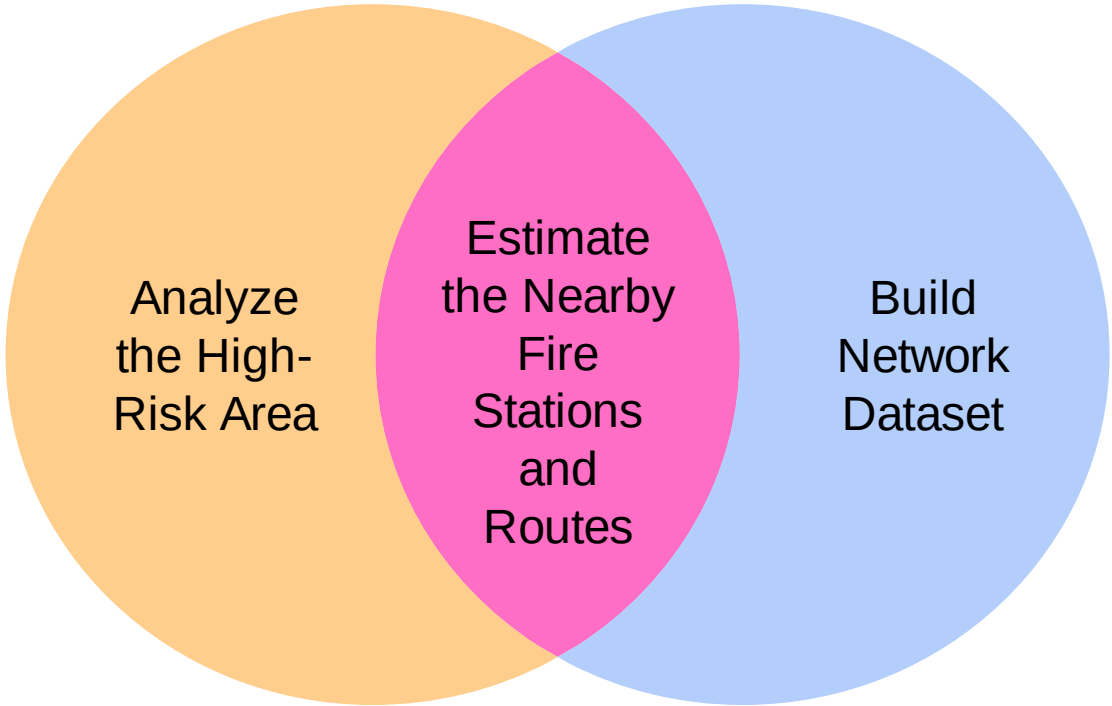
Integrated Assessment of Flooding Risk Factors and Optimal Rescue Routes

Tzu Yu Ma

Problem

The study area was focusing on the southern part of Taiwan, an area prone to frequent flooding, especially during the approach of typhoons. This often results in damage to roads, bridges, and buildings. My objective is to determine safe and efficient routes for rescue teams, fire stations, to reach the affected areas and facilitate timely assistance.

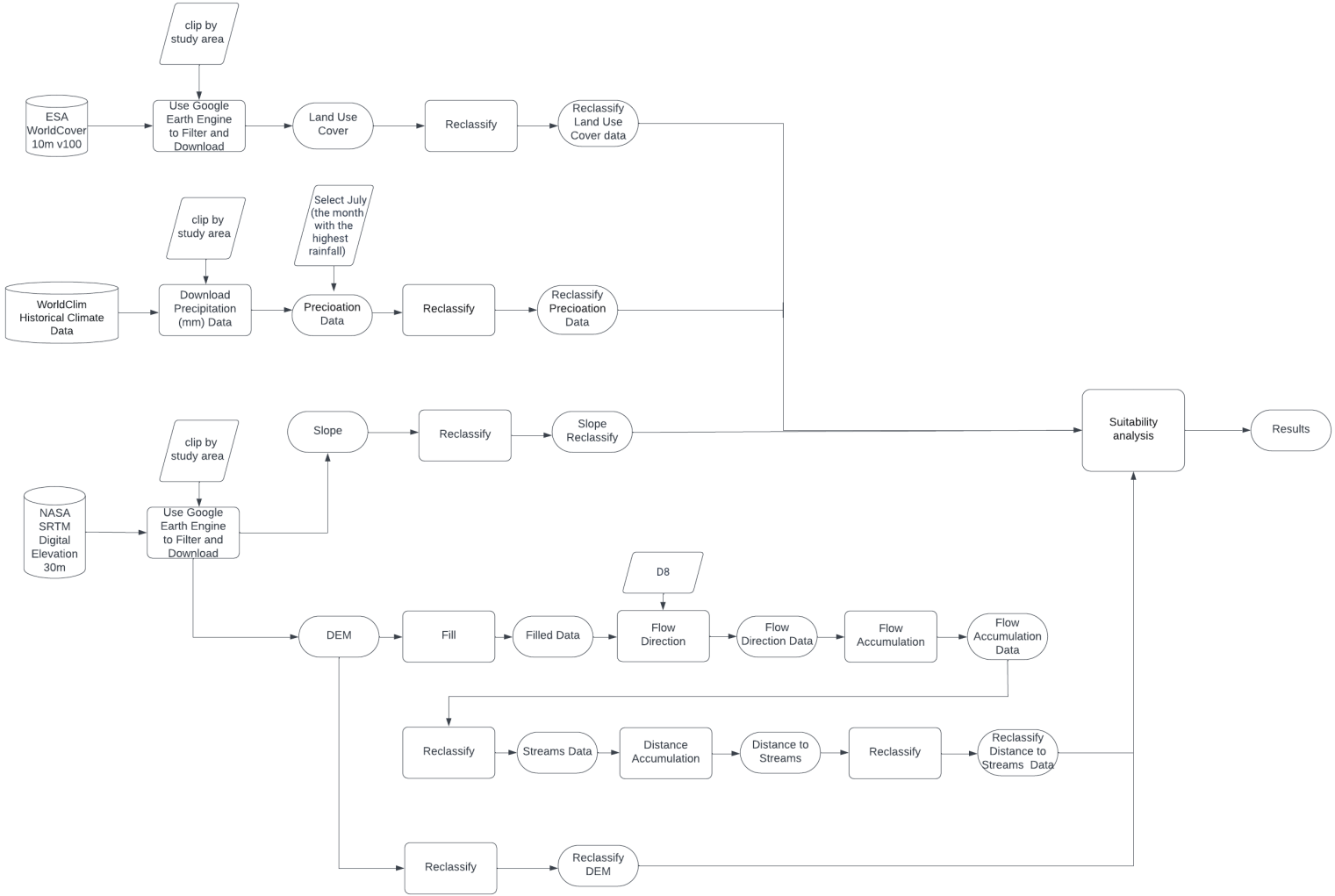
Problem Statement



Method

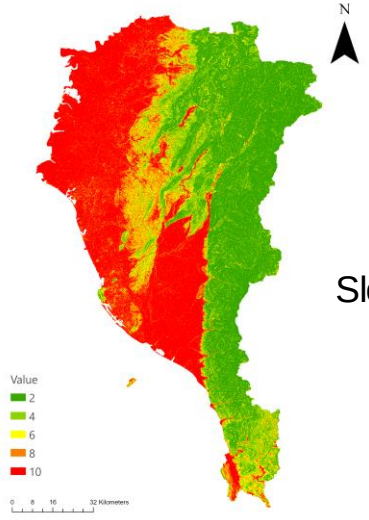
Necessary Data:

