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Chair of Geoinformatics, TU Dresden

How to evaluate and reduce the complexity of geospatial provenance graphs?

01.09.2020

P R O V E N A N C E

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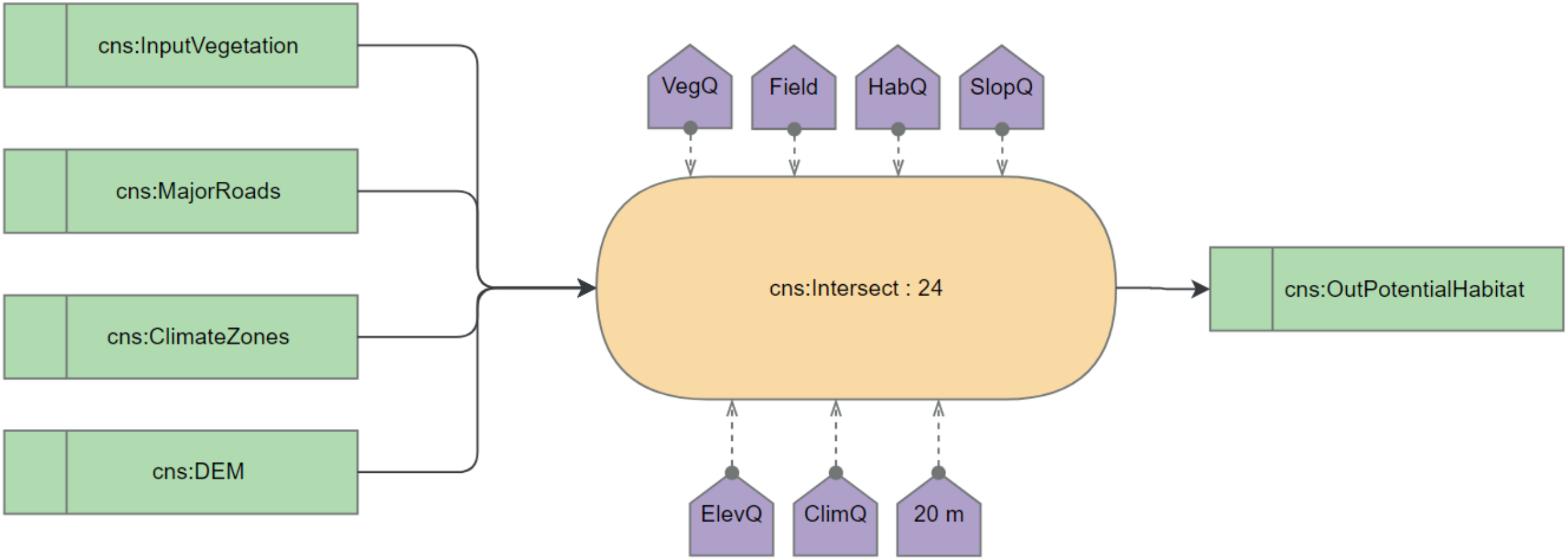
How to make use of such provenance data?

Leverage standardized provenance data to enhance the understandability of the origination history of geospatial data.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cns:ClimateZones
cns:DEM
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HabQ
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cns:Intersect : 24
ElevQ
ClimQ
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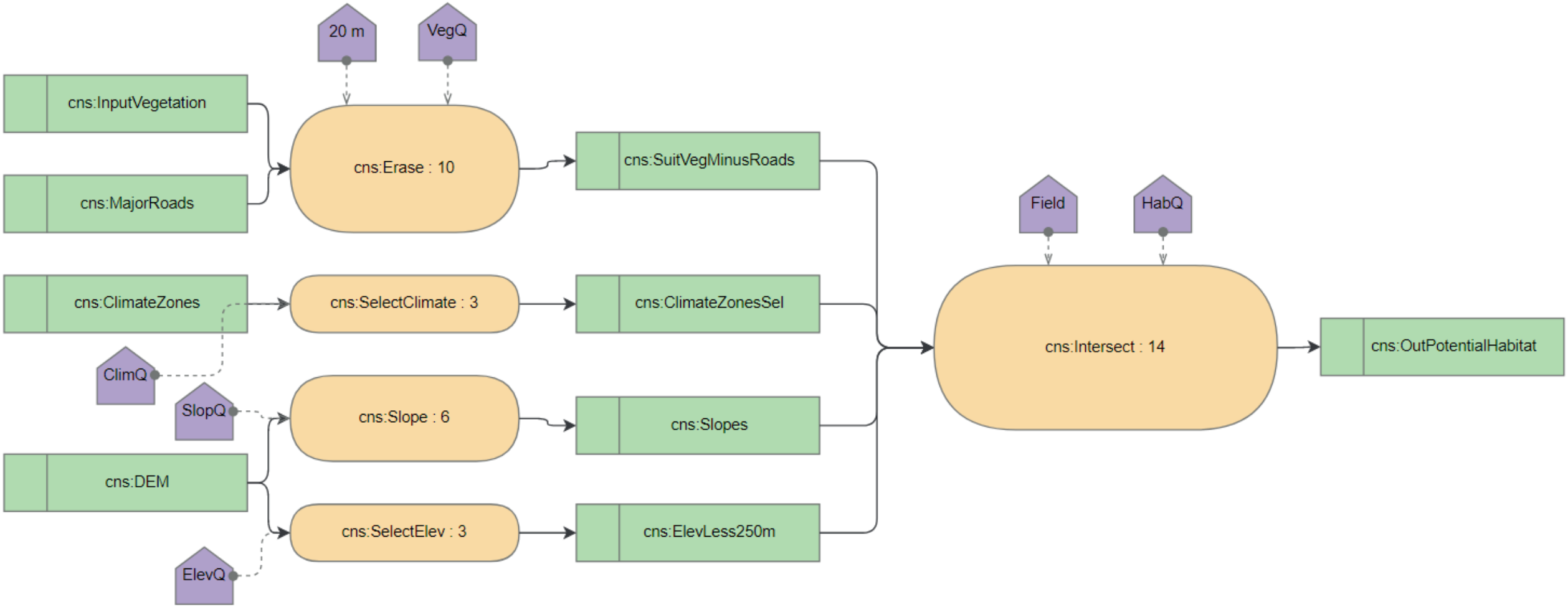
cns:OutPotentialHabitat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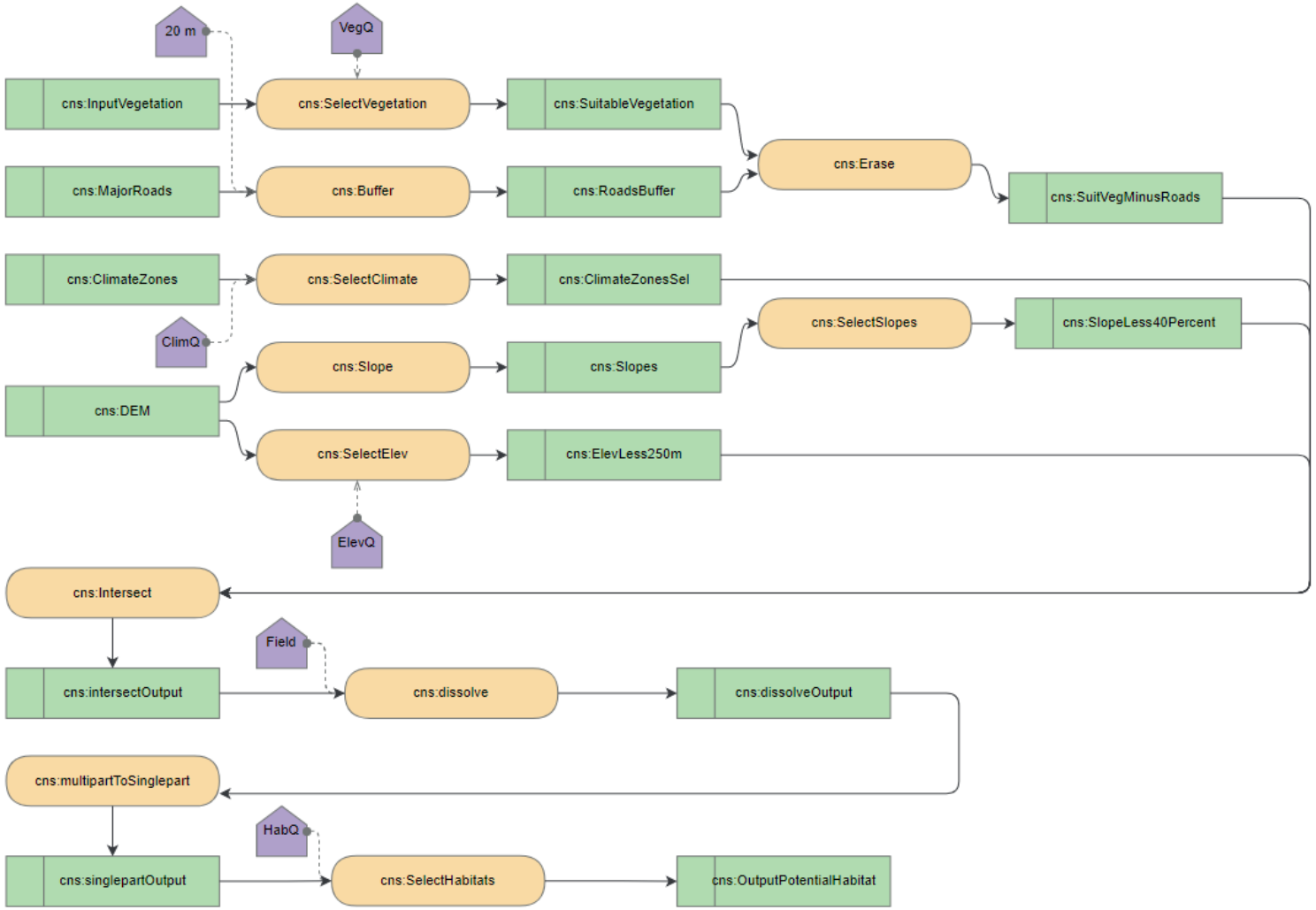
Field
HabQ
cns:Intersect : 14
cns:OutPotentialHabitat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cns:SelectClimate
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cns:SlopeLess40Percent
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cns:Slopes
cns:DEM
cns:SelectElev
cns:ElevLess250m
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cns:SelectHabitats
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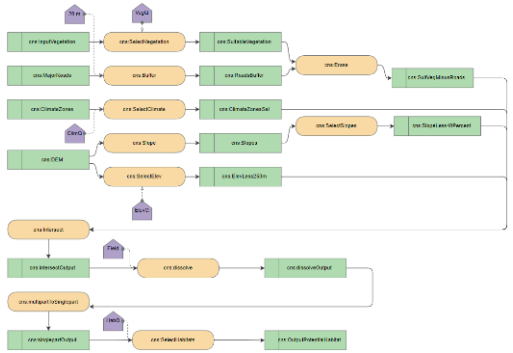
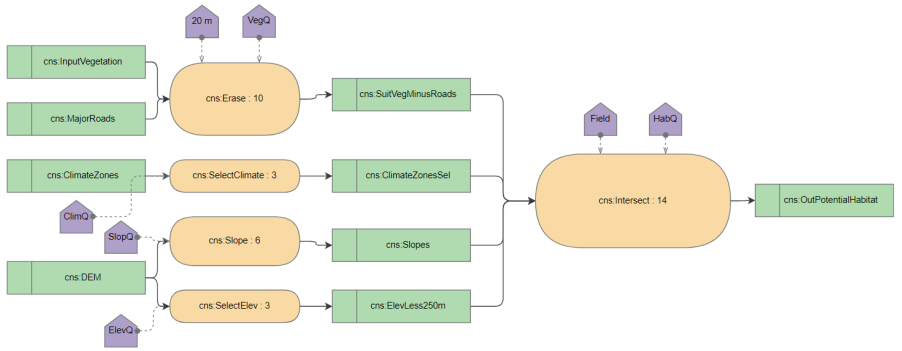
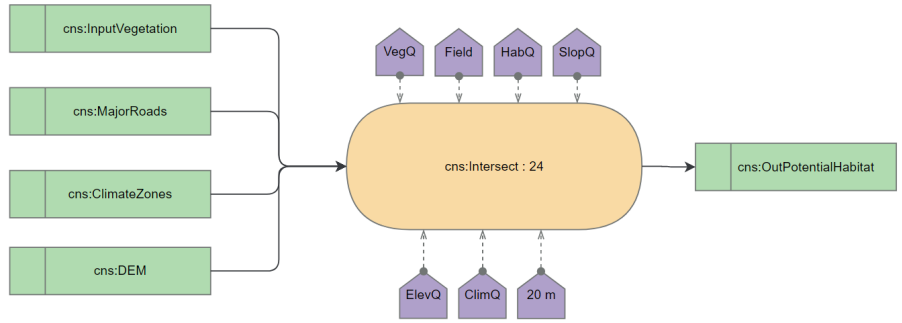
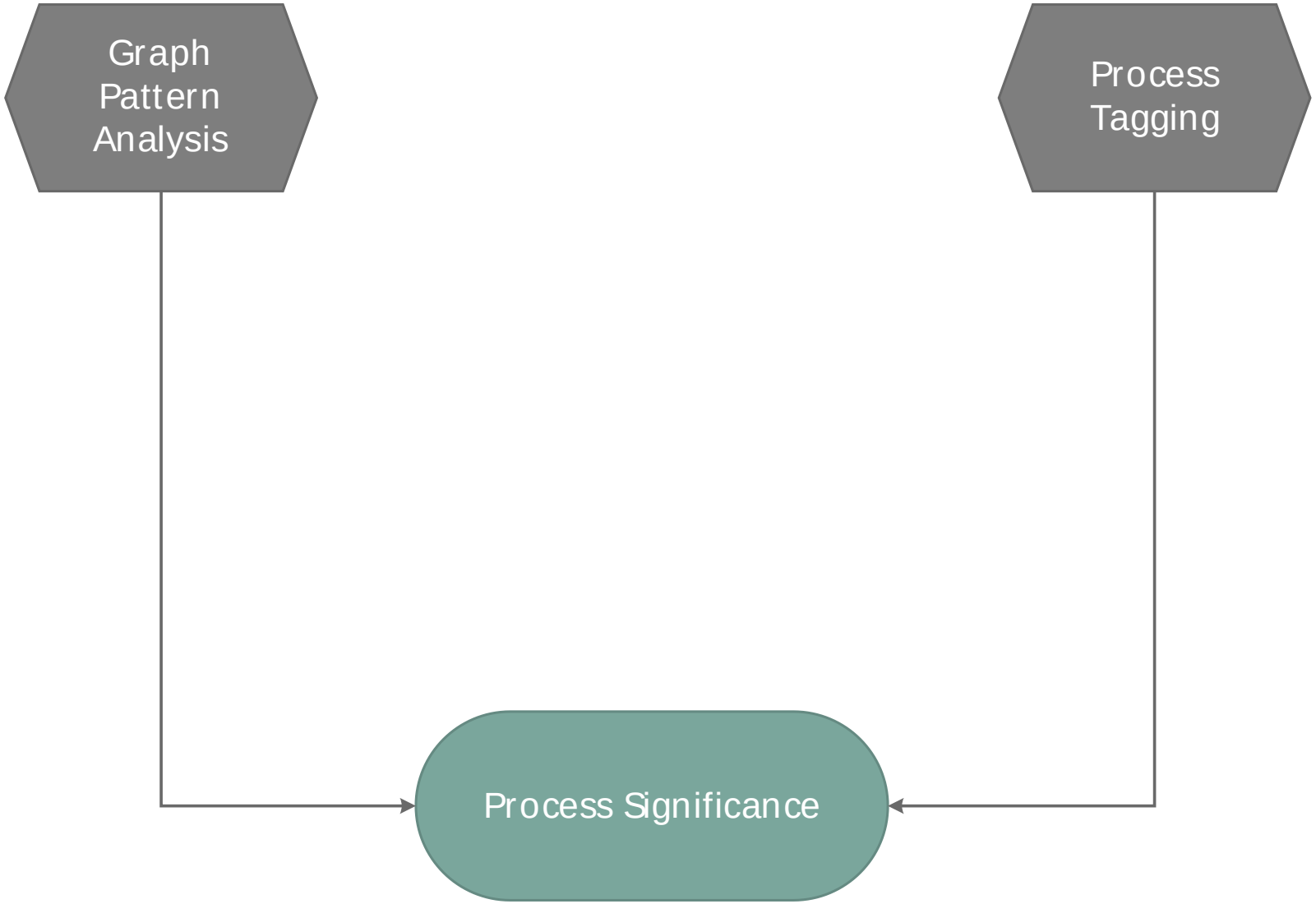


