スリランカ民主社会主義共和国
都市開発庁

スリランカ国都市開発計画能力強化プロジェクト

分冊５

研修技術マニュアル

2025 年 7 月

独立行政法人
国際協力機構(JICA)

株式会社オリエンタルコンサルタンツグローバル
株式会社アルメック

Training Manual (Technical Manuals)

EV1-1: Environmental Analysis and Planning (Technical Manual)

LU1(1): Technical Manual for MOLUSCE

LU1(2): Technical Manual for UAV – MAVIC MINI

LU3: GIS Manual for Urban Planning

PC1: How To Use Mentimeter

UD2: Technical Manual for Advanced Technology (2D/3D/DX)

Training Manual (Technical Manuals)

EV1-1: Environmental Analysis and Planning (Technical Manual)

Environmental Analysis and Planning (EV1-1) Technical Manual

March 2025

Table of Contents

Preface....4
1a. Extracting Land Cover from the European Space Agency (ESA) Global Land Cover Dataset. 1
1.1 Background....1
1.2. Lab. Extract Land Cover....2
1.3 Summary....6
1.4 Additional Resources....6
1b. Building Footprint Datasets for Environmental Analysis and Planning....7
1.1 Background....7
1.2 Lab. Extracting Building Footprint from the Microsoft (MS) Building Dataset....7
1.3 Additional Exercises....9
1.4 Code Link....9
1.5 Additional Resources....9
1c. Land Surface Temperature for Environmental Analysis and Planning....10
1.1 Background....10
1.2 Lab. Calculating Land Surface Temperature (LST) in Google Earth Engine....10
1.3 Additional Exercises....13
1.4 Code Link....13
1.5 Additional Resources....13
2a. Assessing Water Quality using Earth Observation Data....14
2.1 Background....14
2.2 Lab. Assessing Water Quality using the Normalized Difference Suspended Sediment Index (NDSSI) in Google Earth Engine....14
2.3 Additional Exercises....19
2.4 Code Link....19
2b. Assessing Air Quality using Earth Observation (EO) Datasets....20
2.1 Background....20
2.2 Lab. Assessing Air Quality using Sentinel-5P NRTI NO2 in Google Earth Engine....20
2.3 Additional Exercises....23
2.4 Code Link....23
3a. Modeling Forest Canopy Height....24
3.1 Background....24
3.2 Lab. Modelling Forest Canopy Height and AGB using GEDI, Sentinel-1 and Sentinel-2 Data in EE....24
3.3 Additional Exercises....40
3.4 Code Link....40
3b. Modeling Aboveground Biomass (AGB) Density....41
3.1 Background....41
3.2 Lab. Modeling Forest AGB using GEDI, S1, and S2 data in EE....41
3.3 Additional Exercises....54
3.4 Code Link....54
4. Environmental Planning and Site Suitability Analysis of Green Infrastructure....55
4.1 Background....55
4.2 Lab. Green Infrastructure Site Suitability Analysis....56
4.3 Additional Exercises....59

4.4 Code Link.....59
Reference.....59
Appendix.....60

Preface

Environmental monitoring, urban planning, and resource management have become increasingly reliant on geospatial technologies, particularly Earth observation (EO) data. The availability of high-resolution datasets and cloud computing platforms like Google Earth Engine (GEE) has transformed how land cover, urban infrastructure, climate parameters, and environmental dynamics are analyzed. This technical manual serves as a comprehensive guide to utilizing GEE for geospatial analysis, with a focus on land cover mapping, environmental assessment, and modeling.

This manual is designed for Urban Development Authority (UDA) professionals and researchers seeking to enhance their proficiency in processing and analyzing EO data using cloud-based platforms. Through step-by-step instructions, practical examples, and code implementations, readers will learn how to extract land cover data, analyze environmental variables, and model forest attributes using EO datasets from the European Space Agency (ESA), NASA, and other reputable sources.

Each section of this manual presents a specific geospatial application, including:

i. Land cover mapping - Extracting and visualizing land cover data from the ESA WorldCover dataset.
ii. Building footprint extraction - Analyzing urban infrastructure using the Microsoft Building Footprint dataset.
iii. Land surface temperature (LST) calculation - Using Landsat thermal imagery to assess urban heat islands and climate change impacts.
iv. Water and air quality assessment - Leveraging Sentinel-5P and Landsat data to analyze pollution levels.
v. Forest canopy height and aboveground biomass (AGB) modeling - Employing GEDI LiDAR, Sentinel-1, and Sentinel-2 data for vegetation structure analysis.
vi. Green infrastructure planning - Conducting suitability analysis for environmental conservation and urban sustainability projects.

By following the structured workflows provided in each section, users will gain hands-on experience in scripting, data processing, visualization, and model validation. The integration of cloud computing capabilities enables large-scale geospatial analysis with minimal computational constraints, making advanced geospatial techniques more accessible than ever before.

This manual is structured to support self-paced learning and practical application. Each module is accompanied by code snippets, dataset descriptions, and additional exercises to reinforce learning outcomes. Whether you are new to GEE or looking to refine your geospatial analytics skills, this manual serves as a valuable resource for leveraging EO data in environmental and urban studies.

1a. Extracting Land Cover from the European Space Agency (ESA) Global Land Cover Dataset

1.1 Background

Land cover represents the physical and ecological features of the earth's surface, including forests, wetlands, urban areas, agricultural lands, and water bodies. Understanding land cover is essential for environmental monitoring, urban planning, and land use management. Land cover data helps researchers, urban planners, and environmental scientists analyze how land is utilized and how it changes over time. The European Space Agency (ESA) WorldCover 2020 dataset provides a high-resolution (10m) global land cover map, generated using Sentinel-1 and Sentinel-2 satellite imagery. This dataset is particularly useful for applications such as urban infrastructure development, agricultural monitoring, biodiversity conservation, and climate change adaptation.

Urbanization, deforestation, and agricultural expansion significantly impact natural ecosystems, making it necessary to monitor land cover changes continuously. By using satellite-based datasets, we can assess and map different land cover classes such as forests, croplands, wetlands, built-up areas, and water bodies. This information enables effective decision-making for sustainable environmental management.

In this lab, we will use Google Earth Engine (GEE) to extract, visualize, and analyze land cover data from the ESA WorldCover 2020 dataset. Additionally, we will integrate elevation data from the JAXA ALOS AW3D30 digital elevation model (DEM) to examine topographical variations in the study area. By the end of this lab, participants will gain practical experience in processing and analyzing land cover and elevation datasets within GEE.

1.1.1 Objectives

The objective of this lab is to guide users in extracting and visualizing land cover data from the ESA Global Land Cover Dataset using Google Earth Engine. Users will also learn how to extract and visualize elevation data using the JAXA ALOS AW3D30 Digital Elevation Model (DEM). By the end of this lab, participants will gain proficiency in Google Earth Engine scripting for handling large-scale spatial datasets.

1.1.2 Required tools and data

To successfully complete this lab, participants need access to essential tools and datasets. The primary tool required is a Google Earth Engine (GEE) account, which can be registered for free. GEE provides a cloud-based platform that allows users to process and analyze large-scale geospatial datasets efficiently. Additionally, a web browser with internet access is necessary to execute GEE scripts and interact with the datasets.

The datasets used in this lab include the ESA WorldCover 2020 Land Cover Dataset, which provides high-resolution global land cover information and is referenced as ESA/WorldCover/v100 in GEE. To complement the land cover analysis, we will also use the JAXA ALOS AW3D30 Digital Elevation Model (DEM) dataset, labeled as JAXA/ALOS/AW3D30_V1_1, which provides global elevation data to examine topographical variations. Finally, the Administrative Boundary Dataset, available under projects/sat-io/open-datasets/field-maps/edge-matched-open/adm3_polygons, will be used to define and extract land cover within specific administrative boundaries.

These datasets are freely accessible through Google Earth Engine, making them ideal for large-scale environmental analysis and urban planning applications.

1.2. Lab. Extract Land Cover

1.2.1 Procedure

1.2.1.1 Setting up Google Earth Engine

Ensure you have a Google Earth Engine account set up and ready for use (Figure 1).

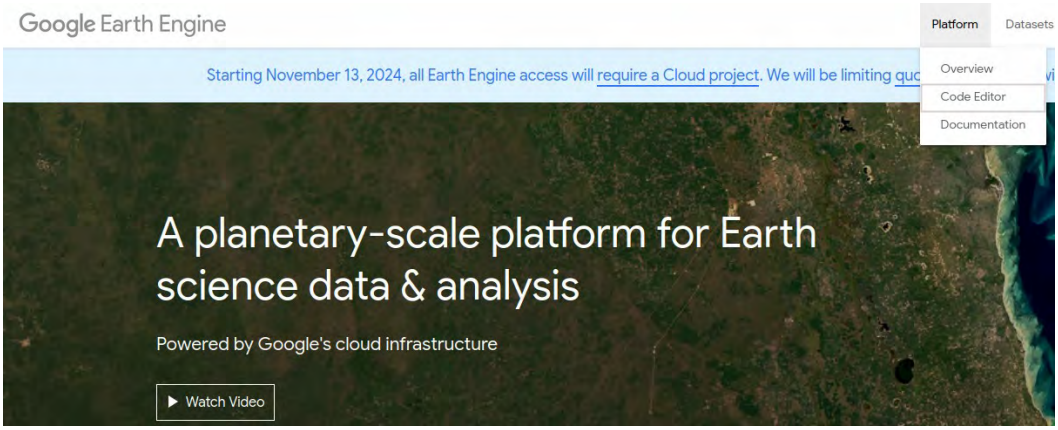


Figure 1. Log in to the *Code Editor*.

i. To access and log into Google Earth Engine (GEE), follow these steps:

a. Register for Google Earth Engine

b. Visit ‘Google Earth Engine Code Editor’ (Figure 1).

c. If you do not have a Google account, create one by clicking "Create account." Otherwise, log in with your existing Google account.

d. After logging in, GEE will request access to your Google account. Click "Allow".

e. Complete the registration form by providing details such as your name, institution, intended use of GEE, and agreement to the terms of use.

f. Submit the application and wait for the confirmation email titled “Welcome to Google Earth Engine!”.

ii. Log into Google Earth Engine
Once your registration is approved, go back to
code.earthengine.google.com and log in using your registered Google account.

iii. Set up a Cloud Project
Create a Google Cloud Project via the [Google Cloud Console](https://console.cloud.google.com).
Enable the Earth Engine API for your project.
Register the project for either commercial or non-commercial use.

1.2.1.2 Setting up the workspace
Load the boundary for the selected region (e.g., Kaduwela) into Google Earth Engine.

```
// Load administrative boundary data
var ADM3 = ee.FeatureCollection('projects/sat-io/open-datasets/field-maps/edge-matched-open/adm3_polygons');
// Filter for specific boundary
var boundary = ADM3.filter(ee.Filter.eq('ADM3_EN', 'Kaduwela'));
```

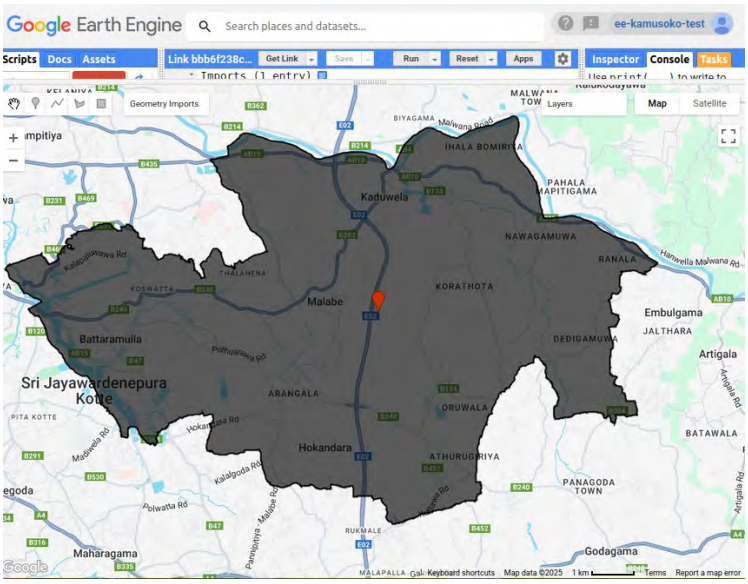


Figure 2. Load boundary for Kaduwela.

1.2.1.3 Extracting land cover data
Access the ESA Global Land Cover dataset and clip it to the administrative boundary.

```
// Load ESA Global Land Cover dataset
var dataset = ee.ImageCollection('ESA/WorldCover/v100').first();
```

```
// Clip the dataset to the selected administrative boundary
var ESA_LC_2020 = dataset.clip(boundary);
```

1.2.1.4 Visualizing land cover data

Prepare visualization parameters and display the land cover data.

```
// Define visualization parameters for the land cover data
var visualization = {
  bands: ['Map'],
};
// Set map view to region of interest
Map.setCenter(79.9814, 6.9037, 14);
// Add the ESA Land Cover layer to the map
Map.addLayer(ESA_LC_2020, visualization, 'ESA Land Cover 2020');
```

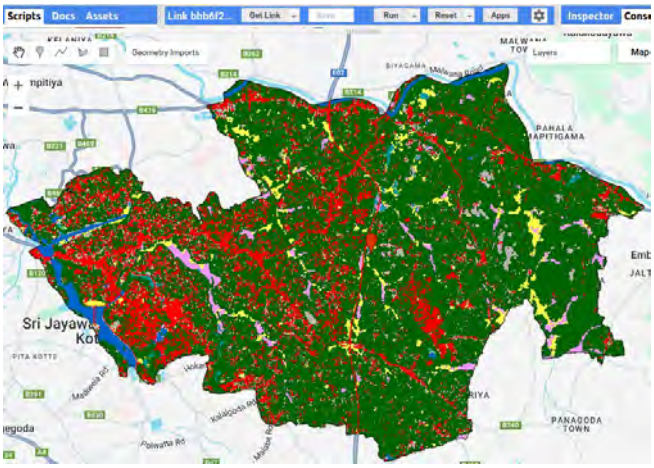


Figure 3. Kaduwela ESA land cover map.

1.2.1.5 Exporting land cover data

Export the clipped land cover data to Google Drive.

```
// Export the land cover data to Google Drive
Export.image.toDrive({
  image: ESA_LC_2020,
  description: 'Kaduwela_LC_2020',
  scale: 10,
  crs: 'EPSG:4326',
  maxPixels: 6756353855,
  region: boundary
});
```

1.2.1.6 Extracting elevation data

Extract elevation data using the JAXA ALOS AW3D30 digital elevation model.

```
// Load elevation data from JAXA ALOS dataset
var elevationDataset = ee.Image('JAXA/ALOS/AW3D30_V1_1');

// Select elevation band and clip to boundary
var elevation = elevationDataset.select('AVE').clip(boundary);
```

1.2.1.7 Visualizing elevation data

Prepare visualization parameters and display the elevation data.

```
// Define visualization parameters for elevation
var elevationVis = {
  min: 0.0,
  max: 200.0,
  palette: ['0000ff', '00ffff', 'ffff00', 'ff0000'],
};

// Add elevation layer to the map
Map.addLayer(elevation, elevationVis, 'Elevation');
```

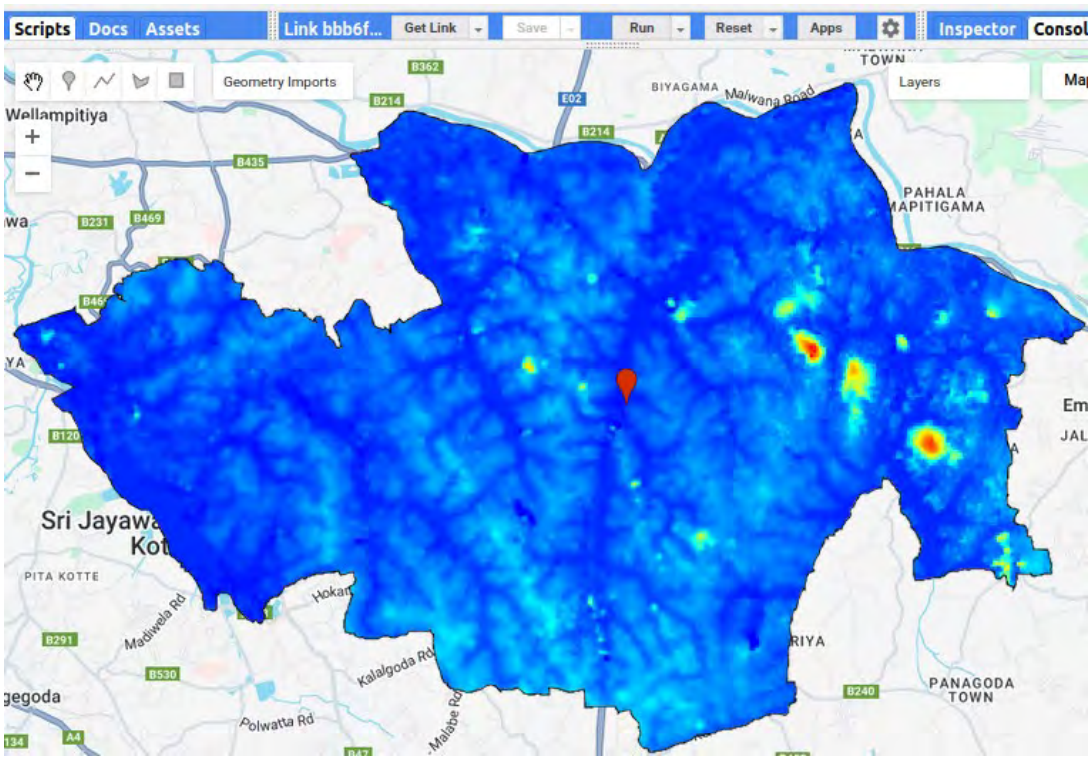


Figure 4. Kaduwela digital elevation model (DEM).

1.2.1.8 Exporting elevation data

Export the elevation data to Google Drive.

```
// Export elevation data to Google Drive
Export.image.toDrive({
  image: elevation,
  description: 'Kaduwela_Elevation',
  scale: 10,
  crs: 'EPSG:32644',
  maxPixels: 6756353855,
  region: boundary
});
```

1.2.2 Additional exercises

i. Extract land cover data for a different administrative area in Sri Lanka (e.g., Colombo).
ii. Analyze elevation data for a different administrative area in Sri Lanka (e.g., Colombo).
Iii. Compare land cover and elevation data for different administrative areas in Sri Lanka

1.3 Summary

This lab has demonstrated the process of extracting, visualizing, and analyzing land cover data from the ESA WorldCover 2020 dataset using Google Earth Engine. By following the outlined procedures, users can efficiently process large-scale geospatial datasets and gain insights into land cover patterns within a given study area. The integration of elevation data from the JAXA ALOS AW3D30 dataset further enhances environmental analysis by providing topographical context to land cover distributions.

The ability to extract and manipulate satellite-derived datasets is crucial for urban planners, environmental analysts, and researchers working on land use planning, climate change studies, and ecological assessments. Through practical experience in scripting and geospatial analysis, this lab has equipped users with the necessary skills to utilize Earth observation data for informed decision-making. The techniques learned in this lab can be extended to other regions and datasets, making them applicable to a wide range of environmental monitoring and land management projects.

1.4 Additional Resources

i. Code link: *https://code.earthengine.google.com/bbb6f238c3898c502bb205e0d59b4b5e*
ii. ESA WorldCover Dataset Documentation
iii. Google Earth Engine Dataset Catalog
iv. JAXA ALOS AW3D30 DEM Documentation
v. YouTube Tutorial for ESA WorldCover

1b. Building Footprint Datasets for Environmental Analysis and Planning

1.1 Background

Building footprint data is essential for geospatial analysis in urban areas, offering valuable insights for various purposes. First, it aids in urban planning by enabling the analysis of building footprints relative to available land, assisting city planners in balancing buildings and infrastructure while preserving space for public parks, and conservation areas. Second, building footprint data plays a crucial role in disaster management by identifying areas at risk of natural disasters such as flooding or landslides. This data assists urban dynamics monitoring, risk assessment, and effective disaster response. Additionally, building footprint data is utilised in real estate to determine property value based on building and land size and identify suitable areas for development.

1.2 Lab. Extracting Building Footprint from the Microsoft (MS) Building Dataset

1.2.1 Introduction

This tutorial will load and visualise the MS Global buildings footprint dataset in Google Earth Engine (GEE). The MS buildings dataset is from Bing Maps imagery acquired between 2014 and 2021.

1.2.2 Objective

• Extract building footprint from MS building footprint dataset in Google Earth Engine.

1.2.3 Procedure

Following are the steps.

Step 1: Load the administrative boundary level 3 dataset

First, load the administrative boundary level 3 dataset from the edge-matched-open/adm3_polygons.

```
var ADM3 = ee.FeatureCollection('projects/sat-io/open-datasets/field-maps/edge-matched-open/adm3_polygons');
```

Step 2: Filter the feature collection for Kaduwela

Next, we filter the *FeatureCollection* for Kaduwela.

```
var extractADM3 = ADM3.filter(ee.Filter.eq('adm3_name', 'Kaduwela'));
```

Step 3: Use the geometry of the image (administrative layer)

We use the geometry of the image (administrative layer) as follows.

```
var boundary = extractADM3.geometry()
```

Step 4: Load the MS Global building footprints for Sri Lanka

Load the MS Global building footprints for Sri Lanka.

```
var feature = ee.FeatureCollection('projects/sat-io/open-datasets/MSBuildings/Sri_Lanka');
```

Step 5: Filter to only Kaduwela building footprints
Filter to only Kaduwela building footprints.
var ml_bld = feature.filterBounds(boundary);

Step 6: Add the map centre and zoom level
Add the map centre and zoom level.
Map.setCenter(79.97957580983135,6.904329786802445, 14);

Step 7: Display the city boundary
Next, display the city boundary.
Map.addLayer(boundary, {}, 'Kaduwela');

Step 8: Display the building footprints
Display the building footprints (Figure 1b).
Map.addLayer(ml_bld.style({fillColor: '00000000', color: 'FF5500'}), {}, 'Kaduwela');

Step 9: Set the map to display satellite imagery
Set the map to show satellite imagery.
Map.setOptions('SATELLITE');

Step 10: Export the feature collection to a KML file
Finally, export the *FeatureCollection* to a KML file.

```
Export.table.toDrive({
  collection: ml_bld,
  description:'Kaduwela_MS_Bld',
  fileFormat: 'KML'
})
```

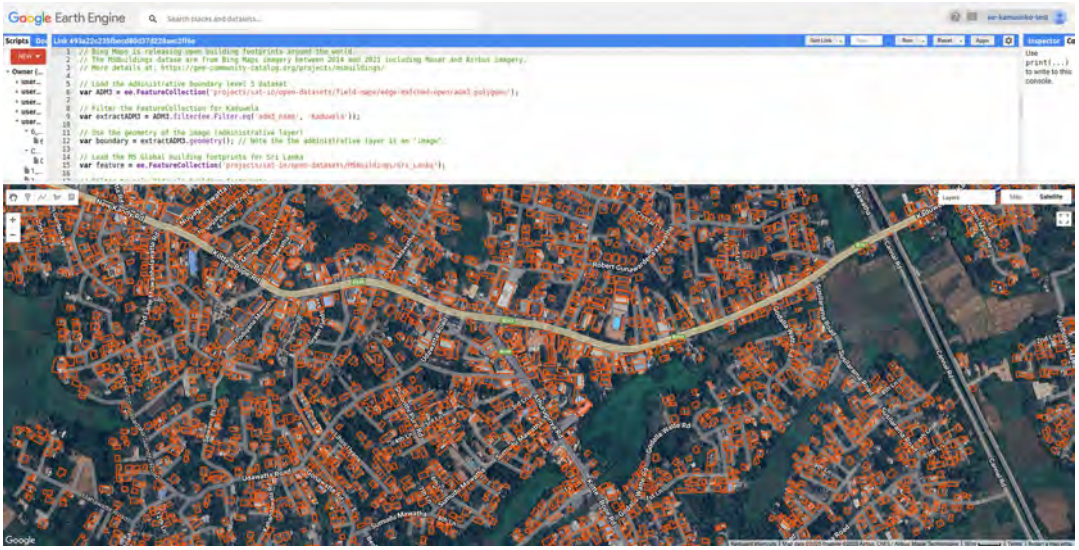


Figure 1b. Kaduwela building footprints.

1.3.4 Summary

This tutorial taught us how to load and visualise building footprint data in Google Earth Engine (GEE). We have also learned how to load the MS Global building footprints for Sri Lanka, filter to only Kaduwela building footprints, display the city boundary, show the building footprints, set the map to display satellite imagery and export the *FeatureCollection* to a KML file. The building footprint dataset is an important data point for geospatial analysis that can be used in fields like real estate, urban planning, and environmental research.

1.3 Additional Exercises

i.Extract building footprint data from Google's Open Buildings in Earth Engine.
ii.Compare building footprint data from MS Bing and Google's Open Buildings.

1.4 Code Link

https://code.earthengine.google.com/493a22c235fbecd80d37d228aec2ff6e

1.5 Additional Resources

Websites and data portals for building footprint datasets
https://gee-community-catalog.org/projects/msbuildings/
https://github.com/microsoft/GlobalMLBuildingFootprints
https://developers.google.com/earth-engine/datasets/catalog/GOOGLE_Research_open-buildings_v2_polygons
https://mygeoblog.com/2022/10/13/building-footprints/
https://www.youtube.com/watch?v=Fh9y9B5pAUQ

1c. Land Surface Temperature for Environmental Analysis and Planning

1.1 Background

Land surface temperature (LST) is a crucial parameter in urban environmental analysis. It helps in understanding the Urban Heat Island (UHI) effect, studying the impacts of climate change on urban areas, analyzing the influence of vegetation and land cover on temperature, and assessing implications for human health. By calculating LST, researchers gain insights into the severity of the UHI effect, identify vulnerable areas to climate change, develop strategies to mitigate urbanization's environmental impacts and protect public health from heat-related illnesses. LST is a valuable tool for understanding and mitigating the adverse effects of urbanization.

1.2 Lab. Calculating Land Surface Temperature (LST) in Google Earth Engine

1.2.1 Introduction

Land Surface Temperature (LST) is an important parameter to study in urban environmental analysis. We will use Landsat 8 thermal band to calculate LST in Google Earth Engine.

1.2.2 Objective

- Calculate land surface temperature (LST) using Landsat 8 in Google Earth Engine.

1.2.3 Procedure

Following are the steps.

Step 1: Load the administrative boundary level 3 dataset

First, load the administrative boundary level 3 dataset for Kaduwela district.

```
var ADM3=ee.FeatureCollection('projects/sat-io/open-datasets/field-maps/edge-matched-open/
adm3_polygons');
var extractADM3 = ADM3.filter(ee.Filter.eq('adm3_name', 'Kaduwela'));
var boundary = extractADM3.geometry();
```

Step 2: Cloud and shadow masking function

Next, add a Function to mask clouds and shadows using the correct QA_PIXEL band.

```
// Function to mask clouds and shadows using the correct QA_PIXEL band
function maskL8sr(image) {
  var cloudShadowBitMask = (1 << 4); // Cloud Shadow in Collection 2
  var cloudsBitMask = (1 << 6);      // Clouds in Collection 2

  var qa = image.select('QA_PIXEL');
  var mask = qa.bitwiseAnd(cloudShadowBitMask).eq(0)
          .and(qa.bitwiseAnd(cloudsBitMask).eq(0));

  return image.updateMask(mask);
}
```

Step 3: Define visualization parameters

Next, define the visualization parameters. We specify the Near Infrared (NIR), Shortwave Infrared (SWIR1), and Red bands for visualization. The Landsat 8 Surface Reflectance values range from 0 to 65535, but scaled reflectance typically ranges from 0 to ~25000. Note that the minimum (0) sets the darkest pixels, while the maximum (25000(sets the brightest pixels.

```
// Define visualization parameters
var vizParams = {
  bands: ['SR_B5', 'SR_B6', 'SR_B4'], // Updated bands
  min: 0,
  max: 25000,
  gamma: [1, 0.9, 1.1]
};
```

Step 4: Load and filter the Landsat 8 surface reflectance image collection

Next, we will load the Landsat 8 Surface Reflectance image collection and apply a cloud mask. We will also filter the image collection by date and boundary and compute the quality mosaic based on thermal band (best cloud-free pixel selection.

```
// Load Landsat 8 Collection 2, Level 2 with Cloud Cover Filtering
var col = ee.ImageCollection('LANDSAT/LC08/C02/T1_L2')
  .filter(ee.Filter.lte('CLOUD_COVER', 30)) // Select images with less than 10% cloud cover
  .map(maskL8sr) // Apply cloud mask
  .filterDate('2021-02-01', '2021-12-30')
  .filterBounds(boundary)
  .map(function(image) { return image.clip(boundary); });

// Print the image collection to the console
print(col, 'Cloud-free collection');

// Compute the quality mosaic based on thermal band (best cloud-free pixel selection)
var image = col.qualityMosaic('ST_B10').clip(boundary);

// Print the clipped image to the console
print(image, 'Cloud-free image');

// Add the clipped image to the map using the correct visualization parameters
Map.addLayer(image, vizParams, 'Cloud-free L8');
```

Step 5: Calculate the land surface temperature (LST)

We will calculate the land surface temperature (LST) using the thermal band of the Landsat 8 image.

```
// Calculate the Land Surface Temperature using the corrected thermal band
var tempC = image.select("ST_B10") // Updated to correct band
            .multiply(0.00341802)
            .add(149.0)
            .subtract(273.5); // Convert to Celsius
```

Step 6: Visualize and export the LST image

Finally, we will add the LST layer to the map using a colour palette and range (Figure 1c).

// Add the Land Surface Temperature layer to the map
Map.addLayer(tempC, {palette:['blue','green','orange','red'], min:18, max:30}, 'LST °C');

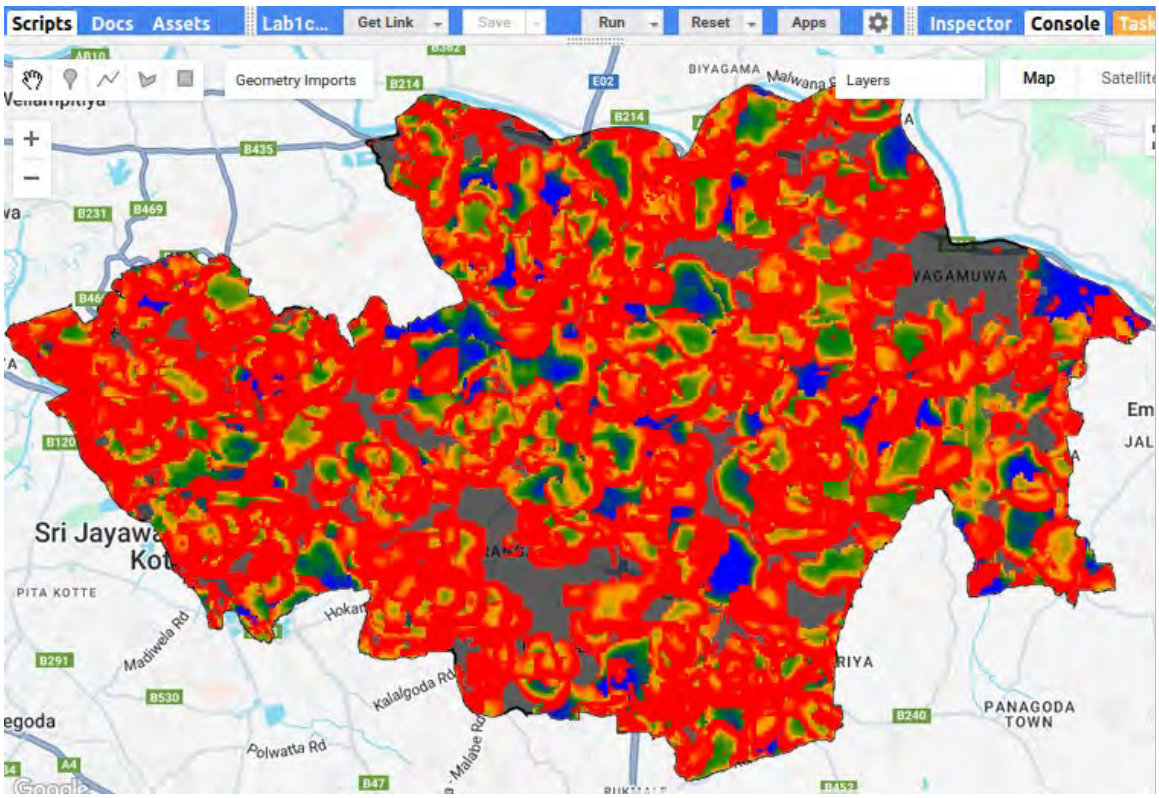


Figure 1c. Kaduwela Land surface temperature (LST).

We will also export the LST image to Google Drive.

Export.image.toDrive({
image: tempC,
description: 'Kad_Mean_LST22',
scale: 30,
crs: 'EPSG:32644', // WGS 84 UTM Zone 44 N
maxPixels: 6756353855,
region: boundary
})

1.2.4 Summary

Land surface temperature (LST) is an essential tool for understanding the impacts of urbanization on the environment and developing strategies to mitigate its negative effects. Google Earth Engine provides a powerful platform for analyzing and visualizing

geospatial data, including LST. By following this tutorial, you can calculate LST for your project area and gain insights into the impacts of urbanization on the environment.

1.3 Additional Exercises

i. Calculate land surface temperature (LST) for other administrative districts in Sri Lanka.
ii. Compare land surface temperature (LST) in any other two administrative districts in Sri Lanka.

1.4 Code Link

https://code.earthengine.google.com/29a68f8797450d6a0330806f72897d73

1.5 Additional Resources

Websites and data portals for calculating land surface temperature (LST).
https://github.com/leonsnill/lst_landsat
https://github.com/sofiaermida/Landsat_SMW_LST
https://www.youtube.com/watch?v=rdruFoGo_Ko

2a. Assessing Water Quality using Earth Observation Data

2.1 Background

Access to clean water is an urgent global concern due to population growth and increased pollutant loads from climate change and land use. Water pollution and eutrophication have severe economic consequences and cause numerous deaths annually. Therefore, developing methods for monitoring water quality at local and national levels is crucial. Water quality encompasses biological, chemical, and physical characteristics necessary for drinking, irrigation, and recreation.

Parameters like turbidity, chlorophyll-a concentration, pollution-sediment, dissolved oxygen, nutrients, and harmful algae are measured. Pollution-sediment refers to suspended-sediment concentration (SSC) or total suspended solids (TSS). TSS includes chlorophyll-a and calculates the total organic and inorganic suspended solids in a water column. SSC and TSS determine the amount of solid-phase material in water, differing in their analytical methods. SSC uses all sediment in a mixture, while TSS employs a subsample. Total dissolved solids (TDS) quantify dissolved inorganic chemicals, primarily salts and some organic matter, originating from agricultural and residential runoff and sewage treatment plant contaminants.

Conventional water quality monitoring relies on extensive field networks, including on-site measurements, sampling, and laboratory analysis. However, these approaches are time-consuming, costly, and provide limited spatial and temporal data coverage. In contrast, Earth observation (EO) data and remote sensing techniques offer cost-effective solutions, providing broad-scale and long-term water quality information. When combined with in-situ measurements, satellite-based models produce useful water quality indicators to predict and address potential water quality issues.

While EO data is critical for water quality assessment, some limitations exist. For example, EO data is limited by the spatial and temporal resolution of the satellite imagery used to collect the data. Additionally, EO data is sensitive to atmospheric conditions, such as cloud cover and aerosols, which can affect the accuracy of the data. Finally, EO data does not provide information on all water quality parameters, such as nutrient concentrations and dissolved oxygen levels. Despite these limitations, EO data can still be a valuable tool for assessing water quality trends and changes in freshwater resources.

2.2 Lab. Assessing Water Quality using the Normalized Difference Suspended Sediment Index (NDSSI) in Google Earth Engine

2.2.1 Introduction

This lab exercise will compute the normalized difference in the suspended sediment index (NDSSI). NDSSI is an index derived from remote sensing data, specifically Landsat imagery's near-infrared (NIR) and green bands. It helps estimate and map

suspended sediment concentration in rivers and lakes. By calculating the difference between the NIR and green bands and dividing it by their sum, we can obtain the NDSSI values. Negative NDSSI values indicate higher suspended sediment concentrations, while positive values indicate lower concentrations (Hossain et al., 2010). We will use Landsat 8 imagery to calculate NDSSI.

2.2.2 Objective

- Assess water quality using NDSSI in Google Earth Engine.

2.2.3 Procedure

Following are the steps.

Step 1: Define the project area

First, define the project area as Colombo District in Sri Lanka using the FAO/GAUL dataset.

```
// Define the study area as Colombo District, Sri Lanka.
var boundary = ee.FeatureCollection('FAO/GAUL/2015/level2')
  .filterMetadata('ADM2_NAME', 'equals', 'Colombo');
```

Next, add the boundary of the Colombo District to the map for visualization

```
// Display the city boundary
Map.addLayer(boundary, {}, 'Colombo');
```

Step 2: Import and mask water areas

Import the global surface water layer from the JRC/GSW1_3 dataset.

```
// Import the global surface water layer we will use to mask water areas
var gsw = ee.Image("JRC/GSW1_3/GlobalSurfaceWater");
```

Select the 'max_extent' band from the water layer and clip it to the Colombo District boundary.

```
// Select the 'max_extent' band
var water = gsw.select('max_extent').clip(boundary); // max_extent band has values 0 or 1
```

Create a mask by keeping only the water areas (values of 1) and apply it to the water layer.

```
// Keep the water areas only (1)
var masked = water.updateMask(water);
```

Add the masked water layer to the map for visualization.

```
// Finally, mask out 0 values and retain only water areas (1)
var masked = water.selfMask();
Map.addLayer(masked, {}, 'Water');
```

Step 3: Cloud masking

Define a function called maskL8sr to perform cloud masking on Landsat 8 Surface Reflectance (SR) data. Note that, inside the function, define masks for different types of

clouds and shadows using the pixel_qa and QA_RADSAT bands. Then apply scaling factors to the optical and thermal bands of the image.

```
// Function to cloud mask from the pixel_qa band of Landsat 8 SR data.
var maskL8sr = function(image) {
  // Bit 0 - Fill; Bit 1 - Dilated Cloud; Bit 2 - Cirrus; Bit 3 - Cloud; Bit 4 - Cloud Shadow
  var qaMask = image.select('QA_PIXEL').bitwiseAnd(parseInt('11111', 2)).eq(0);
  var saturationMask = image.select('QA_RADSAT').eq(0);
  // Apply the scaling factors to the appropriate bands.
  var opticalBands = image.select('SR_B.').multiply(0.0000275).add(-0.2);
  var thermalBands = image.select('ST_B.*').multiply(0.00341802).add(149.0);
  // Replace the original bands with the scaled ones and apply the masks.
  return image.addBands(opticalBands, null, true)
    .addBands(thermalBands, null, true)
    .updateMask(qaMask)
    .updateMask(saturationMask)
    .updateMask(masked);
};
```

Step 4: Calculation of NDSSI

Define a function called *addVariables* to calculate the NDSSI and add additional variables to the Landsat images. Then, compute the time in fractional years since the epoch using the date of the image. Finally, return the image with the added NDSSI, time, and constant bands.

```
// Function to calculate NDSSI.
var addVariables = function(image) {
  // Compute time in fractional years since the epoch.
  var date = image.date();
  var years = date.difference(ee.Date('1970-01-01'), 'year');
  // Return the image with the added bands.
  return image
    // Add an NDSSI band.
    .addBands(image.normalizedDifference(['SR_B5', 'SR_B2']).rename('NDSSI'))
    // Add a time band.
    .addBands(ee.Image(years).rename('t')).float()
    // Add a constant band.
    .addBands(ee.Image.constant(1));
};
```

Step 5: Filter and prepare Landsat data

Filter the Landsat 8 SR data to the Colombo District boundary and a specific date range. Next, apply cloud masking to the filtered images using the maskL8sr function. Then calculate NDSSI and add variables to the masked images using the *addVariables* function.

```
// Remove clouds, add variables and filter to the area of interest.
var filteredLandsat = landsat8Sr
  .filterBounds(boundary)
  .filterDate('2014', '2021')
  .map(maskL8sr)
  .map(addVariables);
```

Step 6: Visualization

Define the RGB parameters for visualization using the Landsat 8 SR data.

```
// Display RGB parameters
var rgb = landsat8Sr.select('SR_B5', 'SR_B4','SR_B3');
// Plot a time series of NDSSI at a single location.
Map.setCenter(80.04686706959697, 6.853287288926003, 12);
```

Next, choose a palette for displaying the NDSSI values.

```
// Load and define a continuous palette
var palettes = require('users/gena/packages:palettes');
// Choose and define NDSSI display palette
var palette = palettes.misc.jet[7];
var viz = {min: 0, max: 1, palette: palette};
```

Create a legend for the NDSSI values, add it to the map.

```
// Set the position of the panel
var legend = ui.Panel({
  style: {
    position: 'bottom-left',
    padding: '8px 15px'
  }
});
// Create a legend title
var legendTitle = ui.Label({
  value: 'NDSSI',
  style: {
    fontWeight: 'bold',
    fontSize: '18px',
    margin: '0 0 4px 0',
    padding: '0'
  }
});
// Add the title to the panel
legend.add(legendTitle);
// Create the legend image
var lon = ee.Image.pixelLonLat().select('latitude');
var gradient = lon.multiply((viz.max - viz.min) / 100.0).add(viz.min);
var legendImage = gradient.visualize(viz);
// Create text on top of the legend
var panel = ui.Panel({
  widgets: [
    ui.Label(viz['max'])
  ],
});
legend.add(panel);
// Create a thumbnail from the image
var thumbnail = ui.Thumbnail({
  image: legendImage,
  params: { bbox: '0,0,10,100', dimensions: '10x200' },
  style: { padding: '1px', position: 'bottom-center' }
});
```

```
// Add the thumbnail to the legend
.add(thumbnail);
// Create text on top of the legend
var panel = ui.Panel({
  widgets: [
    ui.Label(viz['min'])
  ],
});
legend.add(panel);
Map.add(legend);
```

Finally, add the NDSSI layer to the map for visualization.

```
// Display the NDSSI map
var NDSSI = filteredLandsat.select('NDSSI');
Map.addLayer(NDSSI, viz, 'NDSSI Mosaic');
```

Step 7: Interactive inspection

Create a panel to hold interactive widgets.

```
// Create a panel to hold our widgets.
var panel = ui.Panel();
panel.style().set('width', '300px');
```

Create an intro panel with labels to provide information about the tool.

```
// Create an intro panel with labels.
var intro = ui.Panel([
  ui.Label({
    value: 'NDSSI & SR Chart Inspector',
    style: { fontSize: '20px', fontWeight: 'bold' }
  }),
  ui.Label('Click a point on the map to inspect.')
]);
panel.add(intro);
```

Create panels to display the longitude and latitude values of the clicked point.

```
// Create panels to hold lon/lat values.
var lon = ui.Label();
var lat = ui.Label();
panel.add(ui.Panel([lon, lat], ui.Panel.Layout.flow('horizontal')));
```

Register a callback on the map click event to update the lon/lat panel and display a red dot at the clicked point.

```
// Register a callback on the default map to be invoked when the map is clicked.
Map.onClick(function (coords) {
  // Update the lon/lat panel with values from the click event.
  lon.setValue('lon: ' + coords.lon.toFixed(2)),
    lat.setValue('lat: ' + coords.lat.toFixed(2));
  // Add a red dot for the point clicked on.
  var point = ee.Geometry.Point(coords.lon, coords.lat);
  var dot = ui.Map.Layer(point, { color: 'FF0000' });
  Map.layers().set(1, dot);
```

Create an NDSSI chart for the clicked point using the *ui.Chart.image.series* function (Figure 2a).

```
// Create an NDSSI chart.
var NDSSIChart = ui.Chart.image.series(NDSSI, point, ee.Reducer.mean(), 500);
NDSSIChart.setOptions({
  title: 'NDSSI Over Time',
  vAxis: { title: 'NDSSI' },
  hAxis: { title: 'date', format: 'MM-yy', gridlines: { count: 7 } },
});
panel.widgets().set(2, NDSSIChart);
```

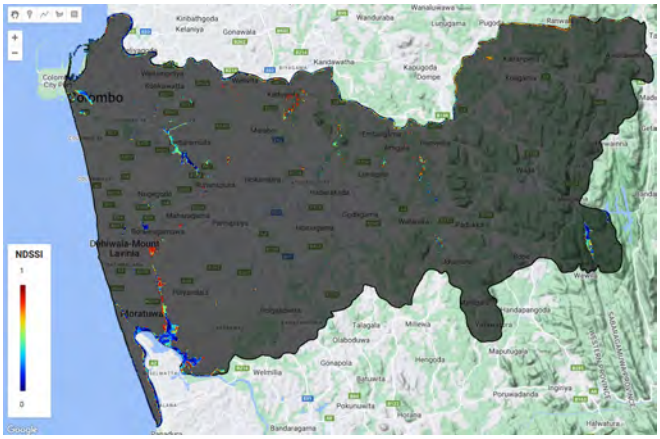


Figure 2a. Estimating water quality using NDSSI (Colombo).

Create an RGB spectrum chart for the clicked point using the *ui.Chart.image.series* function.

```
  // Create an RGB spectrum chart.
  var rgbChart = ui.Chart.image.series(rgb, point)
    .setOptions({
      title: 'RGB Reflectance Over Time',
      vAxis: { title: 'band value' },
      hAxis: { title: 'date', format: 'MM-yy', gridlines: { count: 7 } },
    });
  panel.widgets().set(3, rgbChart);
});
Map.style().set('cursor', 'crosshair');
```

Finally, add the panels and charts to the main panel.

```
// Add the panel to the ui.root.
ui.root.insert(0, panel);
```

2.3 Additional Exercises

i.Create NDSSI maps for different administrative areas in Sri Lanka.
ii.Calculate the normalized difference turbidity index (NDTI) for Kaduwela district.

2.4 Code Link

https://code.earthengine.google.com/dd147c4e390c63f856ad10f61393a3bd

2b. Assessing Air Quality using Earth Observation (EO) Datasets

2.1 Background

Assessing air quality using Earth observation (EO) data can be done using the Sentinel-5P NRTI NO2 dataset. This dataset provides near real-time high-resolution imagery of NO2 concentrations. Nitrogen oxides (NO2 and NO) are essential trace gases in the Earth's atmosphere, present in both the troposphere and the stratosphere. They enter the atmosphere due to anthropogenic activities (notably fossil fuel combustion and biomass burning) and natural processes (wildfires, lightning, and microbiological processes in soils). The European Space Agency launched the Sentinel-5P satellite to monitor air pollution, and the onboard sensor, Tropomi, provides high-resolution imagery of NO2 concentrations. Environmental experts use other EO datasets, such as the Moderate Resolution Imaging Spectroradiometer (MODIS), to monitor air quality. Although EO datasets are critical for monitoring air quality, they have the following limitations.

- Satellite air quality data have coarse temporal and spatial resolutions. This can make obtaining detailed information about air quality at specific times and locations difficult.
- Obscuring the effect of clouds and aerosols can limit the accuracy of satellite-based air quality measurements. This can make it challenging to obtain accurate air quality measurements in areas with high levels of cloud cover or aerosols.
- Limited availability of ground monitoring stations. This can make it challenging to validate satellite-based air quality measurements and obtain accurate air quality measurements in areas without a ground monitor.
- Limited ability to measure certain air pollutants. While satellite data can indicate criteria for air pollutants (e.g., PM2.5 and NO2) and greenhouse gases (e.g., CH4 and CO_2), there are limitations to the ability of satellites to measure certain air pollutants. For example, satellites may not be able to measure the concentration of some volatile organic compounds (VOCs) that are essential contributors to air pollution.

Despite these limitations, EO data can still be a valuable tool for monitoring air quality, especially in areas with limited or non-existent ground monitoring stations. Each approach to monitoring air quality has unique advantages and, when deployed together, could compensate for weaknesses.