LULC
Precipitation
Slope
DEM
Distance to stream

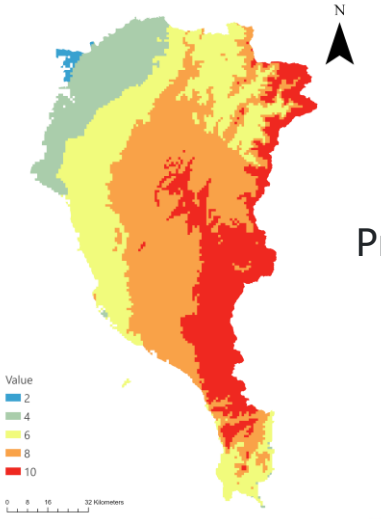


Method cont.

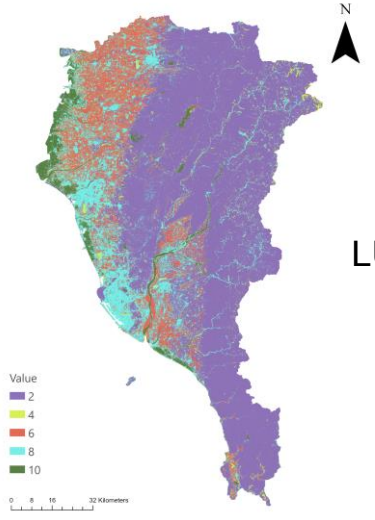
Study Area



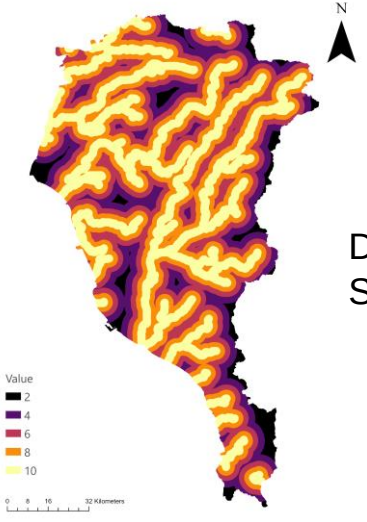
Slope



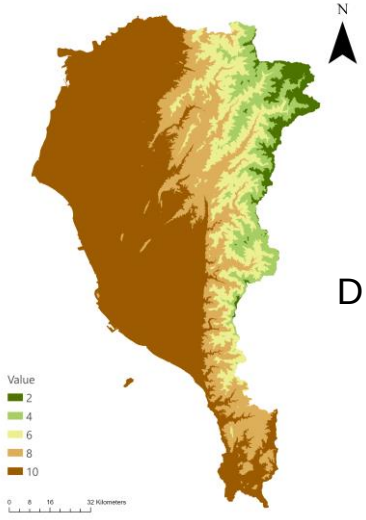
Precipitation



LULC



Distance to Streams



DEM

Method cont.

Analytic Hierarchy Process (AHP)

- a multi-criteria decision analysis method developed by Thomas L. Saaty in the 1980s.
- Hierarchical Structure
- Pairwise Comparison Matrix
- Calculate the Consistency Ratio (CR):

If CR is less than or equal to 0.1, the consistency is considered acceptable.

If CR is greater than 0.1, it indicates a lack of consistency, and adjustments may be needed.

Numeric Scale	Definition
1	Equal Importance
3	Moderate Importance
5	Strong Importance
7	Very Strong Importance
9	Extreme Importance
2,4,6,8	Intermediate Values
Reciprocal of 1~9	Inverse Comparison

	Slope	DEM	Distance to river	LULC	Precipitation
Slope	1	1/2	1/4	1/3	1/7
DEM	2	1	1/5	1/2	1/6
Distance to river	4	5	1	5	1/3
LULC	3	2	1/5	1	1/5
Precipitation	7	6	3	5	1

Method cont.

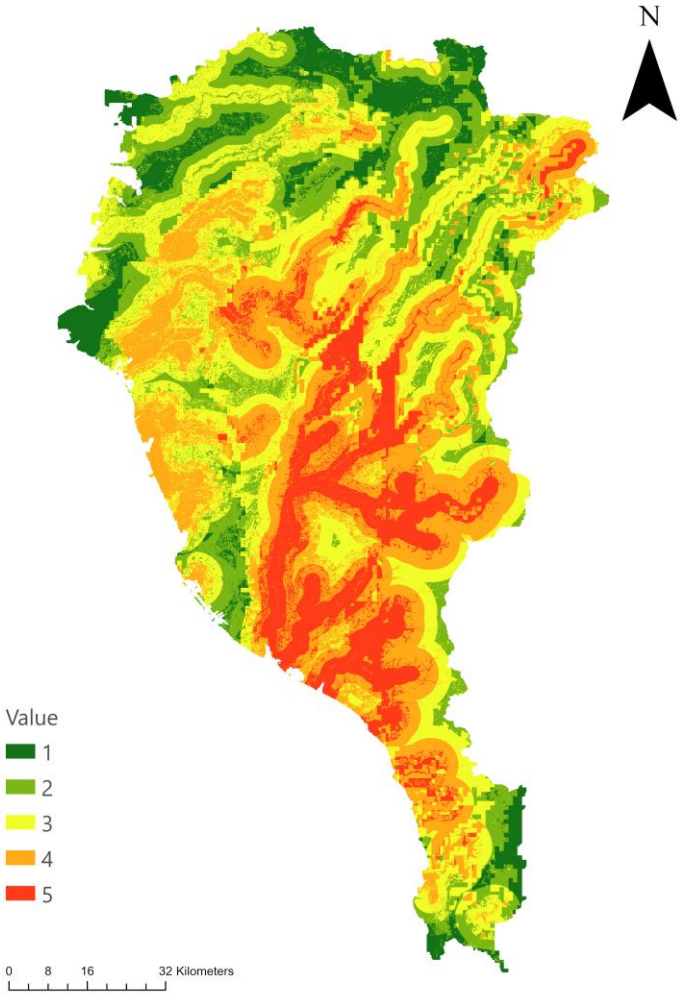
	Slope	DEM	Distance to river	LULC	Precipation		$\bar{w}_i$	w_i			
Slope	1	0.5	0.25	0.333333	0.1428571	0.005952381	0.358871	0.04941		C.I	0.067425
DEM	2	1	0.2	0.5	0.1666667	0.033333333	0.506496	0.069735		C.R.	0.060201
Distance to river	4	5	1	5	0.3333333	33.33333333	2.016396	0.277621			
LULC	3	2	0.2	1	0.2	0.24	0.751696	0.103495			
Precipation	7	6	3	5	1	630	3.629678	0.49974			
								1			