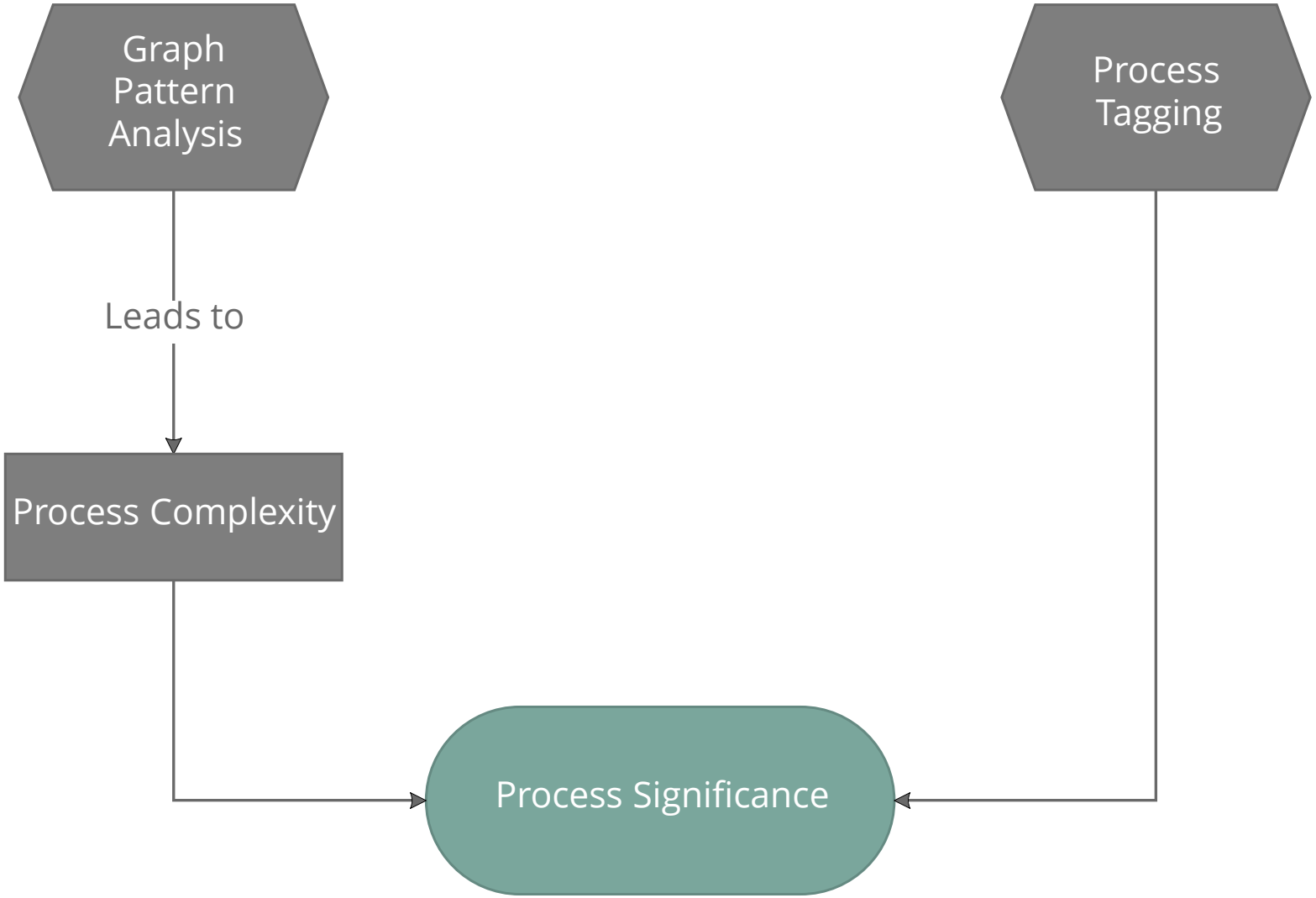


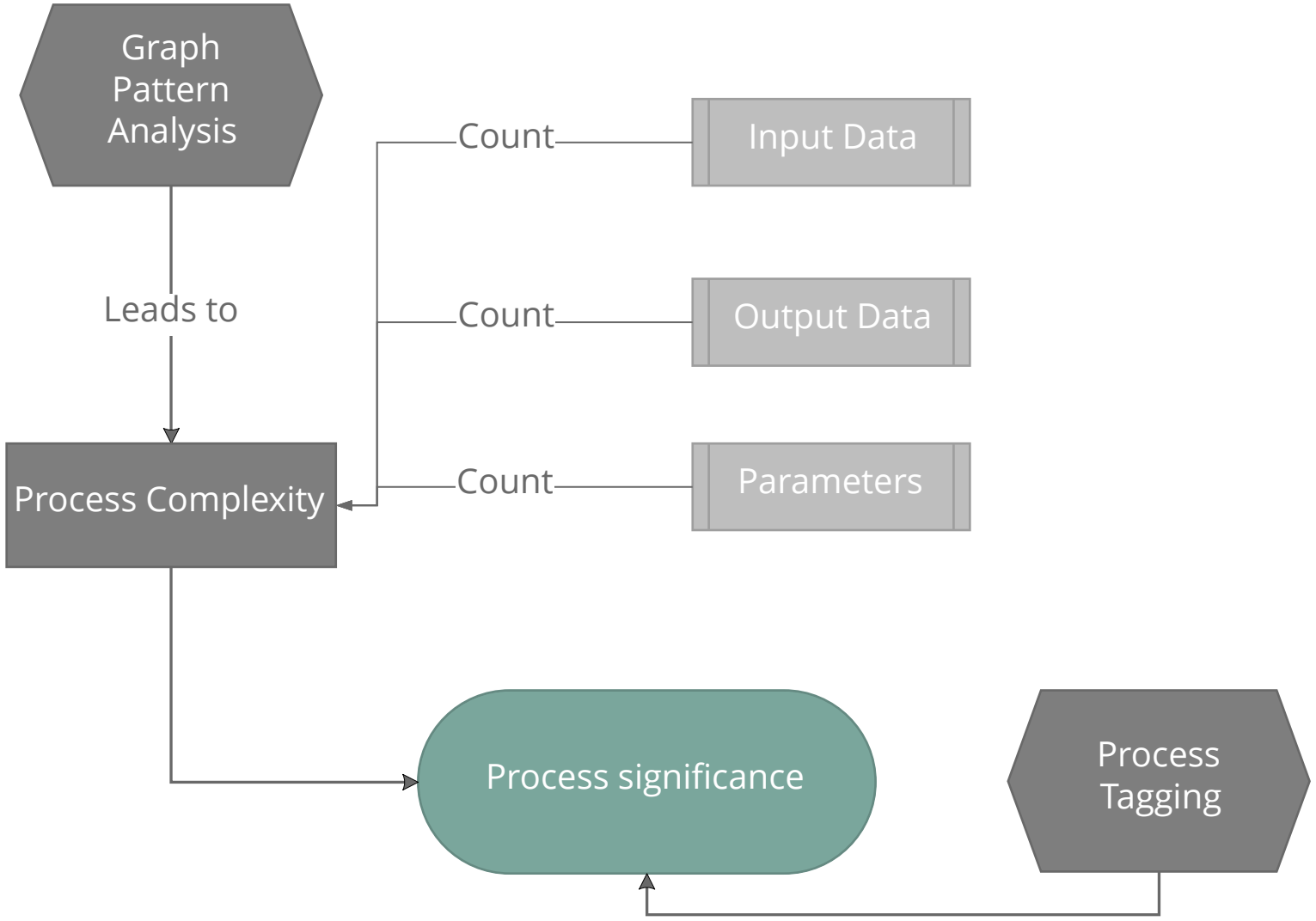


How to get from the left to the right?

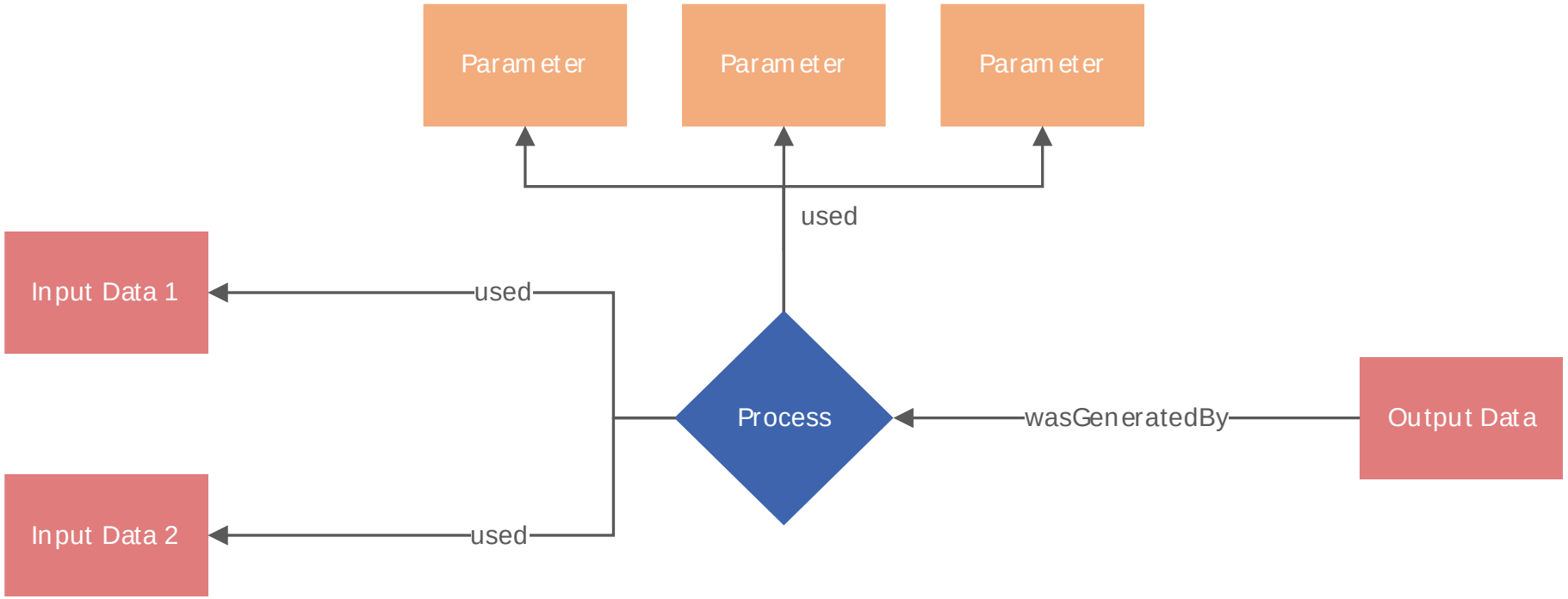
-> **Process-significance based generalization**


