Safety-driven road width estimations from vector data

Master of Science in Geomatics for the Built Environment

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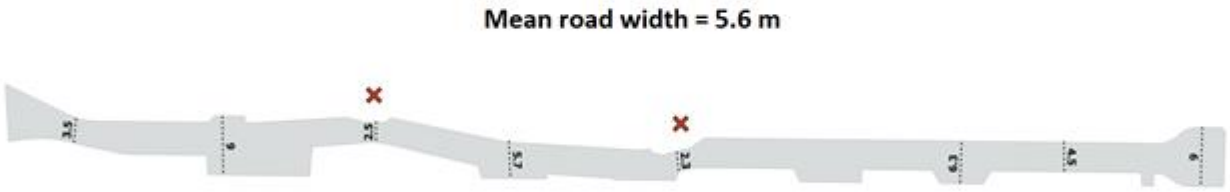
Motivation

- What do we mean by road width?

Motivation

- Road width and Road safety management



Motivation

- Most studies so far → LiDAR PC, Sensing Images

- ✓ Availability
- ✓ Accessibility
- ✓ Simple structure

- Existing methodology uses vector data (Hoffmans 2018) → Specific application (snow removal) , Specific dataset (BGT)
- Expand functionality → Road safety management application, Work with data from different sources

Research Questions

“H*ow road width estimations can be derived from vector data to benefit road safety management application?”*

“How can road width affect the safety of different road users?“

"How can road vector data be standardized in such a way as to benefit the development of a generic methodology for estimating road width?"

“In what way original roads could be divided to benefit road safety management application?”

“How do the different aspects of the final width estimation methodology affect the process and result of a road safety analysis?”

Road safety and Road width

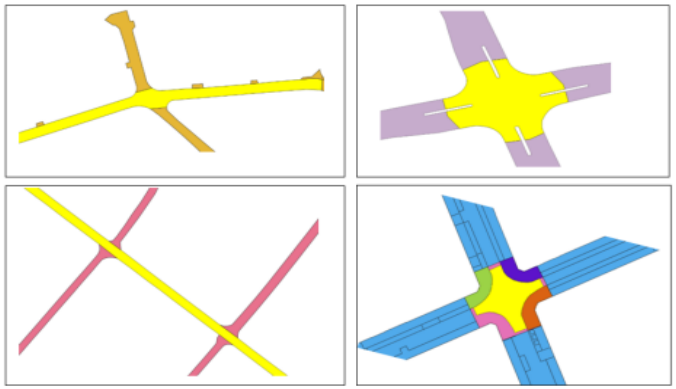
- Different users → Different needs

- Change in width of a road usually indicates a characteristic of that is related with road safety (on-street parking, change in number of lanes, temporary narrowings etc.)

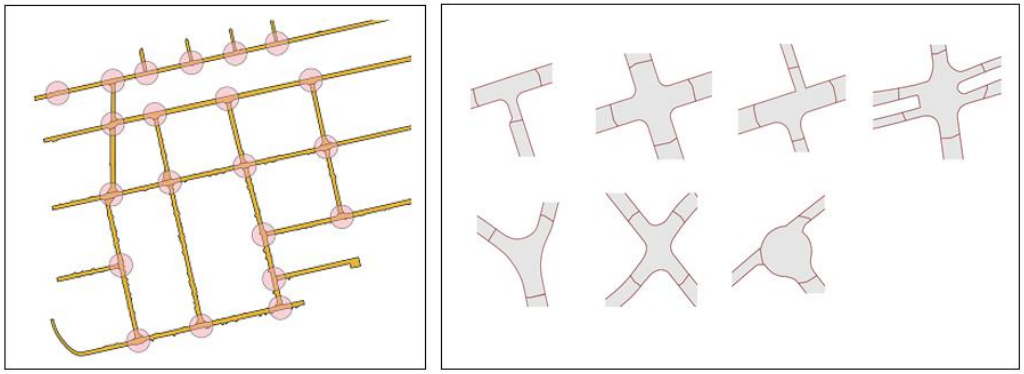
- Common point → Relation of road width with traffic accidents (Controversial theories exist)

Road vector data from different sources

Main challenge? → No unique way of modeling roads with vector data

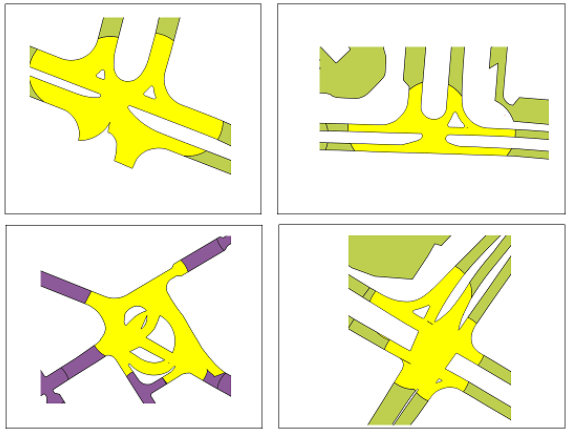


Solution? → Standardize roads based on a selected prototype modelling approach

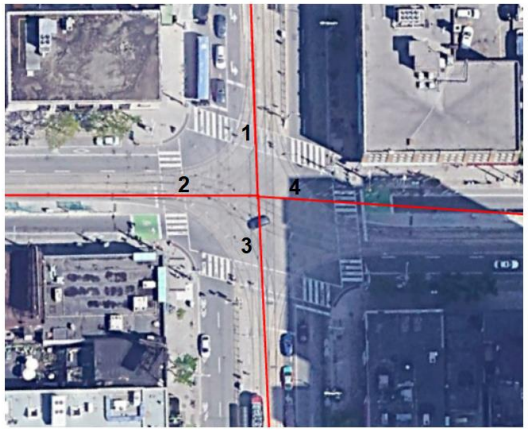


Intersections

- Most complex parts of road networks



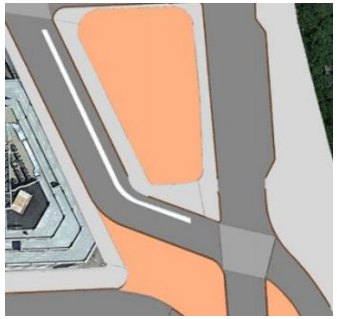
- Most challenging cases for road width estimation



Unit of measure

- What do we consider as a road?
  - Which vector representation type?

Road polygon

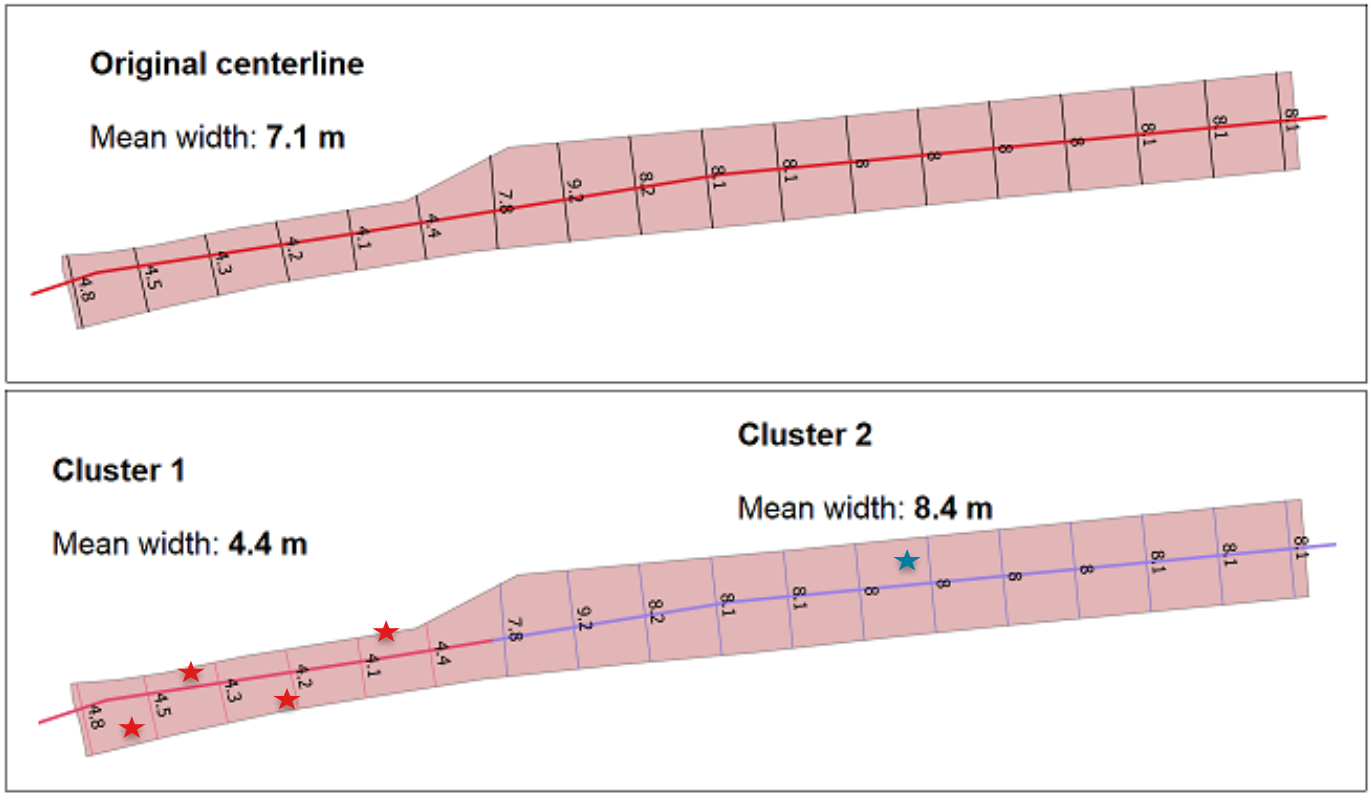


Road centerline

  - How do we divide road?

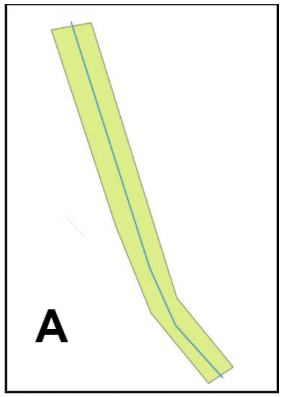
Width clustering for road safety

2) Clustered roads, more representative in terms of geometry

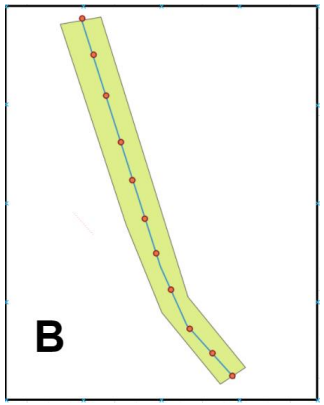


Width estimation

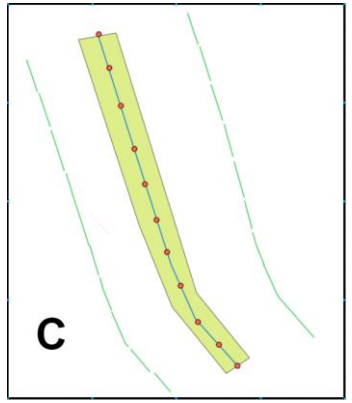
Road polygon and centerline



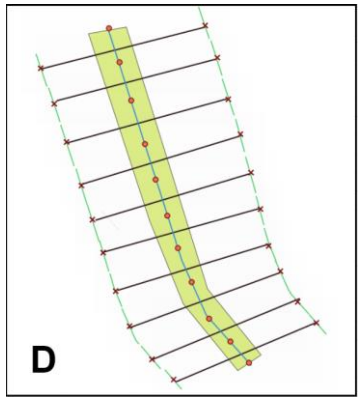
Initial centerline 'cut' into shorter lines (based on a measuring interval)



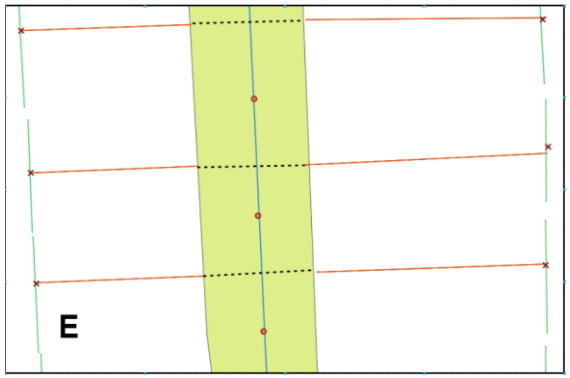
2 offsets (1 left , 1 right) for each short line



Connect the midpoints of the 2 offsets



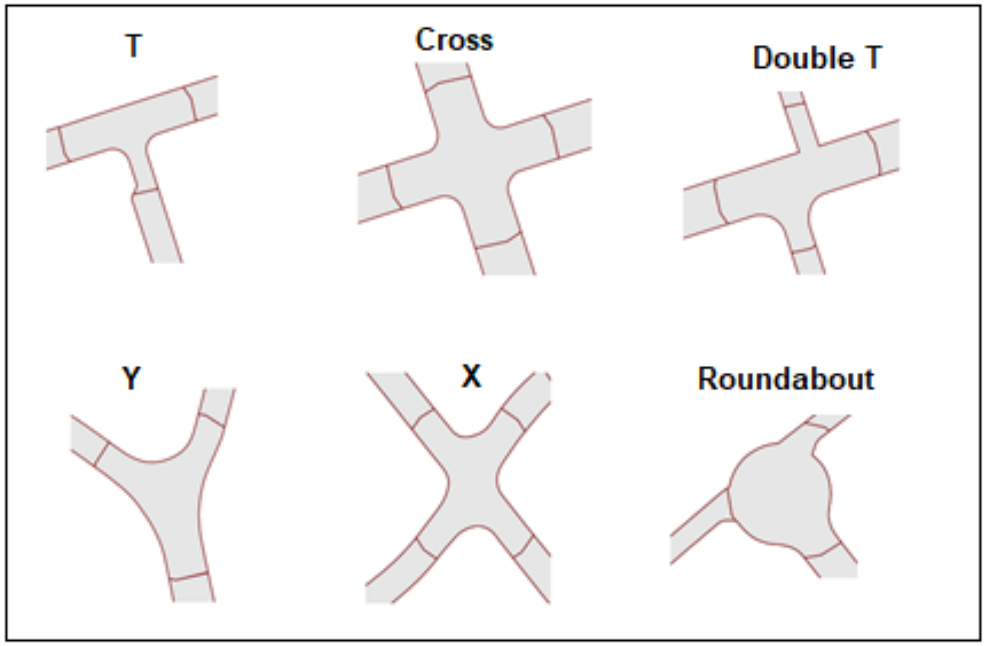
Intersection between polygon and perpendicular line to define the measuring lines