2.2 Lab. Assessing Air Quality using Sentinel-5P NRTI NO2 in Google Earth Engine

2.2.1 Introduction

In this tutorial, we will analyze the concentration of Nitrogen dioxide (NO2) in Colombo, Sri Lanka using the Sentinel-5P NRTI NO2 dataset. Sentinel-5 Precursor is a satellite launched by the European Space Agency to monitor air pollution.

2.2.2 Objective

• Assess NO2 concentration in Colombo using Sentinel-5P NRTI NO2 in Google Earth Engine.

2.2.3 Procedure

Following are the steps.

Step 1: Define the project area

We will define the study area as the Colombo District in Sri Lanka. To do this, we will use the *ee.FeatureCollection()* function from the Google Earth Engine API to filter the FAO/GAUL/2015/level2 dataset by the ADM2_NAME property, which is the name of the second-level administrative subdivision. We will then add the city's boundary to the map using the *Map.addLayer()* function.

```
var boundary = ee.FeatureCollection('FAO/GAUL/2015/level2')
  .filterMetadata('ADM2_NAME', 'equals', 'Colombo');
  Map.setCenter(80.03924123158131,6.843100868423103, 12);
Map.addLayer(boundary, {}, 'Colombo');
```

Step 2: Import NO2 values

We will import the NO2 values using the *ee.ImageCollection()* function from the Google Earth Engine API. We will select the NO2_column_number_density band from the COPERNICUS/S5P/NRTI/L3_NO2 dataset, which provides near real-time high-resolution imagery of NO2 concentrations. We will then filter the NO2 values by month and year using the *ee.Filter.calendarRange()* function. Finally, we will calculate the mean NO2 concentration for the filtered values and clip the result to the study area boundary.

```
// Load the image collection
var NO2ic = ee.ImageCollection('COPERNICUS/S5P/NRTI/L3_NO2').select('NO2_column_number_density');

var filterMonth = ee.Filter.calendarRange(2, 5, 'month');
var NO2 = NO2ic.filter(filterMonth);
var filter19 = ee.Filter.calendarRange(2020, 2020, 'year');
var filter20 = ee.Filter.calendarRange(2022, 2022, 'year');
var NO2pre  = NO2.filter(filter19).mean().multiply(1e6).clip(boundary);
var NO2post = NO2.filter(filter20).mean().multiply(1e6).clip(boundary);
```

Step 3: Visualize NO2 concentration

We will visualize the NO2 concentration using the *Map.addLayer()* function. We will set the minimum and maximum values of the colour scale using the min and max parameters and specify a colour palette using the palette parameter.

```
// Prepare the visualization parameters
var vizParams = {
  min: 0,
  max: 200,
  palette: ['black', 'purple', 'green', 'red']
};
```

Next, add the NO2 concentration maps using the *Map.addLayer()* function.

```
// Add the map layers
Map.addLayer(NO2pre, vizParams, 'NO2pre');
Map.addLayer(NO2post, vizParams, 'NO2post');
```

Step 4: Visualize maps using a screen split display

We will visualize the NO2 concentration map using a screen split display (Figure 2b). We will create a new map using the *ui.Map()* function and add the second NO2 concentration map to it. We will then link the two maps using the *ui.Map.Linker()* function and create a split panel using the *ui.SplitPanel()* function. Finally, we will set the split panel as the only thing in the root using the *ui.root.widgets().reset()* function.

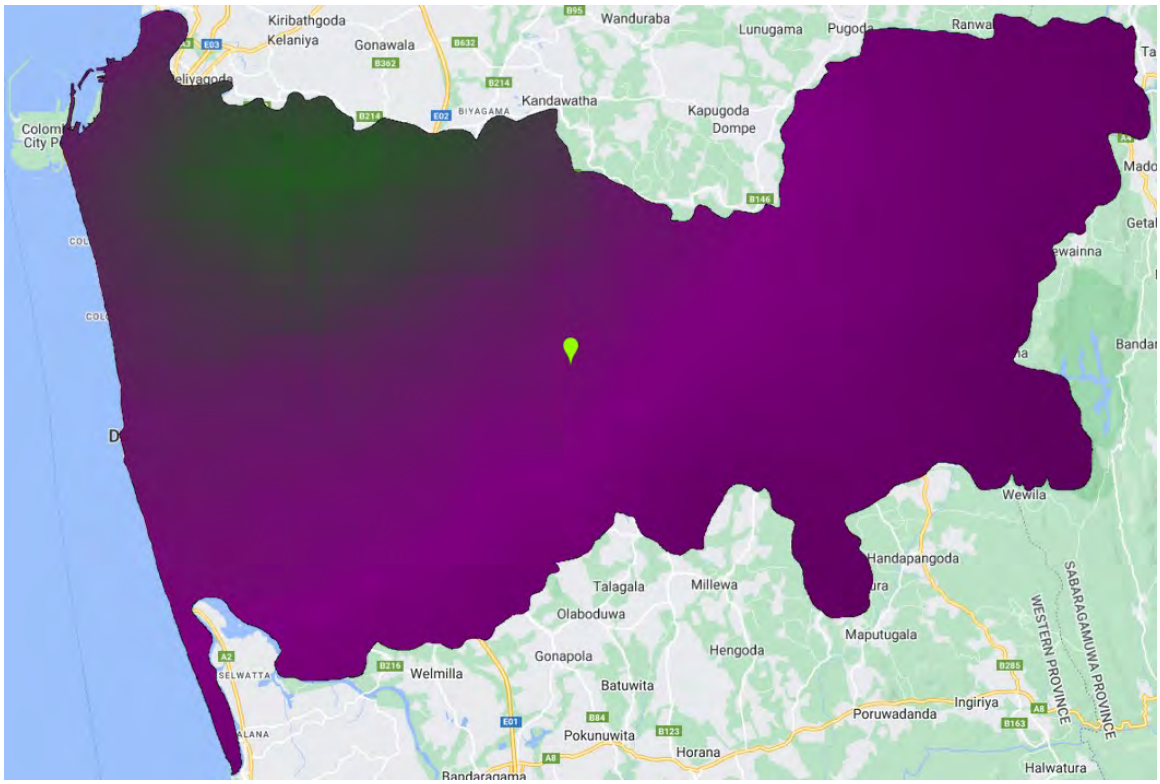


Figure 2b. Estimating air quality based on NO2 concentration map.

```
//Visualize the NO2 concentration map using a screen split display
var Map2 = ui.Map();
Map2.addLayer(NO2post, vizParams, 'splitpost');

// create a new map
var linker = ui.Map.Linker([ui.root.widgets().get(0), Map2]);

// link the two maps
var splitPanel = ui.SplitPanel({
  firstPanel: linker.get(0),
  secondPanel: linker.get(1),
```

```
  orientation: 'horizontal',
  wipe: true,
  style: {stretch: 'both'}
});
ui.root.widgets().reset([splitPanel]);
linker.get(0).setCenter(80.01967183460866,6.857758353263657, 12);
```

2.2.4 Summary

In this tutorial, we analyzed the concentration of NO2 in Colombo, Sri Lanka using the Sentinel-5P NRTI NO2 dataset. We defined the study area, imported the NO2 values, and visualized the NO2 concentration using a screen split display. This tutorial can be used as a starting point for further analysis of air pollution using satellite data.

2.3 Additional Exercises

i. Assess the concentration of NO2 different in other administrative areas in Sri Lanka.
ii. Compare the concentration of NO2 in Colombo and other administrative areas in Sri Lanka.

2.4 Code Link

https://code.earthengine.google.com/8d1e77f6e9b34268c40ae16de133d90b

3a. Modeling Forest Canopy Height

3.1 Background

Forest canopy height is a critical attribute of the forest ecosystem, providing valuable information on aboveground biomass density (AGBG), carbon stock density, and forest habitat quality. Forest researchers and ecologists use forest canopy height data to monitor ecosystem response to climate and land-use changes and assess biodiversity. Therefore, reliable and current information on forest canopy height and other attributes is crucial for effective forest resource management. Forest researchers and ecologists have traditionally relied on field measurements to collect forest canopy data, but this approach can be time-consuming, costly, and spatially limited.

Earth observation data has become crucial in mapping global and regional forest canopy height and AGB. Researchers have been using passive optical imagery and active and passive microwave sensors, and LiDAR. Passive optical imagery provides information on chlorophyll-rich vegetation, while active microwave sensors such as SAR provide information on forest moisture, structure, and soil and plant surfaces. SAR is beneficial because it can acquire images even in cloudy regions.

LiDAR sensors estimate canopy height by measuring the time between emitted and received light pulses. Remote sensing analysts have used LiDAR to map forest canopy height. LiDAR is an active remote sensing sensor that captures the forest canopy's three-dimensional structure. LiDAR encompasses different platforms, such as terrestrial laser scanning (TLS), airborne laser scanning (ALS), drone LiDAR, and spaceborne LiDAR. While TLS and ALS provide more accurate forest canopy data, they are costly and need more spatial and temporal coverage in large forest areas.

3.2 Lab. Modelling Forest Canopy Height and AGB using GEDI, Sentinel-1 and Sentinel-2 Data in EE

3.2.1 Introduction

This lab will model forest canopy height using Global Ecosystem Dynamics Investigation (GEDI) forest canopy height measurements, Sentinel-1, Sentinel-2, SRTM elevation, and slope data. We will use the random forest (RF) classifier to model forest canopy height in Earth Engine.

Earth Observation (EO) systems such as NASA's GEDI LiDAR instrument (Dubayah et al. 2021) onboard the International Space Station have collected vegetation structure data since April 2019. GEDI is a full waveform LiDAR designed to measure ecosystem structure and provides global coverage from 51.6° south to 51.6° north. It acquires forest vertical structure measurements in temperate and tropical forests. The LiDAR system consists of three lasers that produce eight parallel observation tracks. Each laser illuminates a 25-meter spot on the surface, where the 3D structure is measured. Every 25-

meter site is separated by 60 meters along the track. There are about 600 meters between each of the eight tracks, and the system acquires data along these tracks.

3.2.2 Objective

iii.Model forest canopy height using EO data and random forest (RF) classifier

3.2.3 Procedure

Following are the steps.

Step 1: Import and display the project area boundary

First, load the project area boundary, which will be used to clip the imagery collection.

```
// Load the project area boundary for Kaduwela.
var boundary = ee.FeatureCollection('users/kamas72_ML_Zim_Cities/Kaduwela_DSDivision_UN')
```

Next, display the project area boundary

```
// Display the boundary
Map.addLayer(boundary, {}, 'Kaduwela');
// Set the map centre and visualize the dataset
Map.setCenter(79.97957580983135,6.904329786802445, 14);
```

Step 2: Load raster variables (Sentinel-1, Sentinel-2, elevation, and slope data)

Next, load a stack of images called Image Collections. This creates an ee.ImageCollection object called S1_PRS for Sentinel-1 GRD data (Ground Range Detected). We will filter the image according to date, polarization, instrument mode, orbit pass, and study area boundary.

```
// Load Sentinel-1 (S1) for the selected period.
var S1_PRS = ee.ImageCollection('COPERNICUS/S1_GRD')
   .filterDate('2021-04-01', '2022-06-30')
   .filter(ee.Filter.listContains('transmitterReceiverPolarisation', 'VV'))
   .filter(ee.Filter.listContains('transmitterReceiverPolarisation', 'VH'))
   .filter(ee.Filter.eq('instrumentMode', 'IW'))
   .filter(ee.Filter.eq('orbitProperties_pass', 'ASCENDING'))
   .filterBounds(boundary);
```

Next, let's calculate the inter-quartile range (IQR) for the VV (vertical transmit and vertical receive) and VH (vertical transmit and horizontal receive) polarization. The IQR is a measure of Sentinel-1 backscatter variability. We will also reproject the VV and VH datasets.

```
// Prepare inter-quartile range (IQR)
var S1_PRS_pc = S1_PRS.reduce(ee.Reducer.percentile([25,50,75]));
```

The above code applies a percentile reducer to the S1_PRS image collection and computes the 25th, 50th (median), and 75th percentile values for each pixel, resulting in a 3-band image for each polarization.

Next, we will convert the percentiles to natural units (linear units) using a base-10 exponentiation to average the values.

```
// Convert to natural units (linear units, which can be averaged)
var S1_PRS_pc = ee.Image(10).pow(S1_PRS_pc.divide(10));
```

Select the 50th percentile band for both VV and VH polarizations, clip the resulting 2-band image to the boundary geometry, and assigns it to the S1_PRS_pc_Feats variable.

```
var S1_PRS_pc_Feats = S1_PRS_pc.select(['VH_p50','VV_p50']).clip(boundary);
```

Next, reproject the S1_PRS_pc_Feats image to WGS 84 UTM zone 44N, which has an EPSG code of 32644 and a pixel scale of 30 meters.

```
// Reproject to WGS 84 UTM zone 44N
var S2_composite = composite.median().reproject({crs: 'EPSG:32644' , scale: 30});
```

Print the projection information (*crs and crs_transform*) of the S1_PRS_pc_Feats image to the console.

```
// Check projection information
print('Projection, crs, and crs_transform:', S1_PRS_pc_Feats.projection());
```

Next, let us calculate the interquartile range (IQR) for the VV and VH polarizations of the Sentinel-1 SAR images using the percentile information obtained in the previous steps. The two new variables, PRS_VV_iqr and PRS_VH_iqr will hold the calculated IQR values for the VV and VH polarizations, respectively.

```
// Calculate IQR for the VV polarization
var PRS_VV_iqr = S1_PRS_pc_Feats
        .addBands((S1_PRS_pc.select('VV_p75')
        .subtract(S1_PRS_pc.select('VV_p25')))
        .rename('VV_iqr'));
// Calculate IQR for the VH polarization
var PRS_VH_iqr = S1_PRS_pc_Feats
        .addBands((S1_PRS_pc.select('VH_p75')
        .subtract(S1_PRS_pc.select('VH_p25')))
        .rename('VH_iqr'));
```

The S1_PRS_pc_Feats image is first used as a base image to calculate the IQR for the VV polarization. The *addBands()* function is then called, which adds a new band to the image. The values of this new band are calculated as the difference between the 75th percentile (*VV_p75*) and the 25th percentile (*VV_p25*) of the Sentinel-1 data. The *rename()* function gives the new band the name '*VV_iqr*'. This calculation is also performed for the VH polarization, with the result stored in the PRS_VH_iqr variable.

Next, print both the PRS_VV_iqr and PRS_VH_iqr images to the console using the *print()* function. This allows the user to view information about the newly calculated images, such as their band names, projections, and other metadata.

```
// Print the image to the console
print('Post-rainy Season VV IQR', PRS_VV_iqr);

// Print the image to the console
print('Post-rainy Season VV IQR', PRS_VH_iqr);
```

Let's visualize the VV and VH datasets using the *Map.addLayer()* function. The images are clipped to the boundary variable defined earlier to limit the area displayed. The '*bands*', '*min*', and *'max*' arguments specify which band to display and the colour scale.

```
// Display S1 inter-quartile range imagery
Map.addLayer(PRS_VV_iqr.clip(boundary), {'bands': 'VV_iqr', min: 0,max: 0.1}, 'Sentinel-1 IW VV');
Map.addLayer( PRS_VH_iqr.clip(boundary), {'bands': 'VH_iqr', min: 0,max: 0.1}, 'Sentinel-1 IW VH');
```

Notes:
The interquartile range (IQR) is a statistical measure that indicates the spread of a dataset. In analyzing Sentinel-1 SAR images, the IQR can be used to estimate the variability of backscattering values for different polarization channels. The VV and VH polarization channels provide information on the orientation and size of scatterers on the ground, respectively.

By computing the IQR for the VV and VH polarization channels separately, we can better understand the variability of backscattering values for different scatterers. For instance, the IQR would be small in areas with homogeneous surfaces, such as water bodies. In contrast, the IQR would be more significant in regions with heterogeneous surfaces, such as forests. Overall, using the IQR for the VV and VH polarization channels of Sentinel-1 SAR images allows for a more comprehensive analysis of the backscattering values and provides insight into the variability of different land cover types.

Next, let us load the Sentinel-2 surface reflectance image collection.

```
// Load Sentinel-2 spectral reflectance data.
var s2 = ee.ImageCollection('COPERNICUS/S2_SR');
```

Next, define a cloud masking function using the Sentinel-2 QA band. The "*maskS2clouds*" function is applied to each image in the imageCollection.

```
// Create a function to mask clouds using the Sentinel-2 QA band.
function maskS2clouds(image) {
  var qa = image.select('QA60');

  // Bits 10 and 11 are clouds and cirrus, respectively.
  var cloudBitMask = ee.Number(2).pow(10).int();
  var cirrusBitMask = ee.Number(2).pow(11).int();

  // Both flags should be set to zero, indicating clear conditions.
  var mask = qa.bitwiseAnd(cloudBitMask).eq(0).and(
         qa.bitwiseAnd(cirrusBitMask).eq(0));
  // Return the masked and scaled data.
  return image.updateMask(mask).divide(10000);
}
```

Next, filter the ImageCollection by date, cloud cover ('CLOUDY_PIXEL_PERCENTAGE') cloud mask. Select the bands that you will need to use. Note that: B2 = Blue (10m), B3 = Green (10m), B4 = Red (10m), B8 = NIR (10m),

B5 = Red Edge 1 (20m), B6 = Red Edge 2 (20m), B7 = Red Edge 3 (20m), B8A = Red Edge 4 (20m), B11 = SWIR 1 (20m), and B12 = SWIR 2 (20m).

```
// Filter S2 SR image collection by date, cloud cover, and cloud mask.
var composite = s2.filterDate('2022-04-01', '2022-06-30')
            // Pre-filter to get less cloudy granules.
            .filter(ee.Filter.lt('CLOUDY_PIXEL_PERCENTAGE', 20))
            .map(maskS2clouds)
            .select('B2', 'B3', 'B4','B5','B6','B7','B8','B11', 'B12');
```

Next, reproject and display the S2 SR median composite image.

```
// Reproject to WGS 84 UTM zone 44N
var S2_composite = composite.median().reproject({crs: 'EPSG:32644' , scale: 30})
// Check projection information
print('Projection, crs, and crs_transform:', S2_composite.projection());

// Display a composite S2 imagery
Map.addLayer(S2_composite.clip(boundary), {bands: ['B11', 'B8', 'B3'], min: 0, max: 0.3});
```

Next, import SRTM DEM and clip it to the study area boundary.

```
// Load SRTM DEM and clip it to the study area
var SRTM = ee.Image("USGS/SRTMGL1_003");

// Clip Elevation
var elevation = SRTM.clip(boundary);

// Reproject 'elevation' to WGS 84 UTM zone 44N
var elevation = elevation.reproject({crs: 'EPSG:32644',scale: 30});

// Check projection information
print('Projection, crs, and crs_transform:', elevation.projection());
```

We are also going to extract the slope from the SRTM DEM.

```
// Derive slope from the SRTM
var slope = ee.Terrain.slope(SRTM).clip(boundary);

// Reproject 'slope' to WGS 84 UTM zone 44N
var slope = slope.reproject({crs: 'EPSG:32644',scale: 30});

// Check projection information
print('Projection, crs, and crs_transform:', slope.projection());
```

Next, we will add a forest mask derived from ESA World Cover (2020) and clip it to the study area boundary.

```
// Load ESA World Cover data
var dataset = ee.ImageCollection("ESA/WorldCover/v100").first();

// Clip the land cover to the boundary
var ESA_LC_2020 = dataset.clip(boundary);
```

```
// Extract forest areas from the land cover
var forest_mask = ESA_LC_2020.updateMask(
  ESA_LC_2020.eq(10) // Only keep pixels where class equals 2
);
// Display forests only
var visualization = {bands: ['Map'],};
Map.addLayer(forest_mask, visualization, "Trees");
```

Step 3: Combine all raster variables

Next, we will prepare a dataset that can be used for classification purposes. We are going to combine various predictor variables to create a new dataset. Here, we use the *addBands()* function to combine the variables. The S2_composite variable contains the Sentinel-2 imagery for the study area, while PRS_VV_iqr and PRS_VH_iqr variables have the interquartile range for the VV and VH polarizations of the Sentinel-1 SAR imagery. The elevation variable contains the elevation data for the study area, the slope contains the slope data, and the forest_mask includes a binary forest mask that identifies areas of forest cover. The *addBands()* function is used repeatedly to add each variable to the new dataset.

```
// Merge the predictor variables
var mergedCollection = S2_composite
  .addBands(PRS_VV_iqr
  .addBands(PRS_VH_iqr
  .addBands(elevation
  .addBands(slope
  .addBands(forest_mask))))));
```

Next, clip the merged dataset to the boundary of the study area

```
// Clip to the output image to the Harare study area boundary.
var clippedmergedCollection = mergedCollection.clips collection(boundary);
print('clippedmergedCollection: ', clippedmergedCollection);
```

Create an object (bands) that contains all raster variables, which will be used for the model. The bands variable includes the spectral bands from Sentinel-2 (*B2-B8*, *B11*, and *B12*), the interquartile range for the VV and VH polarizations of the Sentinel-1 SAR imagery (*VV_iqr* and *VH_iqr*), the elevation data (*elevation*), the slope data (*slope*), and the forest mask (*Map*).

```
// Bands to include in the classification
var bands = ['B2', 'B3', 'B4', 'B5', 'B6', 'B7', 'B8', 'B11', 'B12', 'VV_iqr', 'VH_iqr', 'elevation', 'slope', 'Map'];
```

Step 4: Prepare training data

We will use GEDI's Level 2A Geolocated Elevation and Height Metrics Product (*GEDI02_A*). This dataset comprises 100 Relative Height (RH) metrics, which collectively describe the waveform collected by GEDI. The original GEDI02_A product is a table of points with a spatial resolution (average footprint) of 25 meters. You can get more information at https://lpdaac.usgs.gov/documents/986/GEDI02_UserGuide_V2.pd

Let's start by defining a mask and importing the '*GEDI02_A_002_MONTHLY*' dataset. The *qualityMask* function takes an input image and returns an updated image with a mask applied to remove low-quality data. The mask is created by selecting pixels with a quality flag of 1 and a degrade flag of 0. These flags are included in the GEDI dataset to indicate the quality and reliability of the data.

```
// Define a mask
var qualityMask = function(im) {
  return im.updateMask(im.select('quality_flag').eq(1))
     .updateMask(im.select('degrade_flag').eq(0));
};
```

Next, we will use the *ee.ImageCollection()* function to import the GEDI02_A_002_MONTHLY dataset as an image collection.

```
// Import the "EDI02_A_002_MONTHLY: dataset
var dataset = ee.ImageCollection('LARSE/GEDI/GEDI02_A_002_MONTHLY')
              .map(qualityMask)
              .select('rh98').filterBounds(boundary);
```

The qualityMask function is applied to each image in the image collection to remove low-quality data. The RH98 metric is a percentile-based height metric that estimates the height of the tallest vegetation within the footprint of the GEDI laser pulse. It represents the height at which 98% of the vegetation within the pulse footprint is located below.
Next, let's create a palette and display the GEDI02_A dataset.

```
// Create a pallete to visualize the dataset
var gediVis = {
  min: 1,
  max: 60,
  palette: 'darkred,red,orange,green,darkgreen',
};

// Display the dataset
Map.addLayer(dataset, gediVis, 'rh98');
```

Next, we define projection and scale parameters for the GEDI02_A dataset. The projection and scale parameters are defined using the first image in the dataset variable. The *projection()* function is called on this image to retrieve its projection information. It is then assigned to the projection variable using the *aside(print)* function to print it to the console. The *nominalScale()* function is called on the projection variable to retrieve the nominal scale of the image, which is assigned to the scale variable using the *aside(print)* function to print it to the console.

```
// Define projection and scale parameters
var projection = dataset.first().projection().aside(print);
var scale = projection.nominalScale().aside(print);
```

After defining the projection and scale variables, the *mosaic()* function is called on the dataset variable to create a single image mosaic from all the images in the collection. The *setDefaultProjection()* function is called on this mosaic image and is given an object with

the crs and scale parameters set to the projection and scale variables, respectively. This sets the projection and scale of the image to be the same as the first image in the dataset variable.

```
var mosaic = dataset.mosaic().setDefaultProjection({crs:projection, scale:scale});
```

Next, we will sample 10,000 forest canopy height points from the GEDI02_A dataset.

```
// Sample 10,000 points from the dataset
var numTrainingPoints = 10000; // Specify the number of training points
var points = mosaic.sample({
  region: boundary,
  scale: 10,
  numPixels: numTrainingPoints * 100, // Increase numPixels to ensure sufficient samples
  geometries: true,
});
```

In the code above, 10,000 points are randomly sampled from the mosaic image using the *sampl*ing method. The *region* parameter specifies the region from which the samples should be taken, and *the boundary* is used as the region of interest. The *scale parameter* sets the scale to take the samples, and *projection* ensures that the samples are projected in the correct coordinate system. The numPixels parameter specifies the number of pixels to generate the samples. Finally, the *geometries* parameter is set to true to ensure that the output feature collection contains the geometries of the sampled points.

We will check the training points and visualize them on the Map or imagery.

```
// Check the number of the training points
print(points.size());
print(points.limit(10));
// Display the training points
Map.addLayer(points);
```

In machine learning, splitting the data into training and testing sets is essential to evaluate the model's performance. So we will split the training data into a training set and a test (validation) set. First, we will use the *randomColumn()* function to add a new column named '*random*' to the points dataset with random values between 0 and 1. The second argument is the seed value (*27*) used to generate random values. Using a seed value ensures that the random values are the same every time we run the code, which helps in the repeatability of the experiment.

```
// Add a random column (named random) and specify the seed value for repeatability.
var datawithColumn = points.randomColumn('random', 27);
```

Next, split the training data set into training and validation or testing. The variable split defines the percentage of data that should be used for training. In this case, 70% of the data is used for training, and 30% is used for validation.

```
// Separate 70% for training, 30% for validation
var split = 0.7;
```

We apply the ee.Filter.lt filter to the datawithColumn dataset, so it filters the data where the value of the '*random*' column is less than the split value. This gives us the training data.

```
var trainingData = datawithColumn.filter(ee.Filter.lt('random', split));
```

We use the *print()* function to print the training and validation datasets to the console. This helps us to verify that the datasets are correctly created and have the expected number of features.

```
print('training data', trainingData);
```

Next, we apply the *ee.Filter.gte* filter is applied to the datawithColumn dataset, and it filters the data where the value of the 'random' column is greater than or equal to the split value. This gives us the validation data.

```
var validationData = datawithColumn.filter(ee.Filter.gte('random', split));
print('validation data', validationData);
```

Step 5: Train the random forest (RF) model

To train and evaluate the model, we will use a dataset of the GEDI's canopy top heights (RH98), that is the height of the 98th percentile of the cumulative waveform energy relative to the ground.

Next, create a training dataset using the *sampleRegions()* method on the clippedmergedCollection object. It selects the bands defined in the band's list and sets the scale to 30 to avoid running out of memory. The collection argument is set to trainingData, the dataset created earlier containing 70% of the randomly sampled points. Note that Earth Engine imposes usage limits. An error is usually returned when limits are exceeded. For example, if there are many training points.

```
// Collect training data
var training = clippedmergedCollection.select(bands).sampleRegions({
  collection: trainingData,
  properties: ['rh98'],
  scale: 30 // Need to change the scale of training data to avoid the 'out of memory problem
  });
```

Next, a random forest classifier is trained on the training dataset using the *smileRandomForest()* method from Earth Engine. The *setOutputMode()* method sets the output mode to REGRESSION, indicating that we want to perform a regression analysis. The *train()* method is called to train the classifier, with the features argument set to training, classProperty set to "rh98", and inputProperties set to bands.

```
// Train a random forest classifier for regression
var classifier = ee.Classifier.smileRandomForest(50)
  .setOutputMode('REGRESSION')
  .train({
    features: training,
    classProperty: "rh98",
```

```
  inputProperties: bands
  });
```

You can also tune the RF model by changing the "*NumberOfTrees*" parameter. Increasing the "*NumberOfTrees*" parameter from 100 to 500 may result in an error, or Earth Engine may take longer to train. However, fewer trees may also result in less statistically robust RF models.

After training, the *classify()* function is called on the clippedmergedCollection object using the trained classifier to generate a predicted regression dataset. The resulting dataset is clipped to the boundary polygon using the *clip()* function.

```
//Run the regression and clip it to the boundary
var regression = clippedmergedCollection
            .select(bands)
            .classify(classifier, 'predicted')
            .clip(boundary);
```

Load a continuous palette from the following package available at "https://github.com/gee-community/ee-palettes."

```
// Load and define a continuous palette
var palettes = require('users/gena/packages:palettes');
var palette = palettes.colorbrewer.YlGn[5];
```

Next, we calculate the regression classification's minimum and maximum predicted values for the study area. This is done using the *reduceRegion()* function, which calculates a statistic over a specified region. In this case, the *min()* and *max()* reducers are used to calculate the minimum and maximum values of the regression classification, respectively.

```
// Display the input imagery and the regression output.
 // get dictionaries of min & max predicted value
 var regressionMin = (regression.reduceRegion({
  reducer: ee.Reducer.min(),
  scale: 30,
  crs: 'EPSG:32644', // WGS 84 UTM Zone 44 N
  geometry: boundary,
  bestEffort: true,
  tileScale: 5
 }));

 var regressionMax = (regression.reduceRegion({
  reducer: ee.Reducer.max(),
  scale: 30,
  crs: 'EPSG:32644', // WGS 84 UTM Zone 44 N
  geometry: boundary,
  bestEffort: true,
  tileScale: 5
 }));
```

The *reduceRegion()* function takes several parameters:

i. reducer: specifies the reducer to use (in this case, *min()* or *max()*).
ii. scale: the spatial resolution at which to compute the statistic.
iii. crs: the coordinate reference system to use for the output.
iv. geometry: the region over which to compute the statistic (in this case, the boundary variable).
v. bestEffort: whether to use a best-effort algorithm to reduce the computation time.
vi. tileScale: the scale of the tiles to use for computation.

The *reduceRegion()* function results are stored in two variables, regressionMin, and regressionMax, which are dictionaries containing the minimum and maximum predicted values, respectively. These variables will be used later to set the range of values for the colour palette.

The code adds the regression layer to the map with a colour palette defined in the previous step.

```
// Add to Map
var viz = {palette: palette, min: regressionMin.getNumber('predicted').getInfo(), max: regressionMax.getNumber('predicted').getInfo()};
Map.addLayer(regression, viz, 'Regression');
```

Next, create a legend that comes with the forest canopy height map. We create a panel to hold the legend items, and its style is defined with a position and padding. A label for the legend title is made with a bold font and a larger size, and its value is set to "TC Height."

```
// Create the panel for the legend items.
var legend = ui.Panel({
  style: {
    position: 'bottom-left',
    padding: '8px 15px'
  }
});
```

Create a label for the legend title with a bold font and a larger size, and its value is set to "TC Height"

```
// Create and add the legend title.
var legendTitle = ui.Label({
  value: 'TC Height',
  style: {
    fontWeight: 'bold',
    fontSize: '18px',
    margin: '0 0 4px 0',
    padding: '0'
  }
});
legend.add(legendTitle);
```

The following code block creates a legend for the regression layer added to the map earlier. First, an image is created to show a gradient representing the range of predicted TC height values. The lon variable is an image with two bands, one for longitude and one for latitude. The multiply function is used to scale the latitude values based on the range of predicted TC height values. The minimum and maximum values for the legend are specified in the viz dictionary created earlier.

```
// create the legend image
var lon = ee.Image.pixelLonLat().select('latitude');
var gradient = lon.multiply((viz.max-viz.min)/100.0).add(viz.min);
var legendImage = gradient.visualize(viz);
```

Next, a *ui.Panel* widget is created to display the maximum value of the predicted TC height. This is added to the legend panel along with the legendImage thumbnail.

```
//Create text on top of legend
var panel = ui.Panel({
widgets: [
ui.Label(viz['max'])
],
});
 legend.add(panel);

//Create a thumbnail from the image
var thumbnail = ui.Thumbnail({
image: legendImage,
params: {bbox:'0,0,10,100', dimensions:'10x200'},
style: {padding: '1px', position: 'bottom-center'}
});
```

Next, add the thumbnail (a small image representation of a larger image) to the legend using the *legend.add()* function.

```
// add the thumbnail to the legend
legend.add(thumbnail);
```

Create another *ui.Panel* widget is created to display the minimum value of the predicted TC height. This is also added to the legend panel.

```
//Create text on top of legend
var panel = ui.Panel({
widgets: [
ui.Label(viz['min'])
],
});
```

Next, add the legend panel to the map using the *Map.add()* function.

```
legend.add(panel);
Map.add(legend);
```

We can also centre the Map on the boundary of the study area using the *Map.centerObject()* function.

```
// Zoom to the regression on the Map
Map.centerObject(boundary, 11);
```

Step 6. Check RF model performance

Next, check the RF model performance. We will use the *explain() method* to compute variable importance and create model training statistics.

We will use the *explain()* function to explain the importance values of the ee.Classifier object classifier. The result is then stored in the classifier_details variable.

```
// Get details of classifier
var classifier_details = classifier.explain();
```

Next, the importance dictionary is extracted from the classifier_details using the *ee.Dictionary()* method and stored in the variable_importance variable as an ee.Feature object.

```
// Explain the classifier with importance values
var variable_importance = ee.Feature(null, ee.Dictionary(classifier_details).get('importance'));
```

Next, create a chart using the *ui.Chart.feature.byProperty()* method, with the variable_importance feature passed as an argument. The chart is set to be a column chart using the *setChartType()* method, titled "*Random Forest Variable Importance*". The legend is turned off using the legend option, and the hAxis and vAxis options are set to label the bands and importance values, respectively.

```
var chart =
  ui.Chart.feature.byProperty(variable_importance)
  .setChartType('ColumnChart')
  .setOptions({
  title: 'Random Forest Variable Importance',
  legend: {position: 'none'},
  hAxis: {title: 'Bands'},
  vAxis: {title: 'Importance'}
});
```

Print the chart using the *print()* function with the "*Variable importance*" label. The resulting chart will show the importance values for each band used in the random forest regression classifier.

```
// Plot a chart
print("Variable importance:", chart);
```

Next, we will sample the regression image at the trainingData feature collection points and store the resulting predicted values in a new feature collection called predictedTraining. Note that geometries are set to true so that each point's geometry (i.e., location) in training data is included in predictedTraining.

```
// Create model assessment statistics
// Get predicted regression points in the same location as training data
var predictedTraining = regression.sampleRegions({collection:trainingData, geometries: true});
```

Next, we select the rh98 and predicted properties from predictedTraining and store them in a new feature collection called sampleTraining. The rh98 property contains the observed target variable (tree canopy height), while the predicted property contains the predicted target variable based on the input features.

```
// Separate the observed (agb_GEDI) and predicted (regression) properties
var sampleTraining = predictedTraining.select(['rh98', 'predicted']);
// Create chart
var chartTraining = ui.Chart.feature.byFeature(sampleTraining, 'agbd', 'predicted')
.setChartType('ScatterChart').setOptions({
title: 'Predicted vs Observed - Training data ',
hAxis: {'title': 'observed'},
vAxis: {'title': 'predicted'},
pointSize: 3,
trendlines: { 0: {showR2: true, visibleInLegend: true} ,
1: {showR2: true, visibleInLegend: true}}});
// Print the chart to the console
print(chartTraining);
```

We will use the root mean square error (RMSE) to quantify the deviations between predicted heights and reference heights. We will create an ee.Array object containing the observed values from sample training. The aggregate_array method is used to convert the rh98 property of each feature in sampleTraining into an array.

```
// Compute Root Mean Squared Error (RMSE)
// Get an array of observation and prediction values
var observationTraining = ee.Array(sampleTraining.aggregate_array('rh98'));
```

Next, create an ee.Array object containing the predicted values from sample training. The aggregate_array method is used to convert the predicted property of each feature in sampleTraining into an array.

```
var predictionTraining = ee.Array(sampleTraining.aggregate_array('predicted'));
```

We will compute the residuals (difference between observed and predicted values) for each point in sample training. The *subtract* method subtracts the predicted values from the observed values.

```
// Compute residuals
var residualsTraining = observationTraining.subtract(predictionTraining);
```

Next, we will compute the training data's root mean squared error (RMSE). The residuals are squared, averaged, and square rooted to obtain the RMSE.

```
// Compute RMSE with equation and print the result
var rmseTraining = residualsTraining.pow(2).reduce('mean', [0]).sqrt();
// Print the RMSE to the console
print('Training RMSE', rmseTraining);
```

Step 7. Check RF model accuracy using validation (test) data

Next, we will validate the regression model using the validation or test dataset. The regression image is used to sample points from the validation dataset using the

sampleRegions() method. The points are extracted from the geometries of the features in the validationData collection.

```
//Perform validation. Get predicted regression points in the same location as validation data
var predictedValidation = regression.sampleRegions({collection:validationData, geometries: true});
```

The resulting predictedValidation feature collection contains two properties: rh98 and predicted. rh98 is the observed (reference) value, and predicted is the predicted value of the regression model. These properties are selected using the *select()* method and assigned to a new feature collection sample validation.

```
// Separate the observed (rh98) and predicted (regression) properties
var sampleValidation = predictedValidation.select(['rh98', 'predicted']);
```

Next, a scatter plot of predicted vs observed values is created using the *ui.Chart.feature.byFeature()* method, where predicted is on the horizontal axis, and rh98 is on the vertical axis. The chart is assigned to the variable chartValidation.

```
// Create a chart and print it
var chartValidation = ui.Chart.feature.byFeature(sampleValidation, 'predicted', 'rh98')
.setChartType('ScatterChart').setOptions({
title: 'Predicted vs Observed - Validation data',
hAxis: {'title': 'predicted'},
vAxis: {'title': 'observed'},
pointSize: 3,
trendlines: { 0: {showR2: true, visibleInLegend: true} ,
1: {showR2: true, visibleInLegend: true}}});
```

Next, print the scatter plot to the console using the *print()* method.

```
Print scatter plot results to the console
print(chartValidation);
```

The resulting chart shows how well the predicted values from the regression model match the observed values in the validation dataset. The trendline(s) in the chart establish the relationship between the predicted and observed values, and the R^2 value indicates the strength of the correlation.

Next, compute the RMSE for the validation data. RMSE is a measure of the differences between the predicted and observed values. It estimates the average amount by which the predicted values deviate from the observed values.

```
// Compute RMSE
// Get an array of observation and prediction values
var observationValidation = ee.Array(sampleValidation.aggregate_array('rh98'));
var predictionValidation = ee.Array(sampleValidation.aggregate_array('predicted'));
// Compute residuals
var residualsValidation = observationValidation.subtract(predictionValidation);
// Compute RMSE with equation and print it
var rmseValidation = residualsValidation.pow(2).reduce('mean', [0]).sqrt();
print('Validation RMSE', rmseValidation);
```

The lower the RMSE, the better the model predicts the values. In this case, the validation RMSE is 3.1, which indicates that the model's predictions have an average error of approximately 3 m. Therefore, the model performs relatively well in predicting the tree canopy height for the validation data.

Step 8. Export the results

Finally, export the forest canopy height map (Figure 3a). Run the code below, and you will see that the *Task tab* lights up. Click the *Run* button next to the task to initiate the export task. A timer displaying the execution time since you started the task appears. The export task may take a few minutes to hours. This depends on the size of the study area.

```
// Export the image, specifying scale and region.
Export.image.toDrive({
  image: regression,
  description: 'Kad_TCH_GEDI_2022',
  scale: 10,
  crs: 'EPSG:32644', // WGS 84 UTM Zone 44 N
  maxPixels: 6756353855,
  region: boundary
});
```



Figure 3a. Kaduwela forest canopy height map.

3.3 Additional Exercises

Model forest canopy height for another project site in Sri Lanka using GEDI, Sentinel-1, Sentinel-2, and random forest (RF) models.

Discuss the performance of the RF models for each project site in terms of model performance and the final forest canopy height map.

3.4 Code Link

https://code.earthengine.google.com/0f15a5537d994d5bec3010edd04f11d1

3b. Modeling Aboveground Biomass (AGB) Density

3.1 Background

Accurately estimating the density of aboveground biomass (AGB) density in forests is essential for establishing a baseline of forest carbon stocks, determining anthropogenic emissions from deforestation and forest degradation, and implementing cost-effective carbon emission mitigation and adaptation strategies. Traditionally, forest researchers use field-based plot inventory and destructive biomass sampling approaches to estimate forest AGB density. This approach involves selecting plots, collecting tree structural parameters such as diameter at breast height (DBH) and tree height, and developing allometric equations to estimate AGB density based on the tree structural parameters. However, this approach is expensive, time-consuming, and introduces sampling bias at a local scale, limiting scalability. We use Sentinel-1 and Sentinel-2 imagery from the European Space Agency (ESA) and the Global Ecosystem Dynamics Investigation (GEDI) Level 4A (L4A) in Earth Engine (EE) to model forest AGB density.

3.2 Lab. Modeling Forest AGB using GEDI, S1, and S2 data in EE

3.2.1 Introduction

This module will model forest AGB density using the Global Ecosystem Dynamics Investigation (GEDI) L4A, Sentinel-1, Sentinel-2, SRTM elevation, and slope data. The GEDI L4A are predictions of the aboveground biomass density (AGBD in Mg/ha). We will use the random forest (RF) method to model forest AGB density in Earth Engine.

3.2.2 Objective

iv.Model forest AGB density using EO data and random forest (RF) method

3.2.3 Procedure

Following are the steps.

Step 1: Import and display the project area boundary

First, load the project area boundary, which will be used to clip the image collection.

```
// Load the project area boundary for Kaduwela.
var boundary = ee.FeatureCollection('users/kamas72_ML_Zim_Cities/Kaduwela_DSDivision_UN')
```

Next, display the project area boundary

```
// Display the boundary
Map.addLayer(boundary, {}, 'Kaduwela');
// Set the map centre and visualise the dataset
Map.setCenter(79.97957580983135,6.904329786802445, 14);
```

Step 2: Load raster variables (Sentinel-1, Sentinel-2, elevation, and slope data)

First, we will load Sentinel-1 image collection. We will filter the image according to boundary, instrument mode, and date.

```
// Load the Sentinel-1 Image Collection and filter by boundary, metadata, and date
var collection_S1 = ee.ImageCollection('COPERNICUS/S1_GRD') // Collection of Sentinel-1
  .filterBounds(boundary) // Project site boundary
```

```
  .filterMetadata('instrumentMode', 'equals', 'IW') // Interferometric Wide (IW) Swath (IW)
  .filter(ee.Filter.date('2021-01-01', '2022-04-30')); // Specify the date range or period
```

Then, we will filter the image collection according to polarization. That is, VV (vertical transmit and vertical receive) and VH (vertical transmit and horizontal receive).

```
// Filter to get imagery with VV and VH dual polarization
var collection_S1_VV_VH = collection_S1
  .filter(ee.Filter.listContains('transmitterReceiverPolarisation', 'VV'))
  .filter(ee.Filter.listContains('transmitterReceiverPolarisation', 'VH'));
```

Next, filter the image collection according to orbit mode. In this case, ascending mode.

```
// Filter to get the imagery from the ascending orbit
var collection_S1_ASC = collection_S1_VV_VH
  .filter(ee.Filter.eq('orbitProperties_pass', 'ASCENDING'));
```

Let's calculate the median for the VV (vertical transmit and vertical receive) and VH (vertical transmit and horizontal receive) polarisation. We will also reproject the VV and VH datasets, and also check the information for these datasets.

```
// Compute median for VV polarization and reproject to WGS 84 UTM zone 44N
var S1_median_ASC_VV = collection_S1_ASC
  .select('VV')
  .median()
  .clip(boundary).reproject({crs: 'EPSG:32644', scale: 30});
// Print the VV median image to the console
print('S1_median_ASC_VV', S1_median_ASC_VV);

// Compute median for VH polarization
var S1_median_ASC_VH = collection_S1_ASC
  .select('VH')
  .median()
  .clip(boundary).reproject({crs: 'EPSG:32644', scale: 30});
// Print the VV median image to the console
print('S1_median_ASC_VV', S1_median_ASC_VH);
```

Let's visualise the VV and VH datasets.

```
// Display the median co-polarization and cross-polarization images (VV and VH).
Map.addLayer(S1_median_ASC_VV, {'bands': 'VV', min: -15, max: 5}, 'S-1 Median Asc VV');
Map.addLayer(S1_median_ASC_VH, {'bands': 'VH', min: -25, max: 5}, 'S-1 Median Asc VH');
```

Next, let’s create Sentinel-1 image combining VV, VH and a ratio of VV and VH.

```
// Create the false color RGB
var S1_false_color_RGB = S1_median_ASC_VV
.addBands(S1_median_ASC_VH)
.addBands(S1_median_ASC_VV.divide(S1_median_ASC_VH))
.rename(['VV', 'VH', 'VVVH']);
```

Visualize the VV, VH and VV/VH in false color red (R) green (G) and blue (B).

```
// Display the S1 VV, VH and VV/VH in false color.
Map.addLayer(S1_false_color_RGB, {bands: ['VV', 'VH', 'VVVH'], min: [-15, -25, 0.5], max: [5, 5, 2.5]},
'S-1 False Color RGB');
```

Next, we will load the Sentinel-2 surface reflectance (S2 SR) image collection.

```
// Load Sentinel-2 spectral reflectance data.
var s2 = ee.ImageCollection('COPERNICUS/S2_SR');
```

We will define a cloud masking function using the Sentinel-2 QA band. The "*maskS2clouds*" function is applied to each image in the *imageCollection*.

```
// Create a function to mask clouds using the Sentinel-2 QA band.
function maskS2clouds(image) {
  var qa = image.select('QA60');
  // Bits 10 and 11 are clouds and cirrus, respectively.
  var cloudBitMask = ee.Number(2).pow(10).int();
  var cirrusBitMask = ee.Number(2).pow(11).int();
  // Both flags should be set to zero, indicating clear conditions.
  var mask = qa.bitwiseAnd(cloudBitMask).eq(0).and(
          qa.bitwiseAnd(cirrusBitMask).eq(0));
  // Return the masked and scaled data.
  return image.updateMask(mask).divide(10000);
}
```

Next, filter the *ImageCollection* by date, cloud cover ('*CLOUDY_PIXEL_PERCENTAGE*'), and cloud mask. Select the bands that you will need to use. Note that: B2 = Blue (10m), B3 = Green (10m), B4 = Red (10m), B8 = NIR (10m), B5 = Red Edge 1 (20m), B6 = Red Edge 2 (20m), B7 = Red Edge 3 (20m), B8A = Red Edge 4 (20m), B11 = SWIR 1 (20m), and B12 = SWIR 2 (20m).

```
// Filter S2 SR image collection by date, cloud cover, and cloud mask.
var composite = s2.filterDate('2022-01-01', '2022-02-28')
              // Pre-filter to get less cloudy granules.
              .filter(ee.Filter.lt('CLOUDY_PIXEL_PERCENTAGE', 20))
              .map(maskS2clouds)
              .select('B2', 'B3', 'B4','B5','B6','B7','B8','B11', 'B12');
```

Reproject and display the S2 SR median composite image.

```
// Reproject to WGS 84 UTM zone 44N
var S2_composite = composite.median().reproject({crs: 'EPSG:32644', scale: 30});
// Check projection information
print('Projection, crs, and crs_transform:', S2_composite.projection());
// Display a composite S2 imagery
Map.addLayer(S2_composite.clip(boundary), {bands: ['B11', 'B8', 'B3'], min: 0, max: 0.3});
```

Next, import Shuttle Radar Topography Mission (SRTM) digital elevation model (DEM) and clip it to the project boundary.

```
// Load SRTM DEM and clip it to the study area
var SRTM = ee.Image("USGS/SRTMGL1_003");
// Clip Elevation
var elevation = SRTM.clip(boundary);
// Reproject 'elevation' to WGS 84 UTM zone 44N
var elevation = elevation.reproject({crs: 'EPSG:32644',scale: 30});
 // Check projection information
print('Projection, crs, and crs_transform:', elevation.projection());
```

Let's extract the slope from the SRTM DEM.

```
// Derive slope from the SRTM
var slope = ee.Terrain.slope(SRTM).clip(boundary);
// Reproject 'slope' to WGS 84 UTM zone 44N
var slope = slope.reproject({crs: 'EPSG:32644',scale: 30});
// Check projection information
print('Projection, crs, and crs_transform:', slope.projection());
```

Next, we will add a forest mask derived from ESA World Cover (2020) and clip it to the project area boundary.

```
// Load ESA World Cover data
var dataset = ee.ImageCollection("ESA/WorldCover/v100").first();

// Clip the land cover to the boundary
var ESA_LC_2020 = dataset.clip(boundary);

// Extract forest areas from the land cover
var forest_mask = ESA_LC_2020.updateMask(
  ESA_LC_2020.eq(10) // Only keep pixels where class equals 2
);

// Display forests only
var visualisation = {bands: ['Map'],};
Map.addLayer(forest_mask, visualization, "Trees");
```

Step 3: Combine all raster variables.