Graph Pattern Analysis
Process Tagging
Process Significance

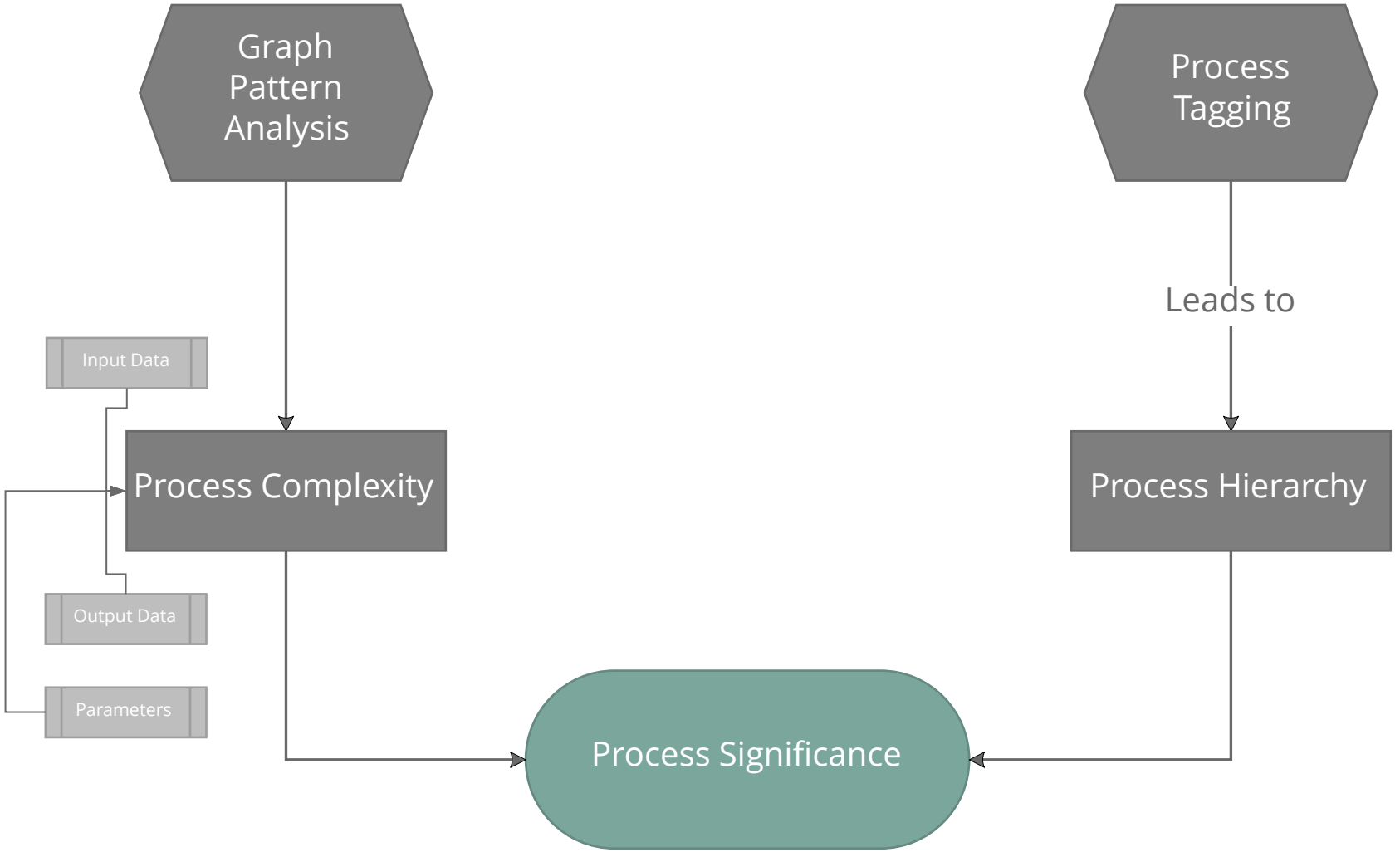

Graph Pattern Analysis
Process Tagging
Leads to
Process Complexity
Process Significance

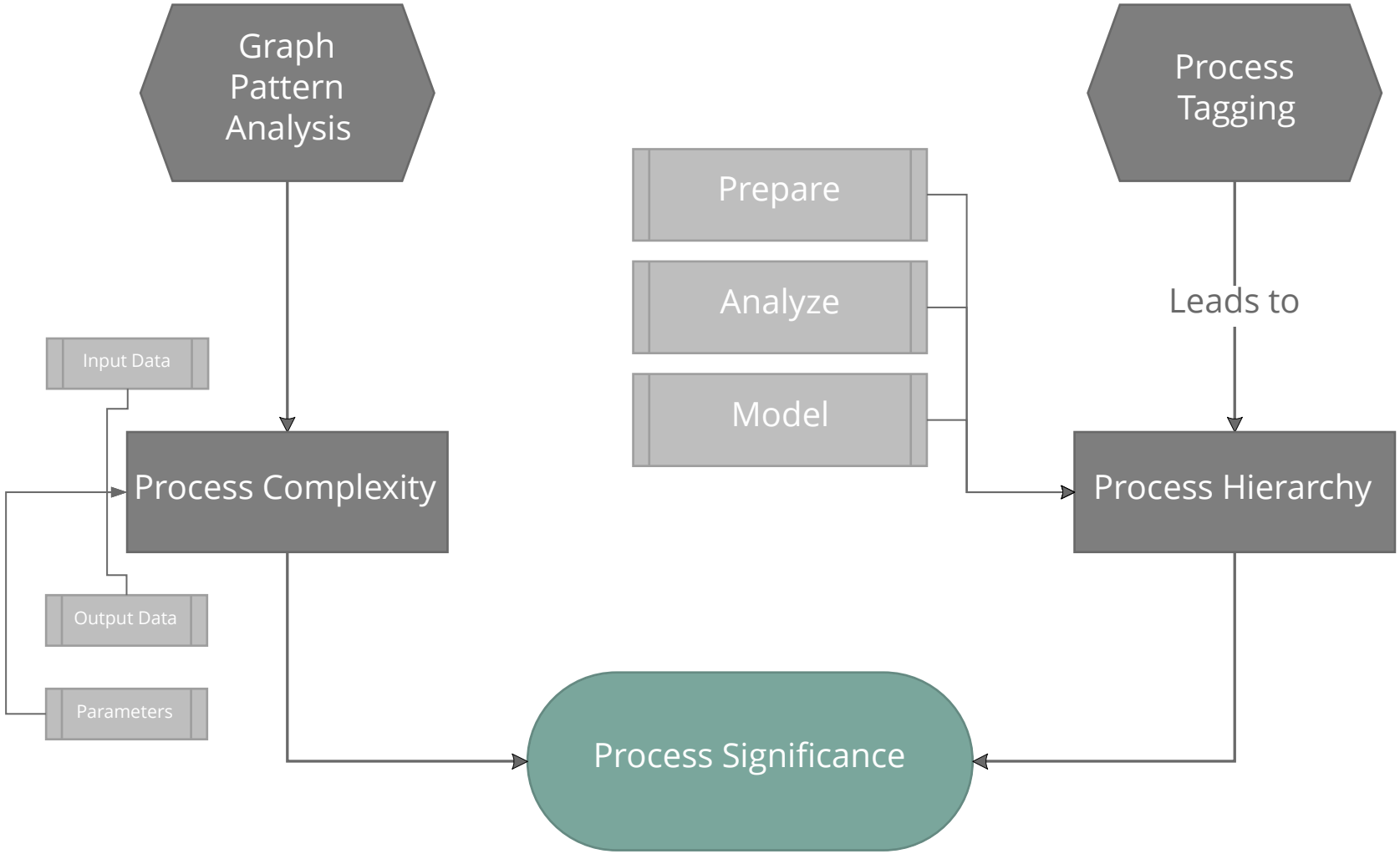

Graph Pattern Analysis
Leads to
Process Complexity
Count
Input Data
Count
Output Data
Count
Parameters
Process significance
Process Tagging

Process complexity analysis by graph pattern



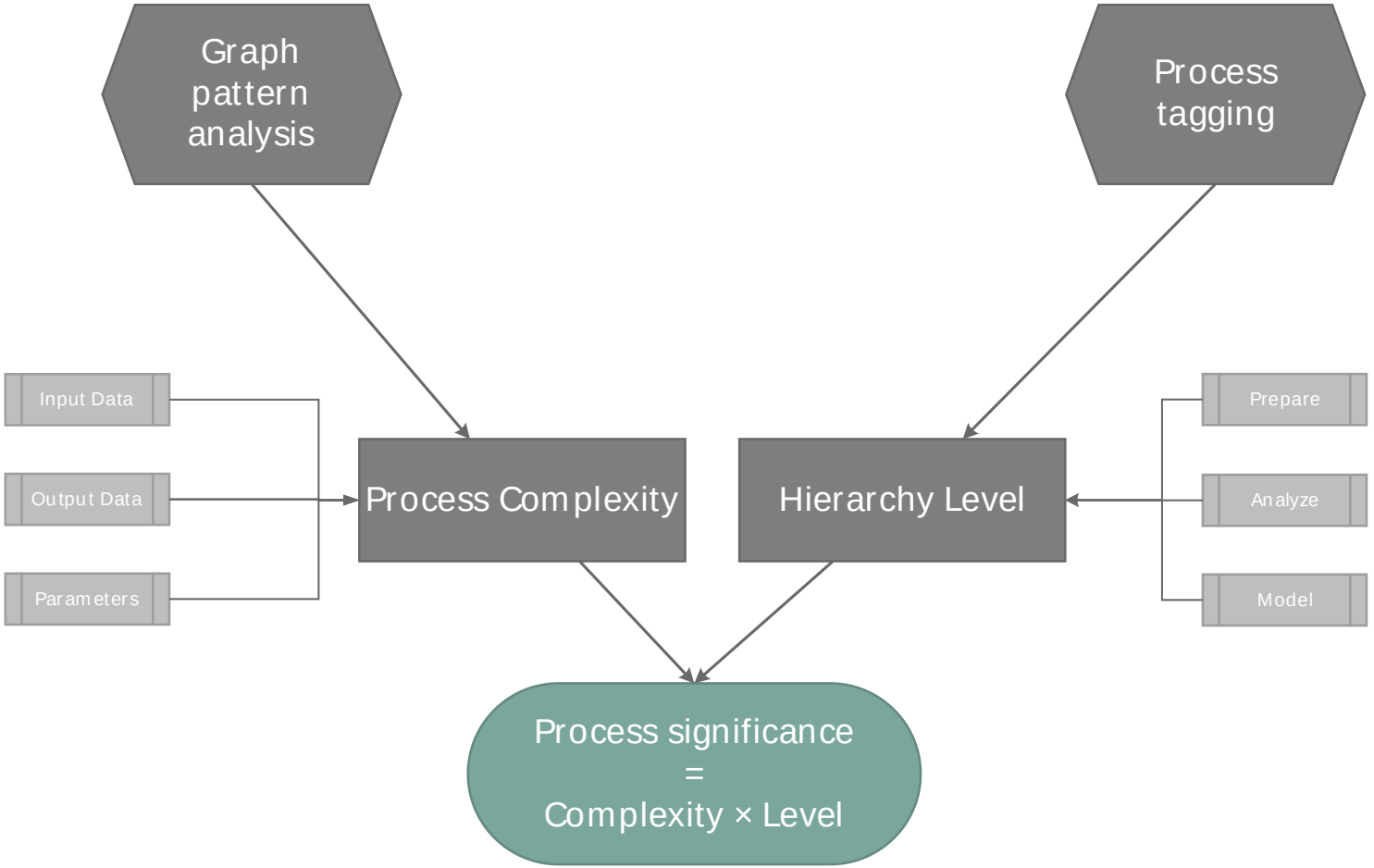
- 2 Inputs, 3 Parameter, 1 Output -> Complexity **C = 2 + 3 + 1 = 6**
- Alternative complexity calculation possible, e.g. sqrt(params)
- Further patterns can be included


Graph Pattern Analysis
Process Tagging
Leads to
Input Data
Process Complexity
Process Hierarchy
Output Data
Parameters
Process Significance