Compute width values (mean, median, max, min) based on measuring lines

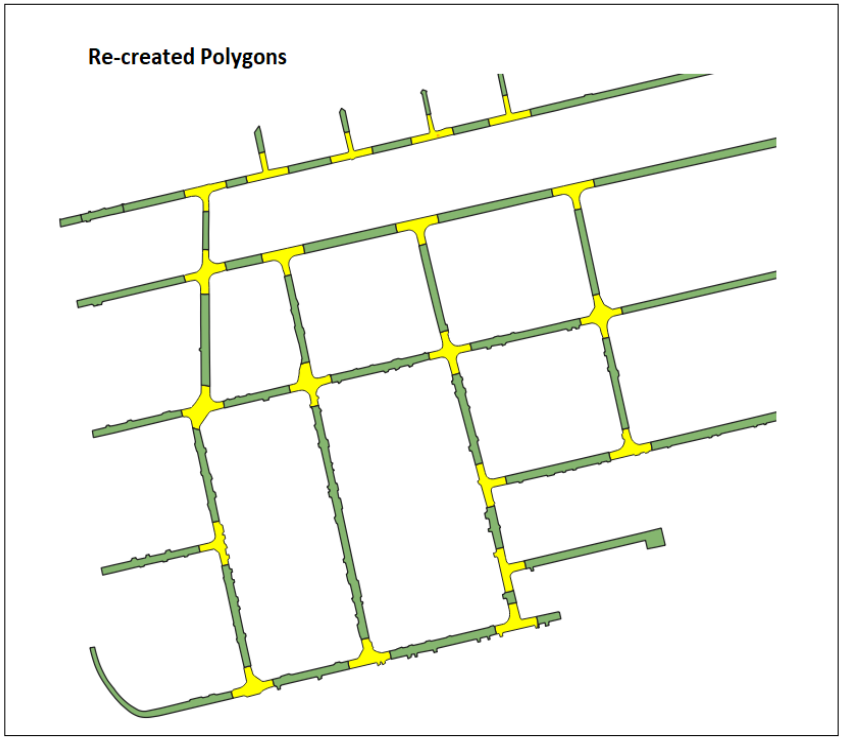
Road's standardization

- Goal → Standardize road vector data based on Toronto modelling
- Why Toronto?→ Simple and consistent way of explicit intersection modelling
- Why do we need intersection polygons? → Intersection identification



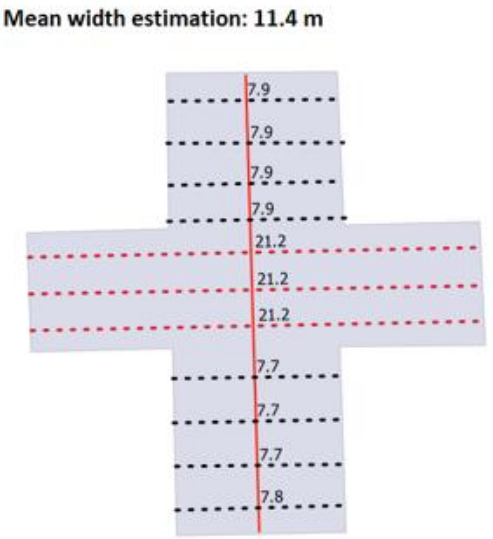
Road's standardization

- How ?



Intersection identification

- Goal → Identify location + type of road intersections
- Why? → Treat them differently
- Why? → They add noise to overall width estimation process
- Solution? → Exclude them

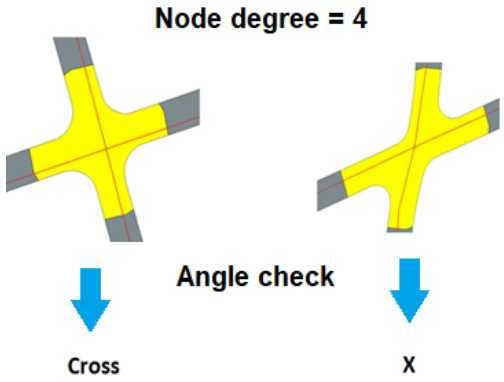


Intersection identification

- How?

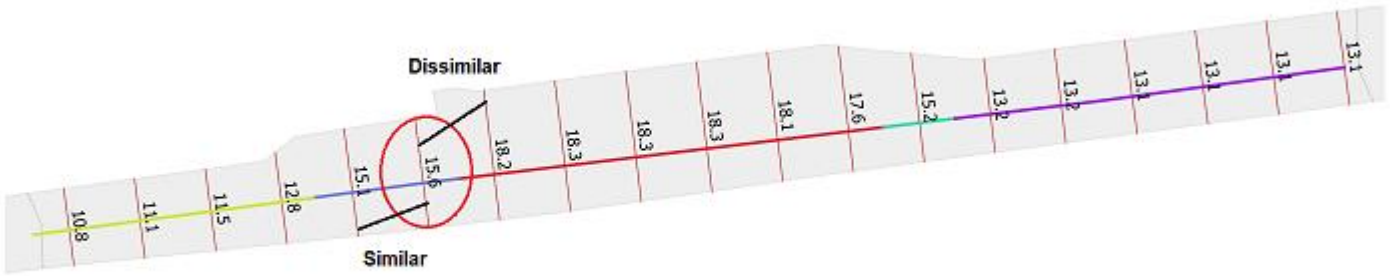
1) Exploit geometry of newly created intersection polygons

2) Use graph nodes + Angle check of intersecting centerlines

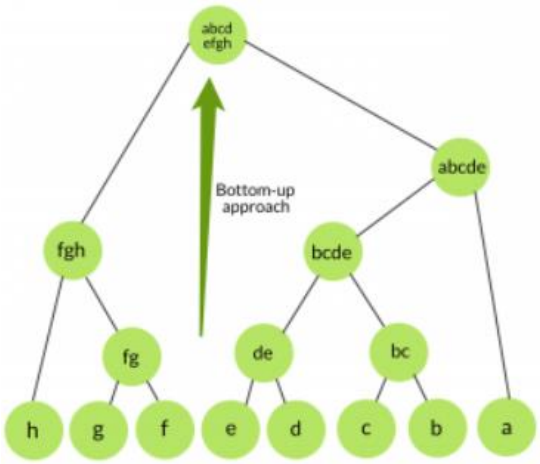


Width clustering

- Divide original centerlines into clusters based on width measurements
  - Collection of width measurements which have “similar” value



  - Agglomerative Hierarchical Clustering

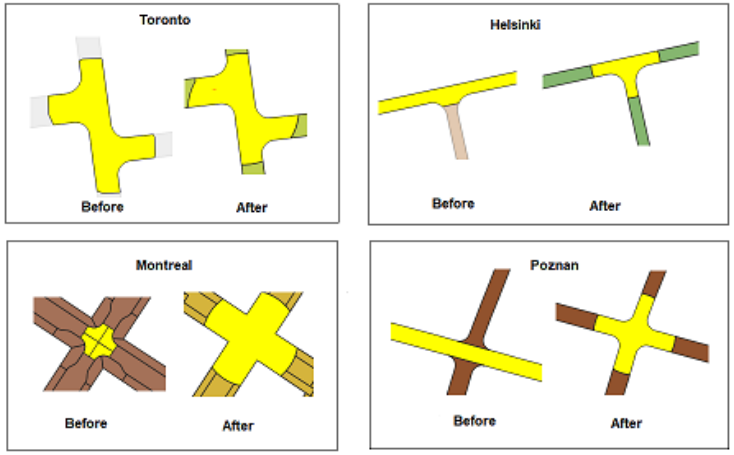


Width clustering

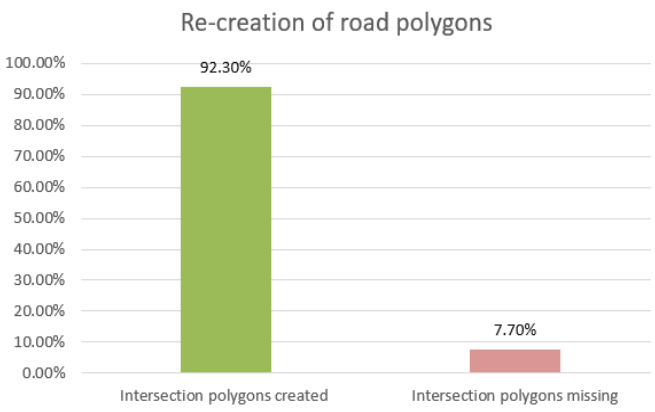
- Distance metric (how the similarity between measurements is computed)
- Distance threshold (after which distance the clusters will stop merging)
- Linkage method (between which points of the cluster the distance is computed)
- Measuring interval (affects total number of measurements)

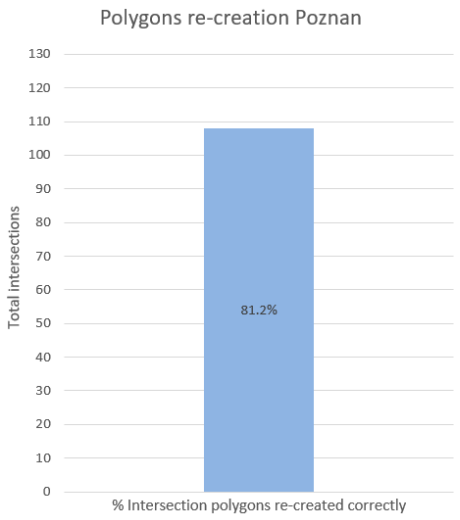
Results Standardization process

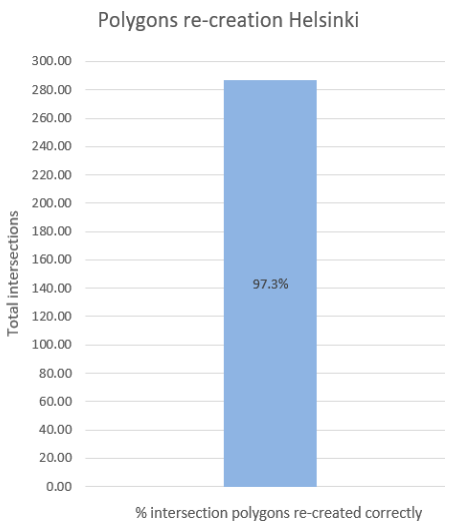
- Tested with 4 different dataset (4 different modeling strategies)



- Achieved for ordinary roads



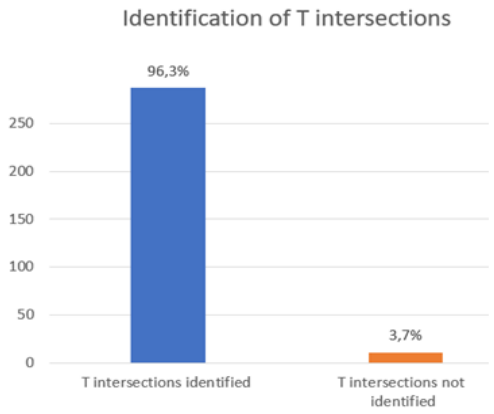


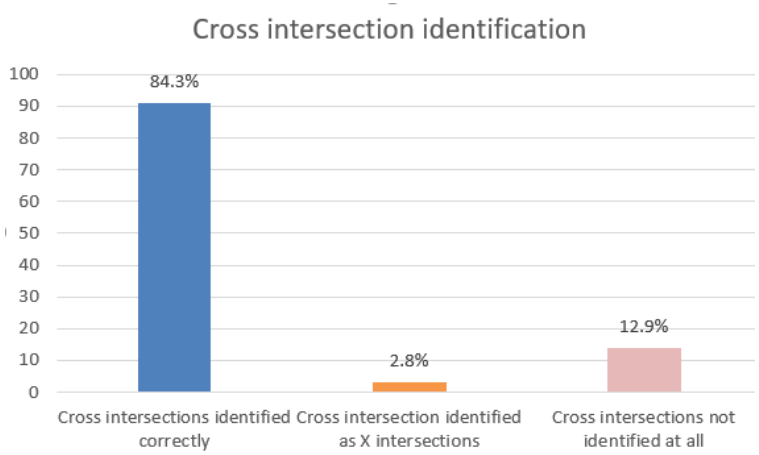


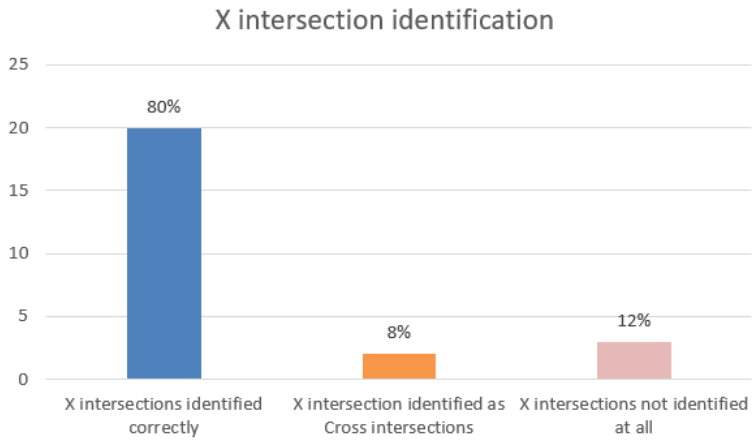
- Not working for motorways, Improvements needed for complex intersections, not tested with too complex datasets

