02. Network Data Model

GE3238 GIS Design and Practices
Geography@NUS
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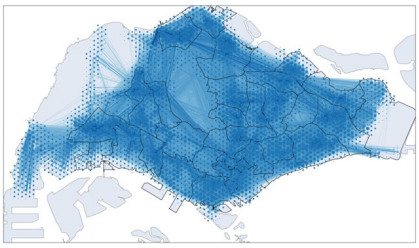
Learning Objectives

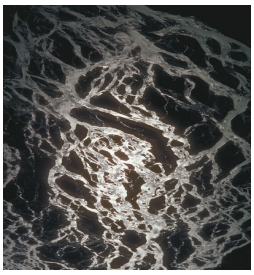
- Network as a broad concept underpinning mobility, social network, hydrologic applications
- What is the underlying model that enables finding, e.g. shortest path, and give directions?
  - You should already know where point, line, and polygon can be applied
- What is a network dataset in Esri's Geodatabase and how to build a simple/basic network dataset?

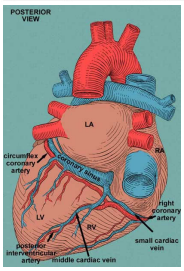
2

2

Examples of Network







Key terms

Network

3

3

Data Model

- Everyone has a mental model of reality or a problem, be it sophisticated or basic
- Data models help make explicit and scaffold our mental models as we use information technology to solve complex problems

Key terms

Mental model
Data model

4

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Spatial Data Model

- A collective term for the process of identifying all the design elements used in the construction of a GIS
- What are the primitive entities?
  - What are the permitted relations between entities?
  - What are the properties of an entity?
  - How do we enforce constraints to avoid problems in the database?

Key terms

Spatial data model
Entity
Property
Relation between entities

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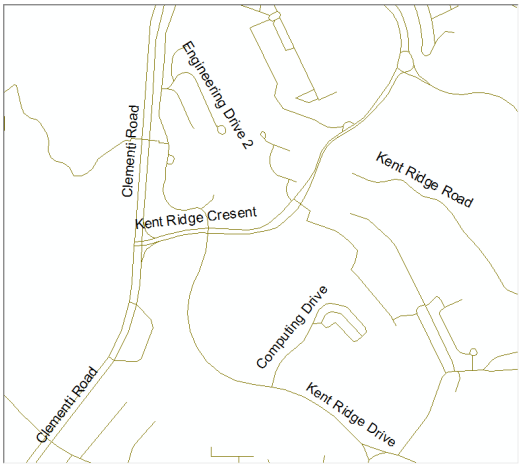
Spatial Data Model?



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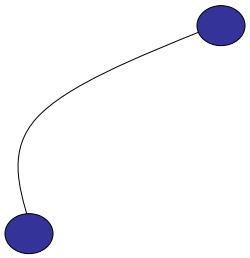
Basic Elements 0: Primitive Entities

- Node
  - A node refers to the end point of a link
- Link (or edge)
  - A link refers to a road segment defined by two end points



Key terms

Primitive
Node
Link

7

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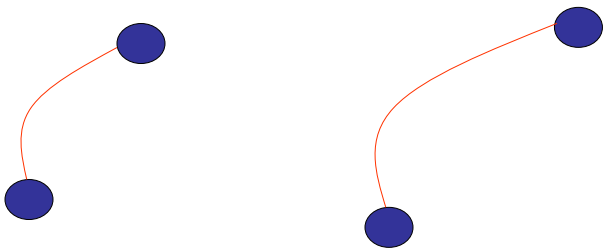
Basic Element 1



Key terms

Topology

8

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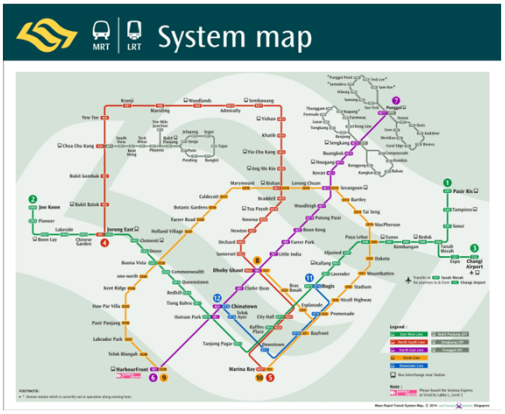
Can we separate geometry from connectivity?