Next, we will combine various predictor variables, which we will use to model AGB density. The S2_composite variable contains the Sentinel-2 imagery for the study area, while the S1_median_ASC_VV and S1_median_ASC_VV variables are Sentinel-1 median VV and VH polarizations. The elevation variable contains the elevation data, the slope contains the slope data, and the forest_mask includes a binary forest mask that identifies forest cover. The *addBands()* function is used repeatedly to add each variable to the new dataset.

```
// Merge the predictor variables
var mergedCollection = S2_composite
   .addBands(S1_median_ASC_VV
   .addBands(S1_median_ASC_VH
   .addBands(elevation
   .addBands(slope
   .addBands(forest_mask)))));
```

Next, let’s clip the combined dataset to the project area boundary.

```
// Clip to the output image to the Kaduwela DS Division boundary.
var clippedmergedCollection = mergedCollection.clipToCollection(boundary);
// Check information of the clipped and merged data collection
print('clippedmergedCollection: ', clippedmergedCollection);
```

Create an object (bands) that contains all raster variables, which will be used for the model. The bands variable includes the spectral bands from Sentinel-2 (*B2-B8*, *B11*, and

B12), the VV and VH median polarizations from Sentinel-1 SAR imagery (*VV* and *VH*), the elevation data (*elevation*), the slope data (*slope*), and the forest mask (*Map*).

```
// Bands to include in the AGBD modeling
var bands = ['B2', 'B3', 'B4', 'B5', 'B6', 'B7', 'B8', 'B11', 'B12', 'VV', 'VH', 'elevation', 'slope', 'Map'];
```

Step 4: Prepare AGB density training data

We will derive aboveground biomass (AGB) density from the GEDI L4A poduct, which we will use as the response (dependent) variable in the model. The GEDI L4A product provides mean AGB density estimates (25 meters). More information about the GEDI L4A products is available at https://developers.google.com/earth-engine/datasets/catalog/LARSE_GEDI_GEDI04_A_002_MONTHLY.

Let's start by preparing the GEDI L4A mask.

```
// Prepare the mask
var qualityMask = function(im) {
  return im.updateMask(im.select('l4_quality_flag').eq(1))
     .updateMask(im.select('degrade_flag').eq(0));
};
```

Next, load the GEDI L4A dataset, which contains the ABG density.

```
// Load the GEDI Level 4A monthly dataset
var dataset = ee.ImageCollection('LARSE/GEDI/GEDI04_A_002_MONTHLY')
              .map(qualityMask)
              .select('agbd').filterBounds(boundary);
```

Next, we define projection and scale parameters for the GEDI L4A dataset. The projection and scale parameters are defined using the first image in the dataset variable. The *projection()* function is called on this image to retrieve its projection information. It is then assigned to the projection variable using the *aside(print)* function to print it to the console. The *nominalScale()* function is called on the projection variable to retrieve the nominal scale of the image, which is assigned to the scale variable using the *aside(print)* function to print it to the console.

```
// Define projection and scale parameters
var projection = dataset.first().projection().aside(print);
var scale = projection.nominalScale().aside(print);
```

After defining the projection and scale variables, the *mosaic()* function is called on the dataset variable to create a single image mosaic from all the images in the collection. The *setDefaultProjection()* function is called on this mosaic image and is given an object with the coordinate reference system (crs) and scale parameters set to the projection and scale variables, respectively. This sets the projection and scale of the image to be the same as the first image in the dataset variable.

```
var mosaic = dataset.mosaic().setDefaultProjection({crs:projection, scale:scale});
```

Next, clip the GEDI L4A dataset to the project boundary.

```
// Clip the dataset to the boundary
var clippedDataset = mosaic.clipToCollection(boundary);
```

Let's create a palette and display the mean AGB density points for the project area.

```
// Create the display parameters
var gediVis = {
  min: 1,
  max: 500,
  palette: 'red, green, blue',
};

// Display the GEDI L4A mean aboveground biomass (AGB) points
Map.addLayer(clippedDataset, gediVis, 'GEDI L4A Mean AGBD points');
```

Next, we will sample sufficient AGB density points from the GEDI L4A dataset.

```
// Sample the training points (ta) from the dataset
var numTrainingPoints = 10000; // Specify the number of training points
var points = clippedDataset.sample({
  region: boundary,
  scale: 10,
  numPixels: numTrainingPoints * 100, // Increase numPixels to ensure sufficient samples
  geometries: true,
});
```

In the code above, 10,000 points are randomly sampled from the mosaic image using the *sampl*ing method. The *region* parameter specifies the region from which the samples should be taken, and *the boundary* is used as the region of interest. The *scale parameter* sets the scale to take the samples, and *projection* ensures that the samples are projected in the correct coordinate system. The numPixels parameter specifies the number of pixels to generate the samples. Finally, the *geometries* parameter is set to true to ensure that the output feature collection contains the geometries of the sampled points.

We will check and visualise the training points on the map or imagery.

```
// Print and display the training (ta) points derived from the GEDI L4A dataset
print(points.size());
print(points.limit(10));

// Display the training points
Map.addLayer(points, {palette: '808080'}, 'AGBD training points');
```

In machine learning, splitting the data into training and testing sets is essential to evaluate the model's performance. So we will split the training data into a training set and a test (validation) set. First, we will use the *randomColumn()* function to add a new column named '*random*' to the points dataset with random values between 0 and 1. The second argument is the seed value (*27*) used to generate random values. Using a seed value ensures that the random values are the same every time we run the code, which helps in the repeatability of the experiment.

```
// Add a random column (named random) and specify the seed value for repeatability
var datawithColumn = points.randomColumn('random', 27);
```

Next, split the training data set into training and validation or testing. The variable split defines the percentage of data that should be used for training. In this case, 70% of the data is used for training, and 30% is used for validation.

```
// Use 70% for training, 30% for validation
var split = 0.7;
```

We apply the *ee.Filter.lt* filter to the *datawithColumn* dataset, so it filters the data where the value of the '*random*' column is less than the split value. This gives us the training data.

```
var trainingData = datawithColumn.filter(ee.Filter.lt('random', split));
```

We use the *print()* function to print the training and validation datasets to the console. This helps us to verify that the datasets are correctly created and have the expected number of features.

```
print('training data', trainingData);
```

Next, we apply the *ee.Filter.gte* filter is applied to the *datawithColumn* dataset, and it filters the data where the value of the 'random' column is greater than or equal to the split value. This gives us the validation data.

```
var validationData = datawithColumn.filter(ee.Filter.gte('random', split));
print('validation data', validationData);
```

Step 5: Train the random forest (RF) model

Next, create a training dataset using the *sampleRegions()* method on the clippedmergedCollection object. It selects the bands defined in the band's list and sets the scale. The collection argument is set to trainingData, the dataset created earlier containing 70% of the randomly sampled points. Note that Earth Engine imposes usage limits. An error is usually returned when limits are exceeded. For example, if there are many training points.

```
// Perform random forest regression
// Collect training data
var training = clippedmergedCollection.select(bands).sampleRegions({
  collection: trainingData,
  properties: ['agbd'],
  scale: 10 // Need to change the scale of training data to avoid the 'out of memory' problem
  });
```

Next, a random forest classifier is trained on the training dataset using the *smileRandomForest()* method from Earth Engine. The *setOutputMode()* method sets the output mode to REGRESSION, indicating that we want to perform a regression analysis. The *train()* method is called to train the model, with the features argument set to training, classProperty set to "agbd", and inputProperties set to bands. We will define the RF model parameters "*number of trees*" as 50. However, you can also tune the RF model by changing the "*NumberOfTrees*" parameter. Increasing the "*NumberOfTrees*" parameter from 100 to 500 may result in an error, or Earth Engine may take longer to train. However, fewer trees may also result in less statistically robust RF models.

```
// Train a random forest classifier for regression
var classifier = ee.Classifier.smileRandomForest(50)
  .setOutputMode('REGRESSION')
  .train({
    features: training,
    classProperty: "agbd",
    inputProperties: bands
    });
```

After training, the *classify()* function is called on the clippedmergedCollection object using the trained classifier to generate a predicted regression dataset. The resulting dataset is clipped to the boundary polygon using the *clip()* function.

```
//Run regression and clip it to the boundary
var regression = clippedmergedCollection.select(bands).classify(classifier, 'predicted').clip(boundary);
```

Next, load a continuous palette from the following package available at "https://github.com/gee-community/ee-palettes."

```
// Load and define a continuous palette
var palettes = require('users/gena/packages:palettes');
// Choose and define a palette
var palette = palettes.colorbrewer.YlGn[5];
```

Next, we calculate the regression classification's minimum and maximum predicted values for the project site. This is done using the *reduceRegion()* function, which calculates a statistic over a specified region. In this case, the *min()* and *max()* reducers are used to calculate the minimum and maximum values of the regression, respectively.

```
// Get dictionaries of min & max predicted value
  var regressionMin = (regression.reduceRegion({
    reducer: ee.Reducer.min(),
    scale: 10,
    crs: 'EPSG:32644',
    geometry: boundary,
    bestEffort: true,
    tileScale: 5
  }));
var regressionMax = (regression.reduceRegion({
    reducer: ee.Reducer.max(),
    scale: 10,
    crs: 'EPSG:32644',
    geometry: boundary,
    bestEffort: true,
    tileScale: 5
  }));
```

The *reduceRegion()* function takes several parameters:

i. reducer: specifies the reducer to use (in this case, *min()* or *max()*).

ii. scale: the spatial resolution at which to compute the statistic.

iii. crs: the coordinate reference system to use for the output.

iv. geometry: the region over which to compute the statistic (in this case, the boundary variable).
v. bestEffort: whether to use a best-effort algorithm to reduce the computation time.
vi. tileScale: the scale of the tiles to use for computation.

The *reduceRegion()* function results are stored in two variables, regressionMin, and regressionMax, which are dictionaries containing the minimum and maximum predicted values, respectively. These variables will be used later to set the range of values for the colour palette.

Prepare the visualisation parameters for the regression output.

```
// Add visualisation parameters
var viz = {palette: palette, min: regressionMin.getNumber('predicted').getInfo(), max: regressionMax.getNumber('predicted').getInfo()};
```

Next, display the AGB density map output.

```
// Display the AGB density map output.
Map.addLayer(regression, viz, 'AGBD map');
```

Create a legend that comes with the AGB density map. We will create a panel to hold the legend items, and its style is defined with a position and padding.

```
// Create the panel for the legend items.
var legend = ui.Panel({
  style: {
    position: 'bottom-left',
    padding: '8px 15px'
  }
});
```

Next, create a label for the legend title with a bold font and a larger size, and its value is set to "ABGD (Mg/ ha)"

```
// Create and add the legend title.
var legendTitle = ui.Label({
  value: 'AGBD (Mg/ha)',
  style: {
    fontWeight: 'bold',
    fontSize: '18px',
    margin: '0 0 4px 0',
    padding: '0'
  }
});
legend.add(legendTitle);
```

The following code block creates a legend for the regression layer added to the map earlier. First, an image is created to show a gradient representing the range of predicted AGB density values. The lon variable is an image with two bands, one for longitude and one for latitude. The multiply function is used to scale the latitude values based on the

range of predicted AGB density values. The minimum and maximum values for the legend are specified in the viz dictionary created earlier.

```
// create the legend image
var lon = ee.Image.pixelLonLat().select('latitude');
var gradient = lon.multiply((viz.max-viz.min)/100.0).add(viz.min);
var legendImage = gradient.visualize(viz);
 // create text on top of legend
var panel = ui.Panel({
widgets: [
ui.Label(viz['max'])
],
});
 legend.add(panel);
```

Create thumbnail (a small image representation of a larger image) to the legend.

```
//Create a thumbnail from the image
var thumbnail = ui.Thumbnail({
image: legendImage,
params: {bbox:'0,0,10,100', dimensions:'10x200'},
style: {padding: '1px', position: 'bottom-center'}
});
```

Next, add the thumbnail to the legend using the *legend.add()* function.

```
//Add the thumbnail to the legend
legend.add(thumbnail);
```

Create another *ui.Panel* widget to display the minimum value of the predicted AGB density. This is also added to the legend panel.

```
//Create text on top of the legend
var panel = ui.Panel({
widgets: [
ui.Label(viz['min'])
],
});
legend.add(panel);
Map.add(legend);
```

Step 6. Check RF model performance

Next, check the RF model performance. We will use the *explain()* function to explain the importance values of the ee.Classifier object classifier. The result is then stored in the classifier_details variable.

```
// Get details of classifier
var classifier_details = classifier.explain();
```

Next, the importance dictionary is extracted from the classifier_details using the *ee.Dictionary()* method and stored in the variable_importance variable as an ee.Feature object.

```
// Explain the classifier with importance values
var variable_importance = ee.Feature(null, ee.Dictionary(classifier_details).get('importance'));
```

Next, create a chart using the *ui.Chart.feature.byProperty()* method, with the variable_importance feature passed as an argument. The chart is set to be a column chart using the *setChartType()* method, titled "*Random Forest Variable Importance*". The legend is turned off using the legend option, and the hAxis and vAxis options are set to label the bands and importance values, respectively.

```
// Create a chart
var chart =
  ui.Chart.feature.byProperty(variable_importance)
  .setChartType('ColumnChart')
  .setOptions({
  title: 'Random Forest Variable Importance',
  legend: {position: 'none'},
  hAxis: {title: 'Bands'},
  vAxis: {title: 'Importance'}
});
```

Print the chart using the *print()* function with the "*Variable importance*" label. The resulting chart will show the importance values for each band used in the random forest regression classifier.

```
// Plot a chart
print("Variable importance:", chart);
```

Next, we will sample the regression image at the trainingData feature collection points and store the resulting predicted values in a new feature collection called predictedTraining. Note that geometries are set to true so that each point's geometry (i.e., location) in training data is included in predictedTraining.

```
// Create model assessment statistics
// Get predicted regression points in the same location as training data
var predictedTraining = regression.sampleRegions({collection:trainingData, geometries: true});
```

Next, we select the *agbd* and predicted properties from predictedTraining and store them in a new feature collection called sampleTraining. The agbd property contains the observed target variable (*agbd*), while the predicted property contains the predicted target variable based on the input features.

```
// Separate the observed (agbd_GEDI) and predicted (regression) properties
var sampleTraining = predictedTraining.select(['agbd', 'predicted']););
```

Create a scatter plot chart using the ui.Chart module.

```
// Create chart
var chartTraining = ui.Chart.feature.byFeature(sampleTraining, 'agbd', 'predicted')
.setChartType('ScatterChart').setOptions({
title: 'Predicted vs Observed - Training data ',
hAxis: {'title': 'observed'},
vAxis: {'title': 'predicted'},
pointSize: 3,
trendlines: { 0: {showR2: true, visibleInLegend: true} ,
1: {showR2: true, visibleInLegend: true}}});
// Print the chart to the console
print(chartTraining);
```

We will use the root mean square error (RMSE) to quantify the deviations between predicted and reference AGB density. We will create an ee.Array object containing the observed values from sample training. The aggregate_array method is used to convert the agbd property of each feature in sampleTraining into an array.

```
// Compute Root Mean Squared Error (RMSE)
// Get array of observation and prediction values
var observationTraining = ee.Array(sampleTraining.aggregate_array('agbd'));
```

Next, create an ee.Array object containing the predicted values from sample training. The aggregate_array method is used to convert the predicted property of each feature in sampleTraining into an array.

```
var predictionTraining = ee.Array(sampleTraining.aggregate_array('predicted'));
```

We will compute the residuals (difference between observed and predicted values) for each point in sample training. The *subtract* method subtracts the predicted values from the observed values.

```
// Compute residuals
var residualsTraining = observationTraining.subtract(predictionTraining);
```

Next, we will compute the training data's root mean squared error (RMSE). The residuals are squared, averaged, and square rooted to obtain the RMSE.

```
// Compute RMSE with equation and print the result
var rmseTraining = residualsTraining.pow(2).reduce('mean', [0]).sqrt();
print('Training RMSE', rmseTraining);
```

Step 7. Check RF model accuracy using validation (test) data

Next, we will validate the regression model using the validation or test dataset. The regression image is used to sample points from the validation dataset using the *sampleRegions()* method. The points are extracted from the geometries of the features in the validationData collection.

```
//Perform validation
// Get predicted regression points in same location as validation data
var predictedValidation = regression.sampleRegions({collection:validationData, geometries: true});
```

The resulting predictedValidation feature collection contains two properties: agbd and predicted. The agbd is the observed (reference) value, and predicted is the predicted value of the regression model. These properties are selected using the *select()* method and assigned to a new feature collection sample validation.

```
// Separate the observed (AGBD) and predicted (regression) properties
var sampleValidation = predictedValidation.select(['agbd', 'predicted']);
```

Next, a scatter plot of predicted vs observed values is created using the *ui.Chart.feature.byFeature()* method, where predicted is on the horizontal axis, and *agbd* is on the vertical axis. The chart is assigned to the variable chartValidation.

```
// Create chart and print it
var chartValidation = ui.Chart.feature.byFeature(sampleValidation, 'predicted', 'agbd')
.setChartType('ScatterChart').setOptions({
```

```
title: 'Predicted vs Observed - Validation data',
hAxis: {'title': 'predicted'},
vAxis: {'title': 'observed'},
pointSize: 3,
trendlines: { 0: {showR2: true, visibleInLegend: true} ,
1: {showR2: true, visibleInLegend: true}}});
print(chartValidation);
```

The resulting chart shows how well the predicted values from the regression model match the observed values in the validation dataset. The trendline(s) in the chart establish the relationship between the predicted and observed values, and the R^2 value indicates the strength of the correlation.

Next, compute the RMSE for the validation data. RMSE is a measure of the differences between the predicted and observed values. It estimates the average amount by which the predicted values deviate from the observed values.

```
// Compute RMSE
// Get array of observation and prediction values
var observationValidation = ee.Array(sampleValidation.aggregate_array('agbd'));
var predictionValidation = ee.Array(sampleValidation.aggregate_array('predicted'));

// Compute residuals
var residualsValidation = observationValidation.subtract(predictionValidation);

// Compute RMSE with equation and print it
var rmseValidation = residualsValidation.pow(2).reduce('mean', [0]).sqrt();
print('Validation RMSE', rmseValidation);
```

The lower the RMSE, the better the model predicts the values. In this case, the validation RMSE is 23 Mg/ ha, which indicates the model's average error. Therefore, the model performs relatively well in predicting the AGB density for the validation data.

Step 8. Export the results

Finally, export the AGB density map (Figure 3b). Run the code below, and you will see that the *Task tab* lights up. Click the *Run* button next to the task to initiate the export task. A timer displaying the execution time since you started the task appears. The export task may take a few minutes to hours. This depends on the size of the project area.

```
// Export the image, specifying scale and boundary.
Export.image.toDrive({
  image: regression,
  description: 'Kad_AGBD_GEDI_2022',
  scale: 10,
  crs: 'EPSG:32644', // WGS 84 UTM Zone 44N
  maxPixels: 6756353855,
  region: boundary
});
```



Figure 3b. Kaduwela forest aboveground biomass density map.

3.3 Additional Exercises

i. Model tree canopy height for your project site using GEDI, Sentinel-1 and Sentinel-2 dataset, and the random forest (RF) model. Use the following code link as a guide (https://code.earthengine.google.com/28445485a0a184a77483019ea3865628).

ii. Model aboveground biomass (AGB) density for your project site using GEDI, Sentinel-1 and Sentinel-2 dataset, and the random forest (RF) model.

3.4 Code Link

https://code.earthengine.google.com/94479165782b6a6f4a3fcedfc40df73b

4. Environmental Planning and Site Suitability Analysis of Green Infrastructure

4.1 Background

Green infrastructure offers many benefits, such as better air and water quality, protection against floods, storms, and erosion, preservation of wildlife and natural habitats, and creation of healthier, more sustainable communities with increased property values. To ensure its effectiveness, it is crucial to carefully select locations for green infrastructure development that will have the most significant impact on communities. One approach to achieve this is conducting a green infrastructure site suitability analysis, which involves assessing potential project sites based on various criteria. Several standard criteria are commonly used in green infrastructure site suitability analysis. These include:

i. Land use

The existing land use of a site can influence its suitability for green infrastructure projects. For instance, areas with extensive impervious surfaces may be less suitable than those with more permeable surfaces.

ii. Soil type

The type of soil on a site can affect the rate at which stormwater infiltrates, which, in turn, impacts the effectiveness of green infrastructure practices like rain gardens and bioretention.

iii. Slope

The slope of a site plays a role in erosion potential and the effectiveness of green infrastructure features such as swales and retention ponds.

iv. Hydrology

The site's current hydrological conditions can determine its suitability for green infrastructure projects. For example, areas with high groundwater tables may be better suited for infiltration-based practices.

v. Proximity to water bodies

Sites near water bodies are often more suitable for green infrastructure projects that aim to improve water quality and reduce stormwater runoff volume and velocity.

vi. Vegetation

The presence of vegetation on a site can impact its suitability for specific green infrastructure projects. For instance, areas with existing vegetation may be well-suited for projects involving green roofs or carbon sequestration.

Various modelling tools, including GIS-based suitability analysis and multi-criteria evaluations, can be utilized to evaluate these criteria. By employing these techniques, a

comprehensive analysis can be conducted to identify potential opportunities for green infrastructure and rank potential sites based on multiple criteria.

4.2 Lab. Green Infrastructure Site Suitability Analysis

4.2.1 Introduction

This tutorial will perform a suitability analysis to locate suitable green infrastructure sites in the Kaduwela Divisional Secretariat (DS) Division. The suitability analysis will be based on various criteria, including land cover, forest canopy height, and aboveground biomass (AGB) density.

4.2.2 Objectives

v.develop a criteria-based system for the evaluation of potential sites in Kaduwela; and
vi.map ideal locations for green infrastructure in Earth Engine.

4.2.3 Procedure

Following are the steps.

Step 1: Load administrative boundary data

First, load the administrative boundary level 3 dataset from the level 3 boundaries.

```
// Load the administrative boundary level 3 dataset
var ADM3 = ee.FeatureCollection('projects/ee-kamusoko-test/assets/geoBoundaries-LKA-ADM3');
```

We will select Kaduwela DS Division.

```
// Filter the administrative boundary level 3 dataset for Kaduwela Divisional Secretariat Division.
var boundary = ADM3.filter(ee.Filter.eq('shapeName', 'Kaduwela'));
```

Next, we will set up the map center and display the project site boundary.

```
// Set the map center and visualize the dataset
Map.setCenter(79.97957580983135,6.904329786802445, 14);
// Display the boundary
Map.addLayer(boundary, {}, 'Kaduwela Boundary');
```

*Step 2: Load land cover da*ta

Load the ESA World Cover data and clip the land cover to the Kaduwela boundary.

```
// Load ESA World Cover data
var dataset = ee.ImageCollection("ESA/WorldCover/v100").first();
// Clip the land cover to the boundary
var ESA_LC_2020 = dataset.clip(boundary);
```

Extract forest areas from the land cover and display forests only.

```
// Extract forest areas from the land cover
var forest_mask = ESA_LC_2020.updateMask(
ESA_LC_2020.eq(10) // Only keep pixels where class equals 2 (forest)
);
```

Next, show the forest areas on map.

```
// Display forests only
```

```
var visualization = {bands: ['Map'],};
Map.addLayer(forest_mask, visualization, "Trees");
```

Step 3: Compute NDVI

Next, compute NDVI using the Planet-NICFI image.

```
// Compute NDVI using the Planet-NICFI image
var nicfi = ee.ImageCollection('projects/planet-nicfi/assets/base maps/asia');
var basemap = nicfi.filter(ee.Filter.date('2022-01-01','2022-12-30')).first();
var nicfi_image = basemap.clip(boundary);
var ndvi = nicfi_image.normalizedDifference(['N','R']).rename('NDVI');
```

We will then reclassify NDVI values into three classes.

```
// Reclassify NDVI values into three classes
var ndvi_reclassified = ndvi
  .where(ndvi.gt(0.75), 3) // high
  .where(ndvi.gt(0.5).and(ndvi.lte(0.75)), 2) // medium
  .where(ndvi.lte(0.5), 1); // low
```

Step 4: Display and Reclassify forest canopy height

Next, display the forest canopy height map. We will import the forest canopy height map we created in lab 3a.

```
// Display forest canopy height map
var fchVis = {min: 0, max: 30, palette: ['black', 'brown', 'green']};
Map.addLayer(forest_CH, fchVis, 'Forest Canopy Height');
```

Reclassify forest canopy height values into three classes.

```
// Reclassify forest canopy height values into three classes
var fch_reclassified = forest_CH
  .where(forest_CH.gt(12), 3) // high
  .where(forest_CH.gt(8).and(forest_CH.lte(12)), 2) // medium
  .where(forest_CH.lte(8), 1); // low
```

Step 5: Display and reclassify aboveground biomass density (AGBD)

Display the AGBD map. We will import the AGBD map we created in lab 3b.

```
// Display aboveground biomass density map
var agbdVis = {min: 0, max: 100, palette: ['black', 'brown', 'green']};
Map.addLayer(AGBD, agbdVis, 'Aboveground Biomass Density');
```

Next, reclassify forest aboveground biomass density values into three classes.

```
// Reclassify forest aboveground biomass density values into three classes
var agbd_reclassified = AGBD
  .where(AGBD.gt(40), 3) // high
  .where(AGBD.gt(20).and(AGBD.lte(40)), 2) // medium
  .where(AGBD.lte(20), 1) //low
```

Step 6: Combine the reclassified layers

Combine the reclassified layers using a weighted overlay.

```
// Combine the reclassified layers using weighted overlay
var suitability_index = ndvi_reclassified.multiply(0.2)
```

```
  .add(fch_reclassified.multiply(0.4))
  .add(agbd_reclassified.multiply(0.4));
```

Next, display the suitability index.

```
// Display the suitability index
var suitabilityVis = {min: 1, max: 3, palette: ['red', 'yellow', 'green']};
Map.addLayer(suitability_index, suitabilityVis, 'Suitability Index');
```

Step 7: Reclassify the suitability index

Reclassify the suitability index into three classes.

```
// Reclassify the suitability index into three classes
var suitability_classes = suitability_index
  .where(suitability_index.gt(2.5), 3) // high suitable
  .where(suitability_index.gt(1.5).and(suitability_index.lte(2.5)), 2) // medium suitable
  .where(suitability_index.lte(1.5), 1) // not suitable
```

Next, display the suitability classes (Figure 4).

```
// Display the suitability classes
var suitabilityClassesVis = {min: 1, max: 3, palette: ['red', 'yellow', 'green']};
Map.addLayer(suitability_classes, suitabilityClassesVis, 'Suitability Classes');
```

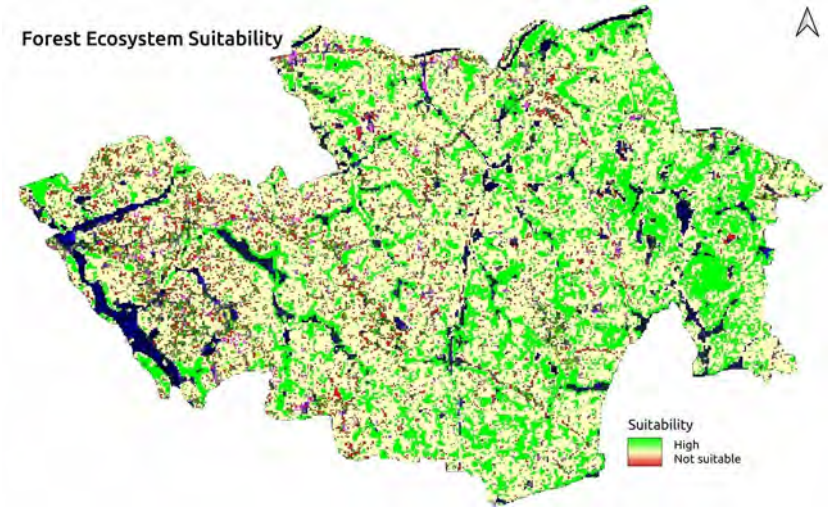


Figure 4. Kaduwela forest canopy height map.

Step 8: Export the suitability map

Finally, export the suitability map as a GeoTIFF file to Google Drive.

```
// Export the suitability map
Export.image.toDrive({
 image: suitability_classes,
 description: 'suitability_map',
 region: boundary,
 scale: 30,
 maxPixels: 1e13
})
```

4.3 Additional Exercises

i. Explore sources of geospatial data such as land cover, inland water, roads, railroads, elevation, population, and climate that you can use to conduct green infrastructure site suitability analysis in your selected project site.

ii. Conduct a site suitability analysis for developing new green infrastructure in your project site using multi-criteria evaluation in Earth Engine.

4.4 Code Link

https://code.earthengine.google.com/4ac8cbb06172b29c44bd2e9480875e39

Reference

Dubayah, R., Hofton, M., J. B. Blair, Armston, J., Tang, H., Luthcke, S. (2021). GEDI L2A Elevation and Height Metrics Data Global Footprint Level V002 [Data set]. NASA EOSDIS Land Processes DAAC. Accessed 2022-04-13 from https://doi.org/10.5067/GEDI/GEDI02_A.002.

Dubayah, R., J.B. Blair, S. Goetz, L. Fatoyinbo, M. Hansen, S. Healey, M. Hofton, G. Hurtt, J. Kellner, S. Luthcke, J. Armston, H. Tang, L. Duncanson, S. Hancock, P. Jantz, S. Marselis, P.L. Patterson, W. Qi, and C. Silva. 2020. The Global Ecosystem Dynamics Investigation: High-resolution laser ranging of the Earth's forests and topography. Science of Remote Sensing 1:100002. https://doi.org/10.1016/j.srs.2020.100002

Dubayah, R., Tang, H., Armston, J., Luthcke, S., Hofton, M., J. B. Blair (2021). GEDI L2B Canopy Cover and Vertical Profile Metrics Data Global Footprint Level V002 [Data set]. NASA EOSDIS Land Processes DAAC. Accessed 2022-04-13 from https://doi.org/10.5067/GEDI/GEDI02_B.002

Duncanson, L., J.R. Kellner, J. Armston, R. Dubayah, D.M. Minor, S. Hancock, et al. 2022. Aboveground biomass density models for NASA's Global Ecosystem Dynamics Investigation (GEDI) lidar mission. Remote Sensing of Environment 270:112845. https://doi.org/10.1016/j.rse.2021.112845

Hossain, A., Jia, T., & Chao, X. (2007.) Development of Remote Sending Based Index for Estimating/Mapping Suspended Sediment Concentration in River or Lake Environments. 8th International Symposium on ECOHYDRAULICS (ISE 2010), Paper No. 0435, 578-585 Huc10: USGS watershed boundary dataset of Watersheds

Appendix

1. Access additional datasets from awesome-gee-community-catalog

i. Edge-matched Global, Subnational and operational Boundaries (https://gee-community-catalog.org/projects/edge_matched/)

ii. Global Google-Microsoft Open Buildings Dataset (https://gee-community-catalog.org/projects/global_buildings/?h=build)

iii. Global Google-Microsoft Open Buildings Dataset (https://gee-community-catalog.org/projects/global_buildings/?h=build)

2. Access tutorials

i. Modeling Forest Biomass with GEDI L4A Data, Planet Imagery, and Machine Learning (https://www.youtube.com/watch?v=GtwoQa_why0)

ii. Introducing the AGBD Modeler App: Simplifying Biomass Mapping in Google Earth Engine (https://www.youtube.com/watch?v=Q6rHzU470ZI&t=95s)

iii. End-to-End Google Earth Engine (https://courses.spatialthoughts.com/end-to-end-gee.html)

iv. Urban growth and air quality - https://www.youtube.com/watch?v=F7aWhUnhttU

v. Urban green space - https://www.youtube.com/watch?v=BP_UtJ1i_MY

vi. Urban air pollution - https://www.youtube.com/watch?v=E6oguIdM8FQ

Training Manual (Technical Manuals)

LU1(1): Technical Manual for MOLUSCE





MOLUSCE

Modules for Land Use Change Evaluation

Quick Help

License
Except where otherwise noted, content of this work is licensed under a Creative Commons Attribution-ShareAlike 3.0 Unported License.

Contents

1 Plug-in overview **2**
- 1.1 Introduction . . . 2
- 1.2 What is MOLUSCE? . . . 2
- 1.3 Functions . . . 3

2 How to use MOLUSCE **4**
- 2.1 Inputs . . . 4
- 2.2 Evaluating correlation . . . 5
- 2.3 Area Changes . . . 6
- 2.4 Transition potential modeling . . . 6
  - 2.4.1 Artificial Neural Network (ANN) . . . 7
  - 2.4.2 Multi Criteria Evaluation (MCE) . . . 12
  - 2.4.3 Weights of Evidence (WoE) . . . 13
  - 2.4.4 Logistic Regression (LR) . . . 13
- 2.5 Cellular Automata Simulation . . . 15
- 2.6 Validation . . . 16

3 Technical details **18**
- 3.1 Data types . . . 18
- 3.2 Change map and area analysis . . . 19
- 3.3 Sampling of points and data transformation . . . 19
  - 3.3.1 Dummy coding . . . 20
  - 3.3.2 Normalization . . . 20
  - 3.3.3 Sampling process . . . 20
- 3.4 Some words about modeling . . . 22
  - 3.4.1 ANN: Multilayer perceptron . . . 22
  - 3.4.2 Logistic regression . . . 23
  - 3.4.3 Weight of evidence . . . 24
  - 3.4.4 Multi criteria evaluation . . . 25
- 3.5 Simulation . . . 25
- 3.6 Validation . . . 26
  - 3.6.1 Kappa . . . 26
  - 3.6.2 Error budget . . . 27

Chapter 1

Plug-in overview

1.1 Introduction

Open source software platforms are progressively becoming widely used in the public and private sectors. In Geographical Information System (GIS), open source software packages such as QGIS are actively being developed. More importantly, customization and further development is possible since developers create specific plug-ins with flexibility.

Asia Air Survey Co., Ltd. (AAS) started to move towards open source software since 2012 becoming the first QGIS gold sponsor worldwide. Furthermore, open source software started to be used more extensively for internal use and in international project. Alongside with these recent changes AAS also started to develop open source solutions aiming to further extend its market.

1.2 What is MOLUSCE?

AAS released MOLUSCE (Modules for Land Use Change Evaluation) at FOSS4G 2013. MOLUSCE is a user-friendly plug-in for QGIS 2.0 and above. MOLUSE is designed to analyze, model and simulate land use/cover changes. The plug-in incorporates well-known algorithms, which can be used in land use/cover change analysis, urban analysis as well as forestry applications and projects.

MOLUSCE is well suited to:

- analyze land use and forest cover changes between different time periods;
- model land use/cover transition potential or areas at risk of deforestation;
- and simulate future land use and forest cover changes

1.3 Functions

MOLUSCE user interface offers an easy-to-use interface with specific modules and functions. Following is a brief description of basic modules in MOLUSCE.

Input module Land use/cover maps from different epochs, biophysical and socio-economic driving factor data such as road network, rivers, topography, population etc., are loaded in the input module.

Area change analysis Computes land use/cover changes between two time periods (T1 and T2). Land use/cover change transition matrices as well as land use change maps are produced.

Modeling methods Four methods, namely Artificial Neural Networks (ANN), Logistic Regression (LR), Multi-Criteria Evaluation (MCE) and Weights of Evidence (WoE) are used for modeling land use/cover change transition potential.

Simulation Displays transition potential maps, certainty function (experimental) and simulation results. A simulated (projected) land use/cover map is produced based on a Monte Carlo Cellular-automata modeling approach.

Validation This sub-module incorporates Kappa statistics (standard Kappa, Kappa histogram and Kappa location), which will be used to validate the accuracy of the simulated land use/cover maps.

Chapter 2

How to use MOLUSCE

2.1 Inputs

A screenshot of `Inputs` tab is shown in Figure 2.1.

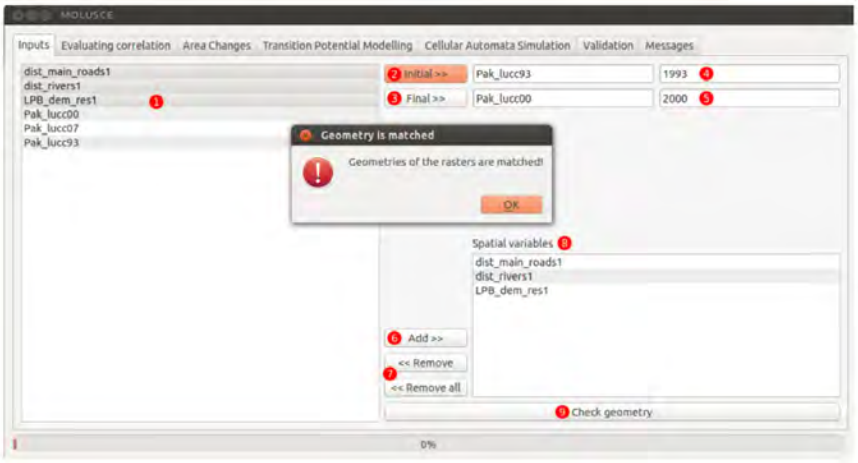


Figure 2.1: Inputs tab

Data can be loaded using the inputs tab. To load your data follow the next steps (Figure 2.1).

- Step 1. Load all rasters that you need in the input tab.
- Load the initial and final land use/cover maps as shown in steps 2 and 3. The base map determines the geometry of all the output files, pixel size, scaling and projection.
- Steps 4 and 5 show the corresponding years. (The user can type here If the corresponding years do not appear automatically).

- Steps 6 and 7 show how the add/remove buttons used to add or remove spatial variables.
- The selected spatial variables are shown in step 8.
- The check geometry button is a mandatory step to check if the geometry of the selected raster is matched (step 9).

Note: It is important when layers are added to QGIS that the No Data Value (NDV) is set. If this is not done, MOLUSCE will process NDV areas as land use/cover classes, increasing processing time and confusing the model calibration. MOLUSCE picks up the NDV of the input (base) layer and propagates it to any output maps generated, along with the geometry of the base layer.

2.2 Evaluating correlation

The `evaluating correlation` module contains three techniques for performing correlation analysis:

1. Pearson's correlation.
2. Cramer's coefficient.
3. Joint information uncertainty.

The user can choose between a two-way raster comparison by selecting `first raster` and `second raster` or `check all rasters` loaded into MOLUSCE.

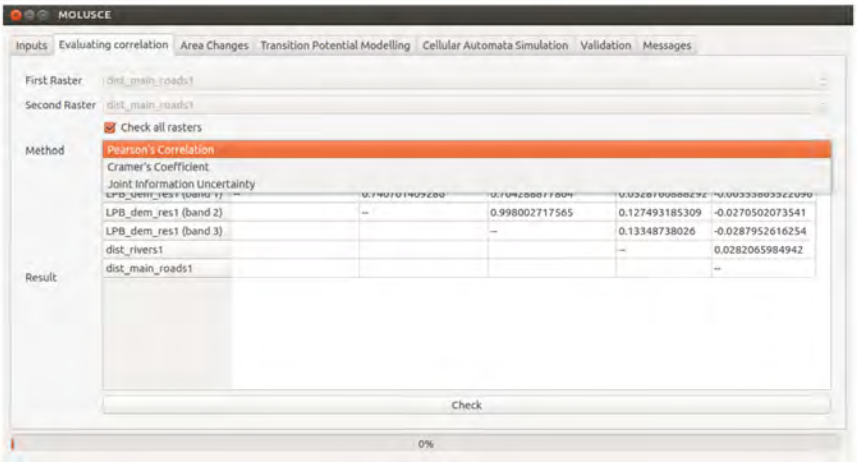


Figure 2.2: Evaluation correlation tab

The user can run correlation by pressing the `check` button located at the bottom of the window (see Figure 2.2).

Note: The `Cramer's coefficient` and `joint information uncertainty` work only with categorical data. The data should be converted to categorical data (eg. using GRASS).

2.3 Area Changes

A screenshot of `Area Changes` tab is shown in Figure 2.3.

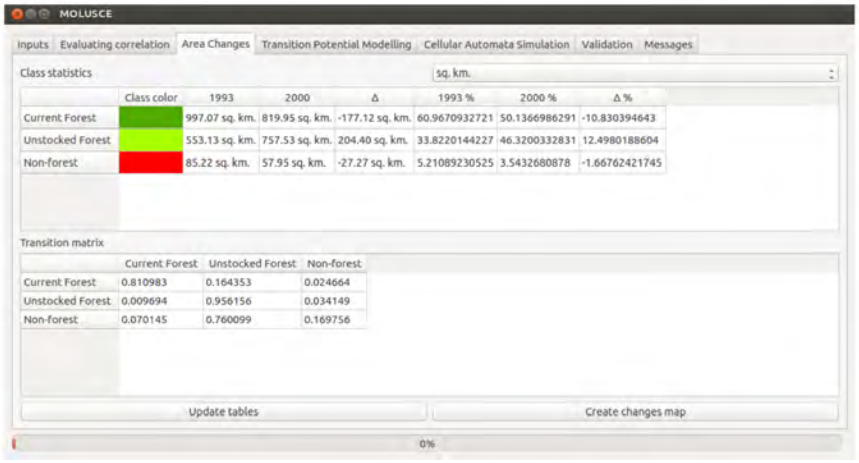


Figure 2.3: Area Changes tab

The `update tables` button produces `class statistics` and `transition matrix` tables.

The `class statistics` table shows the initial and final land use/cover change (LUC) areas.

The `transition matrix` shows the proportions of pixels changing from one land use/cover to another.

The `create change map` button will generate a map of change classes. This will be added automatically to QGIS and saved as a GeoTiff.

Note: Data from tables can be copied and pasted directly into spreadsheet programs, simply by selecting the desired rows/columns and by pressing the "Ctrl + C" keyboard combination.

2.4 Transition potential modeling

MOLUSCE uses Artificial Neural Network (ANN), Multi Criteria Evaluation (MCE), Weights of Evidence (WoE) and Logistic Regression (LR) methods to model land use/cover transition potential. The user can select a `method` from the drop down menu.

ANN, WoE and LR are machine learning models; they "look" at the training samples and try to find patterns that are "hidden" in the samples. However MCE is different: it is a model in which an expert (the user) describes the importance of factors according to his/her knowledge of the domain area. After that, the expert's knowledge is transformed into a computational model that estimates transition potentials.

The models are trained using samples, so the sampling process is important for the results, see Section 3.3.3 for the reference about sample modes.

2.4.1 Artificial Neural Network (ANN)

MOLUSCE uses full-connected Multi-Layer Perceprtron for modeling. A screenshot of an example of `ANN model settings` is shown in Figure 2.4.

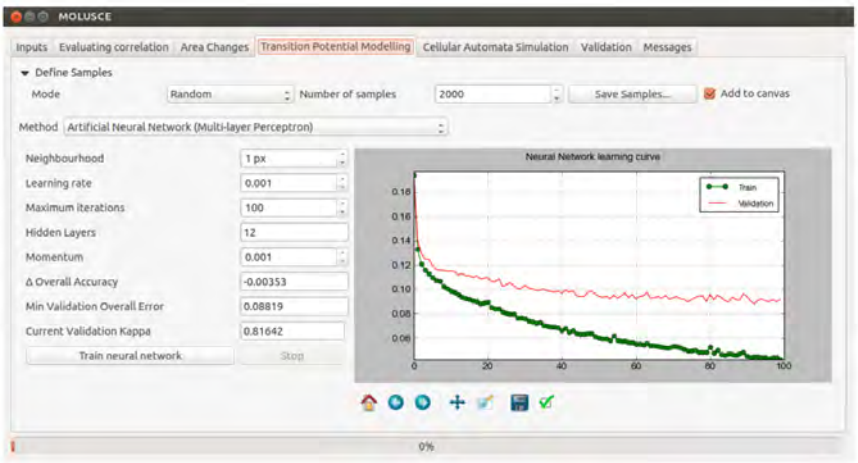


Figure 2.4: Transition potential modeling: ANN model

The `define samples` function specify number of samples and sampling mode. In addition, the sampling points created can be saved and displayed.

Inputs Five inputs are used to customize the ANN modeling:

- The `neighbourhood` defines count of neighbour pixels around current pixel. Size=1 means 9 pixels (3x3 region), size=2 means 25 pixels (5x5), etc.
- `Learning rate`, `momentum` and `max iterations number` define parameters of learning. Big learning rate and momentum allow fast learning, but the learning process can be unstable (spikes on the graph). Small learning rate and momentum means stable but slow learning.

- `Hidden layers` input string takes a list of numbers: N_1, N_2, ..., N_k, where N_1 is number of neurons in 1st hidden layer, N_2 is number of neurons in 2nd hidden layer and so on, N_k is the number of neurons of the last hidden layer (k-th layer). For example if the user types in the input string "2" then a network with 1 hidden layer and 2 neurons will be created. In order to create a network with 2 hidden layers the user should insert 2 numbers, such as "10 2" which will create a network with 10 neurons in the first hidden layer and 2 neurons in the second.

Outputs The following outputs are proposed (for the current learning iteration):

- The graph area. Contains errors of training and validation sets. It is the main information about learning process. The graph can be edited and saved as image.
- The `min validation overall error` contains information about min reached error on validation set of samples.
- The `delta overall accuracy` contains difference between min reached error and current error.
- The `current validation Kappa` shows the Kappa value.

The training process can be started by pressing on the `train neural network` button and stopped at any time using the `stop` button.

Learning algorithm analyses the reached accuracy on training and validation sets of samples and stores the best neural net in memory. The training process finishes when the `maximum iteration number` is reached, and the best neural net will be used to produce transition potentials.

How to train the model

There are few parameters that can dramatically change quality of trained model. The main of them are:

- ANN complexity (number of layers and neurons): complex models are more powerful, but training them properly is hard process, complex models require more samples to train etc.
- learning rate and momentum: large values of learning rate allow to train quickly, but the training process may be unstable in this case; momentum helps stabilize the training.
- sample count: large sample count allows to train complex models, but the training becomes slow and requires more computer memory (which can be issue for large rasters).

So process of ANN training is a trial and error method: during the training the uses searches "good" parameters that lead to "good" model. The training graph is the main tool that provide information about the training process and model quality.

Bellow we provide an example of ANN training, discuss some potential caveats and how to fix them.

Unstable learning Figure 2.5 shows an example of unstable learning process: there are a lot of spikes on the graph. Note that the learning rate is 0.1.

A stable training process is one of the necessary conditions for good ANN model: we can't expect to learn something useful if the values of its parameters show dramatic changes with every iteration.