Results Intersection identification

- Tested with 3 different intersection types (T, X, Cross) at 2 sample areas





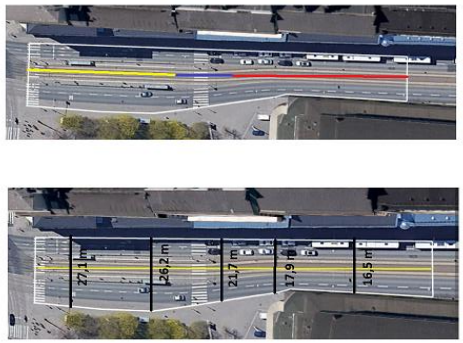


- Intersections where more than 4 roads met → identified as complex intersection type

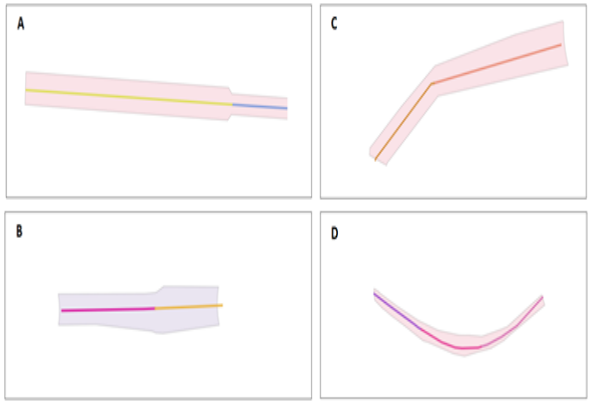
- Y and Double T intersections → identified as other intersection type

Results Width clustering

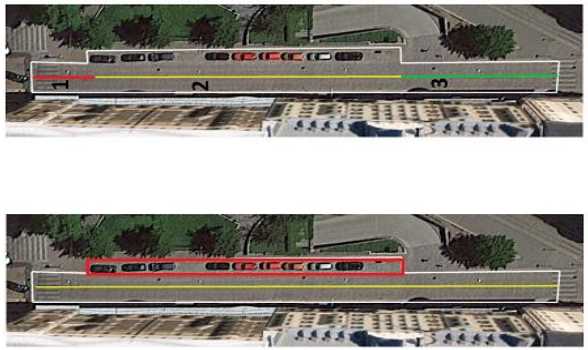
Case 1 – Different clusters when notable change in width occurs



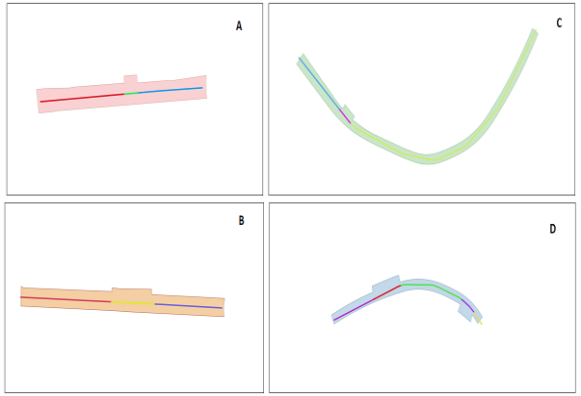
20 Ground truth polygons – 4 categories



Case 2 – Different clusters when on-street parking exist



20 Ground truth polygons – 4 categories



2 clustering approaches tested

- Approach1: Single Linkage, 5.5 meters threshold
- Approach2: Complete Linkage, 15 meters threshold

Results Width clustering

Compare clusters of clustering approaches with clusters of ground truth:

- Comparison based on 3 weighted indicators:
  - 1 → Number of clusters (25%)
  - 2→ Geometry of clusters (50%)
  - 3→ Width values of clusters (25%)

General remarks:

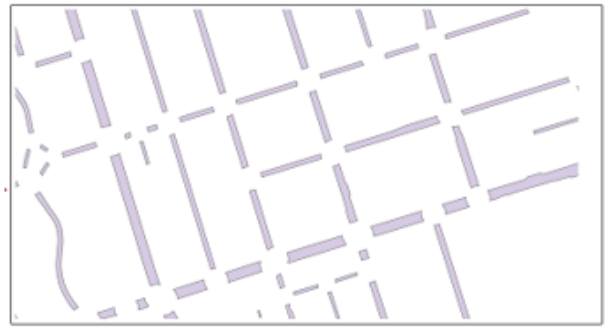
- Approach 1 → Higher final score for both cases (high degree of similarity)
- Approach 1 & Approach 2 → Work better for straight polygons in case 1
- Approach 1 & Approach 2 → Not influenced by sinuosity in case 2
- Approach 1 → Less sensitive in case 1 BUT More sensitive in case 2

Road safety analysis

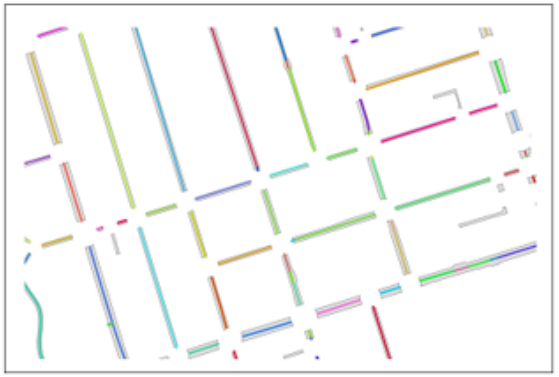
Tested area: Central area of Toronto (3500 meters radius)

- Normalize data based on length and accidents tendency
- Examine correlation between traffic accidents and 3 datasets

Intersection polygons excluded

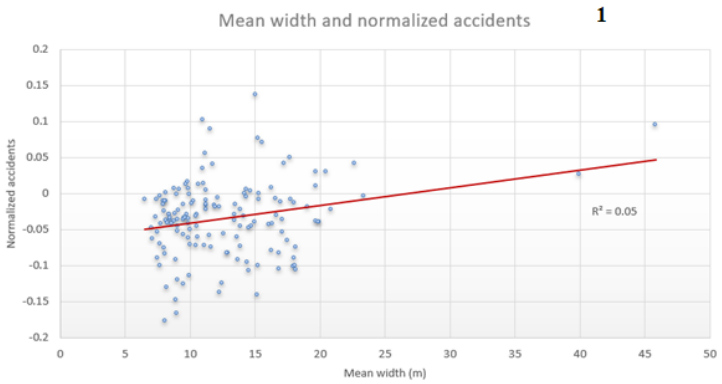


Clustered centerlines

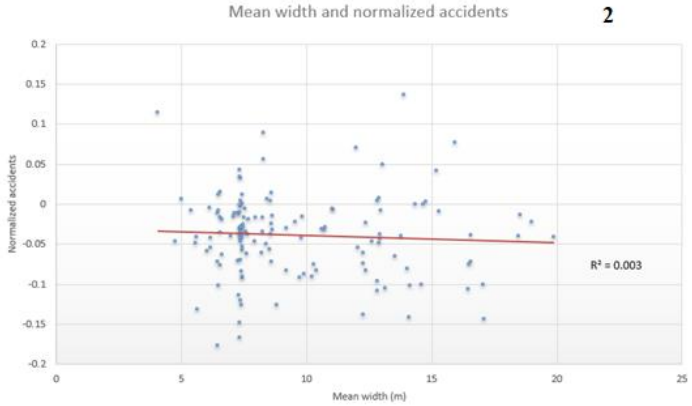


Road safety analysis

- Very weak correlation, wider roads tend to have slightly more accidents



- No correlation



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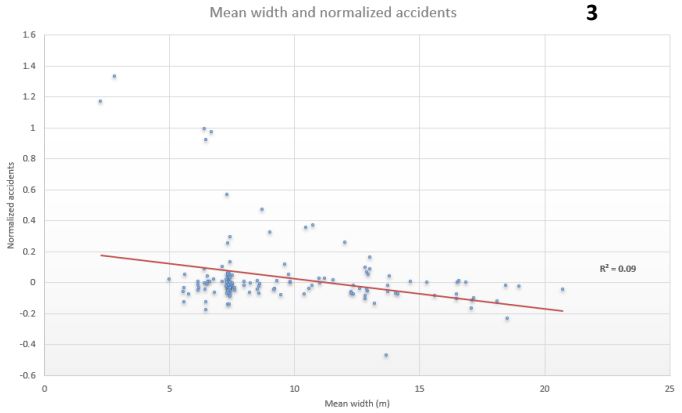

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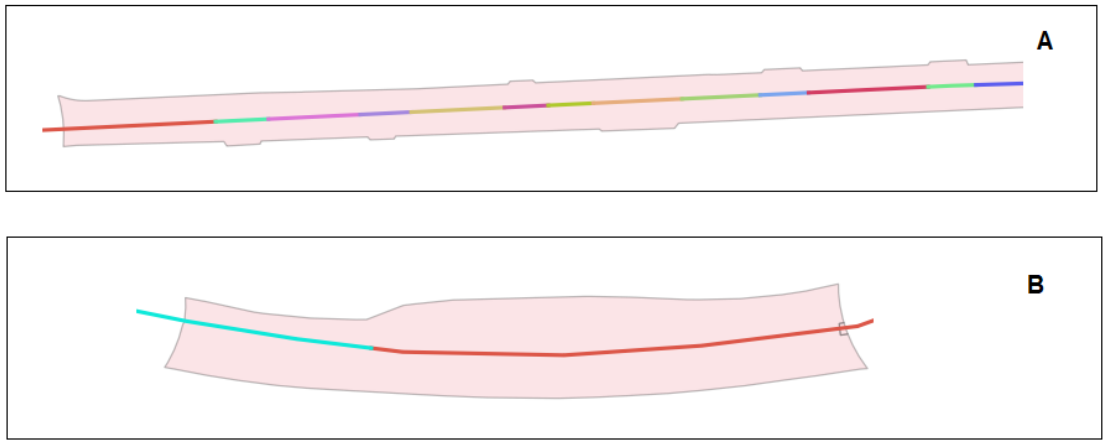
Conclusions & Discussion

Width clustering for Road safety management

- Hypothesis 1 → Identify width changes important for safety of different road users ✓

Not a single 'correct' clustering approach

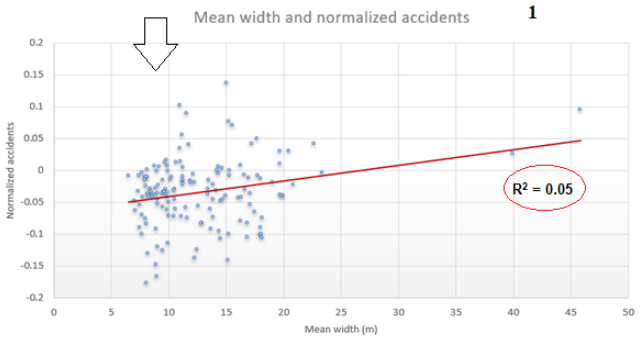


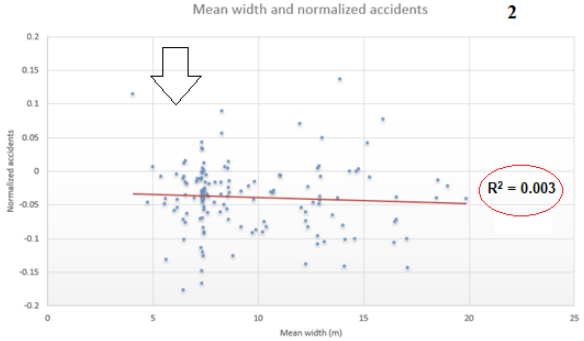
- Hypothesis 2 → Create more detailed roads (clusters) in terms of width values ✓

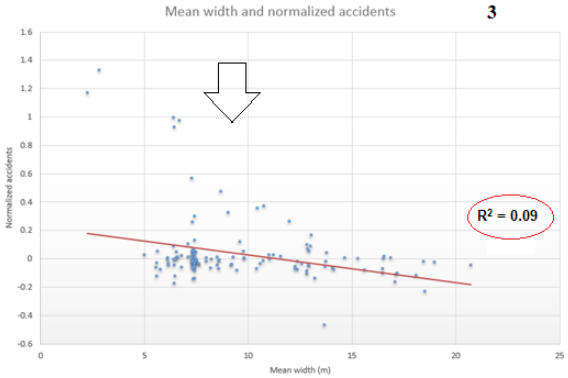
Conclusions & Discussion

Width clustering for Road safety management

- Road safety analysis → Correlation improved significantly!