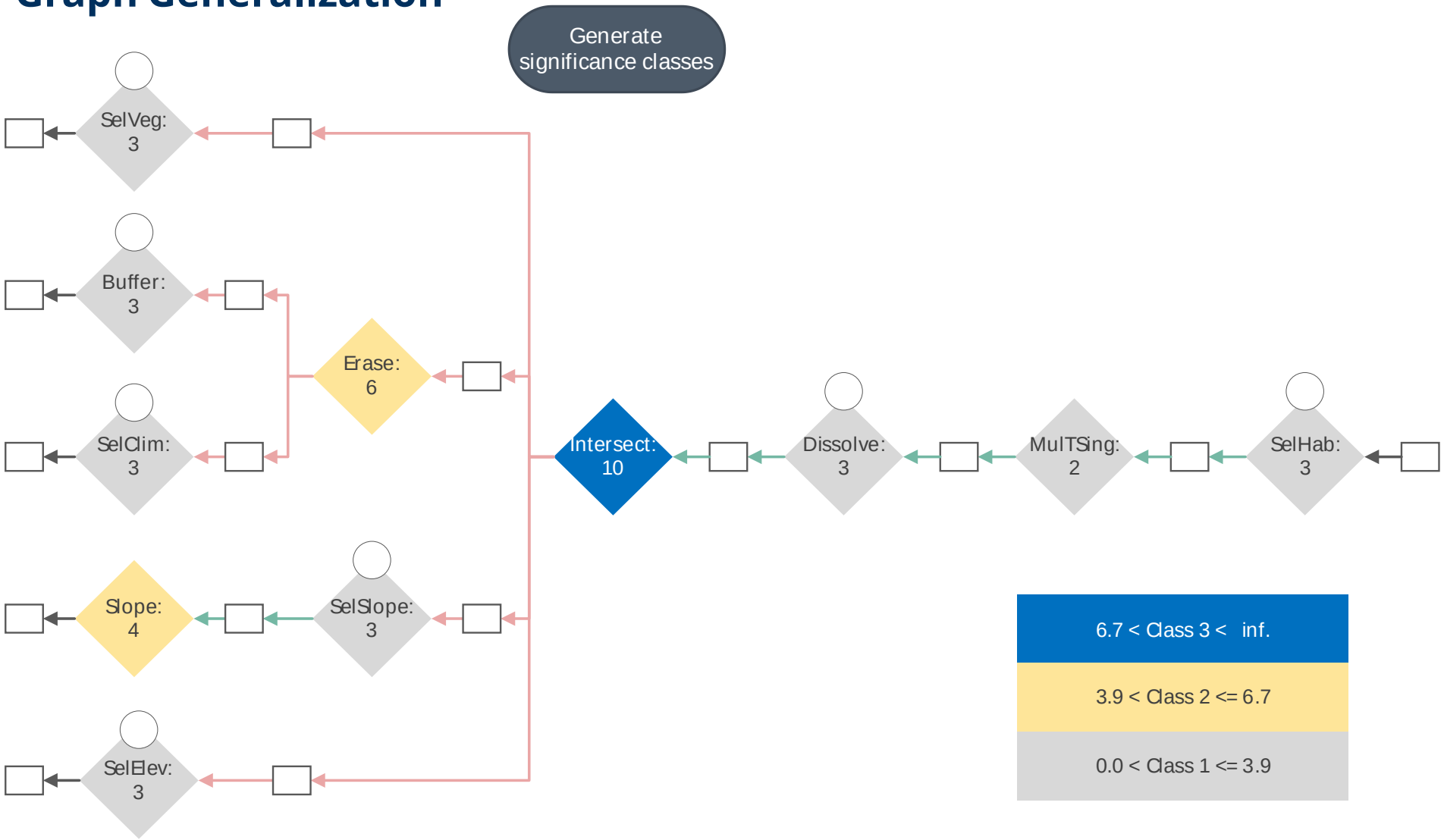

Graph Pattern Analysis
Process Tagging
Prepare
Analyze
Model
Leads to
Input Data
Process Complexity
Process Hierarchy
Output Data
Parameters
Process Significance

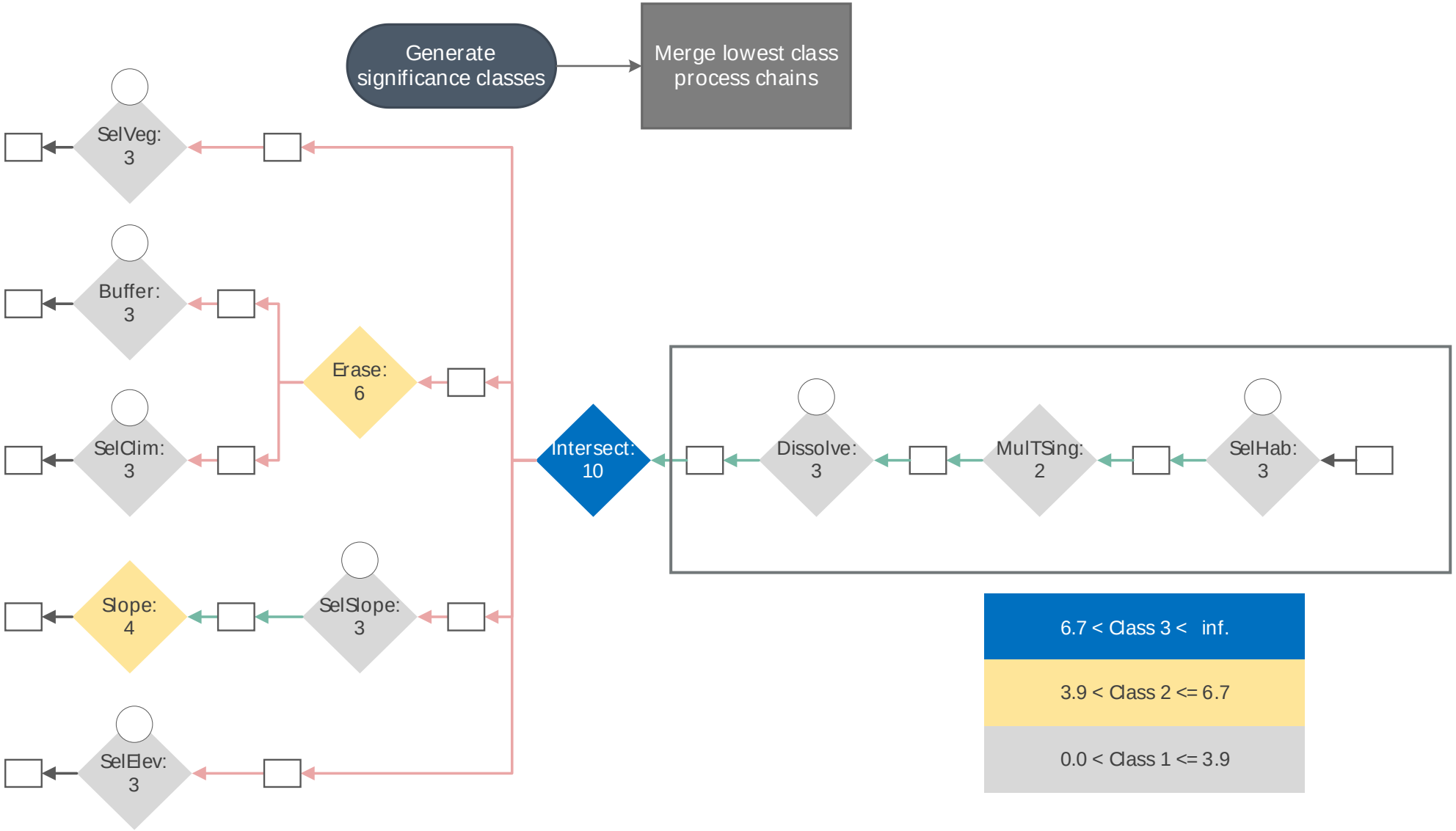
Prepare	Analyze	Model
▪ Selection ▪ Transformation ▪ Reclassification ▪ Geometric Computation ▪ Visualization	▪ Neighborhood Analysis ▪ Map Overlay ▪ Network ▪ Statistics	▪ Model (back-box-modules, neural networks, …)
1	2	3

- Subcategories derived from Albrecht (Albrecht, J. Universal analytical GIS operations: a task-oriented systematization of data structure-independent GIS functionality 1998.)
- Value serves a multiplier


Graph pattern analysis
Process tagging
Input Data
Output Data
Parameters
Process Complexity
Hierarchy Level
Prepare
Analyze
Model
Process significance
=
Complexity × Level

Graph Generalization




Generate significance classes
Merge lowest class process chains
SelVeg: 3
Buffer: 3
Erase: 6
SelClim: 3
Slope: 4
SelSlope: 3
SelElev: 3
Intersect: 10
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SelHab: 3
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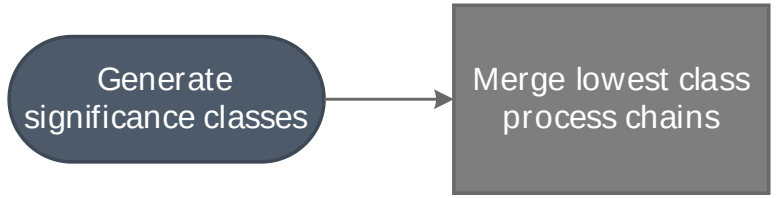
0.0 < Class 1 <= 3.9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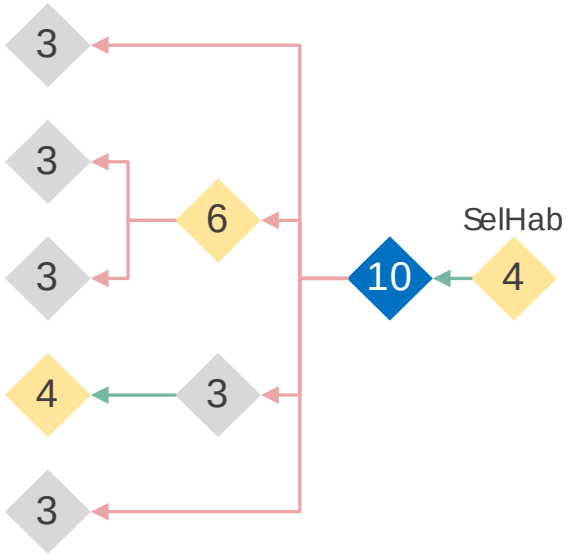
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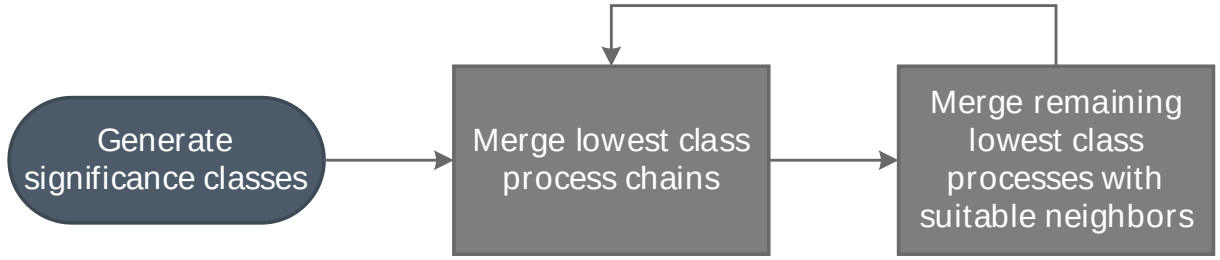
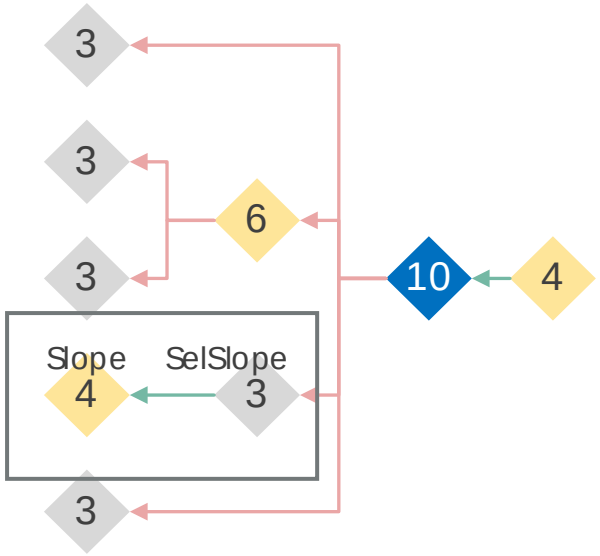

