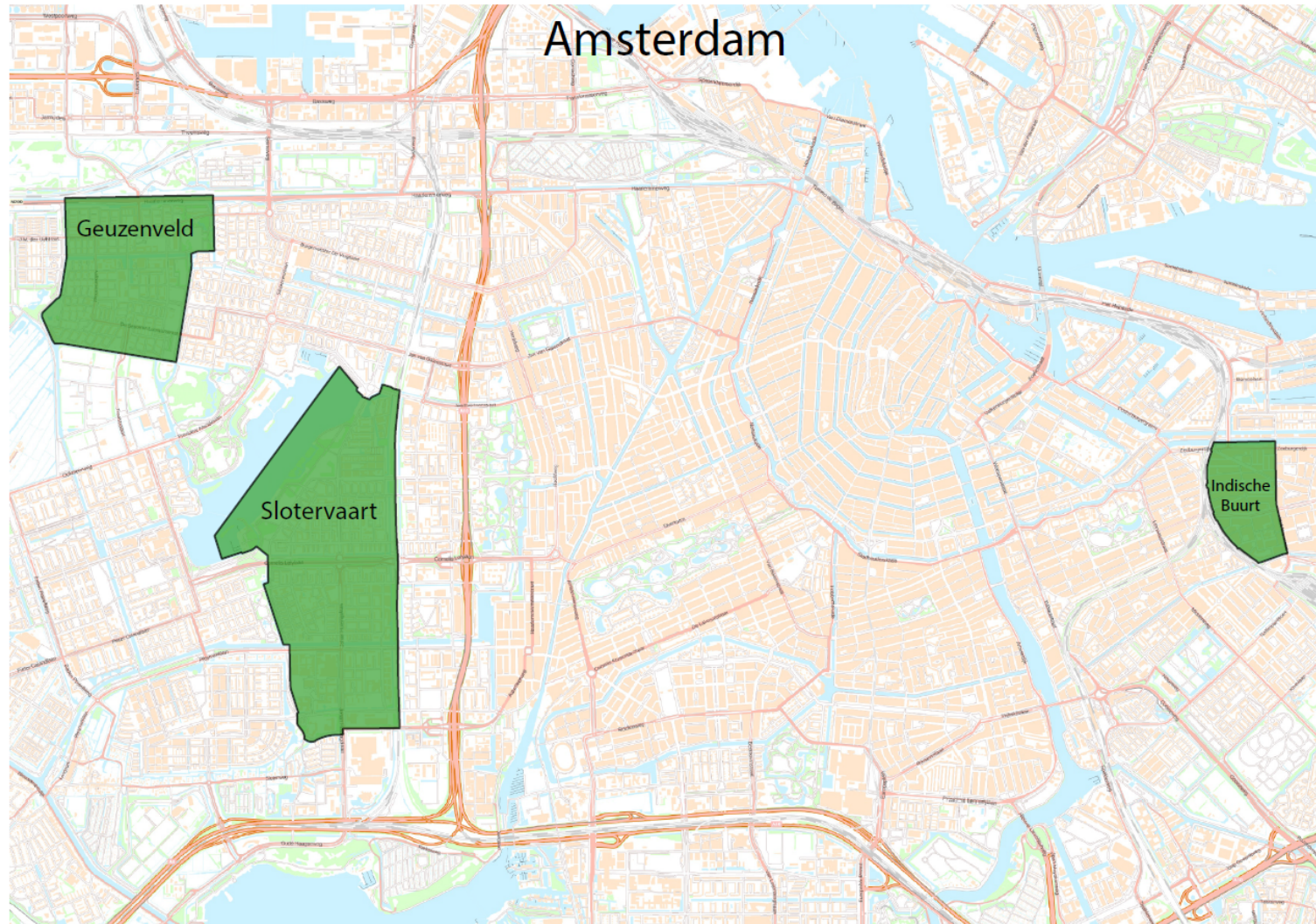
Case study areas

- Case study areas
 - Slotervaart
 - Geuzenveld

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 - Geuzenveld
 - Indische Buurt

Case study areas



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

An aerial photograph of a large-scale mining or industrial site. The foreground is dominated by a massive, terraced earthwork structure, possibly a tailings dam or a large-scale excavation, showing distinct horizontal layers of earth and rock. The colors range from dark blue and grey to light tan and brown. To the right, there is a complex of industrial buildings, including several large circular tanks or silos, and a network of roads and tracks. The background shows more of the site's infrastructure, including a long conveyor belt system stretching across the landscape. The overall scene is one of intense industrial activity and large-scale earthmoving.

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?

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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

An aerial photograph of a large-scale industrial or mining operation. The image shows a complex network of roads, tracks, and various structures. In the foreground, there are large, terraced areas with distinct horizontal lines, possibly representing a large-scale excavation or a series of terraced fields. The background features a dense cluster of industrial buildings, pipes, and other infrastructure. The overall scene is a detailed view of a large-scale project.