Think about this intuitive example



Key terms

Topology

Connectivity

9

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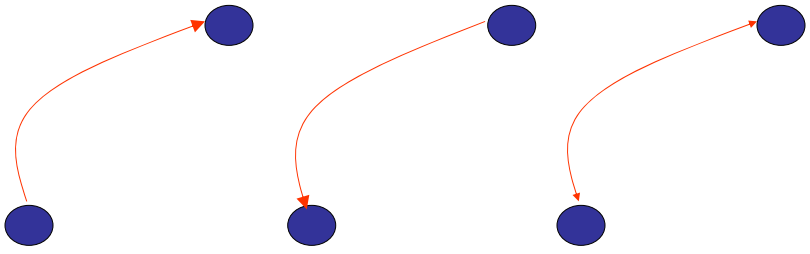
Basic Element 2



Key terms

Direction

10

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Basic Element 3a: Link Impedance

- The cost of traversing a link
  - Length of a link?
  - Traveling speed?

Key terms

Forms of cost
Edge or link

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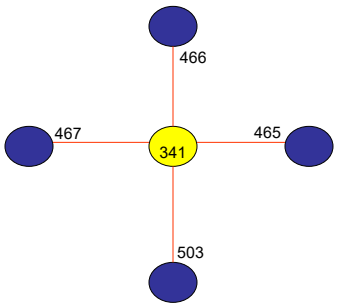
Basic Element 3b: Junction Impedance



Node#	Arc1#	Arc2#	Angle	Minutes
341	503	467	90	0.500
341	503	466	0	0.250
341	503	465	–90	0.250
341	467	503	–90	0.250
341	467	466	90	0.500
341	467	465	0	0.250
341	466	503	0	0.250
341	466	467	–90	0.250
341	466	465	90	0.500
341	465	503	90	0.500
341	465	467	0	0.250
341	465	466	–90	0.250

Key terms

Cost
Junction

12

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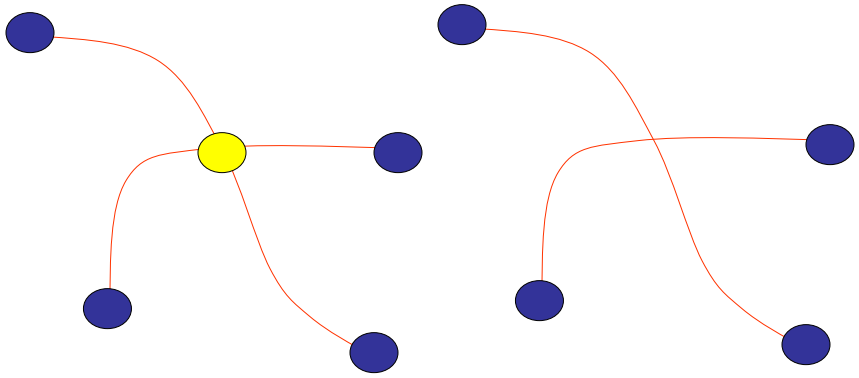
Basic Element 4

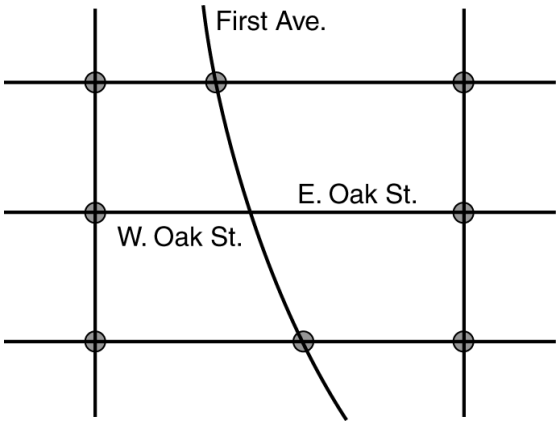


Key terms

Connectedness

Junction

13



First Ave. crosses Oak St. with an overpass. A nonplanar representation with no nodes is used at the intersection of Oak St. and First Ave.