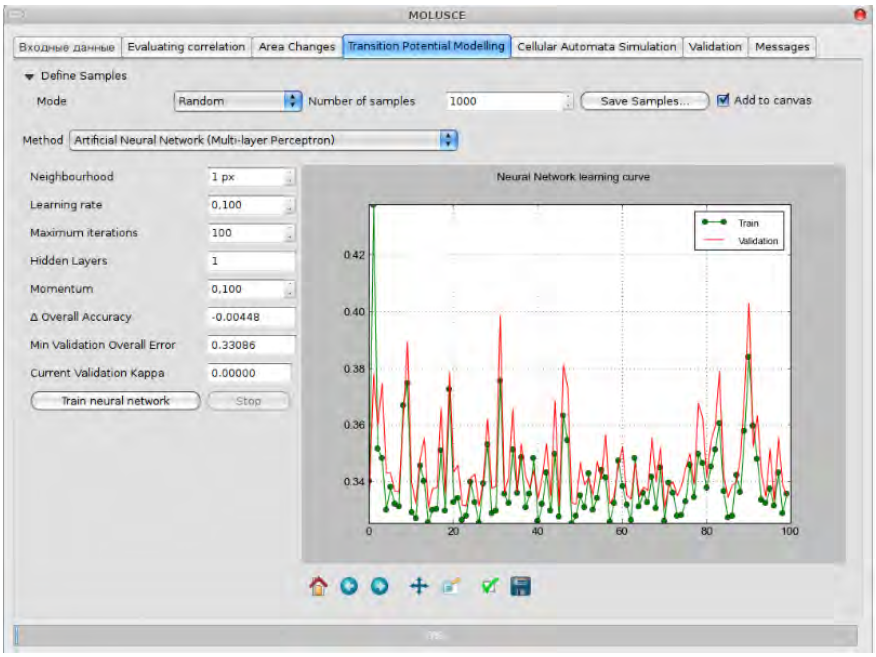


Figure 2.5: ANN model: spikes on the graph (unstable training)

We can fix the issue if decrease the value of this parameter. Figure 2.6 shows that if we set learning rate to 0.001 the learning curves become smooth. The smooth form of lines for training and validation errors indicates a stable training process. This means that the internal values of the parameters of ANN model do not change suddenly with every iteration.

But we can see that the model isn't perfect (look at the Kappa and validation error).

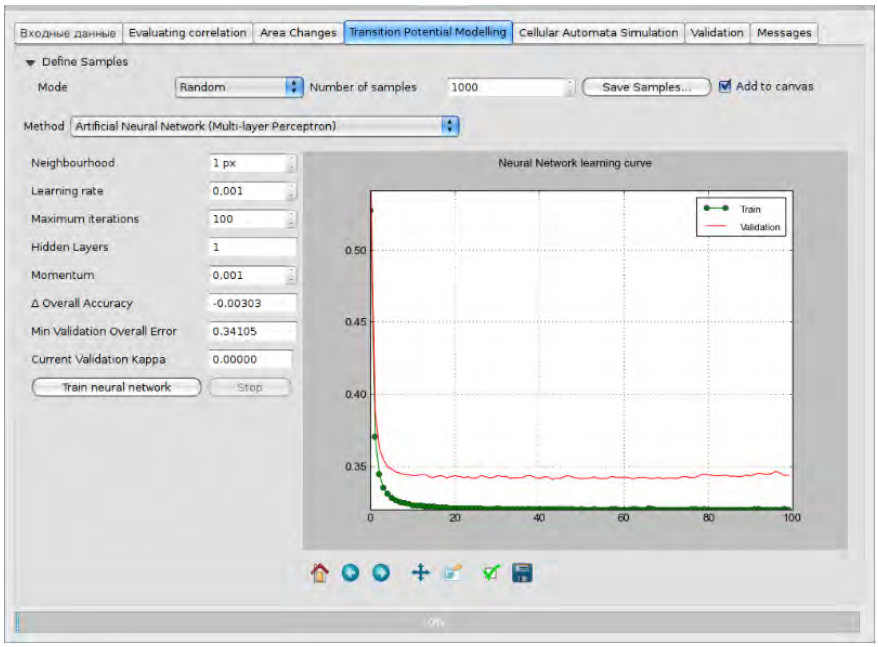


Figure 2.6: ANN model: smooth learning curves

Improving the quality Validation error and Kappa show than the model is not perfect (see Figure 2.6).

We can add a neuron for the hidden layer, it makes the net more complex. The learning curves are shown in Figure 2.7. We can see that Kappa is not zero and validation error decreases. It means that the model is getting better.

What about the over-fitting? The model shows some over-fitting (there is some difference between validation and training errors) but it is not significant.

To get an example of clearer over-fitting, set 12 neurons in the hidden layer. The result presented in Figure 2.8.

We can see that the training error is decreasing but the validation error is still nearly constant. It is clear signal about over-fitting. To avoid it we have two choices:

- decrease number of neurons;
- increase sample count.

Figure 2.9 shows training on 20,000 samples.

We can see that the training and validation errors are close. Over-fitting is not present.

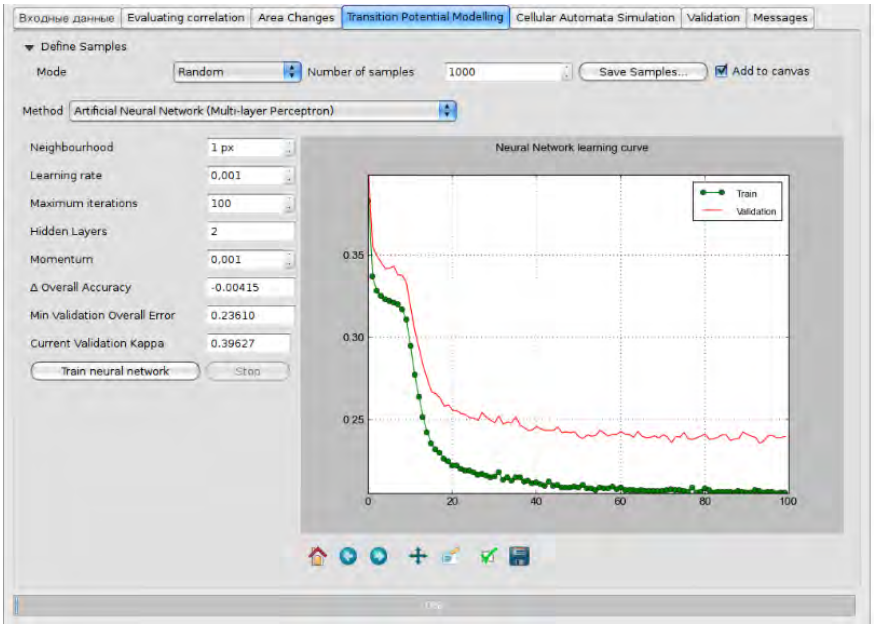


Figure 2.7: ANN model: better model with slight over-fitting

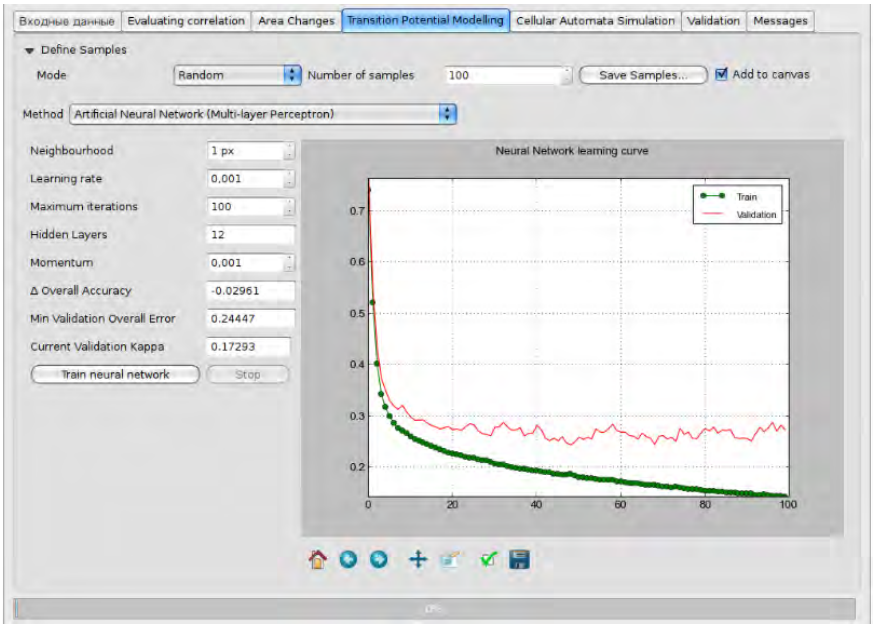


Figure 2.8: ANN model: over-fitting example

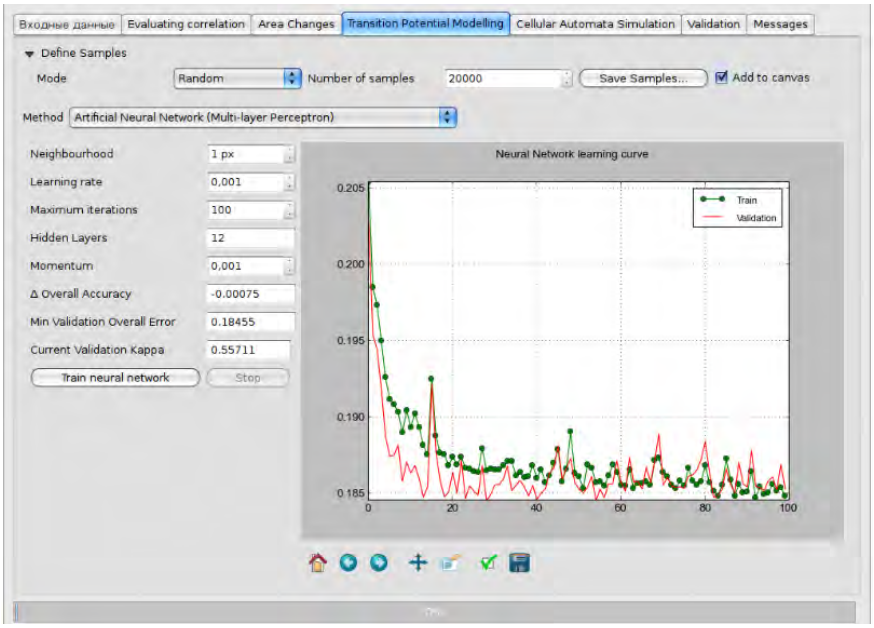


Figure 2.9: ANN model: final example

Table 2.1: Saaty's scale

Rating	**Preference**
1	Equal importance
3	Moderate importance
5	Strong importance
7	Very strong importance
9	Extreme importance
2, 4, 6, 8	Intermediate values

2.4.2 Multi Criteria Evaluation (MCE)

The MCE model [2] takes into account the expert point of view regarding the importance of the predictors. The user makes pairwise comparisons of the factors and describes their importance for the transition potentials. The comparisons are made using Saaty's scale (see Table 2.1).

For example, coefficient "1" between factors A and B means that the factors have equal importance for the transition process. Coefficient "9" between factors A and B means that factor A absolutely exceeds factor B in importance.

A screenshot of an example of `MCE model settings` is shown in Figure 2.10.

The user can set the values inside the `pairwise comparison matrix`.

The user can also select which classes to use to train the model by changing the `from class` and `to class` values located at the bottom of the window.

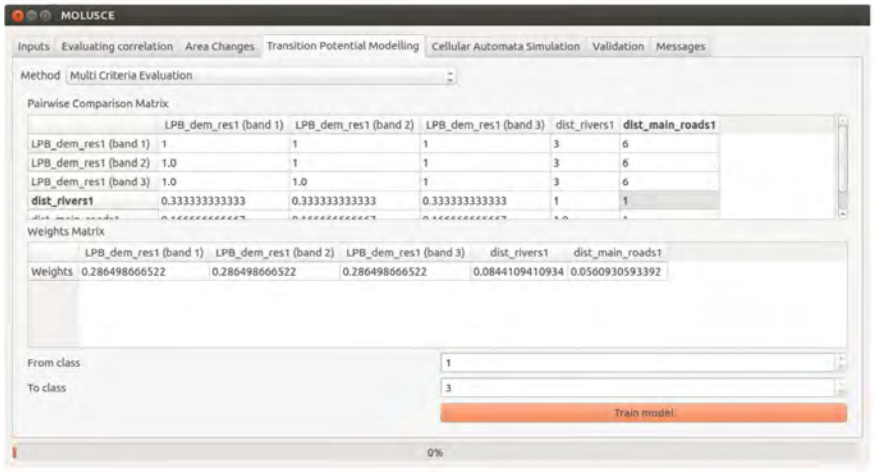


Figure 2.10: Transition potential modeling: MCE model

The model can be started by pressing the `train model` button.
The weights of the spatial variable will then appear in the `weights matrix`.

2.4.3 Weights of Evidence (WoE)

The WoE [1] method proposes two ways of defining the range breaks. The user can define a `number of intervals` or specify the `range breaks` values.

When the `calculate range breaks` button is pressed the weights information for each transition are produced.

Once the user is satisfied with the weights the `train model` button can then be pressed.

An example of WoE model settings is shown in Figure 2.11.

2.4.4 Logistic Regression (LR)

An example of LR model settings is shown in Figure 2.12.

The LR method offers the possibility to `define samples` (number of samples and sampling mode) as well as save and display the sampling points created.

Inputs Two inputs are used to customize the LR modeling:

- The `maximum iteration` defines the total number of iterations.
- The `neighbourhood` defines count of neighbour pixels around current pixel. Size=1 means 9 pixels (3x3 region), size=2 means 25 pixels (5x5), etc.

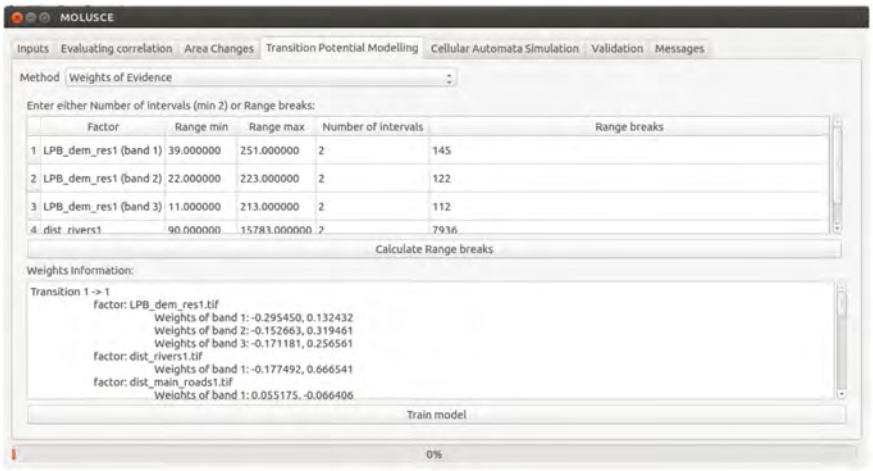


Figure 2.11: Transition potential modeling: WOE model

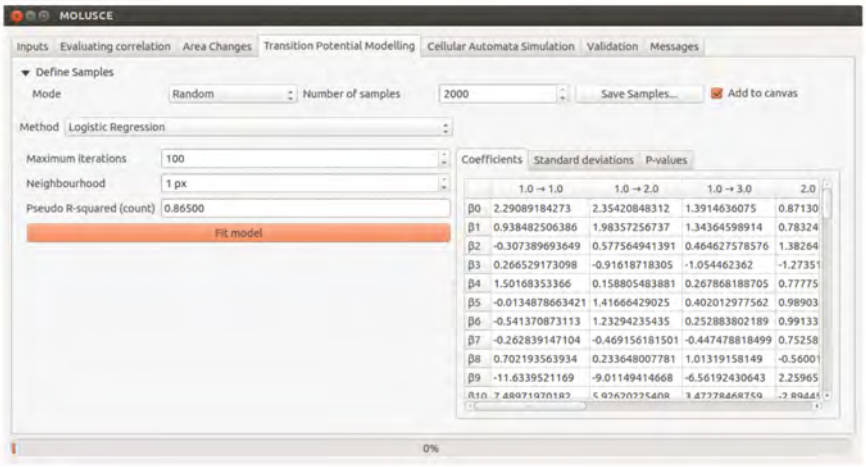


Figure 2.12: Transition potential modeling: LR model

Outputs The following outputs are proposed (for the current learning iteration):

- The `pseudo R-squared` shows the goodness-of-fit.
- The `coefficients` tab.
- The `standard deviations` tab.
- The `p-values` tab.

The user can run the model by pressing on the `fit model` button.

Note: For additional information on the LR outputs please consult the "Technical information: Methods and Algorithms" manual.

2.5 Cellular Automata Simulation

Once one method has been chosen and trained from the `transition potential` modeling tab, the user can then access to the `cellular automata` simulation tab.

Be aware that MOLUSCE will keep in memory the latest method processed, if for example the user runs first the ANN and then the LR methods, the cellular automata simulation tab will retain the results from the LR.

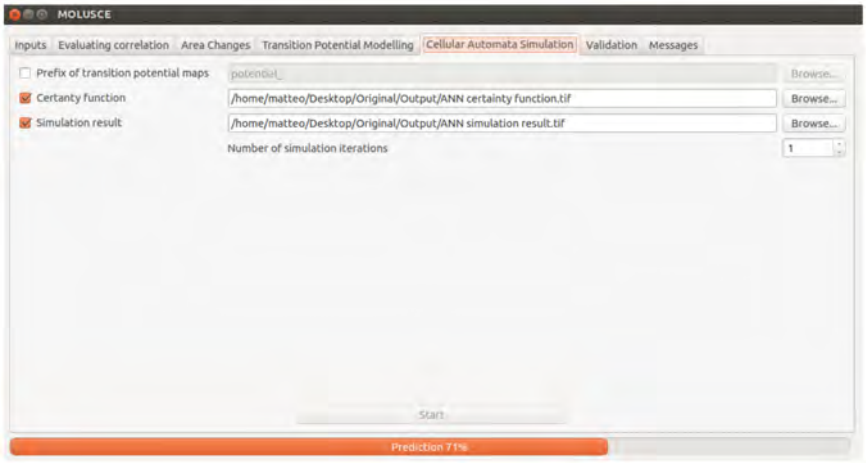


Figure 2.13: Simulation tab

Three type of output maps are produced. A check box at the beginning of each output is provided to allow the user to enable only what it is necessary. A `browse...` button located at the end of each output allows to save each map.

- The `prefix of transition potential maps` button allows to select prefix of the names of transition potential maps. Transition potential map shows the probability or potential to change from one land use/cover class to another. Transition potential values range from 0 (low transition potential of change) 100 (high transition potential). Transition potential maps will be produced from the corresponding land use/cover changes (e.g., "forest to unstocked forest" transition potential, "forest to non-forest transition potential).
- The `certainty function`.
- The `simulation result` produces a simulated land use/cover map.

An example of simulation tab is shown in Figure 2.13.

2.6 Validation

The `validation` tab allows the user to check, validate and compare the simulation results. `Reference` and `simulated land use/cover maps` must be loaded in order to start the validation process. The former indicates a land use/cover map (T_3). T_1 refers to the initial land use/cover, while T_2 refers to the final land use/cover used in the model). A `browse` button located at the end of each output allows to load the desired map. A two way map comparison is performed from reference land use/cover (T_3) and simulated land use/cover maps.

In order to perform a three way map comparison, the user can check the `risk class validation map` check-box. Although it is not shown explicitly, the three-way map comparison uses the initial land use/cover map (T_1), the reference land use/cover map (T_3) and the simulated land use/cover map.

The `multiple-resolution budget` method [3, Chapter 17] is also used in MOLUSCE. The user can decide the `number of validation iterations` and can start the process by pressing the `start validation button`. The graph can be edited and saved as image.

The overall accuracy (`% of correctness`, `Kappa (overall)`, `Kappa (histo)` and `Kappa (loc)`) can be executed by clicking the `calculate Kappa` button.

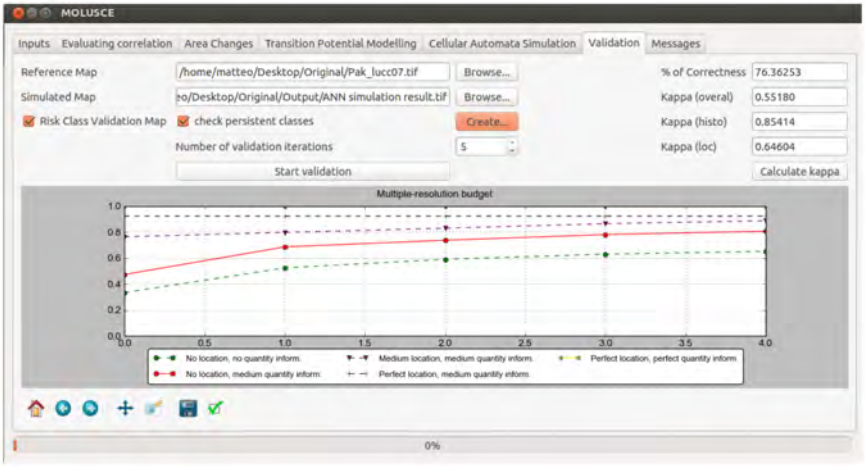


Figure 2.14: Validation tab

An example of validation tab is shown in Figure 2.14. We discuss here some parts of the graph, see full details in [3, Chapter 17]. The chapter propose 15 types of statistic, but MOLUSCE calculates and plots 5 of the most important of them:

- No location information, no quantity information;

- No location information, medium quantity information;
- Medium location information, medium quantity information;
- Perfect location information, medium quantity information;
- Perfect location information, perfect quantity information.

These lines agreement metrics. They are measured for maps at different scales. The zero point on the abscissa axis corresponds to the original scale of the maps, the point one corresponds the maps scaled down by half (2^1), the point two corresponds the maps scaled down by quarter (2^2), etc.

Medium location information, medium quantity information is "the main" line. It represents sequence of measures of agreement between the reference map and the simulated map. Higher values of the line show higher agreement.

Other lines show measures of agreement between the reference map and those that describe different hypothetical situations. For example the line "No location information, no quantity information" is the agreement due to chance. Usually it lies below the "Medium-Medium" line, in this case the simulated map has better agreement with the reference then random generated map.

The upper line, "Perfect-Perfect," represents the highest possible agreement. It corresponds to the case when we have complete information about the reference map in advance and can place all changes in their correct locations during the simulation. Thus, this line shows the case when no errors are committed. Usually the "Medium-Medium" line lies below this line.

Other lines represents other hypothetical situations when we know more or less information about the reference map. This information consists of two parts: information about the quantity of pixels (quantity of changes in our case) and information about the locations of changes.

Chapter 3

Technical details

This chapter describes some algorithm and math details used for QGIS MOLUSCE plugin. In this chapter we use the next terminology:

A model is an algorithm that is used for predicting land use changes (transitions).

A state raster is a one-band raster where each pixel is assigned a land use category.

The input state raster is a one-band raster describing the past.

The output state raster is a one-band raster describing the present. It is the desired result of the prediction for the model (a user trains the model to predict (input raster, factors) -¿ output raster).

A factor raster is a raster of explanatory variables. The rasters can be one-band or multi-band.

A transition class, or simply transition,' is information about land use change. Every change (for example, forest — non-forest) can be viewed as a transition of land use categories (encoded as pixels) from the input state raster to the output state raster.

A change map is an integer one-band raster that stores information about transitions. The category values of the change map are mapped one-to-one to transition classes.

The user declares the input and output state rasters, as well as the factor rasters, via the GUI.

3.1 Data types

The next assumptions are currently used by the plugin:

Table 3.1: Change map encoding schema

	Category 1	**Category 2**	...	**Category N**
Category 1	0	1	...	N-1
Category 2	N	N+1	...	2N-1
...	...	...	...	...
Category N	(N-1)*N	(N-1)*N + 1	...	N*N -1

Table 3.2: Change map encoding example

	Agriculture (1)	Forest (2)	Urban (3)	Water (4)
Agriculture (1)	0	1	2	3
Forest (2)	4	5	6	7
Urban (3)	8	9	10	11
Water (4)	12	13	14	15

- Initial and final state rasters are categorical one-band rasters; therefore a change map is categorical one-band raster too (see Section 3.2).
- For the ANN, MCE, and LR models, factor rasters are assumed to be ordinal or continuous (one-band or multi-band), but not categorical. These assumptions are very important because categorical data requires dummy encoding (see Section 3.3.1), while ordinal and continuous data need normalization (see Section 3.3.2).

3.2 Change map and area analysis

The output of the Area Analysis stage is a change map; it is a raster where each pixel is assigned an integer value indicating its transition. The module uses the following scheme for transition encoding (see Table 3.1).

For example, for 4 classes (N=4), there are 4*4=16 possible transitions (see Table 3.2). For example, if in the state rasters category "Forest" coded as "2", category "Urban" coded as "3", then transition "Forest" - "Urban" in the change map will be coded as "6".

One row (in this case it is Water) consists of zeros. It is important because otherwise the dummy variables became linear-dependent. The condition of linear independence of data is crucial for Logistic regression and strongly recommended for Multilayer Percepton.

3.3 Sampling of points and data transformation

Before the modeling stage some internal data transformations are made. The transformations are not visible to the user, but understanding of them can help improve the quality of modeling results.

The transformations are made during data sampling stage.

Table 3.3: Dummy coding example

	Dummy (1)	Dummy (2)	Dummy (3)
Agriculture	0	0	1
Forest	0	1	0
Urban	1	0	0
Water	0	0	0

3.3.1 Dummy coding

As the initial state raster and change map are categorical, each of them must be transformed to set of independent variables.

To do that the plugin uses dummy coding – a categorical variable of N levels is divided into N-1 dummy variables. For example, if our land use map has 4 classes (Agriculture, Forest, Urban, Water), we have to use 3 dummy variables (see Table 3.3).

One row (in this case it is Water) consists of zeros. This is important because otherwise the dummy variables became linear-dependent. The condition of linear independence of data is crucial for Logistic regression and strongly recommended for Multilayer Percepton.

3.3.2 Normalization

The next stage of initialization/sampling procedure is normalization of factor data. Usually normalization allows to achieve more efficient training and more accurate prediction result. The plugin uses linear normalization:

$$X_{norm} = \frac{X - m_x}{\sigma_x}.$$

Here X is our variable, X_{norm} is the normalized variable, m_x is mean of X and σ_x is standard deviation of X.

Note that MCE method uses slightly different normalization (see Section 3.4.4).

3.3.3 Sampling process

Sampling procedure processes single pixels and a neighborhood of pixels. This means that a user can take into account a set of pixels around current pixel. The implementation of the algorithm uses Moore neighborhood.

For example (see Figure 3.1), if the user sets up 1-size neighborhood then sampling procedure reads the current pixel and all pixels located in immediate vicinity (3x3 window size). If the user set up 2-size neighborhood then sampling procedure reads the current pixel and all pixels located in 5x5 window size and so on. Every neighborhood is stored as vector (9 elements, 25 elements and so on). Sampling is performed for every input raster (initial state raster and factors).

Thus a sample contains:

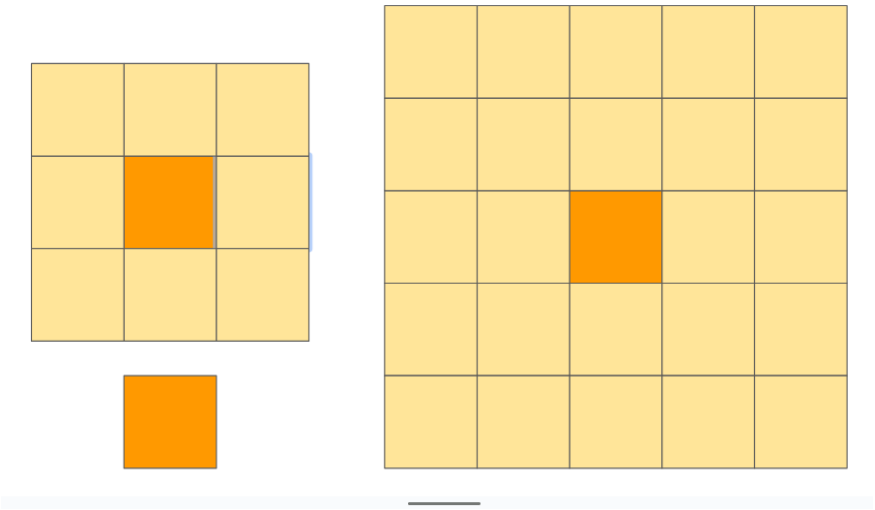


Figure 3.1: Example of three neighbourhoods: 0-size (a pixel), 1-size and 2-size.

- coordinates of the pixel (the coordinates doesn't used during training processes, they are used in some internal parts of the plugin),
- input data; that is used as input for models (for training and inference stages), the data consists of 2 parts:
  - state pixel vector is the neighborhood that is read from 1-band raster, this raster contains initial states (categories). The raster is divided into set of dummy variables before sampling (see Section 3.3.1).
  - factor pixel vectors are the neighborhoods extracted from factor rasters (they can be multiband); every raster band is normalized before sampling (see Section 3.3.2).
- output data is read from 1-band raster, this raster contains final states or the change map.

Sampling modes

The plugin has three sampling modes:

All. This mode extracts information for all pixels of the input and output rasters Among other methods this mode of sampling needs the biggest amount of RAM and CPU time

Random. This mode extracts information for randomly selected samples: if raster has N pixels, then the every pixel has equal ($\frac{1}{N}$) probability of being selected during sampling

Stratified. This mode randomly undersamples major categories (large areas) and/or oversamples minor categories (small areas) If C is desired count of samples and K is number of output categories, then the sampling procedure select K random groups of pixels of equal size $\frac{C}{K}$ Every group will contain pixels of one certain category

3.4 Some words about modeling

A user has a number of factors, init state raster and final state raster. The goal of modeling stage is to create a model that can predict land use changes between those states. Before discussing prediction methods we need to explain common preparation stage.

3.4.1 ANN: Multilayer perceptron

The plugin uses classic realization of Multilayer perceptron. The input data is a collection of pixels of initial state raster and factor rasters. The target output data is the change map.

So, the perceptron model performs the next actions:

1. Initial preprocessing of the data (dummy coding and normalization).
2. Sampling.
3. Training.

The initial stages are described (in general) in the previous sections (see Sections 3.3.1 and 3.3.2), this subsection discussed the structure of the neural net, the training procedure and particular features of initialization.

MOLUSCE uses multilayer percepron with `numpy.tanh` sigmoid function. Therefore target variables (the change map categories) should be scaled to $(-1, 1)$ interval during dummy coding instead of classic $(0, 1)$. This process is performed automatically during the preparation.

The user can set arbitrary number of hidden layers (one or more) and arbitrary number (one or more) of neurons in the layers. Finally the created net has:

- $(C-1)(2N+1)^2 + B(2N+1)^2$ input neurons;
- about M output neurons (it depends on sampling mode, see below);

here C is the count of land use categories, N is the neighborhood size specified by the user, B is the summary band count of factor rasters (for example if two factors are one-band and three-band, then $B = 4$). M usually is a count of unique categories in the change map (C^2). But the count of output neurons can be less then M, it depends on the sampling mode. If mode "Random" is used, some small classes could be omitted during sampling procedure.

The module uses classic backpropagation algorithm with momentum for the learning procedure. Weights correction are performed as:

$$w(n+1) = r * dw(n) + m * dw(n-1),$$

where w is a vector of neuron weights, dw is a vector of weights changes, n is an iteration number, r is learning rate, m is the momentum value.

Training set is divided in two parts: learning set (80% of samples by default) and validation set (20% of samples).

The module uses on-line learning with stochastic: a random sample is selected from the learning set, the weights of the net are updated during forward/backward propagation.

A error of fitting (for a sample) is the average square error of partial outputs of the net:

$$E = \frac{t_i - o_i}{/} d$$

where E is a sample error, t_i is the target value of a output neuron for given sample, o_i is the real output value of the neuron, d is the count of output neurons.

3.4.2 Logistic regression

Logistic regression model behavior is very similar to the ANN. The input data is a collection of pixels of initial state raster and factor rasters. The target output data is the change map.

So, the logistic regression model also performs the next actions:

1. Initial preprocessing of the data (dummy coding and normalization).
2. Sampling.
3. Training.

The created model has M $(((C-1)(2N+1)^2 + B(2N+1)^2 + 1)$ coefficients, but only $(M-1)((C-1)(2N+1)^2 + B(2N+1)^2)$ are independent. As before (see Section 3.4.1), C is the count of land use categories, N is neighborhood size specified by the user, B is summary band count of factor rasters (for example if two factors are user one-band and three-band, then $B = 4$). M usually is count of unique categories in the change map C^2). M depends on the sampling mode also (see Section 3.4.1).

Examples

Example 1. For example we discuss coefficients of one transition class (transition from land use category 2 to land use category 3, for example). If we have four land use categories 1,2,3,4 and we select one one-band factor and we use 0-neighborhood, we have 5 coefficients per transition class:

- b_0 is the intercept;
- b_1, b_2, b_3 are the coefficients of dummy variables of current landuse state (categories of the raster are coded as: 1 = (0, 0, 1); 2 = (0, 1, 0); 3 = (1, 0, 0); 4 = (0, 0, 0), see Section 3.3.1); b_4 is the coefficient of factor pixel (0-neighborhood).

Example 2. If we select two one-band factors, we have 6 coefficients per transition class:

- b_0 is the intercept;
- b_1, b_2, b_3 are the coefficients of dummy variables of current landuse state;
- b_4 is the coefficient of the first factor (0-neighborhood).
- b_5 is the coefficient of the second factor (0-neighborhood).

Example 3. if we use 1-neighborhood and two one-band factors, we have 37 coefficients per transition class:

- b_0 is the intercept;
- coefficients from b_1 thru b_{27} are the coefficients of dummy variables of current landuse state: ($b_1, \ldots, b_3$ are dummy variables for the upper-left corner of 3x3 neighborhood window);
- coefficients from b_{28} thru b_{36} are the coefficients of the first raster pixels (1-neighborhood uses 9 pixels or 3x3 window);
- coefficients from b_{37} thru b_{45} are the coefficients of the second raster pixels.

3.4.3 Weight of evidence

Initially Weight of Evidence method was developed to process binary variables, but the method was later modified in order to enable it to handle multiple categories of variables. If the user uses rasters with continuous values, he/she has to transform them into categorical variables.

MOLUSCE implementation uses the next one modification. To handle continuous factors user must split raster values into several categories (range binning). The GUI has a form that allows to perform transformation into categorical variables. A compromise is needed here: if the user set up too many binning values, then a small amount of pixels might fall into a category and accuracy of statistical calculations will be poor; on contrary if the user set up few bins, which will lead to few of weights are formed, that leads to poor accuracy again.

In the binning form GUI doesn't display all of the used rasters: if a raster is already categorical, it doesn't need transformation and it doesn't appear in the form. Currently a simple procedure is used to decide if rasters as categorical: if a

raster has more then `MAX_CAT` (=100) unique values, then the raster is supposed to be continuous, otherwise the raster is treated as categorical.

The WoE fitting procedure starts after the transformation continuous — categorical.The change map is divided into series of binary maps (one map per a transition class), then the set of weights are estimated for every binary map.

3.4.4 Multi criteria evaluation

The goal of the method is to predict a transition class encoded in the change map. Factor rasters are input data, places where a transition occurs are target values. MCE takes pairwise comparison matrix of factors and calculates weights of every factor. This means, that a user must specify the comparison matrix for every transition class. But count of transition classes increases as $O(n^2)$, where n is count of landuse categories (for example if $n = 4$, we have 16 transition classes). To specify all comparison matrices for all transitions is too long and boring, that's why the MCE model predicts one transition class only.

The method needs normalization of factor rasters: this implementation uses a linear combination of factors, therefore they should be transformed to $[0, 1]$. The module uses the next transformation (it differs from ANN and LR normalization, see Section 3.3.2):

$$X_{norm} = \frac{X - X_{min}}{X_{max} - X_{min}}$$

where X_{norm} is normalized raster value, X is initial raster value, X_{min} is the min value of the raster, X_{max} is the max value of the raster.

3.5 Simulation

Simulation module performs land use change evaluation procedure. It takes as input the next data:

- Initial state raster;
- Factor rasters;
- Model.

Initial state raster contains information about current land use categories, factor rasters contain information about explanatory variables. Model is a predictor that calculates transition potentials in the condition of the factors and current land use.

So module doesn't uses implicit transition rules, it uses transition potentials generated by the models. The neighborhood effect is achieved if a model uses neighborhood during training, for example logistic regression has a coefficient for every neighbor and the coefficient affects the transition potential. If model doesn't uses neighborhood, Simulator takes into account only general patterns.

The module works as follow scheme:

1. Simulator takes transition probabilities from the transition matrix and calculates count of pixels that has to be changed (for every transition class);
2. Simulator calls a model, pass to it initial state raster and factor rasters;
3. The model scans pixels of the rasters (and its neighbors if the model uses neighborhood) and calculates transition potentials of every transition class;
4. Simulator constructs a 'certancy' raster: the pixel of the raster are the difference between two most large potentials of correspondent pixels of transition potential rasters. As result the raster contains the model confidence: the bigger is difference, the bigger is confidence;
5. Simulator constructs a raster of the most probable transitions: the pixels of the raster are the transition class with the biggest potential of transition. This raster is an auxiliary raster; it is used during the next stage;
6. For every transition class Simulator searches in the raster of the most probable transitions a needed count of pixels with the greatest confidence and changes the category of the pixels. If confidence of two or more pixels are close, then random choice of the pixel is used.

The described scheme is used if the user specified only one iteration of simulation. If several iterations have to be preformed, in general the scheme is the same, but initial state rasters are changed on the next iterations: the first simulated map is the initial state map for thy second iteration, the result of the second iteration is the initial states of the third iteration and so on.

3.6 Validation

Validation module allows to check accuracy of the simulation. MOLUSCE has three types of validation:

- Kappa statistics;
- Error budget validation;
- Error map validation.

3.6.1 Kappa

The module calculates three types of kappa statistic. Let

- c is count of raster categories,
- p_{ij} is the i, j-th cell of contingency table,

Table 3.4: Two-class error table.

	Reference map C1	**Reference map C2**
Simulated map C1	Hit	Misses
Simulated map C2	False alarms	Hit

- p_{iT} is the sum of all cells in i-th row, p_{Tj} is the sum of all cells in j-th column,
- $P(A) = \sum_{i=1}^{c} p_{ii}$,
- $P(E) = \sum_{i=1}^{c} p_{iT} p_{Ti}$,
- $P_{max} = \sum_{i=1}^{c} min(p_{iT}, p_{Ti})$

In this case the kappa statistics can be defined by the next rules.

Kappa:

$$K = \frac{P(A) - P(E)}{1 - P(E)}$$

Kappa location:

$$K_{loc} = \frac{P(A) - P(E)}{P_{max} - P(E)}$$

Kappa histogram:

$$K_h = \frac{P_{max} - P(E)}{1 - P(E)}$$

3.6.2 Error budget

MOLUSCE uses Error Budget technique [3, Chapter 17]. Currently the pdf can be found here: `http://www.econgeography.org/~rpontius/pontius_suedmeyer_2004_rsgisaa.pdf`

Error map

MOLUSCE produces map of errors. This map contains information about false predictions in simulated raster. The error map can be constructed by compassion of simulated map and reference map. The errors of simulation are stored in the error map.

Error map creating procedure has two modifications: two map comparison case and three map comparison case.

Two maps comparison case. This modification compares simulated map and reference map.

Traditional approach to two class (C1 and C2) problem uses three types of prediction statuses (see Table 3.4): "hits, misses, false alarm".

But in case of N class problem the classification "hits, misses, false alarm" is not so good because the terms "Misses" and "False Alarms" became ambiguous: there are different types misses/false alarms between different classes.

MOLUSCE uses common N-class approach, when error map contains every transition type error marked by a particular color, "Hits" are transparent. The errors are coded as transitions in change maps (see Section 3.2).

If a transition for a certain location was simulated correctly then the pixel is transparent (white color on the picture). If the transition was simulated incorrect, then the pixel is colored.

Three maps comparison case. This modification uses three rasters for checking: simulated map, reference map and initial map.

The same idea of comparison is used for checking persistent classes and simulation errors. Persistent classes are pixels that are constant in initial raster, reference raster and simulated raster. Such pixels are marked by a certain color, "Hits" are transparent and transition errors are marked as in the two-map comparison problem.

Bibliography

[1] Graeme F Bonham-Carter. Weights of evidence modelling: a new approach to mapping mineral potential. *Statistical applications in the earth sciences*, pages 171–183, 1989.

[2] J Ronald Eastman. Multi-criteria evaluation and gis. *Geographical information systems*, 1(1):493–502, 1999.

[3] Robert Pontius and Beth Suedmeyer. *Components of Agreement between Categorical Maps at Multiple Resolutions. Chapter 17 in Ross S Lunetta and John G Lyon (eds). Remote Sensing and GIS Accuracy Assessment.*, pages 233–251. CRC Press: Boca Raton FL.

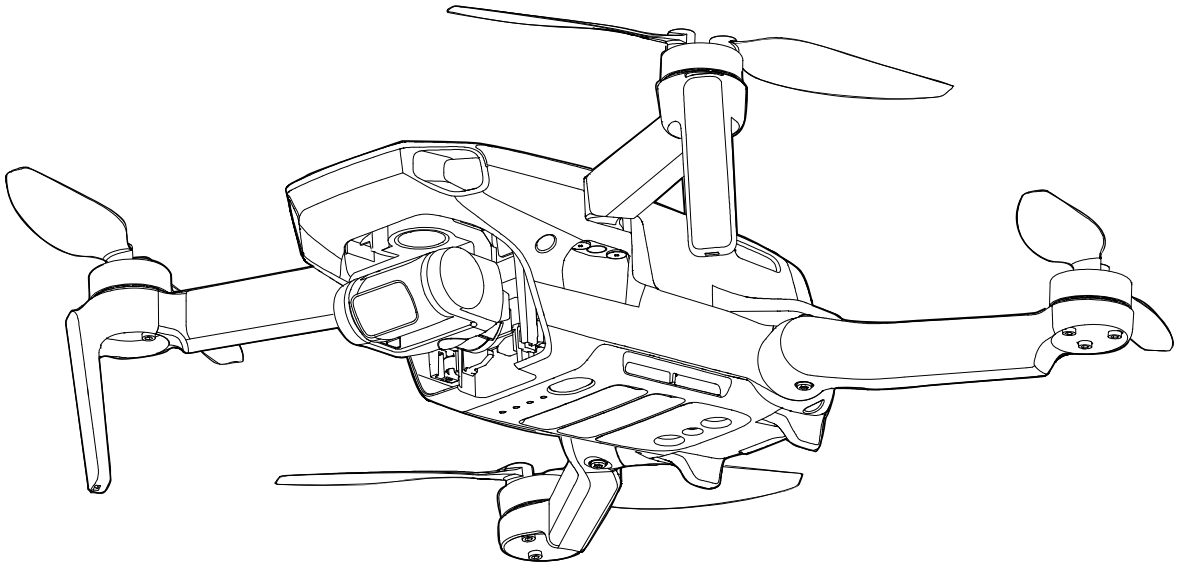
Training Manual (Technical Manuals)

LU1(2): Technical Manual for UAV – MAVIC MINI

MAVIC MINI

User Manual v1.0

2019.11



Searching for Keywords

Search for keywords such as □battery□and □install□to find a topic. If you are using Adobe Acrobat Reader to read this document, press □trl□F on □indows or □ommand□F on Mac to begin a search.

Navigating to a Topic

□iew a complete list of topics in the table of contents. □lick on a topic to navigate to that section.

Printing this Document

This document supports high resolution printing.

Using this Manual

Legend

Warning Important Hints and Tips Reference

Read Before the First Flight

Read the following documents before using the DJI™ MAVIC™ Mini:

1. In the Box
2. User Manual
3. Quick Start Guide
4. Disclaimer and Safety Guidelines

It is recommend to watch all tutorial videos on the official DJI website and read the disclaimer and safety guidelines before using for the first time. Prepare for your first flight by reviewing the quick start guide and refer to this user manual for more information.

Video Tutorials

Go to the address below or scan the QR code on the right to watch the Mavic Mini tutorial videos, which demonstrate how to use the Mavic Mini safely:

http://www.dji.com/mavic-mini/info#video

Download the DJI Fly App

Make sure to use DJI Fly during flight. Scan the QR code on the right to download the latest version.

The Android version of DJI Fly is compatible with Android v6.0 and later. The iOS version of DJI Fly is compatible with iOS v10.0.2 and later.

* For increased safety, flight is restricted to a height of 98.4 ft (30 m) and range of 164 ft (50 m) when not connected or logged into the app during flight. This applies to DJI Fly and all apps compatible with DJI aircraft.

Download DJI Assistant 2 for Mavic

Download DJI Assistant 2 for Mavic at http://www.dji.com/mavic-mini/info#downloads.

The operating temperature of this product is 0° to 40° C. It does not meet the standard operating temperature for military grade application (-55° to 125° C), which is required to endure greater environmental variability. Operate the product appropriately and only for applications that it meets the operating temperature range requirements of that grade.

 © 2019 DJI All Rights Reserved.

Contents

Using this Manual 2

Legend 2

Read Before the First Flight 2

Video Tutorials 2

Download the DJI Fly App 2

Download DJI Assistant 2 for Mavic 2

Product Profile 6

Introduction 6

Feature Highlights 6

Preparing the Aircraft 6

Preparing the Remote Controller 7

Aircraft Diagram 8

Remote Controller Diagram 8

Activation 9

Aircraft 11

Flight Modes 11

Aircraft Status Indicator 12

Return to Home 12

Vision System and Infrared Sensing System 15

Intelligent Flight Mode 16

Flight Recorder 18

Propellers 18

Intelligent Flight Battery 19

Gimbal and Camera 23

Remote Controller 26

Remote Controller Profile 26

Using the Remote Controller 26

Optimal Transmission Zone 29

Linking the Remote Controller 29

DJI Fly App 31

Home 31

Camera View 32

© 2019 DJI All Rights Reserved.

Flight 36
Flight Environment Requirements 36
Flight Limits and GEO Zones 36
Pre-Flight Checklist 37
Auto Takeoff/Landing 38
Starting/Stopping the Motors 38
Flight Test 39
Appendix 41
Specifications 41
Calibrating the Compass 44
Firmware Update 46
After-sales information 47

 © 2019 DJI All Rights Reserved.

Product Profile

This section introduces Mavic Mini and lists the components of the aircraft and remote controller.

© 2019 DJI All Rights Reserved.

Product Profile

Introduction

Featuring a Downward Vision System and Infrared Sensing System, DJI Mavic Mini can hover and fly indoors as well as outdoors and Return to Home automatically. With a fully stabilized 3-axis gimbal and 1/2.3” sensor camera, Mavic Mini shoots 2.7k video and 12 MP photos. Mavic Mini has a maximum flight speed of 29 mph (46.8 kph) and a maximum flight time of 30 minutes.

Feature Highlights

Mavic Mini boasts a folded design and an ultralight weight of 249 g, making it easy to transport. The Intelligent Flight Mode QuickShots provide four sub modes, which can automatically shoot and generate different styles of video.

Using the advanced DJI flight controller, Mavic Mini is able to provide a safe and reliable flight experience. The aircraft is able to automatically return to its Home Point when the remote controller signal is lost or the battery level is low, as well as being able to hover indoors at low altitudes.

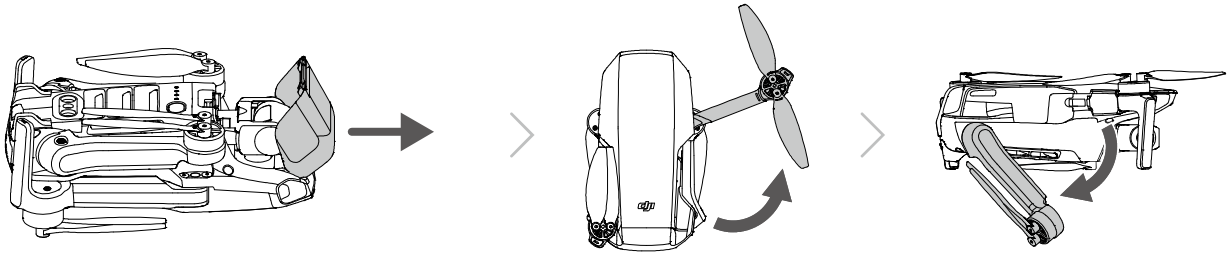
DJI's enhanced Wi-Fi technology is built into the remote controller, supporting both 2.4 GHz and 5.8 GHz frequencies and a transmission range of up to 2.49 mi (4 km), making it possible to stream 720p video to your mobile device.

- Maximum flight time was tested in an environment with no wind while flying at a consistent speed of 8.7 mph (14 kph) and the maximum flight speed was tested at sea level altitude with no wind. These values are for reference only.
- The remote controller reaches its maximum transmission distance (FCC) in a wide-open area with no electromagnetic interference at an altitude of about 400 ft (120 m). The maximum runtime was tested in a laboratory environment. This value is for reference only.
- 5.8 GHz is not supported in some regions. Observe the local laws and regulations.