Generate significance classes
Merge lowest class process chains
Merge remaining lowest class processes with suitable neighbors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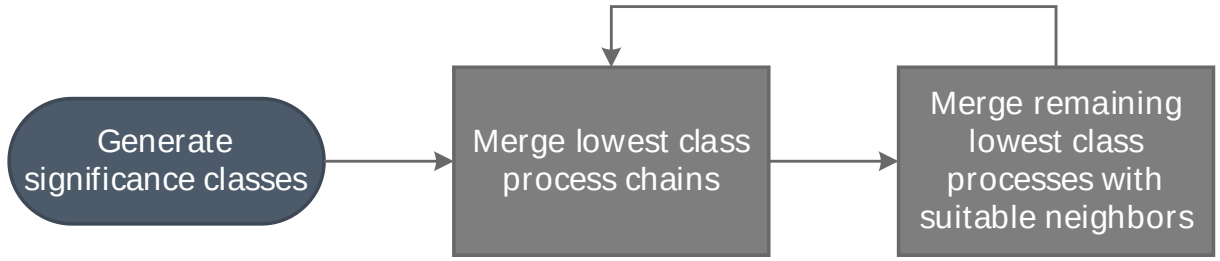
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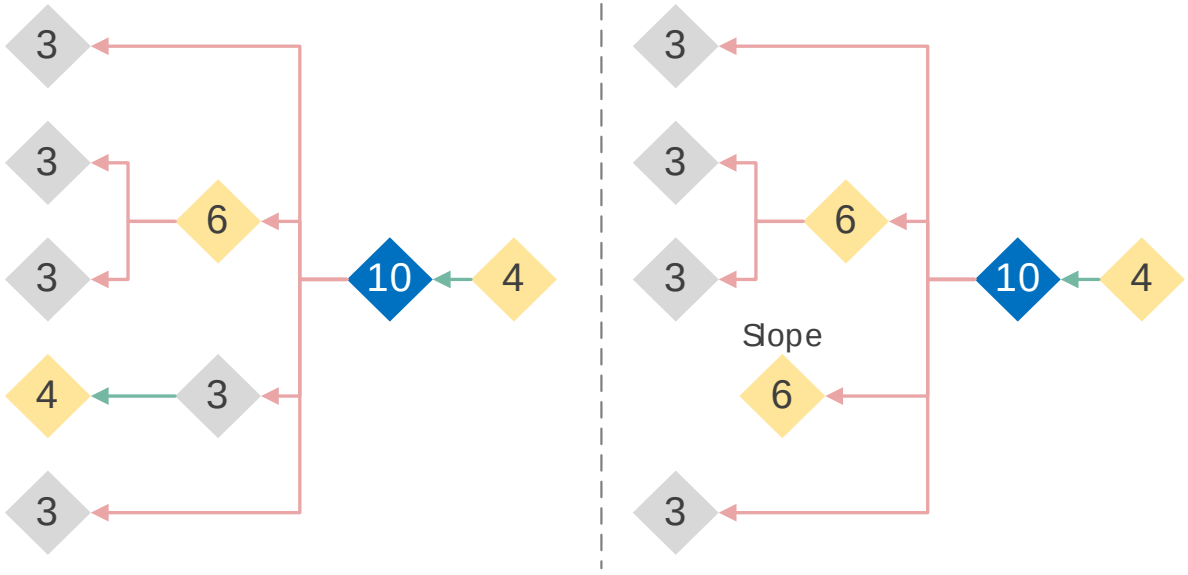
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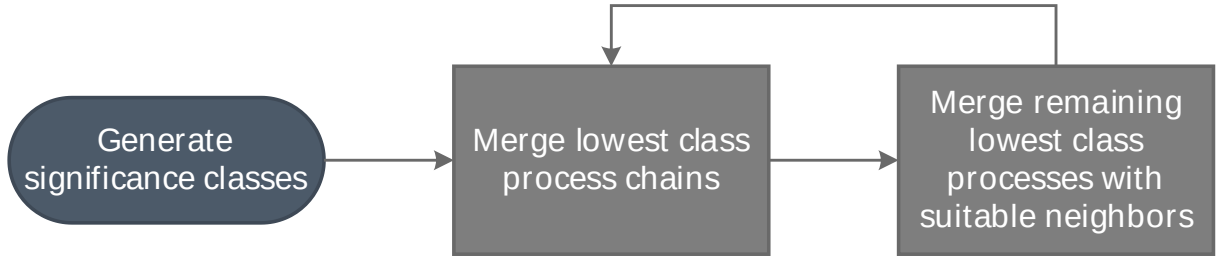
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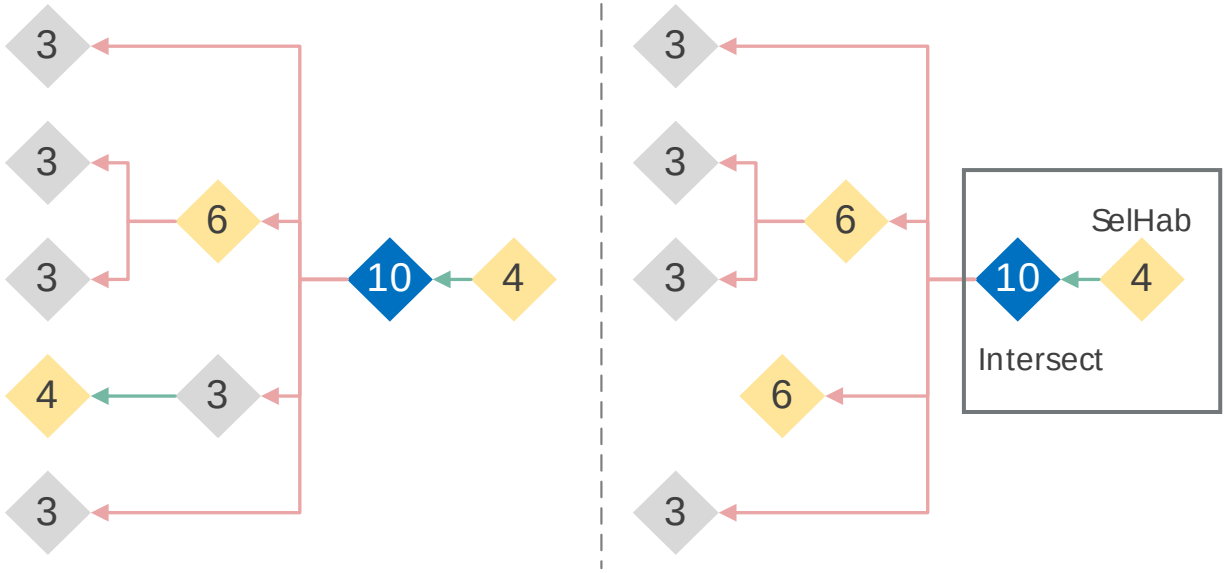
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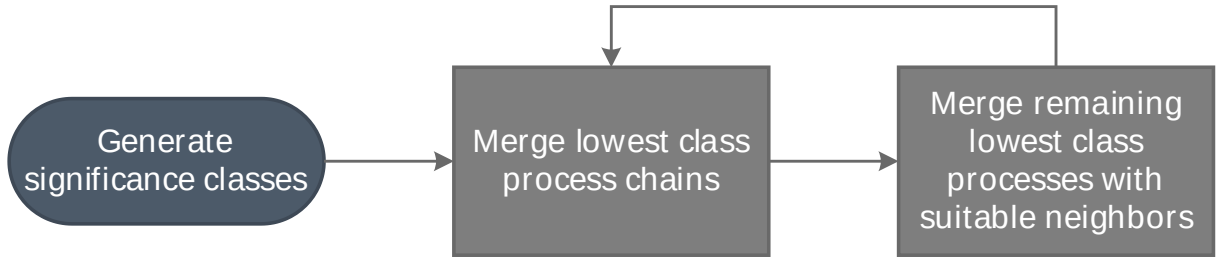
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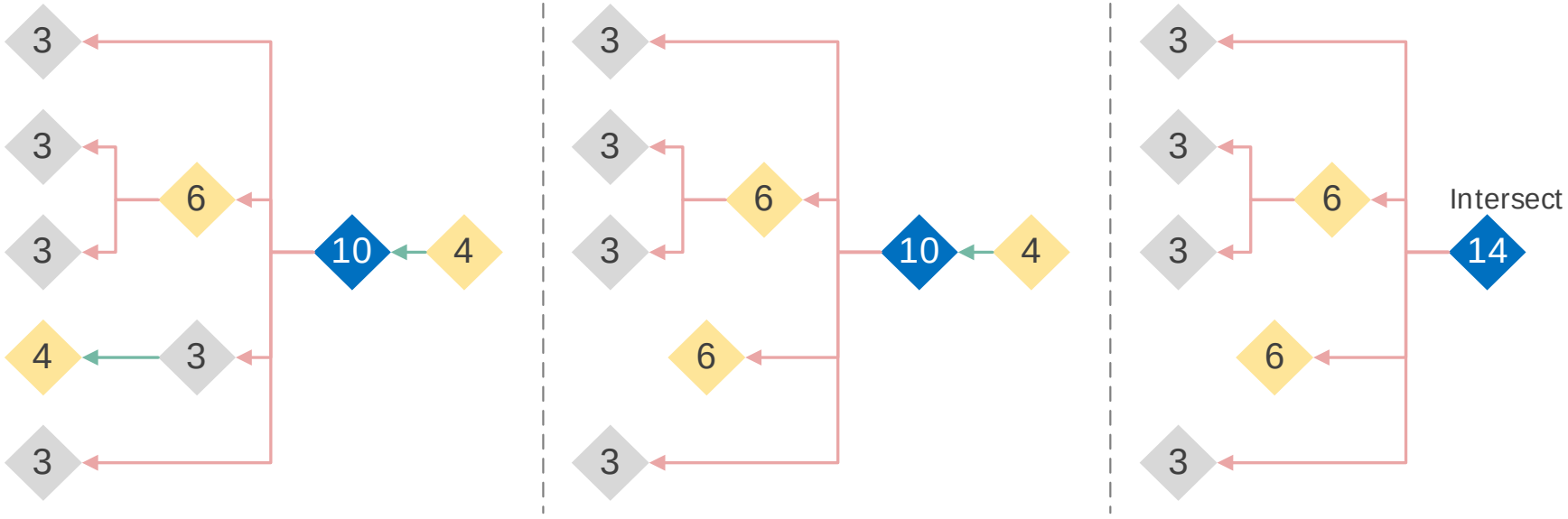
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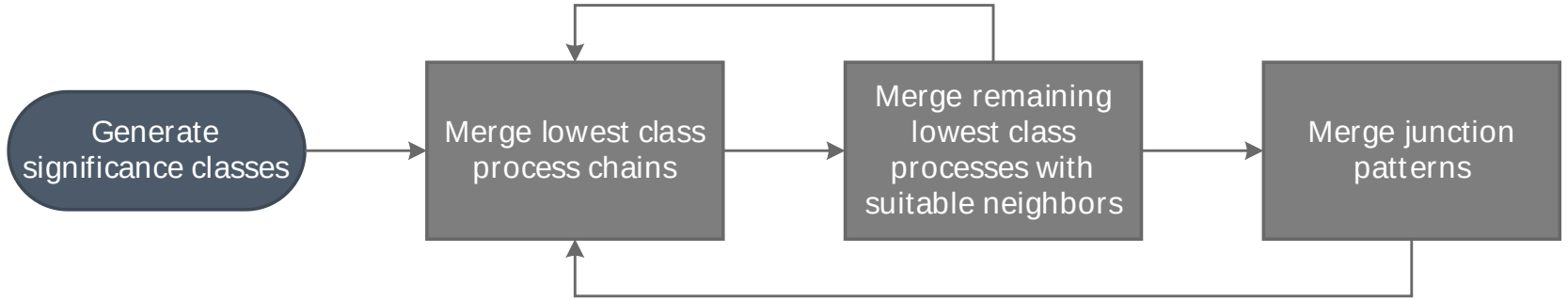
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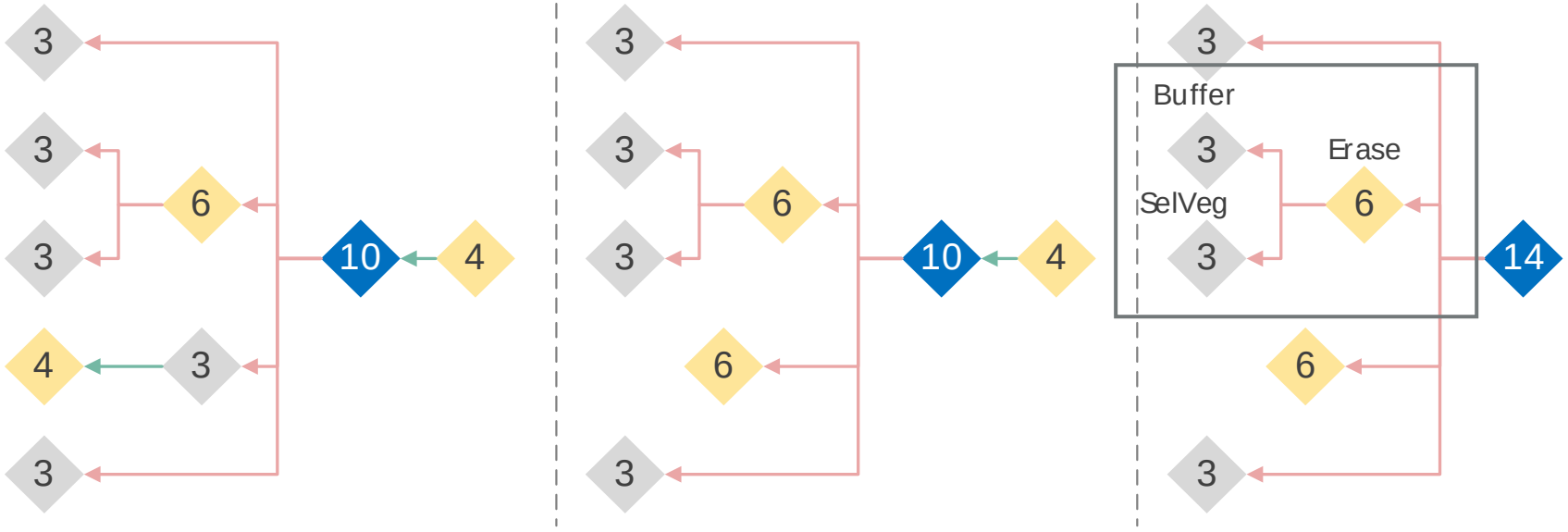
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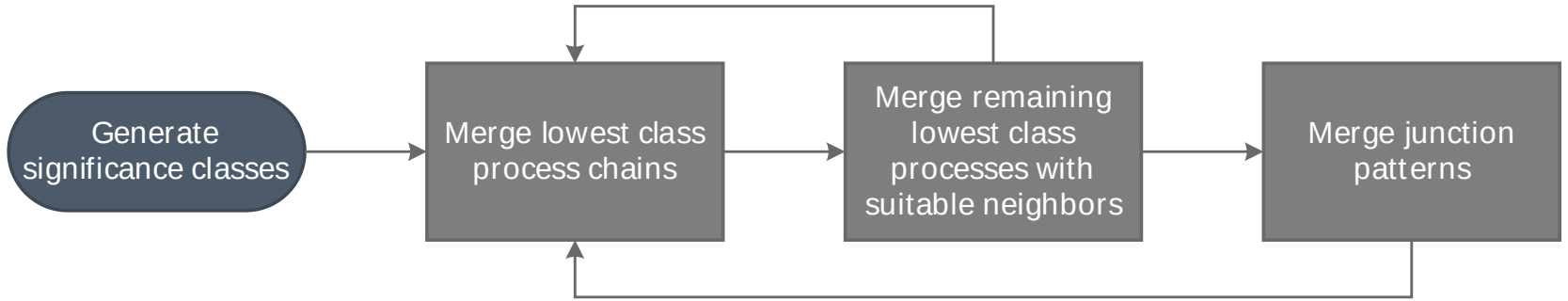
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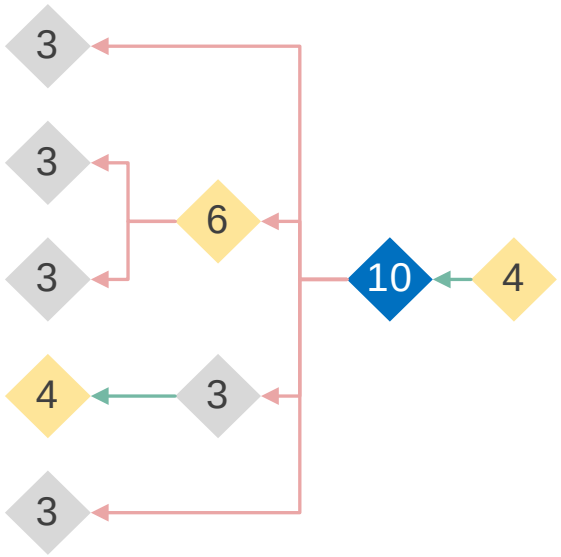
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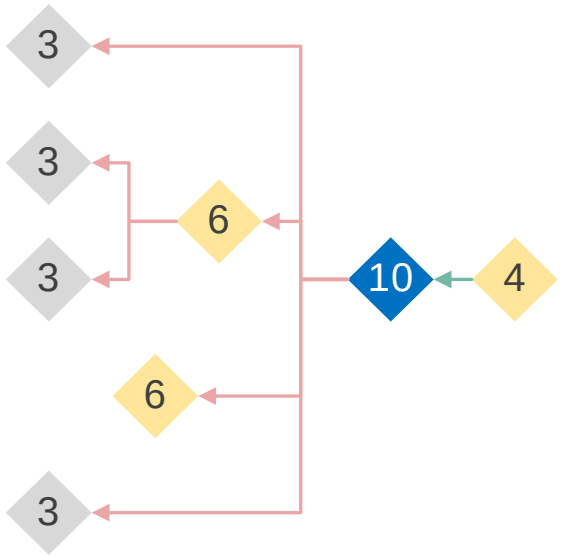
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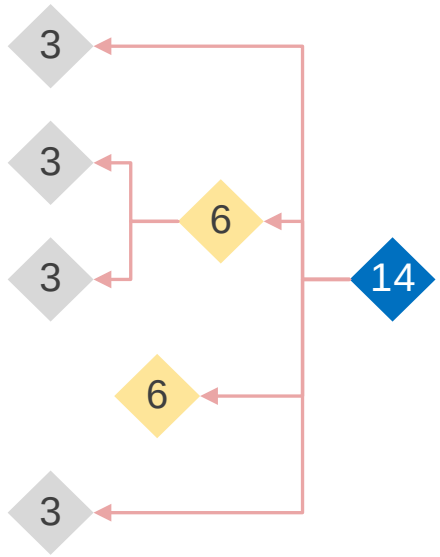
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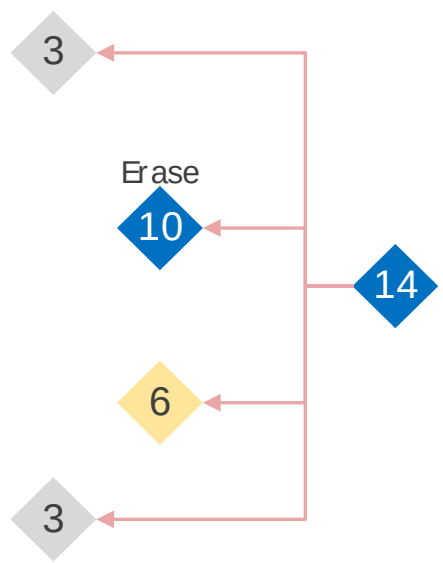
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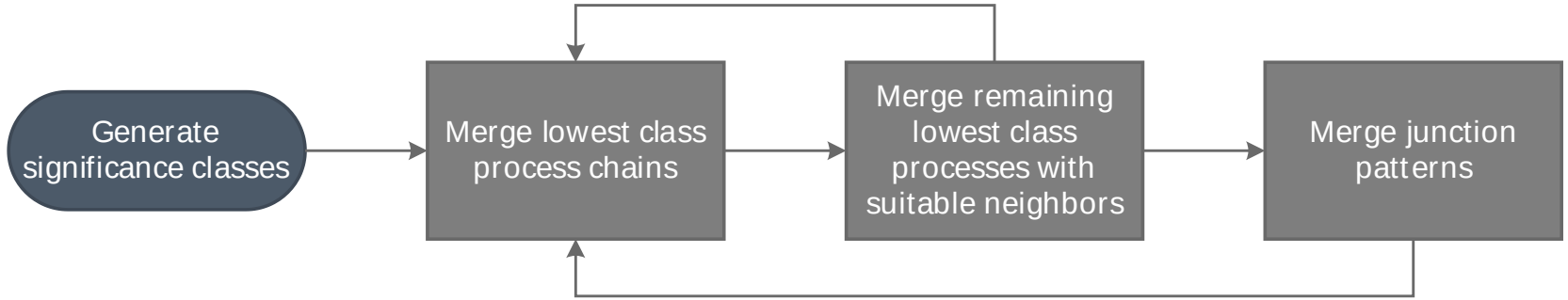
Generate significance classes
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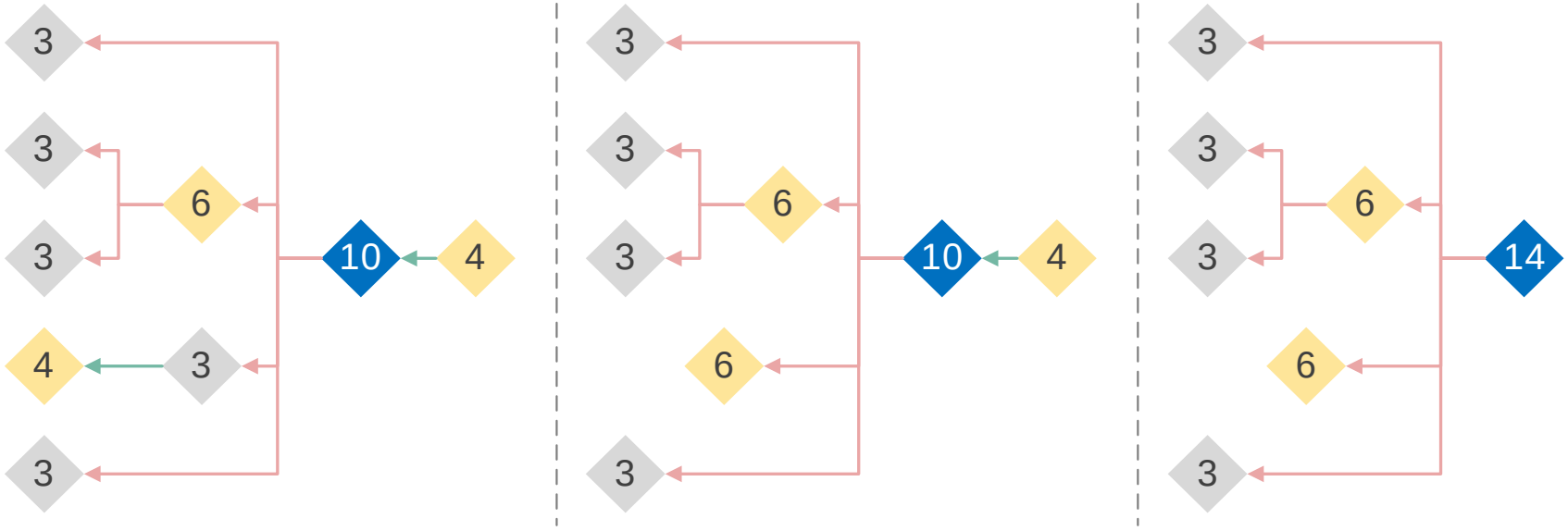
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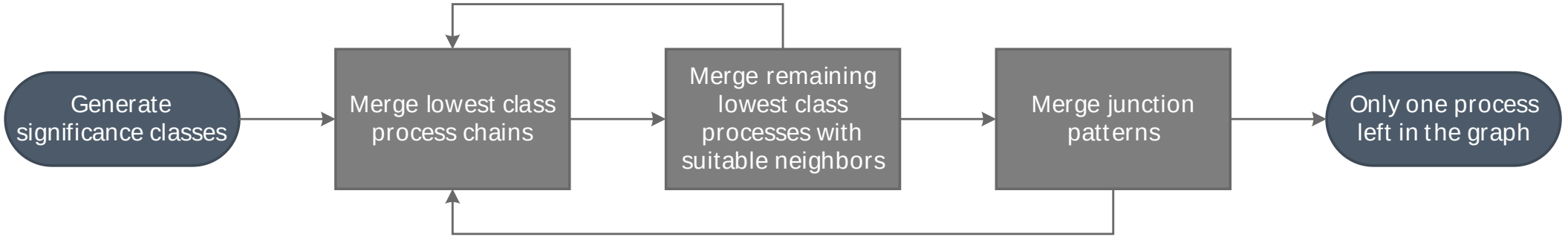
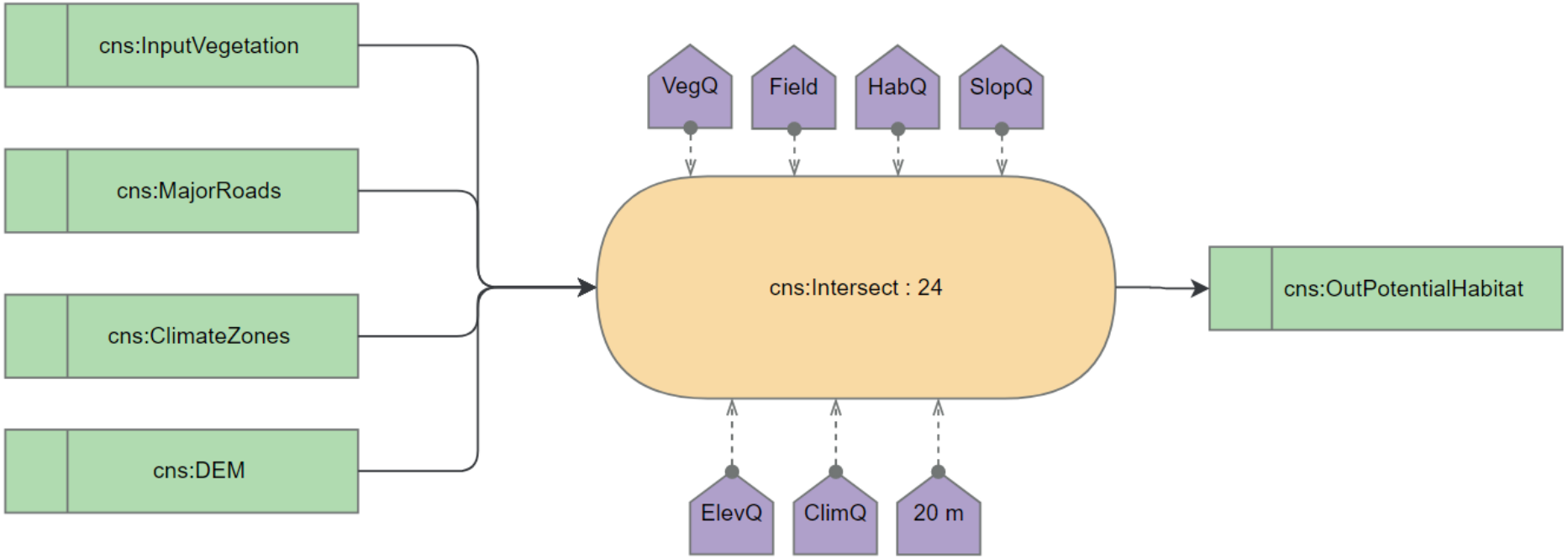