PROCESS

Datasets

Datasets



Datasets



Datasets



Datasets



Connecting points to the network

- NWB is only a collection of lines

Connecting points to the network

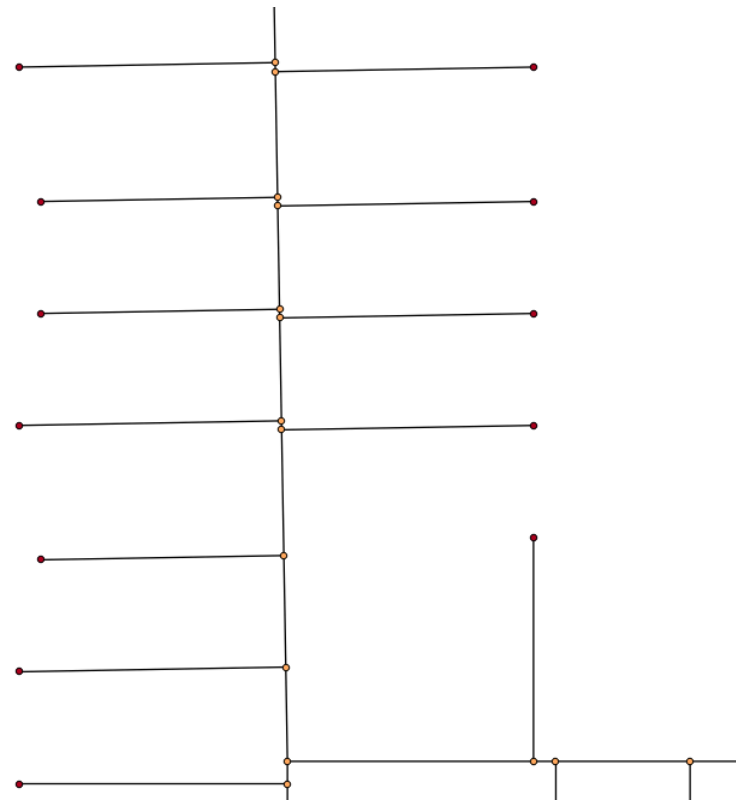
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Connecting points to the network

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 - Geometrically connect buildings and transformers
 - 3 methods:

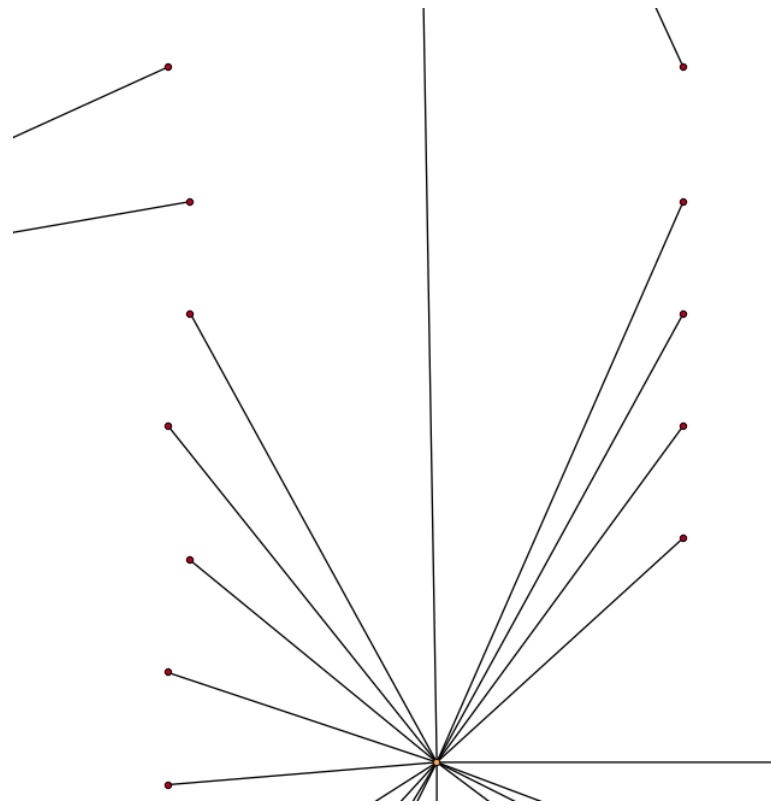
Connecting points to the network

- NWB is only a collection of lines
 - Geometrically connect buildings and transformers
 - 3 methods:
- Closest Point