Key terms

Non-planar representation

Overpass or underpass

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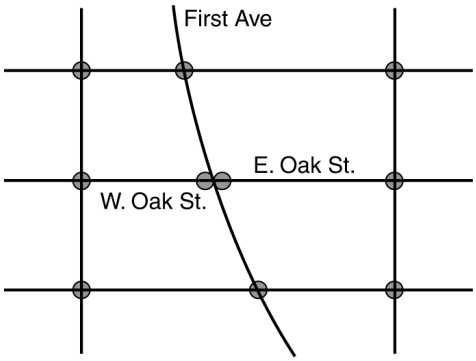

First Ave. crosses Oak St. with an overpass. A planar representation with two nodes is used at the intersection: one for First Ave., and the other for Oak St. First Ave has 1 for the T-elev and F-elev values, indicating that the overpass is on First Ave.

Street name	F-elev	T-elev
First Ave	0	1
First Ave	1	0
W. Oak St.	0	0
E. Oak St.	0	0

Key terms

Planar representation

Overpass or underpass

Binary (0 or 1) encoding

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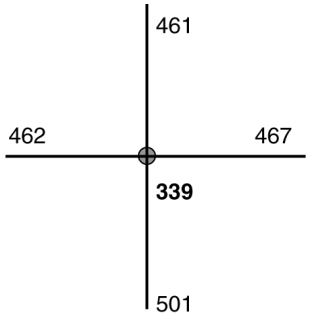
Basic Element 5



Key terms

Turns (directions on two edges)

16

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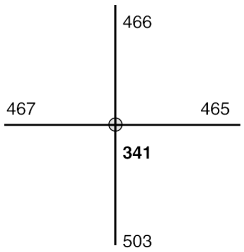

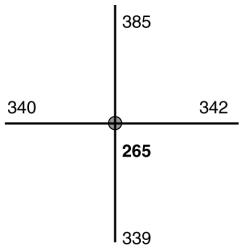

Key terms

Turn table

Node#	Arc1#	Arc2#	Angle	Minutes
341	503	467	90	0.500
341	503	466	0	0.250
341	503	465	–90	0.250
341	467	503	–90	0.250
341	467	466	90	0.500
341	467	465	0	0.250
341	466	503	0	0.250
341	466	467	–90	0.250
341	466	465	90	0.500
341	465	503	90	0.500
341	465	467	0	0.250
341	465	466	–90	0.250

Node#	Arc1#	Arc2#	Angle	Minutes
265	339	342	–87.412	0.000
265	339	340	92.065	0.000
265	339	385	7.899	0.000
265	342	339	87.412	0.500
265	342	340	–0.523	0.250
265	342	385	–84.689	0.250
265	340	339	–92.065	0.250
265	340	342	0.523	0.250
265	340	385	95.834	0.500
265	385	339	–7.899	0.000
265	385	342	84.689	0.000
265	385	340	–95.834	0.000

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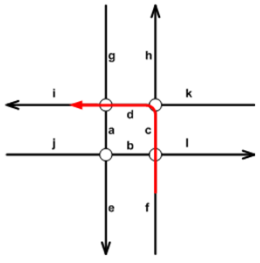
Side note

- There is a more powerful tool for turns in Geodatabase – turn feature class

https://pro.arcgis.com/en/pro-app/latest/help/analysis/networks/turns-in-the-network-dataset.htm



