MSc. Geomatics Thesis P5

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Reconstructing a high-detailed 2D areal representation of road network based on OSM data

TU Delft

29th October 2024

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Key words:

✓ OpenStreetMap, Road, Intersection,
✓ Road network model, Lane-level network, Linear representation, Areal representation,
✓ Topology, Graph, Geometry, Road centerline, Semantics, Traffic modes.

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Introduction & Background

Motivation:

- **Road network in real world**

Physical road networks are complex structured system composed of **a large number of road segments and intersections, shaping the layout of cities** and built environment;

vs. Digital road network

A **virtual representation** of real-world road infrastructure: it encompasses the geometry, topology, and attributes of roads, intersections, etc., stored in a **digital format**.

Reality

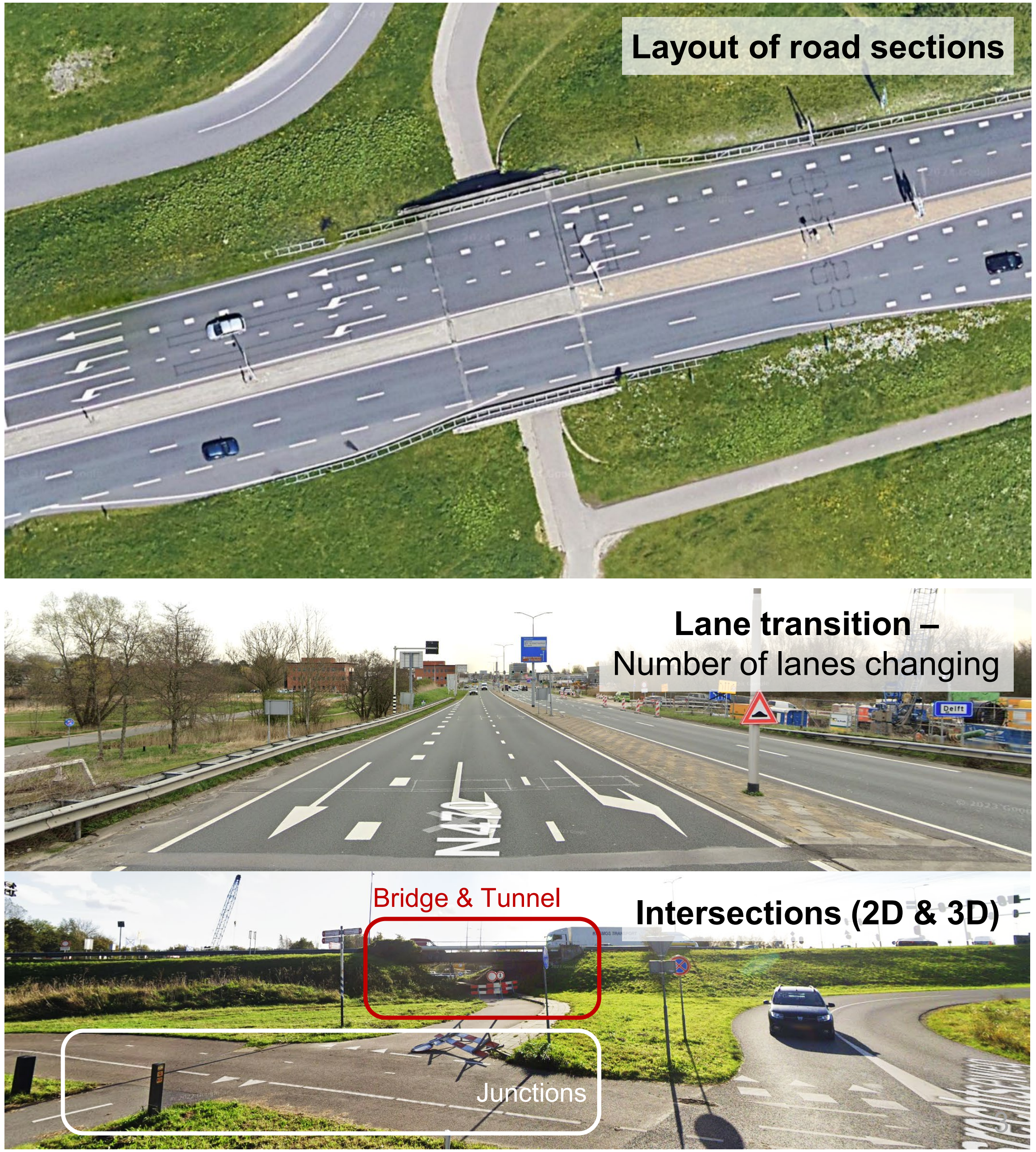


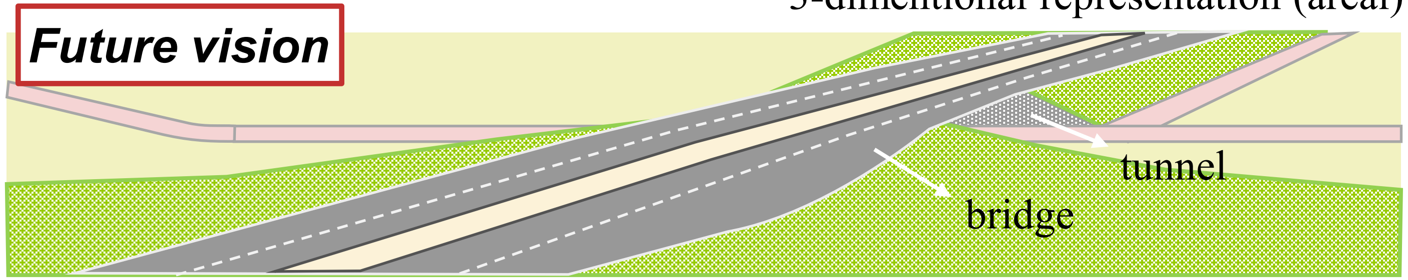
Figure source: Google Map

Introduction & Background

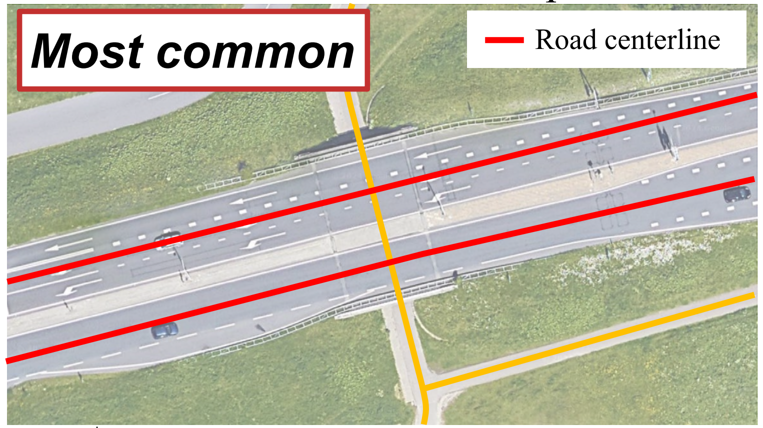
Motivation:

- **Types of road network representation**
  1. Linear representation
  2. Parametric representation
  3. Areal representation
  4. 3D representation (linear, areal, volumetric)

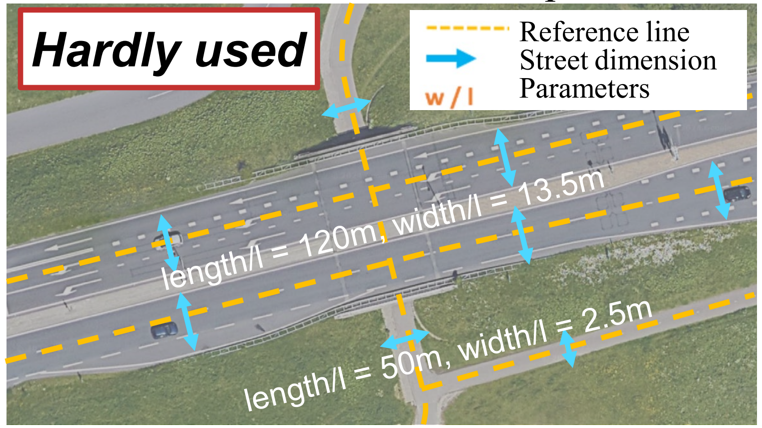
3-dimentional representation (areal)



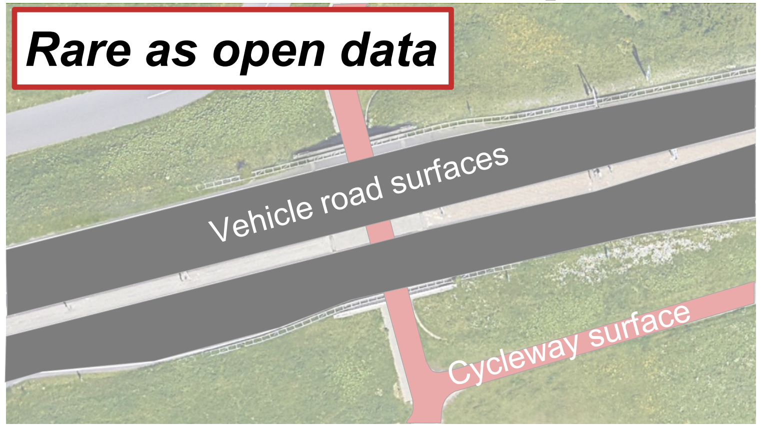
Linear representation



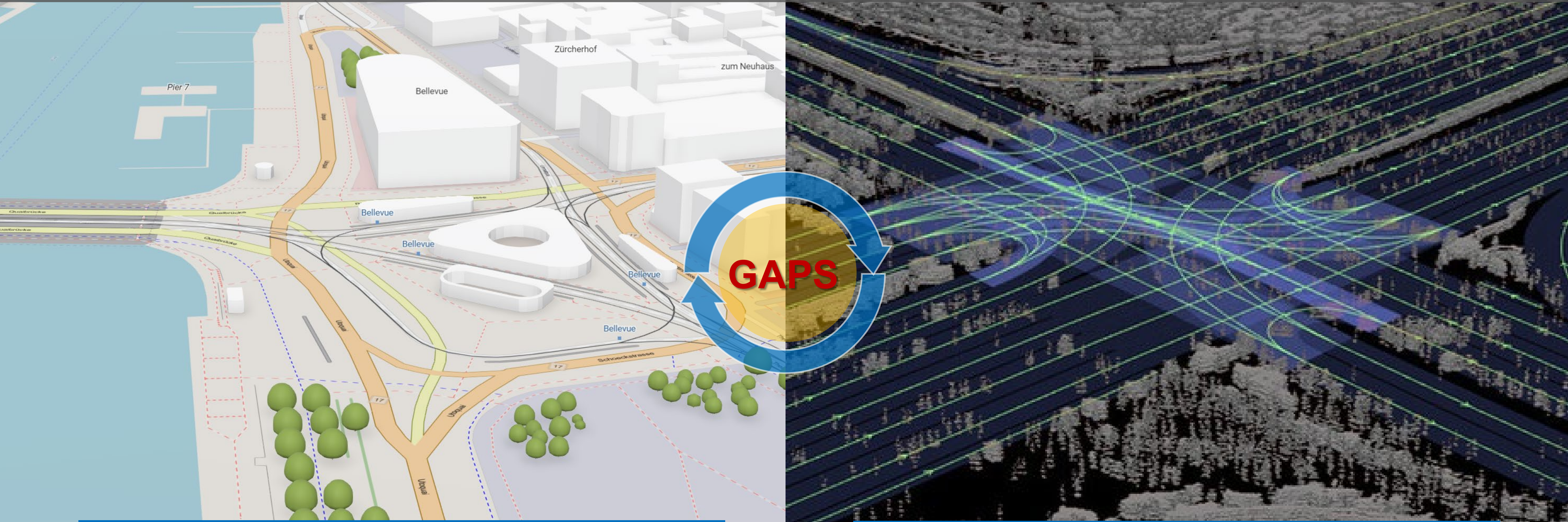
Parametric representation



Areal representation



Why reconstructing a high-detailed 2D areal representation of road network still matters?



3D building, terrain and vegetation models

Linear representation and driving trajectories

OSM (street for 3D) Arcgis online viewer

https://www.slashgear.com/806714/nvidia-is-mapping-earths-digital-twin-and-your-car-could-help/

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Introduction & Background

Motivation:

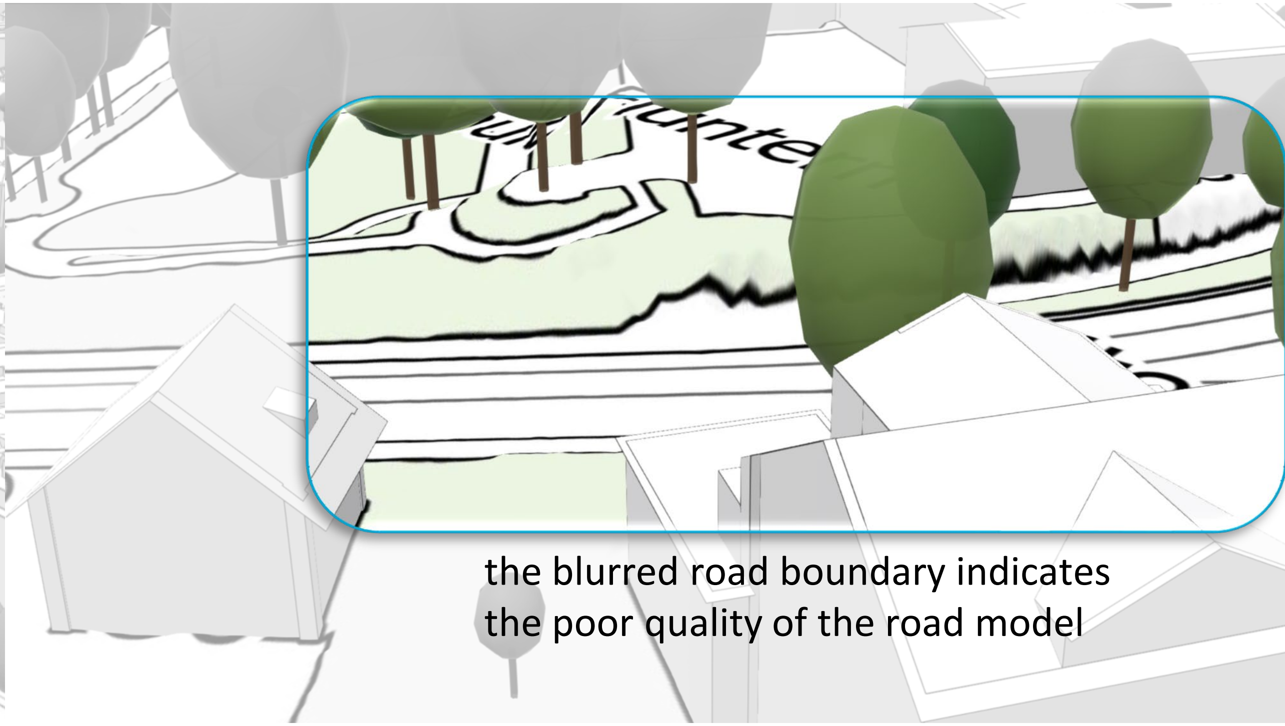
- **Start-of-the-art 3D city model**

https://www.stadt-zuerich.ch/content/ted/de/index/geoz/plan-und-datenbezug/3d-stadtmodell.html

Introduction & Background

Motivation:

- **Research gaps among current studies**



the blurred road boundary indicates
the poor quality of the road model

1.Not compact 2D polygon
2.Cannot connect to the real 2.5D or 3D objects

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https://www.stadt-zuerich.ch/content/ted/de/index/geoz/plan-und-datenbezug/3d-stadtmodell.html

Introduction & Background

Motivation:

- **A high-detailed 2D areal representation and its importance**

Types	Focus	Topology	Geometry	Semantic
Linear representation	Polyline as a single reference line	✓	?	*
Areal representation	Polygon as the road shape boundary	?	✓	*
3D representation	Road shape/centerline with elevation	From 2D*	2D shape*	From 2D*

Changes of the road width

The ***shift*** from linear to 2D areal representations ------

- **A more accurate description**: Road widths, boundaries, and surface characteristics by translating linear geometries into polygons.
- **Crucial for applications:** Navigation, road safety management, parking space calculations, urban heat island effects, etc.
- **Integration with 3D data:** Ensure that digital road models align seamlessly with other urban elements like buildings, water bodies, and terrain.

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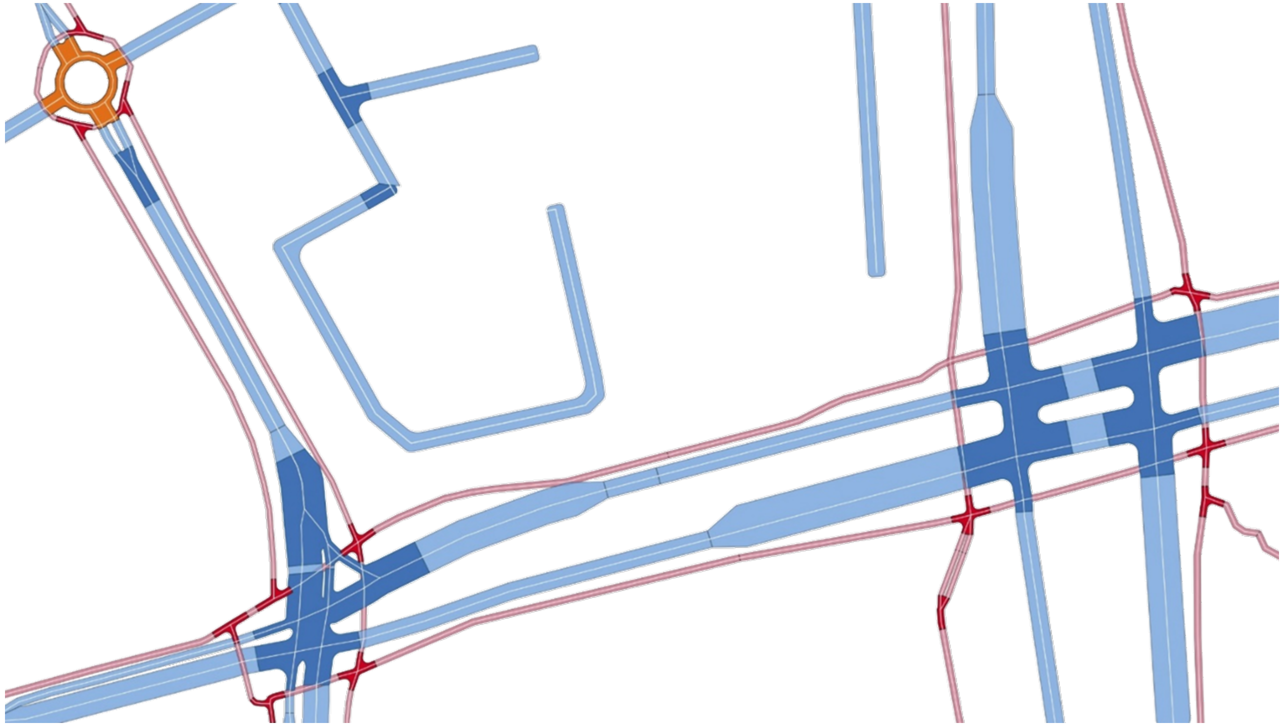
Introduction & Background

Research question:

"How can we achieve a high-detailed areal representation of road network model with topological and geometric correctness, and enrich its semantic information by *only* using the OpenStreetMap dataset?"



Introduction & Background

Background:

- **A high-detailed 2D areal representation and its Level of Details (LoDs)**

- **Variation and changes of roads:**
  1. **Road / Carriageway / Lane**
  2. **Driving direction(s):** one-way road, forward, backward
  3. **Traffic modes**: vehicle, cycling…
  4. **Road/lane width**: symmetric/asymmetric road section
  5. **Intersection shapes**

Lane level centerline →
Lane level polygon →
Complete road polygon

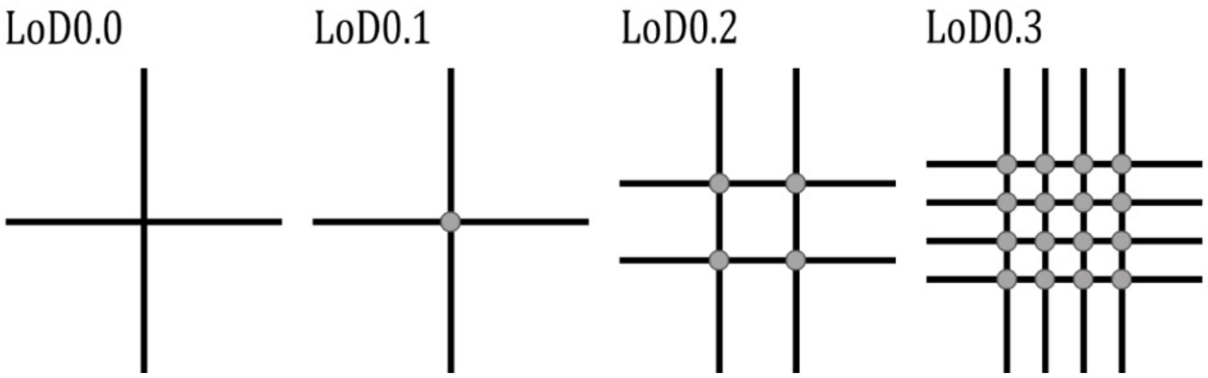


Figure 1. Refinement of the network/linear representation of roads in CityGML

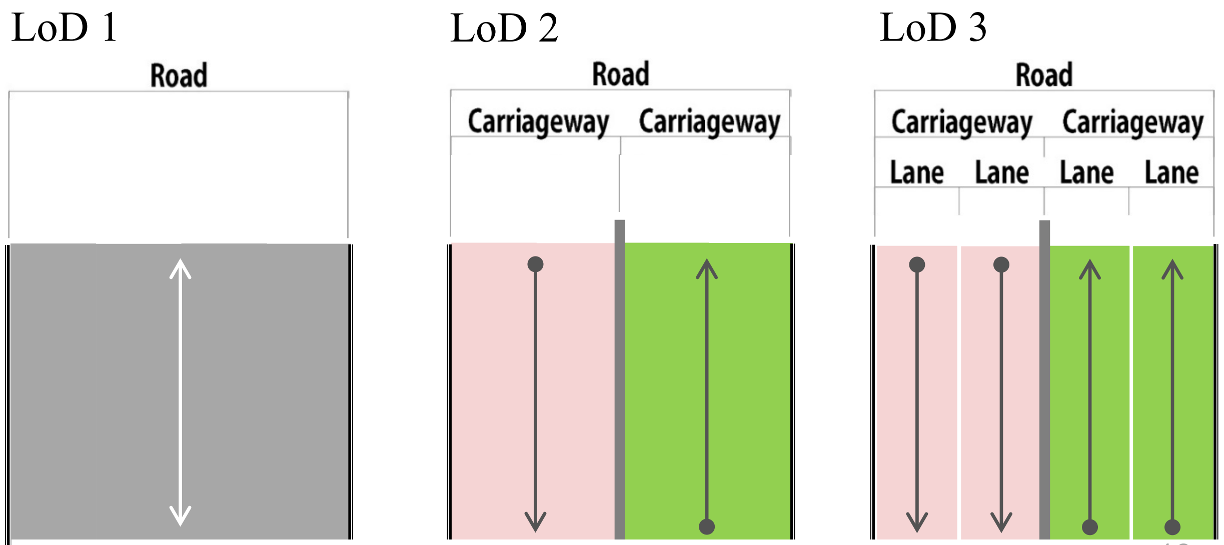


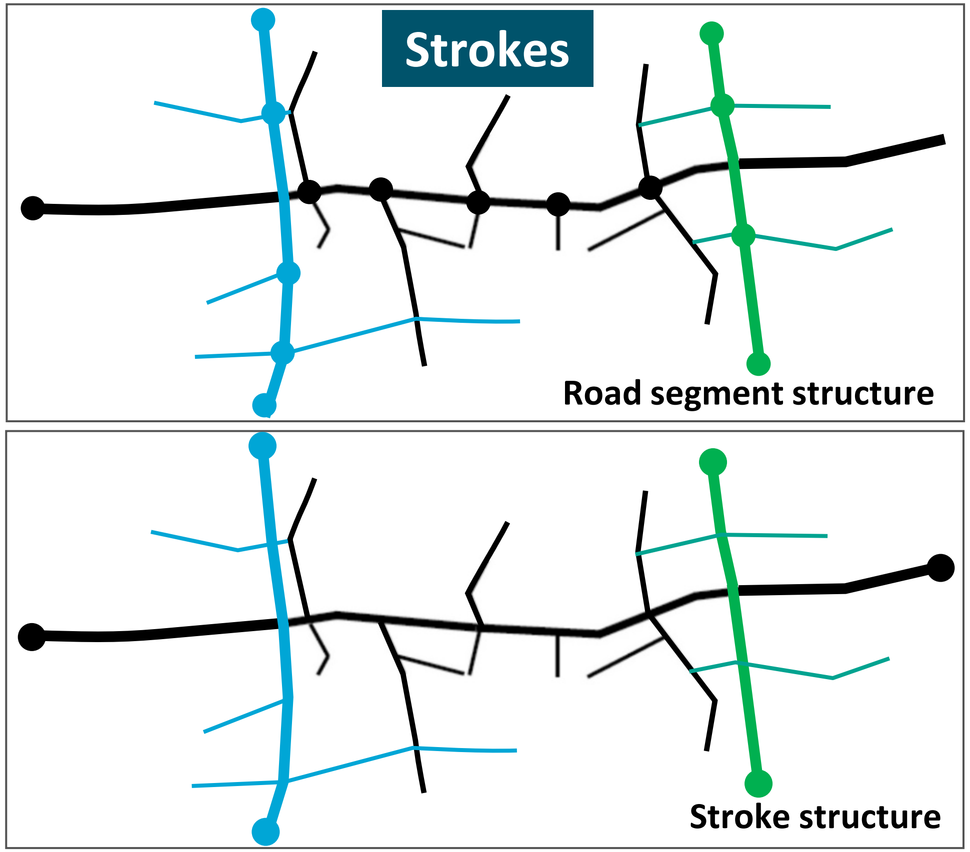
Figure 2. Refinement of the network/areal representation of roads in CityGML

Introduction & Background

Network level: continuity of roads in network
Segment level: layout/arrangement of lanes

Background:

- **Geometric design rules/civil engineering principles**



When observing a road network, natural linear elements will be seen which **extend through junctions** and maintain the **topology and geometry connectivity**, the aggregation of these elements is the "stroke":
"a set of one or more segments in a non-branching and connected chain".