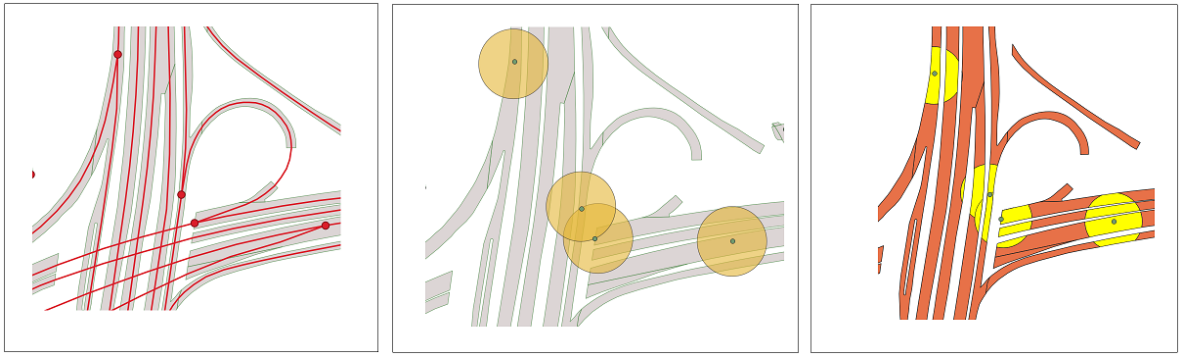




Conclusions & Discussion

Standardization and Intersection identification

- ❑ Ordinary road cases → ✓
- ❑ Complex intersections, Motorways, Flyovers etc. → ✗



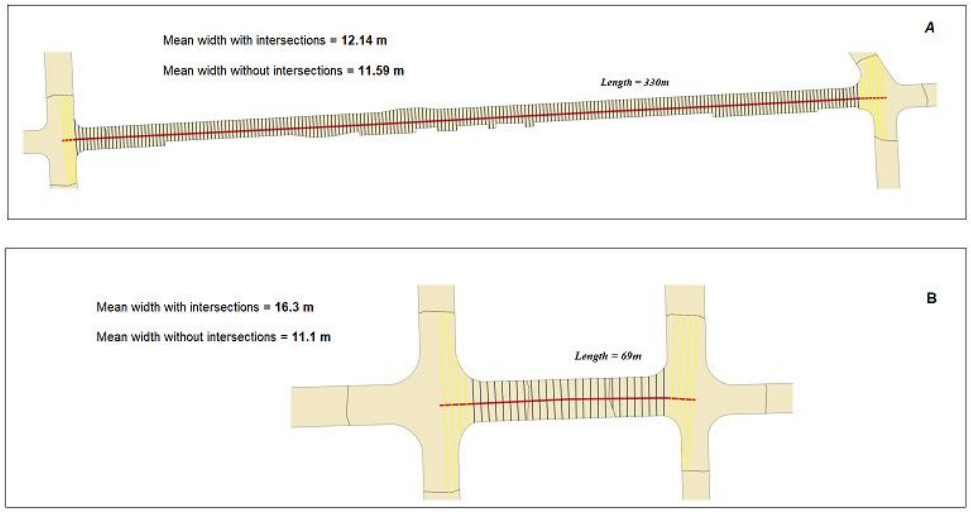
- ❑ Additional benefits?

Conclusions & Discussion

Standardization and Intersection identification

- Road safety analysis → Tendency changes!

Why?

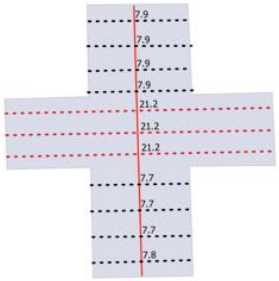


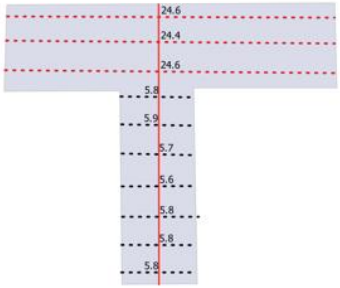
Geographical Implications

- Do these roads look the same?

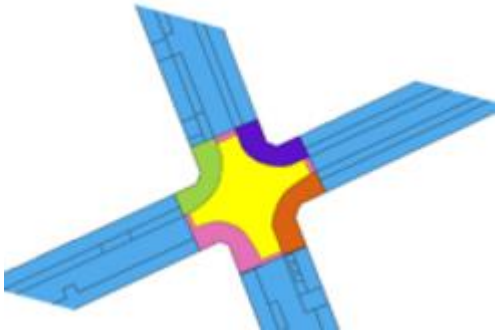
Future Work

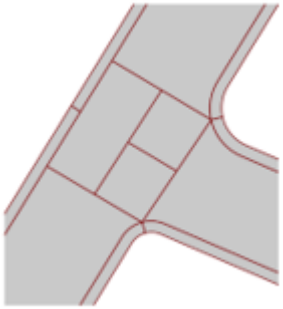
- Handle intersection differently

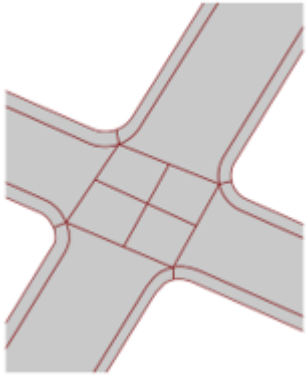




- Standardization based on another prototype



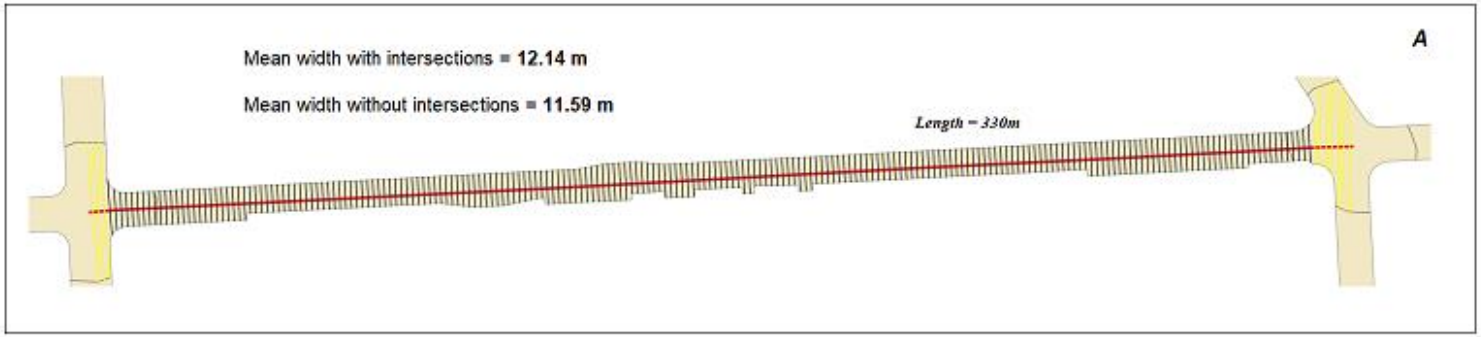


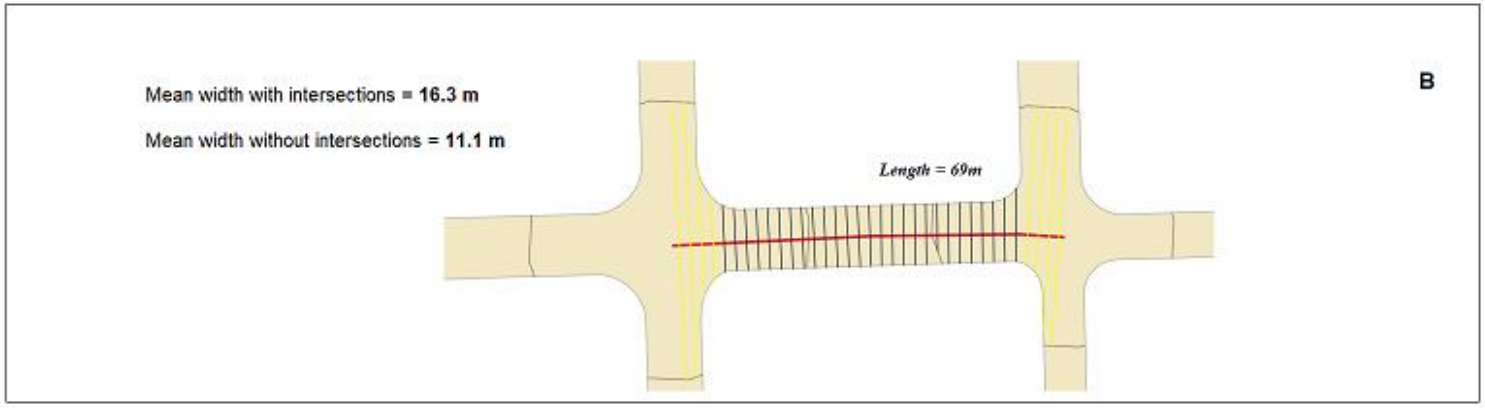


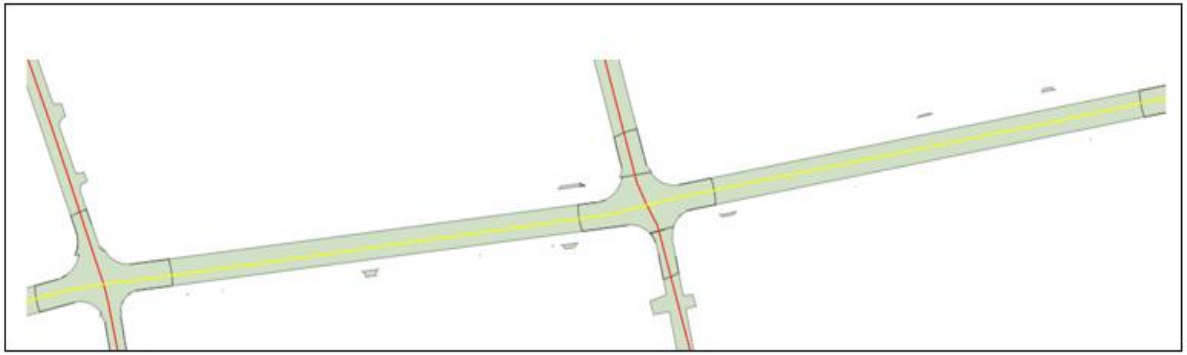
- Width clustering for other applications?

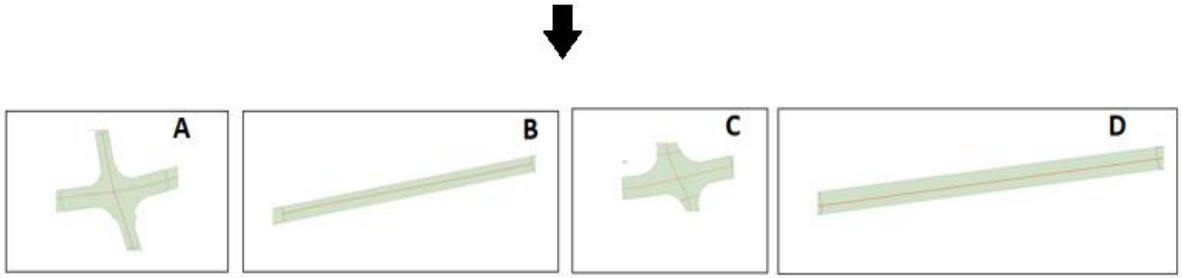
Thank you !!

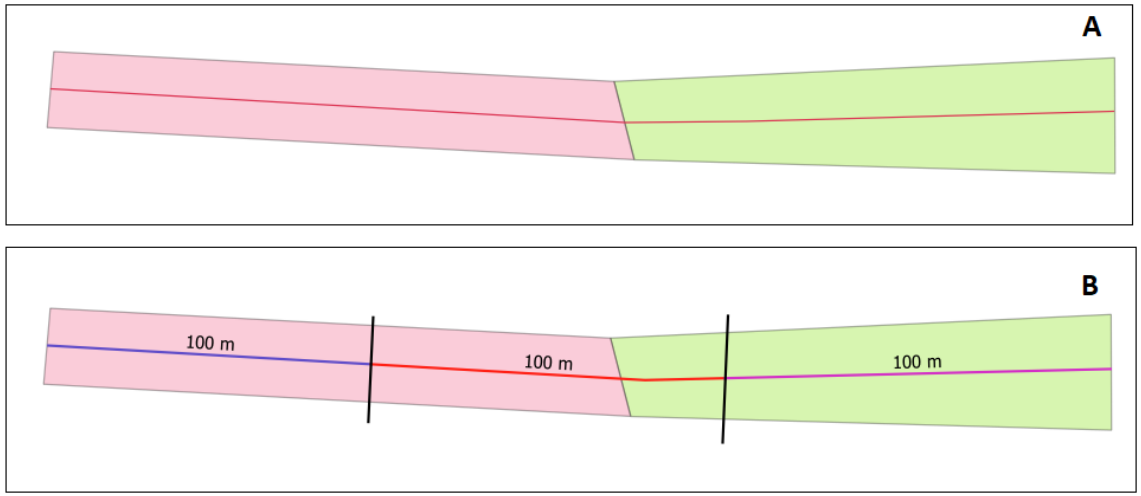
Additional slides

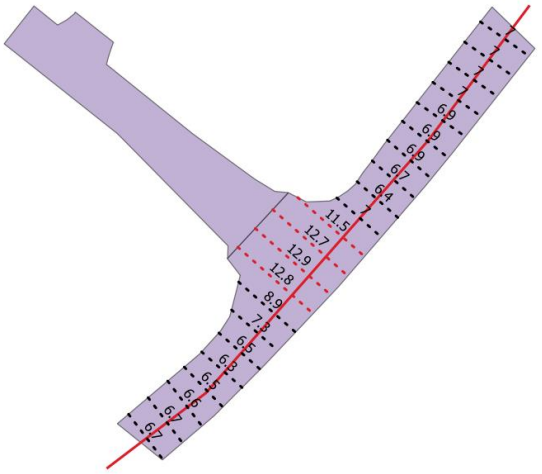




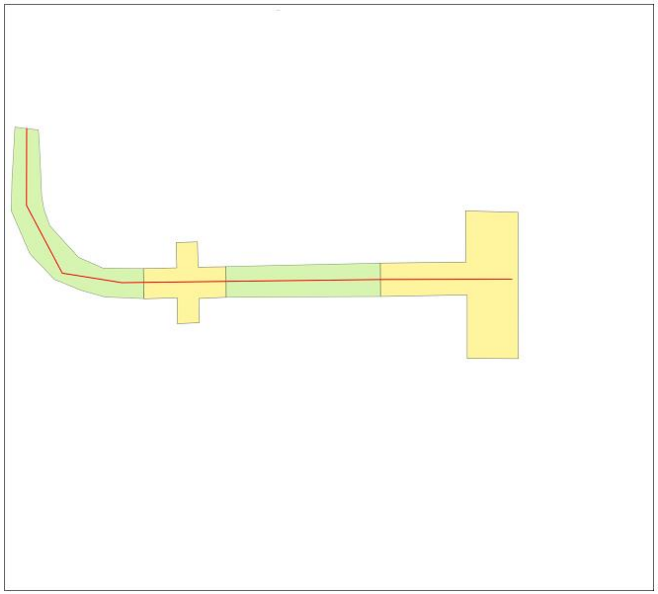


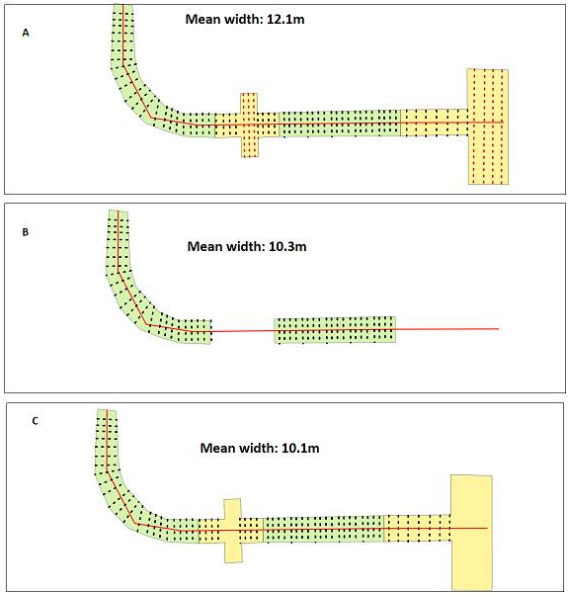






Number of roads	Measuring approach	Mean width (m)	Standard deviation from mean (m)	Median width (m)
50	No explicit modelling of intersection	10.2	1.8	9.93
50	Ground Truth	8.85	0.87	8.39