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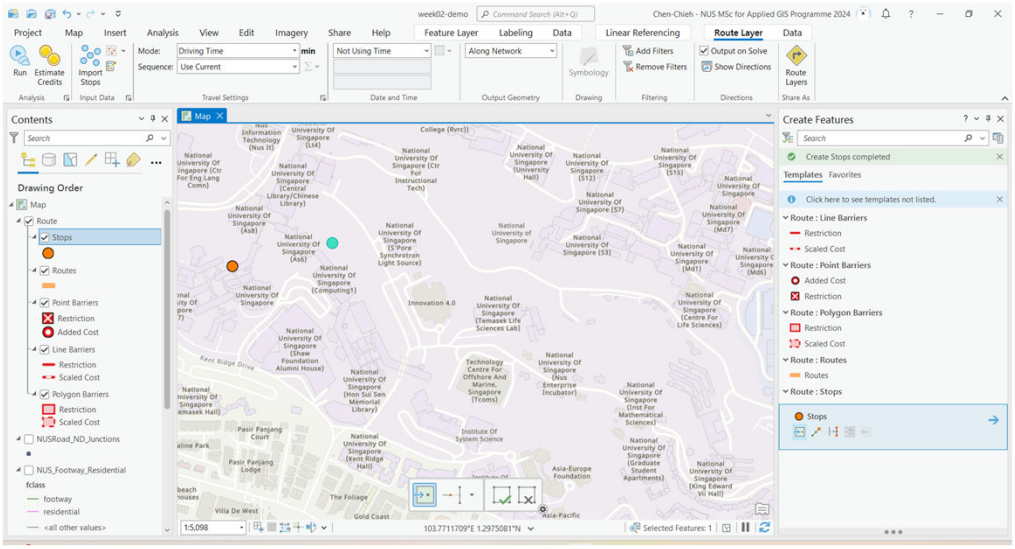
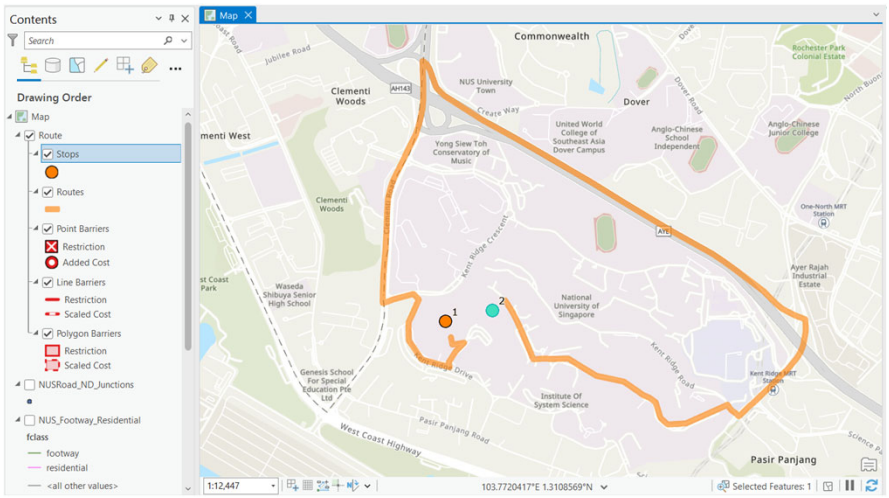
Shortest Path in ArcGIS Pro…



Shortest Path in ArcGIS Pro?



Enabler: Network Dataset (xx_ND)

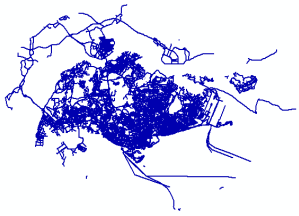
- Practically (and historically)
  - ArcGIS was a vector-based system, and
  - this means that it started with point, line, and polygon, all in 2D space
  - That is, no notion of connectivity involved
- Conceptually?

Putting Together a Network

- Points and lines → nodes and edges
  - Gathering linear features
  - Building topology
  - Adding attributes

Key terms

Workflow
Data sources



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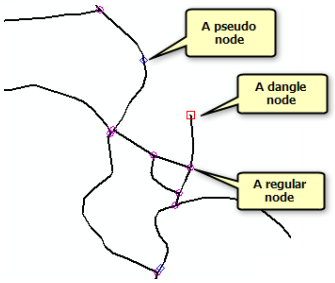
(See also the supplement slides)

Putting Together a Network

- Points and lines → nodes and edges
  - Gathering linear features
  - Building topology
    - Error correction
    - Pseudo nodes
    - Overpass and underpass
  - Adding attributes