- *its hierarchical characteristics*
- *the same road types*
- *no abrupt change in direction, or they intersect at a small angle.*

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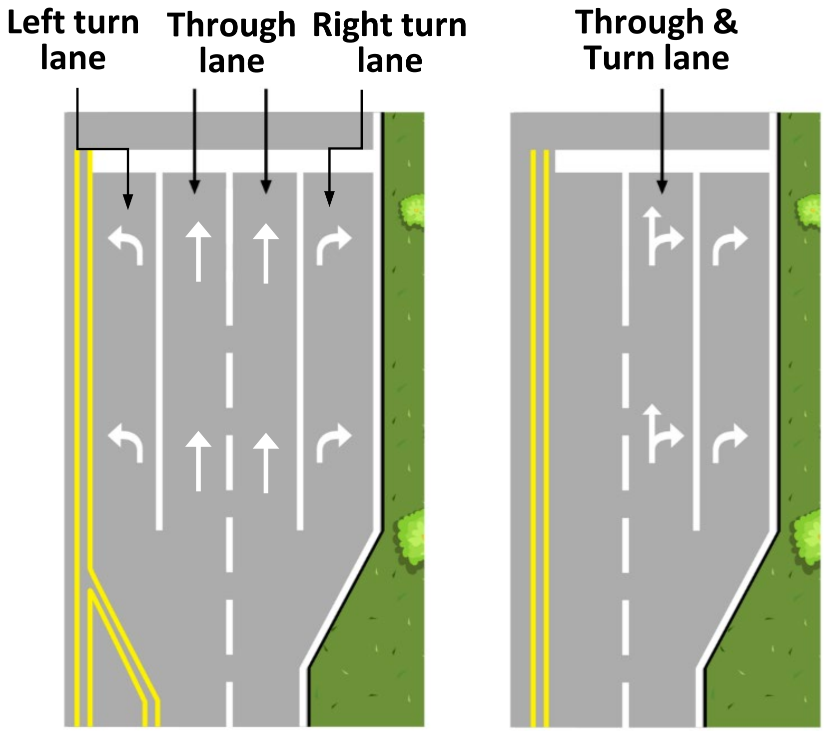
Introduction & Background

Background:

- **Geometric design rules/civil engineering principles**

Network level: continuity of roads in network
Segment level: layout/arrangement/relative location of lanes

Auxiliary lane & 'through' lane



Auxiliary lanes that form the transition between **the main route and the ramp/slip roads**.

An auxiliary lane is a section of the roadway adjacent to the through lanes, designed for purposes such as **turning, storage for turning, that support the movement of 'through' traffic**.

From linear to areal: inherit topology

Introduction & Background

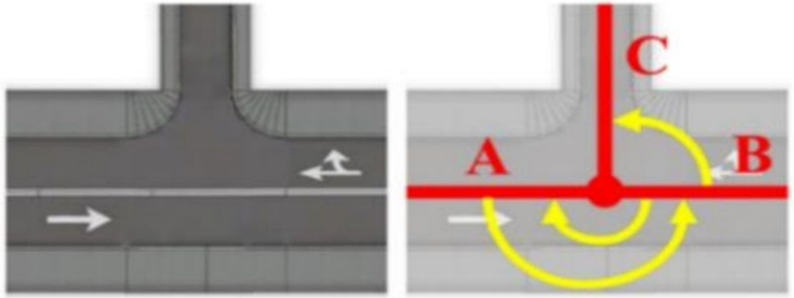
Background:

Graph theory

Topological characteristics in linear representation:

- ***Node***
- ***Edge***
- Edge with direction (adjacency)
- Node has degree as the number of converged edges

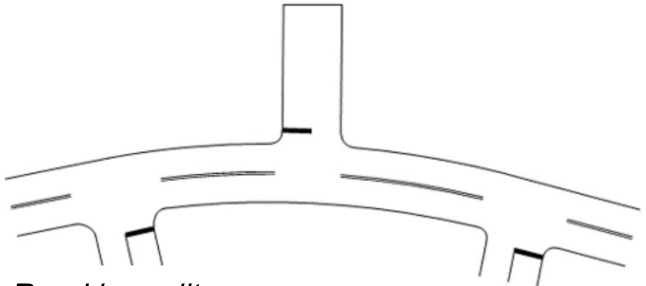
Graph **Digraph** **MultiDigraph**



Adjacency

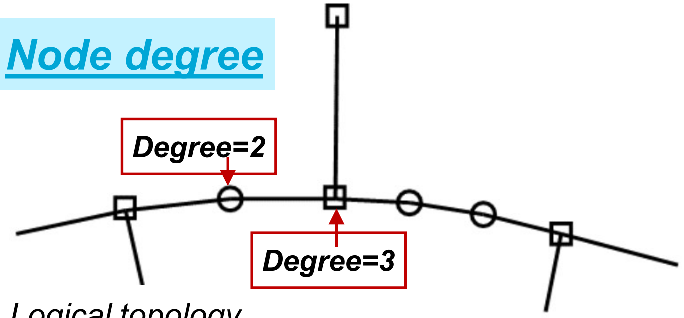
	Predecessor	Successor
A	B	B
B	A	A, C
C	B	-

Road network as Digraph and distinguish the **adjacent connection**

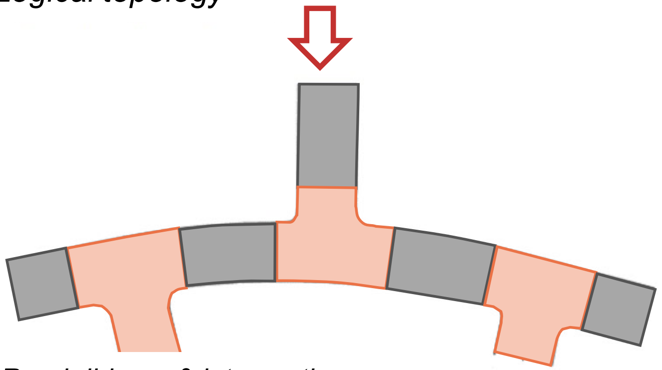


Road in reality

Node degree



Logical topology



Road ribbons & intersections

Node degree and road-level topology
⇔
road polygon representation and generation

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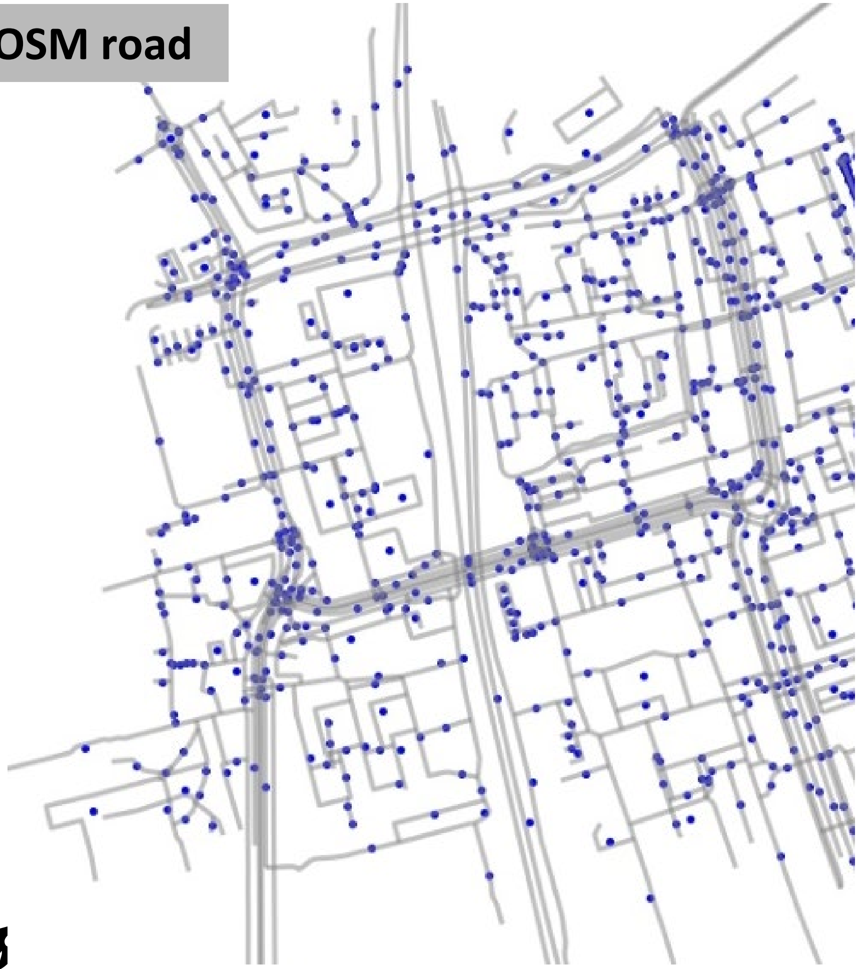
Introduction & Background

Background:

OSM road



OSM road data characteristics

OSM road data as vector, with the various tags and hidden information;

→ **Additional road/lane;**

→ **Multiple lanes;**

→ **Specific junction…**

Polyline

+

Tags

*highway =**
*cycleway =**
*name =**
*lanes =**
*oneway =**
*junction =**
*turn =**
*bridge =**
*tunnel =**

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Objective & Questions

Objectives:

A high-detailed areal representation

Only using OSM data:

- Topology correctness

- Geometry accuracy

- Semantic enrichment

Subquestions:

1. **How can the information and attributes contained in OSM road data be utilized to generate and optimize 2D linear and areal representations of road network models?**
2. **Is it possible to enhance the resolution and LoDs of a road network model from the original road-level to a high-detailed lane-level network using only OSM data?**
3. **Can the topology relationships, lane-to-lane adjacency for representing traffic flow movements, be preserved through OSM data processing and detailed generation methods?**
4. **How can we generate 2D road polygons as errorless geometries to accurately capture road shape details, including changes in road width and intersection variations?**

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Methodology

Integration of Goals, Gaps, Backgrounds

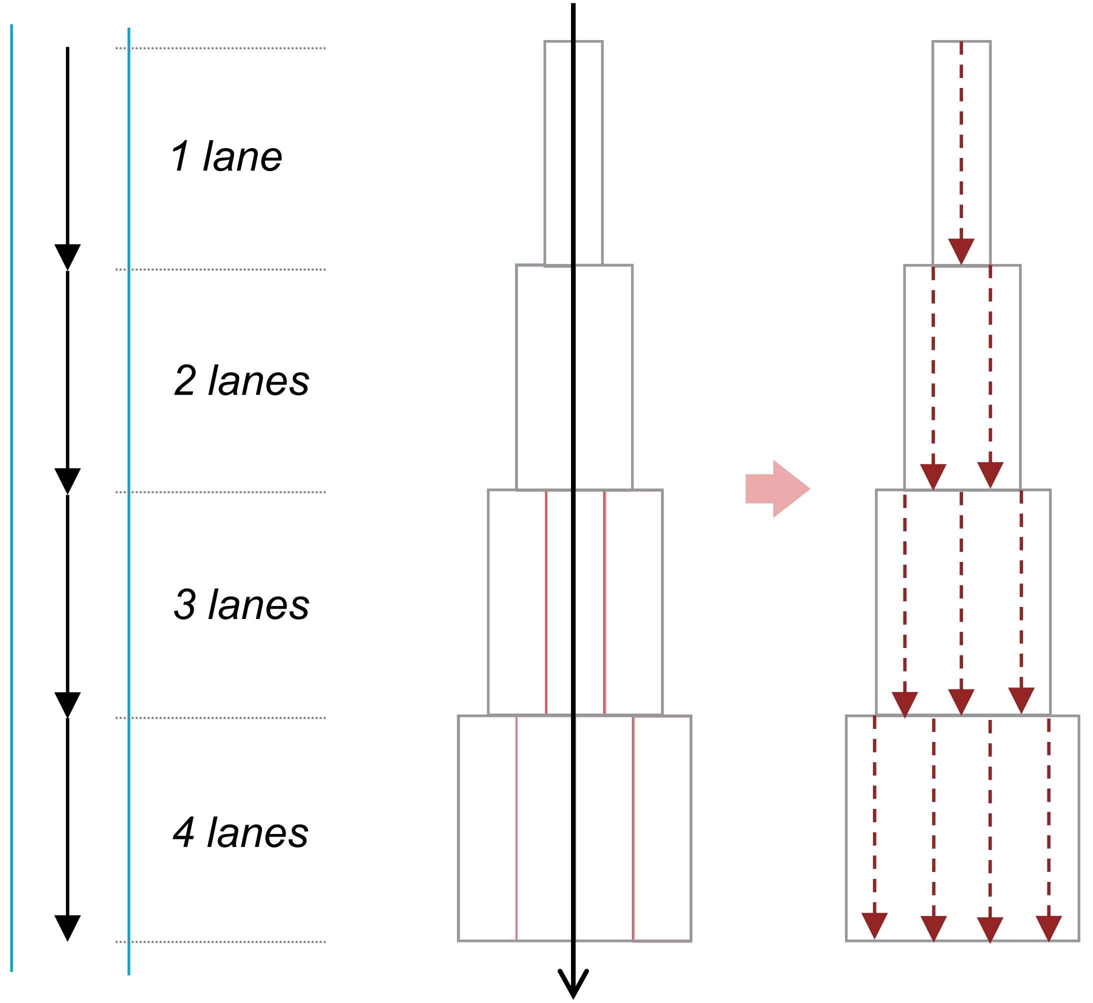
Relation of linear center and areal center:

- Road ***centerline***
- ***Center axis*** of road polygon

- *1 continuous road/stroke*
- ***4*** *road centerlines as sections*
- ***Unknown*** *road* ***width & shape*** *changes*

! ! ! Lane connectivity is not guaranteed

1. Centerline is the center axis of road polygon boundary



Wrong lane connectivity topology ⇔ Unrealistic road boundary

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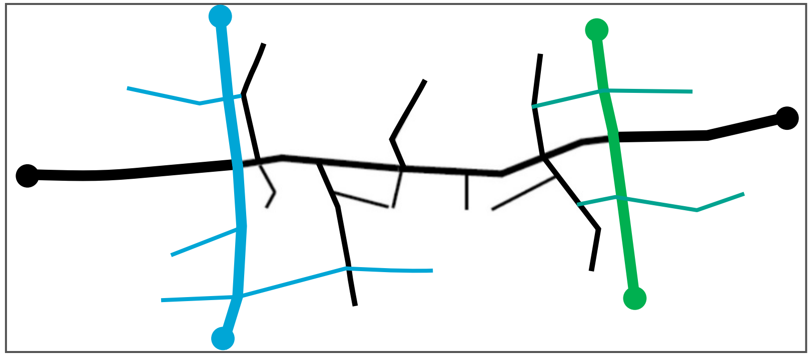
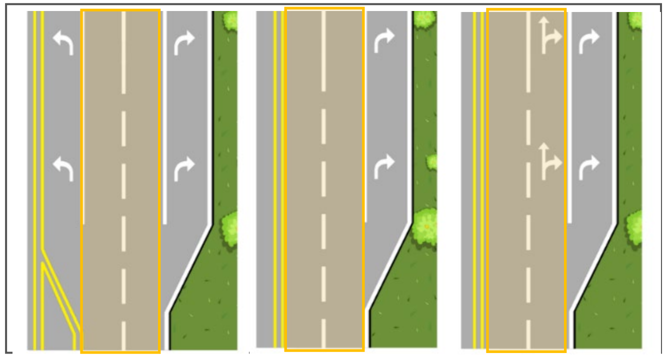
Methodology

Integration of Goals, Gaps, Backgrounds

Strokes



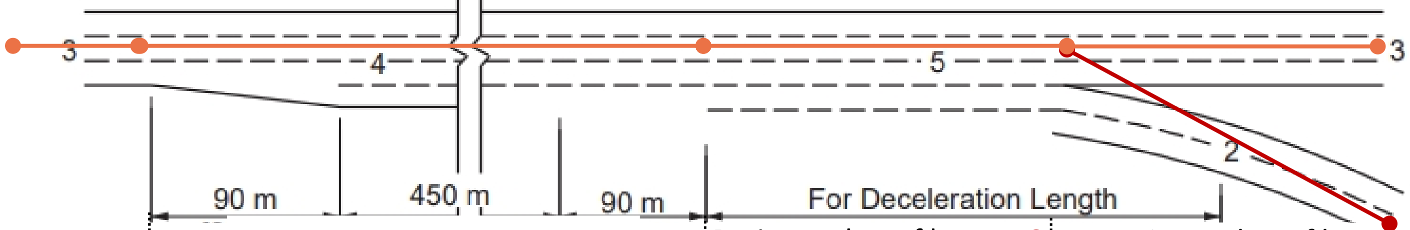
Auxiliary lane & 'through' lane



Main routes with 'Good connectivity' **in the whole road network**

Traffic entering or exiting the main route **of a roadway.**

Basic number of lanes



Basic number of lanes = **3**
Total number of lanes = 3

Basic number of lanes = **3**
Total number of lanes = 4

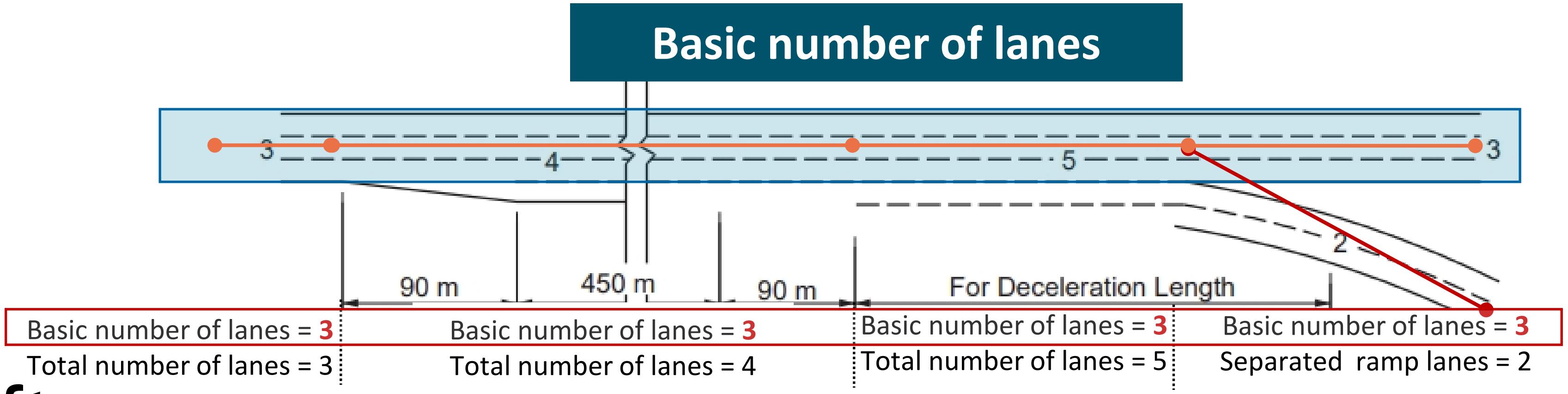
Basic number of lanes = **3**
Total number of lanes = 5

Basic number of lanes = **3**
Separated ramp lanes = 2

Methodology

Integration of Goals, Gaps, Backgrounds

- It represents a **minimum and constant** number of lanes that are designated and sustained over a considerable length of the route, regardless of changes in traffic volume; excluding any auxiliary lanes.
- Maintain consistency in the number of lanes along any arterial route.
- Crucial for the **lane level connectivity**.