AW	Slope	DEM	Distance to river	LULC	Precipation	aw	aw/w
Slope	0.04941	0.034868	0.069405	0.034498	0.0713914	0.259572213	1.050689
DEM	0.09882	0.069735	0.055524	0.051747	0.08329	0.359116326	1.029944
Distance to river	0.19764	0.348676	0.277621	0.517473	0.1665799	1.507989074	1.086367
LULC	0.14823	0.13947	0.055524	0.103495	0.099948	0.546666681	1.056415
Precipation	0.345869	0.418411	0.832862	0.517473	0.4997398	2.614354773	1.046286
						λ_{max}	5.269702

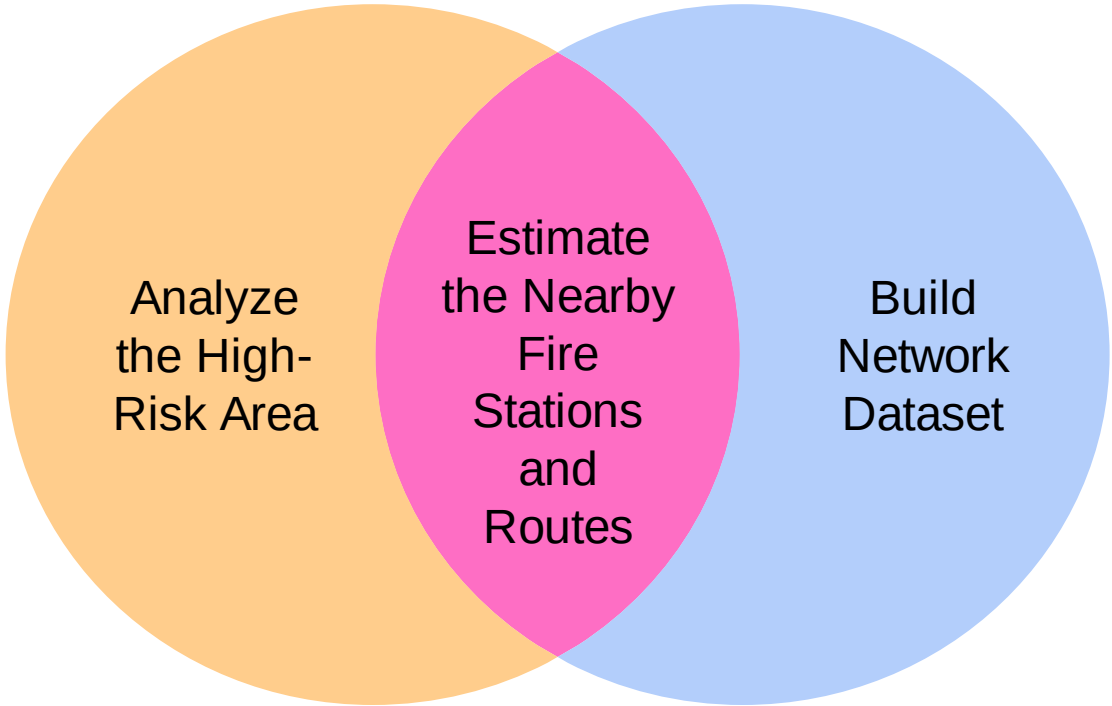
Weights:

Slope 0.049
DEM 0.070
Distance to river 0.278
LULC 0.103
Precipitation 0.500

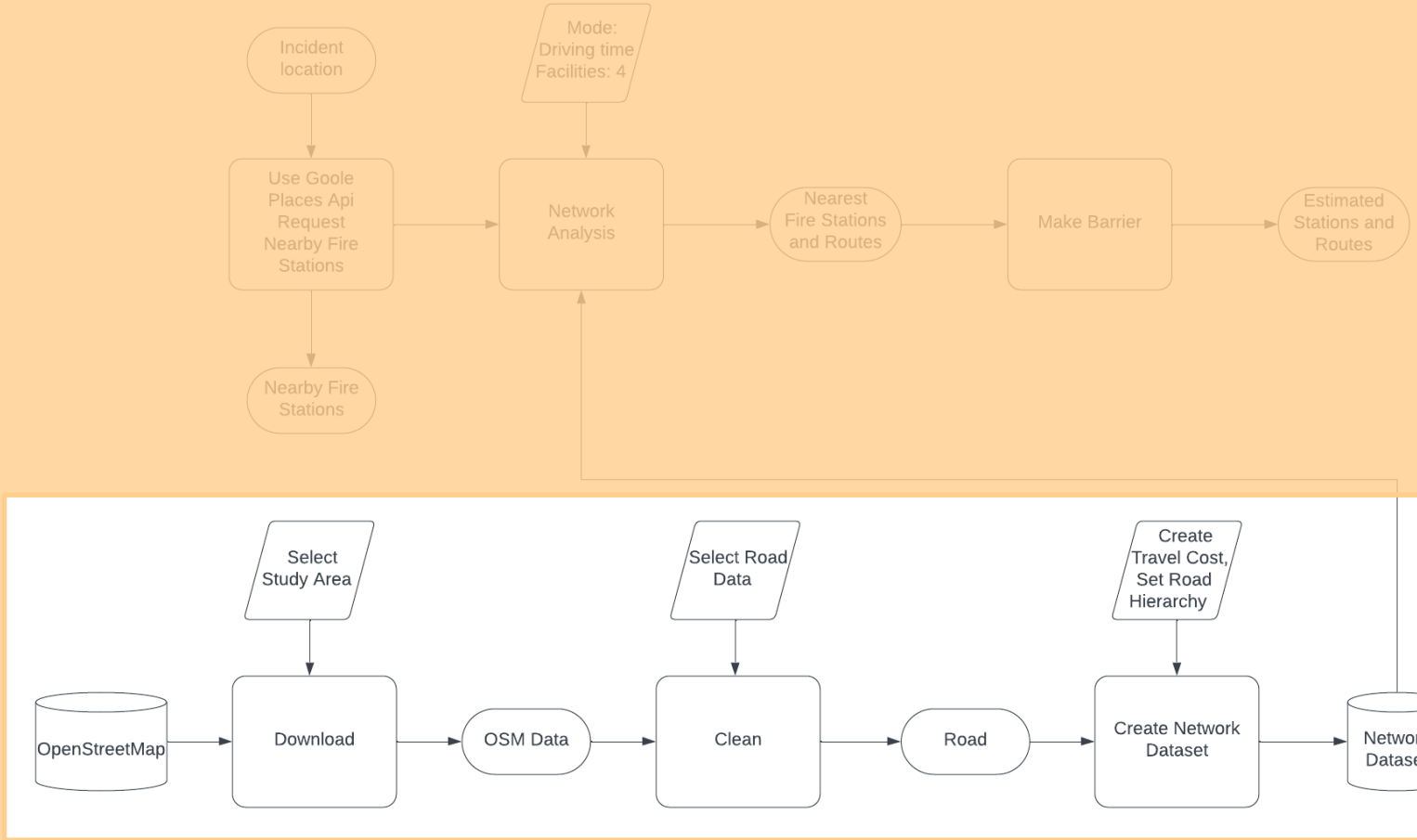
$C.R. = 0.060201261$



Problem Statement



Method cont.