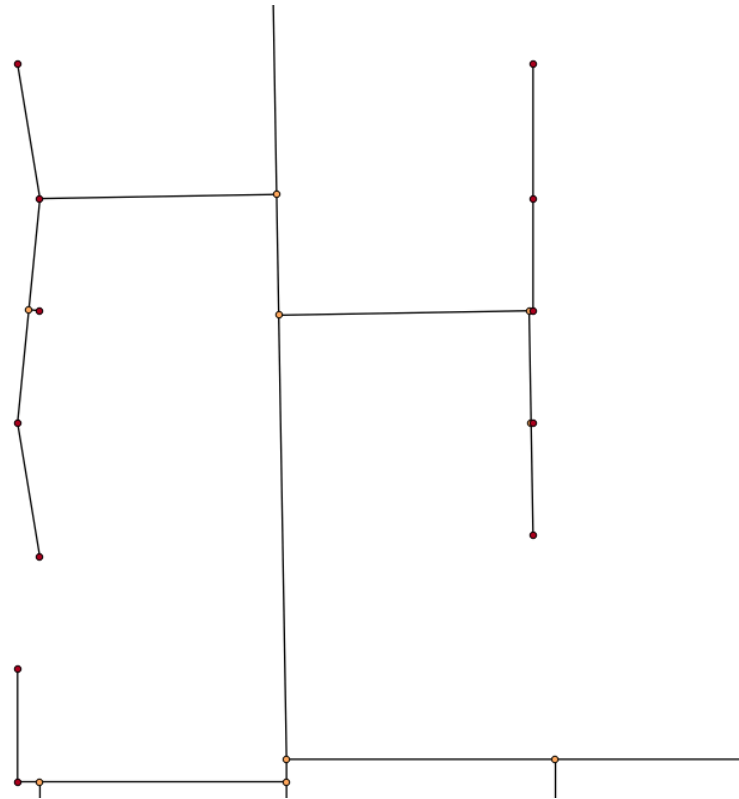
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Connecting points to the network

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 - 3 methods:
- Closest Point
- Closest Junction
- Iterative Closest Junction