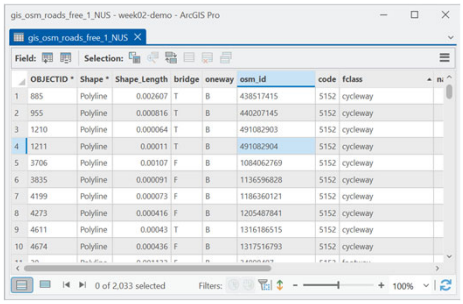


Key terms

Geometry
Topology
Attributes (for topology structure)

Putting Together a Network

- Points and lines → nodes and edges
  - Gathering linear features
  - Building topology
  - Adding attributes
    - Assign cost for example



Key terms

Geometry
Topology
Attributes (for topology structure)

Summary

- What we just did and what are the take home message?
  - Scratched the surface of a specific data model for navigation related applications
  - The physical model is based on Esri's native Geodatabase model
  - Geodatabase (the chosen physical model) accommodates a specific logical model (network dataset) for navigation applications; NUSRoad_ND can be considered at this level
  - Several tools from GE2215 are leveraged for ascertain data quality (e.g., topology checking and projection conversion)
  - The logical model is an implementation of the conceptual model that describes a simplified real world

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SUPPLEMENT SLIDES

(SEE IN-CLASS DEMO)

The data used in the demo is in week02-demo on Canvas

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OSM Data

- https://osmtoday.com/asia/singapore.html
  (last accessed 21 Jan 2025, native format: pbf)
- https://download.geofabrik.de/asia/malaysia-singapore-brunei.html
  (last accessed 21 Jan 2025, native format: pbf, but Shapefile also available)

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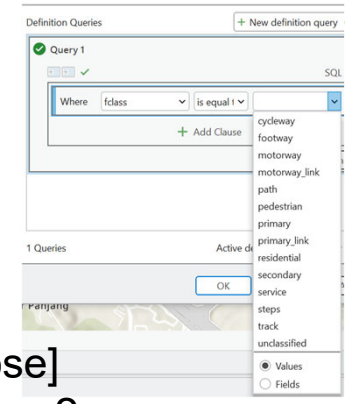
OSM Data, zoom to NUS only

Data-rich environment

- What kinds of roads?
- Do we need all "roads" for [a stated purpose] (navigation in this case)?



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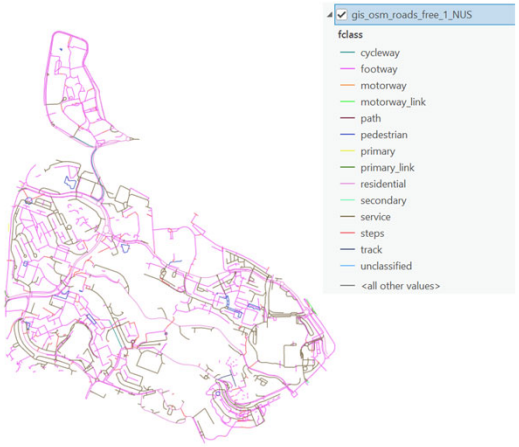
OSM Data, zoom to NUS



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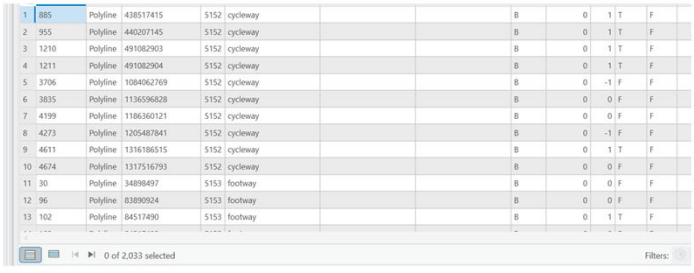
OSM Data, zoom to NUS



1	885	Polyline	438517415	5152	cycleway			B	0	1	T	F
2	955	Polyline	440207145	5152	cycleway			B	0	1	T	F
3	1210	Polyline	491082903	5152	cycleway			B	0	1	T	F
4	1211	Polyline	491082904	5152	cycleway			B	0	1	T	F
5	3706	Polyline	1084062769	5152	cycleway			B	0	-1	F	F
6	3835	Polyline	1136596828	5152	cycleway			B	0	0	F	F
7	4199	Polyline	1186360121	5152	cycleway			B	0	0	F	F
8	4273	Polyline	1205487841	5152	cycleway			B	0	-1	F	F
9	4611	Polyline	1316186515	5152	cycleway			B	0	1	T	F
10	4674	Polyline	1317516793	5152	cycleway			B	0	0	F	F
11	30	Polyline	34898497	5153	footway			B	0	0	F	F
12	96	Polyline	83890924	5153	footway			B	0	0	F	F
13	102	Polyline	84517490	5153	footway			B	0	1	T	F