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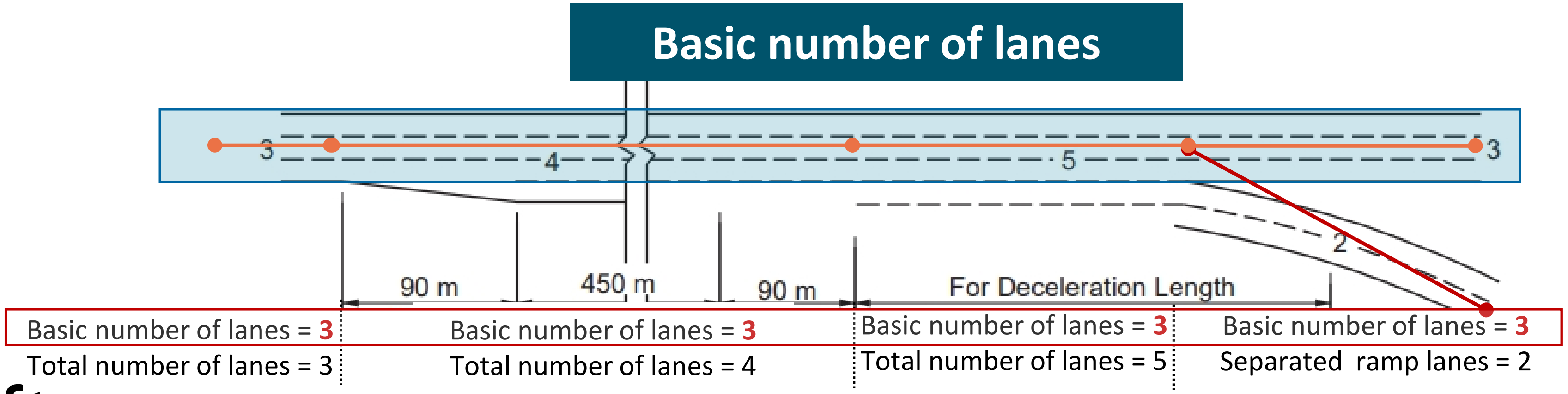
Methodology

Integration of Goals, Gaps, Backgrounds

Basic number of lanes = ***3***
in this section/stroke

***3 through lanes** have*
'good connectivity' in lane level



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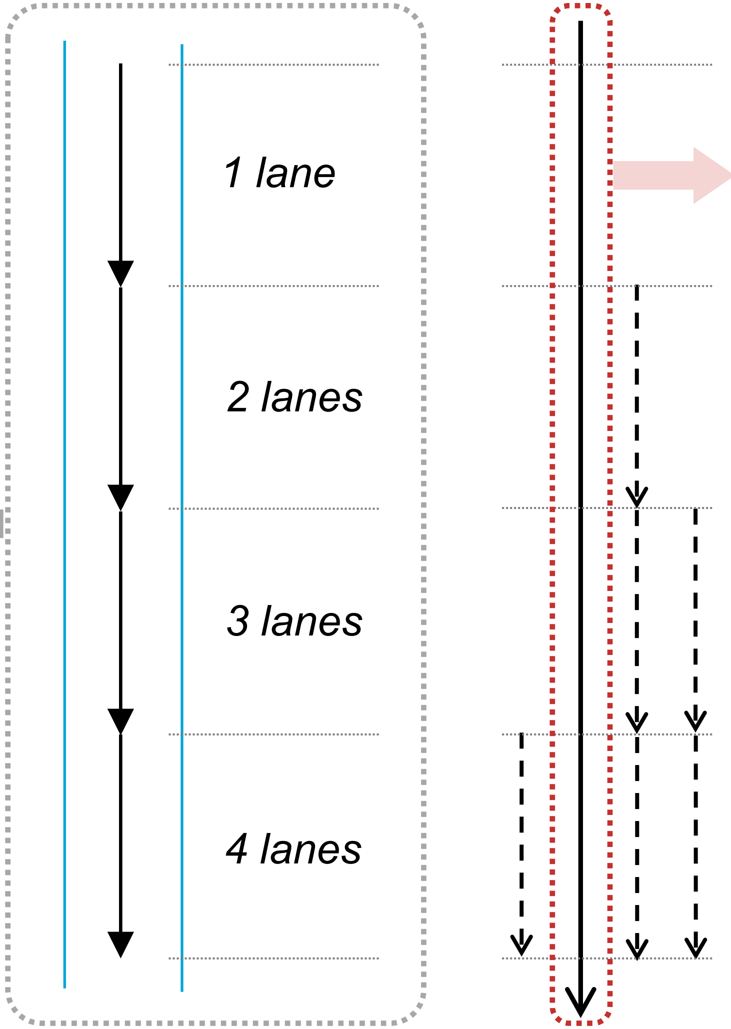
Methodology

Integration of Goals, Gaps, Backgrounds

- **Relation of linear center and areal center:**
  - Road ***centerline***
  - ***Center axis*** of road polygon

2. Centerline as movement shape of road (through lane) representation

Road segments within the same grouped stroke ***S***



'Basic number of lane'

Smin of the grouped stroke represent the lanes that allow the traffic move forward without changing maneuvring

Correct lane connectivity topology

Methodology

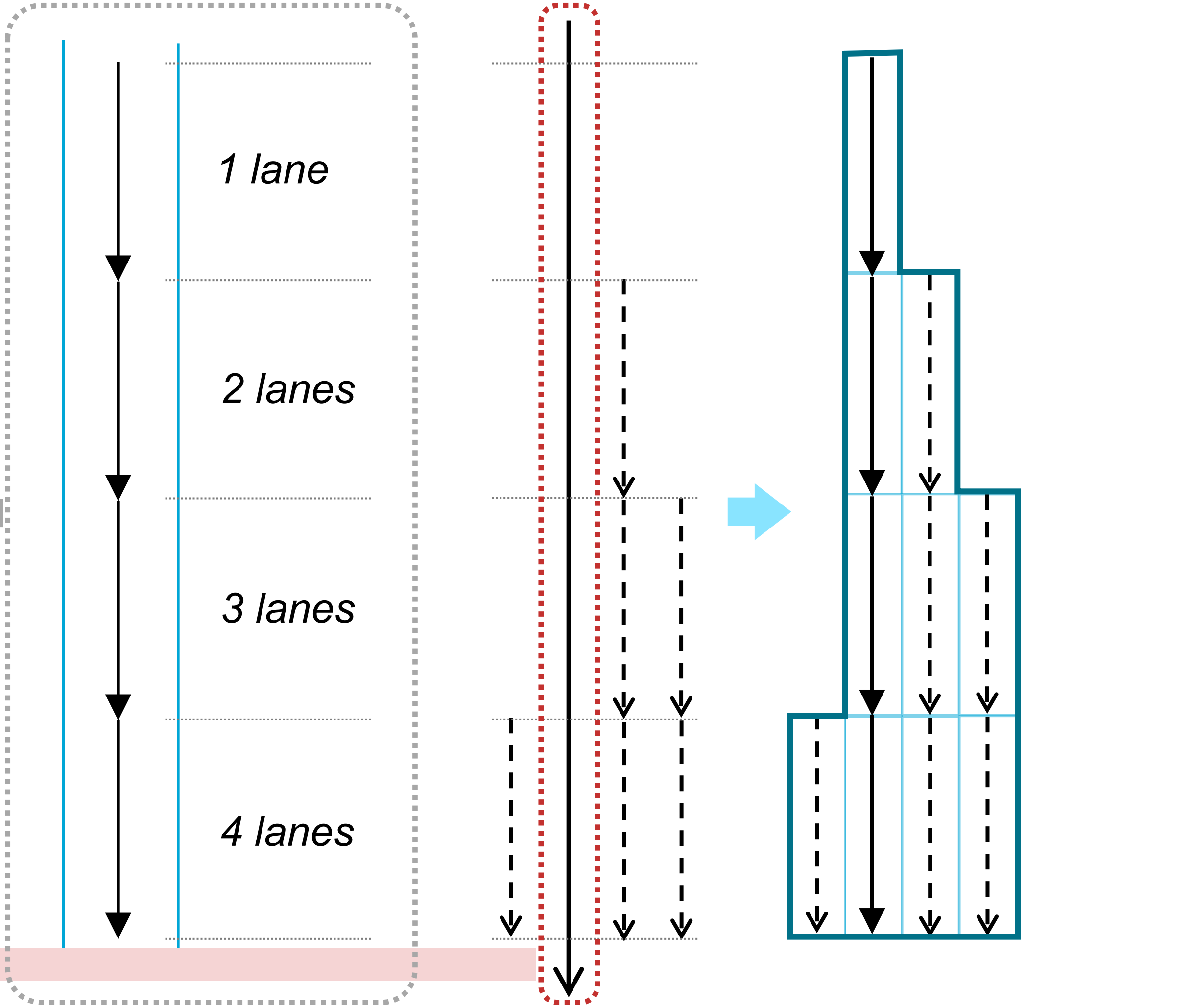
Integration of Goals, Gaps, Backgrounds

- **Relation of linear center and areal center:**
  - Road ***centerline***
  - ***Center axis*** of road polygon

Road segments & Stroke ***S***

'Basic number of lane' ***S**$_{min}$* & 'through' lanes

2. Centerline as movement shape of road (through lane) representation



Correct lane connectivity topology ⇔ Realistic road boundary

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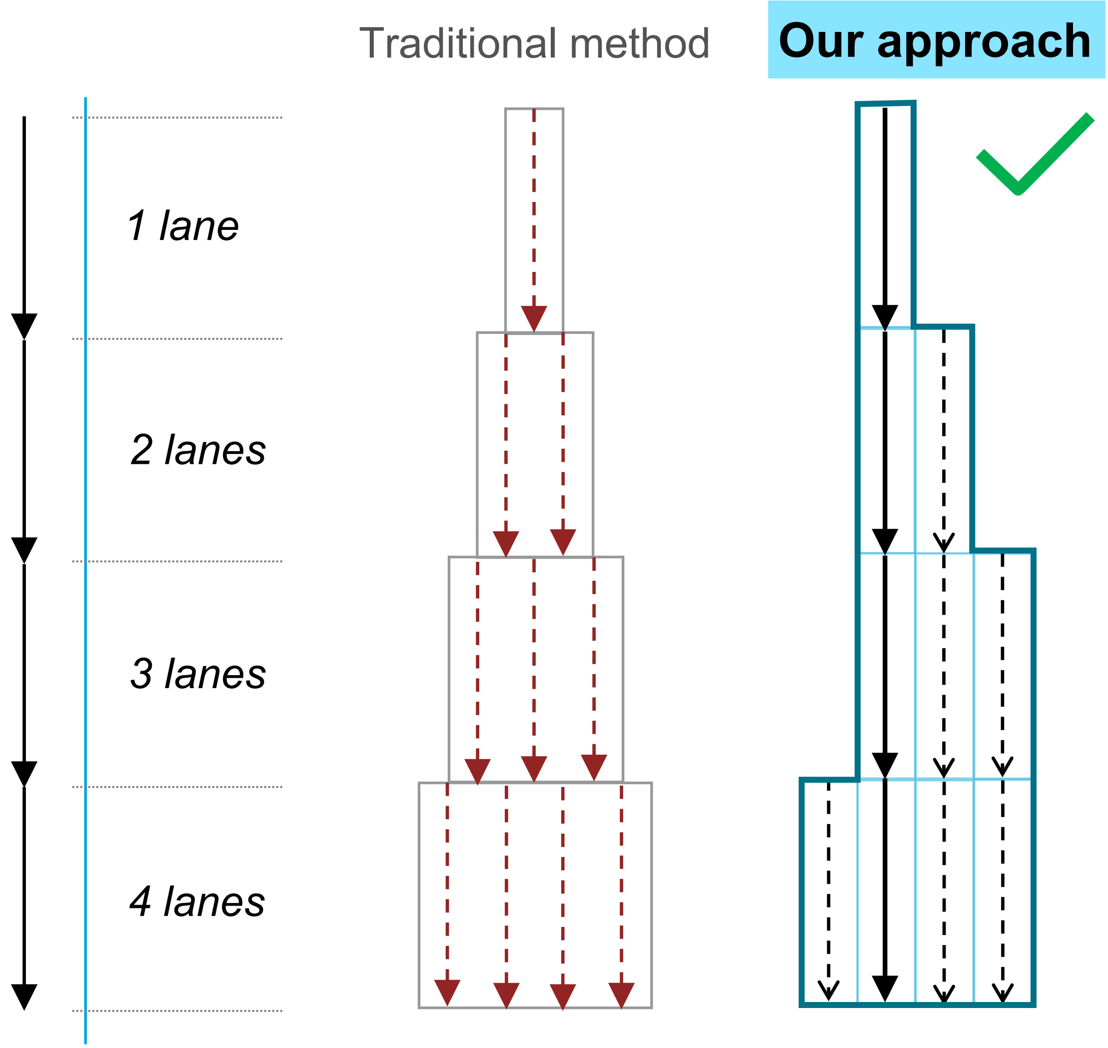
Methodology

Integration of Goals, Gaps, Backgrounds

- **Road level centerline is not always the center axis of road polygon**

Strokes
Basic number of lanes
Lane topology



1. Centerline vertices at the center axis of road polygon boundary

2. Centerline as movement shape representation

Methodology

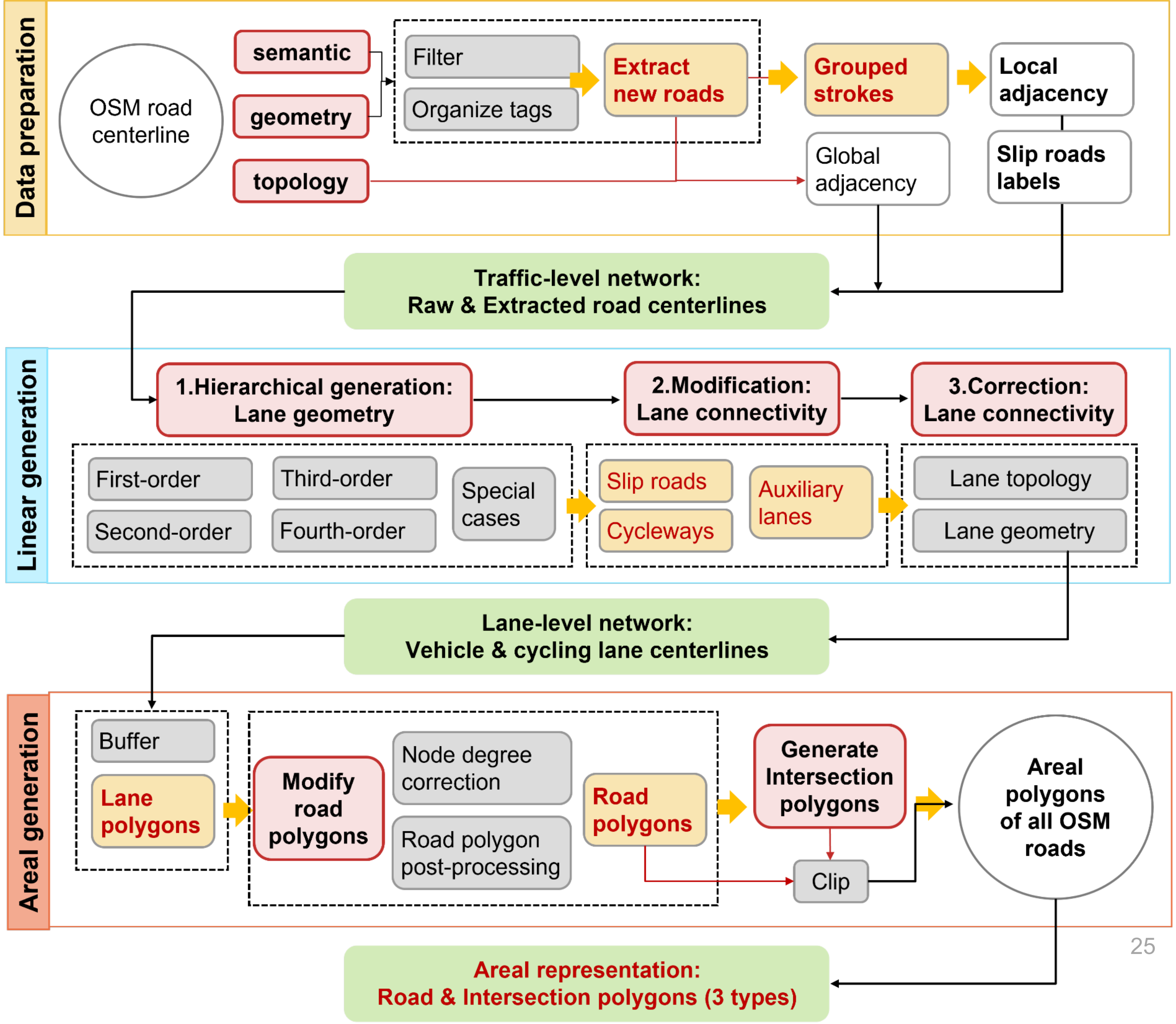
Top-level pipeline:

Model & Method Design	Preparation: OSM **Road** Network and Stroke	Linear Generation: **Lane** Network Reconstruction	Areal Generation: 2D Road **Polygon** Reconstruction

- **Road-level network model**
- **Traffic-level network model**
- **Lane-level network model**
- **Areal representation model**

Methodology

Detailed workflow:



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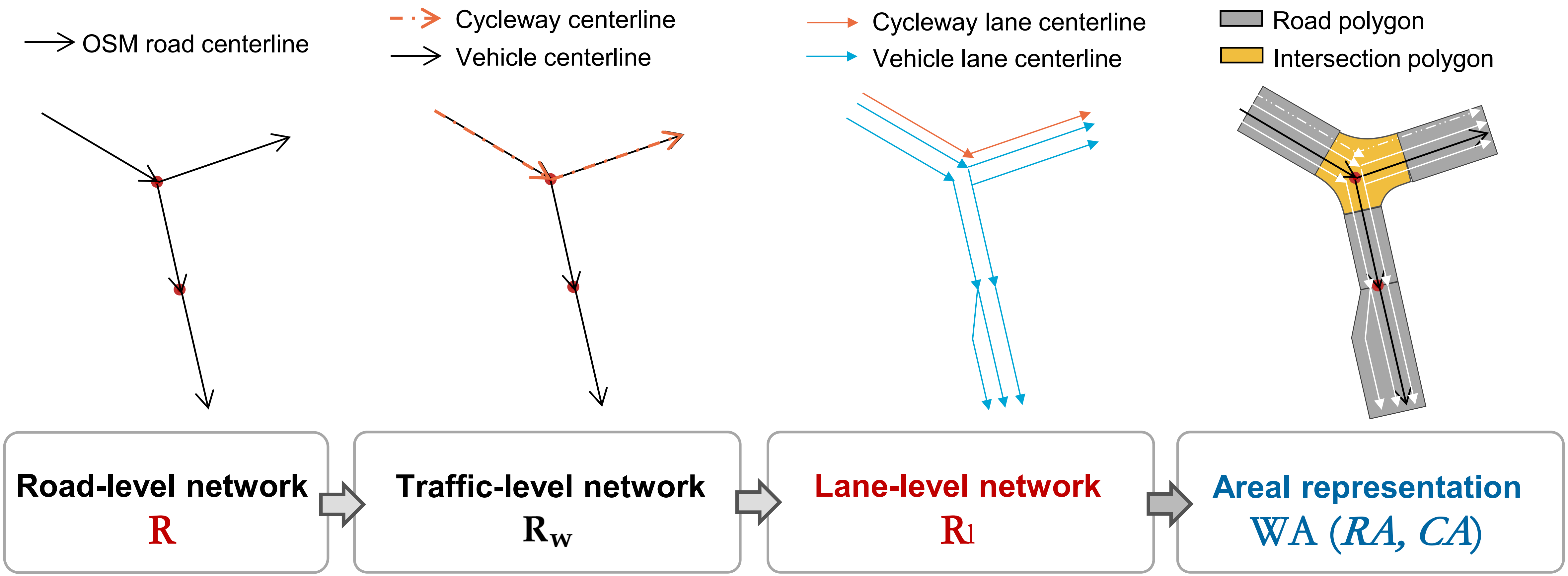
Methodology

Model design: *Procedural method*



Methodology

Model design:

Complete lanes as traffic flows in the network.

Turning attributes for the auxiliary lanes are essential for the reconstruction and alignment for ‘main route and branches’ in a stroke.

Shift linear to areal: Reused the topology connection and node degree to form the road ribbons and intersections.

Road-level network
$\mathbf{R}$

→

Traffic-level network
$\mathbf{R_w}$

- Forward vehicle roads R^{f}_{wv}
- Backward vehicle roads R^{b}_{wv}
- Cycleways & Bike lanes R_{wb}

→

Lane-level network
$\mathbf{R_l}$

- ‘through’ vehicle lanes
- ‘left_turn’ vehicle lanes
- ‘right_turn’ vehicle lanes
- ‘left_side’ bike lanes
- ‘right_side’ bike lanes
- Separate cycleways (one-way & two-ways)

→

Areal representation
$WA\ (RA, CA)$

- Lane polygons
- Road polygons

\+

True node degree

↓

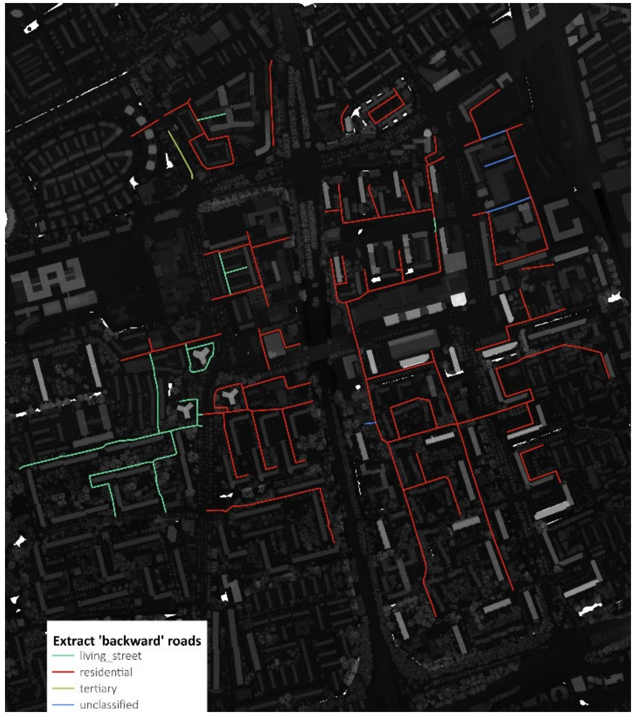
- Polygons of road ribbons
- Polygons of all types of intersections

Methodology & Results

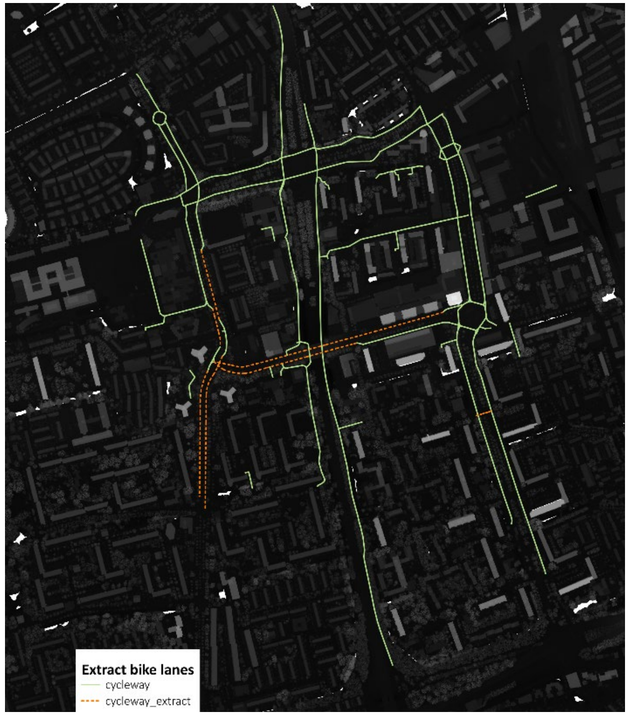
Phase 1 —— **Preparation:** OSM Road Network and Stroke → ***Subquestion 1 & 2***

Semantic information and attributes in OSM road data tags

Raw data has **393** elements as the road centerlines



Identified **120** two-way roads, so added 120 backward road centerlines with the reversed vector direction



Extracted **41** bike lanes, including 3 left bike lanes, and 38 right bike lanes

Total number of elements after data pre-processing is **554**, as the traffic-level road network.
The number of lanes of all roads are from **1 to 5**.

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Methodology & Results

***Phase 1* —— Preparation:** OSM Road Network and

Semantic information and attributes in OSM road data tags

Tags ---

*highway =**
*cycleway =**
*name =**

Raw data has **393** elements as the road centerlines.
Region: Delft.