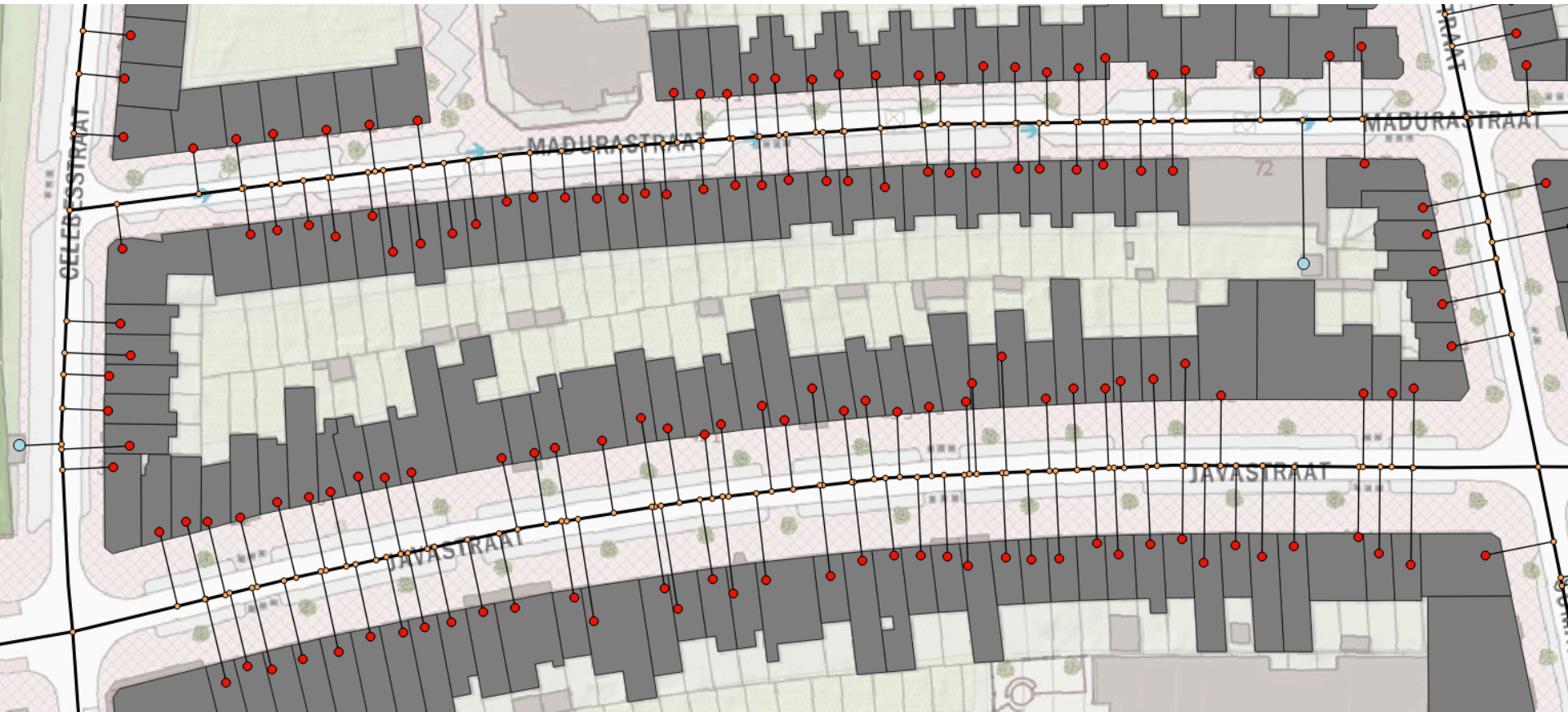


Three topological networks

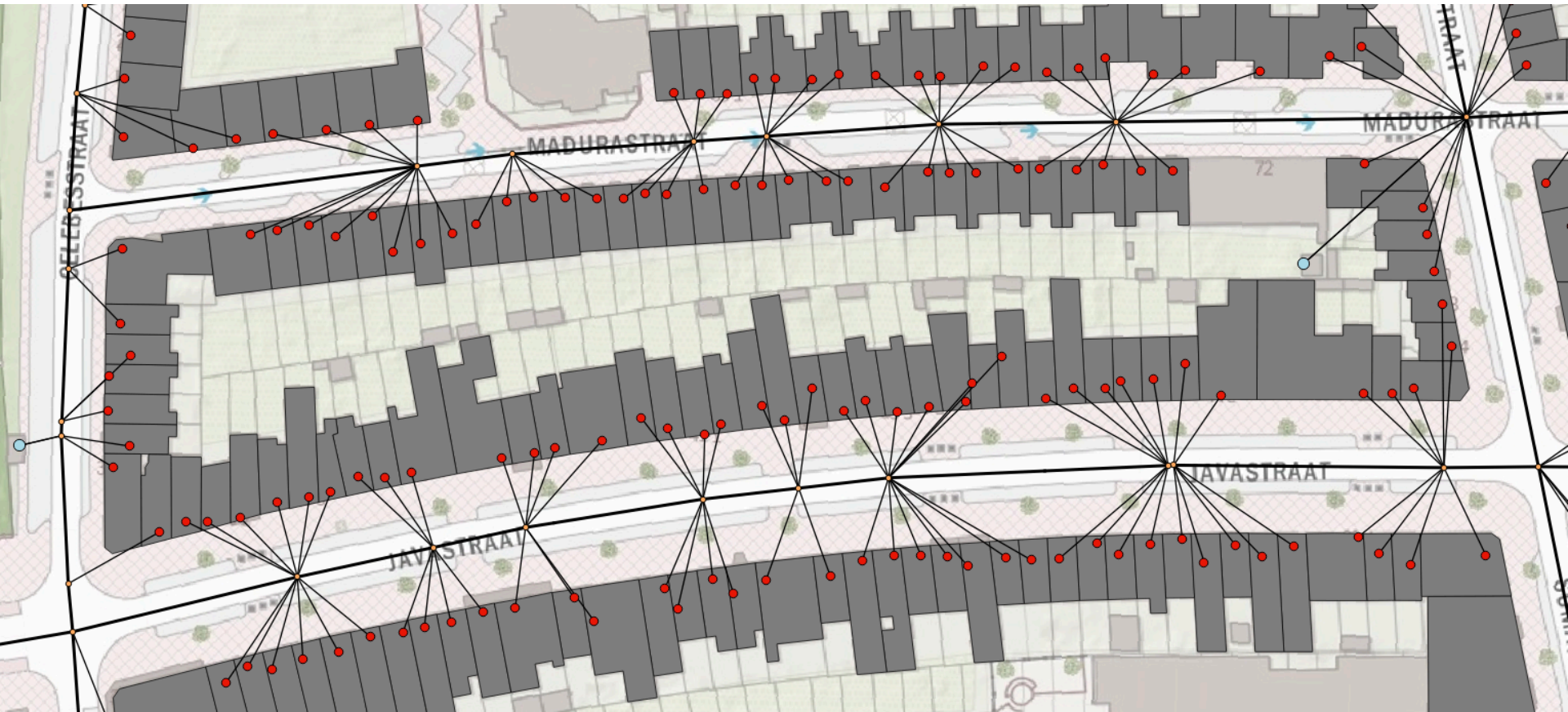
Three topological networks



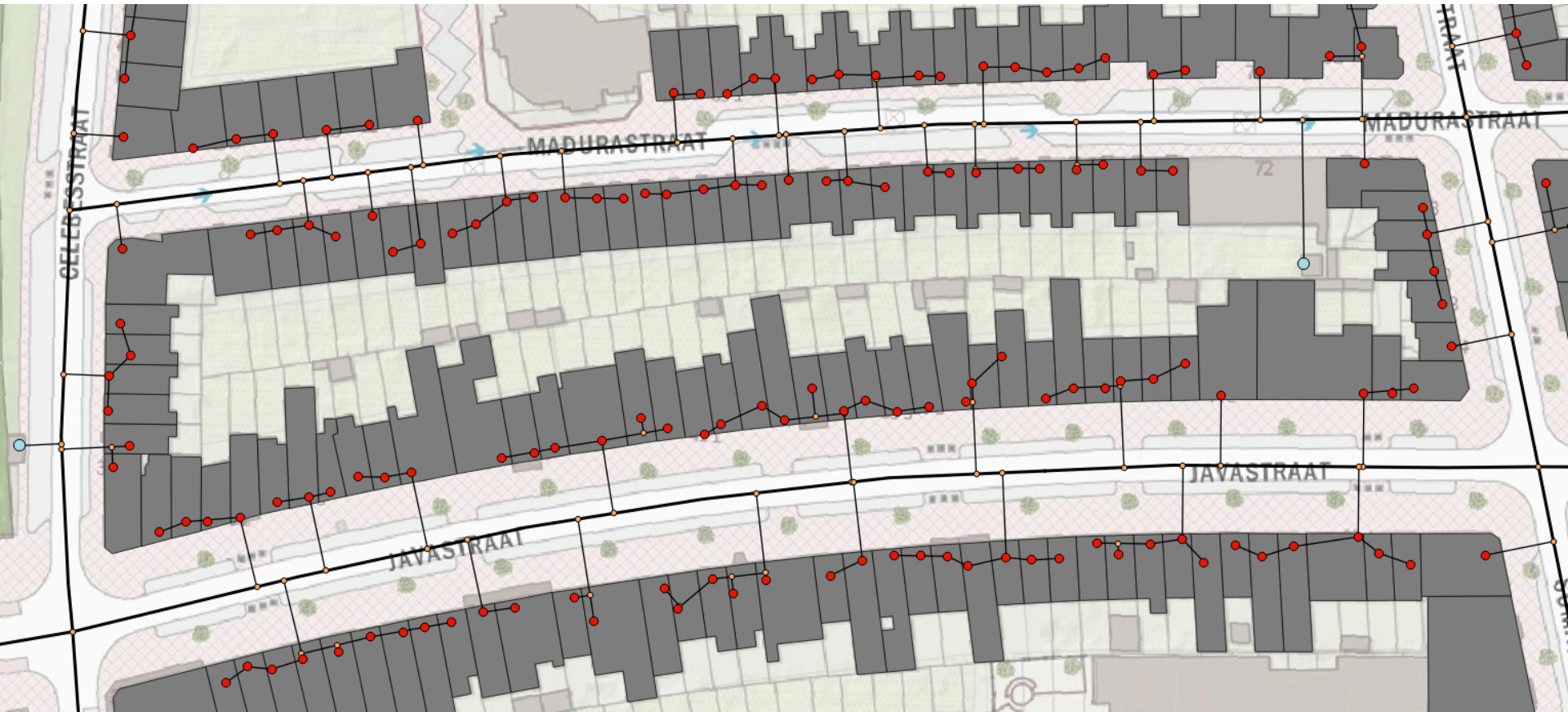
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Three topological networks



Topological networks

<i>Closest Point</i>	<i>vertices</i>	<i>Total edge length (m)</i>	<i>Average edge length (m)</i>
Geuzenveld	4409	59165.47	12.79
Slotervaart	5278	81960.25	14.58
Indische buurt	2415	26016.75	10.43