0 of 2,033 selected Filters:

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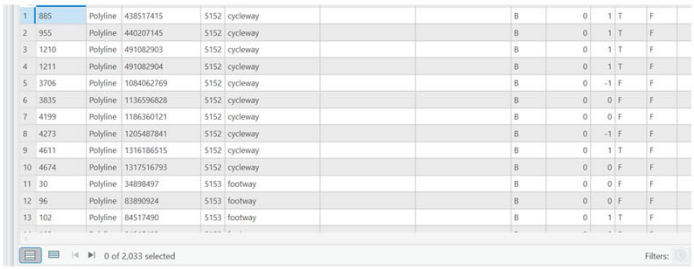
Can you navigate with this dataset?



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2	955	Polyline	440207145	5152	cycleway			B	0	1	T	F
3	1210	Polyline	491082903	5152	cycleway			B	0	1	T	F
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8	4273	Polyline	1205487841	5152	cycleway			B	0	-1	F	F
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10	4674	Polyline	1317516793	5152	cycleway			B	0	0	F	F
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12	96	Polyline	83890924	5153	footway			B	0	0	F	F
13	102	Polyline	84517490	5153	footway			B	0	1	T	F

0 of 2,033 selected

Filters:

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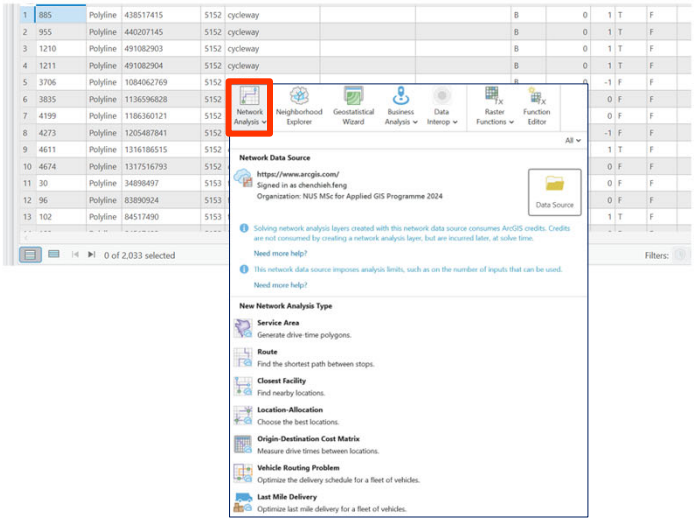
Can you navigate with this dataset (cont.)?



1	885	Polyline	438517415	5152	cycleway			B	0	1	T	F
2	955	Polyline	440207145	5152	cycleway			B	0	1	T	F
3	1210	Polyline	491082903	5152	cycleway			B	0	1	T	F
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9	4611	Polyline	1316186515	5152						1	T	F
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11	30	Polyline	34898497	5153						0	F	F
12	96	Polyline	83890924	5153						0	F	F
13	102	Polyline	84517490	5153						1	T	F

0 of 2,033 selected

Filters:

Network Analysis | Neighborhood Explorer | Geostatistical Wizard | Business Analysis | Data Interop | Raster Functions | Function Editor

All

Network Data Source

https://www.arcgis.com/
Signed in as chenchieh.feng
Organization: NUS MSc for Applied GIS Programme 2024

Data Source

Solving network analysis layers created with this network data source consumes ArcGIS credits. Credits are not consumed by creating a network analysis layer, but are incurred later, at solve time.

Need more help?

This network data source imposes analysis limits, such as on the number of inputs that can be used.

Need more help?

New Network Analysis Type

Service Area
Generate drive time polygons.

Route
Find the shortest path between stops.

Closest Facility
Find nearby locations.

Location-Allocation
Choose the best locations.