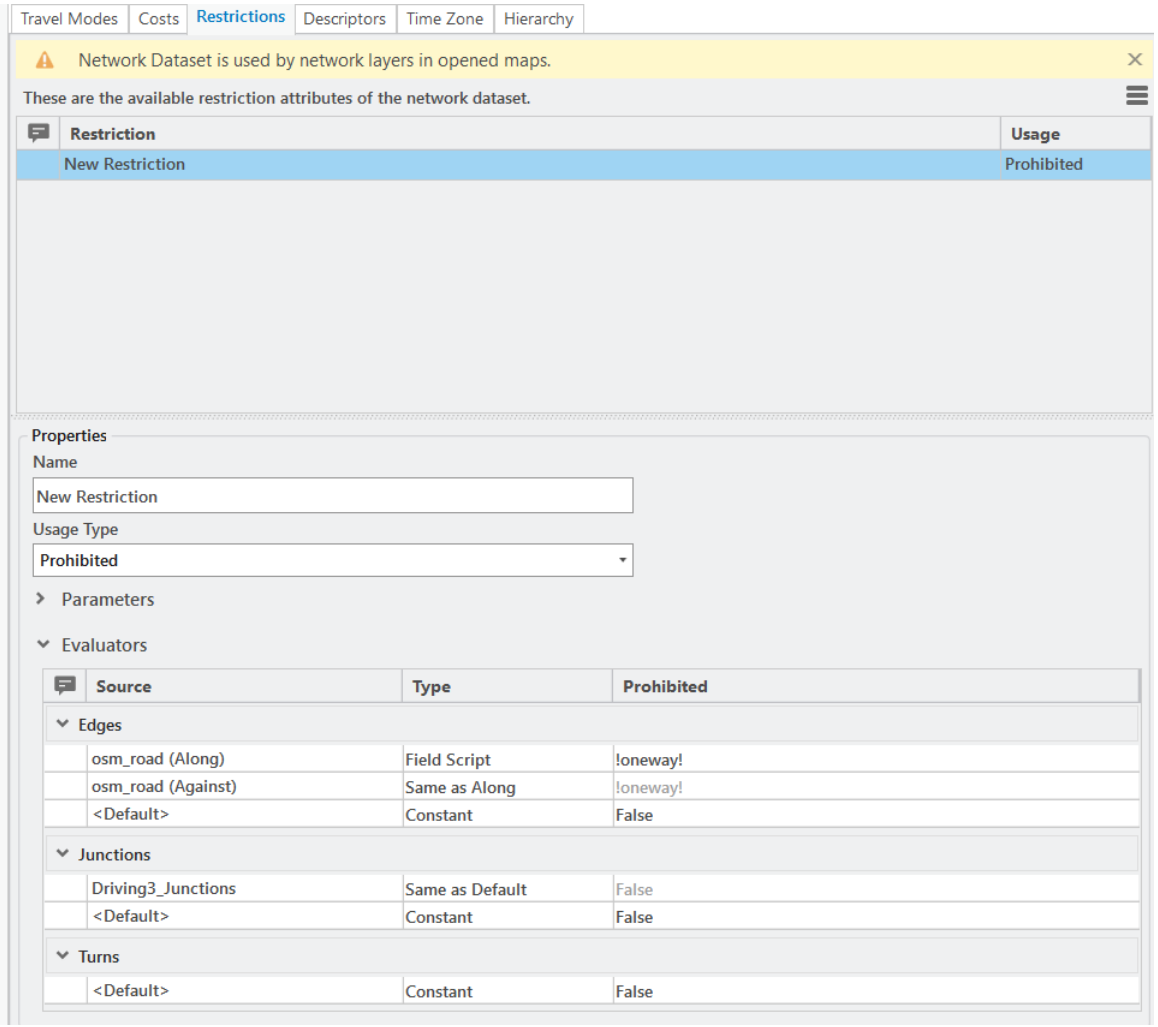

Incident location
Mode: Driving time Facilities: 4
Use Goole Places Api Request Nearby Fire Stations
Network Analysis
Nearest Fire Stations and Routes
Make Barrier
Estimated Stations and Routes
Nearby Fire Stations
Select Study Area
Select Road Data
Create Travel Cost, Set Road Hierarchy
OpenStreetMap
Download
OSM Data
Clean
Road
Create Network Dataset
Network Dataset

Method cont.

- OpenRouteService: Not supported in the study area
- Google routes API: Have avoid options - Tolls, Highways, Ferries, and Indoor, but not support avoiding specific restricted areas
- Leaflet: The interface is not very user-friendly
- ArcGIS REST APIs: count credits
- Use OpenStreetMap data to build Network Dataset

Method cont.

oneway
F
F
F
B
B
B
F
F



Method cont.

F_ELVE	T_ELVE
0	0
0	0
0	0
0	0
0	0
0	0
2	2
3	3

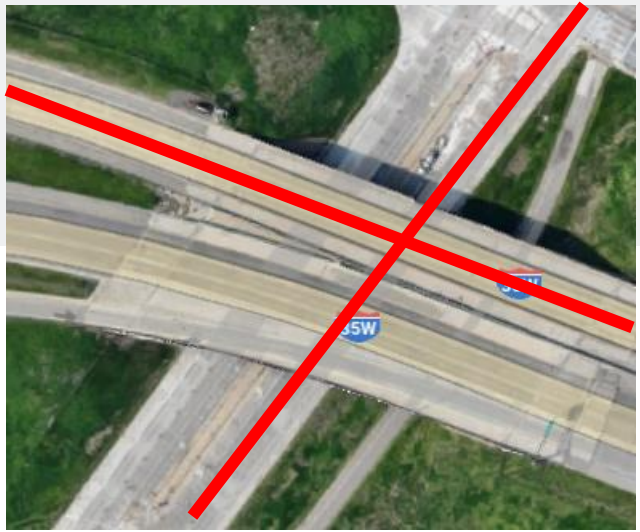
Sources | Vertical Connectivity | Group Connectivity