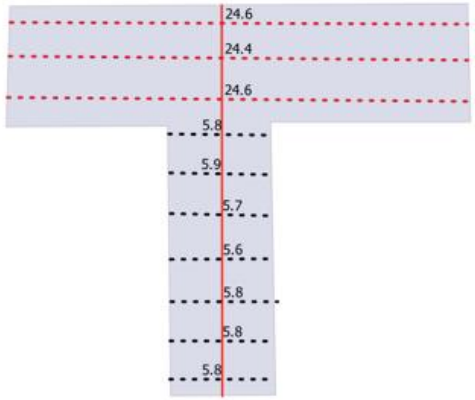


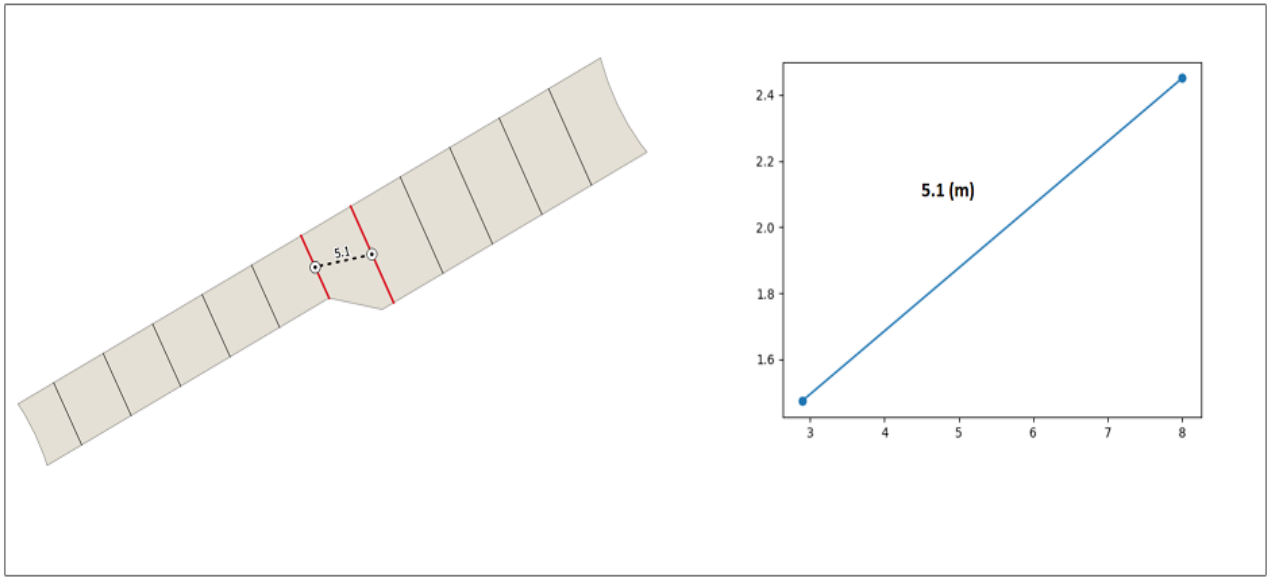


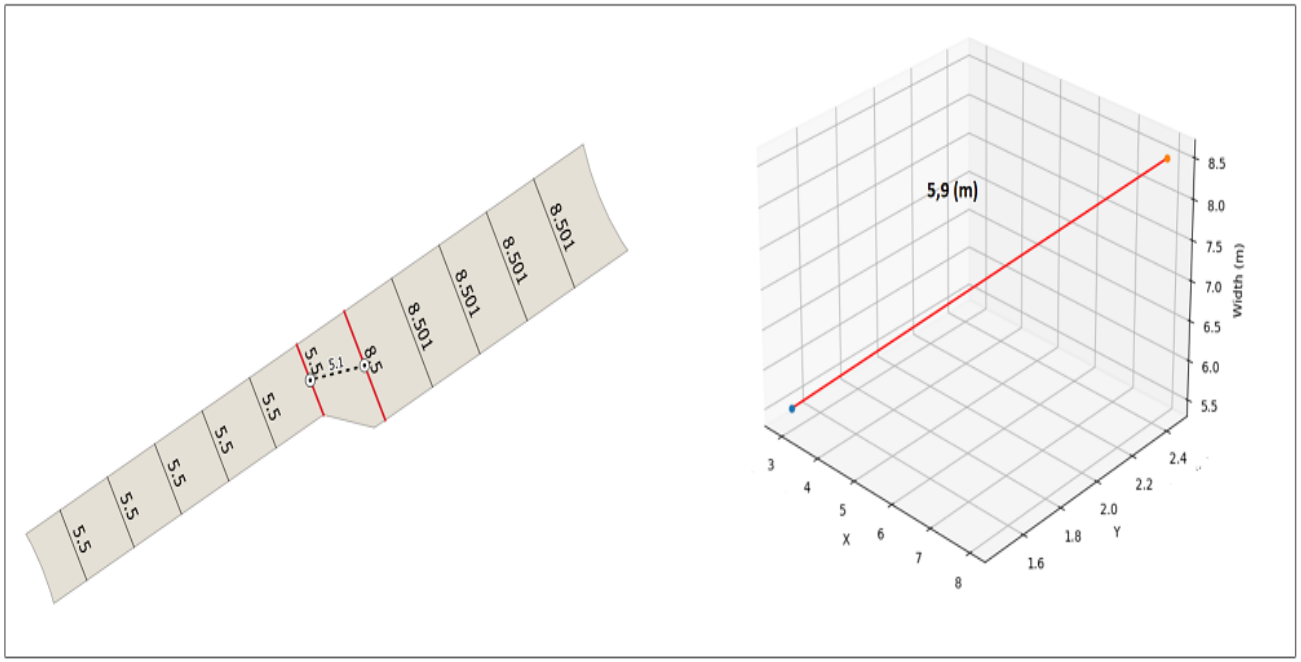
Measuring approach	Mean width (m)	Standard deviation from mean (m)	Median width (m)
Include intersection polygons	11.03	1.73	10.65
Exclude intersection polygons	9.34	1.03	9.1
Ground Truth	9.18	1.06	9

T intersection polygon

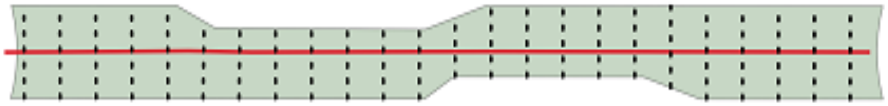
Mean width estimatio: 11.4 m







Initial road centerline



Approach 1 Parameters:

Distance Interval: **5m**

Linkage Method: **Single**

Distance Threshold: **5.3m**

Clustering 1

Clustering 2

Approach 2 Parameters:

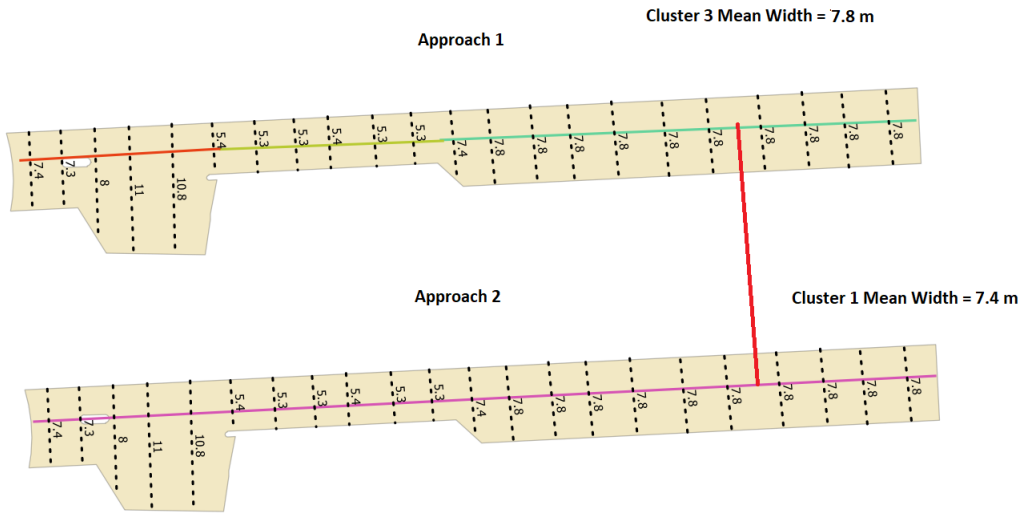
Distance Interval: **5m**

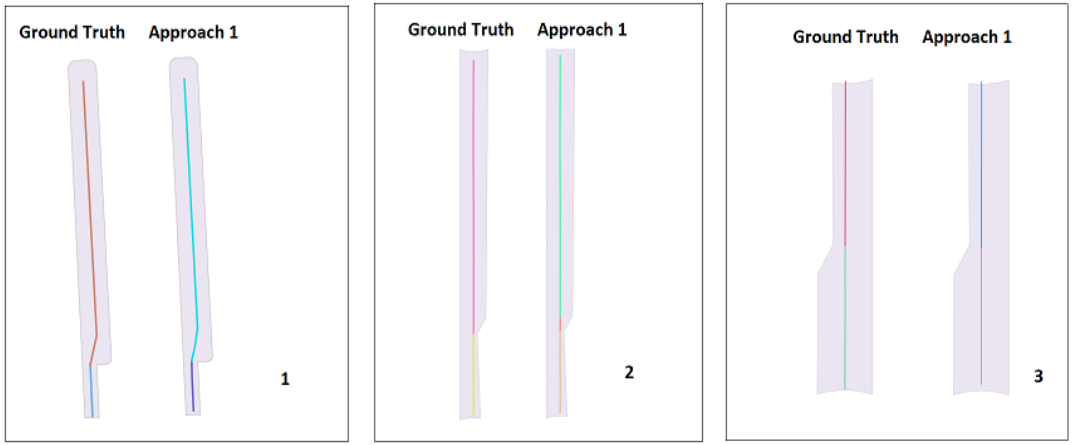
Linkage Method: **Single**

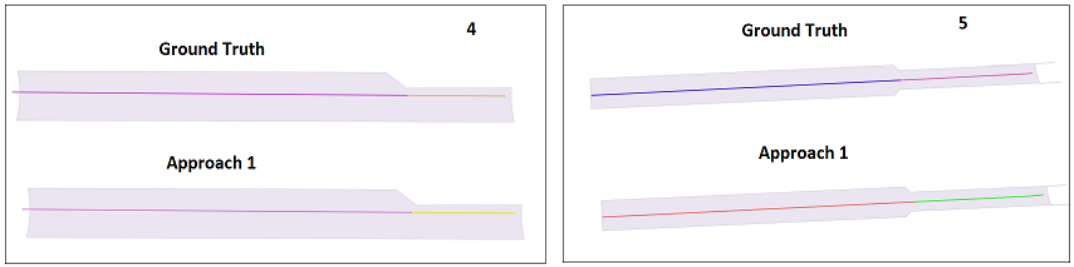
Distance Threshold: **5m**

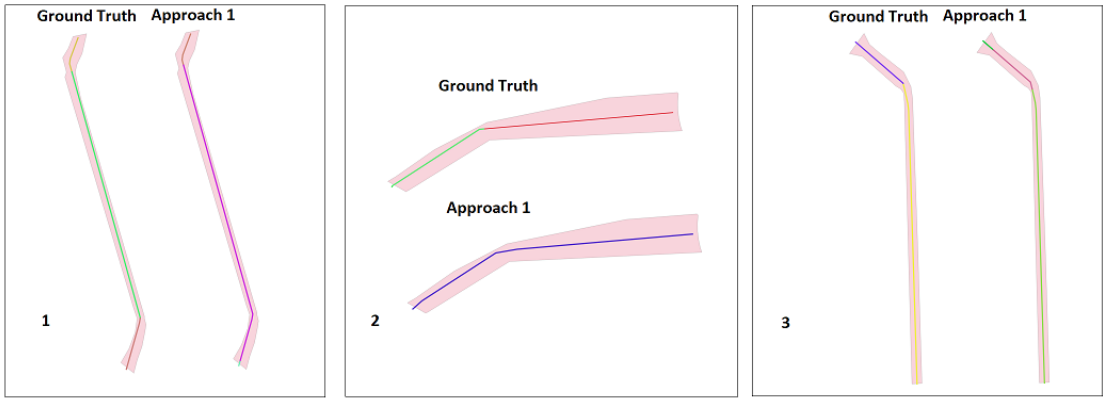
Approach 1 (4 clusters)