Preparing the Aircraft

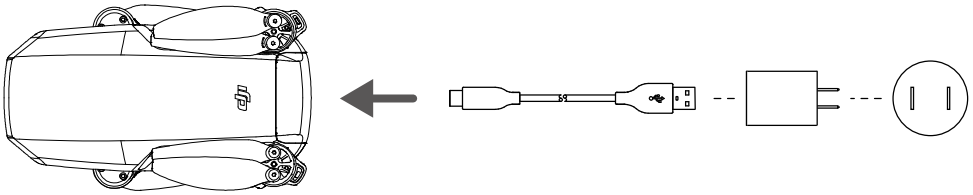
All aircraft arms are folded before the aircraft is packaged. Follow the steps below to unfold the aircraft arms.

1. Remove the gimbal cover from the camera.
2. Unfold the front arms.
3. Unfold the rear arms.



© 2019 DJI All Rights Reserved.

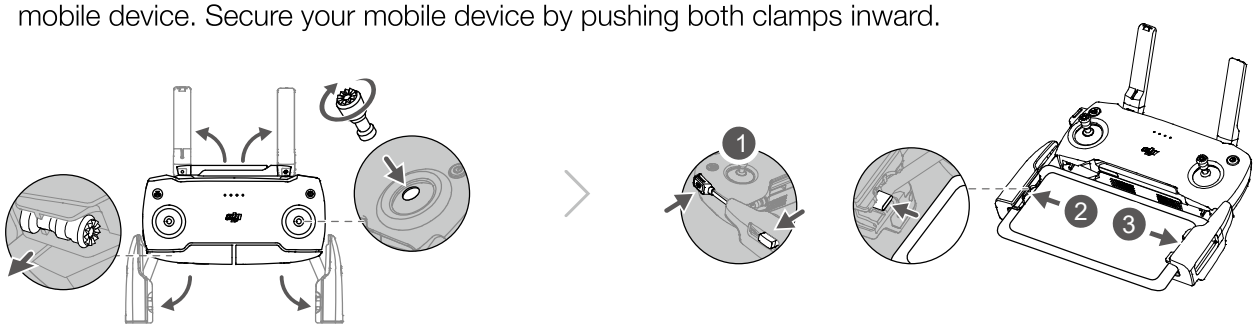
4. All Intelligent Flight Batteries are in hibernation mode before shipment to ensure safety. Use the USB charger to charge and activate Intelligent Flight Batteries for the first time.



⚠
- Unfold the front arms before unfolding the rear arms.
- Make sure the gimbal cover is removed and all arms are unfolded before powering on the aircraft. Otherwise, it may affect the aircraft self-diagnostics.

Preparing the Remote Controller

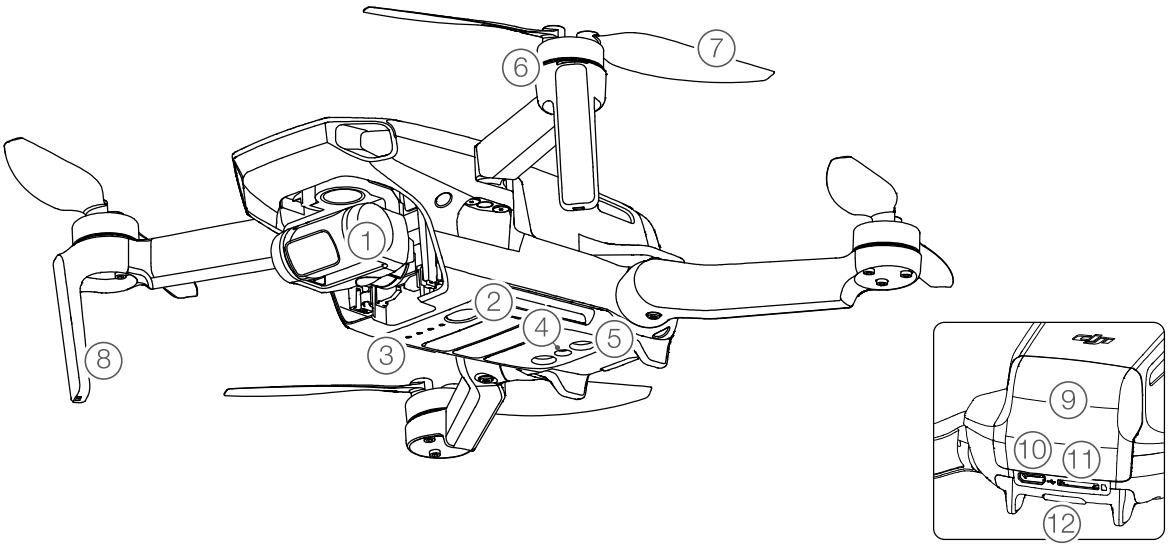
1. Unfold the mobile device clamps and the antennas.
2. Remove the control sticks from their storage slots on the remote controller and screw them into place.
3. Choose an appropriate remote controller cable based on the type of mobile device. A Lightning connector cable, Micro USB cable, and USB-C cable are included in the packaging. Connect the end of the cable with the DJI logo to the remote controller and the other end of the cable to your mobile device. Secure your mobile device by pushing both clamps inward.



⚠
- If a USB connection prompt appears when using an Android mobile device, select the option to charge only. Otherwise, it may result in connection failure.

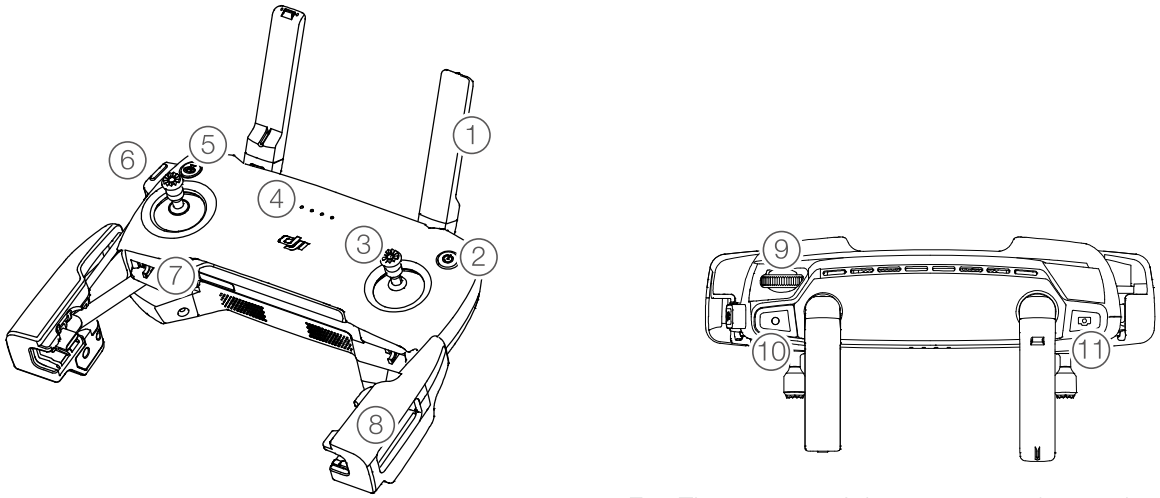
© 2019 DJI All Rights Reserved.

Aircraft Diagram



1. Gimbal and Camera
2. Power Button
3. Battery Level LEDs
4. Downward Vision System
5. Infrared Sensing System
6. Motors
7. Propellers
8. Antennas
9. Battery Compartment Cover
10. Charging Port (Micro USB)
11. microSD Card Slot
12. Aircraft Status Indicator

Remote Controller Diagram



1. Antennas
   Relay aircraft control and video wireless signals.
2. Power Button
   Press once to check the current battery level. Press once, then again, and hold to turn the remote controller on or off.
3. Control Sticks
   Use the control sticks to control the aircraft movements. Set the flight control mode in DJI Fly. The control sticks are removable and easy to store.
4. Battery Level LEDs
   Displays the current battery level of the remote controller.
5. Flight Pause and Return to Home (RTH) Button
   Press once to make the aircraft brake. If the aircraft is performing a QuickShot, Intelligent RTH, or auto landing, press once to make the

 © 2019 DJI All Rights Reserved.

aircraft exit the procedure and hover in place. Press and hold the button to initiate RTH. The aircraft returns to the last recorded Home Point. Press again to cancel RTH.

6. Video-Downlink/Power Port (Micro USB)
   Connect to a mobile device for video linking via the remote controller cable. Connect to the USB charger to charge the remote controller battery.
7. Control Sticks Storage Slots
   For storing the control sticks.
8. Mobile Device Clamps
   Used to securely mount your mobile device to the remote controller.
9. Gimbal Dial
   Controls the camera's tilt.
10. Record Button
    In video mode, press once to start recording. Press again to stop recording. In photo mode, press once to switch to video mode.
11. Shutter Button
    In photo mode, press once to take a photo according to the mode selected in DJI Fly. In video mode, press once to switch to photo mode.

Activation

Mavic Mini requires activation before using for the first time. After powering on the aircraft and remote controller, follow the on-screen instructions to activate Mavic Mini using DJI Fly. An internet connection is required for activation.

© 2019 DJI All Rights Reserved.

Aircraft

Mavic Mini contains a flight controller, video downlink system, vision system, propulsion system, and an Intelligent Flight Battery.

© 2019 DJI All Rights Reserved.

Aircraft

Mavic Mini contains a flight controller, video downlink system, vision system, propulsion system, and an Intelligent Flight Battery. Refer to the aircraft diagram in the Product Profile section for more information.

Flight Modes

Mavic Mini has three flight modes, plus a fourth flight mode that the aircraft switches to in certain situations:

Position Mode: Positon mode works best when the GPS signal is strong. The aircraft utilizes GPS and the Vision System to locate itself and stabilize. Intelligent Flight Mode is enabled in this mode. When the Downward Vision System is enabled and lighting conditions are sufficient, the maximum flight altitude angle is 20° and the maximum flight speed is 8 m/s.

The aircraft automatically changes to Attitude (ATTI) mode when the Vision System is unavailable or disabled and when the GPS signal is weak or the compass experiences interference. When the Vision System is unavailable, the aircraft cannot position itself or brake automatically, which increases the risk of potential flight hazards. In ATTI mode, the aircraft may be more easily affected by its surroundings. Environmental factors such as wind can result in horizontal shifting, which may present hazards, especially when flying in confined spaces.

Sport Mode: In Sport mode, the aircraft uses GPS and Vision System for positioning. In Sport mode, aircraft responses are optimized for agility and speed making it more responsive to control stick movements. The maximum flight speed is 13 m/s, maximum ascent speed is 4 m/s, and maximum descent speed is 3 m/s.

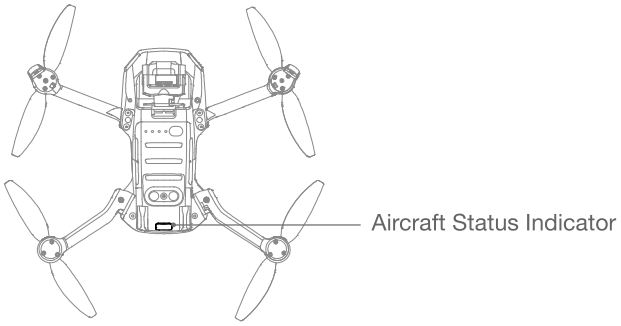
CineSmooth Mode: CineSmooth mode is based on Position mode and the flight speed is limited, making the aircraft more stable during shooting. The maximum flight speed is 4 m/s, maximum ascent speed is 1.5 m/s, and maximum descent speed is 1 m/s.

⚠
- The aircraft's maximum speed and braking distance significantly increase in Sport mode. A minimum braking distance of 30 m is required in windless conditions.
- Descent speed significantly increases in Sport mode. A minimum braking distance of 10 m is required in windless conditions.
- The aircraft's responsiveness significantly increases in Sport mode, which means a small control stick movement on the remote controller translates into the aircraft moving a large distance. Be vigilant and maintain adequate maneuvering space during flight.

© 2019 DJI All Rights Reserved.

Aircraft Status Indicator

The aircraft status indicator is located at the rear of the aircraft. It communicates the status of the aircraft's flight control system. Refer to the table below for more information about the aircraft status indicator.



Aircraft Status Indicator States

Normal States	Color	Blinking/Solid	Description of Aircraft State
R G Y	Alternating red, green, and yellow	Blinking	Powering on and performing self-diagonistic tests
Y	Yellow	Blinks four times	Warming up
G	Green	Blinking slowly	P-mode with GPS
G	Green	Periodically blinks twice	P-mode with Downward Vision System
Y	Yellow	Blinking slowly	No GPS, or Downward Vision System (ATTI mode)
G	Green	Blinking quickly	Braking
Warning States			
Y	Yellow	Blinking quickly	Remote controller signal lost
R	Red	Blinking slowly	Low battery
R	Red	Blinking quickly	Critically low battery
R	Red	Blinking	IMU error
R	Red	Solid	Critical error
R Y	Alternating red and yellow	Blinking quickly	Compass calibration required

Return to Home

The Return to Home (RTH) function brings the aircraft back to the last recorded Home Point. There are three types of RTH: Smart RTH, Low Battery RTH, and Failsafe RTH. This section describes these three types of RTH in detail. RTH will also be triggered if the video link is disconnected.

 © 2019 DJI All Rights Reserved.

	GPS	Description
Home Point		The default Home Point is the first location where your aircraft received strong GNSS signals (the white GNSS icon has at least four white bars). The aircraft status indicator blinks green quickly after the Home Point has been recorded.

Smart RTH

If the GPS signal is sufficiently strong, Smart RTH can be used to bring the aircraft back to the Home Point. Smart RTH is initiated either by tapping in DJI Fly or by pressing and holding the RTH button on the remote controller. Exit Smart RTH by tapping in DJI Fly or by pressing the RTH button on the remote controller.

Low Battery RTH

Low Battery RTH is triggered when the Intelligent Flight Battery is depleted to the point that the safe return of the aircraft may be affected. Return home or land the aircraft immediately when prompted.

DJI Fly displays a warning when the battery level is low. The aircraft will automatically return to the Home Point if no action is taken after a 10 second countdown.

The user can cancel RTH by pressing the RTH button on the remote controller. If RTH is cancelled following a low battery level warning, the Intelligent Flight Battery may not have enough power for the aircraft to land safely, which may lead to the aircraft crashing or being lost.

The aircraft will land automatically if the current battery level can only support the aircraft long enough to descend from its current altitude. The user cannot cancel the auto landing but can use the remote controller to alter the aircraft's direction during the landing process.

Failsafe RTH

If the Home Point was successfully recorded and the compass is functioning normally, Failsafe RTH automatically activates after the remote controller signal is lost for more than 11 seconds.

Other RTH Scenarios

If the video link signal is lost during flight while the remote controller is still able to control the movements of the aircraft, there will be a prompt to initiate RTH. RTH can be cancelled.

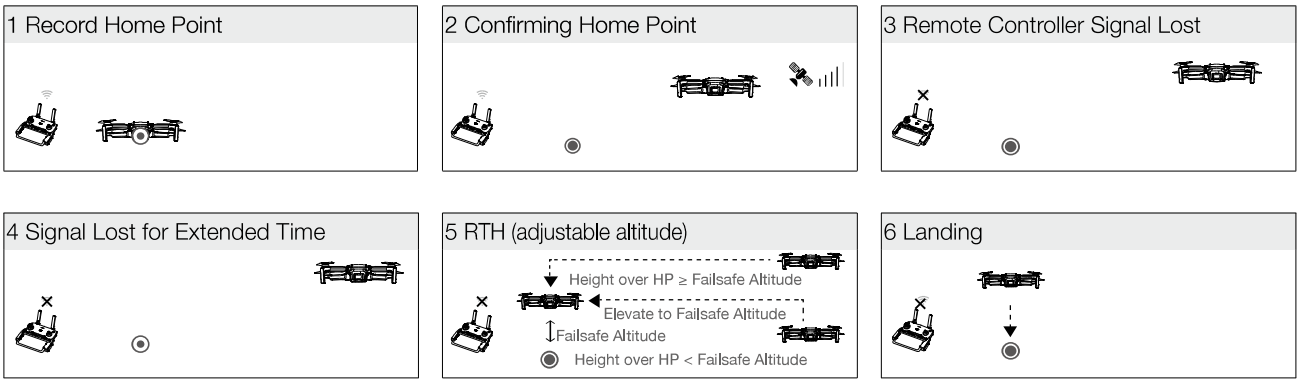
RTH Procedure

1. The Home Point is recorded.
2. RTH is triggered.
3. If the altitude is lower than 20 m, the aircraft ascends to the RTH altitude or 20 m, and then adjusts its orientation. If the altitude is higher than 20 m, the aircraft adjusts its orientation immediately.
4. a. If the aircraft is further than 20 m from the Home Point when the RTH procedure begins, it ascends to the preset RTH altitude and flies to the Home Point at a speed of 8 m/s. If the current altitude is higher than the RTH altitude, the aircraft flies to the Home Point at the current altitude.
   b. If the aircraft is less than 20 m from the Home Point when the RTH procedure begins, it lands immediately.

© 2019 DJI All Rights Reserved.

5. After reaching the Home Point, the aircraft lands and the motors stop.

FailSafe RTH Illustration



- The aircraft cannot return to the Home Point if the GPS signal is weak or unavailable. If the GPS signal become weak or unavailable after RTH is triggered, the aircraft will hover in place for a while, and then start landing.
- It is important to set a suitable RTH altitude before each flight. Launch DJI Fly, and then set the RTH altitude. In Smart RTH and Low Battery RTH, the aircraft automatically ascends to the RTH altitude. If the aircraft is at an altitude of 65 ft (20 m) or higher and has not yet reached the RTH altitude, the throttle stick can be moved to stop the aircraft from ascending. The aircraft will fly directly to the Home Point at its current altitude.
- During RTH, the aircraft's speed, altitude, and the orientation can be controlled using the remote controller or DJI Fly if the remote controller signal is normal, but the direction of flight cannot be controlled.
- GEO zones will affect RTH.
- The aircraft may not be able to return to a Home Point when the wind speed is too high. Fly with caution.

Landing Protection

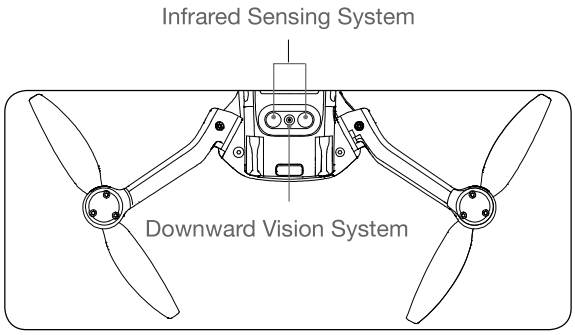
Landing Protection will activate during Smart RTH.

1. During Landing Protection, the aircraft will automatically detect and gently land on suitable ground.
2. If Landing Protection determines that the ground is not suitable for landing, Mavic Mini will hover and wait for pilot confirmation.
3. If Landing Protection is not operational, DJI Fly will display a landing prompt when Mavic Mini descends below 0.5 meters. Pull down on the throttle stick or use the auto landing slider to land.

 © 2019 DJI All Rights Reserved.

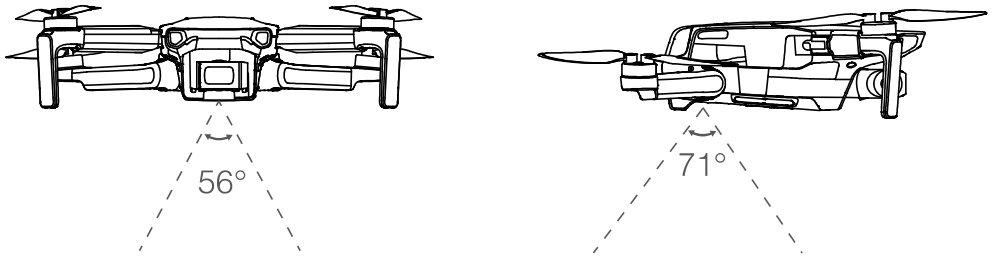
Vision System and Infrared Sensing System

Mavic Mini is equipped with a Downward Vision System and Infrared Sensing System. The Downward Vision System consists of one camera and the Infrared Sensing System consists of two 3D infrared modules. The Downward Vision System and Infrared Sensing System help the aircraft maintain its current position, hover in place more precisely, and to fly indoors or in other environments where GPS is unavailable.



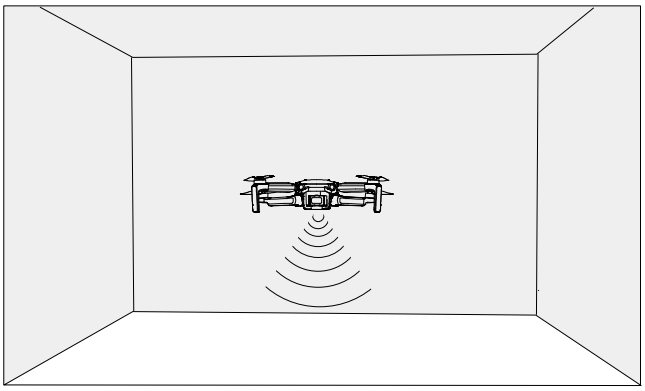
Detection Fields

The Downward Vision System works best when the aircraft is at an altitude of 0.5 to 10 m, and its operating range is 0.5 to 30 m.



Using the Vision System

When GPS is unavailable, the Downward Vision System is enabled if the surface has a discernable surface and sufficient light. The Downward Vision System works best when the aircraft is at an altitude of 0.5 to 10 m. If the aircraft's altitude is above 10 m, the Vision System may be affected, so extra caution is required.



© 2019 DJI All Rights Reserved.

Follow the steps below to use the Downward Vision System

1. Make sure the aircraft is on a flat surface. Power on the aircraft.
2. The aircraft hovers in place after takeoff. The aircraft status indicator blinks green twice, which indicates the Downward Vision System is working.

- The max hover altitude of the aircraft is 5 m if there is no GPS. The Vision System works best when the aircraft is at an altitude from 0.5 to 10 m. If the altitude of the aircraft is above 10 m, the Vision System may be affected, so extra caution is required.
- The Vision System may not function properly when the aircraft is flying over water or snow-covered areas.
- Note that the Vision System may not function properly when the aircraft is flying too fast. Fly with caution when flying at over 10 m/s (32.8 ft/s) at 2 m (6.6 ft) or over 5 m/s (16.4 ft) at 1 m (3.3 ft).
- The Vision System cannot work properly over surfaces that do not have clear pattern variations. The Vision System cannot work properly in any of the following situations. Operate the aircraft cautiously.
  a. Flying over monochrome surfaces (e.g., pure black, pure white, pure green).
  b. Flying over highly reflective surfaces.
  c. Flying over water or transparent surfaces.
  d. Flying over moving surfaces or objects.
  e. Flying in an area where the lighting changes frequently or drastically.
  f. Flying over extremely dark (< 10 lux) or bright (> 40,000 lux) surfaces.
  g. Flying over surfaces that strongly reflect or absorb infrared waves (e.g., mirrors).
  h. Flying over surfaces without clear patterns or texture.
  i. Flying over surfaces with repeating identical patterns or textures (e.g., tiles with the same design).
  j. Flying over obstacles with small surface areas (e.g., tree branches).
- Keep the sensors clean at all times. DO NOT tamper with the sensors. DO NOT use the aircraft in environment with dust and humidity. DO NOT obstruct the Infrared Sensing System.
- DO NOT fly on days that are rainy, smoggy, or if there is limited visibility.
- Check the following every time before takeoff:
  a. Make sure there are no stickers or any other obstructions over the Infrared Sensing and Vision System.
  b. If there is any dirt, dust, or water on the Infrared Sensing and Vision System, clean it with a soft cloth. Do not use any cleanser that contains alcohol.
  c. Contact DJI Support if there is any damage to the glass of the Infrared Sensing and Vision System.

Intelligent Flight Mode

Mavic Mini supports QuickShots Intelligent Flight Mode. QuickShots shooting modes include Dronie, Rocket, Circle, and Helix. Mavic Mini records a video according to the selected shooting mode and automatically generates videos approximately 15-second long. The video can be viewed, edited, or shared to social media from playback.


Dronie: The aircraft flies backward and ascends, with the camera locked on the subject.


Rocket: The aircraft ascends with the camera pointing downward.

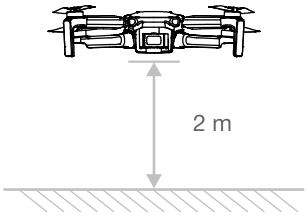

Circle: The aircraft circles around the subject.

 © 2019 DJI All Rights Reserved.

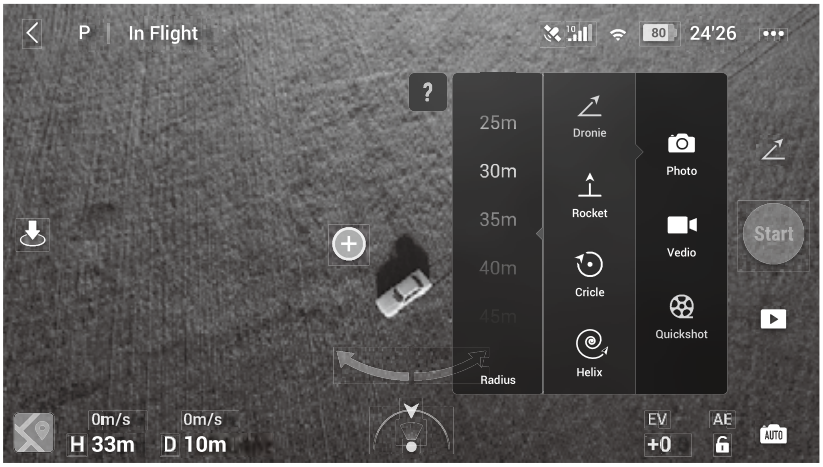
Helix: The aircraft ascends and spirals around the subject.

Using QuickShots

1. Make sure that the Intelligent Flight Battery is sufficiently charged. Take off and hover at least 6.6 ft (2 m) above the ground.



2. In DJI Fly, tap to select QuickShots and follow the prompts. Make sure that the user understands how to use the shooting mode and that there are no obstacles in the surrounding area.
3. Select your target subject in the camera view by tapping the circle on the subject or dragging a box around the subject. Choose a shooting mode and tap “Start” to begin recording. The aircraft flies back to its original position once shooting is finished.



4. Tap to access the video. The video can be edited and shared on social media after downloading to your phone.

Exiting QuickShots

Press the Flight Pause/RTH button once or tap the in DJI Fly to exit QuickShots. The aircraft will hover in place.

© 2019 DJI All Rights Reserved.

- Use QuickShots at locations that are clear of buildings and other obstacles. Make sure that there are no humans, animals, or other obstacles in the flight path.
- Pay attention to objects around the aircraft and use the remote controller to avoid accidents with the aircraft.
- DO NOT use QuickShots in any of the following situations:
  a. When the subject is blocked for an extended period or outside the line of sight.
  b. When the subject is more than 50 m away from the aircraft.
  c. When the subject is similar in color or pattern with the surroundings.
  d. When the subject is in the air.
  e. When the subject moves fast.
  f. The lighting is extremely low (< 300 lux) or high (> 10,000 lux).
- DO NOT use QuickShots in places that are close to buildings or where the GPS signal is weak. Otherwise, the flight path may be unstable.
- Make sure to follow local privacy laws and regulations when using QuickShots.

Flight Recorder

Flight data including flight telemetry, aircraft status information, and other parameters are automatically saved to the internal data recorder of the aircraft. The data can be accessed using DJI Assistant 2 for Mavic.

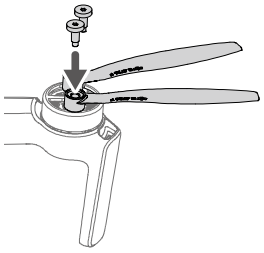
Propellers

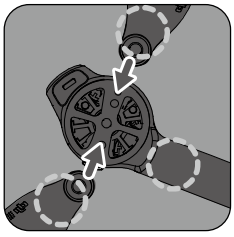
There are two types of Mavic Mini propellers, which are designed to spin in different directions. Marks are used to indicate which propellers should be attached to which motors. The two blades attached to one motor are the same.

Propellers	With marks	Without marks
Illustration		
Mounting Position	Attach to the motors of the arms with marks	Attach to the motors of the arms without marks

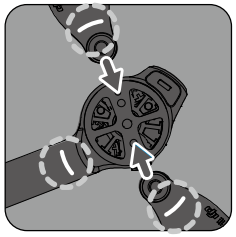
Attaching the Propellers

Attach the propellers with marks to the motors of the arm with marks and the unmarked propellers to the motors of the arm without marks. Use the screwdriver to mount the propellers. Make sure the propellers are secure.





Unmarked



Marks

 © 2019 DJI All Rights Reserved.

Detaching the Propellers

Use the screwdriver to detach the propellers from the motors.

- Propeller blades are sharp. Handle with care.
- The screwdriver is only used to mount the propellers. DO NOT use the screwdriver to disassemble the aircraft.
- If a propeller is broken, remove the two propellers and screws on the corresponding motor and discard them. Use two propellers from the same package. DO NOT mix with propellers from other packages.
- Only use official DJI propellers. DO NOT mix propeller types.
- Purchase the propellers separately if necessary.
- Make sure that the propellers are installed securely before each flight. Check if the screws on the propellers are tightened every 30 hours of flight time (approx. 60 flights).
- Make sure all propellers are in good condition before each flight. DO NOT use aged, chipped, or broken propellers.
- To avoid injury, stand clear of and do not touch propellers or motors when they are spinning.
- DO NOT squeeze or bend the propellers during transportation or storage.
- Make sure the motors are mounted securely and rotating smoothly. Land the aircraft immediately if a motor is stuck and unable to rotate freely.
- DO NOT attempt to modify the structure of the motors.
- DO NOT touch or let your hands or body come in contact with the motors after flight as they may be hot.
- DO NOT block any of the ventilation holes on the motors or the body of the aircraft.
- Make sure the ESCs sound normal when powered on.

Intelligent Flight Battery

The Mavic Mini Intelligent Flight Battery is a 7.2 V, 2400 mAh battery with smart charging and discharging functionality.

Battery Features

1. Balanced Charging: During charging, the voltages of the battery cells are automatically balanced.
2. Overcharge Protection: The battery stops charging automatically once fully charged.
3. Temperature Detection: In order to protect itself, the battery only charges when the temperature is between 41° and 104° F (5° and 40° C). Charging stops automatically if the temperature of the battery exceeds 122° F (0° C) during the charging process.
4. Overcurrent Protection: The battery stops charging if an excess current is detected.
5. Over-discharge Protection: Discharging stops automatically to prevent excess discharge when the battery is not in flight use. Over-discharge protection is not enabled when the battery is in flight use.
6. Short Circuit Protection: The power supply is automatically cut if a short circuit is detected.
7. Battery Cell Damage Protection: DJI Fly displays a warning prompt when a damaged battery cell is detected.
8. Hibernation Mode: If the battery cell voltage is lower than 3.0 V, the battery enters Hibernation mode to prevent over-discharge. Charge the battery to wake it from hibernation.

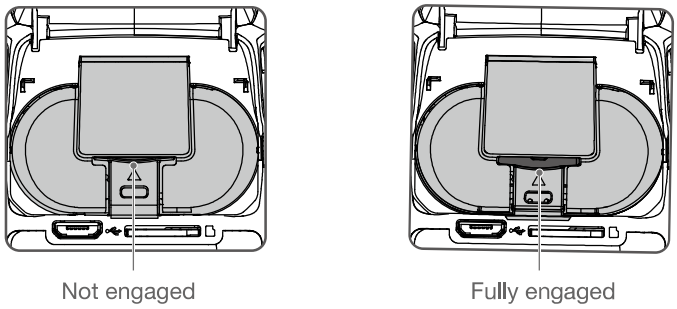
© 2019 DJI All Rights Reserved.

9. Communication: Information about the battery's voltage, capacity, and current is transmitted to the aircraft.

- Refer to the Mavic Mini Disclaimer and Safety Guidelines before use. Users take full responsibility for all operations and usage.
- The Mavic Mini Intelligent Flight Battery cannot discharge automatically. If the battery will not be used for more than 10 days, it is recommended to discharge the battery manually until the battery level is between 39% and 75%.
- Specifications of the Intelligent Flight Battery for the Japanese version are different. Refer to the Specifications section for more information. The battery features are the same for all versions of the Mavic Mini Intelligent Flight Battery.

Using the Battery

Insert the battery in the battery compartment and secure the battery clamp. A clicking sound indicates the battery is fully engaged. Make sure that the battery is fully inserted and the battery cover is secure in place.

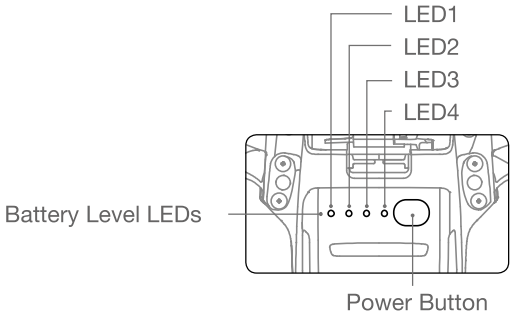


Press the battery clamp and detach the battery from the battery compartment to remove it.

- DO NOT detach the battery when the aircraft is powering on.
- Make sure that the battery is mounted firmly.

Checking Battery Level

Press the power button once to check the battery level.



Battery Level LEDs				
○ : LED is on.	☼ : LED is flashing.		○ : LED is off.	
LED1	LED2	LED3	LED4	Battery Level
○	○	○	○	battery level > 88%
○	○	○	☼	75% < battery level ≤ 88%

 © 2019 DJI All Rights Reserved.

●	●	●	○	63% < battery level ≤ 75%
○	●	☼	○	50% < battery level ≤ 63%
●	●	○	○	38% < battery level ≤ 50%
○	☼	○	○	25% < battery level ≤ 38%
●	○	○	○	13% < battery level ≤ 25%
☼	○	○	○	0% < battery level ≤ 13%

Powering On/Off

Press the power button once, then press again, and hold for two seconds to turn the battery on or off. The battery level LEDs display the battery level when the aircraft is powered on.

Press the power button once and the four battery level LEDs will blink for three seconds. If LED 3 and 4 blink simultaneously without pressing the power button, this indicates the battery is abnormal.

Low Temperature Notice

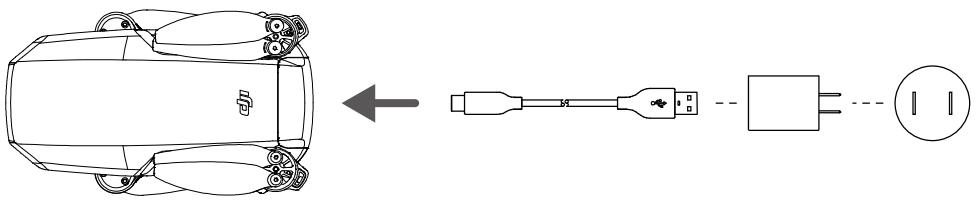
1. Battery capacity is significantly reduced when flying in low-temperature environments of 23° to 41° F (-5° to 5° C). It is recommended to hover the aircraft in place temporarily to heat the battery. Make sure to fully charge the battery before takeoff.
2. To ensure the optimal performance of the battery, keep the battery temperature above 68° F (20° C).
3. The reduced battery capacity in low-temperature environments reduces the wind speed resistance performance of the aircraft. Fly with caution.
4. Fly with extra caution at high sea levels.

⚠ In cold environments, insert the battery into the battery compartment and turn on the aircraft to warm up before taking off.

Charging the Battery

Fully charge the Intelligent Flight Battery before using for the first time.

1. Connect the USB charger to an AC power supply (100-240V, 50/60 Hz). Use a power adapter if necessary.
2. Attach the aircraft to the USB charger.
3. The battery level LEDs display the current battery level during charging.
4. The Intelligent Flight Battery is fully charged when all the battery level LEDs are on. Detach the USB charger when the battery is fully charged.



© 2019 DJI All Rights Reserved.

- The battery cannot be charged if the aircraft is powered on and the aircraft cannot be powered on during charging.
- DO NOT charge an Intelligent Flight Battery immediately after flight as the temperature may be too high. Wait until it cools down to room temperature before charging again.
- The charger stops charging the battery if the battery cell temperature is not within the operating range of 41° to 104° F (5° to 40° C). The ideal charging temperature is 71.6° to 82.4° F (22° to 28° C).
- The Battery Charging Hub (not included) can charge up to three batteries. Visit the official DJI Online Store to learn more.
- Fully charge the battery at least once every three months to maintain battery health.
- DJI does not take any responsibility for damage caused by third-party charger.

Discharging

- It is recommended to discharge the Intelligent Flight Batteries to 30% or lower. This can be done by flying the aircraft outdoors until there is less than 30% charge left.

Battery Level LEDs During Charging

The table below shows battery level during charging.

LED1	LED2	LED3	LED4	Battery Level
☼	☼	○	○	0% < battery level ⩽ 50%
☼	☼	☼	○	50% < battery level ⩽ 75%
☼	☼	☼	☼	75% < battery level < 100%
○	○	○	○	Fully charged

- The blinking frequency of the battery level LEDs will be different when using different USB charger. If the charging speed is fast, the battery level LEDs will blink quickly. If the charging speed is extremely slow, the battery level LEDs will blink slowly (once every two seconds). It is recommended to change the Micro USB cable or USB charger.
- If there is no battery in the aircraft, LED 3 and 4 will blink three times alternatively.
- The four LEDs blink simultaneously to indicate the battery is damaged.

Battery Protection Mechanisms

The battery LED indicator can display battery protection indications triggered by abnormal charging conditions.

Battery Protection Mechanisms					
LED1	LED2	LED3	LED4	Blinking Pattern	Battery Protection Item
○	☼	○	○	LED2 blinks twice per second	Overcurrent detected
○	☼	○	○	LED2 blinks three times per second	Short circuit detected
○	○	☼	○	LED3 blinks twice per second	Overcharge detected
○	○	☼	○	LED3 blinks three times per second	Over-voltage charger detected
○	○	○	☼	LED4 blinks twice per second	Charging temperature is too low

 © 2019 DJI All Rights Reserved.

○	○	○	☼	LED4 blinks three times per second	Charging temperature is too high

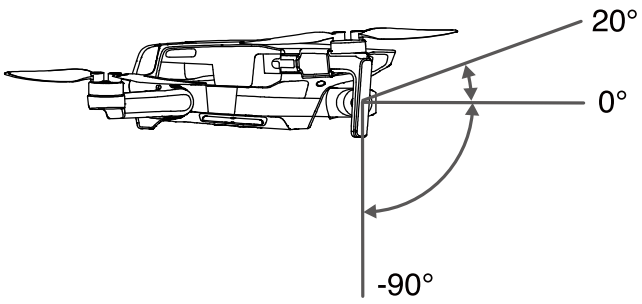
If the charging temperature protection is enabled, the battery will resume charging once the temperature has returned to within the allowable range. If one of the other battery protection mechanisms activate, in order to resume charging it is necessary to press the button to power off the battery, unplug the battery from the charger, and then plug it in again. If the charging temperature is abnormal, wait for the charging temperature to return to normal, and the battery will automatically resume charging without the need to unplug and plug in the charger again.

Gimbal and Camera

Gimbal Profile

Mavic Mini's 3-axis gimbal provides stabilization for the camera, allowing you to capture clear and stable images and video. Use the gimbal dial on the remote controller to control the camera's tilt. Alternatively, enter the camera view in DJI Fly. Press the screen until a circle appears and drag the circle up and down to control the camera's tilt.

The gimbal has a tilt range of -90˚ to +20˚ by enabling "Allow Upward Gimbal Rotation" in DJI Fly. The default control range is -90˚ to 0˚.



Gimbal Operation Modes

Two gimbal operation modes are available. Switch between the different operation modes in DJI Fly.

Follow Mode: The angle between the gimbal's orientation and aircraft front remains constant at all times.

FPV Mode: The gimbal synchronizes with the movement of the aircraft to provide a first-person flying experience.

⚠
- When the aircraft is powered on, do not tap or knock the gimbal. To protect the gimbal during takeoff, take off from open, flat surfaces.
- Precision elements in the gimbal may be damaged in a collision or impact, which may cause the gimbal to function abnormally.
- Avoid getting dust or sand on the gimbal, especially in the gimbal motors.
- A gimbal motor error may occur in the following situations:
  a. The aircraft is on uneven ground or the gimbal is obstructed.
  b. The gimbal experiences excessive external force, such as a collision.
- DO NOT apply external force to the gimbal after the gimbal is powered on. DO NOT add any extra payload to the gimbal as this may cause the gimbal to function abnormally or even lead to permanent motor damage.

© 2019 DJI All Rights Reserved.

- Make sure to remove the gimbal cover before powering on the aircraft. Also, make sure to mount the gimbal cover when the aircraft is not in use.
- Flying in heavy fog or clouds may make the gimbal wet, leading to temporary failure. The gimbal recovers full functionality once it is dry.

Camera Profile

Mavic Mini uses a 1/2.3" CMOS sensor camera, which can shoot up to 2.7K video and 12 MP photos, and supports shooting modes such as Single Shot and Interval.

The aperture of the camera is f/2.8 and can focus from 1 m to infinity.

- Make sure the temperature and humidity are suitable for the camera during usage and storage.
- Use a lens cleanser to clean the lens to avoid damage.
- DO NOT block any ventilation holes on the camera as the heat generated may damage the device and hurt the user.

Storing Photos and Videos

Mavic Mini supports the use of a microSD card to store your photos and videos. A UHS-I Speed Grade 3 rating microSD card is required due to the fast read and write speeds necessary for high-resolution video data. Refer to the Specifications section for more information about recommended microSD cards.

- Do not remove the microSD card from the aircraft while it is turned on. Otherwise, the microSD card may be damaged.
- To ensure the stability of the camera system, single video recordings are limited to 30 minutes.
- Check camera settings before use to ensure they are configured as desired.
- Before shooting important photos or videos, shoot a few images to test the camera is operating correctly.
- Photos or videos cannot be transmitted or copied from the camera if the aircraft powered off.
- Make sure to power off the aircraft correctly. Otherwise, your camera parameters will not be saved and any recorded videos may be damaged. DJI is not responsible for any failure of an image or video to be recorded or having been recorded in a way that is not machine-readable.

 © 2019 DJI All Rights Reserved.

Remote Controller

This section describes the features of the remote controller and includes instructions for controlling the aircraft and the camera.

© 2019 DJI All Rights Reserved.

Remote Controller

Remote Controller Profile

Built into the remote controll is DJI's enhanced Wi-Fi technology, offering 2.4 GHz and 5.8 GHz* transmission frequencies, a maximum transmission distance of 2.49 mi (4 km), and 720p video downlink from the aircraft to DJI Fly on your mobile device. The detachable control sticks make the remote controller easier to store. Refer to the remote controller diagram in the Product Profile section for more information.

The built-in battery has a capacity of 2600 mAh and a maximum run time of 4.5 hours when using an iOS device and 1 hour and 40 minutes when using an Android device. The remote controller charges the Android device with a charging ability of 500 mA@5V. The remote controller automatically charges Android devices.

* The MD1SD25 model remote controller can support both 2.4 GHz and 5.8 GHz. The MR1SS5 model remote controller only supports 5.8 GHz.

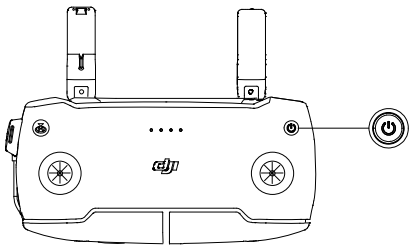
- Compliance Version: The remote controller is compliant with local regulations.
- Control Stick Mode: The control stick mode determines the function of each control stick movement. Three pre-programmed modes (Mode 1, Mode 2, and Mode 3) are available and custom modes can be configured in DJI Fly. The default mode is Mode 2.

Using the Remote Controller

Powering On/Off

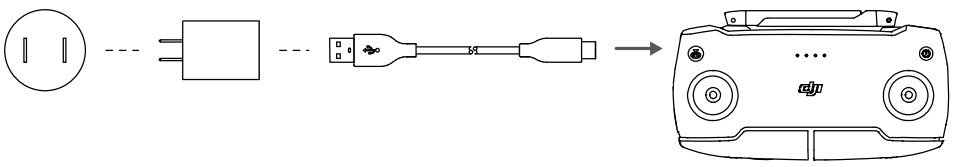
Press the power button once to check the current battery level.

Press once, then again and hold to turn the remote controller on or off. If the battery level is too low, recharge before use.



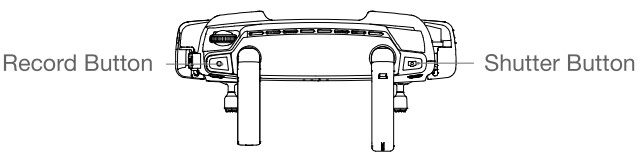
Charging the Battery

Use a Micro USB cable to connect the USB charger to the Micro USB port of the remote controller.



Controlling the Camera

1. Record Button: Press to start/stop recording (Video) or switch to video mode (Photo).
2. Shutter Button: Press to take photo (Photo) or switch to photo mode (Video).

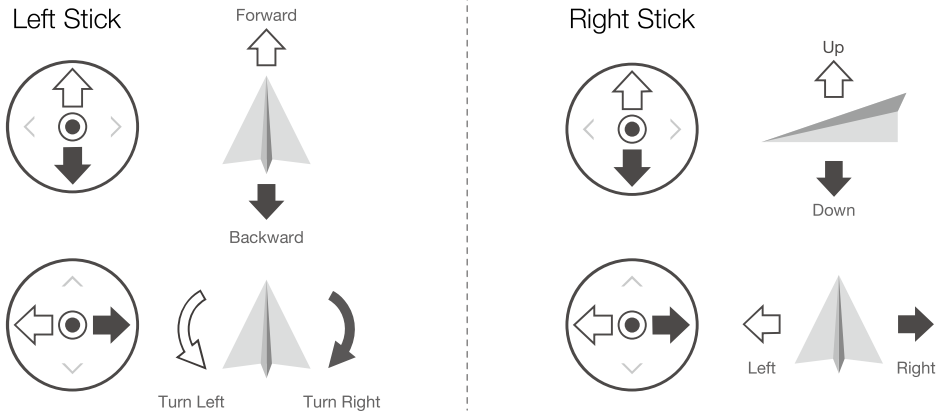


© 2019 DJI All Rights Reserved.

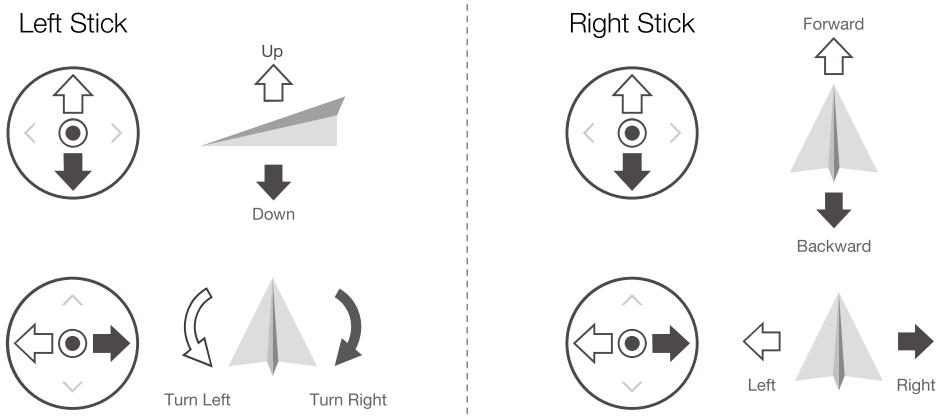
Controlling the Aircraft

Three pre-programmed modes (Mode 1, Mode 2, and Mode 3) are available and custom modes can be defined in the DJI Fly app. The default mode is Mode 2.