<i>Closest Junction</i>	<i>vertices</i>	<i>Total edge length (m)</i>	<i>Average edge length (m)</i>
Geuzenveld	2774	72247.88	24.95
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<i>Iterative Closest Junction</i>	<i>vertices</i>	<i>Total edge length (m)</i>	<i>Average edge length (m)</i>
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Shortest Paths

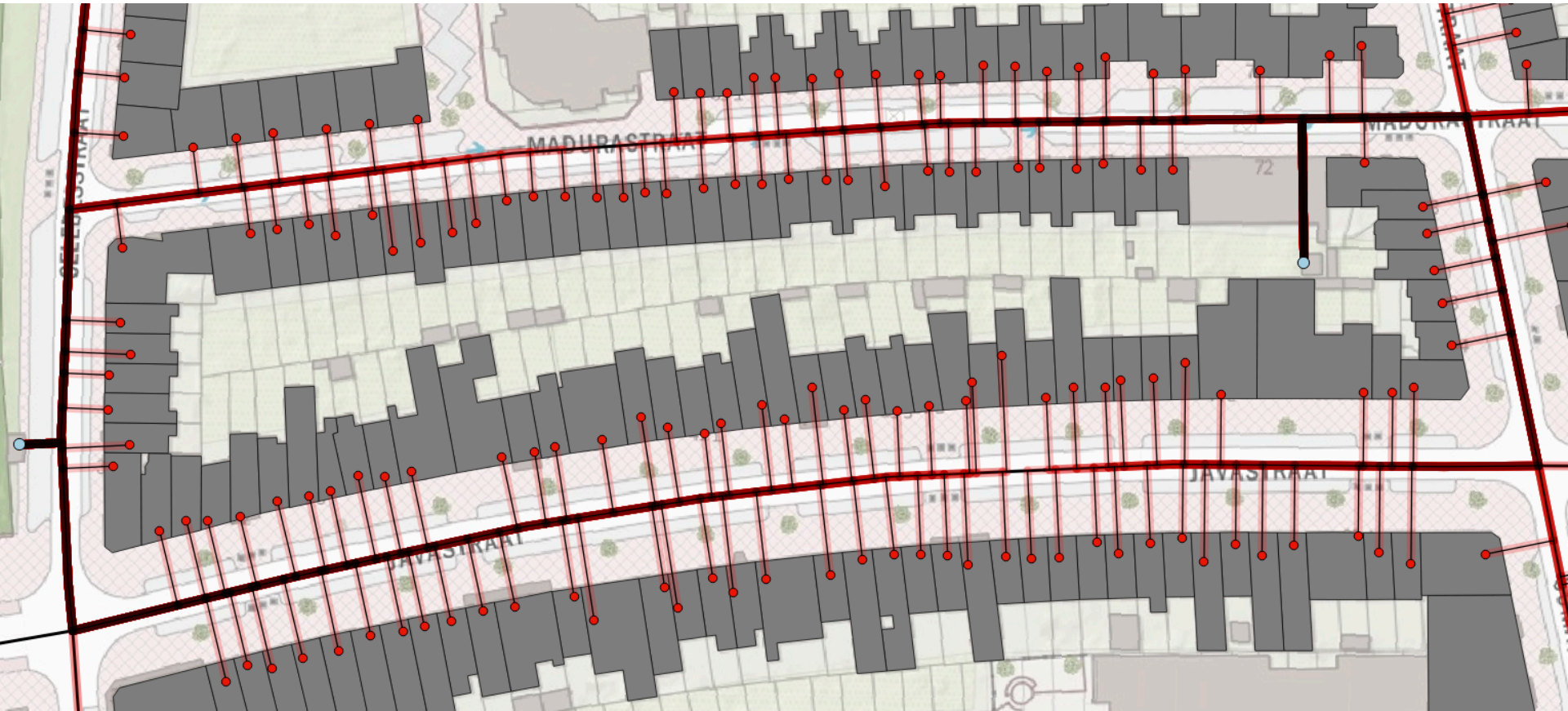
- Finding closest transformer
 - Shortest path from building to all transformers