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Methodology & Results

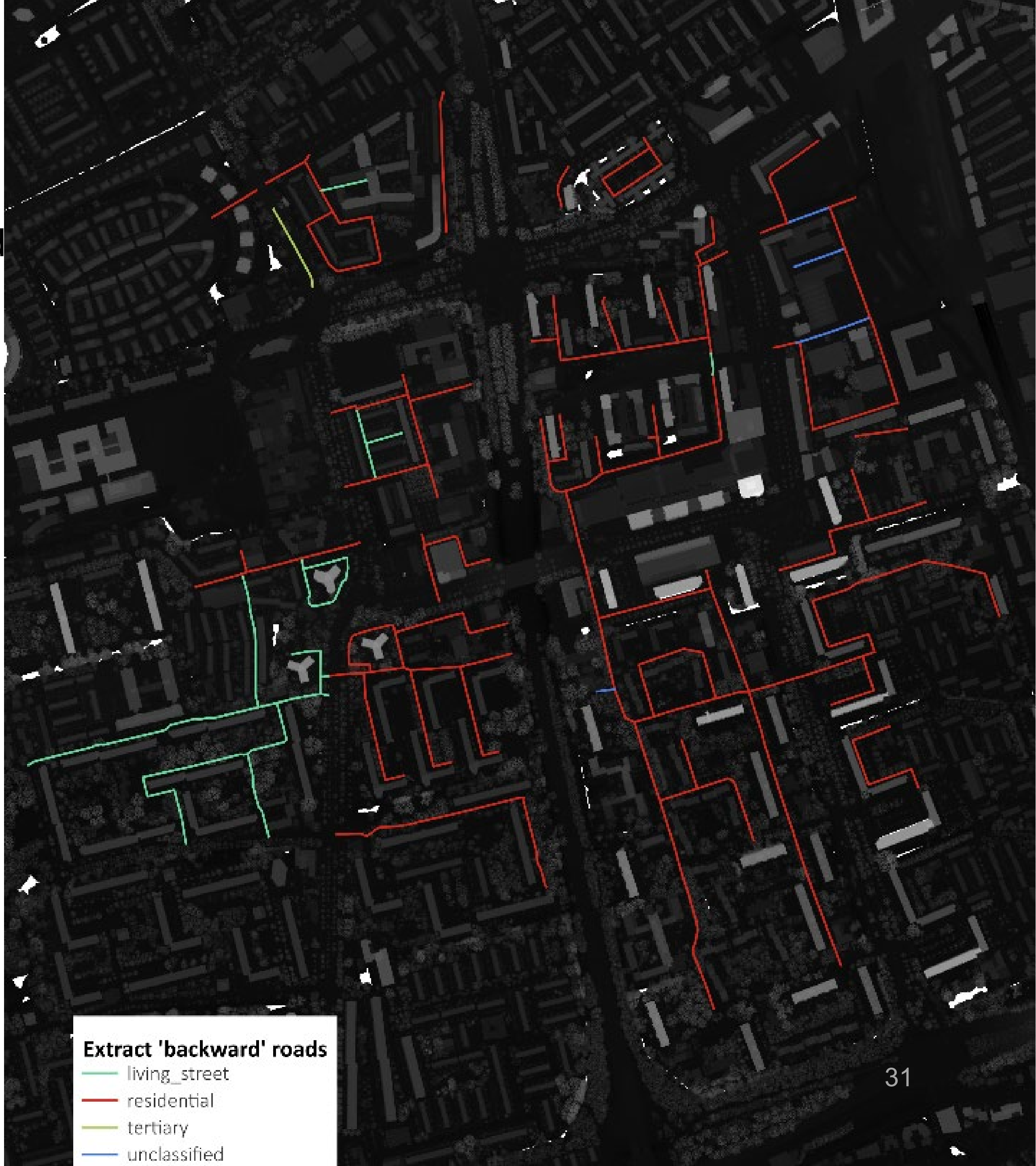
Phase 1 —— **Preparation:** OSM Road Network and

Semantic information and attributes in OSM road data tags

Tags ---

oneway =*
cycleway =*

Identified **120** two-way roads, so added **120 'backward'** road centerlines with the **reversed vector direction.**



Methodology & Results

***Phase 1* —— Preparation:** OSM Road Network and

Semantic information and attributes in OSM road data tags

Tags ---

*cycleway =**

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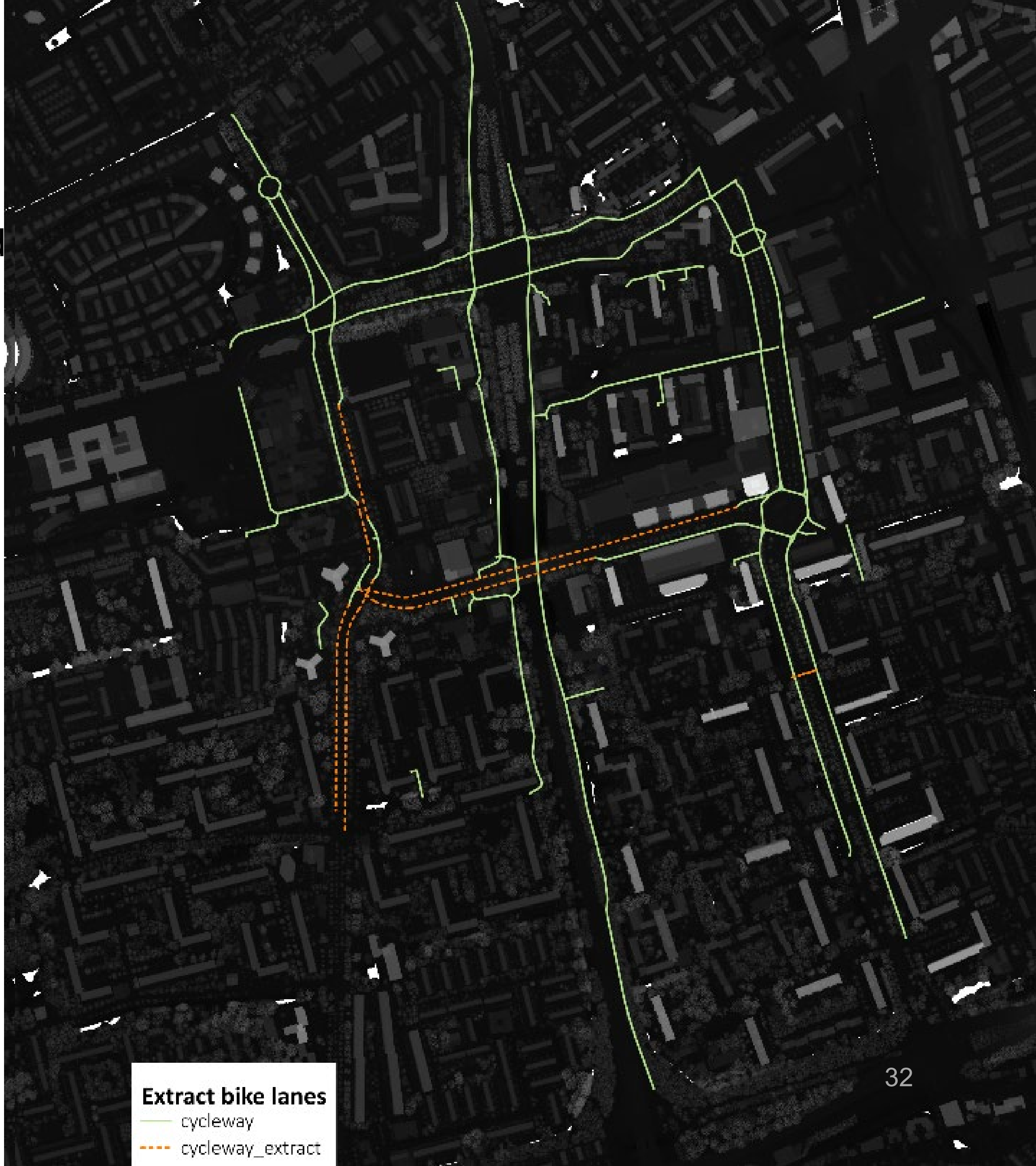


Methodology & Results

***Phase 1* —— Preparation:** OSM Road Network and

Semantic information and attributes in OSM road data tags

Tags ---

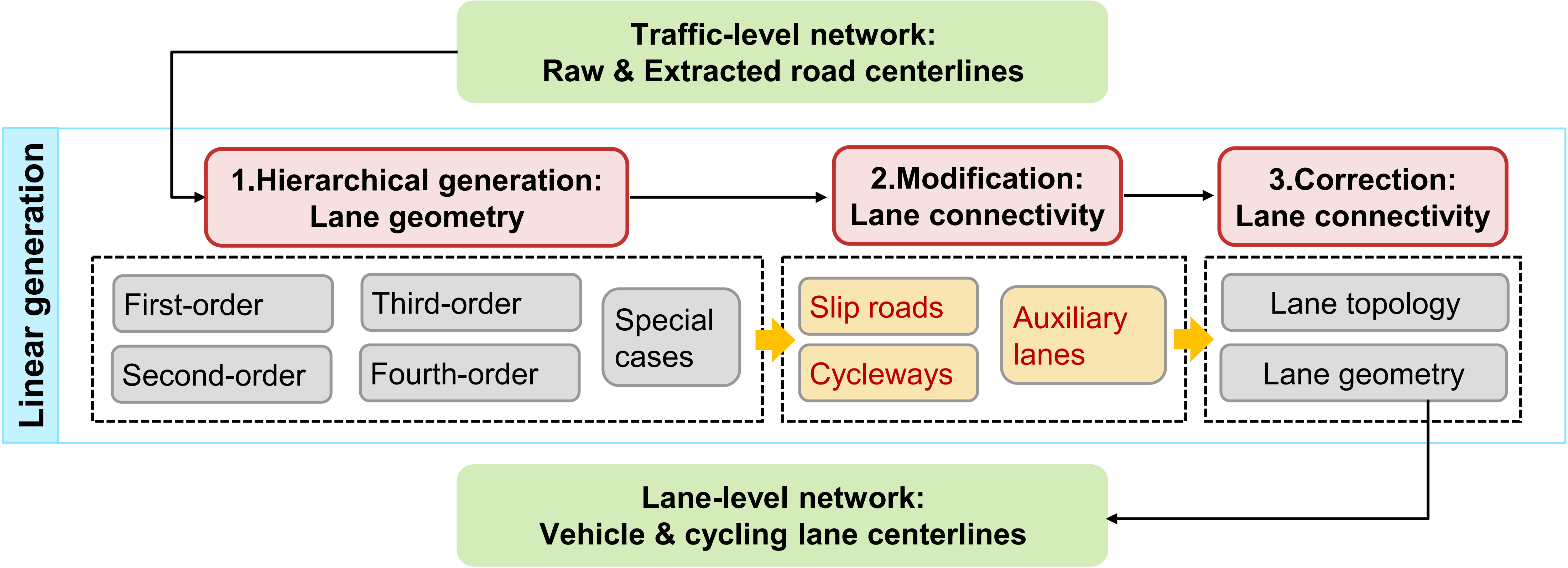
*cycleway =**
*lanes =**
*oneway =**
*turn =**

Total number of elements after data pre-processing is **554**, as the traffic-level road network. The number of lanes of all roads are from **1 to 5**.

Methodology

*Can the topology relationships, **lane-to-lane adjacency** for representing traffic flow movements, be preserved through OSM data processing and detailed generation methods?*

Phase 2 —— **Linear Generation:** Lane Network Reconstruction → ***Subquestion 3***



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Methodology

***Phase 2* —— Linear Generation: Lane Network**

Hierarchical generation: Lane geometry

- Lane topology correctness:
  '***Lane connectivity'***

Road-level:

One-way roads:

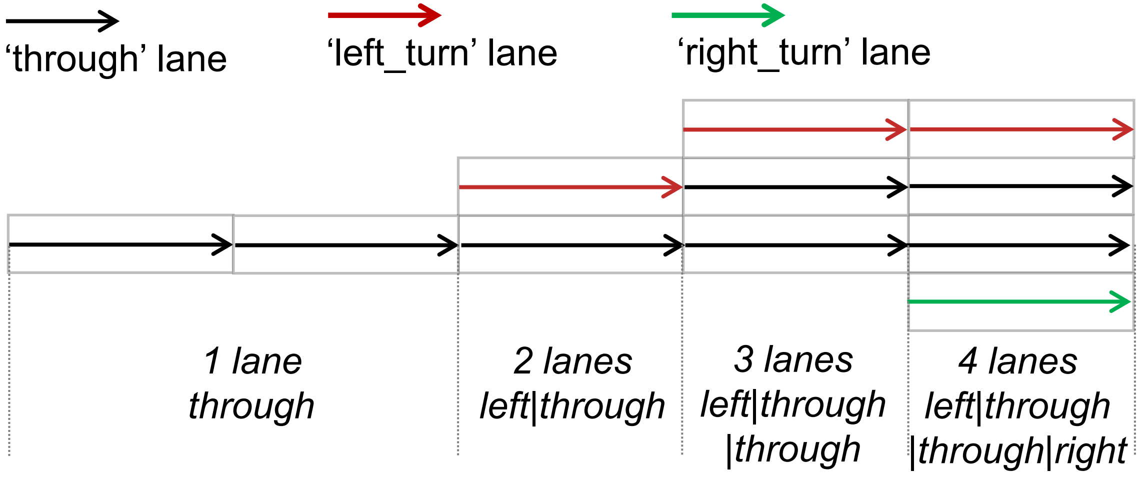
1st -3rd steps
for all the one-way roads

'basic number of lanes' within each 'grouped stroke'

Hierarchical orders of all the roads

Lane-matching method

Hierarchical roads and lane-level stroke



Methodology

***Phase 2* —— Linear Generation:** Lane Network

Hierarchical generation: Lane geometry

- Lane topology correctness: ***'Lane connectivity'***

Road-level:

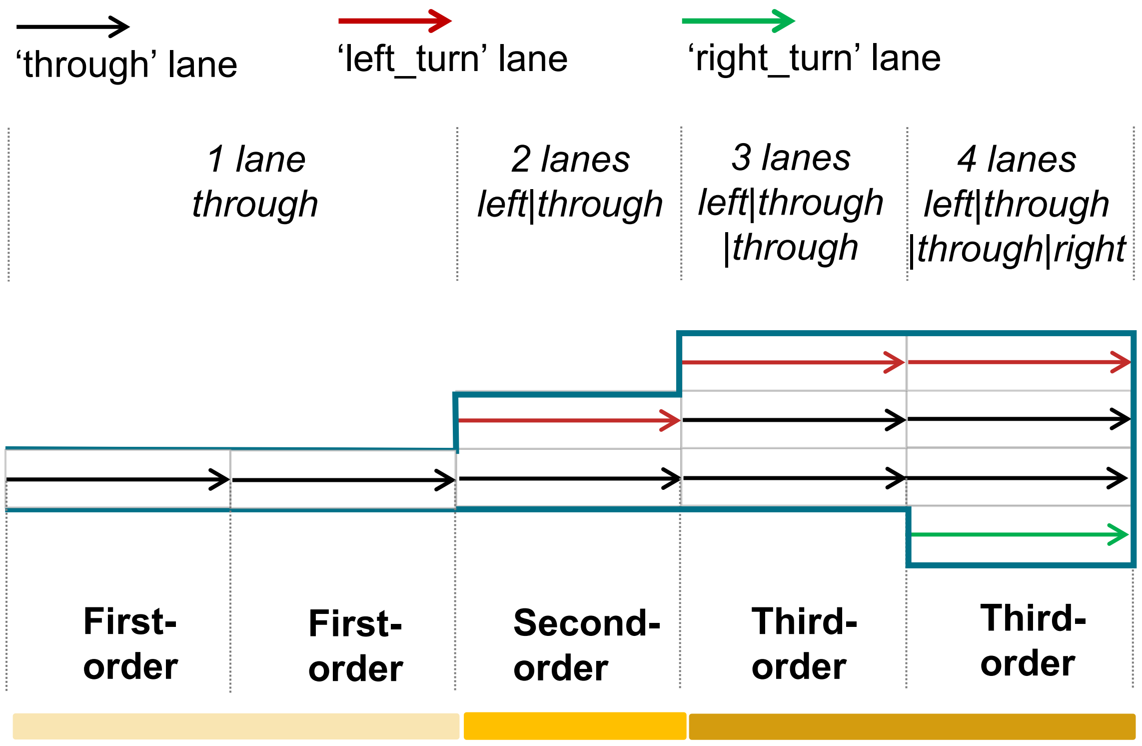
One-way roads:

1^{st} -3^{rd} steps
for all the one-way roads

'basic number of lanes' within each 'grouped stroke'

Hierarchical orders of all the roads

Lane-matching method



Road centerline is also the center axis of road polygon since no auxiliary lanes

Find the **"best-matching"** location for generating the **most connected** result

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Methodology

***Phase 2* —— Linear Generation:** Lane Network Reconstruction

Hierarchical generation: Lane geometry

- Lane topology correctness:
  '***Lane connectivity***'

Traffic-level network
$\mathbf{R_w}$

R^f_{wv} R^b_{wv} R_{wb}

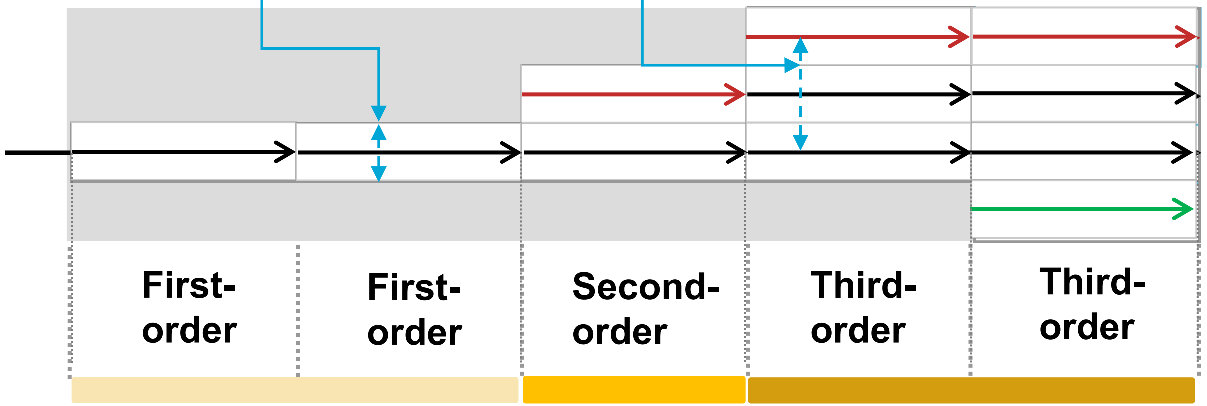
Different traffic flow with the **same geometry and location as the raw centerline**

Lane-level network
$\mathbf{R_l}$

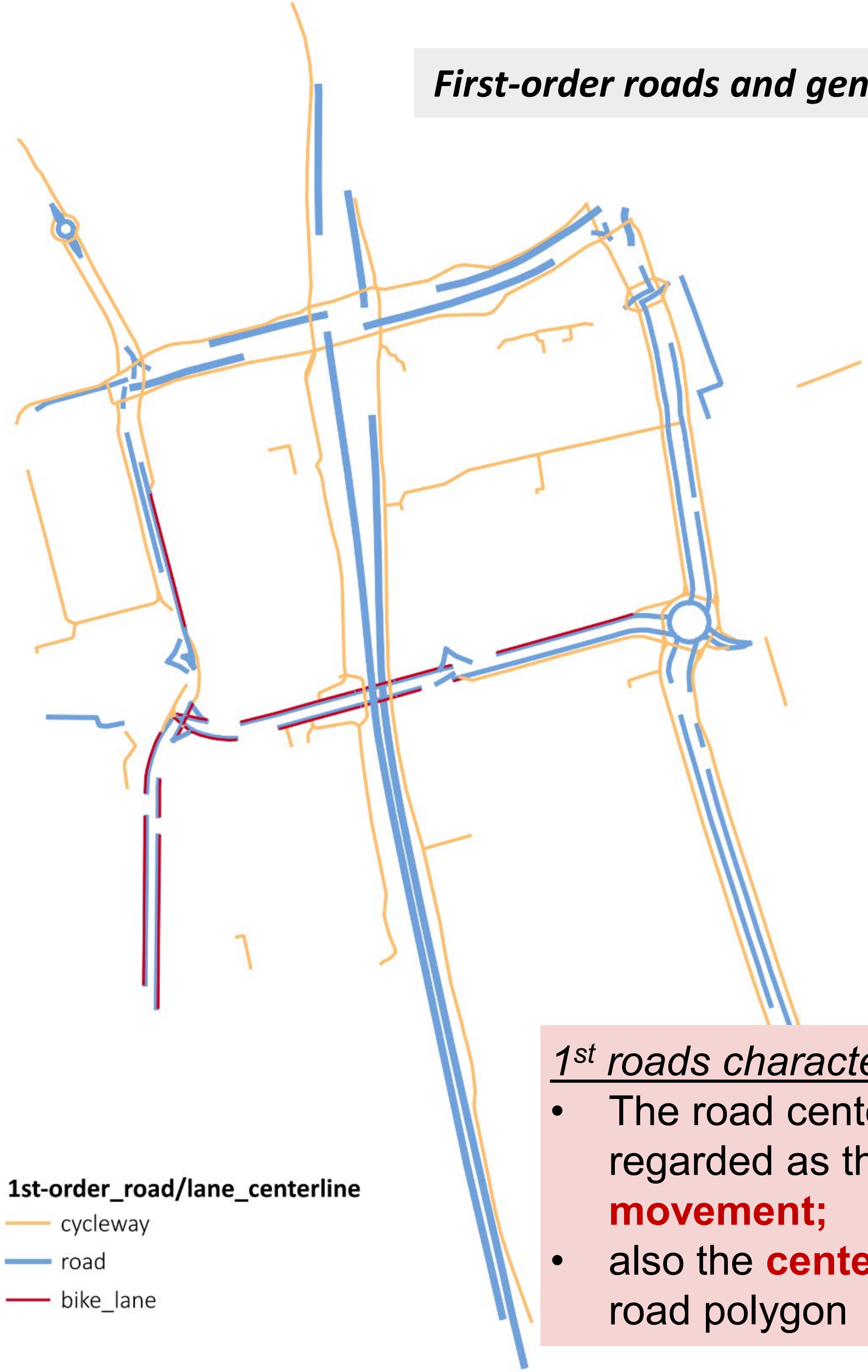
- 'through' vehicle lanes
- 'left_turn' vehicle lanes
- 'right_turn' vehicle lanes
- 'left_side' bike lanes
- 'right_side' bike lanes
- Separate cycleways (one-way & two-ways)

$$\mathbf{r_l} = \mathbf{L_r} = \{\mathbf{l}_i\}_{i=1}^{a}$$
$$\mathbf{l} = (I_r, I_w, V_l, VS_l, VE_l, Q_l)$$
$$\mathbf{Q_l} = (M_l, H_l, T_l, D_l, \boxed{W_l}, \boxed{FD_l})$$

- *Lane width*
- *Relative offset distance to the raw centerline*

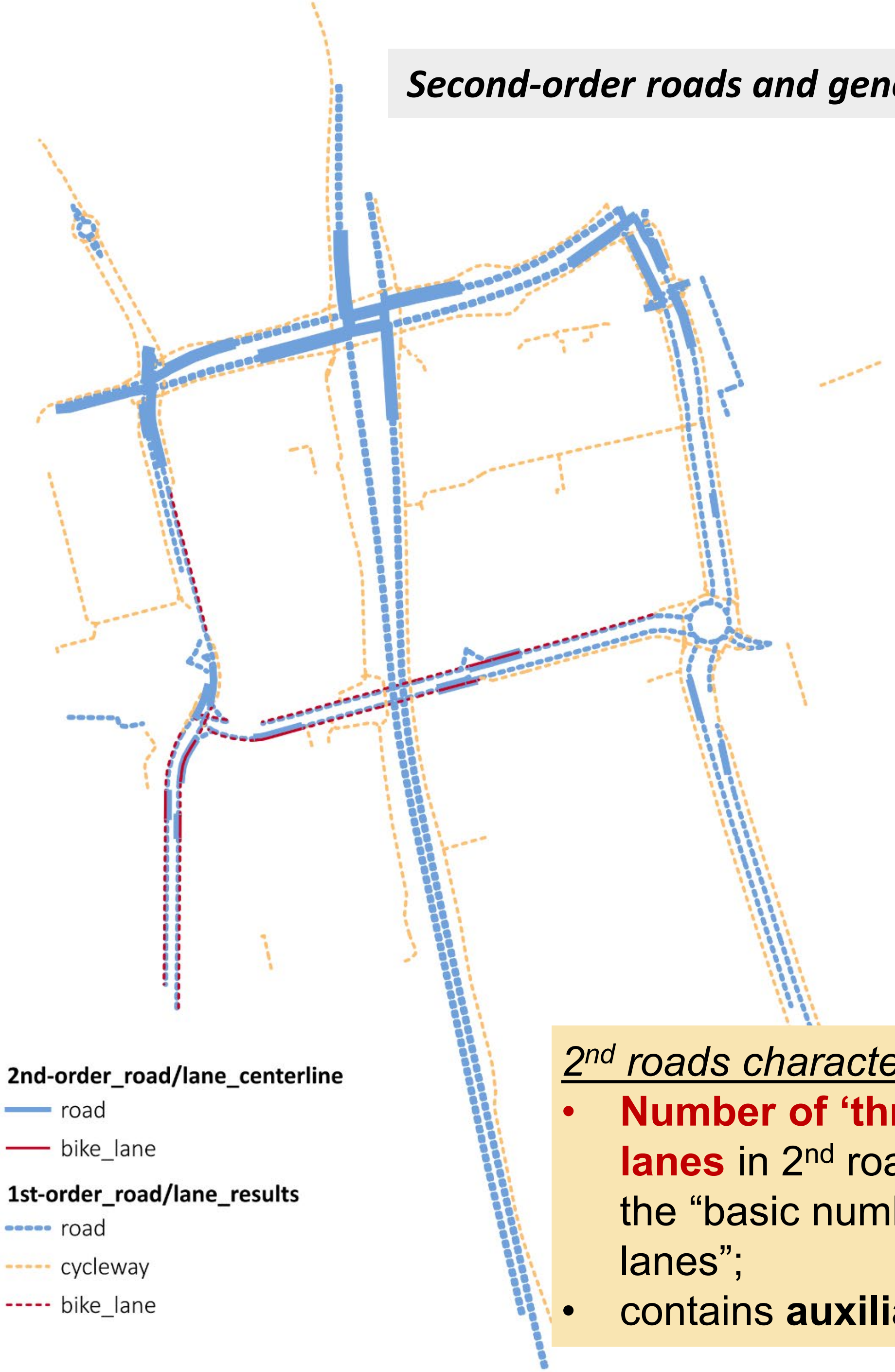


First-order roads and generated lanes



1st roads characteristics:
- The road centerline is regarded as the **shape of movement;**
- also the **center axis** of the road polygon