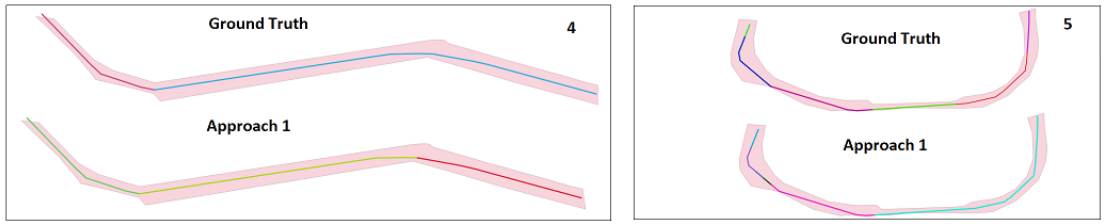
Approach 2 (4 clusters)

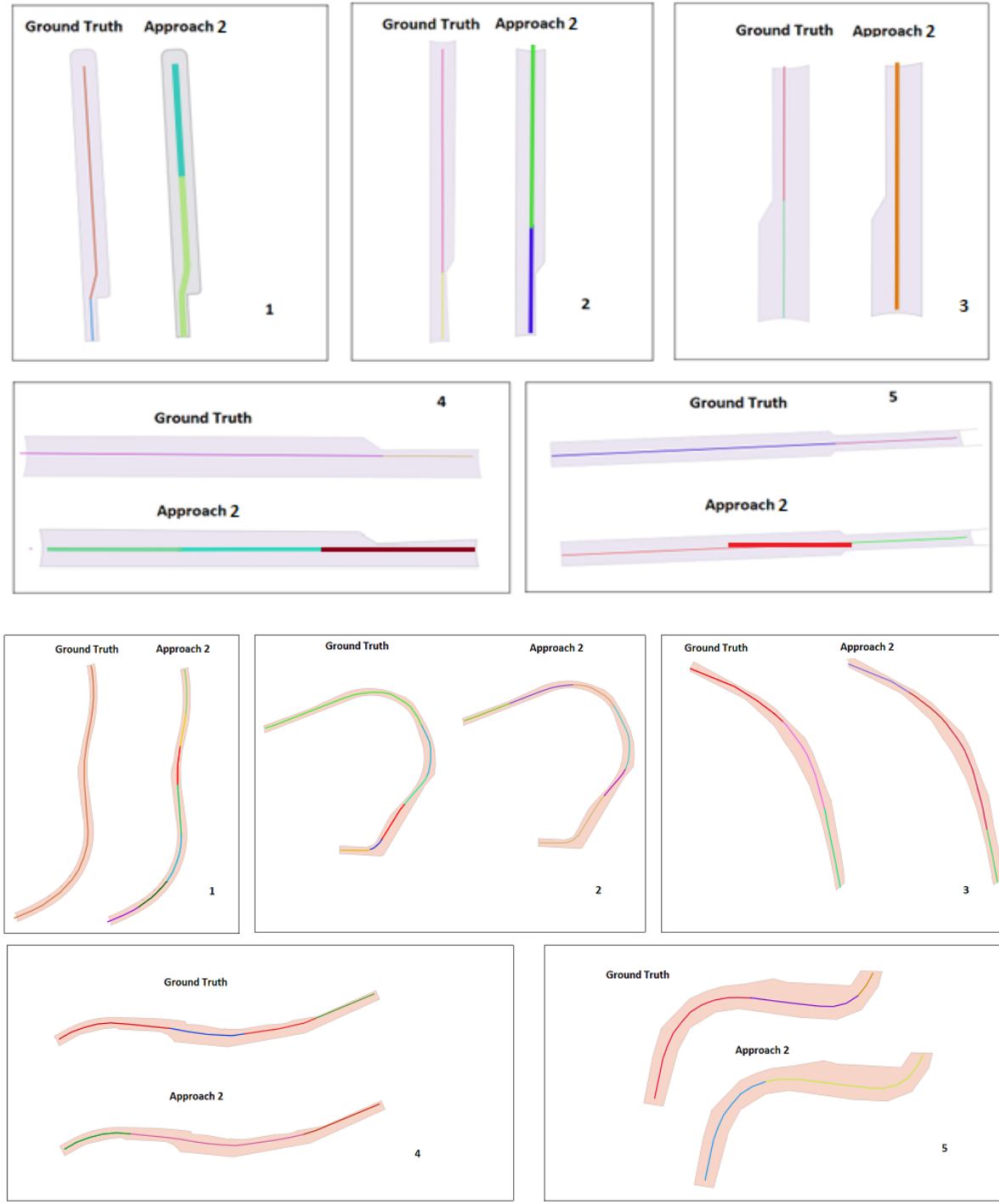


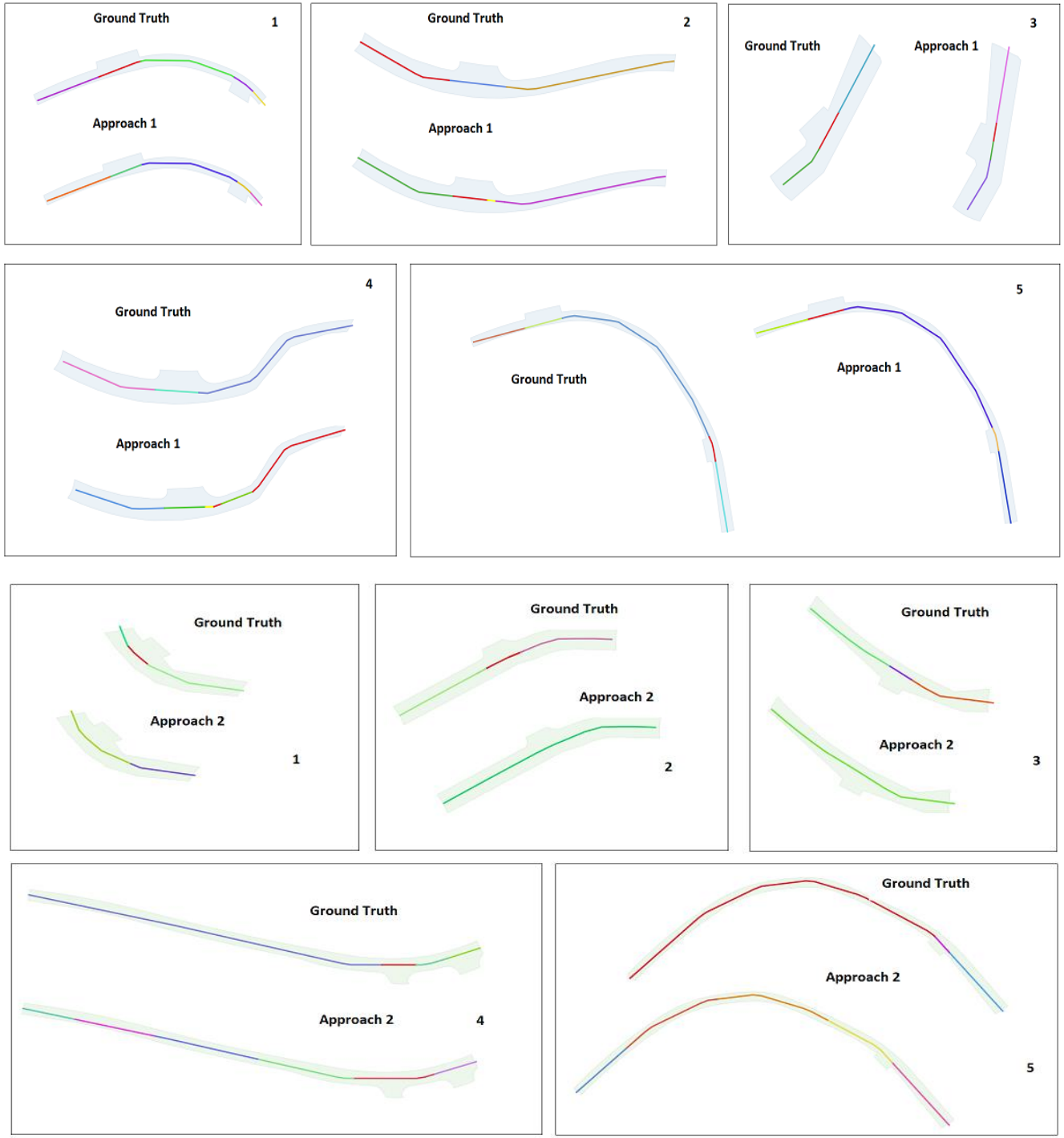


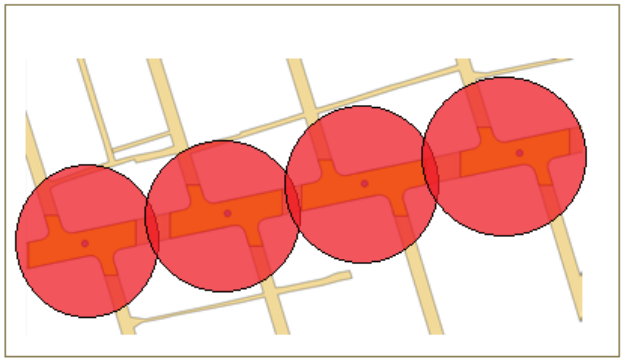


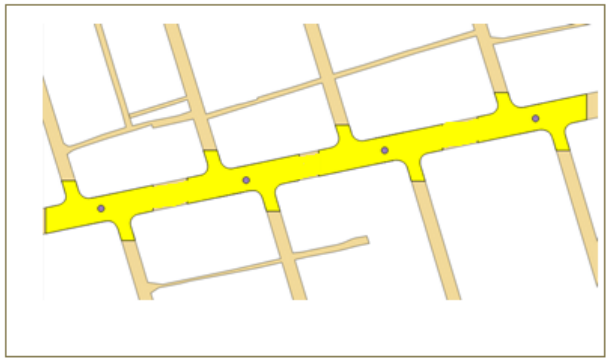


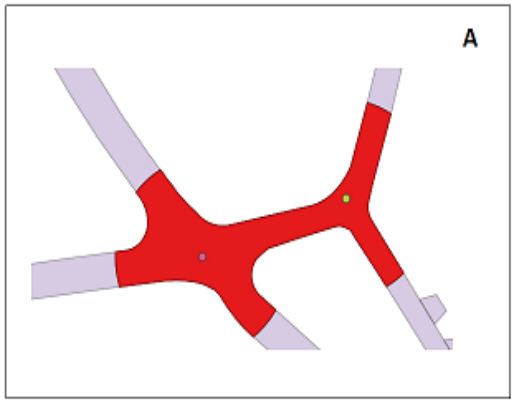


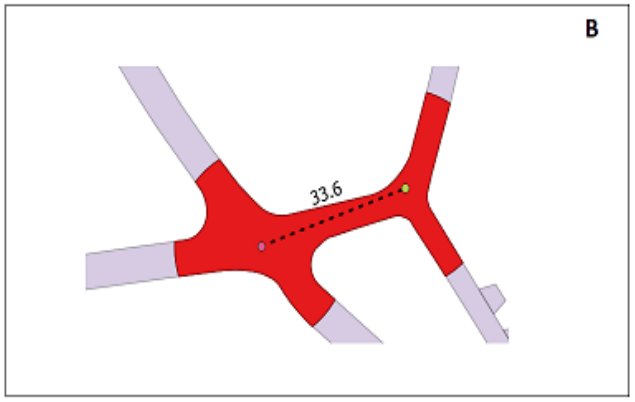


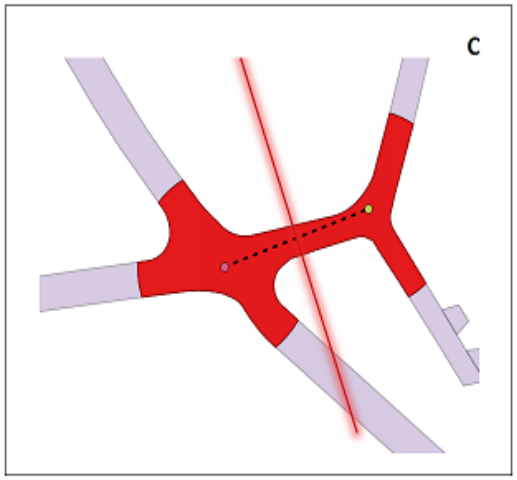


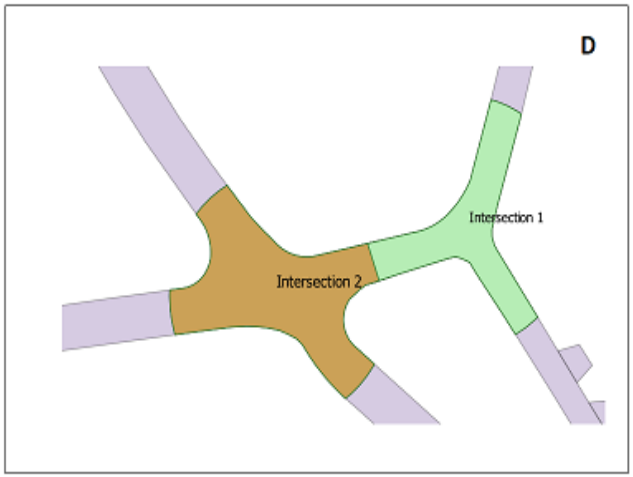


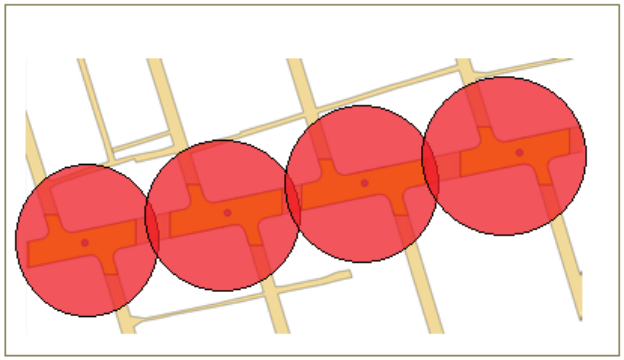


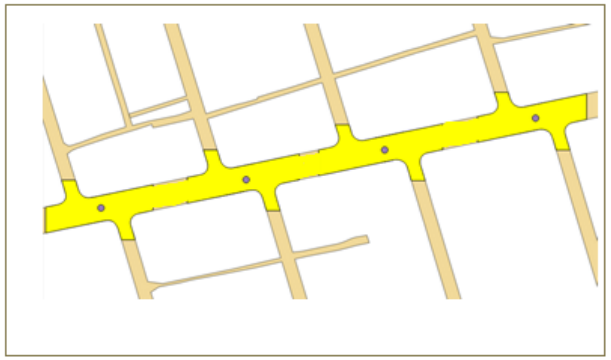


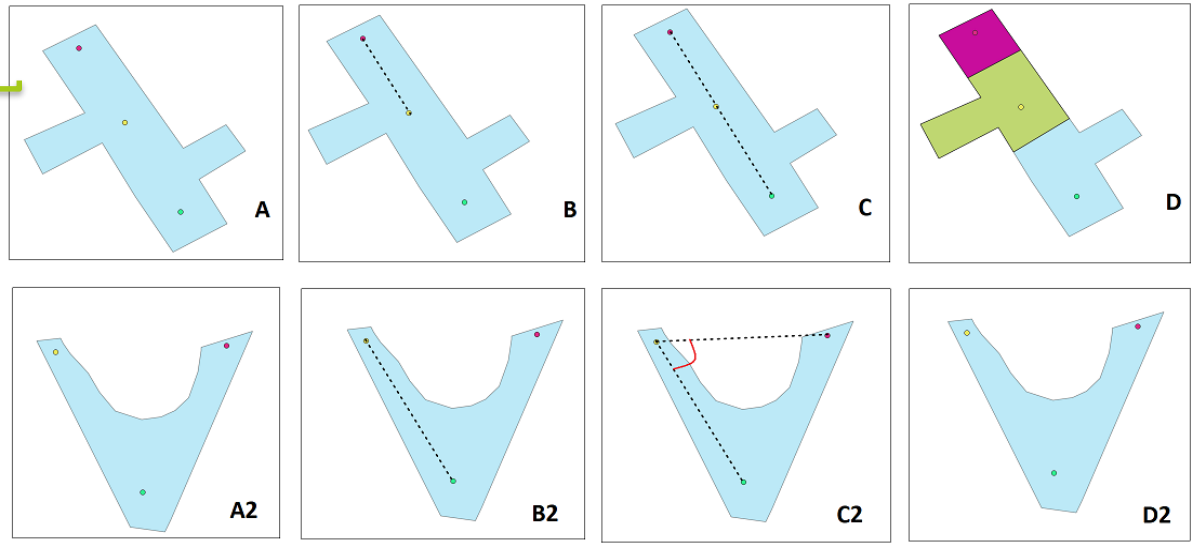


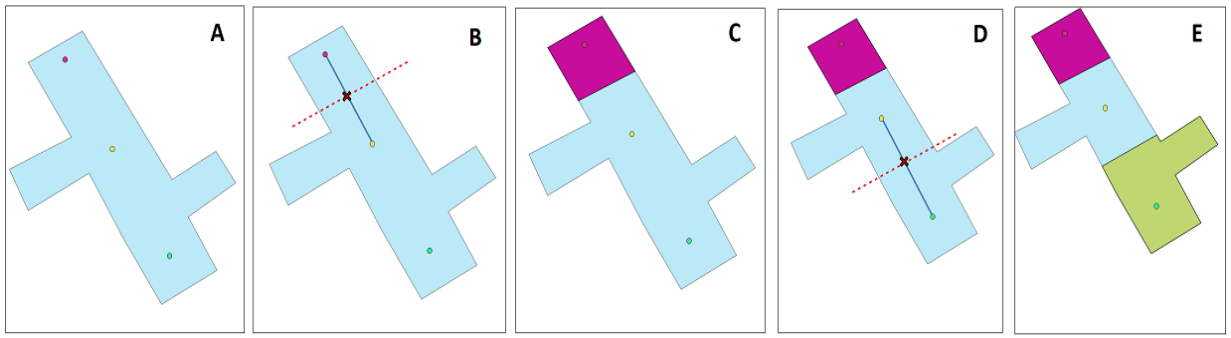