⚠ Network Dataset is used by network layers in opened maps. ✕

Policy: Elevation Fields

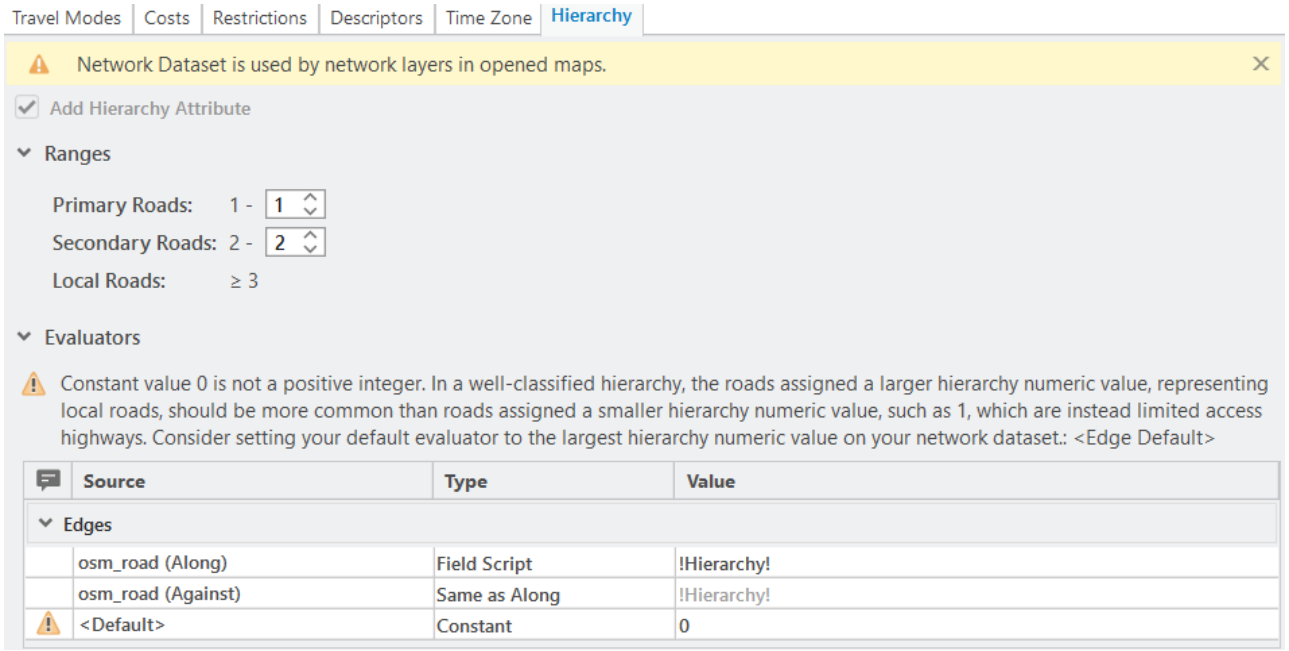
Establish vertical connectivity where end points of source features share these three values: x, y, and elevation field value.

Name	Elevation Field
▾ Edges	
osm_road (From Node)	F_ZLEV
osm_road (To Node)	T_ZLEV



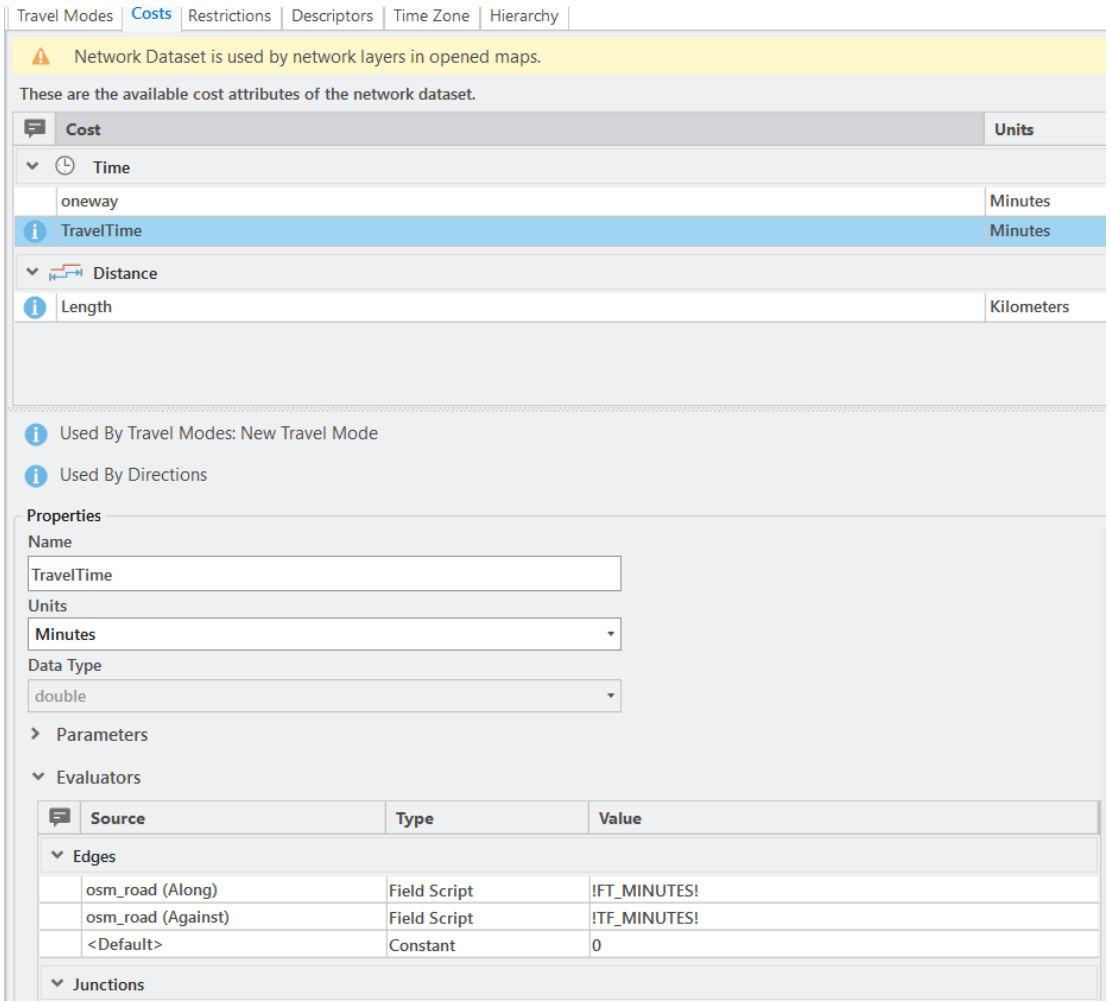
Method cont.