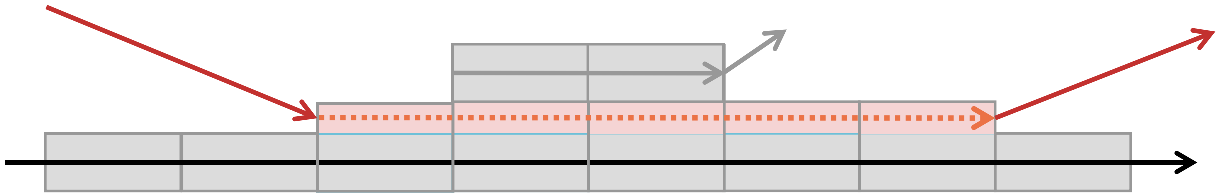
Second-order roads and generated lanes



2nd roads characteristics:
- **Number of 'through' lanes** in 2nd roads equal to the "basic number of lanes";
- contains **auxiliary lanes**

Methodology & Results

Phase 2 —— **Linear Generation:** Lane Network Reconstruction



Vehicle lane centerline

Vehicle lane area

Separated cycleway centerline

Bike lane centerline

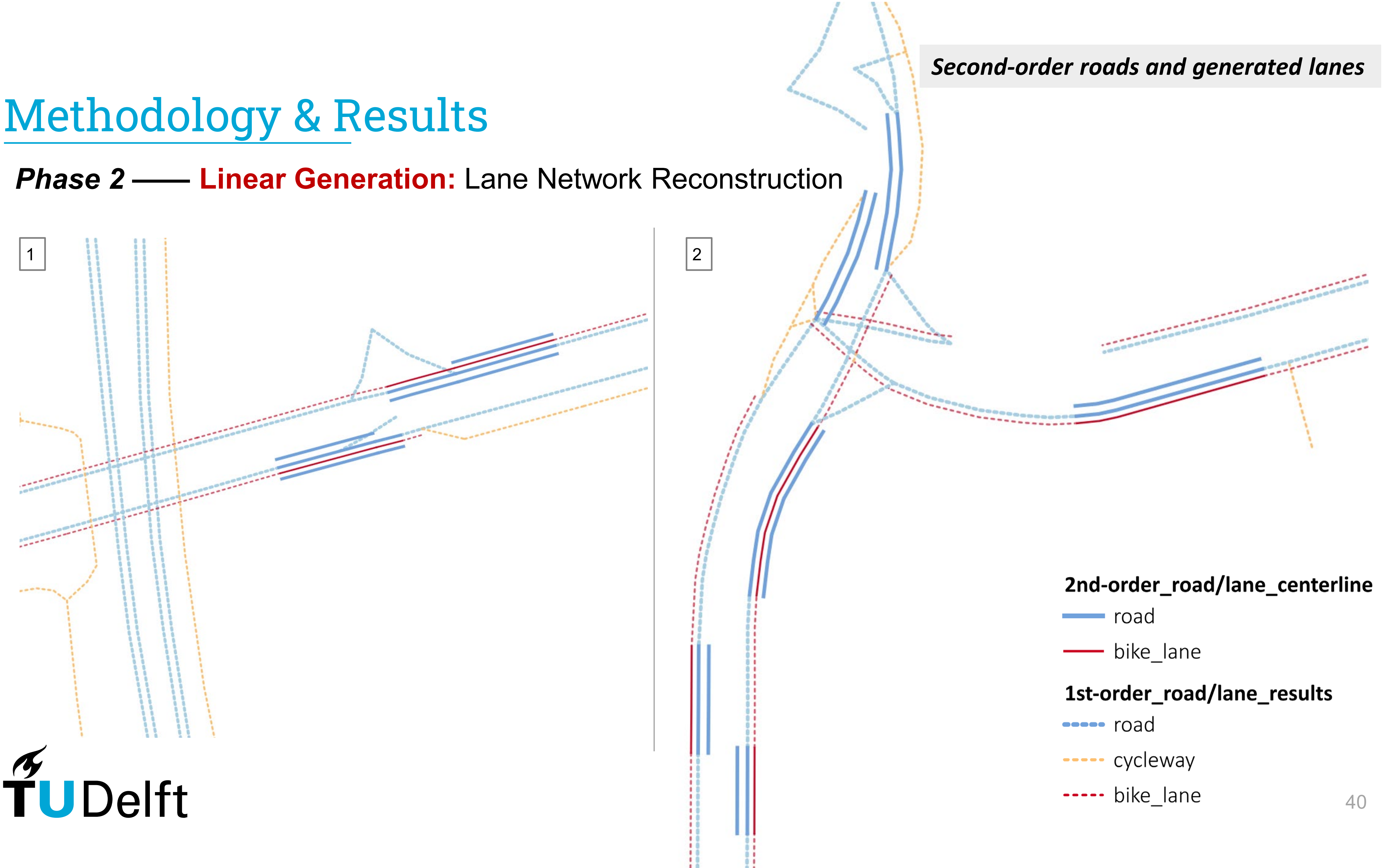
Bike lane area

Lane-matching method in 2nd road step:

- If the adjacent 1st road has generated **"bike lane",** then set the matching priority as: match the adjacent bike lanes firstly.
- Otherwise, match the 'through' lanes.

Methodology & Results

Phase 2 —— **Linear Generation:** Lane Network Reconstruction



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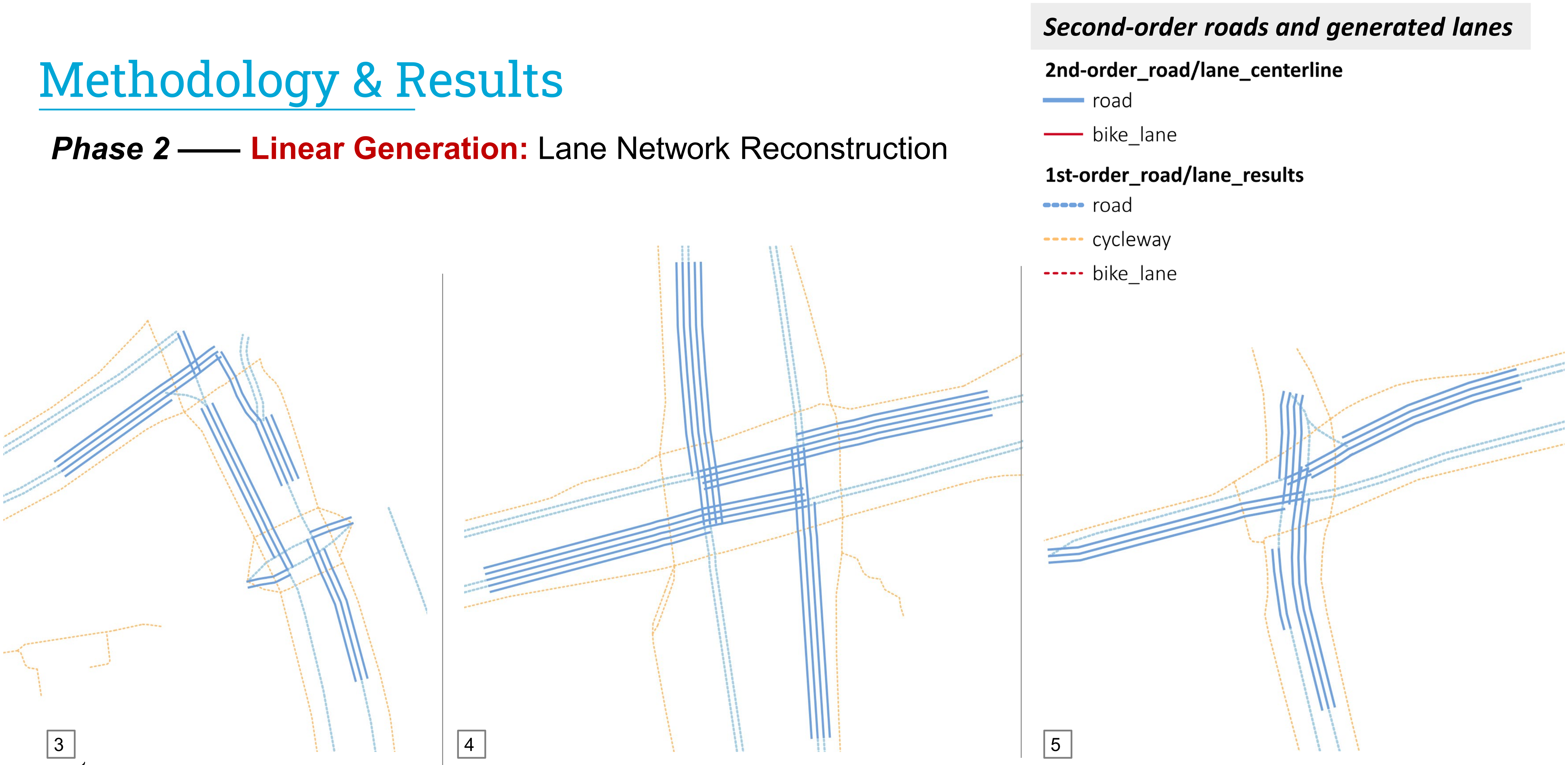
Methodology & Results

***Phase 2* —— Linear Generation: Lane Network Reconstruction**



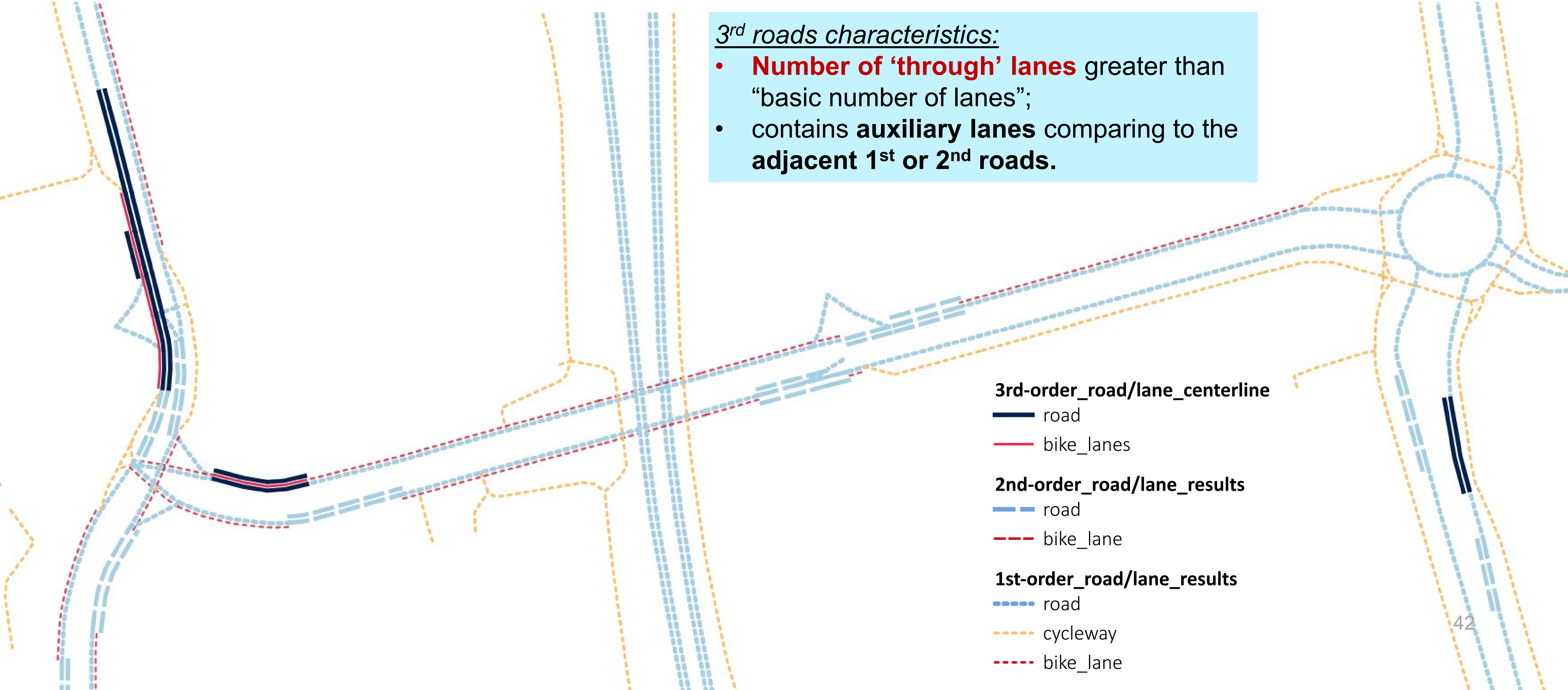
Methodology & Results

***Phase 2* —— Linear Generation:** Lane Network Reconstruction

Third-order roads and generated lanes

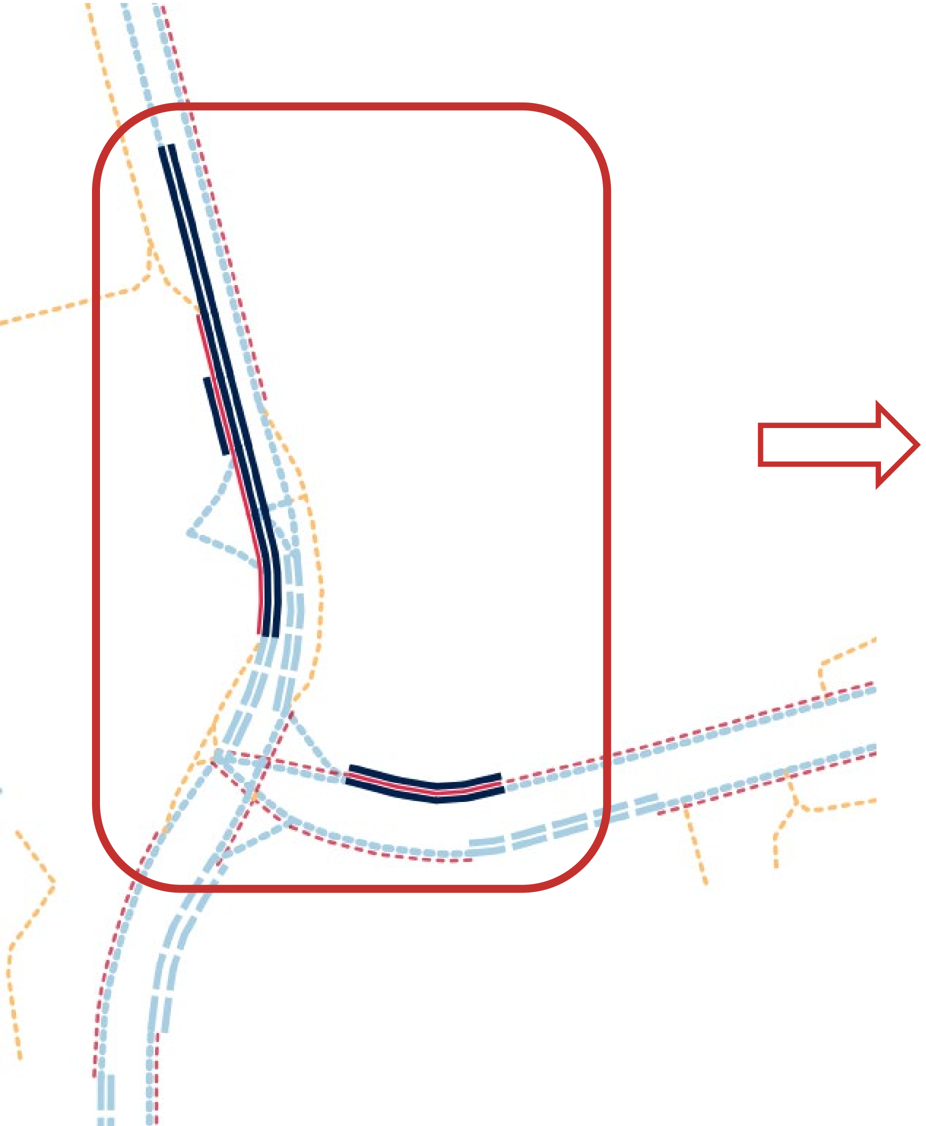
3rd roads characteristics:

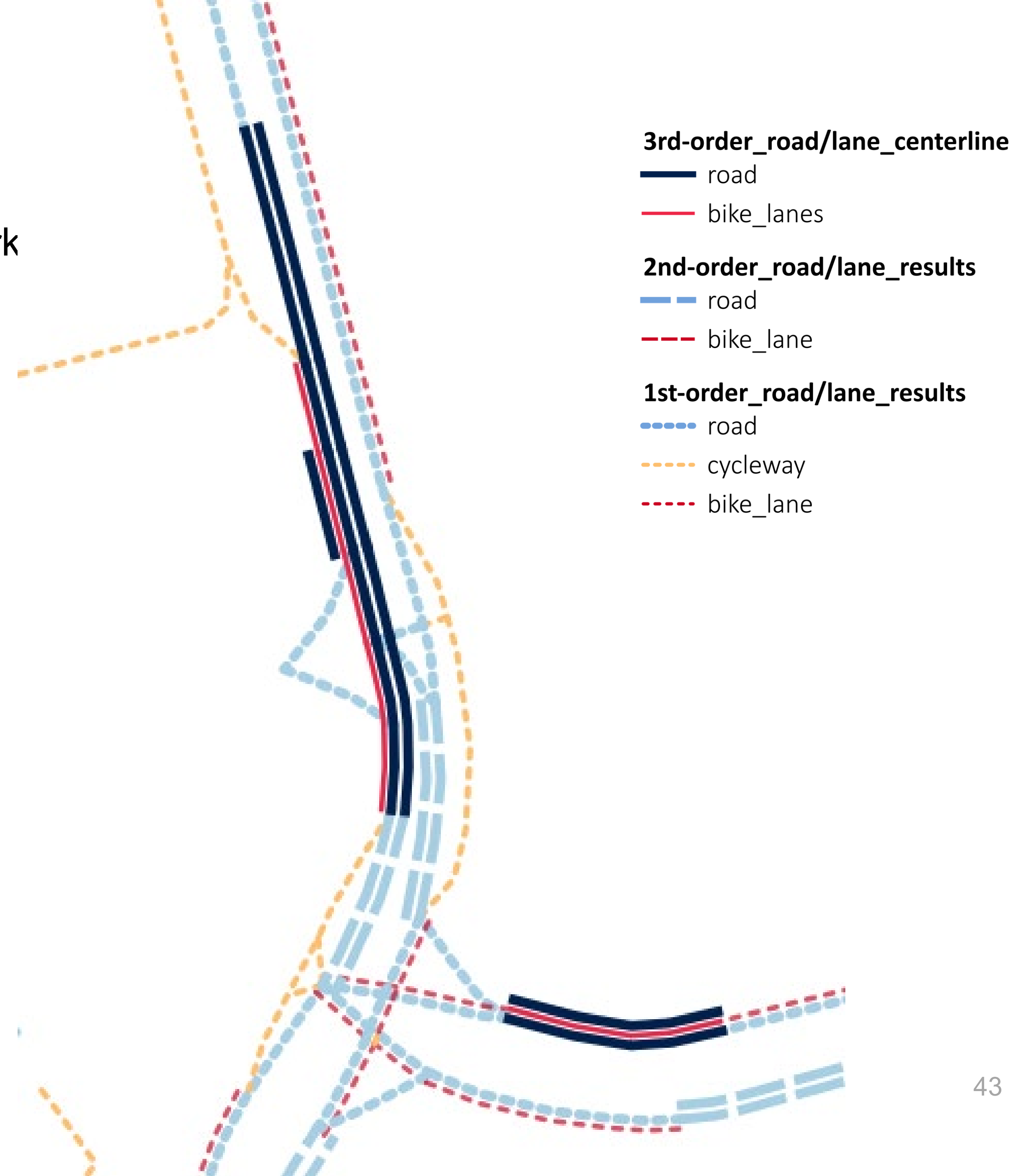
- **Number of 'through' lanes** greater than "basic number of lanes";
- contains **auxiliary lanes** comparing to the **adjacent 1st or 2nd roads.**



Methodology & Results

***Phase 2* —— Linear Generation:** Lane Network



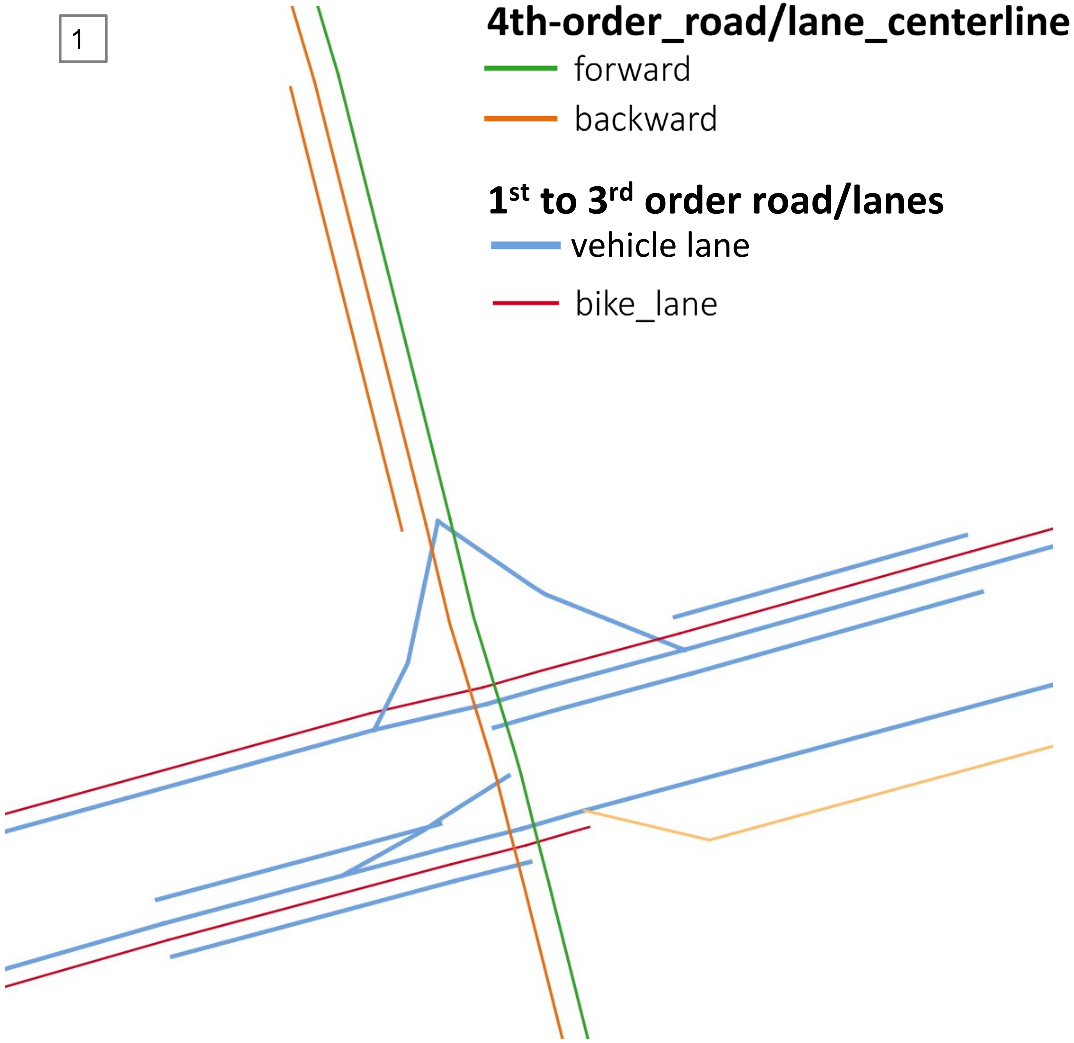


Methodology & Results

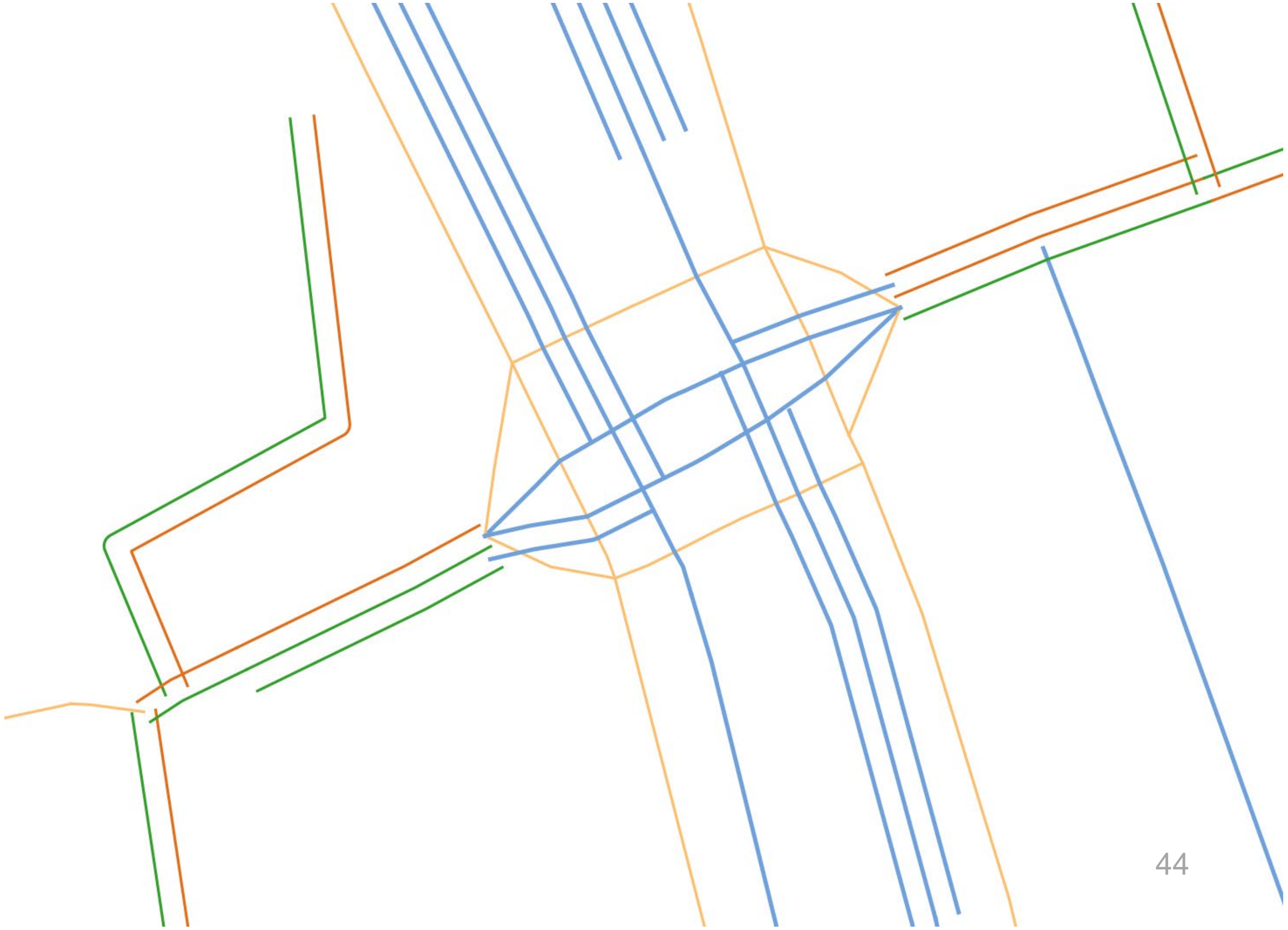
***Phase 2* —— Linear Generation:** Lane Network Reconstruction