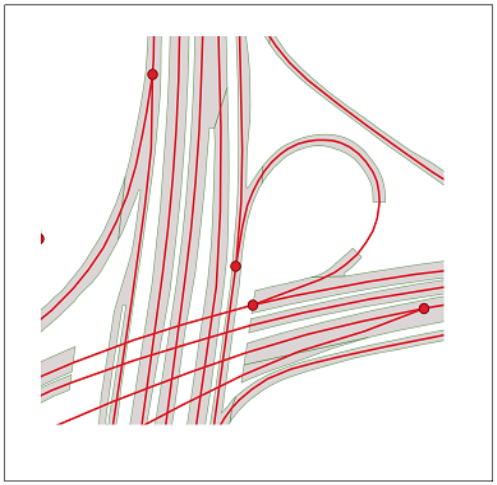


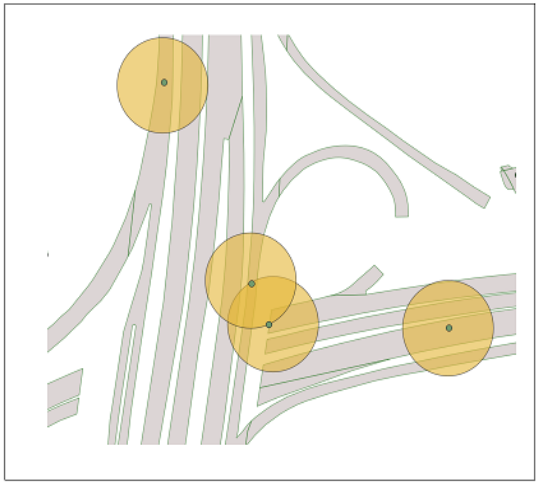


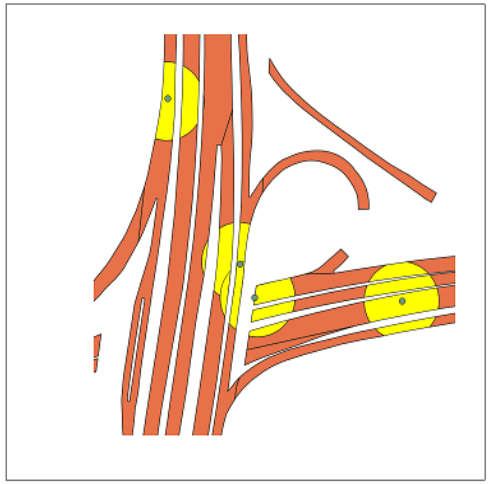


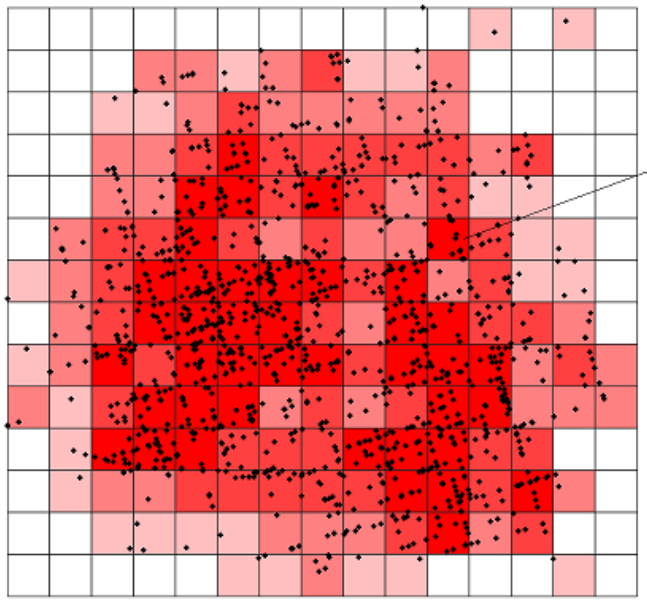


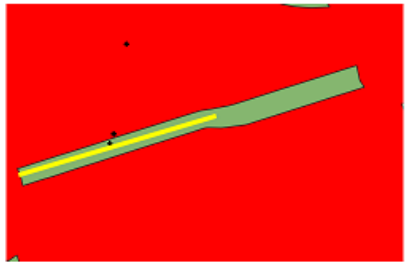








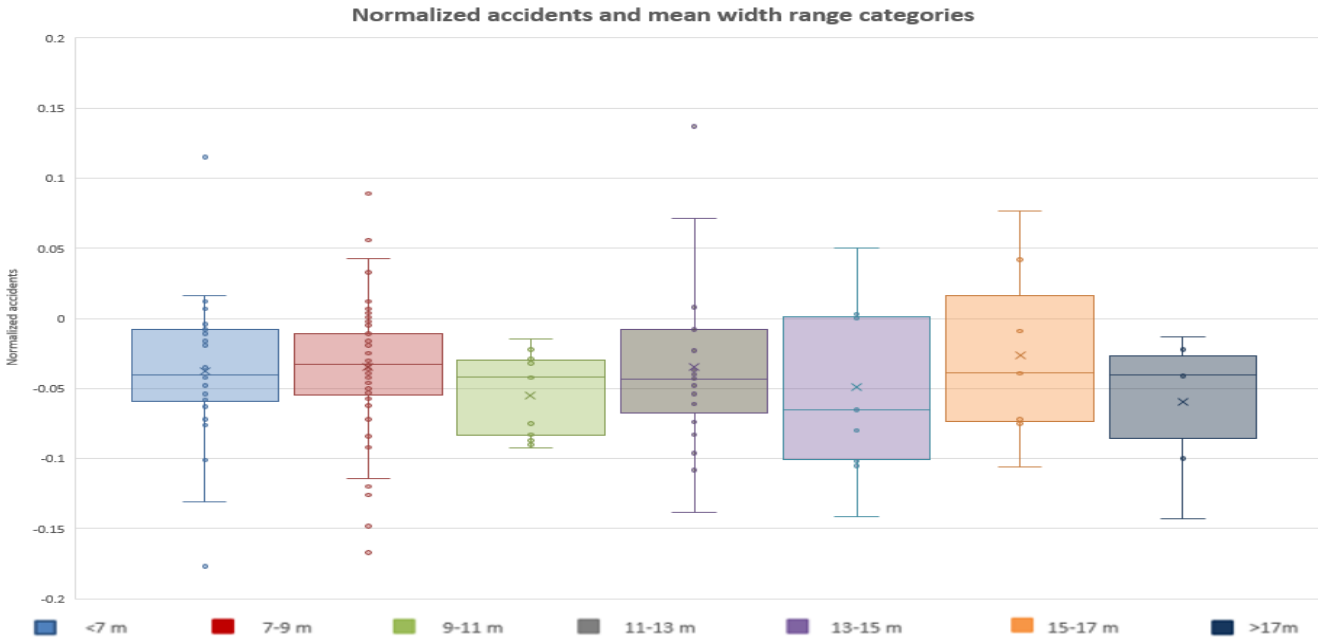


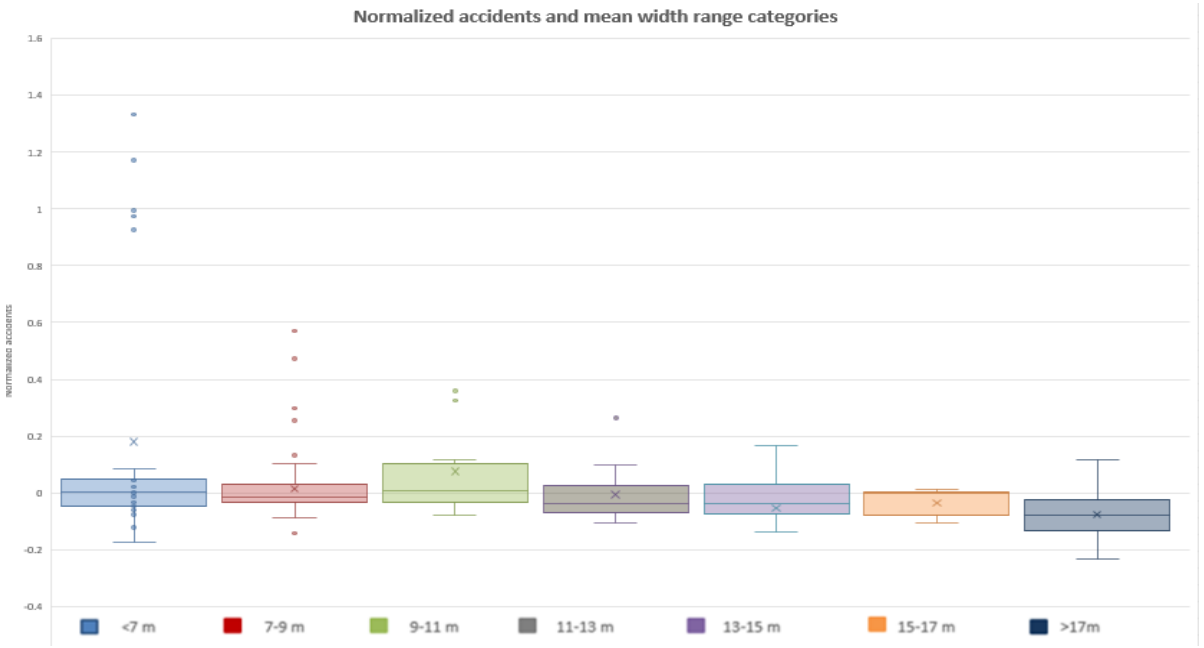


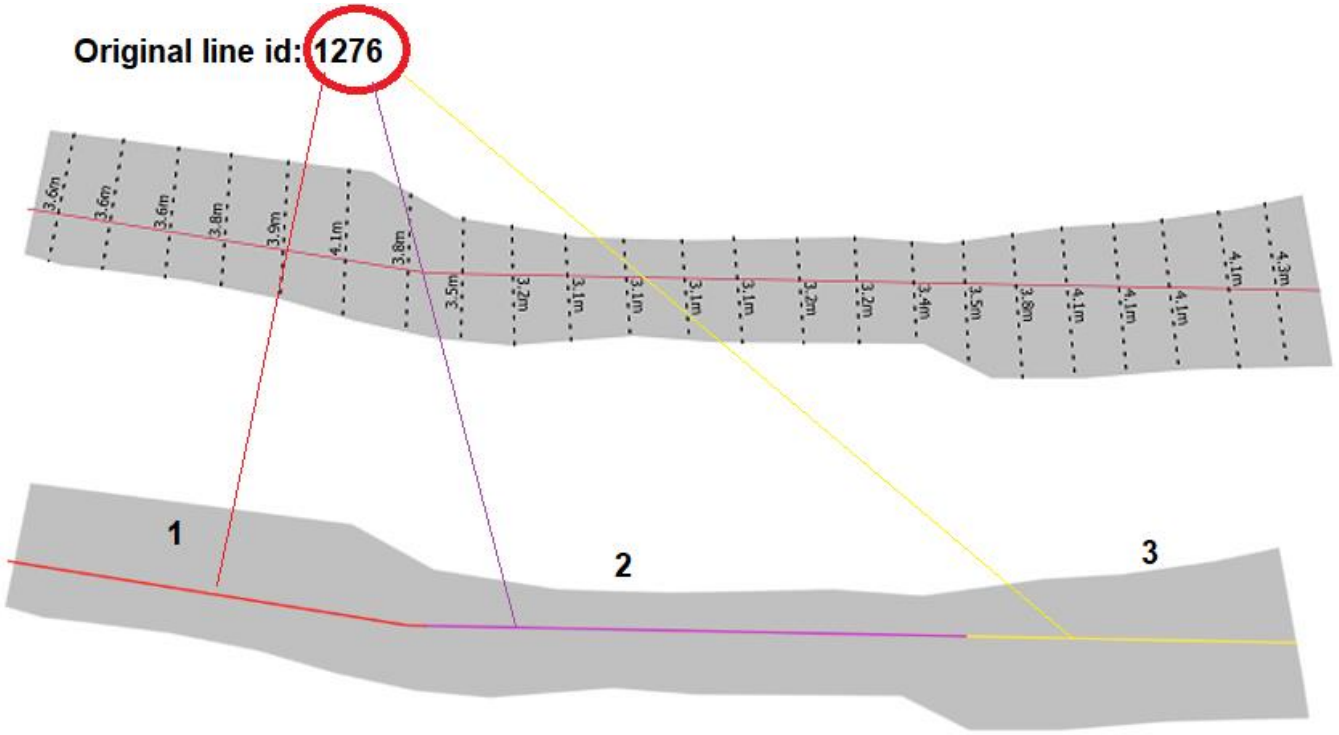
Accidents of cluster per meter = 0.09 (9 accidents, 100m length)

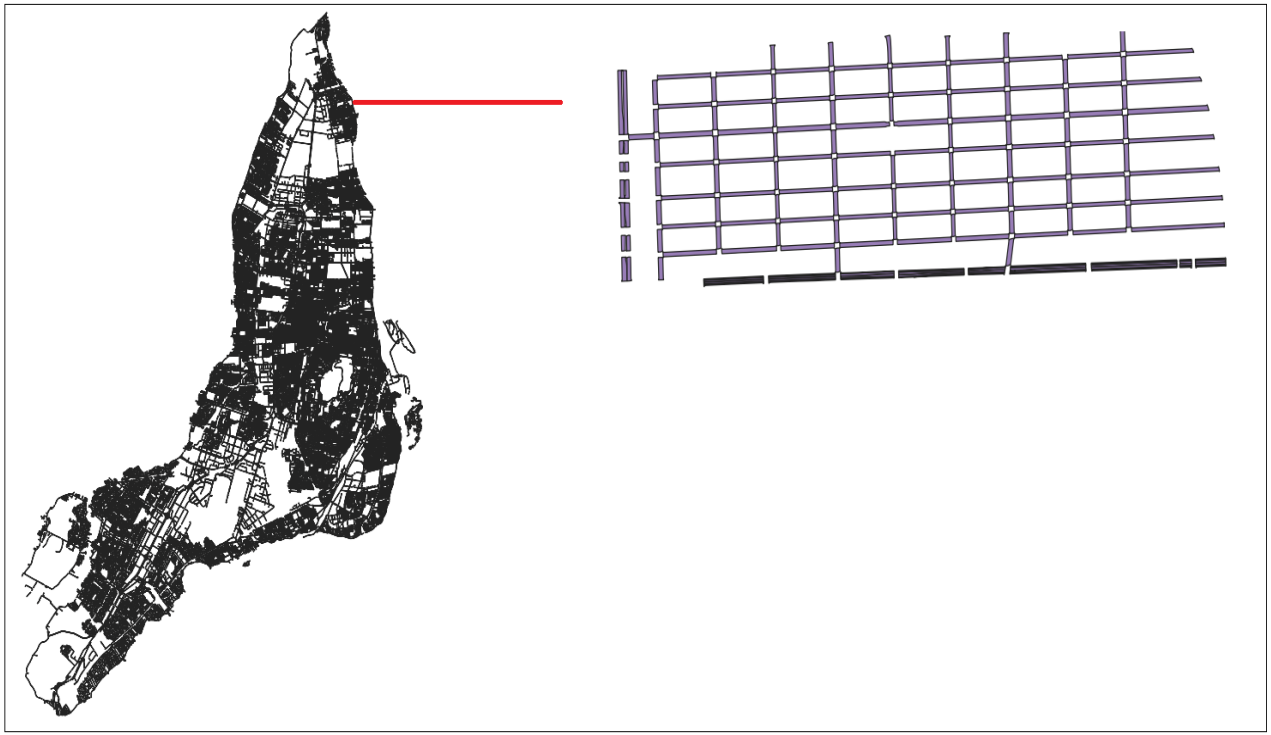
Accident per square meter in grid cell = 0.16 (79 accidents, 500x500 cell size)

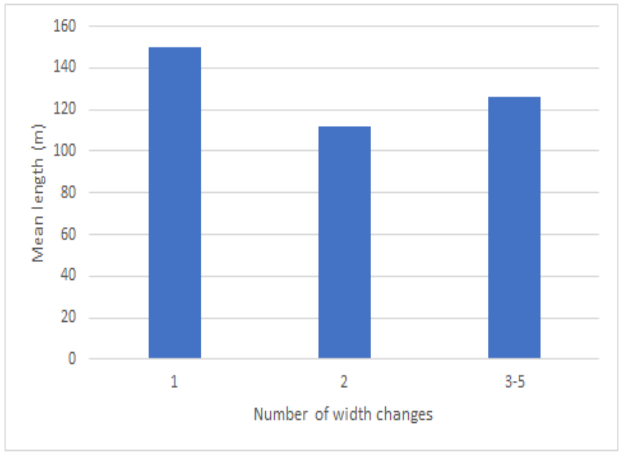