Shortest Paths

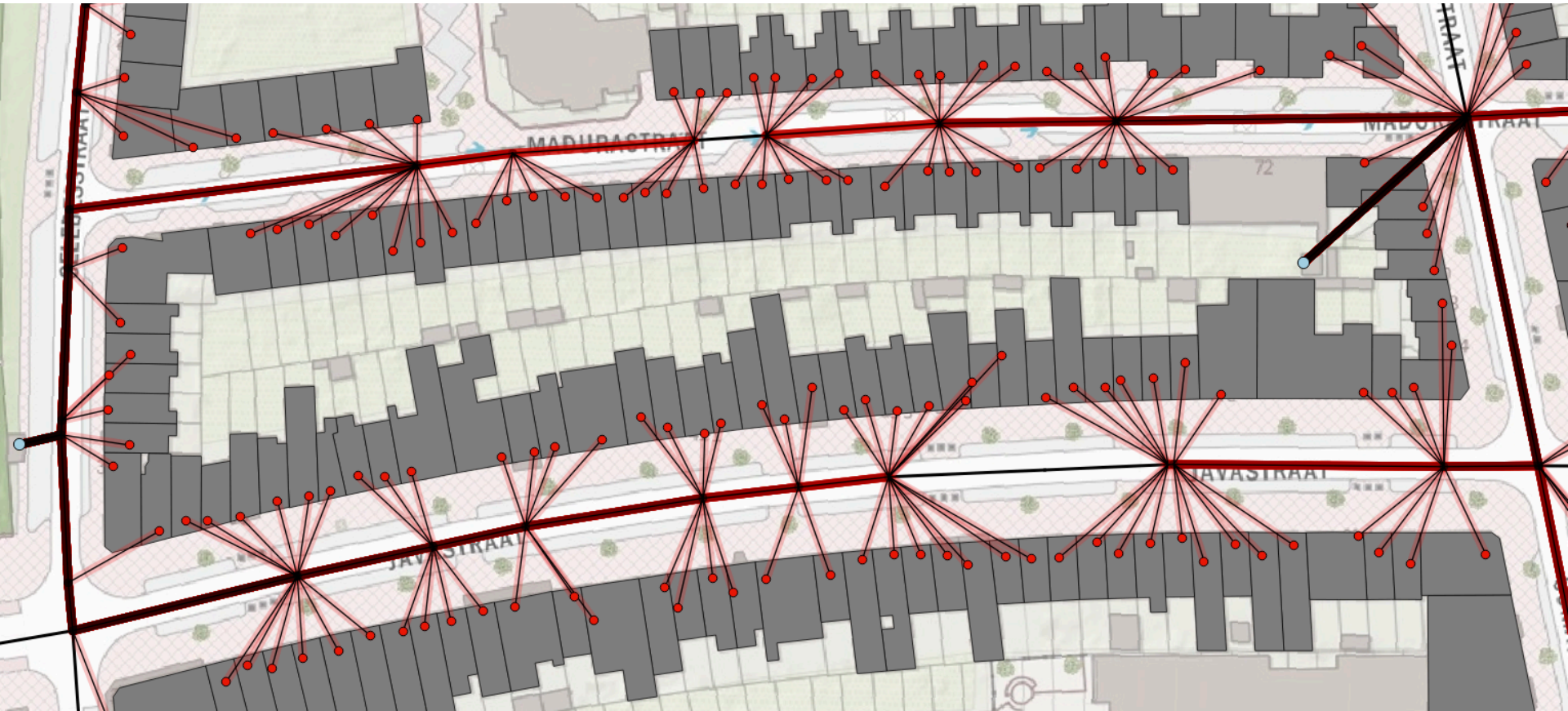


Edge 'betweenness'

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Power consumption

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

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- For each edge
 - Calculate maximum power
 - Compute current supposed to be flowing through a cable