Fourth-order roads and generated lanes

1



2



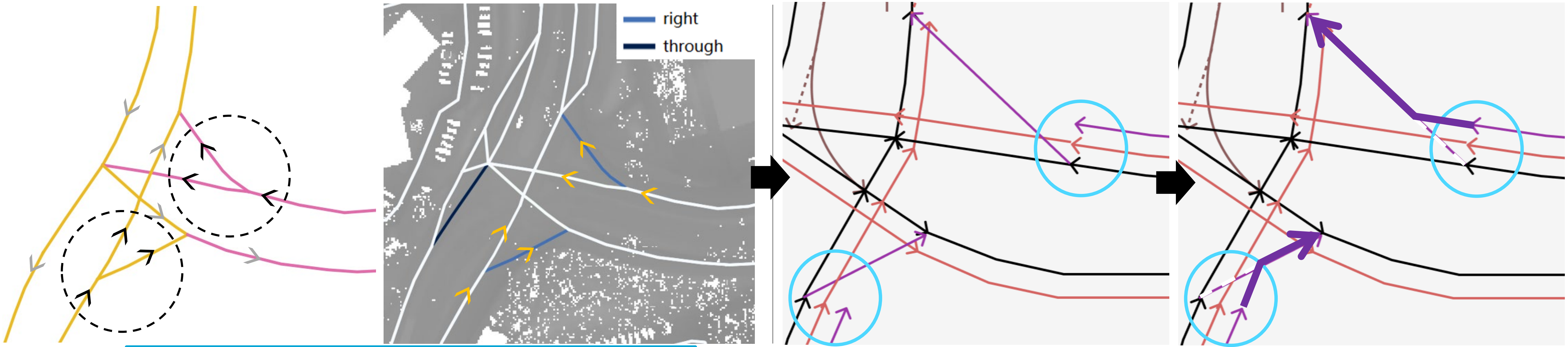
Methodology & Results

Phase 2 —— **Linear Generation:** Lane Network Reconstruction

Lane-level Network Connectivity Modification

- Lane topology correctness: ‘***Lane connectivity’***

Slip roads: •*‘slip road’ label* **+** *Global and local adjacency*



Phase 1: grouped strokes + slip road labels

Slip road topology & geometry modifications

Methodology & Results

Phase 2 —— Linear Generation: Lane Network Reconstruction

Lane-level Network Connectivity Modification

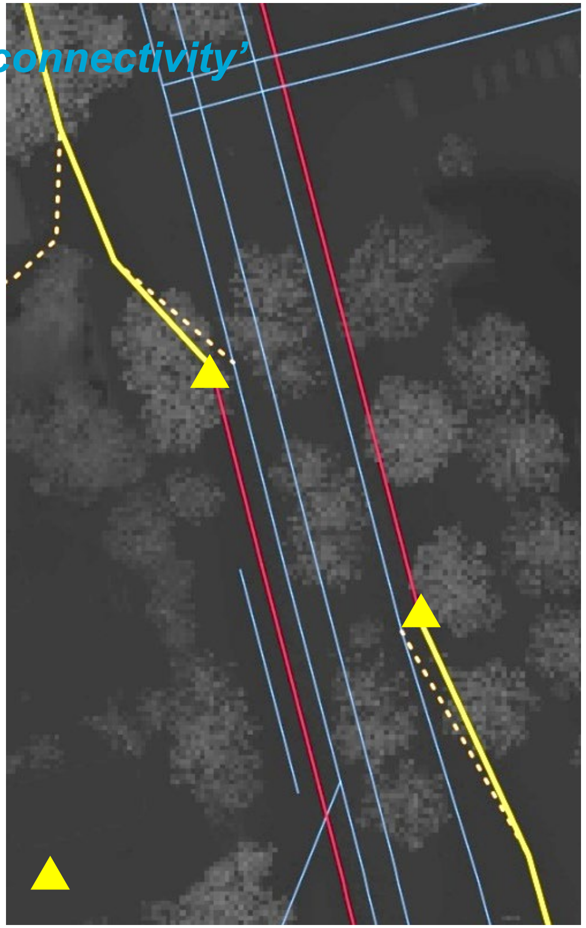
- Lane topology correctness: '***Lane connectivity***'

Separated cycleways:

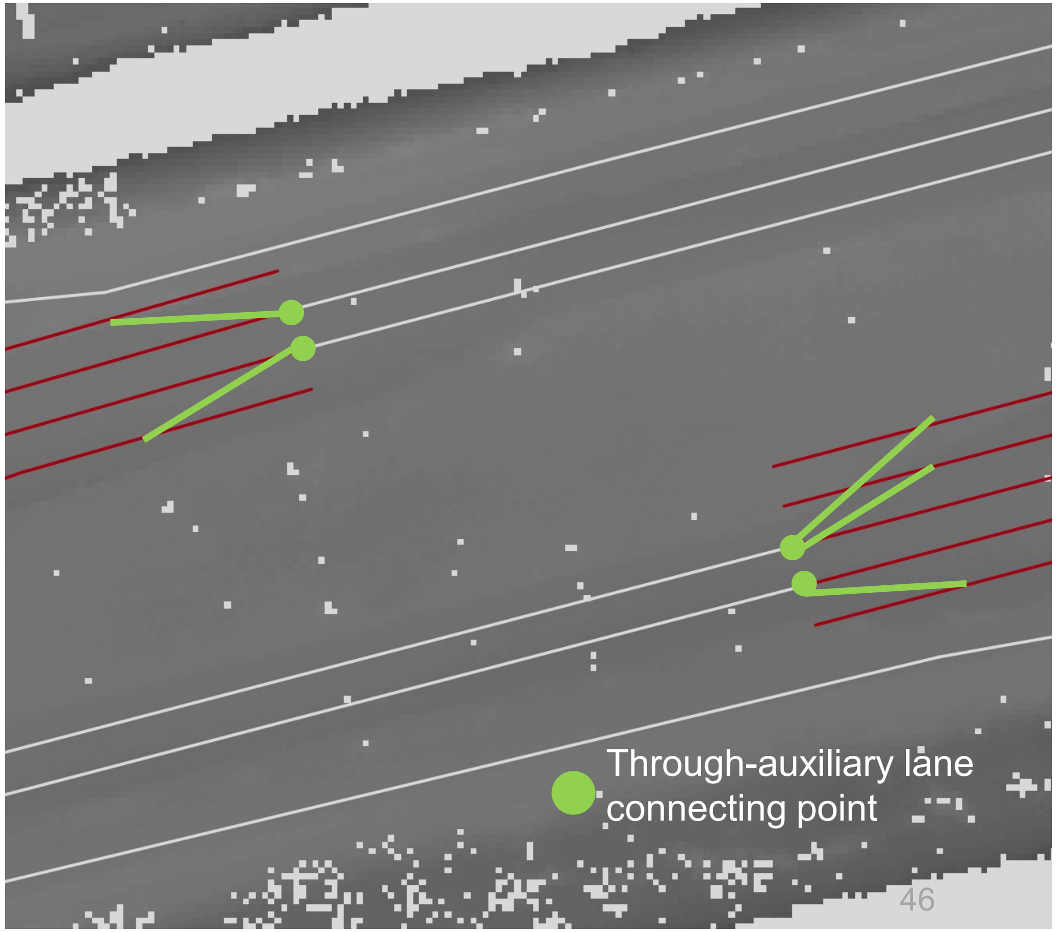
- *'highway=cycleway/bike lane' label*
- *Global and local adjacency*

Auxiliary lanes:

- *'turn' label*
- *Local adjacency*



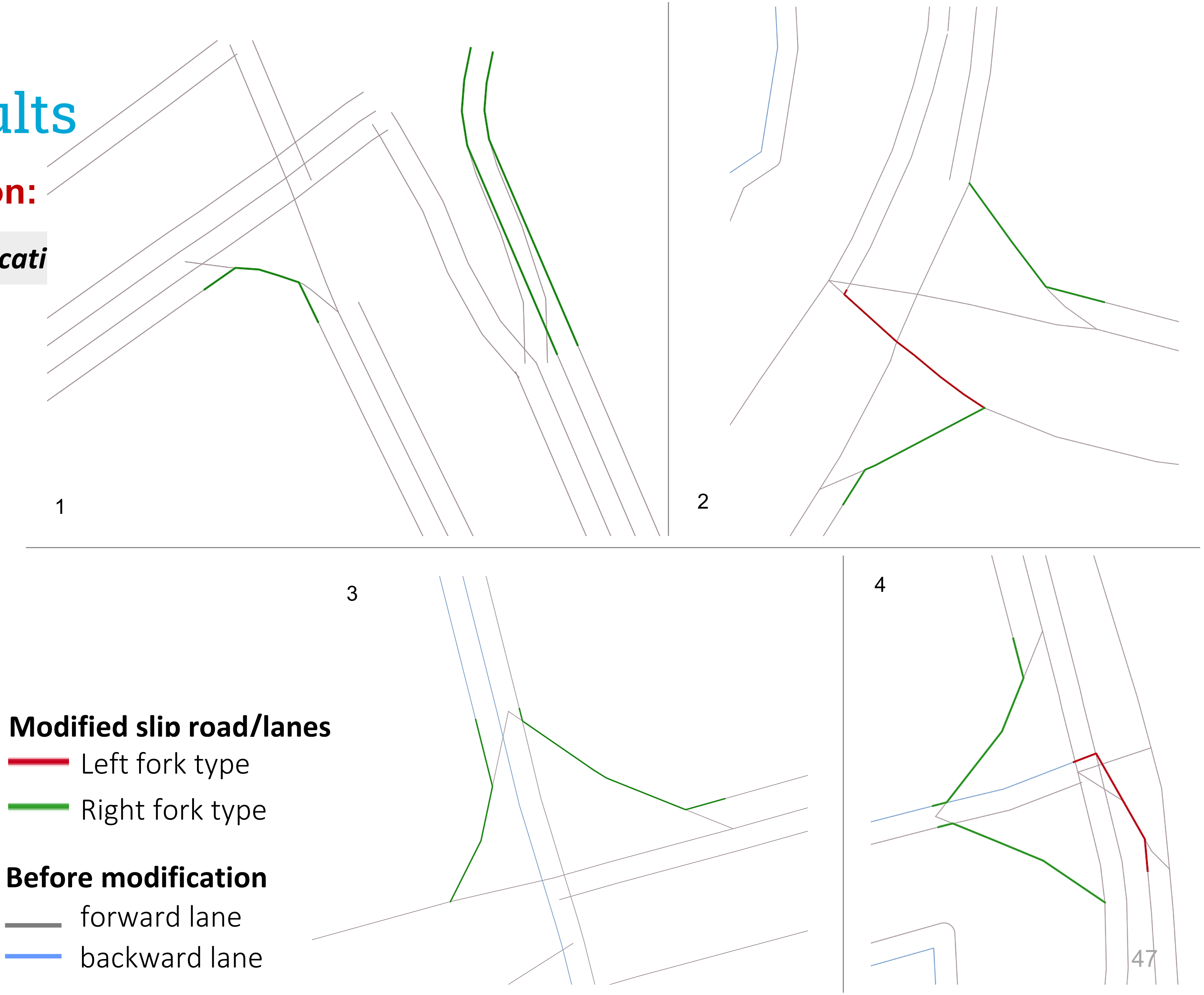
Cycleway-bike lane connecting point



Methodology & Results

***Phase 2* —— Linear Generation:**

Lane-level Network Connectivity Modificati



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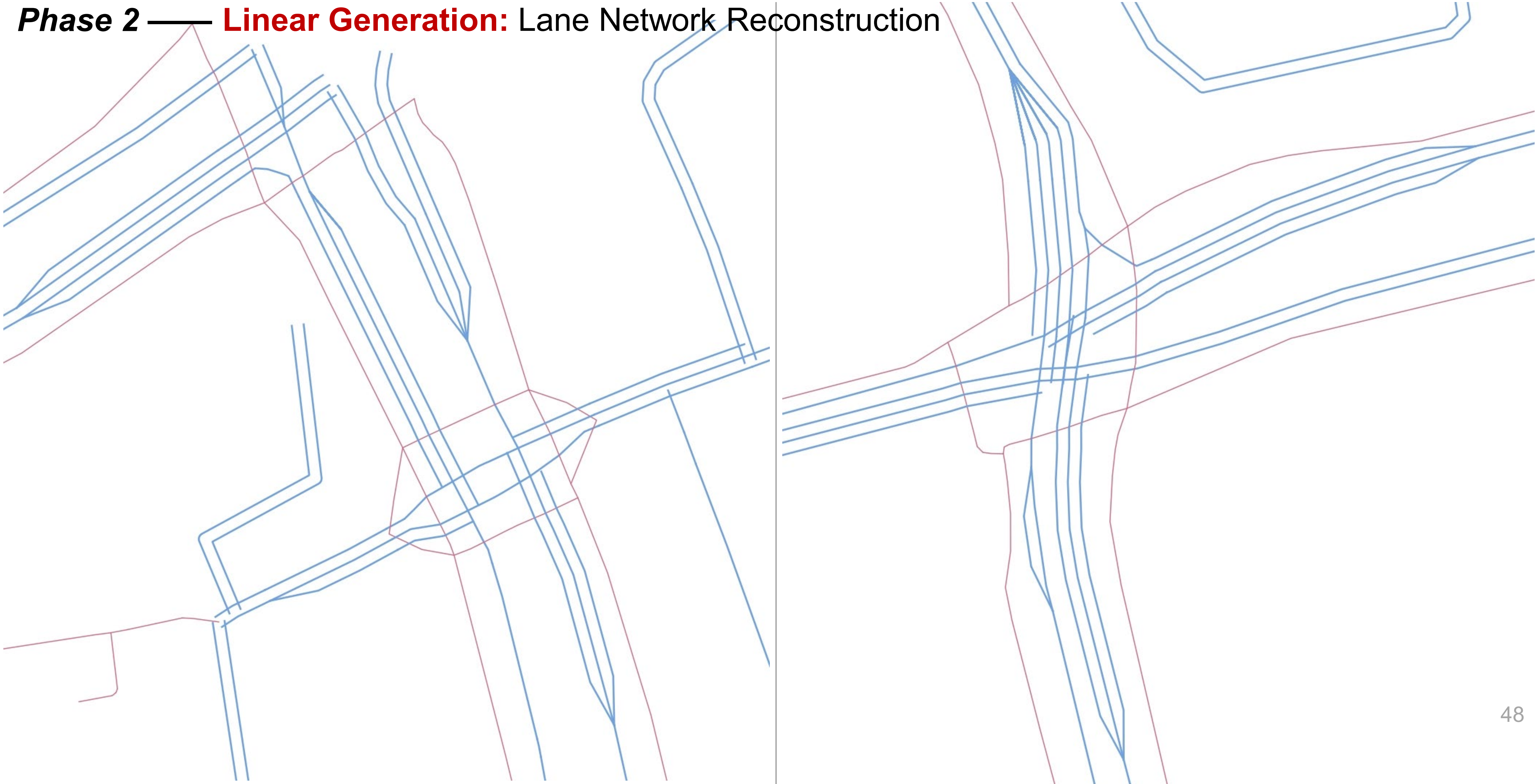
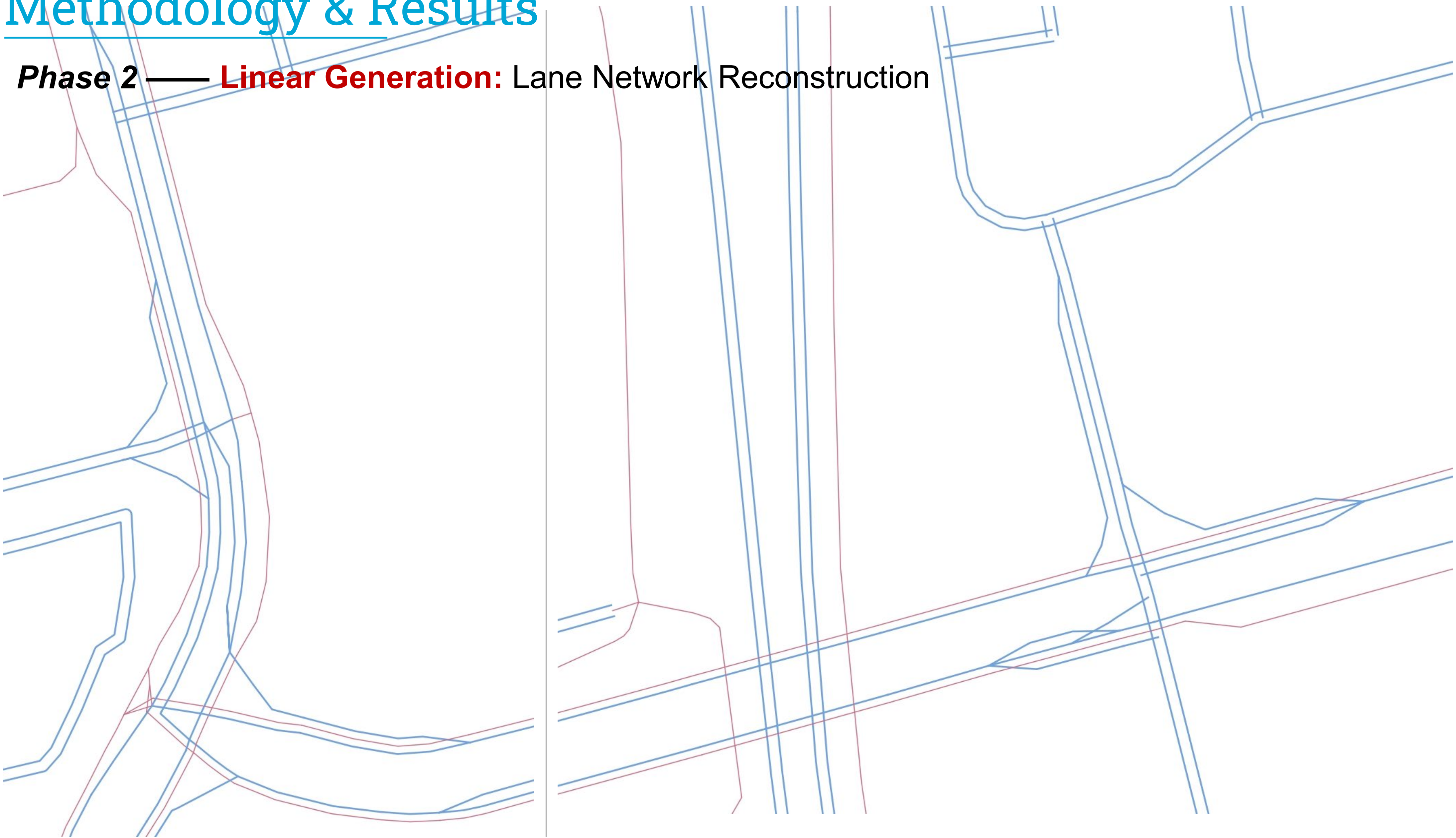
Methodology & Results

Phase 2 —— **Linear Generation:** Lane Network Reconstruction



Methodology & Results

***Phase 2* —— Linear Generation:** Lane Network Reconstruction



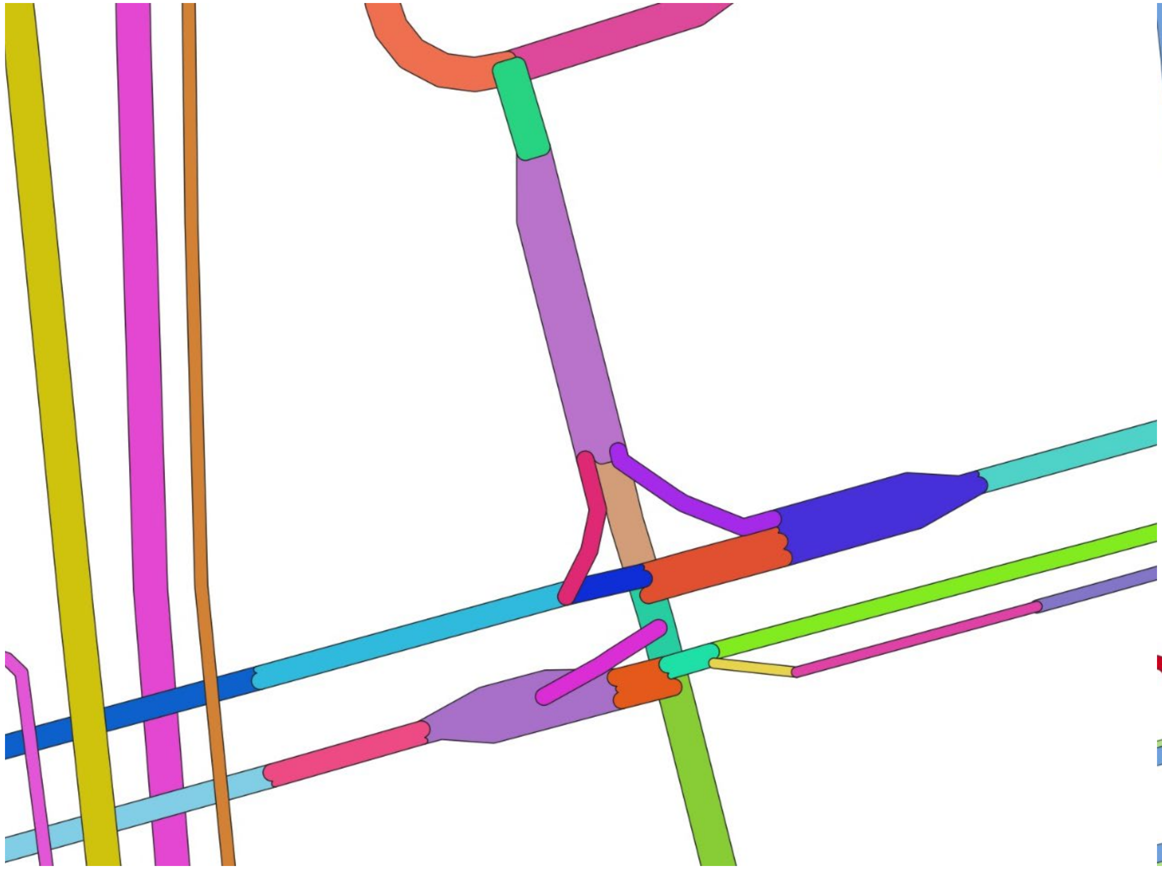
Methodology & Results

How can we generate 2D road polygons as ***errorless*** *geometries to accurately capture* ***road shape details****, including changes in road width and* ***intersection variations****?*