Rate of accidents = -0.07

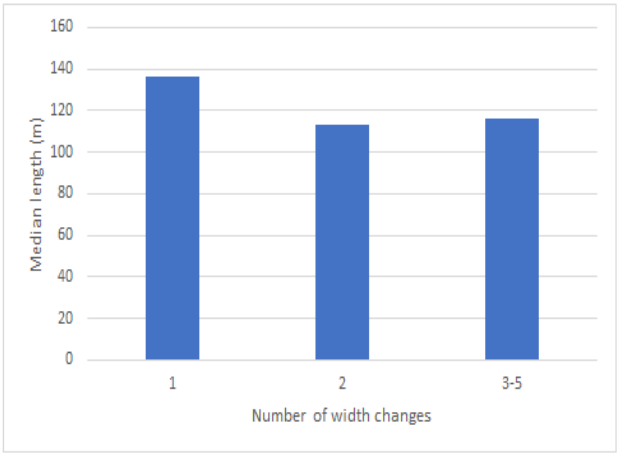


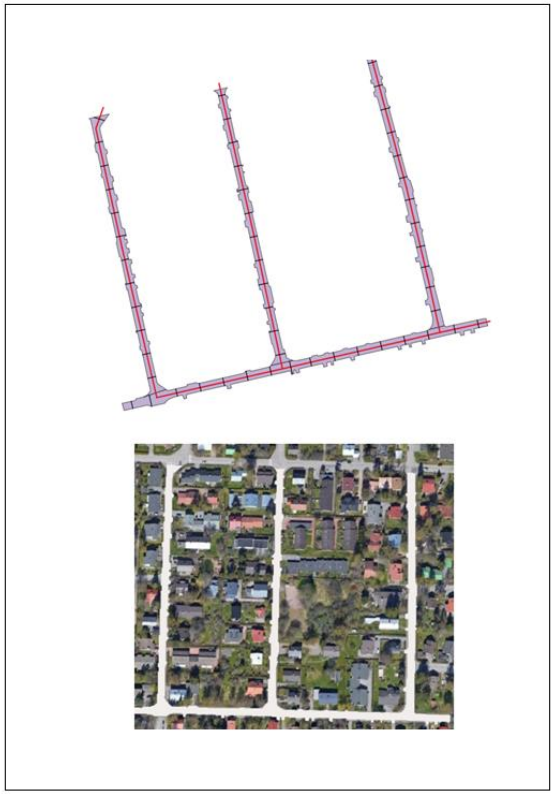




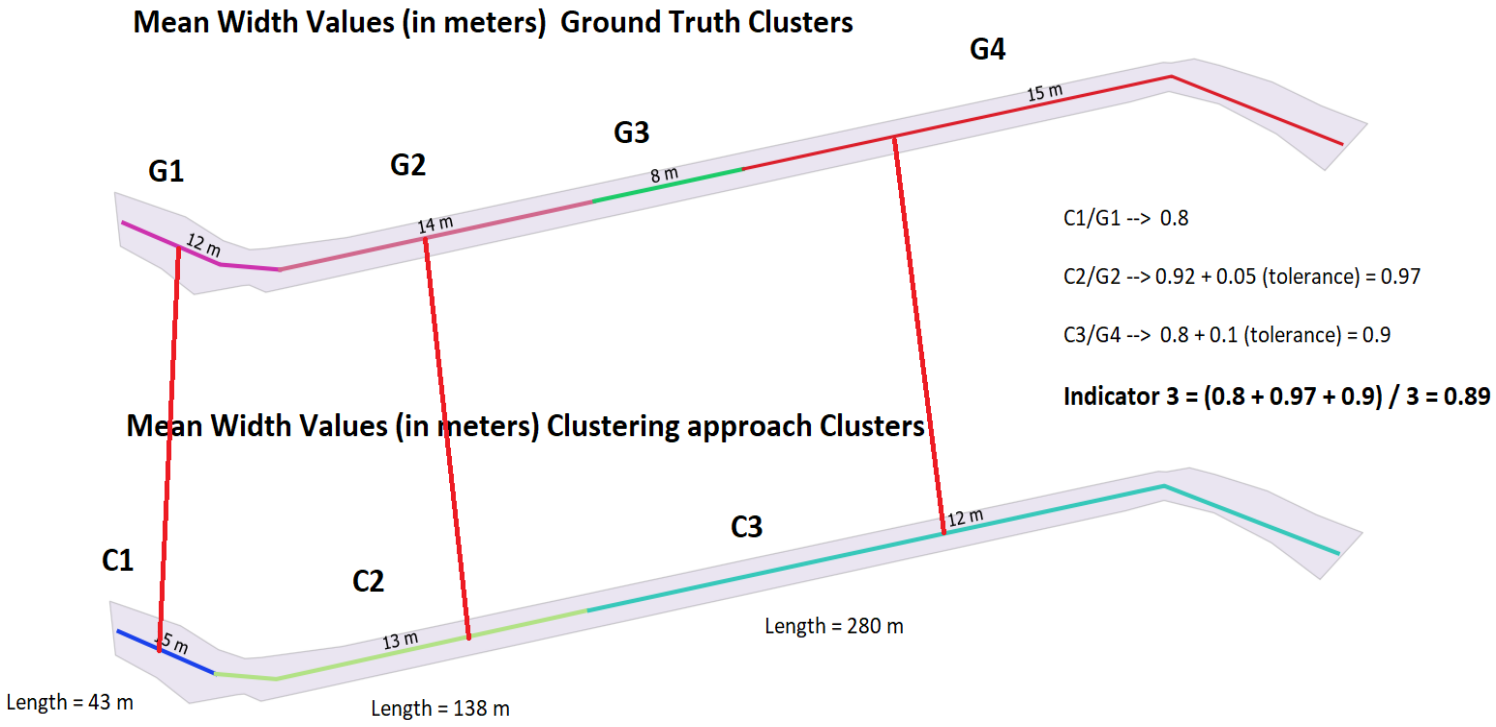








Dataset	Type of measuring	Number of measuring lines (m)	Mean Length of measuring lines (m)	Std around mean (m)	Median length of measuring lines (m)	Range (m)
Helsinki	Initial methodology	48	7.11	1.44	6.95	10.92
Helsinki	Ground truth (measured based on aerial imagery)	48	7.33	1.3	7.21	9.99
Poznan	Initial methodology	52	7.91	0.71	8.08	4.5
Poznan	Ground truth (measured based on aerial imagery)	52	7.84	0.6	7.97	4.01



TU Delft