Generate significance classes
Merge lowest class process chains
Merge remaining lowest class processes with suitable neighbors
Merge junction patterns
Only one process left in the graph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cns:MajorRoads
cns:ClimateZones
cns:DEM
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cns:OutPotentialHabitat
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ClimQ
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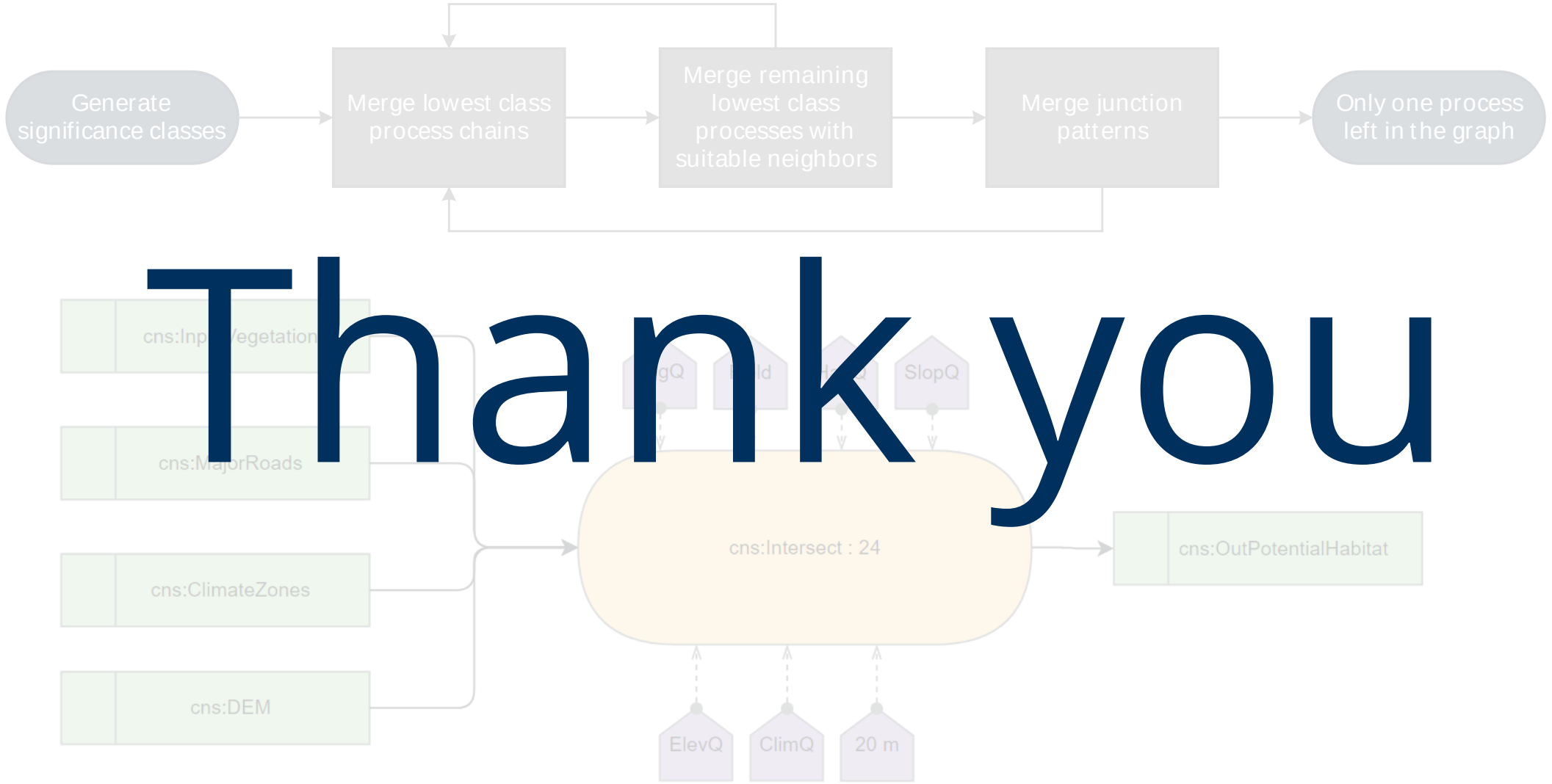
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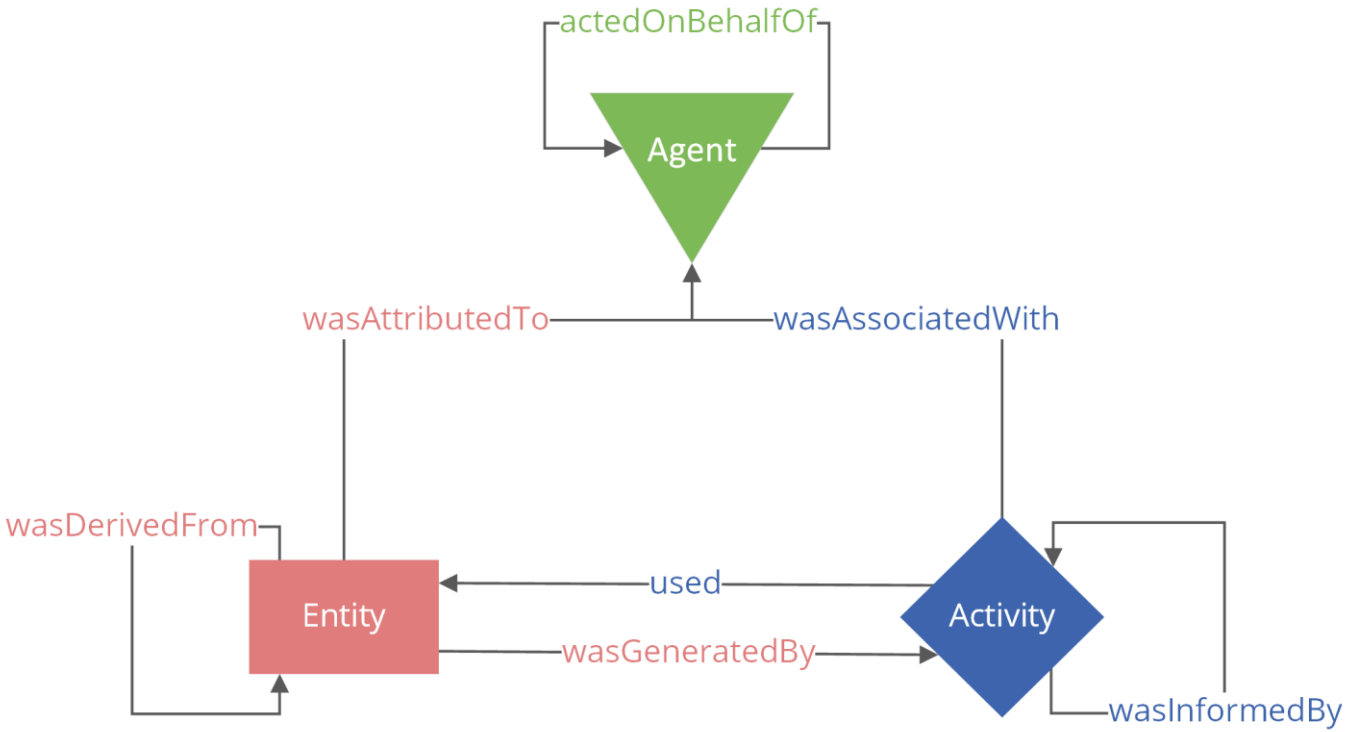
cns:MajorRoads
cns:ClimateZones
cns:DEM
SlopQ
cns:Intersect : 24
cns:OutPotentialHabitat
ElevQ
ClimQ
20 m