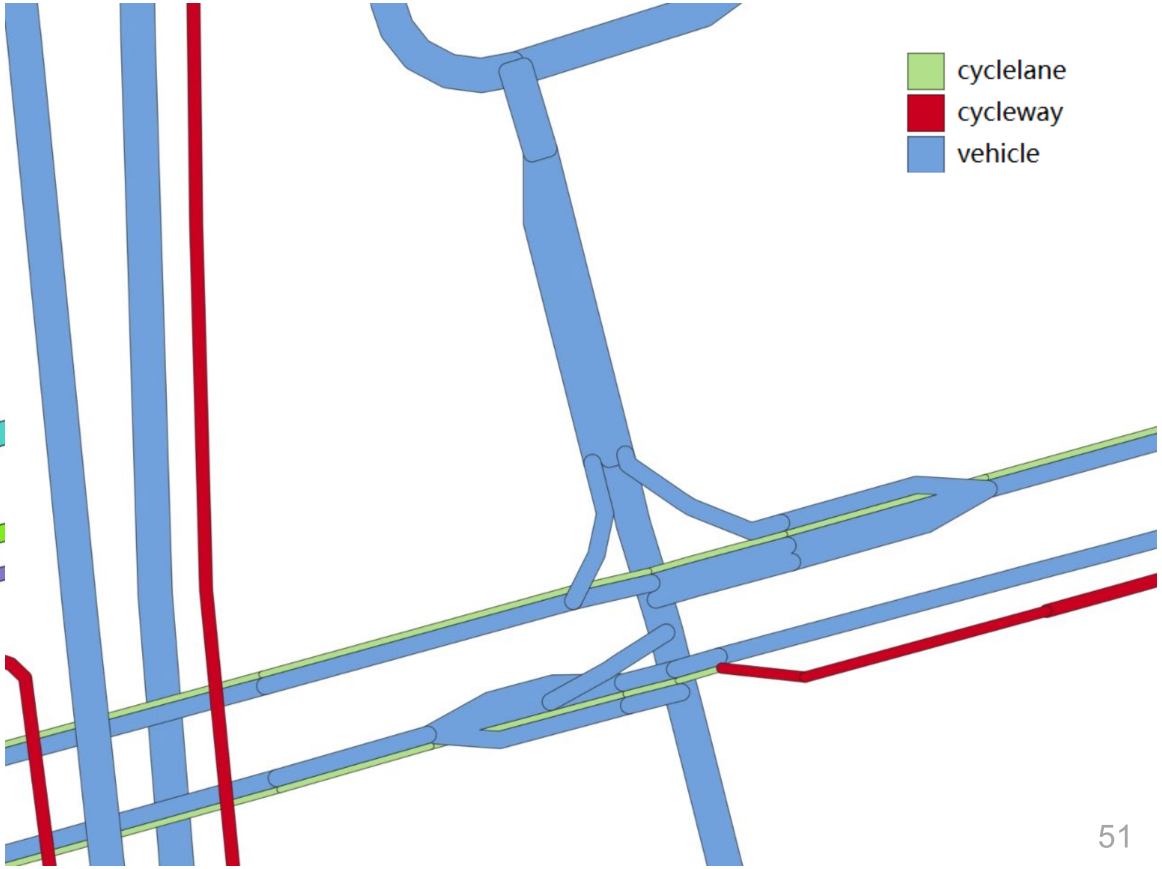
Phase 3 —— Areal Generation: 2D Road Polygon Reconstruction

Subquestion 4

- ***Road polygon merged by road indices***



- ***Road polygon merged by traffic mode types***



Methodology & Results

Phase 3 —— **Areal Generation:** 2D Road Polygon Reconstruction

⇨ ***Subquestion 4***

Node degree-based method for road polygon post-processing

- ***errorless** geometries*

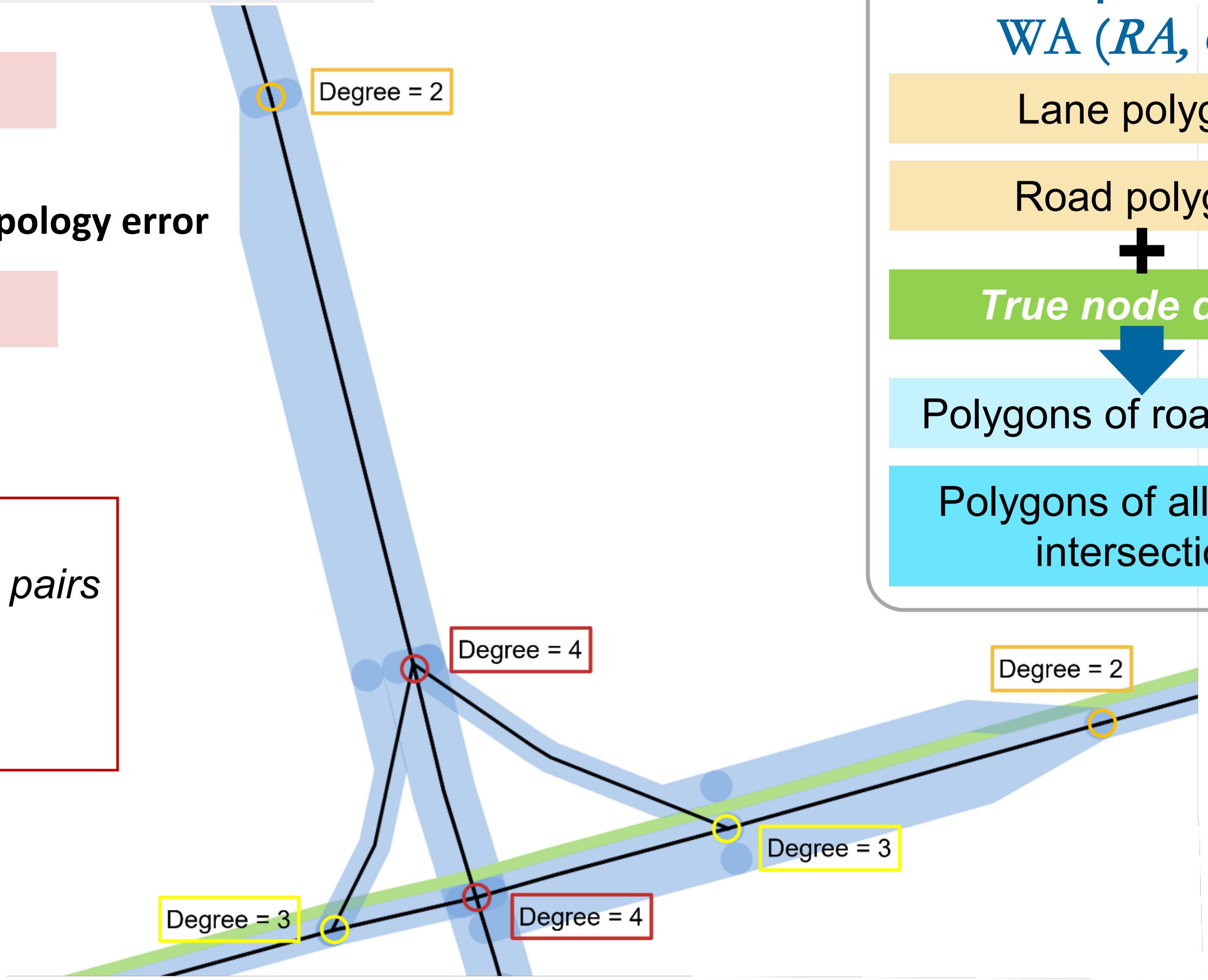
  Road polygons without overlapping;
  Trim the error parts caused by lane topology error

- ***intersection variations***

  Identify all the intersections;
  Generate intersection polygons.

If "true node degree is 2" → *trim the overlapping road polygon as pairs*

Elif "true node degree > 2" → *generate intersection polygon*



Areal representation

WA (*RA*, *CA*)

Lane polygons

Road polygons

+

True node degree

Polygons of road ribbons

Polygons of all types of intersections

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Methodology & Results

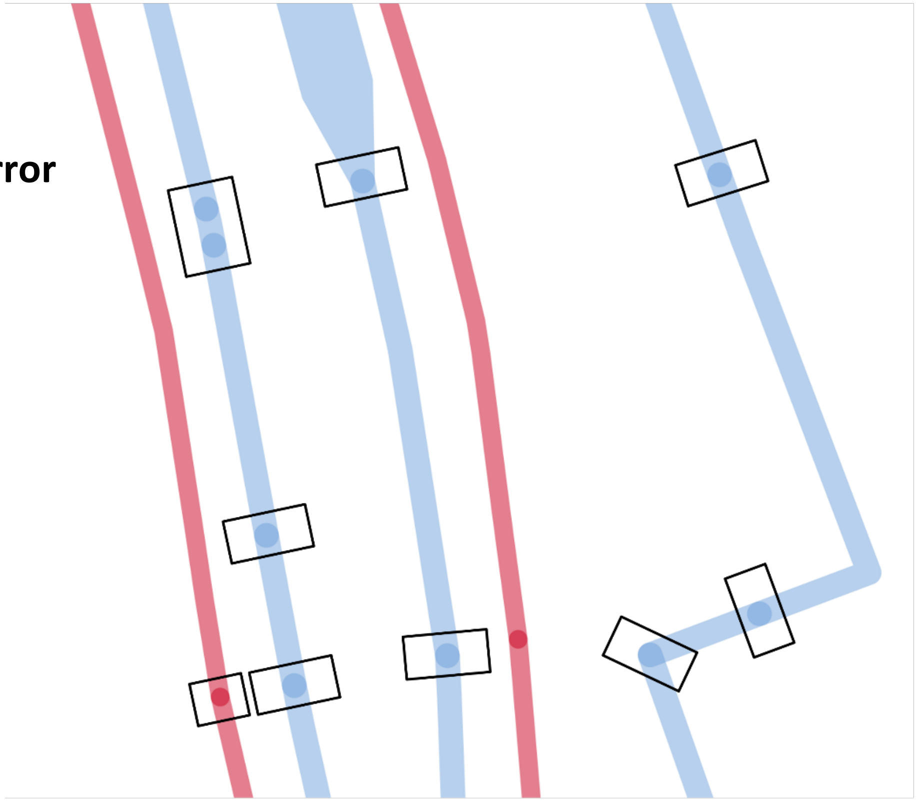
Phase 3 —— Areal Generation: 2D Road Polygon Reconstruction

Node degree-based method for road polygon post-processing

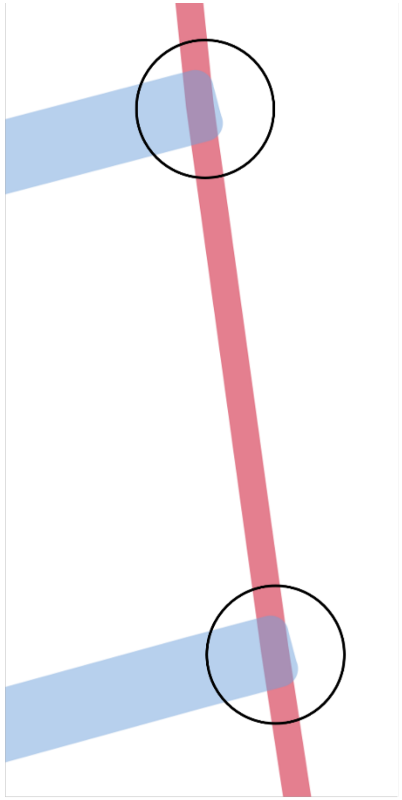
- *errorless geometries*

→ **Road polygons without overlapping;**
Trim the error parts caused by lane topology error

If "true node degree is 2" →
trim the overlapping road polygon as pairs



a) Node degree = 2:
remove overlapping part from adjacent roads



b) Node degree greater than 2,
and road width not equal:
remove protruding part from road

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Methodology & Results

***Phase 3* —— Areal Generation:** 2D Road Polygon Reconstruction

Node degree-based method for road polygon post-processing

- *errorless geometries*

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Methodology & Results

Phase 3 —— **Areal Generation:** 2D Road Polygon Reconstruction

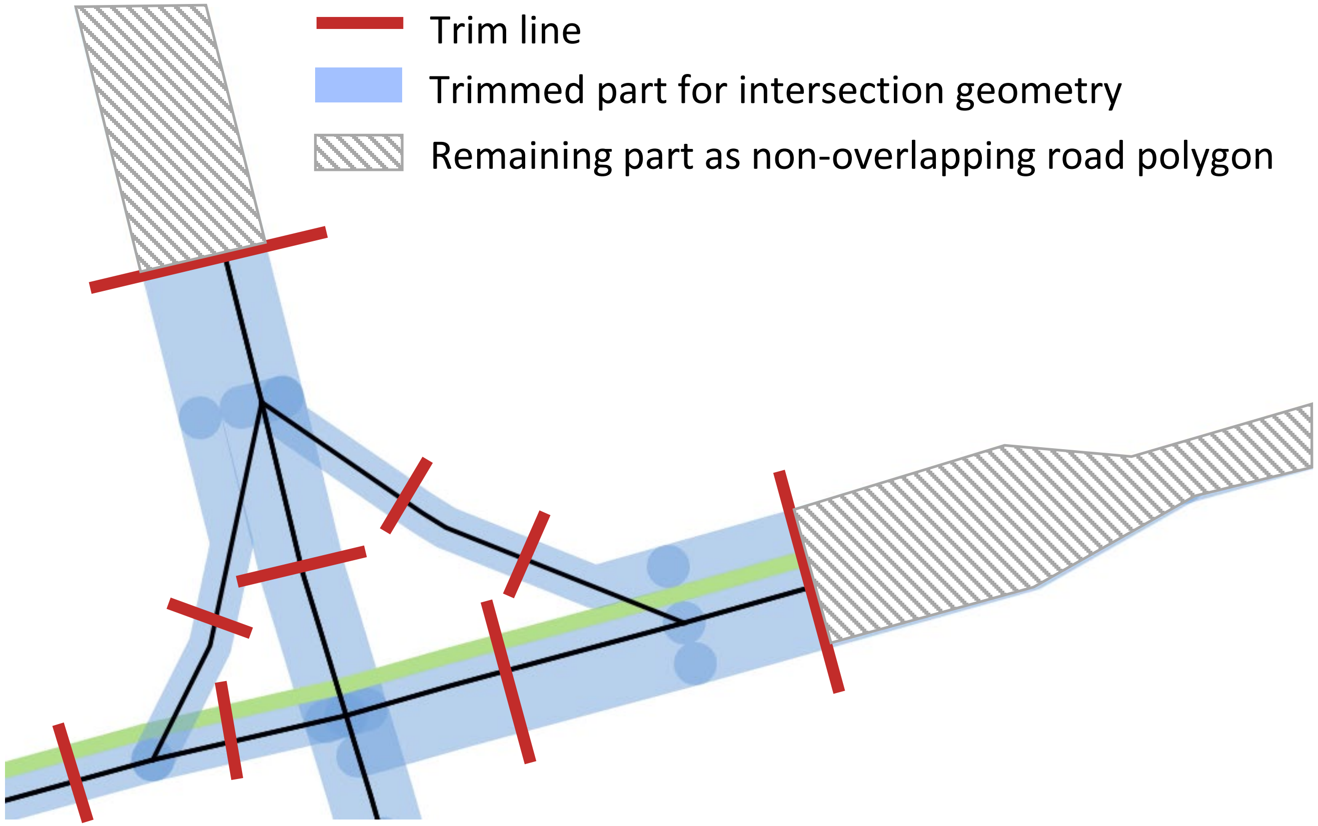
Node degree-based method for road polygon post-processing

- ***intersection variations***

Identify all the intersections;

→ **Generate intersection polygons using a "one-size-fits-all" solution.**

Elif "true node degree > 2" →
generate intersection polygon



Methodology & Results

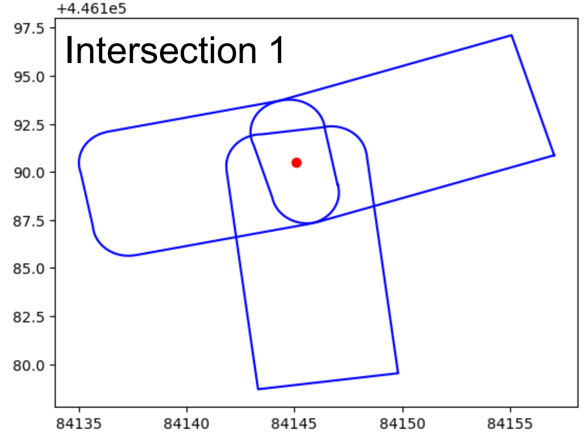
Phase 3 —— **Areal Generation:** 2D Road Polygon Reconstruction

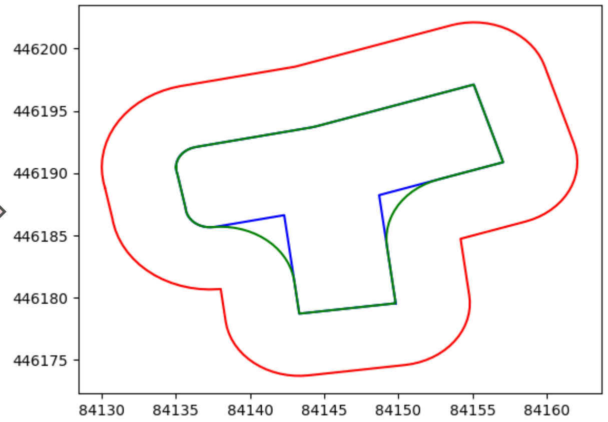
Node degree-based method for road polygon post-processing

- ***intersection variations***

Identify all the intersections;
Generate intersection polygons using a "one-size-fits-all" solution.

Elif "true node degree > 2" → *generate intersection polygon*



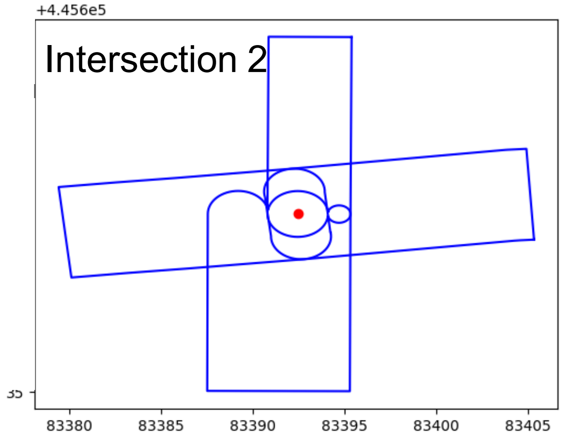


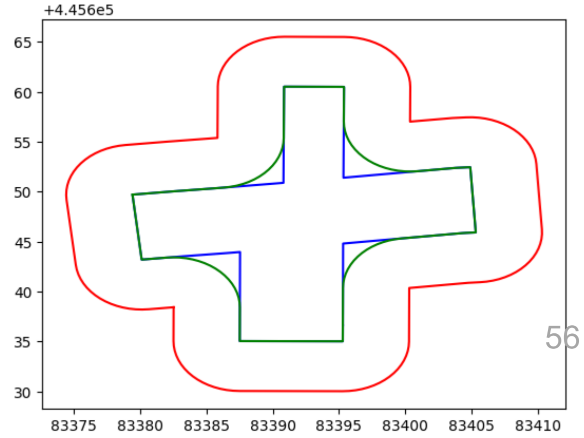
Trimmed converged road polygons

Merged converged road polygons

Polygon after 'positive' buffer

Polygon after 'negative' buffer
------ ***Final result***





Methodology & Results

Phase 3 —— Areal Generation: 2D Road Polygon Reconstruction

Node degree-based method for road polygon post-processing

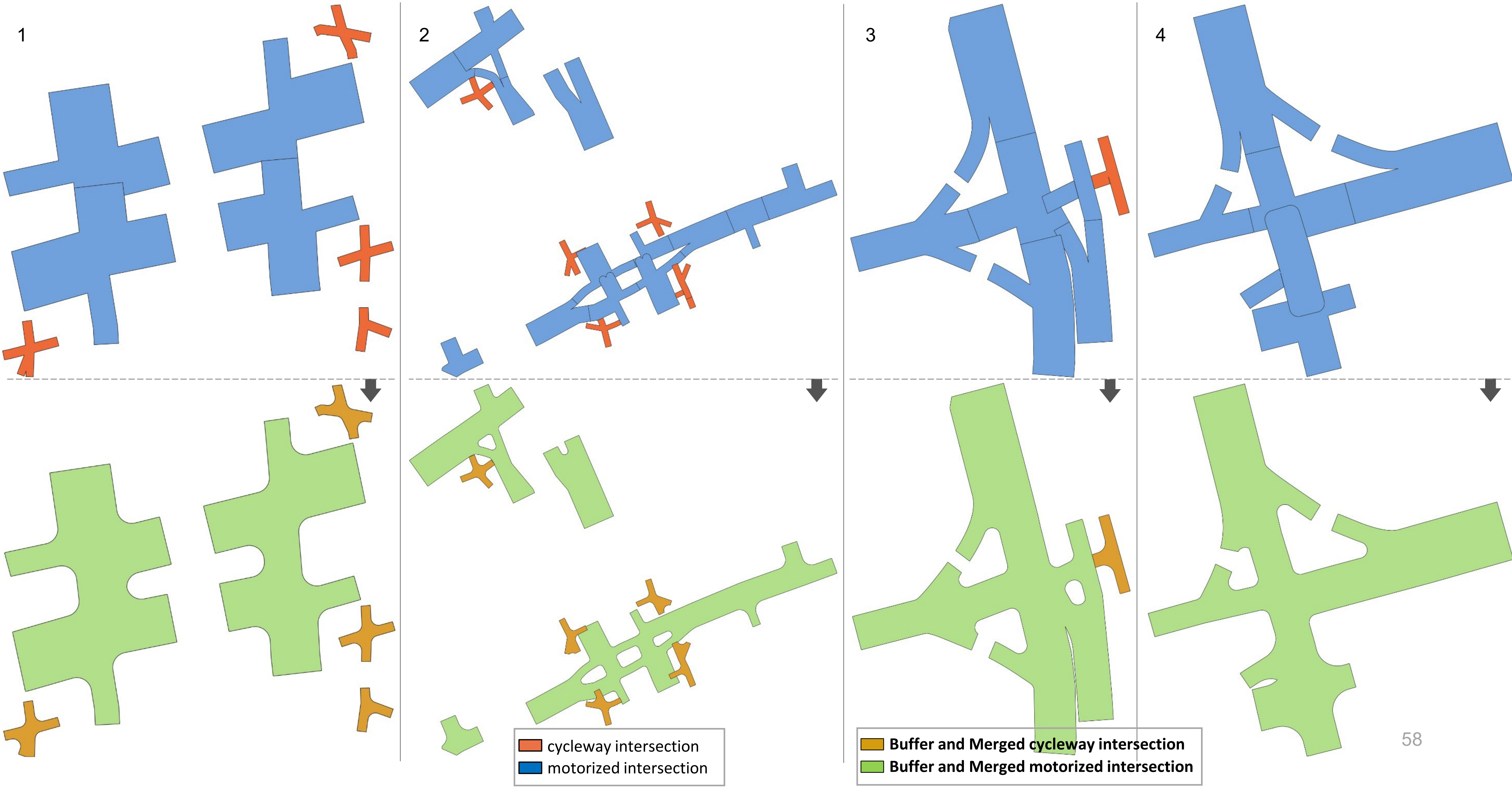
- ***intersection variations***

According to their shapes, the common types are:

- **T/Y intersection;**
- **cross intersection;**
- **three ramps intersection;**
- **asterisk-shape intersection.**

Finally, after 'double-merge' implementation, the number of intersections is 108, of which 66 motorized intersections, 2 roundabouts, and 40 cycleway intersections.