Cable types

	Cu	Al	I (A)
GPLK 3-ad.	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

	Cu	Al	I (A)
XLPE 3-ad.	-	95	215
	-	150	280
	-	240	360

XLPE 1-ad.	95	-	335
	drie hoek	240	355
		400	450
		630	575
	plat	630	645

Quantification

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- 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)

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- 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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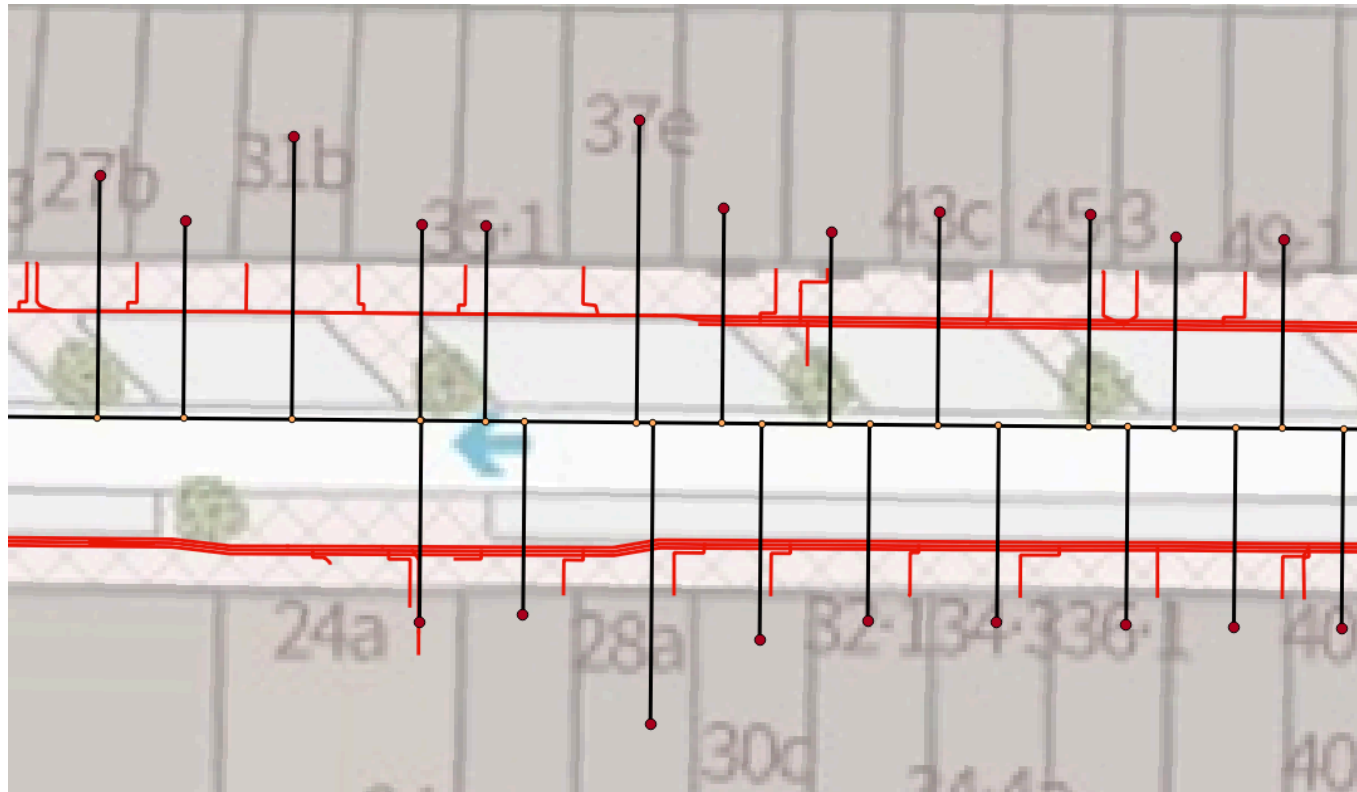
Adjustment

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- Simplification of the NWB results in underestimation of cables
 - Adjustment of quantity to compensate

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Final quantification

Geuzenveld	Iterative est Junction	Clos- est 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)
	<i>Cu (kg)</i>	<i>Al (kg)</i>	<i>Cu (kg)</i>	<i>Al (kg)</i>	<i>Cu (kg)</i>	<i>Al (kg)</i>
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)
	<i>Cu (kg)</i>	<i>Al (kg)</i>	<i>Cu (kg)</i>	<i>Al (kg)</i>	<i>Cu (kg)</i>	<i>Al (kg)</i>
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)
	<i>Cu (kg)</i>	<i>Al (kg)</i>	<i>Cu (kg)</i>	<i>Al (kg)</i>	<i>Cu (kg)</i>	<i>Al (kg)</i>
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%	

Method comparison

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Accuracy

Geuzenveld	Computed metal mass		Real metal mass		Accuracy	
	<i>Cu (kg)</i>	<i>Al (kg)</i>	<i>Cu (kg)</i>	<i>Al (kg)</i>	<i>Cu</i>	<i>Al</i>
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	<i>Cu (kg)</i>	<i>Al (kg)</i>	<i>Cu (kg)</i>	<i>Al (kg)</i>	<i>Cu</i>	<i>Al</i>
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	<i>Cu (kg)</i>	<i>Al (kg)</i>	<i>Cu (kg)</i>	<i>Al (kg)</i>	<i>Cu</i>	<i>Al</i>
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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An aerial photograph of a large-scale mining or industrial site. The image shows a complex network of roads, tracks, and various colored pits and structures. The colors range from deep blues and greys to bright oranges and yellows, suggesting different types of soil, rock, or water. The overall scene is one of intense industrial activity and land modification.