fclass	Hierarchy
primary	2
primary	2
tertiary	2
residential	3
residential	3
residential	3
motorway_link	1
trunk	2



Method cont.

maxspeed	TF_MINUTES	FT_MINUTES	Length
60	1.527289	1.527289	1.527289
50	0.696022	0.696022	0.580018
50	0.392203	0.392203	0.326836
50	0.551853	0.551853	0.459878
50	0.548047	0.548047	0.456706
50	1.239145	1.239145	1.032621
50	0.329317	0.329317	0.274431
50	12.319811	12.319811	10.266509



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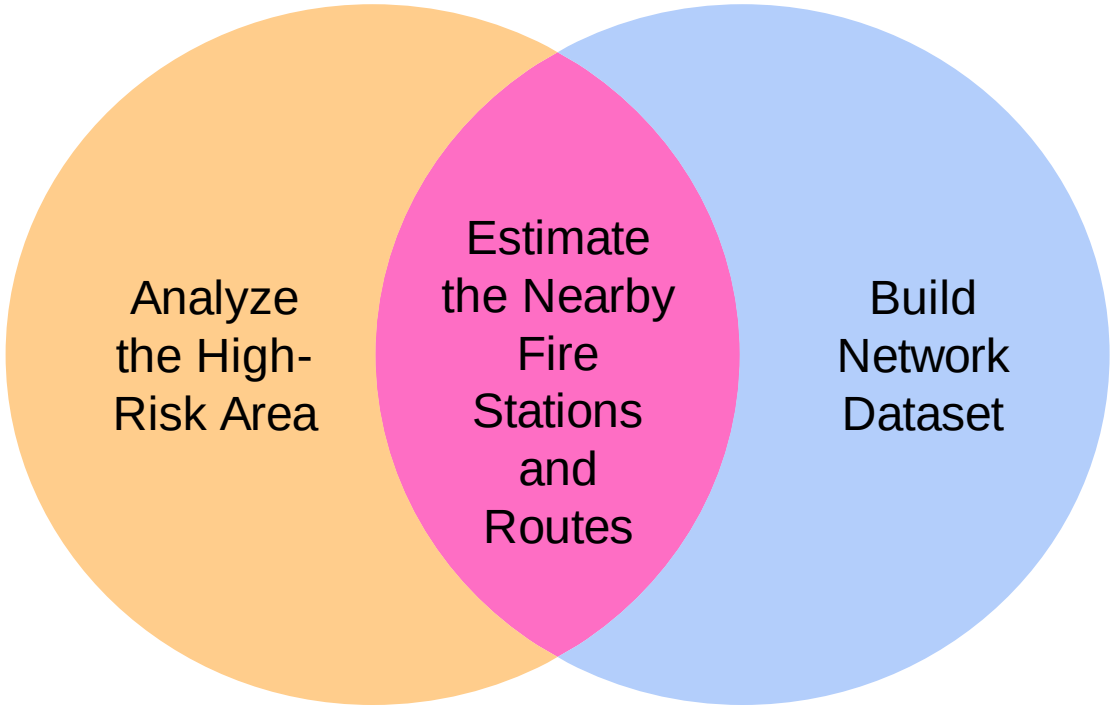
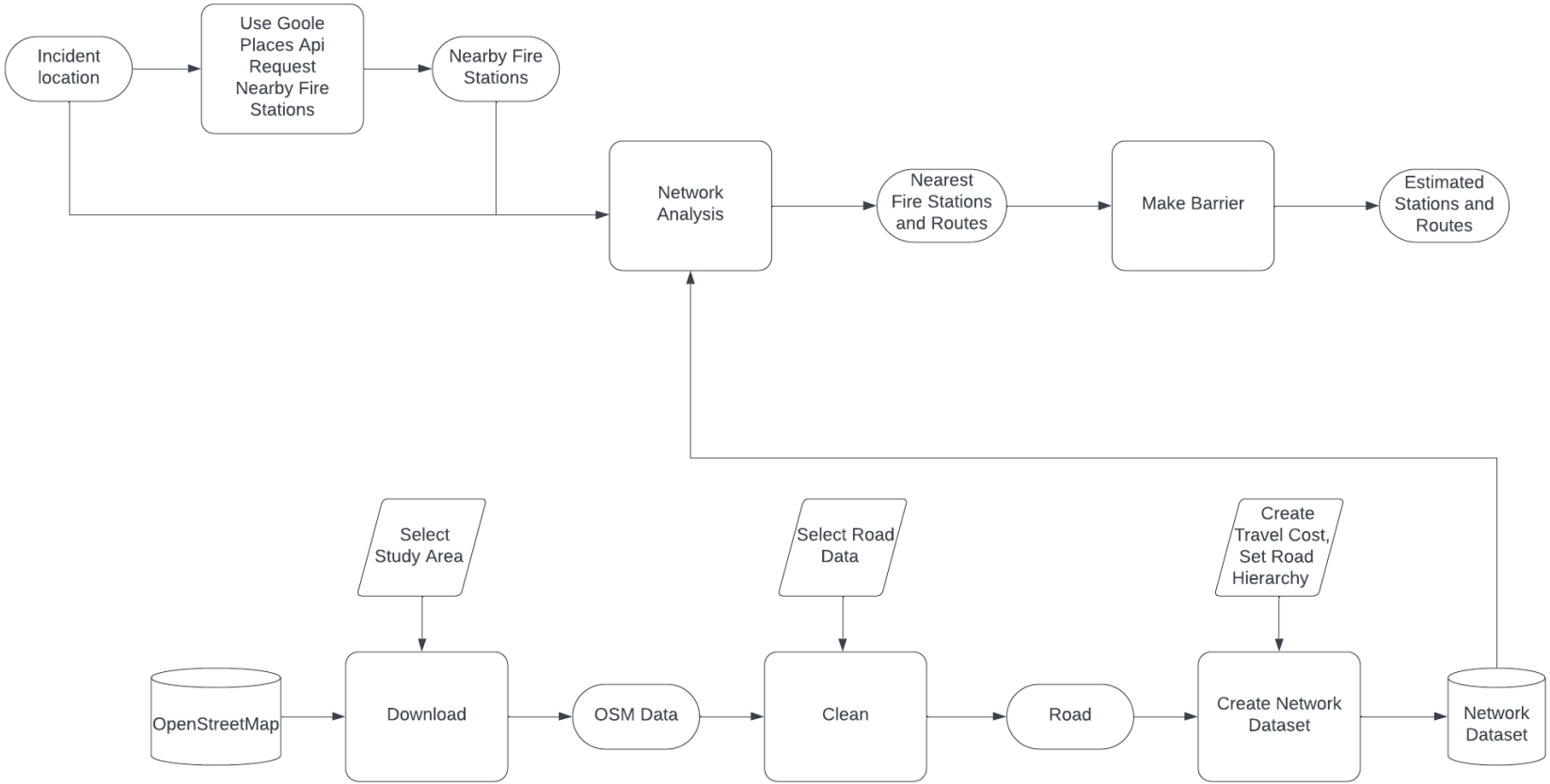