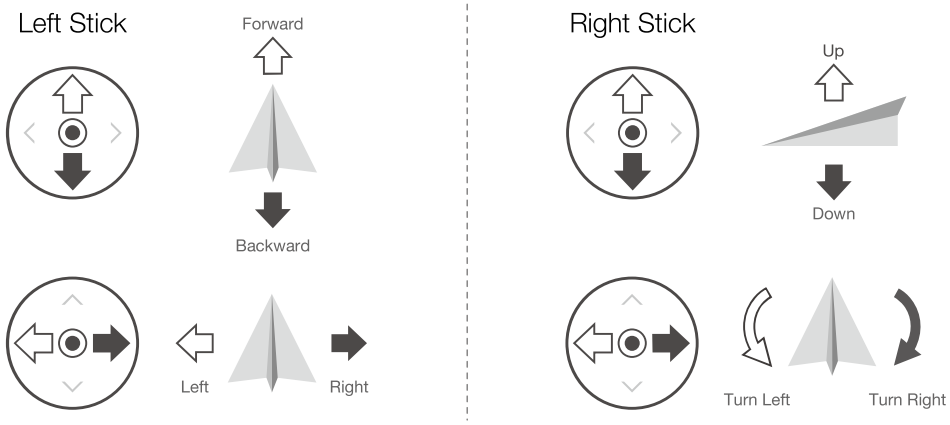
Mode 1



Mode 2

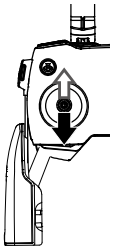
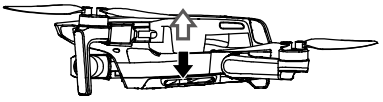
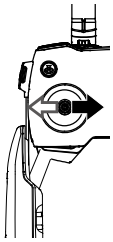
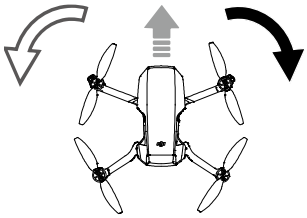
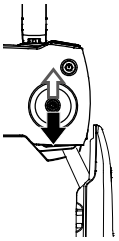
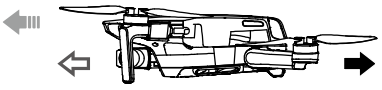
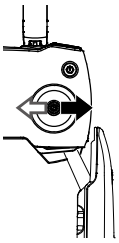
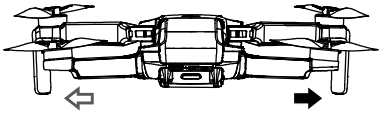


Mode 3



© 2019 DJI All Rights Reserved.

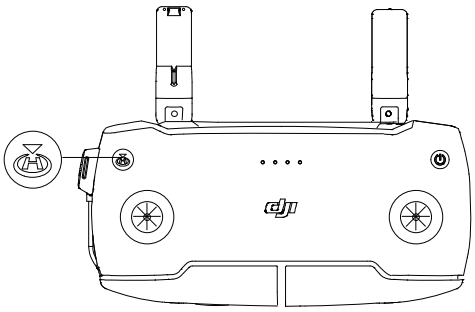
The figure below explains how to use each control stick, using Mode 2 as an example.

Remote Controller (Mode 2)	Aircraft (Indicates Nose Direction)	Remarks
		Moving the left stick up or down changes the aircraft's altitude. Push the stick up to ascend and down to descend. The more the stick is pushed away from the center position, the faster the aircraft will change altitude. Push the stick gently to prevent sudden and unexpected changes in altitude.
		Moving the left stick to the left or right controls the orientation of the aircraft. Push the stick left to rotate the aircraft counter-clockwise and right to rotate the aircraft clockwise. The more the stick is pushed away from the center position, the faster the aircraft will rotate.
		Moving the right stick up and down changes the aircraft's pitch. Push the stick up to fly forward and down to fly backward. The more the stick is pushed away from the center position, the faster the aircraft will move.
		Moving the right stick to the left or right changes the aircraft's roll. Push the stick left to fly left and right to fly right. The more the stick is pushed away from the center position, the faster the aircraft will move.

Flight Pause/RTH Button

Press once to make the aircraft brake and hover in place. If the aircraft is performing a QuickShot, RTH, or auto landing, press once to exit the procedure and hover in place.

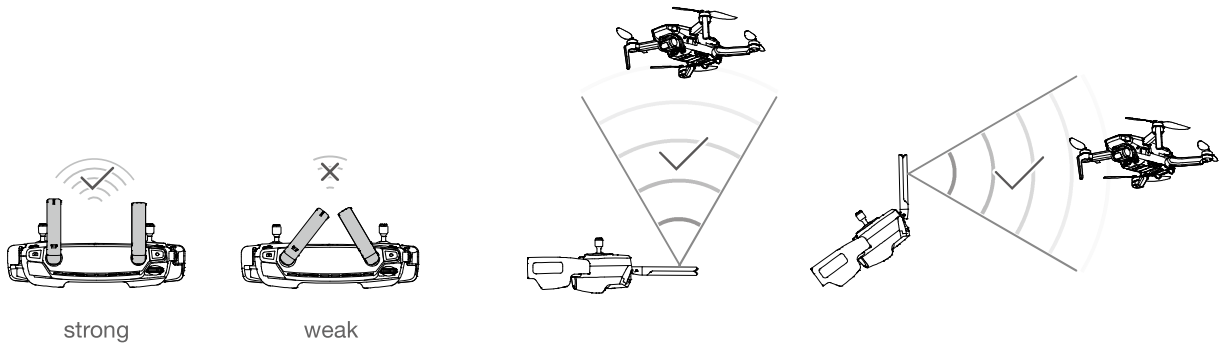
Press and hold the RTH button to start RTH. Press this button again to cancel RTH and regain control of the aircraft. Refer to the Return to Home section for more information about RTH.



 © 2019 DJI All Rights Reserved.

Optimal Transmission Zone

The signal between the aircraft and the remote controller is most reliable when the antennas are positioned in relation to the aircraft as depicted below.



Linking the Remote Controller

The remote controller is linked to the aircraft before delivery. Linking is only required when using a new remote controller for the first time. Follow these steps to link a new remote controller:

1. Power on the remote controller and the aircraft.
2. Launch DJI Fly. In camera view, tap the icon and select Shortcuts and Connect to Aircraft, or press and hold the power button of the remote controller for more than four seconds. The remote controller beeps continuously indicating it is ready to link.
3. Press and hold the power button of the aircraft for more than four seconds. The aircraft beeps once indicating it is ready to link. The aircraft beeps twice indicating linking is successfully.

- Make sure the remote controller is within 0.5 m of the aircraft during linking.
- The remote controller will automatically unlink from an aircraft if a new remote controller is linked to the same aircraft.

- Fully charge the remote controller before each flight.
- If the remote controller is powered on and not in use for five minutes, an alert will sound. After six minutes, the aircraft automatically powers off. Move the control sticks or press any button to cancel the alert.
- Adjust the mobile device clamp to ensure the mobile device is secure.
- Make sure the antennas of the remote controller are unfolded and adjusted to the proper position to achieve optimal transmission quality.
- Repair or replace the remote controller if damaged. A damaged remote controller antenna greatly decreases performance.
- Fully charge the battery at least once every three months to maintain battery health.

© 2019 DJI All Rights Reserved.

DJI Fly App

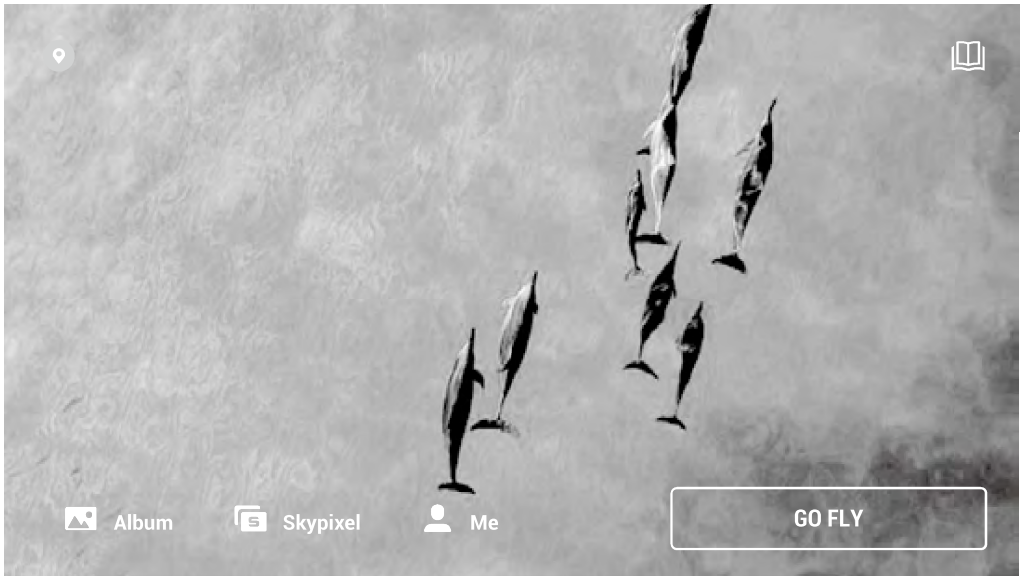
This section introduces the main functions of the DJI Fly app.

 © 2019 DJI All Rights Reserved.

DJI Fly App

Home

Launch DJI Fly and enter the home screen.



Academy

Tap the icon in the top right corner to enter Academy. Product tutorials, flight tips, flight safety, and manual documents can be viewed here.

Album

Allows you to view the DJI Fly and your phone's album. QuickShots videos can be viewed after downloading to your phone. Create contains Templates and Pro. Templates provides auto edit feature for imported footage. Pro allows you to edit the footage manually.

SkyPixel

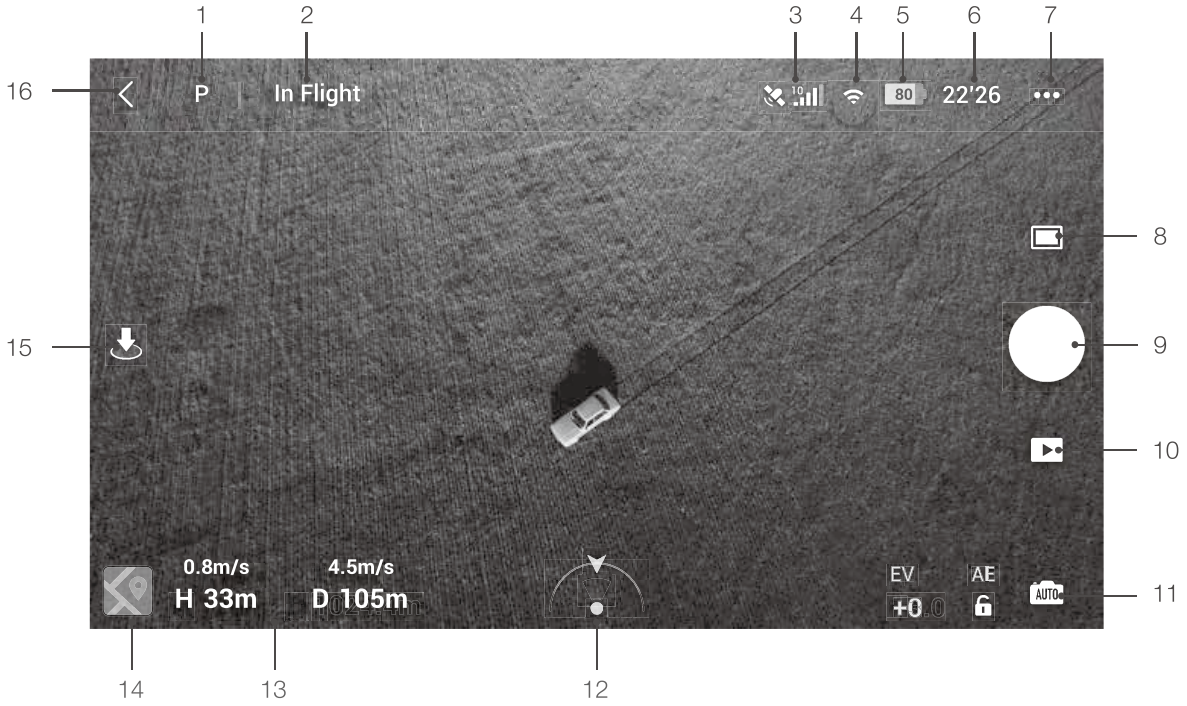
Enter SkyPixel to view videos and photos shared by users.

Profile

View account information, flight records, DJI forum, online store, Find My Drone feature, and other settings.

© 2019 DJI All Rights Reserved.

Camera View



1. Flight Modes

   P : Tap to switch Flight modes between Position, Sport, and CineSmooth mode.

2. System Status Bar

   In Flight : Indicates aircraft flight status and displays various warning messages.

3. GPS Status

   : Shows the current GPS signal strength.

4. Wi-Fi Strength

   : Displays the Wi-Fi strength between the aircraft and remote controller.

5. Battery Level

   80 : Shows the current battery level.

6. Battery Information

   22'26 : Displays battery information such as battery temperature, voltage, and flight time.

7. System Settings

   ••• : There are Safety, Control, Camera, Transmission and About.

   Safety

   Flight Protection: Max Altitude, Max Distance, Auto RTH Altitude settings, and Update Home Point.

   Sensors: View the IMU and compass status and start to calibrate if necessary.

   Advanced Settings including Emergency Propeller Stop and Payload mode. “Emergency Only” indicates that the motors can only be stopped mid-flight in an emergency situation such as if there is a collision, a motor has stalled, the aircraft is rolling in the air, or the aircraft is out of control and ascending or descending very quickly. “Anytime” indicates that the motors can be stopped mid-flight anytime once the user performs a combination stick command (CSC). Stopping the motors mid-flight will cause the aircraft to crash.

   If accessories are mounted to Mavic Mini, it is recommended to enable Payload mode for enhanced safety. After takeoff, Payload mode is enabled automatically if a payload is detected. Note that the Max Service Ceiling above Sea Level is 1500 m and the max flight speed is limited when Payload mode is enabled.
   The Find My Drone feature helps to find the location of the aircraft on the ground.

 © 2019 DJI All Rights Reserved.

Control

Aircraft Settings: Select Flight mode and Units settings.

Gimbal Settings: Switch gimbal mode and calibrate gimbal. Advanced gimbal settings include Pitch Speed, Pitch Smoothness, and Allow Upward Gimbal Rotation.

Remote Controller Settings: Stick mode settings and remote controller calibration.

Beginner Flight Tutorial: View the flight tutorial.

Connect to Aircraft: When the aircraft is not linked to the remote controller, tap to start linking.

Camera

Set the photo size and select the microSD card settings.

Advanced Settings such as Histogram, Gridlines, Overexposure Warning, and Anti-Flicker.

Tap Reset Camera Settings to restore all camera settings to default.

Transmission

Frequency and Channel mode settings.

About

View device information, firmware information, app version, battery version, and more.

8. Shooting Modes

Photo: Choose between Single Shot and Interval.

Video: Video resolution can be set to 2.7K 25/30 fps and 1080P 25/30/50/60 fps.

QuickShots: Choose from Dronie, Circle, Helix, and Rocket.

9. Shutter/Record Button

: Tap to start shooting photos or recording video.

10. Playback

: Tap to enter playback and preview photos and videos as soon as they are captured.

11. Camera Modes Switch

AUTO : Choose between Auto and Manual mode when in photo mode. In Manual mode, shutter and ISO can be set. In Auto mode, AE lock and EV can be set.

12. Aircraft Orientation

: Display the real-time orientation of the aircraft.

13. Flight Telemetry

Displays the distance between the aircraft and the Home Point, height from the Home Point, aircraft horizontal speed, and aircraft vertical speed.

14. Map

: Tap to view the map.

15. Auto Takeoff/Landing/Smart RTH

/ : Tap this icon. When the prompt appears, press and hold the button to initiate auto takeoff or landing.

: Tap to initiate Smart RTH and have the aircraft return to the last recorded Home Point.

16. Back

: Tap to return to the home screen.

© 2019 DJI All Rights Reserved.

⚠
- Make sure to fully charge your mobile device before launching DJI Fly.
- Mobile cellular data is required when using DJI Fly. Contact your wireless carrier for data charges.
- If you are using a mobile phone as your display device, DO NOT accept phone calls or use texting features during flight.
- Read all safety tips, warning messages, and disclaimers carefully. Be familiar with the related regulations in your area. You are solely responsible for being aware of all relevant regulations and flying in a way that is compliant.
  a. Read and understand the warning messages before using the Auto-take off and Auto-landing features.
  b. Read and understand the warning messages and disclaimer before setting the altitude beyond the default limit.
  c. Read and understand the warning messages and disclaimer before switching between flight modes.
  d. Read and understand the warning messages and disclaimer prompts near or in GEO zones.
  e. Read and understand the warning messages before using the Intelligent Flight Mode.
- Land your aircraft immediately at a safe location if a prompt to land appears in the app.
- Review all warning messages on the checklist displayed in the app before each flight.
- Use the in-app tutorial to practice your flight skills if you have never operated the aircraft or if you do not have sufficient experience to operate the aircraft with confidence.
- Cache the map data of the area where you intend to fly the aircraft by connecting to the internet before each flight.
- The app is designed to assist your operation. Use your discretion and DO NOT rely on the app to control your aircraft. Your use of the app is subject to DJI Fly Terms of Use and DJI's Privacy Policy. Read them carefully in the app before flying.

 © 2019 DJI All Rights Reserved.

Flight

This section describes safe flight practices and flight restrictions.

© 2019 DJI All Rights Reserved.

Flight

Once pre-flight preparation is complete, it is recommended to hone your flight skills and practice flying safely. Make sure that all flights are carried out in an open area. Refer to the Remote Controller and DJI Fly sections for information about using the remote controller and the app to control the aircraft.

Flight Environment Requirements

1. Do not use the aircraft in severe weather conditions including wind speeds exceeding 8 m/s, snow, rain, and fog.
2. Fly in open areas. Tall structures and large metal structures may affect the accuracy of the onboard compass and GPS system.
3. Avoid obstacles, crowds, high voltage power lines, trees, and bodies of water.
4. Minimize interference by avoiding areas with high levels of electromagnetism such as locations near power lines, base stations, electrical substations, and broadcasting towers.
5. Aircraft and battery performance are subject to environmental factors such as air density and temperature. Be careful when flying 9842 ft (3000 m) or more above sea level, since battery and aircraft performance may be reduced.
6. Mavic Mini cannot use GPS within the Polar Regions. Use the Downward Vision System when flying in such locations.

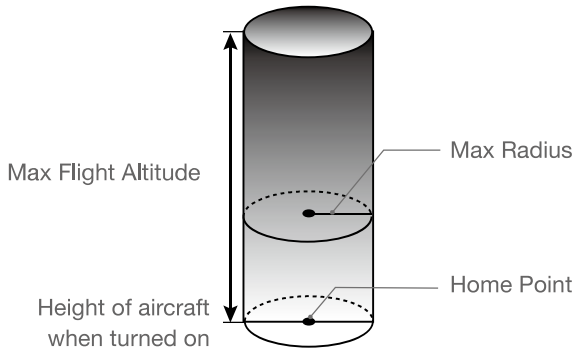
Flight Limits and GEO Zones

Unmanned aerial vehicle (UAV) operators should abide by the regulations from self-regulatory organizations such as the International Civil Aviation Organization, the Federal Aviation Administration, and local aviation authorities. For safety reasons, flight limits are enabled by default to help users operate this aircraft safely and legally. Users can set flight limits on height and distance.

Altitude limits, distance limits, and GEO zones function concurrently to manage flight safety when GPS is available. Only altitude can be limited when GPS is unavailable.

Flight Altitude and Distance Limits

The flight altitude and distance limits can be changed in DJI Fly. Based on these settings, the aircraft will fly in a restricted cylinder, as shown below:



 © 2019 DJI All Rights Reserved.

When GPS is available

	Flight Limits	DJI Fly App	Aircraft Status Indicator
Max Altitude	Aircraft's altitude cannot exceed the specified value	Warning: Height limit reached	Blinks green and red alternatively
Max Radius	Flight distance must be within the max radius	Warning: Distance limit reached	

Only Downward Vision System is available

	Flight Limits	DJI Fly App	Aircraft Status Indicators
Max Altitude	Height is restricted to 16 ft (5 m) when the GPS signal is weak and Downward Vision System is activated. Height is restricted to 98 ft (30 m) when the GPS signal is weak and Downward Vision System is inactive.	Warning: Height limit reached.	Blinks green and red alternatively
Max Radius	Blinks yellow		

- If the aircraft in a GEO zone and there is a weak or no GPS signal, the aircraft status indicator will glow red for five seconds every twelve seconds.
- If the aircraft reaches a limit, you can still control the aircraft, but you cannot fly it any further. If the aircraft flies out of the max radius, it will automatically fly back within range when the GPS signal is strong.
- For safety reasons, do not fly close to airports, highways, railway stations, railway lines, city centers, or other sensitive areas. Fly the aircraft only within your line of sight.

GEO Zones

All GEO zones are listed on the DJI official website at http://www.dji.com/flysafe. GEO zones are divided into different categories and include locations such as airports, flying fields where manned aircraft operate at low altitudes, borders between countries, and sensitive locations such as power plants.

There will be prompts in DJI Fly app alerting users of any nearby GEO zones.

Pre-Flight Checklist

1. Make sure the remote controller, mobile device, and Intelligent Flight Battery are fully charged.
2. Make sure the Intelligent Flight Battery and the propellers are mounted securely.
3. Make sure the aircraft arms are unfolded.
4. Make sure the gimbal and camera are functioning normally.
5. Make sure nothing is obstructing the motors and that they are functioning normally.
6. Make sure DJI Fly is successfully connected to the aircraft.
7. Make sure the camera lens and Vision System sensors are clean.

© 2019 DJI All Rights Reserved.

8. Use only genuine DJI parts or parts certified by DJI. Unauthorized parts or parts from non-DJI certified manufacturers may cause system malfunctions and compromise safety.

Auto Takeoff/Landing

Auto Takeoff

1. Launch DJI Fly and enter the camera view.
2. Complete all steps in the pre-flight checklist.
3. Tap . If conditions are safe for takeoff, press and hold the button to confirm.
4. The aircraft will take off and hover 3.9 ft (1.2 m) above the ground.

⚠
- The aircraft status indicator shows whether the aircraft is using GPS and/or the Downward Vision System for flight control. It is recommended to wait until the GPS signal is strong before using auto takeoff.
- DO NOT takeoff from an moving surface, such as a moving boat or vehicle.

Auto Landing

Use auto landing when the aircraft status indicator blinks green.

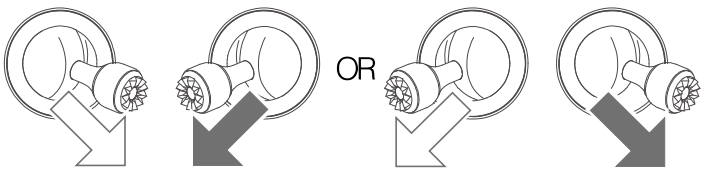
1. Tap . If conditions are safe to land, press and hold the button to confirm.
2. Auto landing can be cancelled by tapping .
3. If the Vision System is working normally, Landing Protection will be enabled.
4. Motors stops after landing.

⚠ Choose the proper place for landing.

Starting/Stopping the Motors

Starting the Motors

A Combination Stick Command (CSC) is used to start the motors. Push both sticks to the bottom inner or outer corners to start the motors. Once the motors have started spinning, release both sticks simultaneously.

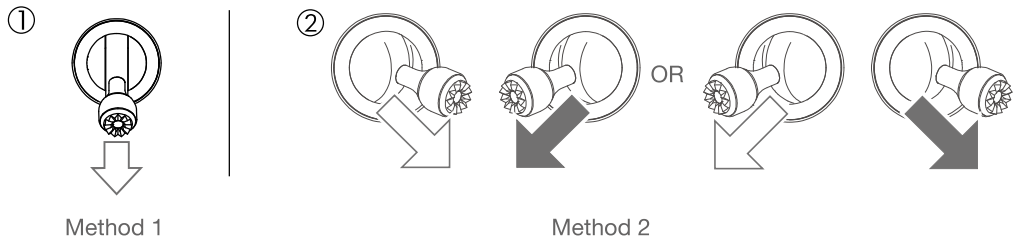


Stopping the Motors

There are two methods to stop the motors.

1. Method 1: When the aircraft has landed, push and hold the left stick down. The motors will stop after three seconds.
2. Method 2: When aircraft has landed, push the left stick down, then conduct the same CSC that was used to start the motors, as described above. The motors will stop immediately. Release both sticks once the motors have stopped.

 © 2019 DJI All Rights Reserved.



Stopping Motors Mid-flight

Stopping motors mid-flight will cause the aircraft to crash. The motors should only be stopped mid-flight in an emergency situation such as if a collision has occurred or if the aircraft is out of control and is ascending/descending very quickly, rolling in the air, or if a motor has stalled. To stop the motors mid-flight use the same CSC that was used to start the motors.

Flight Test

Takeoff/Landing Procedures

1. Place the aircraft in an open, flat area with the aircraft status indicator facing towards you.
2. Turn on the aircraft and the remote controller.
3. Launch DJI Fly and enter the camera view.
4. Wait until the aircraft status indicator blinks green indicating that the Home Point has been recorded and it is now safe to fly.
5. Gently push the throttle stick to take off or use auto-takeoff.
6. Pull the throttle stick or use auto-landing to land the aircraft.
7. After landing, push the throttle stick down and hold. The motors stop after three seconds.
8. Turn off the aircraft and remote controller.

Video Suggestions and Tips

1. The pre-flight checklist is designed to help you fly safely and to ensure that you can shoot video during flight. Go through the full pre-flight checklist before each flight.
2. Select the desired gimbal operation mode in DJI Fly.
3. Shoot video when flying in P-mode or C-mode.
4. DO NOT fly in bad weather conditions such as when it is raining or windy.
5. Choose the camera settings that best suit your needs.
6. Perform flight tests to establish flight routes and to preview scenes.
7. Push the control sticks gently to keep the aircraft movement smooth and stable.

© 2019 DJI All Rights Reserved.

Appendix

 © 2019 DJI All Rights Reserved.

Appendix

Specifications

Aircraft	
Takeoff Weight	249 g / 199 g (JP version)
Dimensions (L×W×H)	Folded: 140×82×57 mm Unfolded: 160×202×55 mm Unfolded (with propellers): 245×290×55 mm
Diagonal Distance	213 mm
Max Ascent Speed	4 m/s (S Mode) 2 m/s (P Mode) 1.5 m/s (C Mode)
Max Descent Speed	3 m/s (S Mode) 1.8 m/s (P Mode) 1 m/s (C Mode)
Max Speed (near sea level, no wind)	13 m/s (S Mode) 8 m/s (P Mode) 4 m/s (C Mode)
Max Service Ceiling Above Sea Level	3000 m
Max Flight Time	30 mins (measured while flying at 14 kph in windless conditions) 18 mins for JP version (measured while flying at 12 kph in windless conditions)
Max Wind Speed Resistance	8 m/s (Scale 4)
Max Tilt Angle	30° (S Mode) 20° (P Mode) 20° (C Mode)
Max Angular Velocity	150°/s (S Mode) 130°/s (P Mode) 30°/s (C Mode)
Operating Temperature Range	0° to 40° C (32° to 104° F)
GNSS	GPS+GLONASS
Operating Frequency	Model MT1SS5: 5.725-5.850 GHz Model MT1SD25: 2.400-2.4835 GHz, 5.725-5.850 GHz
Transmission Power (EIRP)	Model MT1SS5 5.8 GHz: <30 dBm (FCC); <28 dBm (SRRC) Model MT1SD25 2.4 GHz: <19 dBm (MIC/CE) 5.8 GHz: <14 dBm (CE)

© 2019 DJI All Rights Reserved.

Hovering Accuracy Range	Vertical: ±0.1 m (with Vision Positioning), ±0.5 m (with GPS Positioning) Horizontal: ±0.3 m (with Vision Positioning), ±1.5 m (with GPS Positioning)
Gimbal	
Mechanical Range	Tilt: -110° to +35° Roll: -35° to +35° Pan: -20° to +20°
Controllable Range	Tilt: -90° to 0° (default setting), -90° to +20° (extended)
Stabilization	3-axis (tilt, roll, pan)
Max Control Speed (tilt)	120°/s
Angular Vibration Range	±0.01°
Sensing System	
Downward	Operating Range: 0.5-10 m
Operating Environment	Non-reflective, discernable surfaces with diffuse reflectivity of >20% Adequate lighting of lux>15
Camera	
Sensor	1/2.3” CMOS Effective Pixels: 12 MP
Lens	FOV: 83° 35 mm Format Equivalent: 24 mm Aperture: f/2.8 Focus Range: 1 m to ∞
ISO	Video: 100-3200 (Auto) Photo: 100-3200
Shutter Speed	Electronic Shutter: Video: 1/8000-1/fps (Auto) Photo: 4-1/8000 s (Manual), 1-1/8000 s (Auto)
Still Image Size	4:3: 4000×3000 16:9: 4000×2250
Still Photography Modes	Single shot Interval: 2/3/5/7/10/15/20/30/60 s
Video Resolution	2.7K: 2720×1530 25/30 p FHD: 1920×1080 25/30/50/60 p
Max Video Bitrate	40 Mbps
Supported File System	FAT32 (≤ 32 GB) exFA (> 32 GB)
Photo Format	JPEG
Video Format	MP4 (H.264/MPEG-4 AVC)
Remote Controller	
Operating Frequency	Model MR1SS5: 5.725 - 5.850 GHz Model MR1SD25: 2.400 - 2.4835 GHz, 5.725 - 5.850 GHz

 © 2019 DJI All Rights Reserved.

Max Transmission Distance (unobstructed, free of interference)	Model MR1SS5: 5.8 GHz: 4000 m (FCC); 2500 m (SRRC) ModelMR1SD25: 2.4 GHz: 2000 m (MIC/CE) 5.8 GHz: 500 m (CE)
Operating Temperature Range	0° to 40° C (32° to 104° F)
Transmitter Power (EIRP)	ModelMR1SS5: 5.8 GHz: <30 dBm (FCC); <28 dBm (SRRC) ModelMR1SD25: 2.4 GHz: <19 dBm (MIC/CE) 5.8 GHz: <14 dBm (CE)
Battery Capacity	2600 mAh
Operating Current/Voltage	1200 mA 3.6 V (Android) 450 mA 3.6 V (iOS)
Supported Mobile Device Size	Max length: 160 mm Max thickness: 6.5 - 8.5 mm
Supported USB Port Types	Lightning, Micro USB (Type-B), USB-C
Video Transmission System	Enhanced Wi-Fi
Live View Quality	Remote Controller: 720p@30fps
Max. Bitrate	4 Mbps
Latency (depending on environmental conditions and mobile device)	170 - 240 ms
Charger	
Input	100 - 240V, 50/60 Hz, 0.5A
Output	12V 1.5A / 9V 2A / 5V 3A
Rated Power	18 W
Intelligent Flight Battery (General Version)	
Battery Capacity	2400 mAh
Voltage	7.2 V
Max Charging Voltage	8.4 V
Battery Type	Li-ion 2S
Energy	17.28 Wh
Weight	100 g
Charging Temperature Range	5° to 40° C (41° to 104° F)
Max Charging Power	24 W
Intelligent Flight Battery (JP Version)	
Capacity	1100 mAh
Voltage	7.6 V
Max Charging Voltage	8.7 V
Battery Type	LiPo 2S
Energy	8.36 Wh
Weight	50 g
Charging Temperature Range	5° to 40° C (41° to 104° F)

© 2019 DJI All Rights Reserved.

Max Charging Power	18 W
App	
App	DJI Fly
Required Operating System	iOS v10.0.2 or later; Android v6.0 or later
SD Cards	
Supported SD Cards	Requires UHS-I Speed Grade 3 rating microSD card
Recommended microSD Cards	16GB: SanDisk Extreme, Lexar 633x 32GB: Samsung PRO Endurance, Samsung EVO Plus, SanDisk Industrial, SanDisk Extreme V30 A1/A2, SanDisk Extreme PRO V30 A1/A2, Lexar 633x, Lexar 667x 64GB: Samsung PRO Endurance, Samsung EVO Plus, SanDisk Extreme V30 A1, Lexar 633x, Lexar 667x, Lexar 1000x, Toshiba Exceria M303 V30 A1, Netac PRO V30 A1 128GB: Samsung PRO Plus, Samsung EVO Plus, SanDisk Extreme V30 A1, SanDisk Extreme Plus V30 A1/A2, Lexar 633x, Lexar 667x, Lexar 1000x, Toshiba Exceria M303 V30 A1, Netac Pro V30 A1 256GB, SanDisk Extreme V30 A1

- Aircraft takeoff weight includes battery, propellers, and a microSD card.
- Registration not required in some countries and regions. Check local rules and regulations before use.
- These specifications have been determined through tests conducted with the latest firmware. Firmware updates can enhance performance. It is highly recommended to update to the latest firmware.

Calibrating the Compass

It is recommended that the compass is calibrated in any of the following situations when flying outdoors:

1. Flying at a location further than 31 miles (50 km) away from the location the drone was last flown.
2. The aircraft has not been flown for more than 30 days.
3. A compass interference warning appears in DJI Fly and/or the aircraft status indicator blinks red and yellow alternatively.

- DO NOT calibrate the compass in locations where magnetic interference may occur, such as close to magnetite deposits or large metallic structures such as parking structures, steel reinforced basements, bridges, cars, or scaffolding.
- DO NOT carry objects (such as mobile phones) that contain ferromagnetic materials near the aircraft during calibration.
- It is not necessary to calibrate the compass when flying indoors.

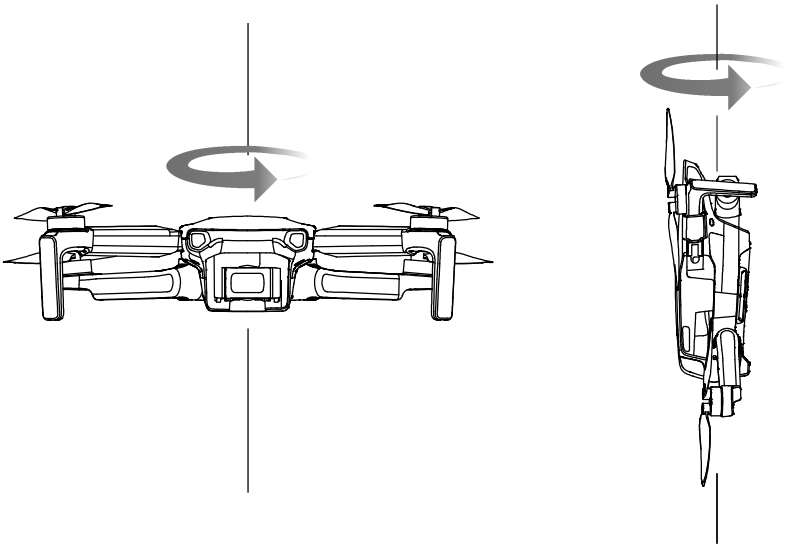
Calibration Procedure

Choose an open area to carry out the following procedure.

1. Tap the System Settings in DJI Fly, select “Control” and then select “Calibrate”, and follow the on-screen instructions. The aircraft status indicator blinks yellow, indicating calibration has start.

 © 2019 DJI All Rights Reserved.

2. Hold the aircraft horizontally and rotate it 360 degrees. The aircraft status indicator will turn solid green.
3. Hold the aircraft vertically and rotate it 360 degrees around a vertical axis.
4. If the aircraft status indicator blinks red, the calibration has failed. Change your location and try the calibration procedure again.



- If the aircraft status indicator blinks red and yellow alternatively after calibration is completed, this indicates that the current location is not suitable for flying the aircraft, due to the level of magnetic interference. Change your location.

- A prompt will appear in DJI Fly if compass calibration is required before takeoff.
- The aircraft can take off immediately once calibration is complete. If you wait more than three minutes to take off after calibration, you may need to repeat the calibration process.

© 2019 DJI All Rights Reserved.

Firmware Update

Use DJI Fly or DJI Assistant 2 for Mavic to update the aircraft and the remote controller firmware.

Using DJI Fly

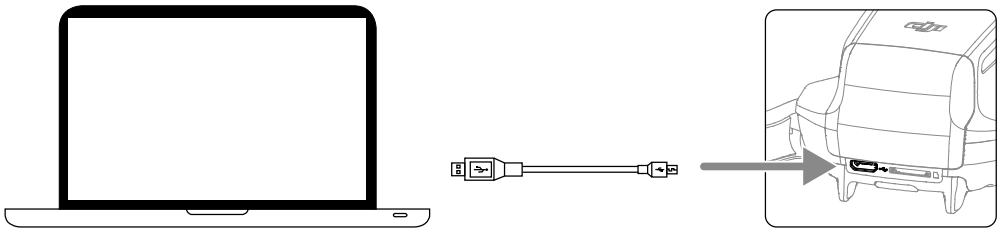
When you connect the aircraft and remote controller to DJI Fly, you will be notified if a new firmware update is available. To start updating, connect your mobile device to the internet and follow the on-screen instructions. Note that you cannot update the firmware if the remote controller is not linked to the aircraft.

Using DJI Assistant 2 for Mavic

Update the aircraft and remote controller firmware separately using DJI Assistant 2 for Mavic.

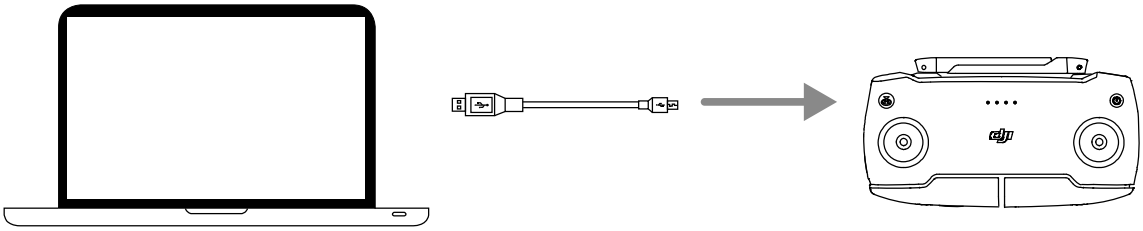
The Micro USB port is used when connecting the aircraft to a computer to update firmware. Follow the instructions below to update the aircraft firmware through DJI Assistant 2 for Mavic:

1. Launch DJI Assistant 2 for Mavic and log in with your DJI account.
2. Power on the aircraft, and then connect the aircraft to a computer via the Micro USB port using a Micro USB cable within 20 seconds.
3. Select “Mavic Mini” and click on Firmware Updates on the left panel.
4. Select the firmware version that you wish to update to.
5. Wait for the firmware to download. The firmware update will start automatically.
6. The aircraft will be powered off automatically after the firmware update is complete.



Follow the instructions below to update the aircraft firmware through DJI Assistant 2 for Mavic:

1. Launch DJI Assistant 2 for Mavic and log in with your DJI account.
2. Power on the remote controller, and then connect to a computer via the Micro USB port using a Micro USB cable.
3. Select “Mavic Mini remote controller” and click on Firmware Updates on the left panel.
4. Select the firmware version that you wish to update to.
5. Wait for the firmware to download. The firmware update will start automatically.
6. Wait for the firmware update to be completed.



 © 2019 DJI All Rights Reserved.

⚠
- Make sure to follow all the steps to update firmware. Otherwise, the update may fail.
- The firmware update will take around 10 minutes. It is normal that the gimbal goes limp, aircraft status indicators blink, and the aircraft reboots. Wait patiently until the update is complete.
- Make sure the computer has access to the internet.
- Before performing an update, make sure the Intelligent Flight Battery and the remote controller have at least 30% power.
- Do not disconnect the device from the computer during an update.
- The remote controller may become unlinked from the aircraft after updating. Relink the remote controller and aircraft. Note that the update may reset various main controller settings, such as the RTH altitude and the maximum flight distance, to default settings. Before updating, take note of your preferred DJI Fly settings, and readjust them after the update.

After-sales information

Visit https://www.dji.com/support to learn more about after-sales service policies, repair services, and support.

© 2019 DJI All Rights Reserved.

DJI Support
http://www.dji.com/support

This content is subject to change.

Download the latest version from
http://www.dji.com/mavic-mini

If you have any questions about this document, please contact DJI by sending a message to **DocSupport@dji.com**.

MAVIC is a trademark of DJI.
Copyright © 2019 DJI All Rights Reserved.

Training Manual (Technical Manuals)

LU3: GIS Manual for Urban Planning

Project on Capacity Development for Urban Planning in Sri Lanka

GIS Manual for Urban Planning

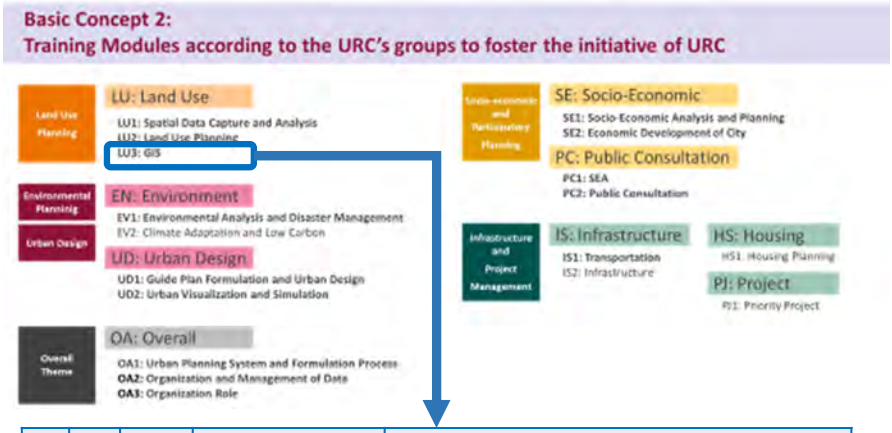
March 2025

Background of the Manual

This GIS manual was compiled by integrating the materials used in the GIS training carried out as part of the CITY-UP project. The content can be broadly divided into two categories, in line with the CITY-UP project training modules. The first is about creating GIS data that can be used for spatial analysis (Module LU3-1), and the second is about the various spatial analyses that can be used for urban planning (Module LU3-2).

This manual also touches on the use of various open data.

CITY-UP Training Module



LU3	**GIS**	**LU3-1**	**GIS and Spatial Data Construction**	This module focuses on the method of spatial data construction, containing database schema concept, coding rules, data editing, error checking, and cleaning with open-source GIS software "QGIS"
		LU3-2	**Spatial Data Analysis by GIS**	Several basic and advanced techniques of GIS is learnt for urban planning for both vector and raster analysis. The aim is to understand how GIS technology can be used to efficiently conduct analyses related to urban planning, including land use, environmental, and other possible analysis, etc.

Overview of the Manual (1)

Click on the "Title of the material" in the table below to jump to the start page of the corresponding material.

No.	Module	Month/year of the training	Title of the material	Contents covered	Slide No.
1	LU3-1	Mar-2023	GIS and Spatial data construction (1)	・QGIS in general ・Access to open data via QGIS and Web site ・GIS data editing (process, tools in QGIS)	5
2	LU3-1	Mar-2023	GIS and Spatial data construction (2)	・GIS data error check ・Advanced editing tools in QGIS ・data error cleaning tool in QGIS (v.clean) ・Layout map in QGIS	37
3	LU3-2	Mar-2023	Introduction of Geographical Modeler in QGIS	・Overview of Geographical Modeler in QGIS ・General Steps to Prepare Geographical Model	70
4	LU3-2	Mar-2023	Example of GIS usage in Planning Activities	・Example of0 development potential nalysis (Raster model) ・Example of development potential Analysis (Vector model) ・Example as Assessment Tool for SEA	79
5	LU3-1/3-2	Oct-2023	Basic Data Set for Urban Planning & Standardization of Data	・Concept of basic dataset for urban planning ・Sample dataset prodiced by Kandy master plan ・Standardization of land use category	130
6	LU3-2	Oct-2023	Network Analysis with ArcMap	・Network analysis in General (for ArcMap 10.x) ・Types of network analysis ・Building Network Dataset ・Workflow of network analysis ・Route analyis (E) ・Service area analysis (E)	146
7	LU3-2	Aug-2024	ArcGIS Pro General	・ArcGIS Pro in General ・Differences: ArcGIS Pro vs. ArcMap ・Create map with ArcGIS Pro ・3D visualization wihtout extension ・Utilization of online resouces in ArcGIS Pro	183

Overview of the Manual (2)

Click on the "Title of the material" in the table below to jump to the start page of the corresponding material.

No.	Module	Month/ year of the training	Title of the material	Contents covered	Slide No.
8	LU3-2	Aug-2024	ArcGIS Pro Spatial Analyst extension	・Spatial Analyst in General ・Understand Interpolation & Surface Analysis ・Conversion from vector data to Raster data ・Understand Reclassification & Raster Overlay ・Collection of Sentinel -2 data and pre-process data for Raster analysis ・Calculate NDVI and NDWI ・Analyze Unsuitable Areas for Development	203
9	LU3-2	Aug-2024	ArcGIS Pro Network Analyst extension	・Network Analyst in General ・Available analysis tools ・Typical Usage of Network Analyst in Urban Planning(E) ・Building Network Dataset	229
10	LU3-2	Mar-2025	Road Density Analysis	・Road density Analysis ・Analyze relationship between Road density and Land cover ・Analyze relationship between Road density and Population	269
11	LU3-2	Mar-2025	Urban area estimation	・Urban area estimation (Utilize land use data by UDA) ・Urban area estimation (Utilize Global cover data by ESA) ・Urban area estimation (Utilize building footprint data by UDA) ・Urban area estimation (Utilize Global human settlement layer data by Copernicus Project under Europian Commission)	300
12	LU3-2	Mar-2025	3D Visualization	・3D visualization with ArcGIS Pro ・Utilization of 3D base map ・Create 3D map of Battaramulla cluster 1 area (E) ・Introduction of procesural symbols for 3D seane	311
13	LU3-2	Mar-2025	Accessibility Analysis	・Accessibility analysis with ArcGIS Pro and Network analyst extension ・Review of building network dataset ・Estimate service area population from proposed LRT station (E)	324

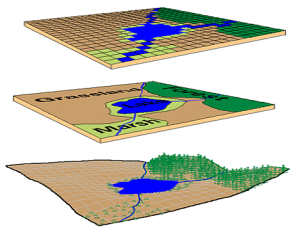
PPT. No.1

Module LU3-1: GIS and Spatial Data Construction

GIS and Spatial data construction (1)

Project on Capacity Development for Urban Planning

The Project Capacity Development for Urban Planning









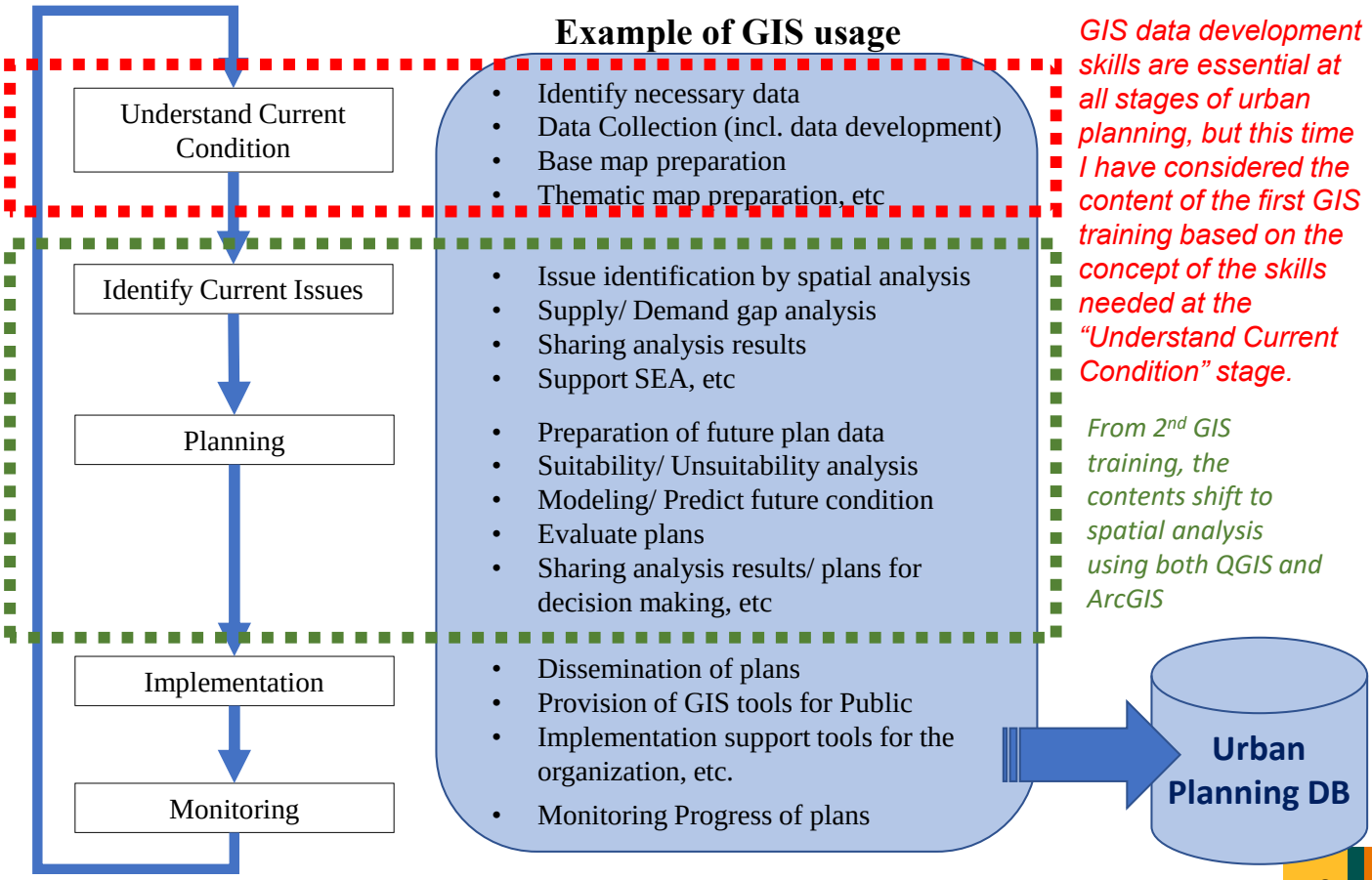
LU3-1:
GIS and Spatial Data Construction
Contents 1 to 4
Feb.- Mar. 2023

Outline of Module LU3: GIS

Major Theme		Training Title		Description	Tentative Training Course Plan	Indicator (Expected Outcome)
LU3	GIS	LU3-1	GIS and Spatial Data Construction	This module focuses on the method of spatial data construction, containing database schema concept, coding rules, data editing, error checking, and cleaning with opensource GIS software QGIS	(1) Lecture: GIS, QGIS general and Spatial Data Construction (2h) (2) Exercise (5h): Preparation of base map (incl. updating road network, administrative boundary, Data edit error check & cleaning, etc.)	[For Overall Goad, Project Purpose 1, Output 1] > GIS techniques are utilized in planning > Spatial data and Maps are organized and standardized > Spatial analysis ready vector data are prepared
		LU3-2	Spatial Data Analysis by GIS	Several basic and advanced techniques of GIS is learnt for urban planning for both vector and raster analysis. The aim is to understand how GIS technology can be used to efficiently conduct analyses related to urban planning, including land use, environmental, and other possible analysis, etc.	(1) Lecture: Utilization of advanced GIS technics for planning (2h) (2) Exercise (5h) : 1) Network analysis (Shortest path, service coverage), 2) Raster analysis (Observation of land cover change)	[For Overall Goad, Project Purpose 1, Output 1] > GIS techniques are utilized in planning > Open data are utilized in the planning process

Outline of Module LU3: GIS

Examples of usage of GIS by Planning Stage



GIS data development skills are essential at all stages of urban planning, but this time I have considered the content of the first GIS training based on the concept of the skills needed at the "Understand Current Condition" stage.