Origin-Destination Cost Matrix
Measure drive times between locations.

Vehicle Routing Problem
Optimize the delivery schedule for a fleet of vehicles.

Last Mile Delivery
Optimize last mile delivery for a fleet of vehicles.

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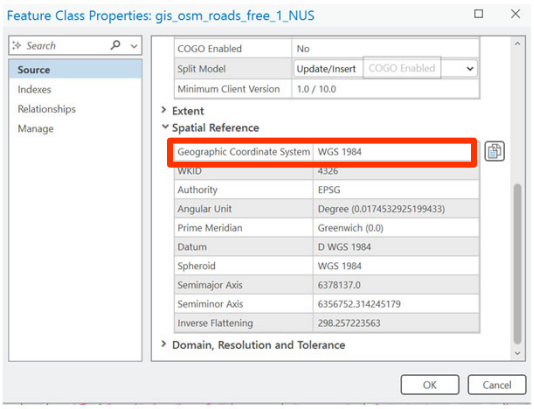
Network Dataset – CONNECTIVITY matters



From GE2215, topology checking in ArcGIS Pro

But is projection an issue?

How is projection related?

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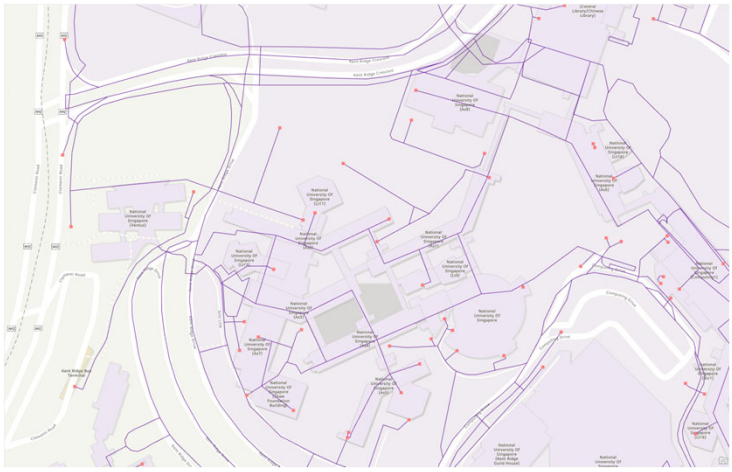
Network Dataset – CONNECTIVITY matters



Does the topologic checking result make sense?

From GE2215, topology checking in ArcGIS Pro

Remember what is a feature dataset?

Why is feature dataset being brought up here?

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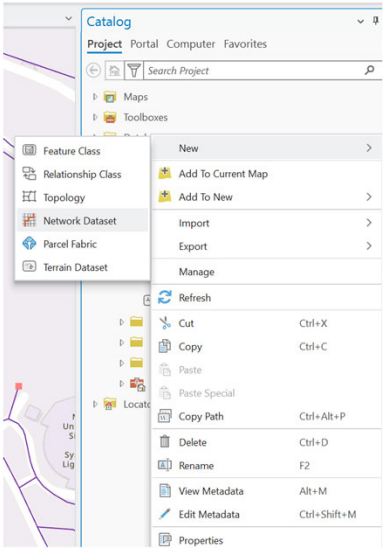
Network Dataset – CONNECTIVITY matters



Network dataset is an option/tool under feature dataset

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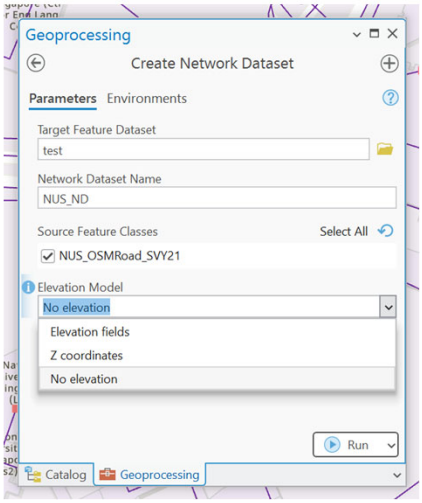
Network Dataset – CONNECTIVITY matters