Method cont.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Estimated Stations and Routes
Select Study Area
Select Road Data
Create Travel Cost, Set Road Hierarchy
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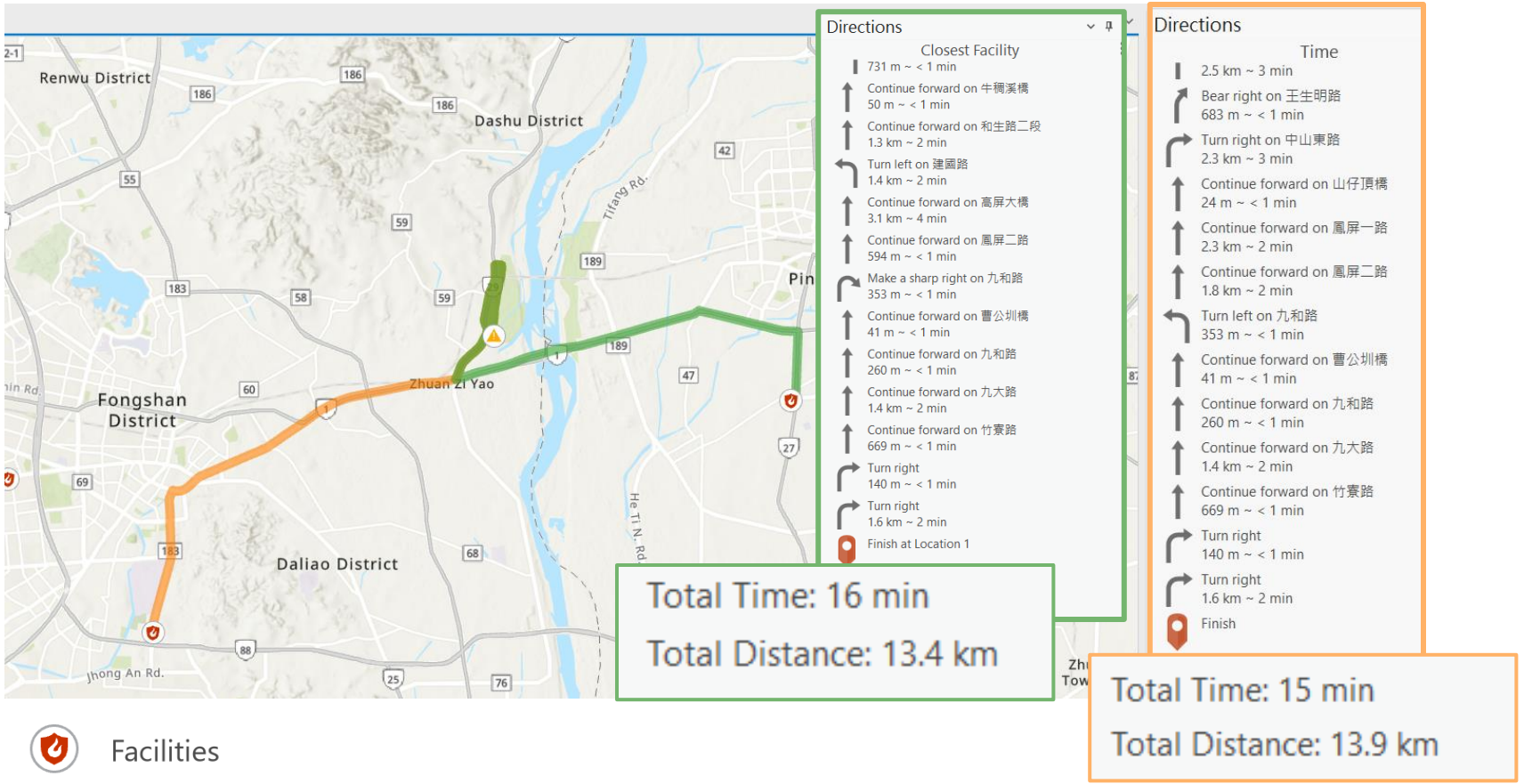
OSM Data
Clean
Road
Create Network Dataset
Network Dataset