Thank you


actedOnBehalfOf
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Entity
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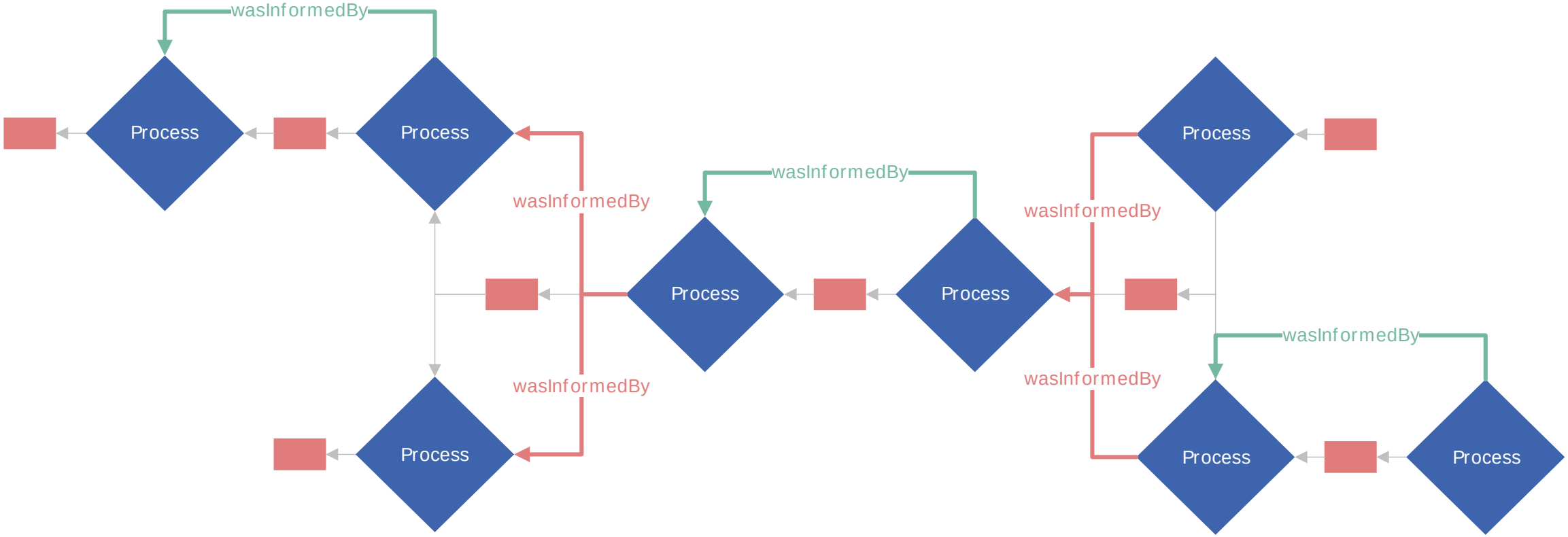
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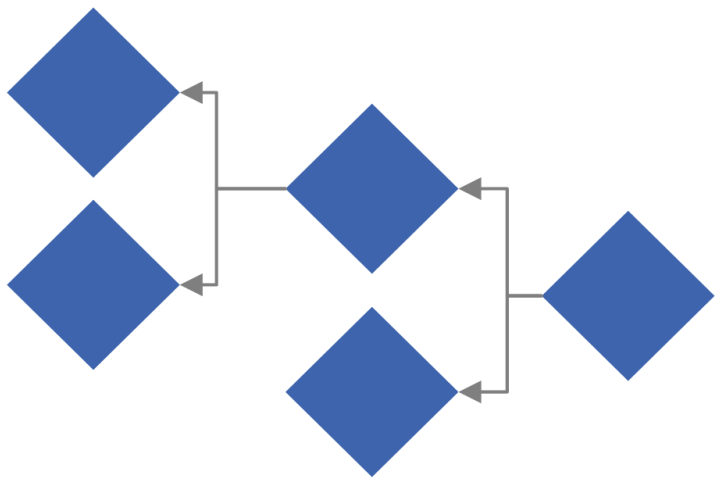
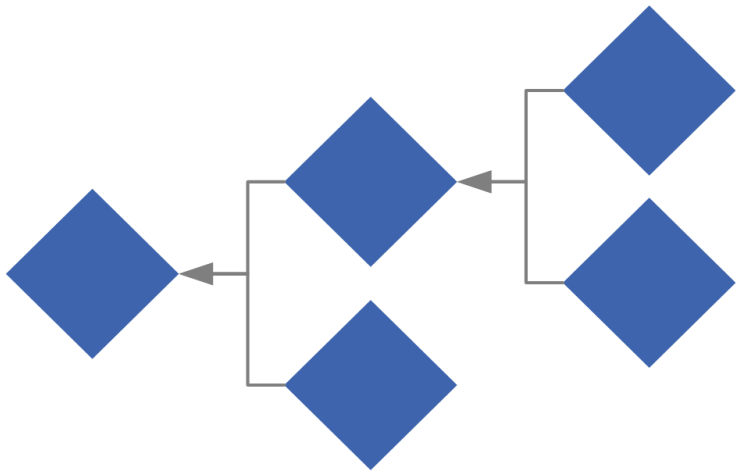
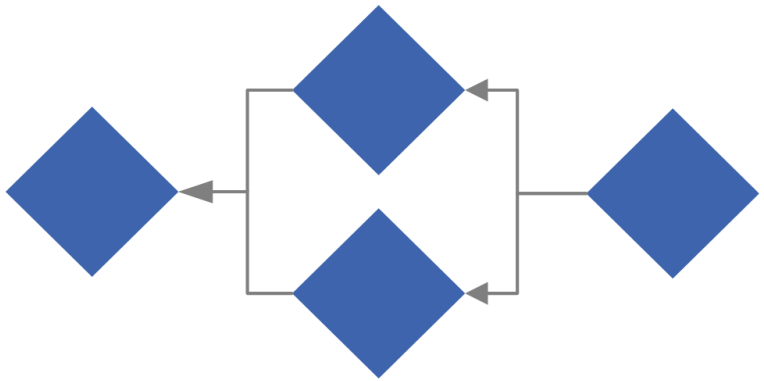