From 2nd GIS training, the contents shift to spatial analysis using both QGIS and ArcGIS

Outline of Module LU3-1: GIS and Spatial Data Construction

Concept of LU3-1

GIS technology is very crucial in analyzing urban growth and its direction of expansion and to find suitable sites/ areas for further development. In order to identify the sites for the urban growth, various factors have to be considered which are accessibility of land, topography of the land, utility of the land and supple of water, etc.

GIS is very convenient in assessment of these multiple factors and has been used not only in urban planning but across a variety of sectors.

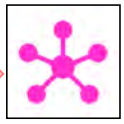
To utilize GIS as urban planning tool, geospatial data is an essential component. However, if your geospatial data is not clean, it can lead to many problems.

And often the case, geospatial data can be inaccurate. It can happen for various reasons during data collection, coordinate systems, topological, or attribute errors.

Data cleaning is vital to ensure accurate analysis. For example, coordinates may be off by 1 kilometer.

Preparing appropriate GIS data is essential for proper spatial analysis. For this reason, the first GIS training session will focus on GIS data preparation, including GIS data error checking and error cleaning

By clicking on this icon, you can open a website for reference.



Project on Capacity Development for Urban Planning

Contents of this Session

	Contents (est. duration exclude exercise time)	**Description**	**Key function to learn with QGIS (or name of plug-in)**
1	**QGIS General (20 min)**	**Understand basic QGIS operation**	**QGIS General tools and difference with ArcMap**
2	**Access to various open data with QGIS (30 min.)**	**Google Satellite, Google Map, Opens street Map, ESRI imageries, etc.**	**HCMGIS, Quick map service, Quick OSM**
3	**Access to various open data through web site (30 min.)**	**Land cover by ESA, Night-time light, etc.**	**(introduction only)**
4	**GIS data editing (60 min.)**	**Understand GIS data editing workflow**	**Understand the process of GIS data editing**
		Update land use data and road data	**Editing tool/ Advanced editing tool**
5	Topological error check (20 min.)	Check land use data, road to identify topological errors	Topology checker (duplicate, gap, overlap, invalid geometry, etc)
6	Topological error cleaning (Manual cleaning) (20 min.)	error cleaning of land use and road data in manual methos	Advanced editing tool
7	Topological error cleaning (Use cleaning tool) (20 min.)	error cleaning of land use and road data with Grass tool	"v.clean" in GRASS tool
8	Layout map (30 min.)	Preparation of map with QGIS	General tools for layout map and Advanced labeling

Contents 1:
QGIS General

Project on Capacity Development for Urban Planning

1. QGIS General

What is QGIS ?

QGIS: Leading **Open-Source** Desktop GIS

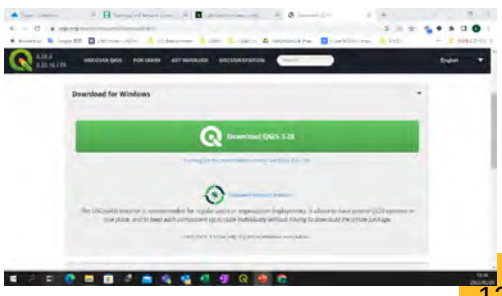
QGIS is a user friendly Open Source Geographic Information System (GIS) licensed under the GNU General Public License.
QGIS is an official project of the Open Source Geospatial Foundation (OSGeo). It runs on Linux, Unix, Mac OSX, Windows and Android and supports numerous vector, raster, and database formats and functionalities.

You can obtain latest QGIS software free of charge via Internet !
https://www.qgis.org/en/site/forusers/download.html
(Recommend to use more stable version "LTR: Long Term Released)

You can access Official Manual and Tutorial materials from following QGIS official site:

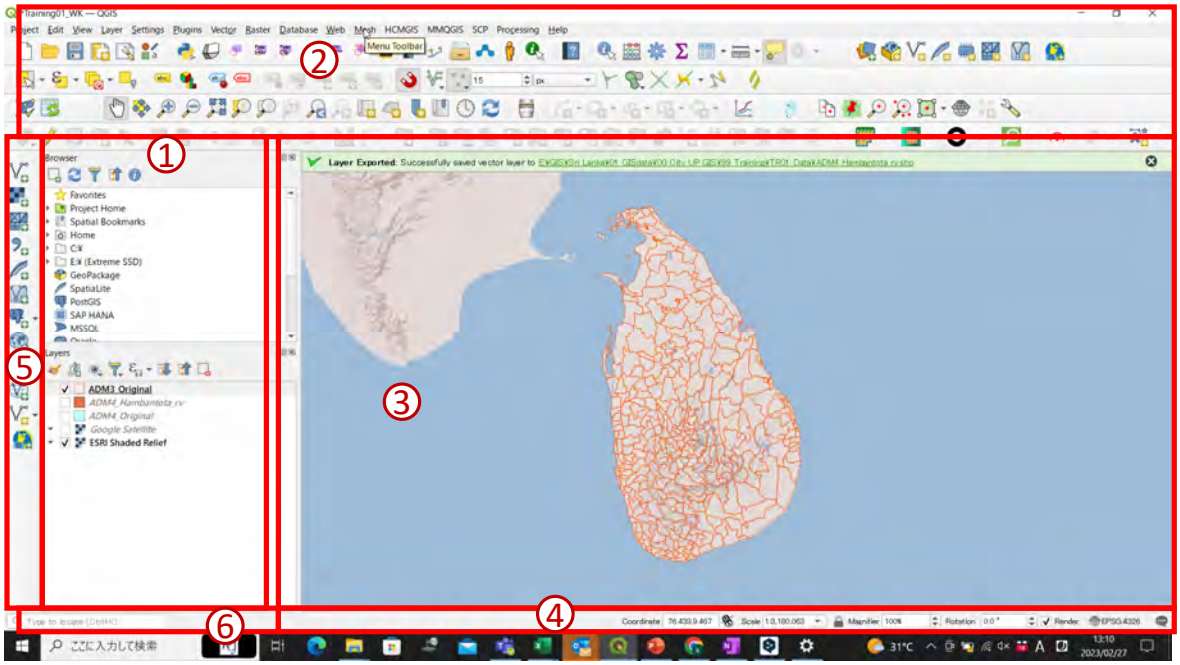
Manual:
https://docs.qgis.org/3.22/en/docs/user_manual/index.html

Tutorial for self learning:
https://docs.qgis.org/3.22/en/docs/training_manual/index.html



1. QGIS General

Main Interface



1. Browser Panel・Layer Panel
2. Toolbars
3. Map canvas
4. Status bar
5. Side Toolbar
6. Locator bar

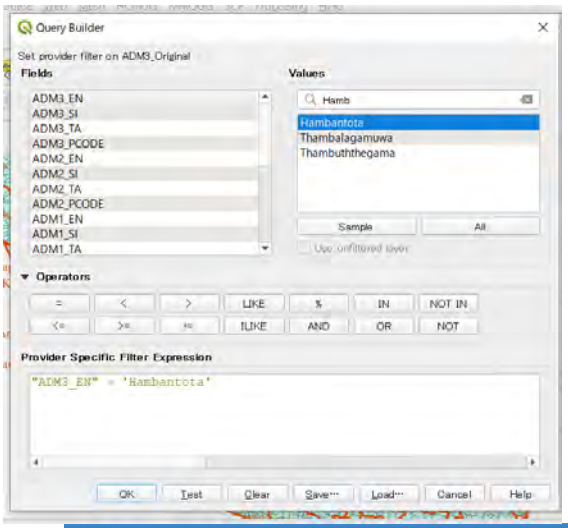
Project on Capacity Development for Urban Planning

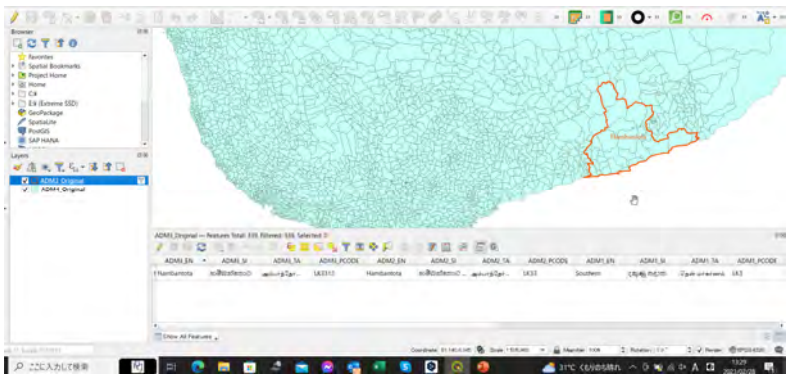
1. QGIS General

Filtering Map Objects: Query Builder

Access to “Query builder”, there are 2-way:

- Right click the name of the target layer – Filter
- Double click the name of target layer –Properties – “Source” tab – Click “Query Builder” Icon





Exercise:

- ***Open Training_Session1_1.qgz***
- ***Select Level-3 administrative unit “Hambantota” using Query Builder/***

1. QGIS General

Extract Map Objects using Attribute Table:

Access to “Select by Expression”: Open Attb. TBL – Click

Basic expression of selection is
"Column_Name" = 'Value_1' (opposite operator is “!=“)

If you want to select multiple…there are 2-way
"Column_Name" = 'Value_1' OR "Column_Name" = 'Value_2'

Also, you can use “IN” operator
"Column_Name" IN ('Value_1', 'Value_2', 'Value_N')

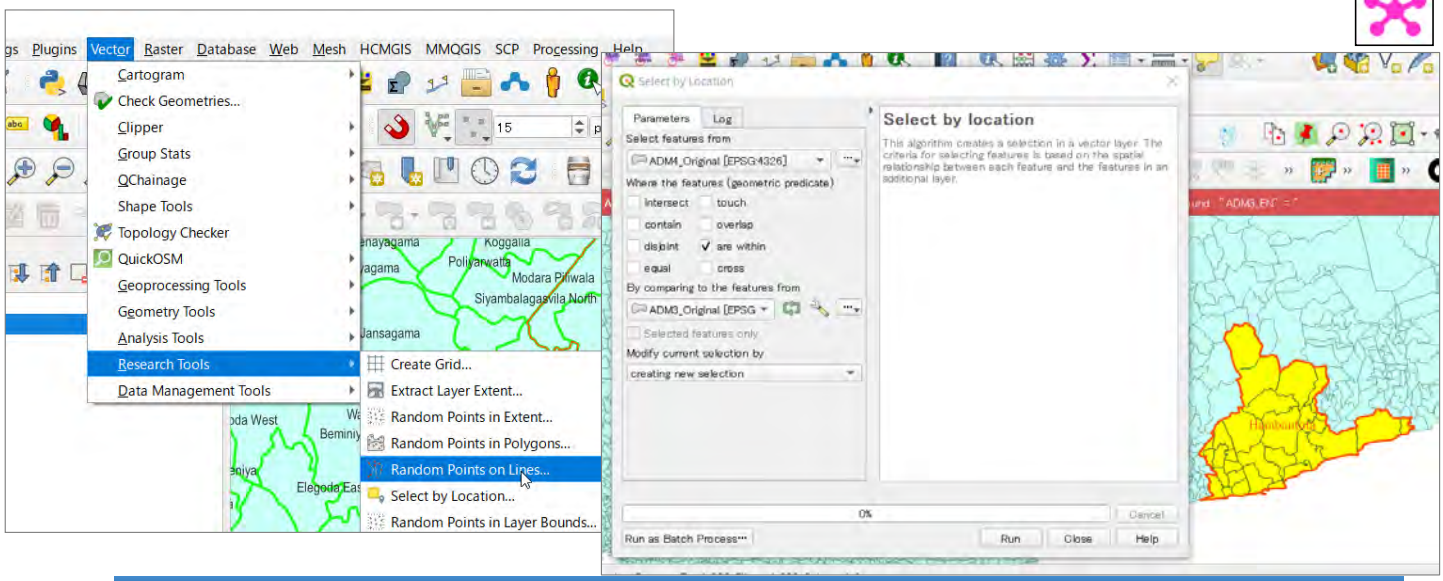
If you want to select data that partially matched the condition,
“Column_Name“ LIKE ‘%South’ (you can select data finish “South”)
“Column_Name“ LIKE ‘%South% (you can select data include “South”, e.g. South- East)

Operator	Description	Example
=	Equal to	“age” = 30
>	Greater than	“income” > 50000
<	Less than	“year_built” < 2000
>=	Greater than or equal to	“area” >= 1000
<=	Less than or equal to	“Temperature” <= 30
LIKE	Contains a specific substring	“address” LIKE ‘%Street%’
IN	If a value is found in a set	“field_name” IN selected_attribute(“layer_name”)
AND	The logical operator used to combine two or more conditions	“income” > 50000 AND “gender” = ‘male’
OR	The logical operator used to combine two or more conditions, returns true if at least one condition is met	“property_type” = ‘apartment’ OR “property_type” = ‘condo’
NOT	The logical operator used to negate a condition	“zipcode” != ‘98101’

1. QGIS General

Select Data by Location

Access to “Select by Location” tools
Vector – Research tool – Select by Location:



Exercise:

- ***Open Training_Session1_1.qgz***
- ***Select all Level-4 administrative unit “GN Division” in “GS Division”= “Hambantota” with using “Select Data by Location” tool***

1. QGIS General

Plug-ins: Customize QGIS to make more powerful App.

QGIS plugins add additional functionality to the QGIS application.

There is a countless collection of plugins ready to be used, available to download. These plugins can also be installed directly from the QGIS Plugin Manager within the QGIS application. (You can find “Plugins” on the QGIS tool bar)

Plugin Name	Functions
QuickMapServices	Simple and easy to use plugin that adds base maps to your QGIS project
Shape Tools	Shape Tools is a collection of geodesic shapes and tools. Tools include "XY to Line" tool, this tool can generate line from X,Y coordinate text file
Topology Checker	look over your vector files and check the topology with several topology rules (e.g. overlap polygon, disjoint, equal, etc) This is very useful when you edit GIS data
Geometry Checker	Powerful core plugin to check and fix the geometry validity of a layer (Default plugin, already installed in your QGIS)
Georeferencer	Tool for generating world files for rasters. This plugin allow you to add coordinates to scaned map/ imagery.
Quick OSM	Download OSM data thanks to the Overpass API. You can also open local OSM or PBF files. A special parser is used to let you see all OSM keys available.

Contents 2:

Access to various open data with QGIS

2. Access to various open data with QGIS

Use Plug-in, You can access various Open-data with QGIS

There is a countless collection of plugins ready to be used, available to download. These plugins can also be installed directly from the QGIS Plugin Manager within the QGIS application. (You can find “Plugins” on the QGIS tool bar)

Name of Plug-in	Accessible Data
QuickOSM	OSM (Open Street Map) data. Not only use as background imagery, but you can also download data
QuickMapService	Bing map, Google (Satellite, Map, traffic etc), Esri (Satellite, shaded relief, terrain, topo, etc), NASA (Earthquake hazard distribution), CARTO and more!
HCMGIS	Google, ESRI, CARTO, etc

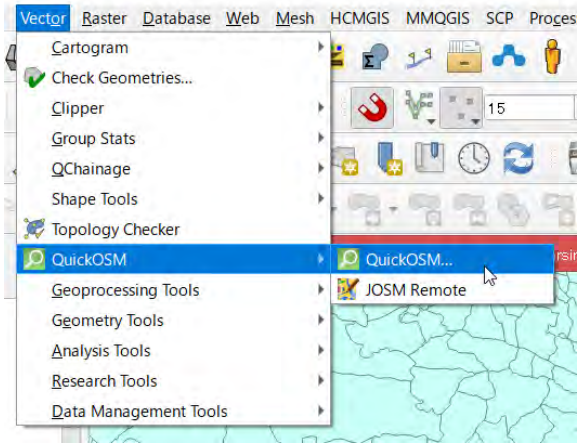
Exercise:
- ***Install all 3 plugins above into your QGIS***
- ***Download OSM data (Road, Water, Waterway)***
- ***Prepare Base Map of Hambantota area***

2. Access to various open data with QGIS

Exercise:
- ***Install all 3 plugins above into your QGIS***
- ***Download OSM data with QuickOSM (Road, Water, Waterway)***
- ***Prepare Base Map of Hambantota area***

Also, In this exercise, use Hambantota boundary data: “ADM3_Hambantota.shp”

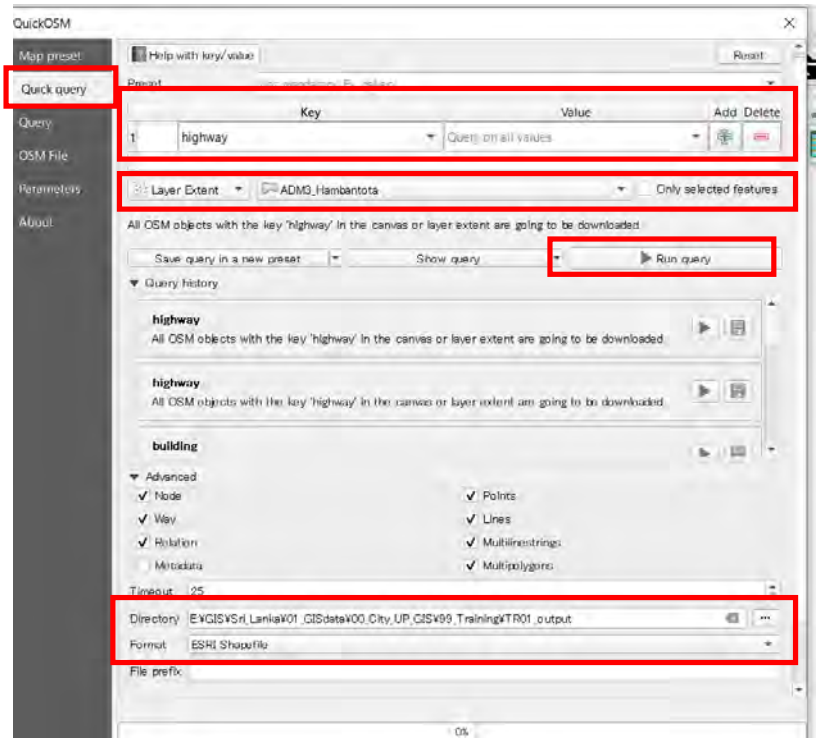
1) Add *“ADM3_Hambantota.shp” on the Map Canvas*
2) *Install all 3 Plugins*
3) *Open QuickOSM and download “road”, “waterbody” and “waterway”*
4) *Symbolize “road”, “waterbody” and “waterway”*
5) *Add “OSM standard” & “Esri Shaded Relief” from “QuickMapServices”*



2. Access to various open data with QGIS

QuickOSM Parameter Settings

① 1) Select Quick query tab
② 2) Input (Select) key “highway”, “water” and “waterway”
③ Input the location of output
④ Select output file type as “ESRI shapefile”
⑤ Click “Run query”

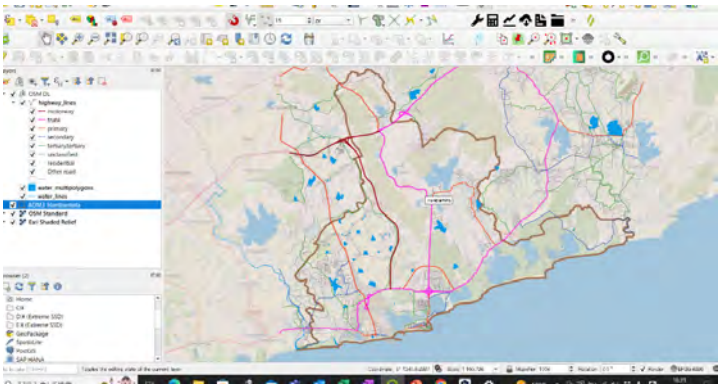


At this moment, multiple layer download doesn’t work well. So, download one by one !

2. Access to various open data with QGIS

Symbolization for OSM “Highway” in this Exercise (1)

① “Layer Properties” – “Symbology” – “Categorized” option to classify road data using “highway” field.
② Merge categories (See the table on the right)
③ Symbolize road (Refer the table on the right for line size and color)

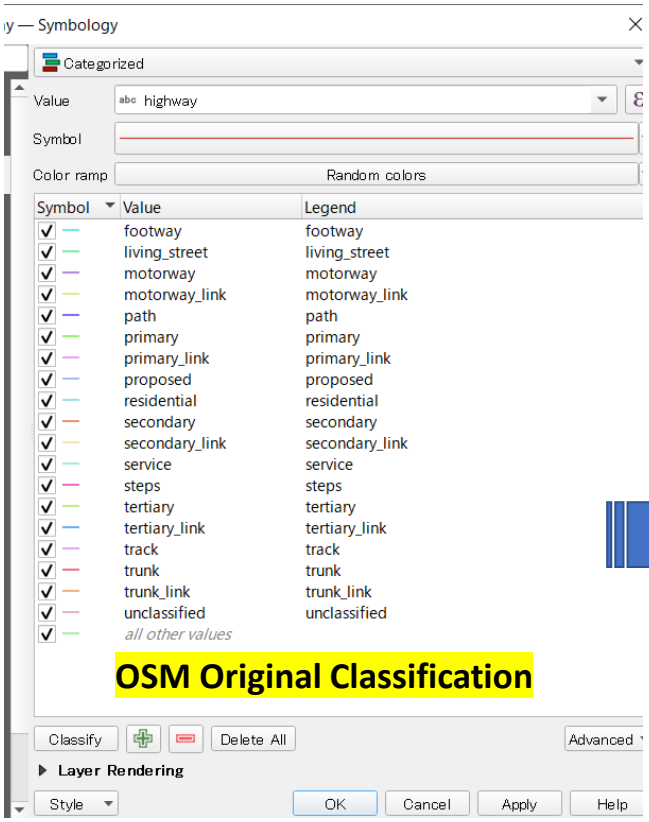


	OSM original category	Simplified category in this session	Line size	Color (HTML)
1	motorway	Highway	0.4	#960004
2	motorway_link	Highway	-	
3	trunk	Trunk	0.4	#ff25f4
4	trunk_link	Trunk	-	
5	primary	Primary	0.2	#f62408
6	primary_link	Primary	-	
7	secondary	Secondary	0.2	#104ed5
8	secondary_link	Secondary	-	
9	tertiary	Tertiary	0.2	#33a02c
10	tertiary_link	Tertiary	-	
11	unclassified	Unclassified	0.1	#000000
12	residential	Residential	0.1	#4e4e4e
13	footway	Other road	0.1	#aeaeae
14	living_street	Other road	-	-
15	path	Other road	-	-
16	service	Other road	-	-
17	steps	Other road	-	-
18	track	Other road	-	-
19	proposed	Other road	-	-

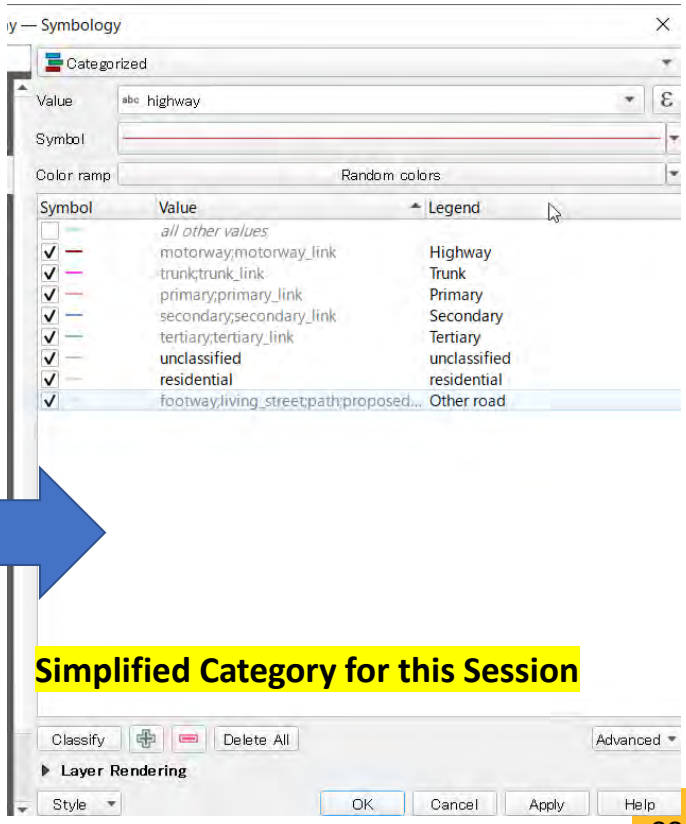
2. Access to various open data with QGIS

Symbolization for OSM "Highway" in this Exercise (2)

Customize Classification: Merge Class, Change symbol, Color…



OSM Original Classification

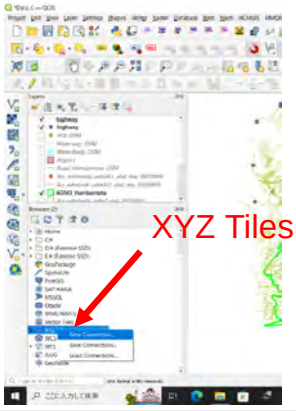


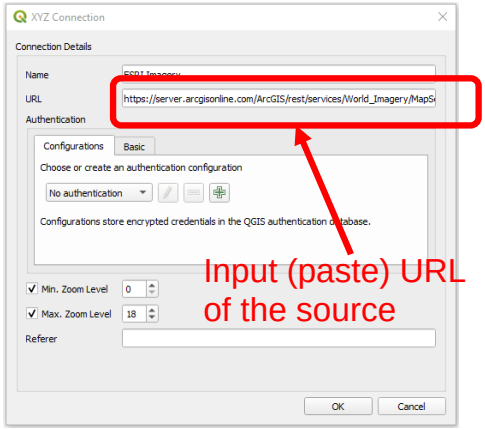
Simplified Category for this Session

Project on Capacity Development for Urban Planning

2. Access to various open data with QGIS

Use "XYZ Tile" Function, You can access various Open-data with QGIS





Links to Data

<Google Satellite>
http://www.google.cn/maps/vt?lyrs=s@189&gl=cn&x={x}&y={y}&z={z}
<Bing Satellite>
http://ecn.t3.tiles.virtualearth.net/tiles/a{q}.jpeg?g=1
<Google Map>
https://mt1.google.com/vt/lyrs=r&x={x}&y={y}&z={z}
<Esri Satellite>
https://server.arcgisonline.com/ArcGIS/rest/services/World_Imagery/MapServer/tile/{z}/{y}/{x}
<Esri World Topo>
https://server.arcgisonline.com/ArcGIS/rest/services/World_Topo_Map/MapServer/tile/{z}/{y}/{x}
<CartoDB>
https://cartodb-basemaps-a.global.ssl.fastly.net/light_all/{z}/{x}/{y}.png
<Open Street Map>
http://tile.openstreetmap.org/{z}/{x}/{y}.png

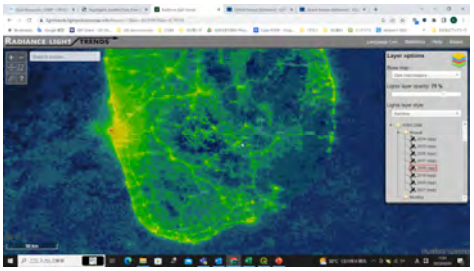
Exercise:

- ***Connect at least 2 Map services with your QGIS***
- ***Access and observe connected map data***

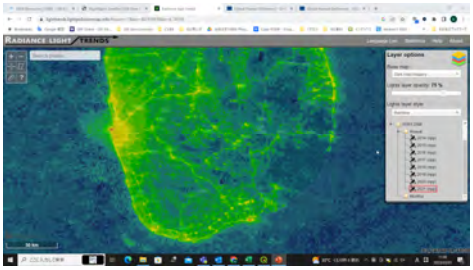
Contents 3:
Access to various open data through Web



2015



2018



2021

Source:
https://lighttrends.lightpollutionmap.info/#zoom=7&lon=80.97483&lat=6.74556

3. Access to various open data through Web

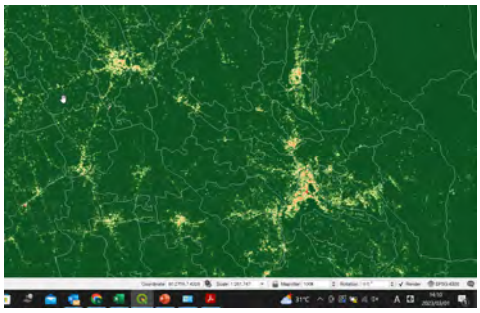
Various authoritative Organization/ Institution open their data for Public.
This is a list of useful data source with Links.

Web site	Available data	Organization	Link
Natural Earth Data	• Cultural, physical, and raster (basemap) data. • Quick start kit (MXD and QGS files) with all the essential stylized layers.	North American Cartographic Information Society	https://www.naturalearthdata.com/downloads/
USGS Earth Explorer	• Landsat, Sentinel-2, and land cover. • Digital Elevation Models such as NASA's ASTER and SRTM.	USGS	https://earthexplorer.usgs.gov/
NASA's Socioeconomic Data and Applications Center	• Socioeconomic data includes a range of topics such as agriculture, climate and health.	NASA	https://sedac.ciesin.columbia.edu/
UNEP Environmental Data Explorer	• Themes include population, forests, emissions, disasters, and GDP for spatial and non-spatial data	UNEP	https://www.unep.org/publications-data
NASA Earth Observations (NEO)	• All raster grids are atmosphere, energy, land, life, and ocean GIS data.	NASA	https://neo.gsfc.nasa.gov/
Sentinel Satellite Data	• Raster data – 11 channels from Sentinel-2. Synthetic aperture radar from Sentinel-1.	ESA	https://scihub.copernicus.eu/dhus/#/home
Global Human Settlement Layer (GHSL)	• Produces global spatial information, evidence-based analytics and knowledge describing the human presence on the planet • Built up area, population distribution in multi year based on Sentinel-2 and other sources	European Commission	https://ghsl.jrc.ec.europa.eu/index.php
Light Pollution Map	• Night time light data based on "VIIRS/NPP Lunar BRDF-Adjusted Nighttime Lights Yearly L3" • This is annual data, but the clouds have been removed, making it easier to observe the nighttime light data.		https://www.lightpollutionmap.info/
WorldCover	• Land cover 2020 and 2021 (10m), overall accuracy of appx. 75%	ESA	https://esa-worldcover.org/en

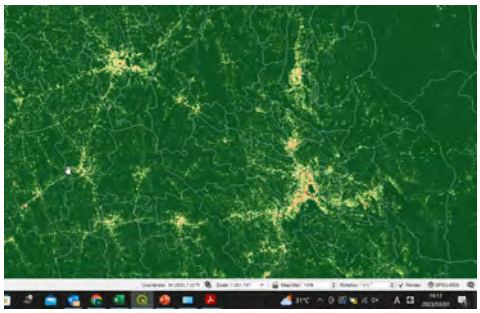
3. Access to various open data through Web

GHS built-up surface: GHS built-up surface grid, derived from Sentinel2 composite and Landsat, multitemporal (1975-2030)

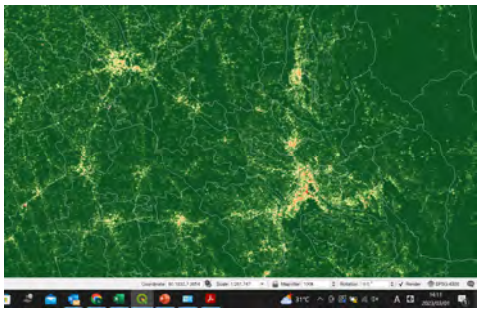
The spatial raster dataset depicts the distribution of built-up surfaces, expressed as number of square meters. The data reports about the **total built-up surface** and the **built-up surface allocated to dominant non-residential** (NRES) uses.
Data are spatial-temporal interpolated from 1975 to 2030 in 5 years intervals.
For the temporal anchor point of 2018 the data is published at 10m as observed from the S2 image data.



2010



2020



2030

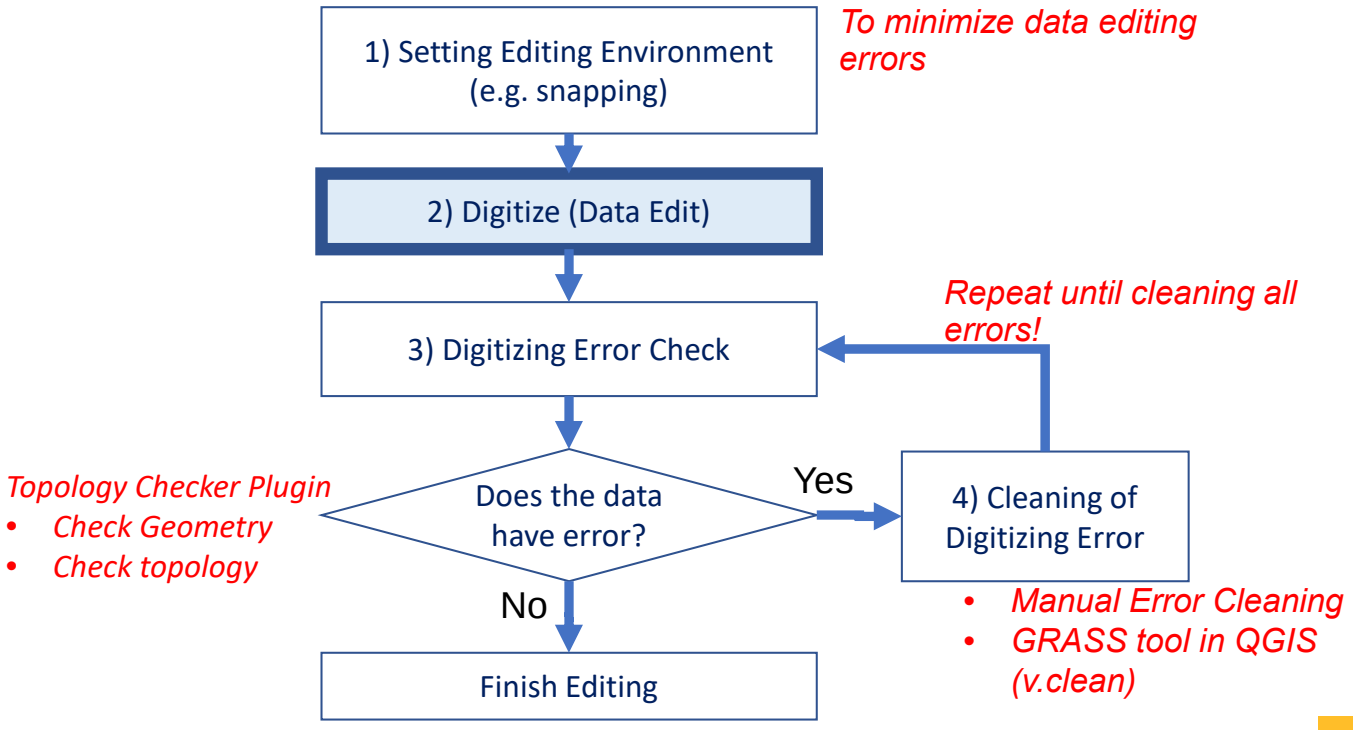
Project on Capacity Development for Urban Planning

Contents 4:

GIS Data Editing

4. GIS Data Editing

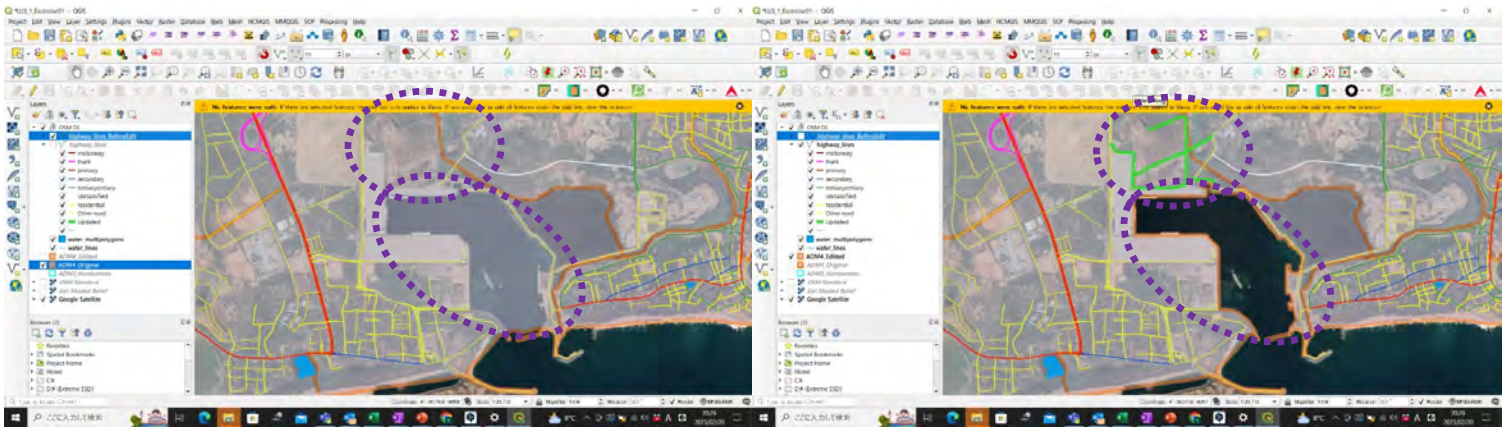
Case Study:
Update Road and Level 4 Administrative boundary



4. GIS Data Editing

Case Study: Input Road and Update Level 4 boundary

As an Urban Planner, you are requested to prepare current condition map, but under-construction road are not yet included in road data, and coastline in Level 4 administrative boundary need to update following satellite imagery.
So, you need to update road data and road data.



Before Edit

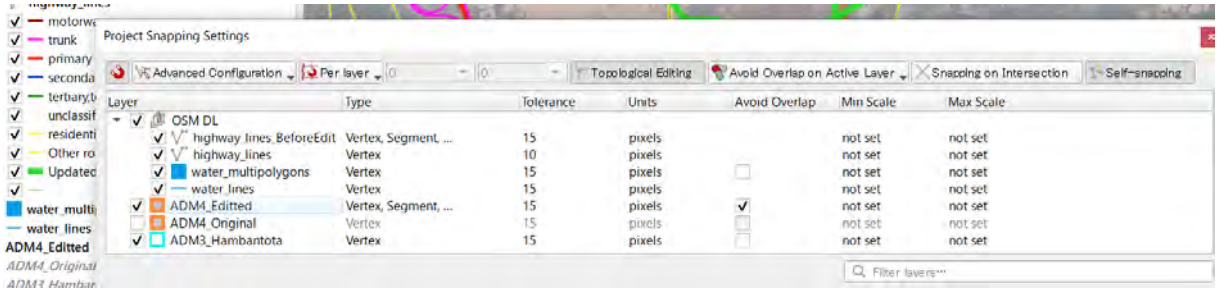
After Edit

Exercise:
- ***Update road data based on Satellite Imagery***
- ***Update Level 4Administrative boundary based on Satellite Imagery***

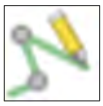
4. GIS Data Editing

1) Setting Editing Environment (e.g. snapping/ digitizing)

- To avoid editing error, you should utilize "**Snapping option**".
- Navigate to the menu entry "**Project**" ▸ "**Snapping Options**"….for Global snapping and Digitizing option



The tolerance values can be set either in the project's map units or in pixels. The advantage of choosing pixels is that it keeps the snapping constant at different map scales. 10 to 12 pixels is normally a good value, but it depends on the DPI of your screen.



The Self-snapping option allows you to snap to the geometry that is being edited. Combined with the advanced digitizing panel, this provides a handy way to digitize new edges relative to the previous edges or vertices. Self-snapping can cause invalid geometries, use with caution.



Topological editing button helps when editing and maintaining features with common boundaries. With this option enabled, QGIS 'detects' shared boundaries. When you move common vertices/segments, QGIS will also move them in the geometries of the neighboring features.

Topological editing works with features from different layers, as long as the layers are visible and in editing mode.

4. GIS Data Editing

2) Digitize (Edit data) -1


Toggle Editing button

In order to begin digitizing, you'll need to enter **edit mode**.

To enter edit mode for the survey location layer:
•Click on the layer in the Layer list to select it. *(Make very sure that the correct layer is selected, otherwise you'll edit the wrong layer!)*
•Click on the Toggle Editing button: edit

If you can't find this button, check that the Digitizing toolbar is enabled. There should be a check mark next to the View ▸ Toolbars ▸ Digitizing menu entry.

As soon as you are in edit mode, you'll see the digitizing tools are now active:



Four other relevant buttons are still inactive, but will become active when we start interacting with our new data:

2) Digitize (Edit data) -2

Adding Features: Depends on Geometry type

To add feature, you can use Add Feature icon on the Toolbar to put the QGIS cursor into digitizing mode.



Add Feature Icon for Point Layer

For each feature, you first digitize the geometry, then enter its attributes. To digitize the geometry, left-click on the map area to create the first point of your new feature.



Add Feature Icon for Line Layer

For lines and polygons, keep on left-clicking for each additional point you wish to capture. When you have finished adding points, right-click anywhere on the map area to confirm you have finished entering the geometry of that feature.



Add Feature Icon for Polygon Layer

The attribute window will appear, allowing you to enter the information for the new feature.

Project on Capacity Development for Urban Planning

4. GIS Data Editing

2) Digitize (Edit data) -3

Vertex Tool



For shapefile-based layers, Node Tool provides manipulation capabilities of feature vertices. It is possible to simply select multiple vertices at once and to move, add or delete them altogether.

This tool is, unlike other tools in QGIS, persistent, so when some operation is done, selection stays active for this feature and tool. If the node tool is unable to find any features, a warning will be displayed.
Start by activating ***Vertex Tool*** and selecting a feature by clicking on it. Red boxes will appear at each vertex of this feature.

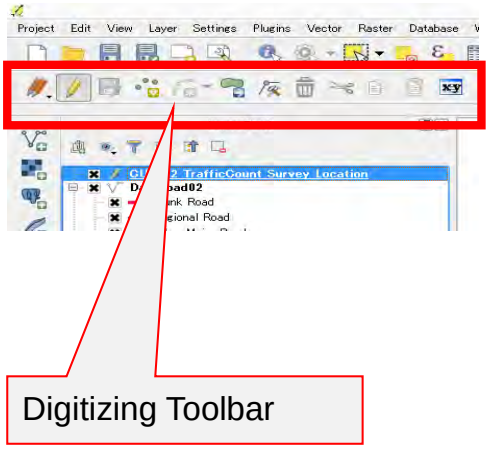


*This tools is useful when you **modify features**.*

2) Digitize (Edit data) -4

Editing Toolbar

In general, tools for editing vector layers are divided into a **Digitizing Toolbar** and an Advanced digitizing Toolbar.
You can select and unselect both toolbar under **"View – Toolbars"**.
Using the basic digitizing tools, you can perform the following functions.



Icon	Purpose	Icon	Purpose
	Access to save, rollback or cancel changes in all or selected layers simultaneously		Turn on or off edit status of selected layer(s) based on the active layer status
	Save edits to the active layer		
	Add new record		Add Feature: Capture Point
	Add Feature: Capture Line		Add Feature: Capture Polygon
	Vertex Tool (All Layers)		Vertex Tool (Current Layer)
	Modify the attributes of all selected features simultaneously		
	Delete Selected features from the active layer		Cut Features from the active layer
	Copy selected Features from the active layer		Paste Features into the active layer
	Undo changes in the active layer		Redo changes in active layer

Thank you!