CONCLUSIONS

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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**

An aerial photograph of a large-scale mining or industrial site. The landscape is characterized by numerous large, irregularly shaped pits and excavations, some filled with water or slurry. The colors of the pits vary significantly, ranging from deep blues and greys to bright oranges and yellows, indicating different geological compositions or stages of processing. A complex network of roads, tracks, and infrastructure is visible throughout the site. In the upper right corner, there is a large industrial facility with several large circular tanks and buildings. The overall scene depicts a highly active and extensive industrial operation.

DISCUSSION & RECOMMENDATIONS

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 - Building points

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 - Transformers

Discussion

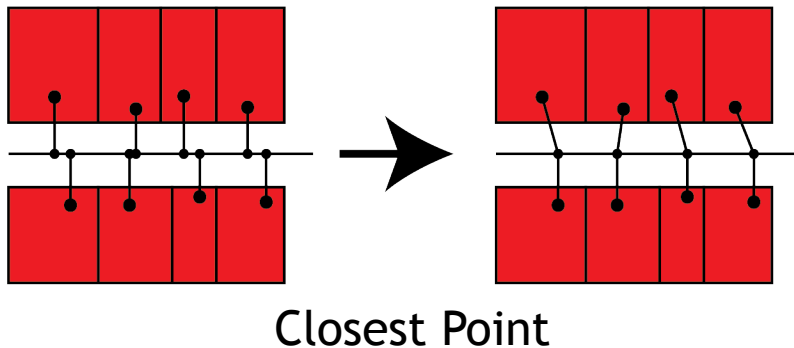
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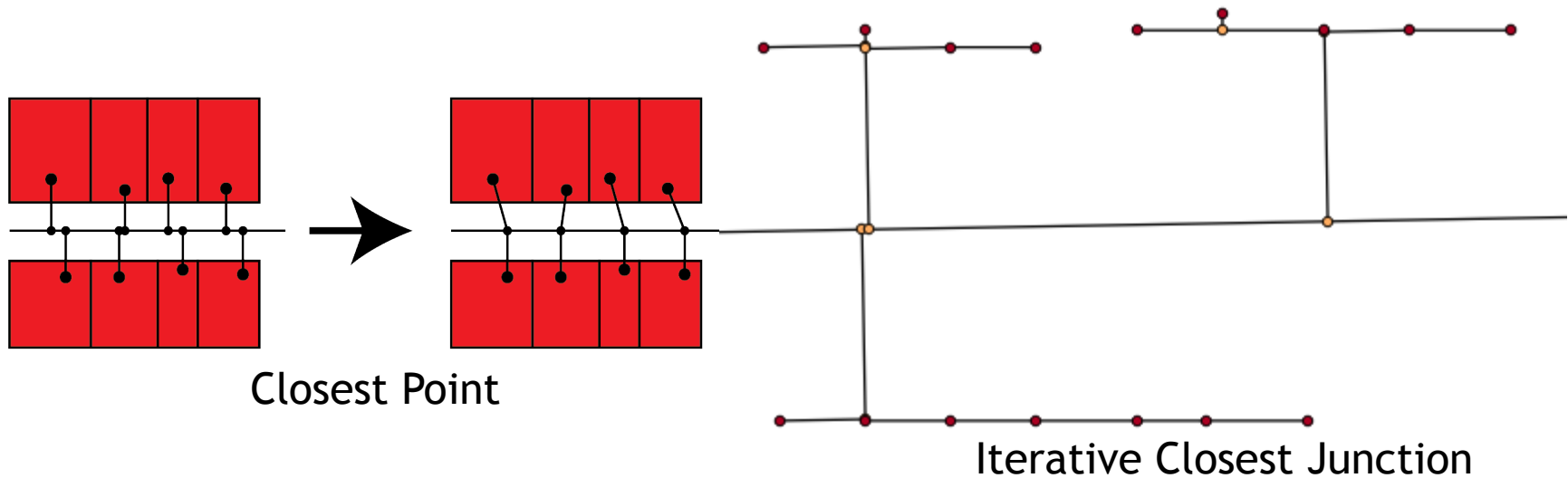
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 - NWB is simplified into a single line
 - Quantity ratio between metals is not exact

Future work & recommendations

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

An aerial photograph of a large-scale industrial or mining operation. The image shows a complex network of roads, tracks, and various colored pits and structures. The colors range from deep blues and greys to bright oranges and yellows, suggesting different types of soil, rock, or water. The overall scene is one of intense human activity and large-scale earthmoving.

THANK YOU FOR YOUR
ATTENTION