nested



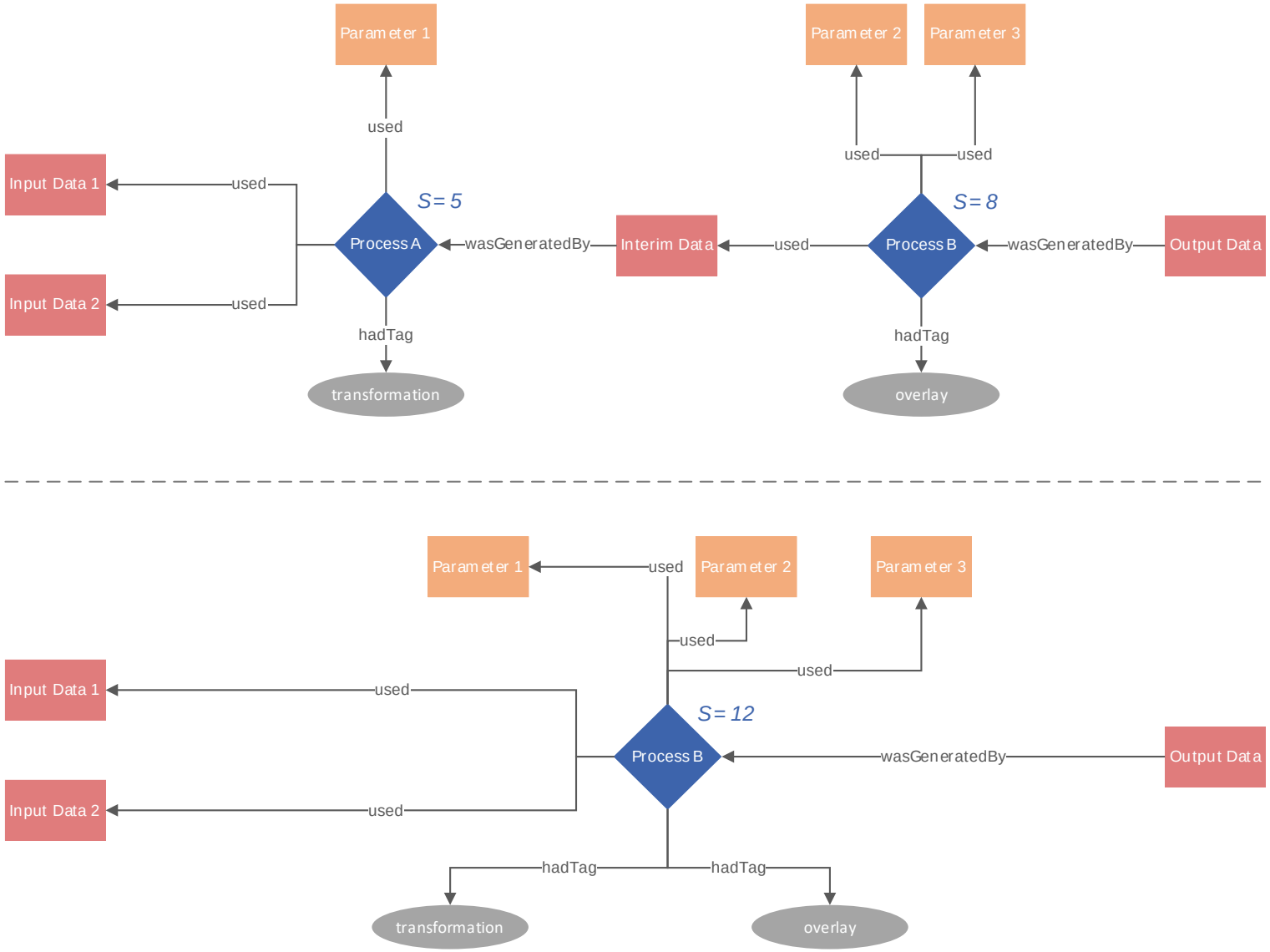
nested

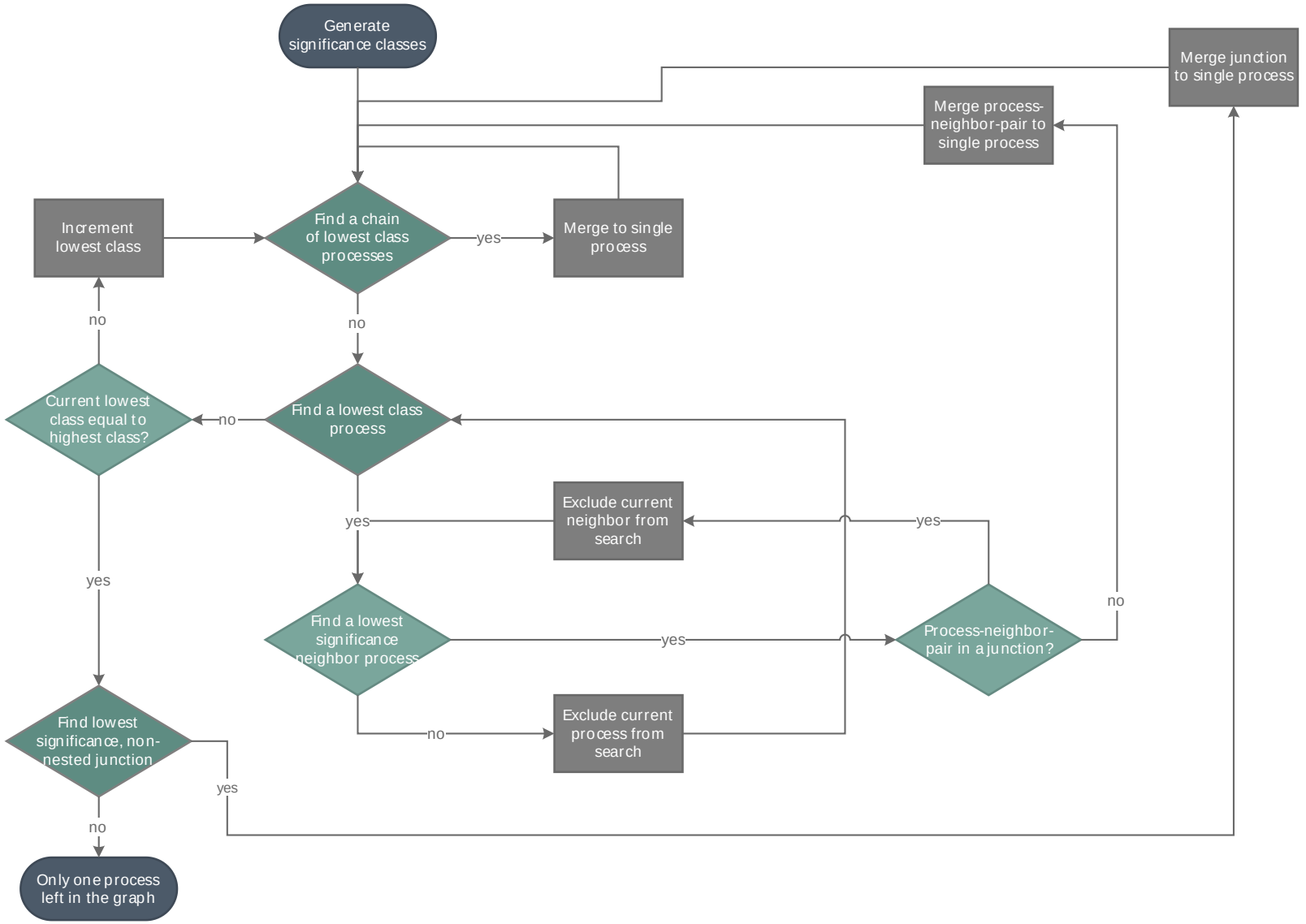


not nested

Merging Rules

- Any interim data between the merged Processes is ignored. Interim data is data that is at the same time input data and output data (only of the Processes that are getting merged).
- The input data of the new Process equals the source data of the merged units. Source data is input data that is no interim data
- The output data of the new Process is equal to the final data of the merged units. Final data is output data that is no interim data.
- The new Process has all parameters of the merged units.
- The new Process has all tags of the merged processes, but without duplicates.
- (The Multiplier of a process with multiple Tags is determined by the highest tag−group (*prepare, analyze, model*) present in the Tags.)
- The name of the process of the new Process is equal to the most significant merged process.


Parameter 1
used
Input Data 1
used
S = 5
Process A
wasGeneratedBy
Interim Data
used
Process B
wasGeneratedBy
Output Data
Input Data 2
used
hadTag
transformation
Parameter 2
Parameter 3
used
used
S = 8
hadTag
overlay
Parameter 1
used
Parameter 2
Parameter 3
used
used
Input Data 1
used
S = 12
Process B
wasGeneratedBy
Output Data
Input Data 2
used
hadTag
hadTag
transformation
overlay


Generate significance classes
Merge junction to single process
Merge process-neighbor-pair to single process
Increment lowest class
Find a chain of lowest class processes
yes
Merge to single process
no
no
Current lowest class equal to highest class?
no
Find a lowest class process
yes
Exclude current neighbor from search
yes
yes
Find a lowest significance neighbor process
yes
Process-neighbor-pair in a junction?
no
Exclude current process from search
no
Find lowest significance, non-nested junction
yes
no
Only one process left in the graph

Group	Tag (original)	Multiplier	Description	Examples (non-comprehensive)
prepare	selection (Selection)	1	Selection operations retrieve data from the database, [...].	Search, Logical/Arithmetic/Algebraic Condition, Suppress, Filter, Data Retrieval
	transformation (Transformation)	1	Transformation operations transform selected data for scale, orientation, projection, and presentation.	Scale Change, Orientation, Projection Change, Georeferencing, Map Registration, Resampling, raster-vector-conversion
	reclassification (Reclassification)	1	Reclassification operations assign new attribute values to a set of objects based on initial attribute values, geometry or topological relations.	Filtering, Merge Attributes, Generalization
	geometric (Geometric Computation)	1	Geometric Computation operations calculate simple geometric values like area, length, perimeter, and distance, but also more complex calculations like buffer zone, and average distance.	Area, Length, Perimeter, Distance, Buffer Zone, Generalization, Centroid, Dissolve Lines, Thiessen, Merge, Surface Calculation, Image Enhancement/Edge Detection
	visualization (Visualization)	1	Visualization covers any data visualization technique. Used in data explorations, process validation, result visualization, etc.	Block Diagram, Scene Generation, Cross Section, Histogram, Choropleth Map, Error Bars

analyze	neighborhood (Neighborhood Analysis)	2	Neighborhood operations use neighborhood information to calculate slope, diversity, profile, and interpolation.	Slope, Diversity, Interpolation, Proximity, Complex Generalization, Connectivity, Adjacency, Nearest Neighbor, Diffusion Model, Line-of-Sight, Pattern Analysis, Viewshed
	overlay (Map Overlay)	2	Map Overlay combines two or more maps; Both spatial and thematic attribute values can be combined.	Line-on-Polygon, Polygon Overlay, Corridors, Line Intersection, Route Allocation, Map Algebra, Optimal Location
	network (Transitive Closure Analysis)	2	Transistive Closure Analysis [...] calculate shortest path, travel time, and maximum flow. This can be done on a line graph or a polygon network.	Shortest Path, Travel Time, Connectivity, Maximum Flow/Flow Analysis, Drainage Network, Watershed Boundaries, Diffusion Model, Catchment
	statistics (Statistics)	2	Statistics operations calculate statistical characteristics like percentage, distribution, frequency, and correlation of objects of different classes over a specified area.	Percentage, Distribution, Frequency, Correlation, Spatial Statistics, Pattern Analysis, Complexity and Variation Measures
model	model	3	Model describes any black-box module. It is also applicatable for scripted processing steps that can not be abstracted by the categories above.	Neural Network,