Semantic information is preserved in areal representation

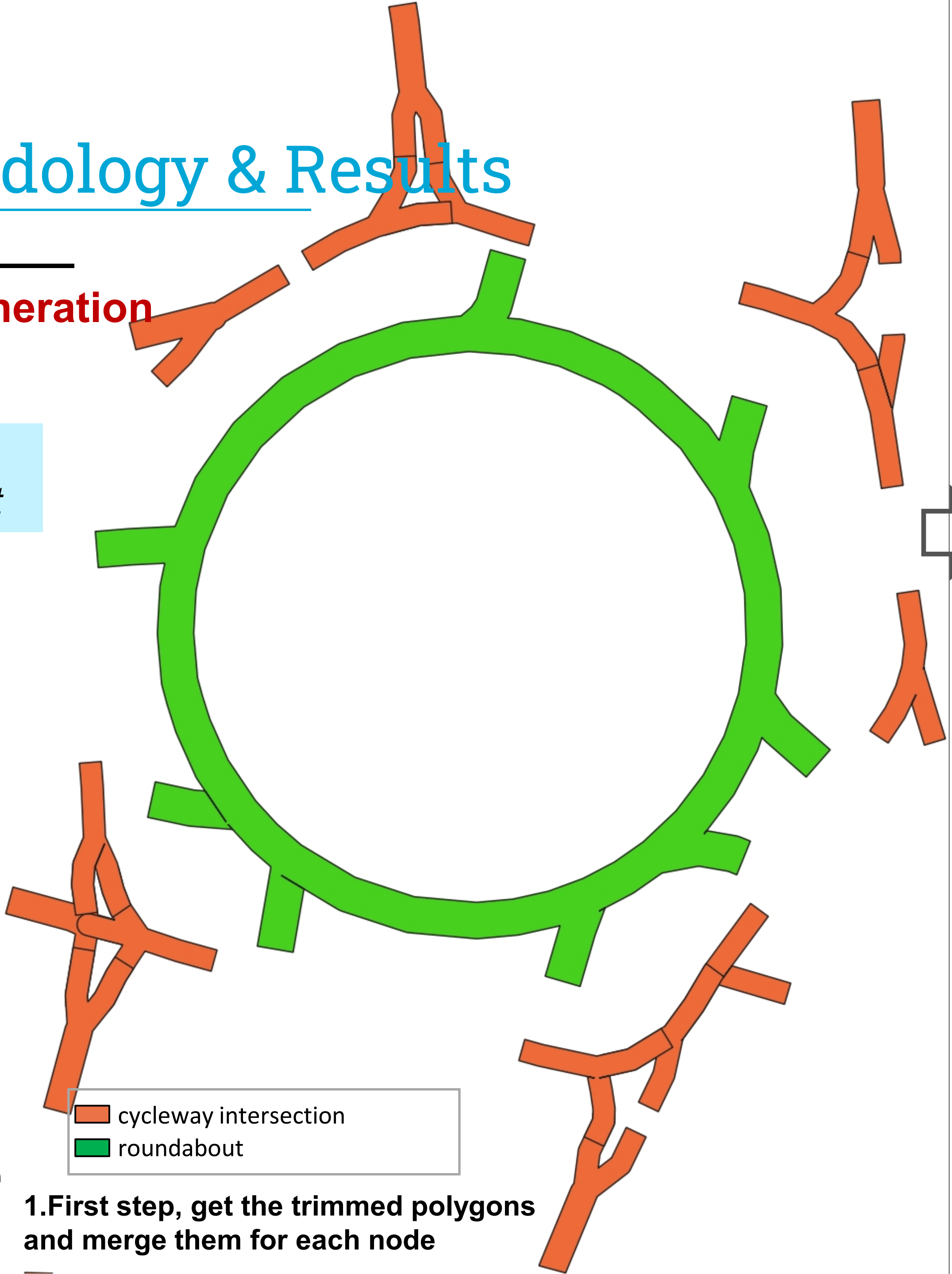


1
2
3
4
cycleway intersection
motorized intersection
Buffer and Merged cycleway intersection
Buffer and Merged motorized intersection

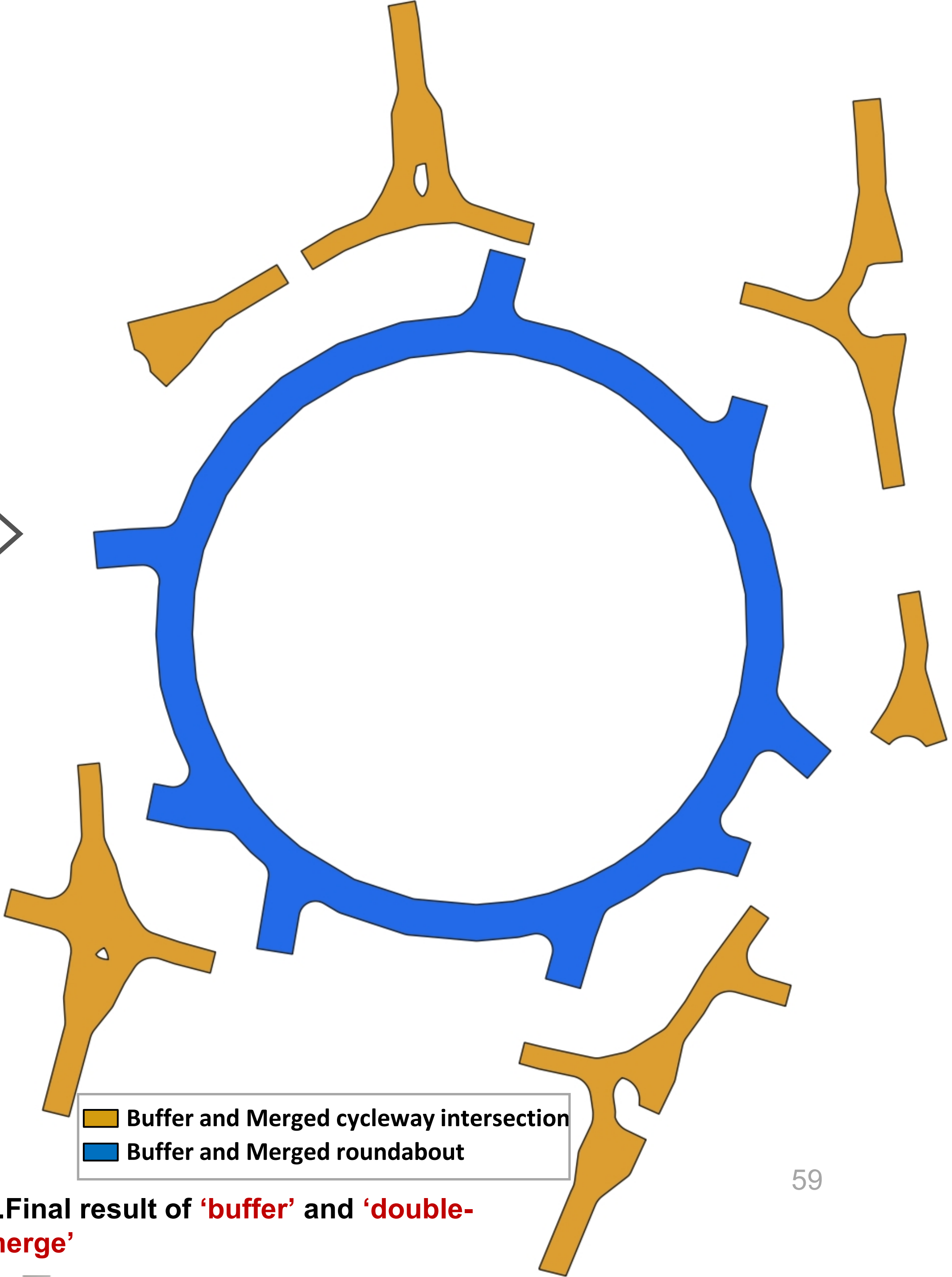
Methodology & Results

Phase 3 ——
Areal Generation

junction = roundabout



1.First step, get the trimmed polygons and merge them for each node



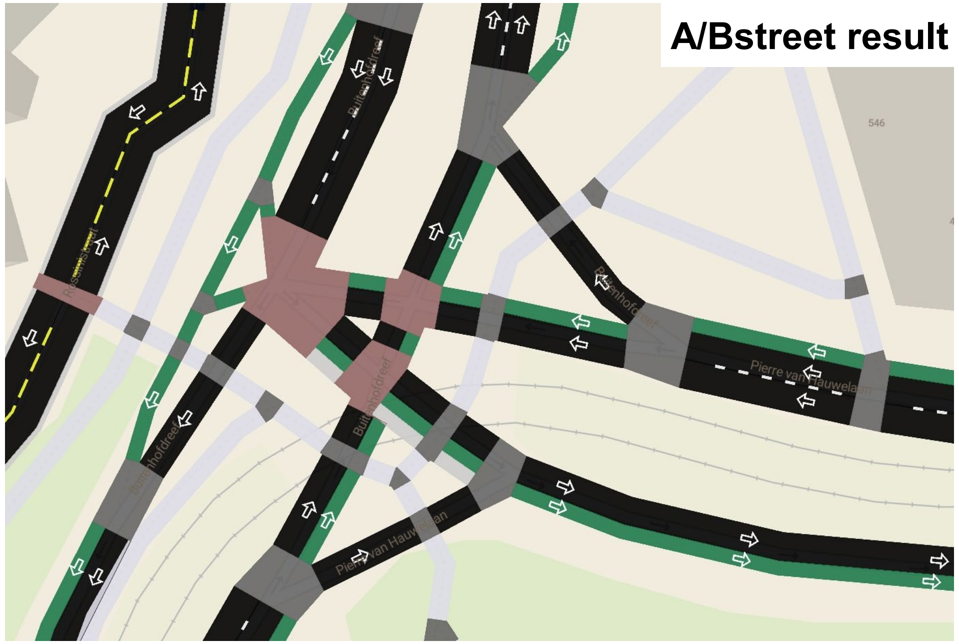
2.Final result of 'buffer' and 'double-merge'


Road polygons
cycleway
mixed (vehicle & bike)
vehicle
Intersection polygons
cycleway intersection
roundabout
vehicle intersection

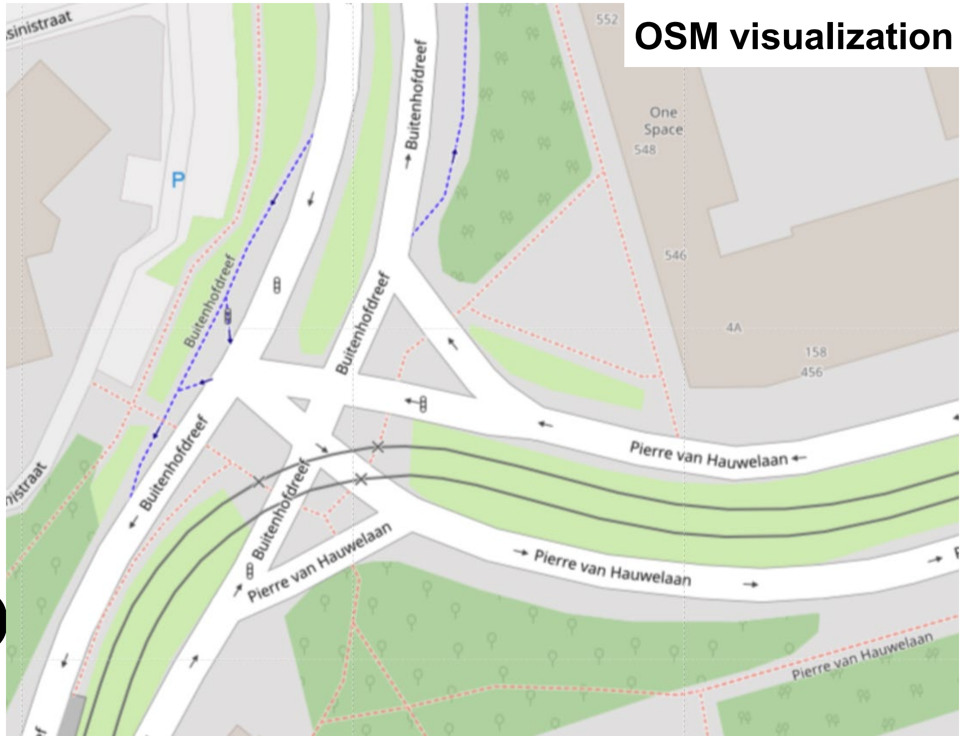

Road polygons
cycleway
mixed (vehicle & bike)
vehicle
Intersection polygons
cycleway intersection
roundabout
vehicle intersection

Our final result

A/Bstreet result



OSM visualization



Google map satellite image

Conclusion

Subquestion 1 & 2: **OSM data utilization and LoDs improvements**

Phases/Tags	*highway*	*cycleway*	*name*	*oneway*	*lanes*	*turn*	*junction*	*bridge*	*tunnel*
Road-level (R)	x	x	-	x	x	x	x	x	x
Traffic-level (R_w)	x	x	x	x	x	-	-	-	-
Lane-level (R_l)	x	x	-	x	x	x	-	-	-
Grouped strokes (S)	x	x	x	x	-	-	-	-	-
Road polygon (RA)	x	x	-	x	x	-	-	-	-
Intersection polygon (C, CA)	x	x	-	-	x	-	x	x	x

Table 7.1: Uasges of the tags and corresponding values.

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Conclusion

Subquestion 3: **Raw topology relationships, lane-to-lane adjacency as the lane-level network**

- ***Hierarchical generation***

'*Main routes*' at lane level

↓

Reliable *relative offset distances* of all the derived lanes

↓

Accurate *locations of lanes* within their road polygon

The first phase of lane generation **identifies reliable lanes** that serve as references for building the topology structure.

By establishing both **global and local adjacency (grouped strokes)**, the method accurately maintains **lane-to-lane** relationships.

Conclusion

Subquestion 3: **Raw topology relationships, lane-to-lane adjacency as the lane-level network**

- ***Lane modification and correction***

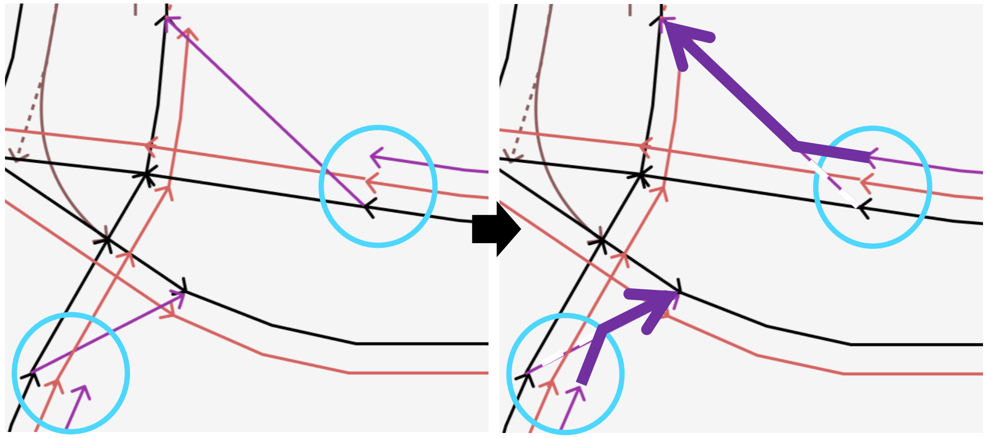
Several strategies to ensure correct lane adjacency:

- 1. Separate generation and modification of vehicle lanes and cycling lanes to prioritize the consistency of correct traffic flows and achieve proper lane matching.

- 2. Slip road labels (F_r) were used to identify turning lanes, ensuring topological correctness through proper connections.

- 3. Turn attributes (T_r and T_l) helped to determine the target lanes for slip road modifications.

- 4. Finally, comparing T_l values and relative offset distances (FD_l) allowed auxiliary lanes to find their corresponding 'through' lanes, completing the wedge-shaped modification of lane geometry.



Conclusion

Subquestion 4: **Error-less areal representation with details information and changes**

- ***Node degree-based approach***

‘*True*’ node degree correction

Error types identification:
- **Overlapping**
- **Protruding**

Intersection detection

- ***Geometric method for post-processing***

Error-free road ribbons

- ***Intersection generation***

Several strength:

- 1. Resolving complex overlapping issues by merging trimmed polygons of converging roads, ensuring a smooth, cohesive shape.
- 2. Incorporating **turning corner curvatures** into intersection polygons, which optimizes the areal representation and follows transportation geometric design principles.
- 3. Addressing lane connectivity errors—especially those caused by missing road information—by generating compact, reliable intersection polygons that reflect real-world road areas.

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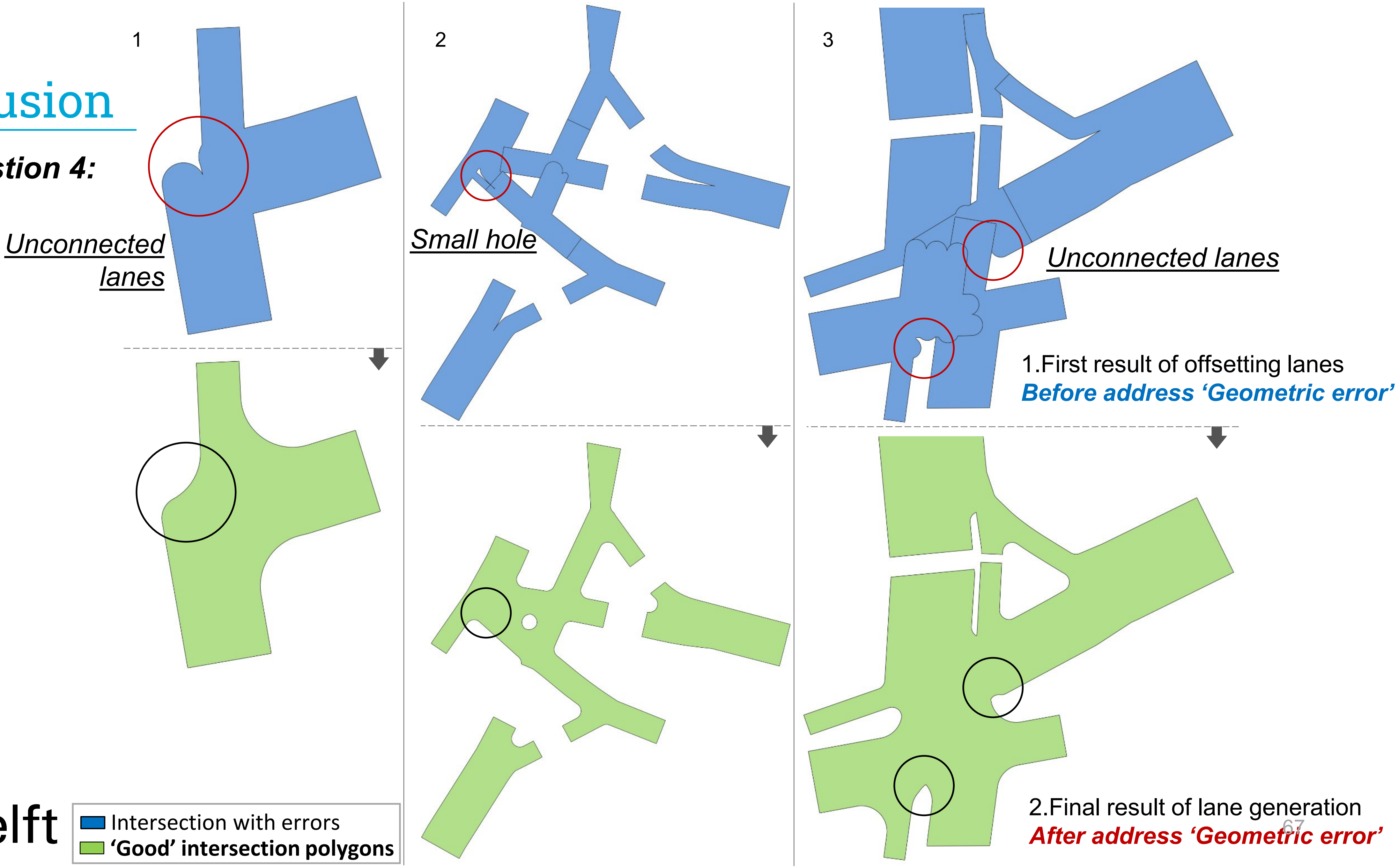
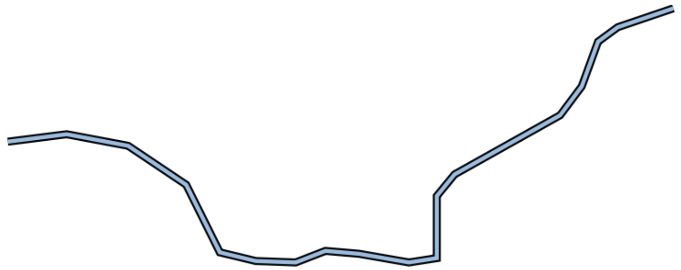
Conclusion

Subquestion 4:

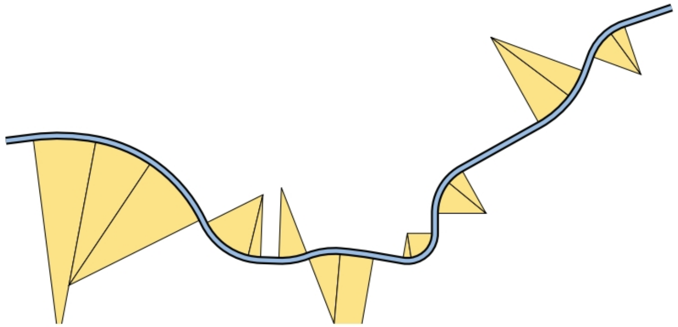


Future work

- Optimize the road centerlines to restore **C1 continuity** before lane generation to satisfy C1 continuity curve for road/lane centerlines and road boundaries.



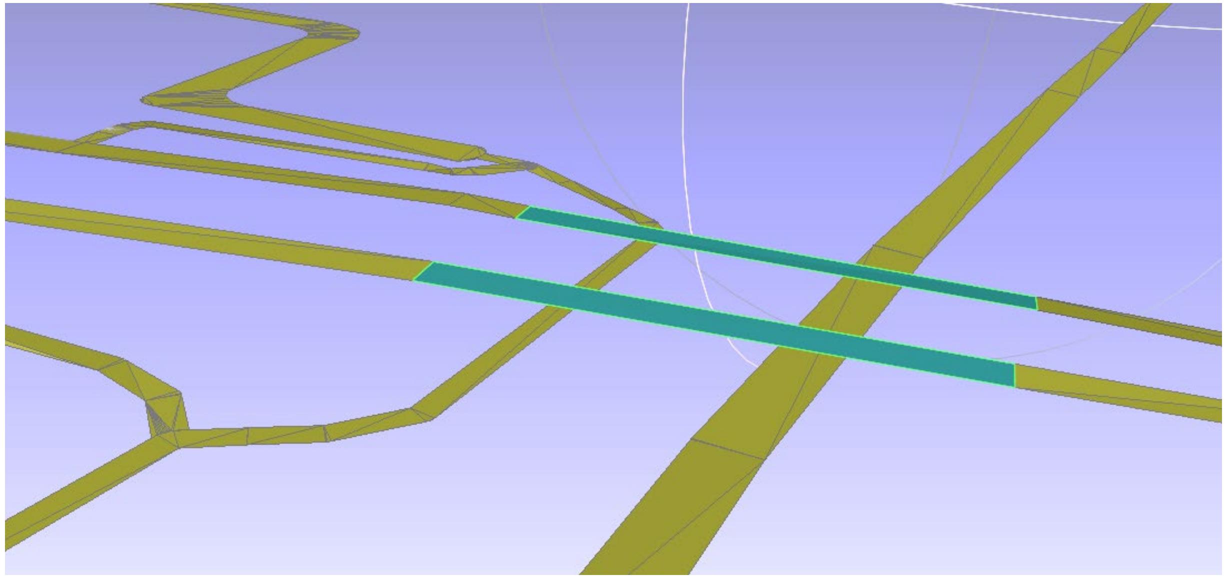
(a) Polyline road geometry (imported from the TIGER® database [4] via OpenStreetMap [5])



(b) An *arc road* derived from the above polyline. The orange arcs show the center and radius of each arc used to give the road its smooth appearance.

- Utilize the intersection-related tags and the areal model, to generate **2.5D/3D model** for bridges, tunnels, overpasses, etc.

*junction =**
*bridge =**
*tunnel =**



Questions ?

Thanks for your attention

Chengzhi Rao