Network dataset is an option/tool under feature dataset

Create network dataset with a random name NUS_ND

Elevation is not about height above mean sea level, but for over- or under-passes

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Network Dataset – CONNECTIVITY matters

Dirty area created by creating the network dataset

Creating a network dataset

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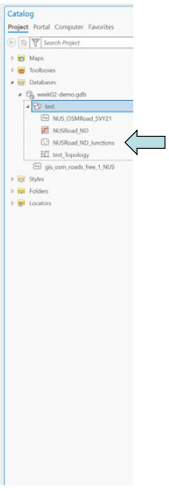
Network Dataset – CONNECTIVITY matters



Building a network dataset

Visually, nothing have changed

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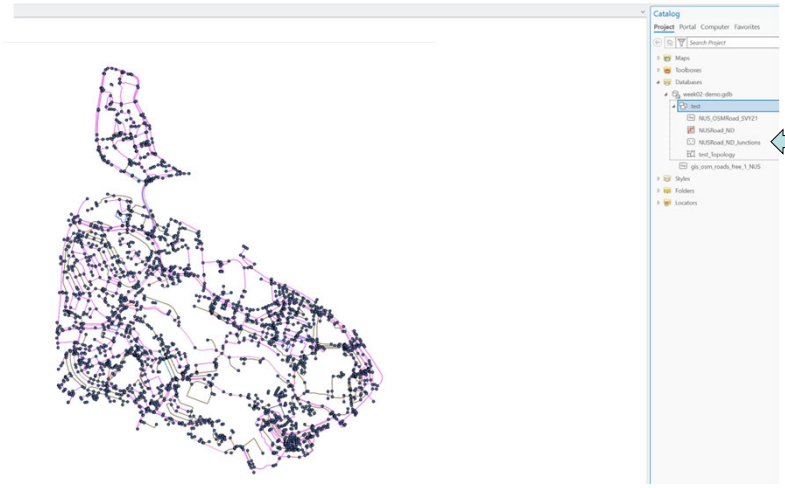
Network Dataset – CONNECTIVITY matters



Building a network dataset

But junctions added automatically

ArcGIS does so only if topology is correct!

Visually, this indicates the connectivity is being explicitly recognized

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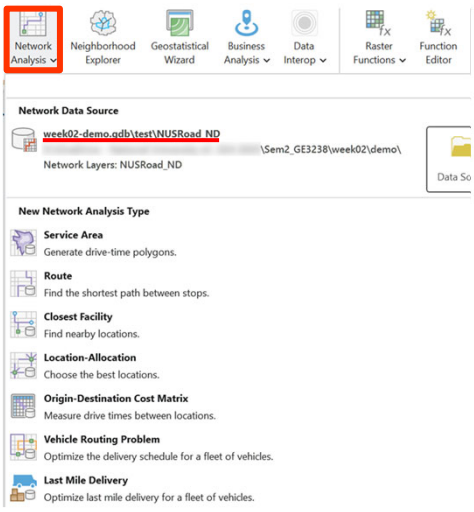
Revisit the question "can you navigate with this dataset?"



Dataset = NUSRoad_ND

Network analysis tools now connected to NUSRoad_ND

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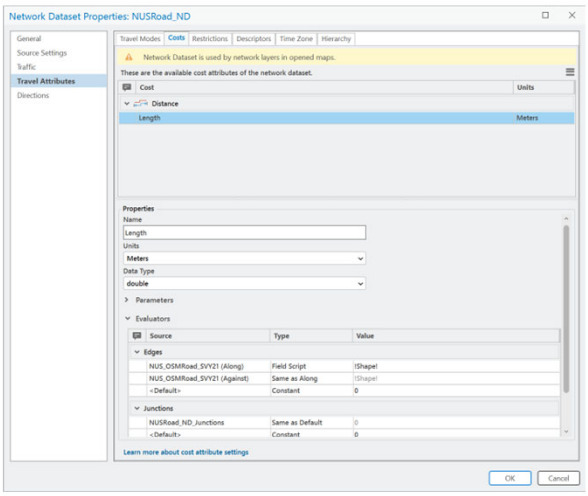
Cost, impedance, and other properties?



What about properties of travel?