Result

Distance

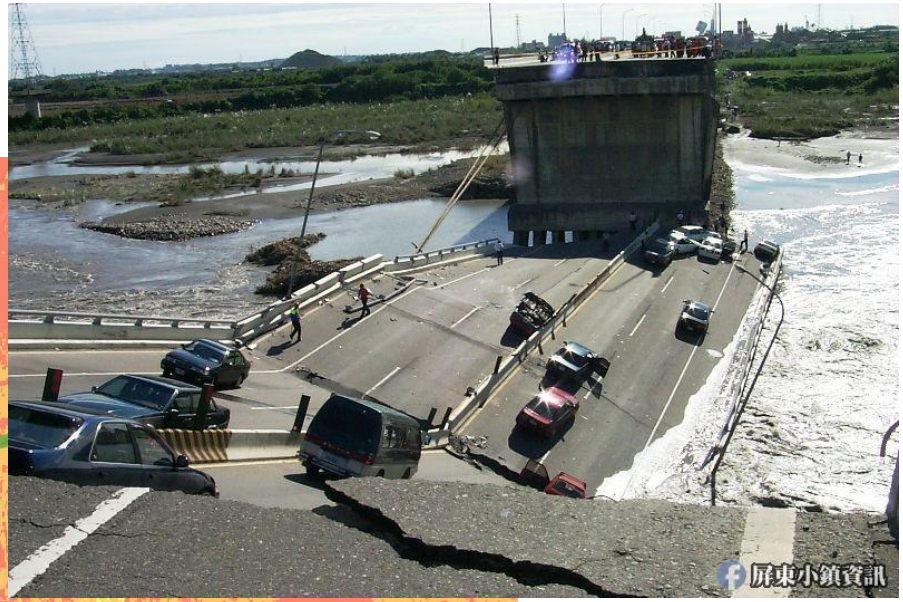
Time Cost



Facilities

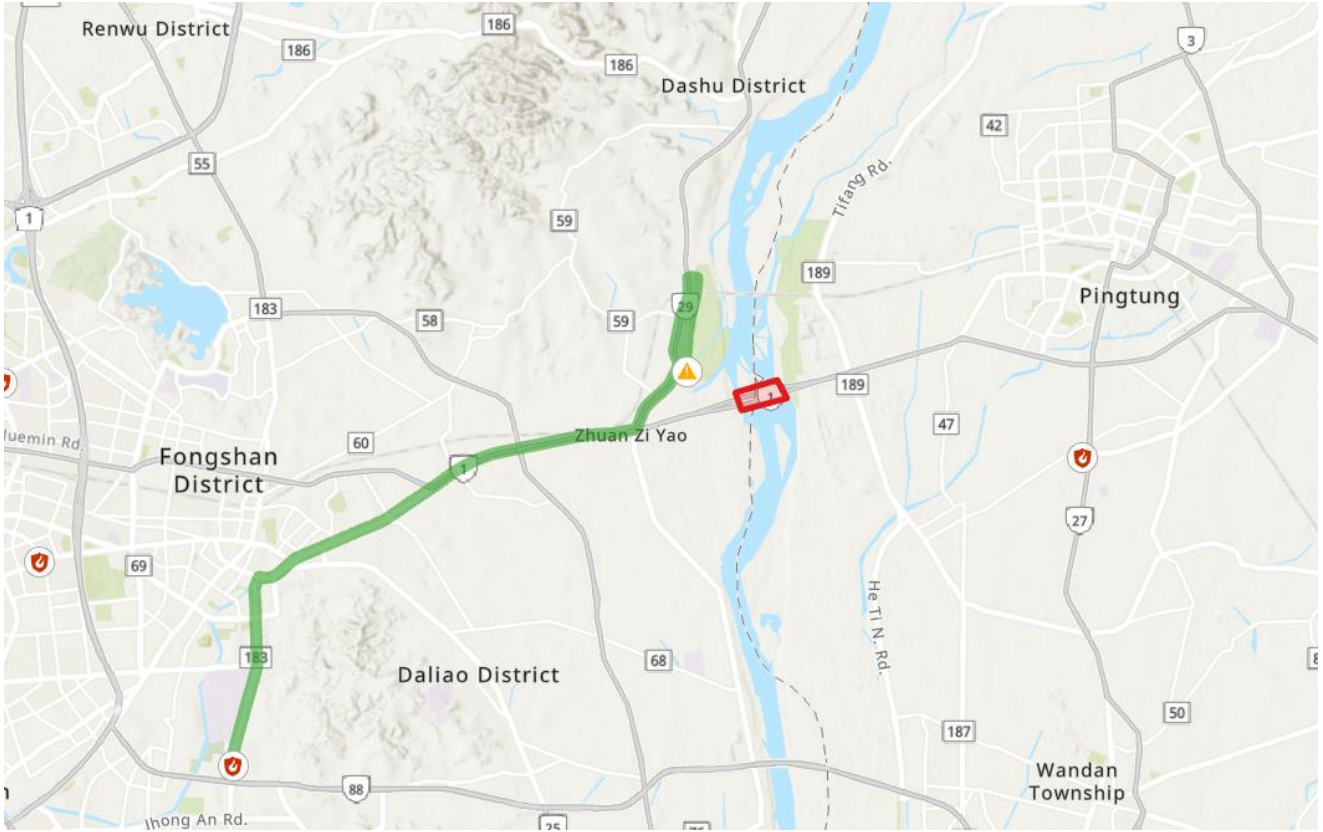
Incidents

Result cont.



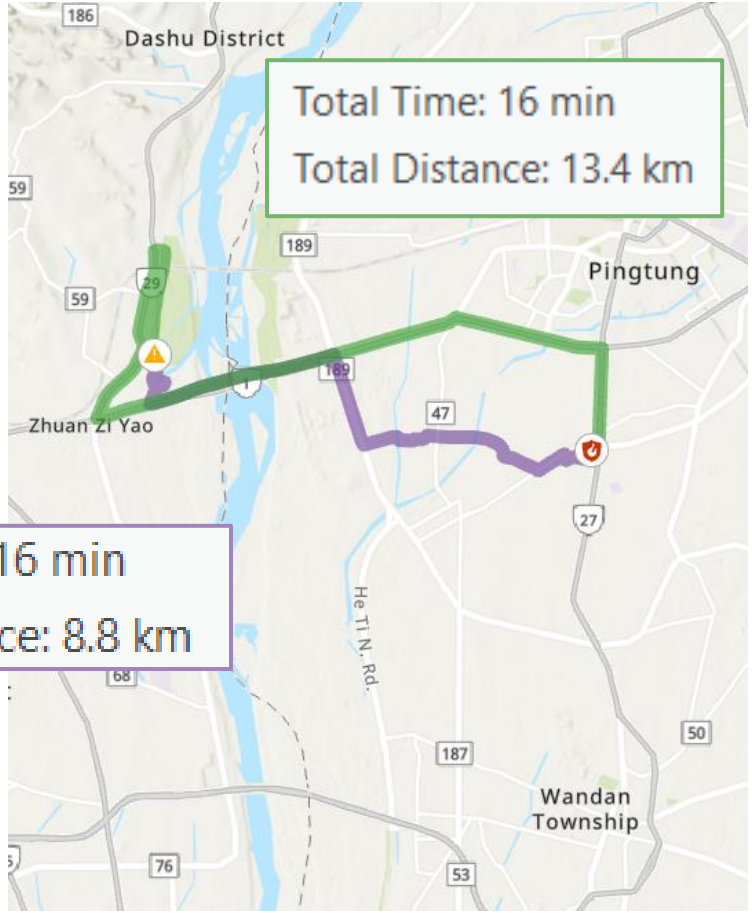
On August 27, 2000, due to the influence of Typhoon Bilis and subsequent heavy rainfall, the piers of the Gao-Ping River Bridge were washed away by the creek.

Result cont.


Renwu District
Dashu District
Tifang Rd.
Pingtung
Zhuan Zi Yao
Fongshan District
Daliao District
He Ti N. Rd.
Wandan Township
Jhong An Rd.
186
186
186
3
42
55
1
59
189
183
58
59
29
189
47
60
1
69
27
183
68
50
187
88

Results Verification

ArcGIS Network



Google Maps

Total Time: 18 min

Total Distance: 10.6 km

Discussion & Conclusion

- Using different modes (Travel or Time) may yield different results.
- Incorporate more factors for analyzing high-risk areas, and extend to cover various types of disasters.
- The current network dataset requires additional information to improve its accuracy. Considering factors like lifetime traffic patterns can contribute to a more precise representation.
- Creating a road network dataset is a complex task. What is the better approach? Rely on the current network dataset but depend on another company, or create our own network dataset but need to work hard on comprehensive setting?

References

ESRI. (n.d.). How Flow Accumulation works | Documentation. https://pro.arcgis.com/en/pro-app/latest/tool-reference/spatial-analyst/how-flow-accumulation-works.htm

Yon Sugiarto, Perdinan, Tri Atmaja and Shalsa Nurhasanah, “Evaluation of the Use of Data Reanalysis for Climate Regionalization” IOP Conference Series: Earth and Environmental Science, October 2017

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entropy weight method”, ICEEB 2020

ESRI. (n.d.). Create a network dataset | Documentation. https://pro.arcgis.com/en/pro-app/latest/help/analysis/networks/how-to-create-a-usable-network-dataset.htm