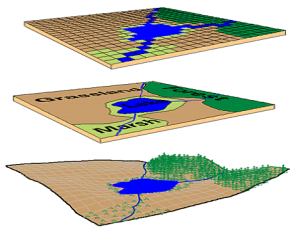
PPT. No.2

Module LU3-1: GIS and Spatial Data Construction

GIS and Spatial data construction (2)

Project on Capacity Development for Urban Planning

The Project Capacity Development for Urban Planning









LU3-1:
GIS and Spatial Data Construction
Contents 5 to 8
Feb.- Mar. 2023

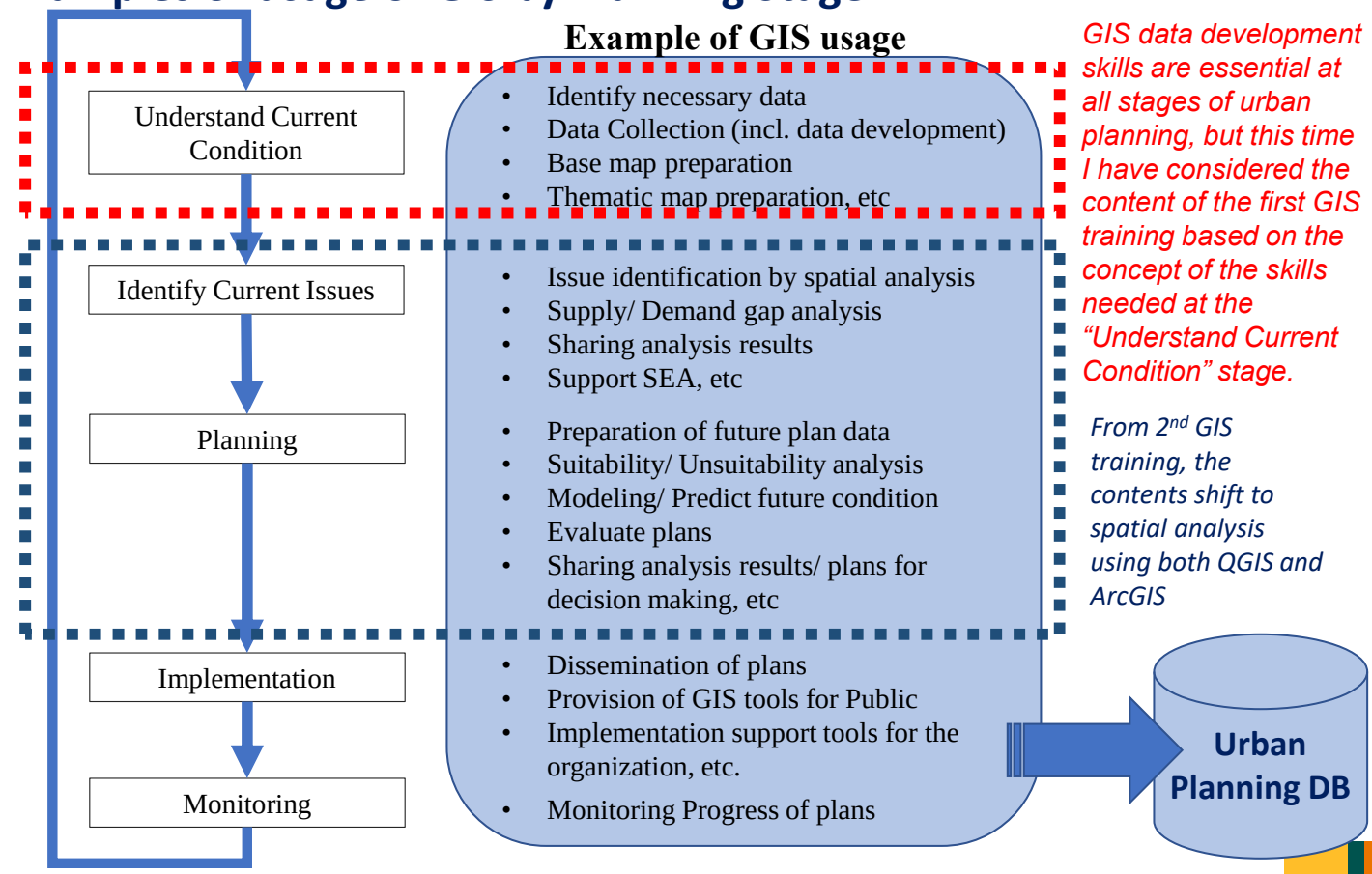
Outline of Module LU3: GIS

Major Theme		Training Title		Description	Tentative Training Course Plan	Indicator (Expected Outcome)	Required Time (Hour)
LU3	GIS	LU3-1	GIS and Spatial Data Construction	This module focuses on the method of spatial data construction, containing database schema concept, coding rules, data editing, error checking, and cleaning with Open source GIS software QGIS	(1) Lecture: GIS, QGIS general and Spatial Data Construction (2h) (2) Exercise (5h): Preparation of base map (incl. updating road network, administrative boundary, Data edit error check & cleaning, etc.)	[For Overall Goad, Project Purpose 1, Output 1] > GIS techniques are utilized in planning > Spatial data and Maps are organized and standardized > Spatial analysis ready vector data are prepared	7
		LU3-2	Spatial Data Analysis by GIS	Several basic and advanced techniques of GIS is learnt for urban planning for both vector and raster analysis. The aim is to understand how GIS technology can be used to efficiently conduct analyses related to urban planning, including land use, environmental, and other possible analysis, etc.	(1) Lecture: Utilization of advanced GIS technics for planning (2h) (2) Exercise (5h) : 1) Network analysis (Shortest path, service coverage), 2) Raster analysis (Observation of land cover change)	[For Overall Goad, Project Purpose 1, Output 1] > GIS techniques are utilized in planning > Open data are utilized in the planning process	7

Project on Capacity Development for Urban Planning

Outline of Module LU3: GIS

Examples of usage of GIS by Planning Stage



GIS data development skills are essential at all stages of urban planning, but this time I have considered the content of the first GIS training based on the concept of the skills needed at the "Understand Current Condition" stage.

From 2nd GIS training, the contents shift to spatial analysis using both QGIS and ArcGIS

Outline of Module LU3-1: GIS and Spatial Data Construction

Concept of LU3-1

GIS technology is very crucial in analyzing urban growth and its direction of expansion and to find suitable sites/ areas for further development. In order to identify the sites for the urban growth, various factors have to be considered which are accessibility of land, topography of the land, utility of the land and supple of water, etc.

GIS is very convenient in assessment of these multiple factors and has been used not only in urban planning but across a variety of sectors.

To utilize GIS as urban planning tool, geospatial data is an essential component. However, if your geospatial data is not clean, it can lead to many problems.

And often the case, geospatial data can be inaccurate. It can happen for various reasons during data collection, coordinate systems, topological, or attribute errors.

Data cleaning is vital to ensure accurate analysis. For example, coordinates may be off by 1 kilometer.

Preparing appropriate GIS data is essential for proper spatial analysis. For this reason, the first GIS training session will focus on GIS data preparation, including GIS data error checking and error cleaning

Contents of this Session

	Contents (est. duration exclude exercise time)	**Description**	**Key function to learn with QGIS (or name of plug-in)**
1	QGIS General (20 min)	Understand basic QGIS operation	QGIS General tools and difference with ArcMap
2	Access to various open data with QGIS (20 min.)	Google Satellite, Google Map, Opens street Map, ESRI imageries, etc.	HCMGIS, Quick map service, Quick OSM
3	Access to various open data through web site (30 min.)	Land cover by ESA, Night-time light, etc.	(introduction only)
4	GIS data editing (40 min.)	Understand GIS data editing workflow	Understand the process of GIS data editing
		Update land use data and road data	Editing tool/ Advanced editing tool
5	**Topological error check (20 min.)**	**Check land use data, road to identify topological errors**	**Topology checker (duplicate, gap, overlap, invalid geometry, etc.)**
6	**Topological error cleaning (Manual cleaning) (20 min.)**	**error cleaning of land use and road data in manual methos**	**Advanced editing tool**
7	**Topological error cleaning (Use cleaning tool) (20 min.)**	**error cleaning of land use and road data with Grass tool**	**"v.clean" in GRASS tool**
8	**Layout map (30 min.)**	**Preparation of map with QGIS**	**General tools for layout map and Advanced labeling**

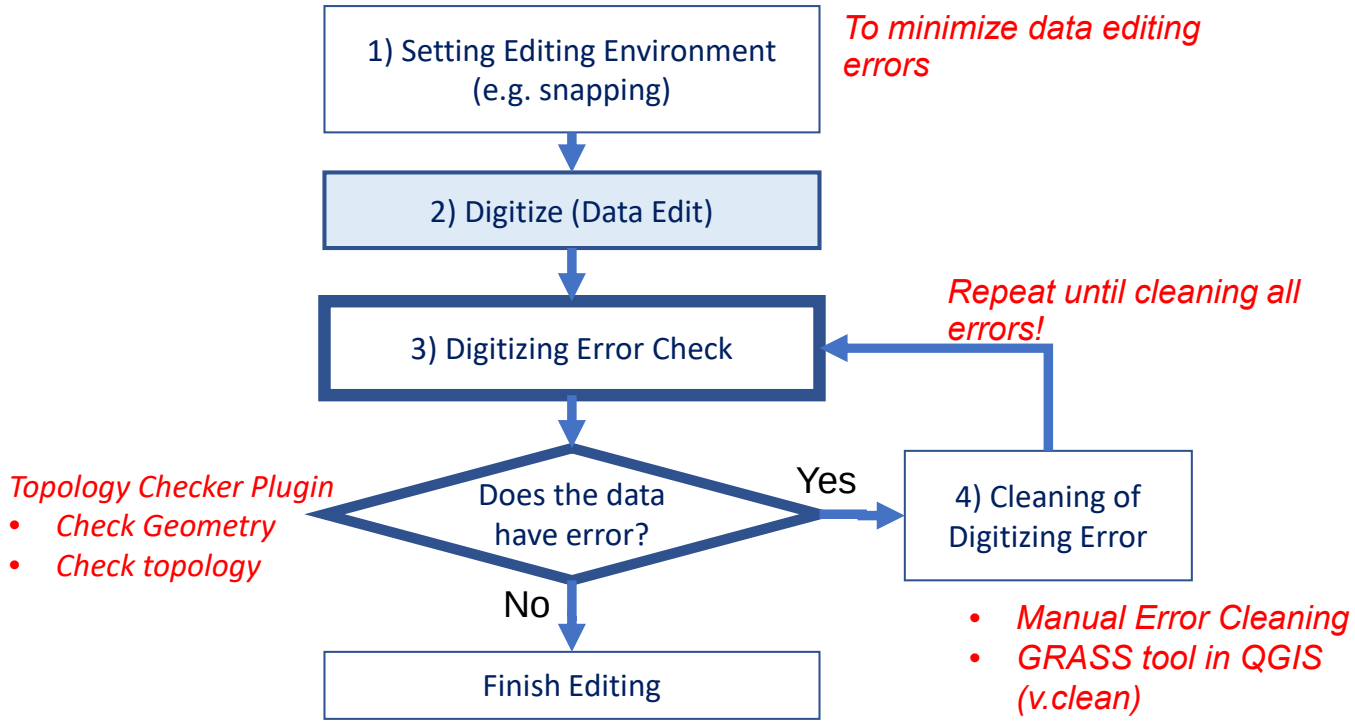
Contents 5:
Topological Error Check

Exercise:
After the lecture, do a topology error check on your updated road data and administrative boundary data

Project on Capacity Development for Urban Planning

5. Editing Error Check

Remind: Editing Workflow



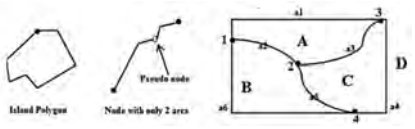
5. Editing Error Check

Digitizing Error Check

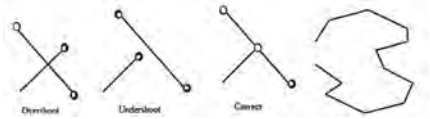
- It is important to check editing error for further spatial analysis
- If your data is not enough quality of analysis, your analysis results are also not enough quality
- Recommend to check errors or validate GIS data when you receive

Major types of topological errors

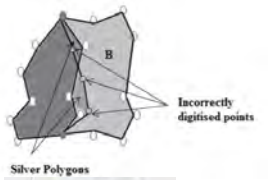
Pseudo Node



Dangling Node



Sliver Polygon



Gap Polygon



Overlap Polygon



Self intersection

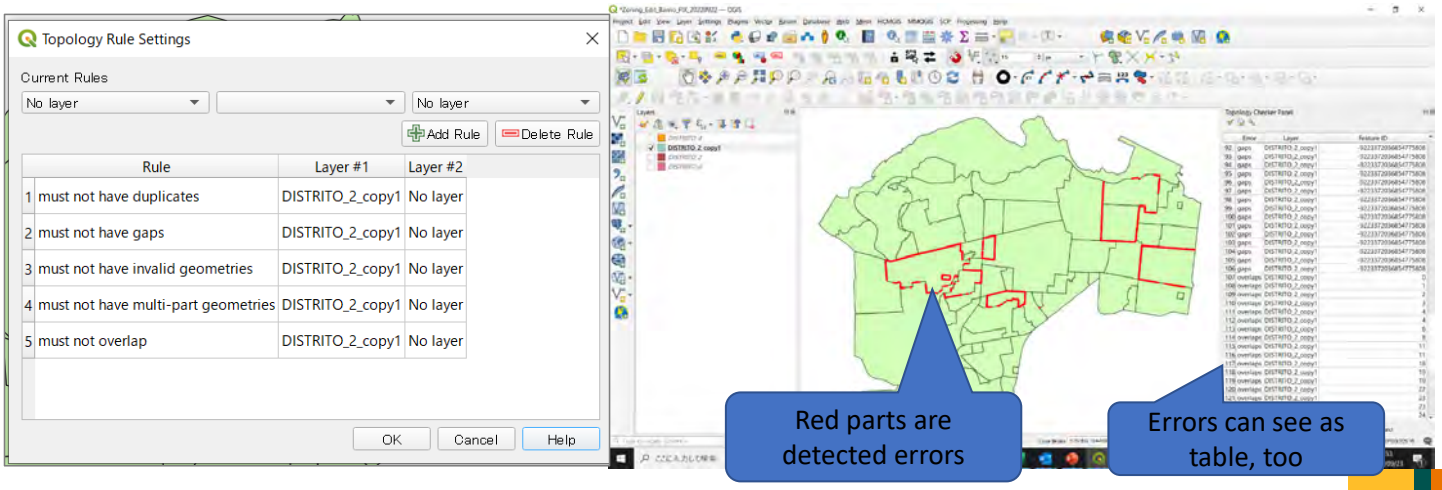


Project on Capacity Development for Urban Planning

5. Editing Error Check

Topology Checker Plugin: (Vector – Topology Checker)

Topology describes the relationships between points, lines and polygons that represent the features of a geographic region. With the Topology Checker plugin, you can ***check the topology with several topology rules. (can't clean topological errors with this plug-in)***
It depends on your individual questions which topology rules you apply to your vector data. QGIS has a built-in topological editing feature, which is great for creating new features without errors. But existing data errors and user-induced errors are hard to find. This plugin helps you find such errors through a list of rules.



5. Editing Error Check

Topological Rules that Topology Checker detect errors (Point/ Line)

Point	**Must be covered by**: Here you can choose a vector layer from your project. Points that aren't covered by the given vector layer occur in the 'Error' field. **Must be covered by endpoints of**: Here you can choose a line layer from your project. **Must be inside**: Here you can choose a polygon layer from your project. The points must be inside a polygon. Otherwise, QGIS writes an 'Error' for the point. **Must not have duplicates**: Whenever a point is represented twice or more, it will occur in the 'Error' field. **Must not have invalid geometries**: Checks whether the geometries are valid. **Must not have multi-part-geometries**: All multi-part points are written into the 'Error' field.
Line	**End points must be covered by**: Here you can select a point layer from your project. **Must not have dangles**: This will show the overshoots in the line layer. **Must not have duplicates**: Whenever a line feature is represented twice or more, it will occur in the 'Error' field. **Must not have invalid geometries**: Checks whether the geometries are valid. **Must not have multi-part geometries**: Sometimes, a geometry is actually a collection of simple (single-part) geometries. Such a geometry is called multi-part geometry. If it contains just one type of simple geometry, we call it multi-point, multi-linestring or multi-polygon. All multi-part lines are written into the 'Error' field. **Must not have pseudos**: A line geometry's endpoint should be connected to the endpoints of two other geometries. If the endpoint is connected to only one other geometry's endpoint, the endpoint is called a pseudo node.

Project on Capacity Development for Urban Planning

5. Editing Error Check

Topological Rules that Topology Checker detect errors (Polygon)

Polygon	**Must contain**: Polygon layer must contain at least one point geometry from the second layer. **Must not have duplicates**: Polygons from the same layer must not have identical geometries. Whenever a polygon feature is represented twice or more it will occur in the 'Error' field. **Must not have gaps**: Adjacent polygons should not form gaps between them. Administrative boundaries could be mentioned as an example (US state polygons do not have any gaps between them…). **Must not have invalid geometries**: Checks whether the geometries are valid. Some of the rules that define a valid geometry are: Polygon rings must close. Rings that define holes should be inside rings that define exterior boundaries. Rings may not self-intersect (they may neither touch nor cross one another). Rings may not touch other rings, except at a point. **Must not have multi-part geometries**: Sometimes, a geometry is actually a collection of simple (single-part) geometries. Such a geometry is called multi-part geometry. If it contains just one type of simple geometry, we call it multi-point, multi-linestring or multi-polygon. For example, a country consisting of multiple islands can be represented as a multi-polygon. **Must not overlap**: Adjacent polygons should not share common area. **Must not overlap with**: Adjacent polygons from one layer should not share common area with polygons from another layer.

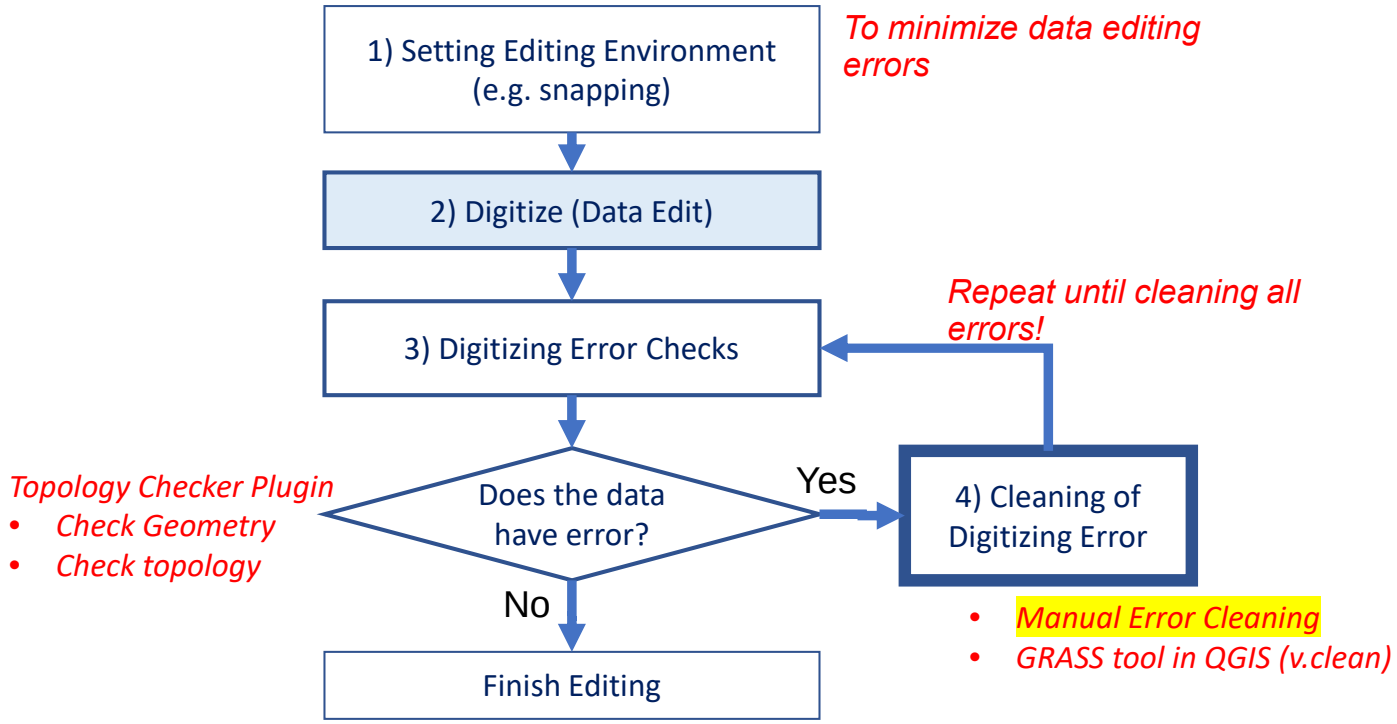
Contents 6:
Topological Error Cleaning
Manual Cleaning

Exercise:
After the lecture, do a topology error cleaning manually
(If necessary, Sample data will be shared for the exercise)

Project on Capacity Development for Urban Planning

6. Topological Error Cleaning (Manual Cleaning)

Remind: Editing Workflow



6. Topological Error Cleaning (Manual Cleaning)

Advanced Editing Toolbar

- The best way to clean topology error is by manual editing
- Advanced Digitizing Tool bar allow you to edit data more flexible than digitizing tool bar. Such as, merge/ split map objects.
- When you edit data, you should open this “Advanced Editing Tool bar” on the screen
- Practically, when you clean data, use both manual cleaning and utilize cleaning tool

Icon	Purpose	Icon	Purpose	Icon	Purpose
	Enable Advanced Digitizing Tools		Delete Ring		Simplify Feature
	Digitize with Curve		Offset Curve		Add Part
	Move Feature(s)		Split Parts		Swap direction
			Merge Attributes of Selected Features		Delete Part
			Rotate Point Symbols		Reshape Features
	Rotate Feature(s)		Trim or Extend Feature		Split Features
	Scale Feature		Enable Stream Digitizing		Merge Selected Features
	Add Ring		Copy and Move Feature(s)		Offset Point Symbols
	Fill Ring				

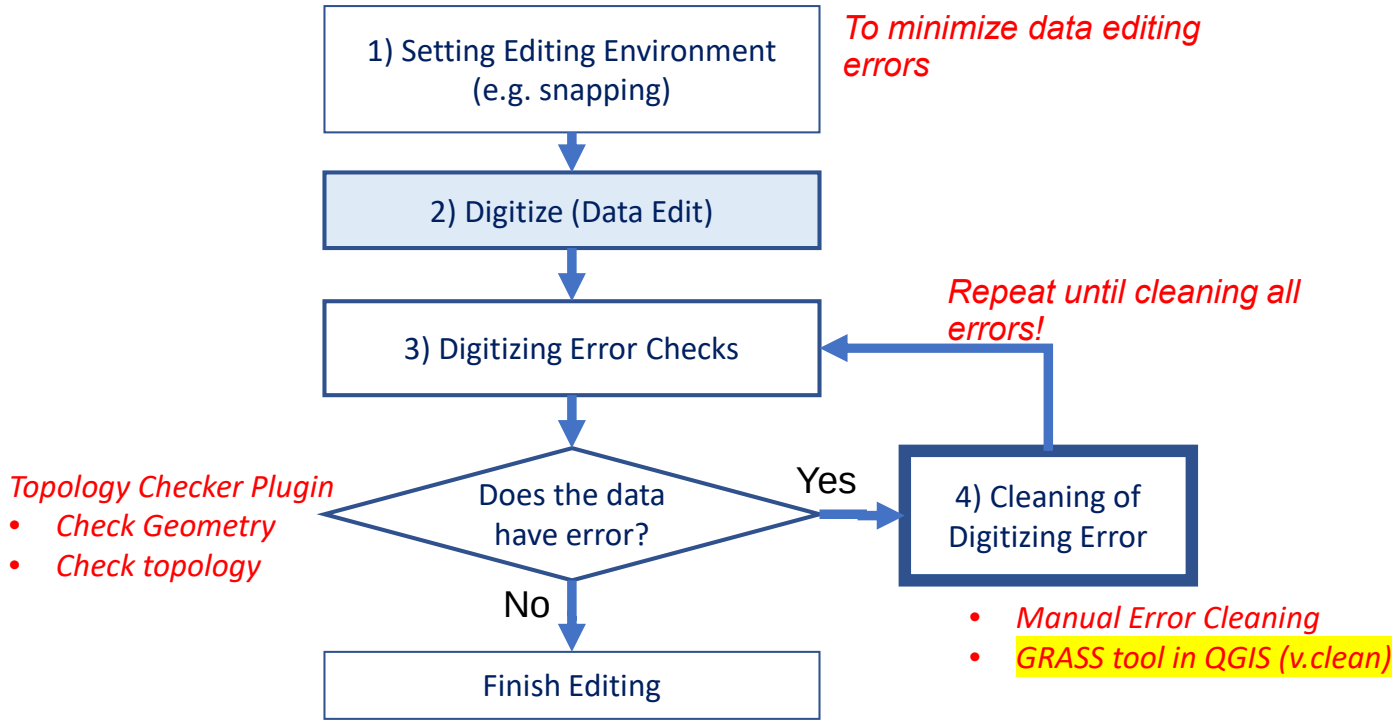
Contents 7:

Topological Error Cleaning Using Cleaning Tool

Exercise:
After the lecture, do a topology error cleaning using v.clean tool
(If necessary, sample data will be shared for the exercise)

7. Topological Error Cleaning (Using Cleaning Tool)

Remind: Editing Workflow

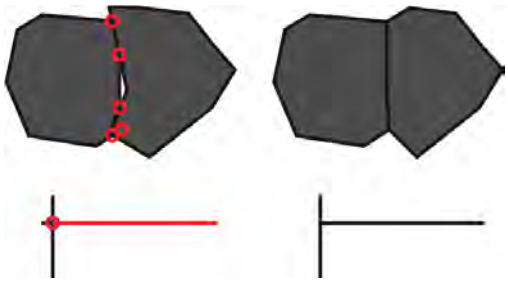


Project on Capacity Development for Urban Planning

7. Topological Error Cleaning (Using Cleaning Tool)

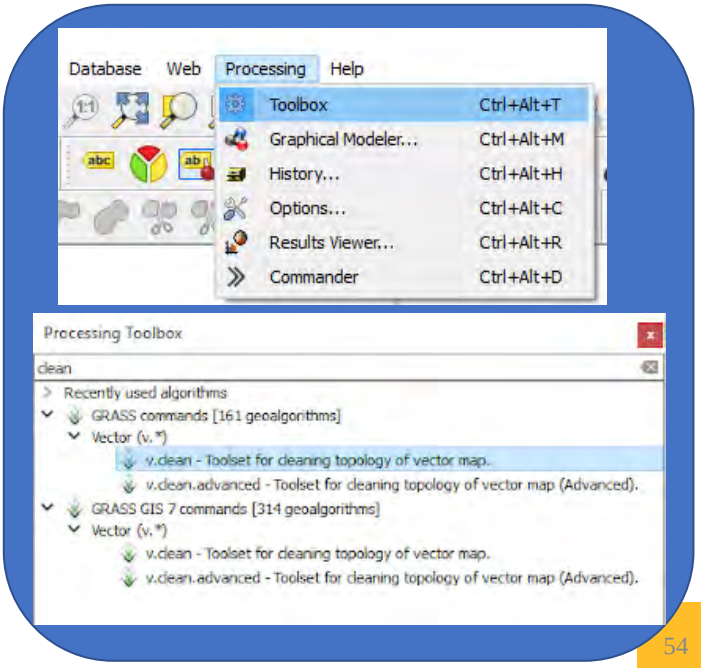
V.Clean: Toolset for cleaning topology of vector data

The best way to clean topology error is by manual editing, but it's tiring and time consuming. Fortunately, there are some tools that can be used to clean topology error in QGIS ***such as Grass v.clean tool***.
But must be kept in mind, using the tools not always working perfectly, but at least it could save time and speed up the process in cleaning topology error.



Topological errors detected in the original data (left) and cleaned data (right)

After V.Clean, it is necessary to do "Topology Checker" to make sure your data is properly cleaned.



7. Topological Error Cleaning (Using Cleaning Tool)

V.Clean: Available Tools

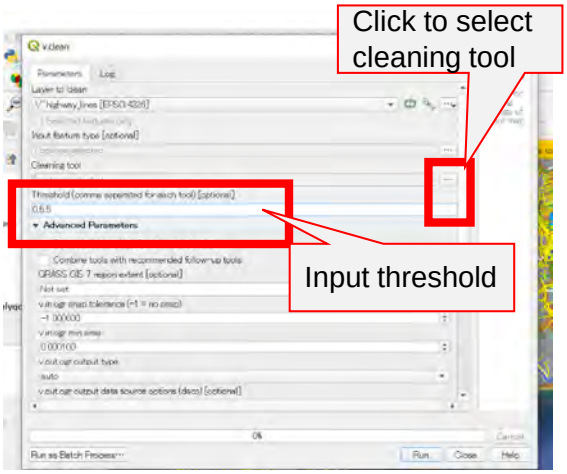
Cleaning Tool	Description
break	break lines at each intersection
snap	snap lines to vertex in threshold
rmdangle	remove dangles, threshold ignored if < 0
chdangle	change the type of boundary dangle to line, threshold ignored if < 0, input line type is ignored
rmbridge	remove bridges connecting area and island or 2 islands
chbridge	change the type of bridges connecting area and island or 2 islands from boundary to line
rmdupl	remove duplicate geometry features (pay attention to categories!)
emdac	remove duplicate area centroids ('type' option ignored)
bpol	break (topologically clean) polygons (imported from non topological format, like ShapeFile). Boundaries are broken on each point shared between 2 and more polygons where angles of segments are different
prune	remove vertices in threshold from lines and boundaries, boundary is pruned only if topology is not damaged (new intersection, changed attachment of centroid), first and last segment of the boundary is never changed
rmarea	remove small areas, the longest boundary with adjacent area is removed
rmline	remove all lines or boundaries of zero length, threshold is ignored
rmsa	remove small angles between lines at nodes

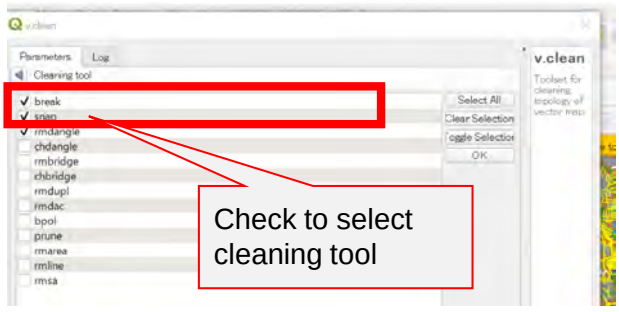
Project on Capacity Development for Urban Planning

7. Topological Error Cleaning (Using Cleaning Tool)

Cleaning Line data

1. Open v.clean. The window of v.clean will appear
2. Select Target layer to clean.
3. Click button on the right side of cleaning tool to select cleaning tool
4. Then select 3 cleaning process: **“break”, “snap” and “remove dangle”.** , then click “OK to back to main window
5. In the Threshold, fill with 0,5,5. Those are the threshold for each process. In this case, “0” for “break” tool. For “break” tool, it is just a dummy value, because it doesn’t need a threshold value. For “snap” and “remove dangle” tool the threshold value is 5. Threshold means the process will apply if it is equal or less than the specified threshold value. Otherwise it will ignore it. That's why specifying an appropriate threshold value is very important. (The threshold unit is in map unit.)
6. The other parameters leave as default
7. Run this v.clean tool.



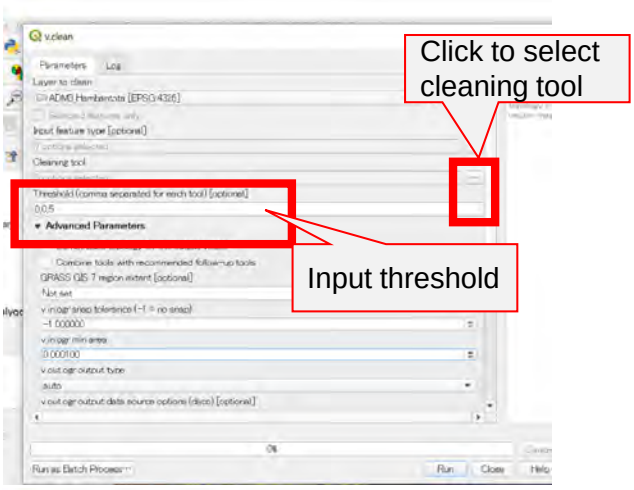


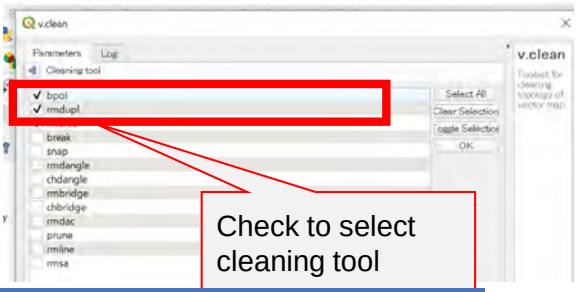
You may need to run this tool several times of this tool to identify suitable threshold value

7. Topological Error Cleaning (Using Cleaning Tool)

Cleaning Polygon data (Cleaning overlap and gap)

1. Open v.clean. The window of v.clean will appear
2. Select Target layer to clean.
3. Click button on the right side of cleaning tool to select cleaning tool
4. To clean the error, there are 3 processes are needed: “break polygon”, “remove duplicate” and “remove area”. Therefore, select Cleaning tools type: **“bpol”, “rmdupl”,”rmarea**”.. , then click “OK to back to main window. Make sure the 3 tools you have selected are in the order “bpol”, “rmdupl”, ”rmarea”, then back to main window
5. Define threshold value. For “bpol” and “rmdupl”, just give a dummy value 0, but for “rmarea”, gave it 3. It means an area less or equal with 3 (map unit square) will be removed.
6. The other parameters leave as default
7. Run this v.clean tool.



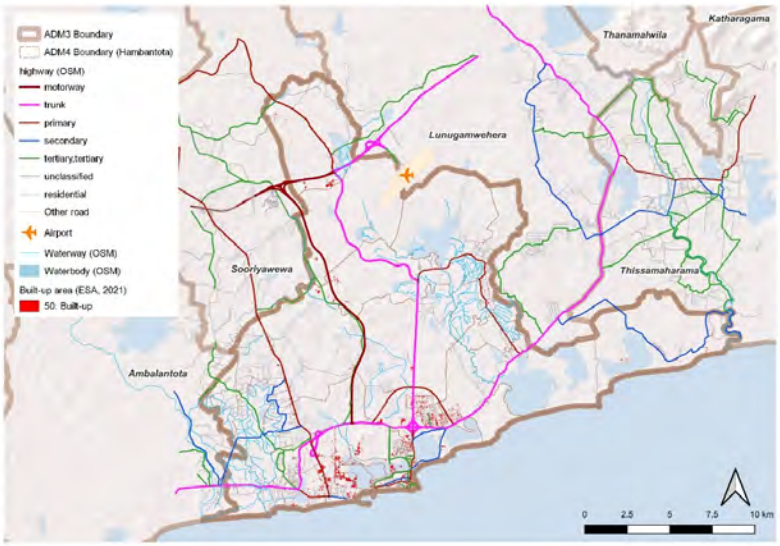


You may run this tool several times of this tool to identify suitable threshold value

Project on Capacity Development for Urban Planning

Contents 8:

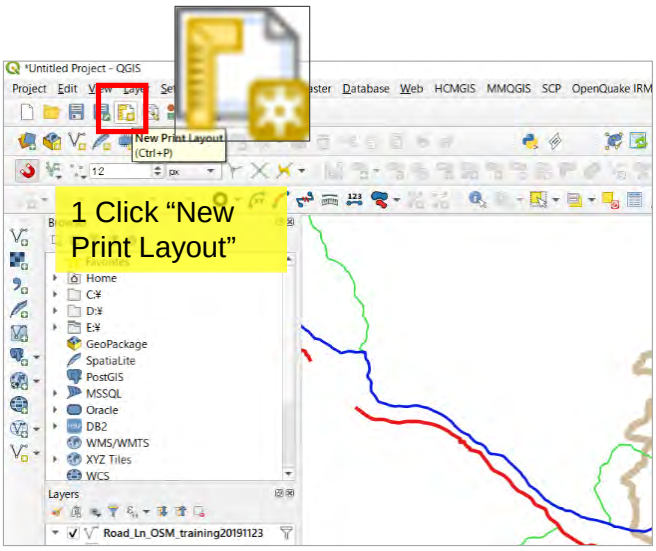
Layout Map with QGIS

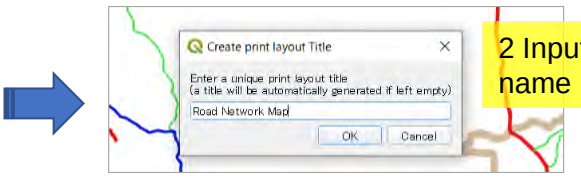


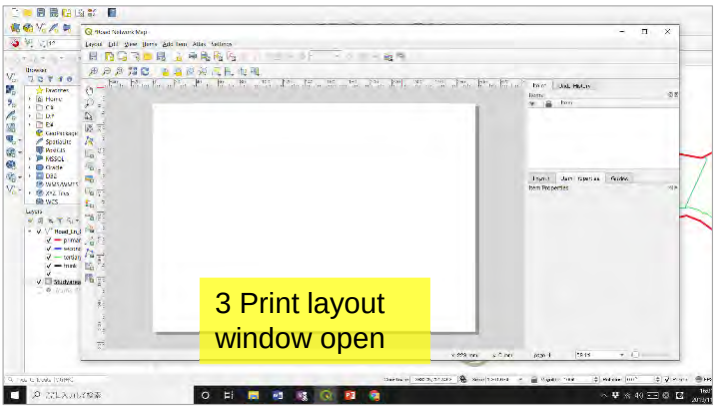
Exercise:
After the lecture, prepare beautiful map for presentation.
(For this exercise, the QGIS project file will be shared)

8. Layout Map with QGIS

Advanced Labeling Tool



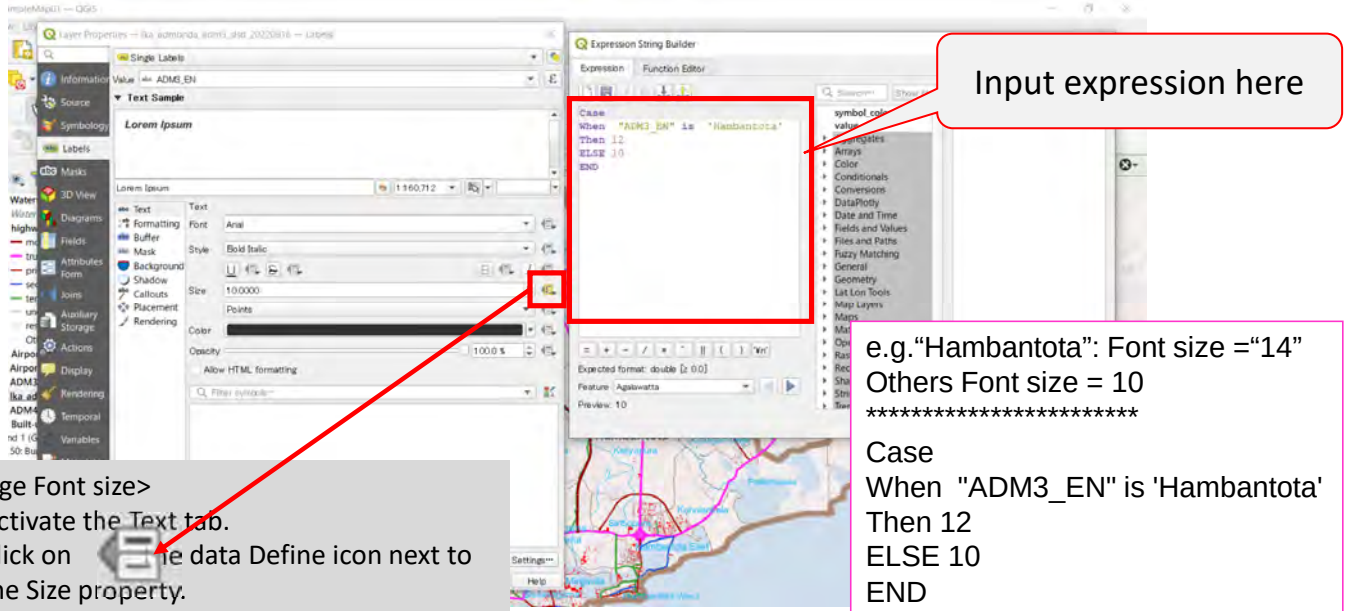




7. Topological Error Cleaning (Using Cleaning Tool)

Label Properties: for Basic Labeling

- Label properties provides you with all the needed and appropriate capabilities to configure smart labeling on vector layers.
- To access label properties: Double click the target layer name – Layer Properties – Labels tab
- You can customize label style using expression



<Change Font size>
1) Activate the Text tab.
2) Click on the data Define icon next to the Size property.
3) Select "Edit…" and type:

e.g."Hambantota": Font size ="14"
Others Font size = 10
****

Case
When "ADM3_EN" is 'Hambantota'
Then 12
ELSE 10
END
****

8. Layout Map with QGIS

Advanced Labeling Skills using Labeling Tool Bar

- Some tools to manipulate label (including their callout) or diagram properties
- You can hide/show label without expression
- You can move freely as you like



1	Highlight Pinned Labels, Diagrams and Callouts	If the vector layer of the item is editable, shows or hides a shaded 'outline' box around the labels that have been manually moved
2	Toggle Display of Unplaced Labels	Allows to determine whether any important labels are missing from the maps
3	Pin/Unpin Labels and Diagrams.	By clicking or dragging an area, you pin overlaid items. If you click or drag an area holding Shift, the items are unpinned.
4	Show/Hide Labels and Diagrams	If you click on the items, or click and drag an area holding Shift, they are hidden. When an item is hidden, you just have to click on the feature to restore its visibility
5	Move a Label, Diagram or Callout	Click to select the item and click to move it to the desired place. The new coordinates are stored in auxiliary field
6	Rotate a Label	Click to select the label and click again to apply the desired rotation. Likewise, the new angle is stored in an auxiliary field
7	Change Label Properties	It opens a dialog to change the clicked label properties; it can be the label itself, its coordinates, angle, font, size, etc.

Project on Capacity Development for Urban Planning

8. Layout Map with QGIS

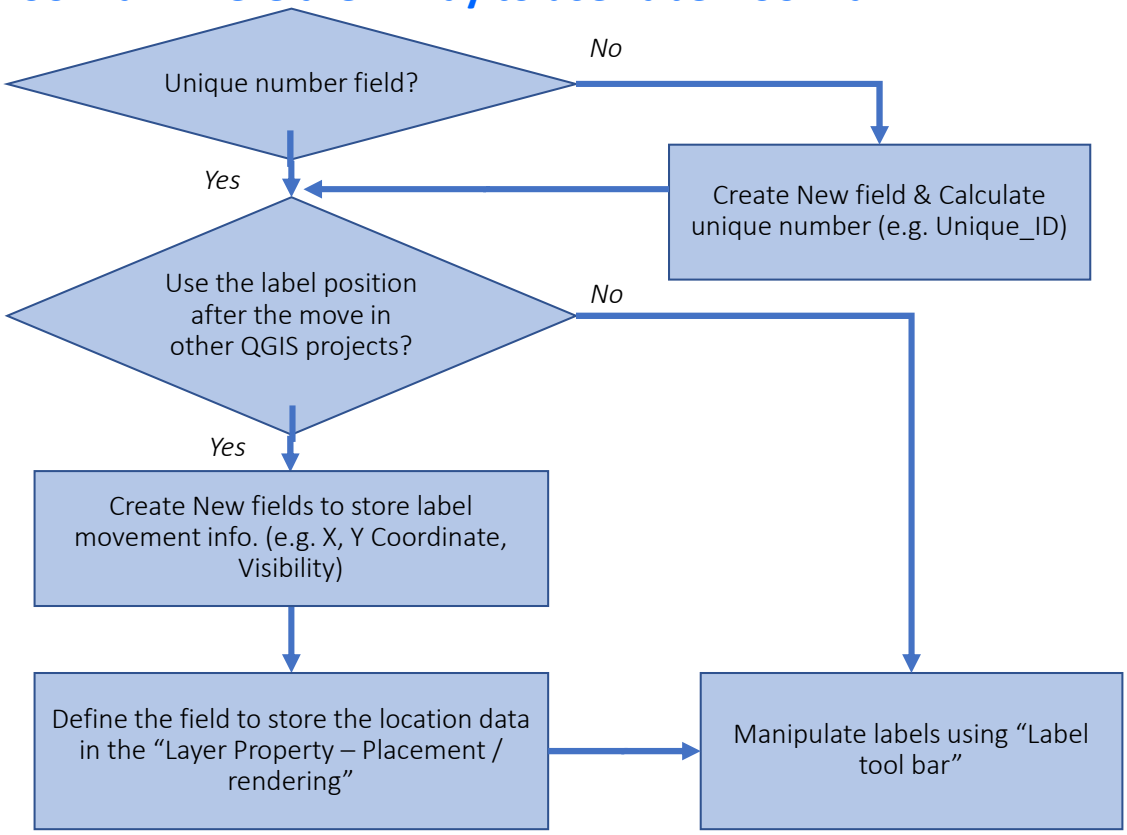
Label Tool Bar: Need to understand before use

<Important !>

1. The unique number field is necessary in the shapefile to use "Label tool bar"
2. If your shapefile doesn't have the unique filed, use Field calculator – "Record and Attribute" group – "$id ", then you can create the unique number field (This field will be "primary key" when you start manipulating label)
3. If you want use the moved location in the another QGIS Project, you need to prepare new fields to store the label location info.
   - *When you use "Move a Label, Diagram or Callout", you need to prepare fields to store "X coordinate" and "Y coordinate" to keep the label location in the attribute table. (Any field name are OK)*
   - *When you use "Show/Hide Labels and Diagrams", you need to prepare fields to store "Hide/ Unhide" information to keep the label visibility in the attribute table. (Any field name are OK)*
   - *Once you start manipulating labels, QGIS automatically store label manipulation information in the attribute table*

8. Layout Map with QGIS

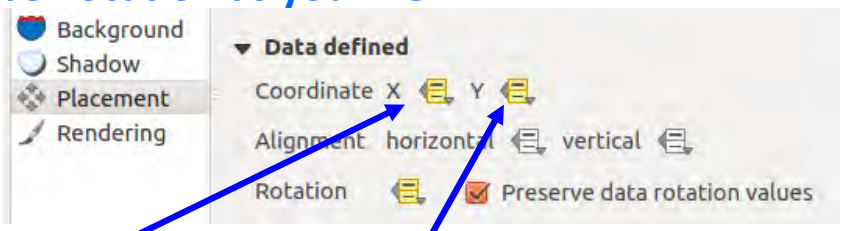
Label Tool Bar: There are 2-way to use Label Tool Bar

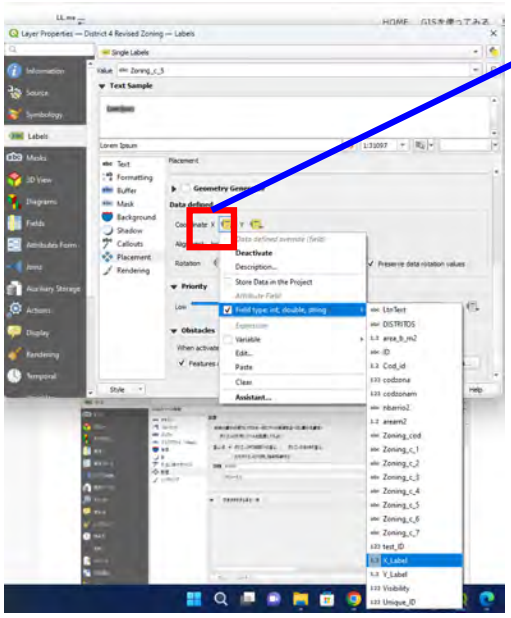


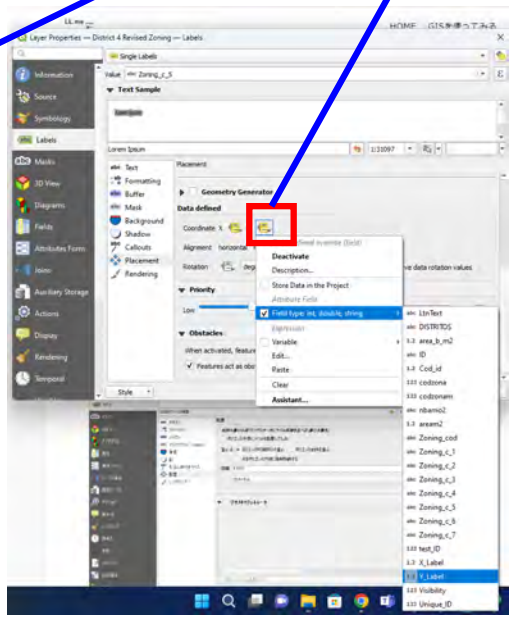
8. Layout Map with QGIS

Label Tool Bar: To move label location as you like

Preparation: Define Field as auxiliary field to Store Label Control Info.



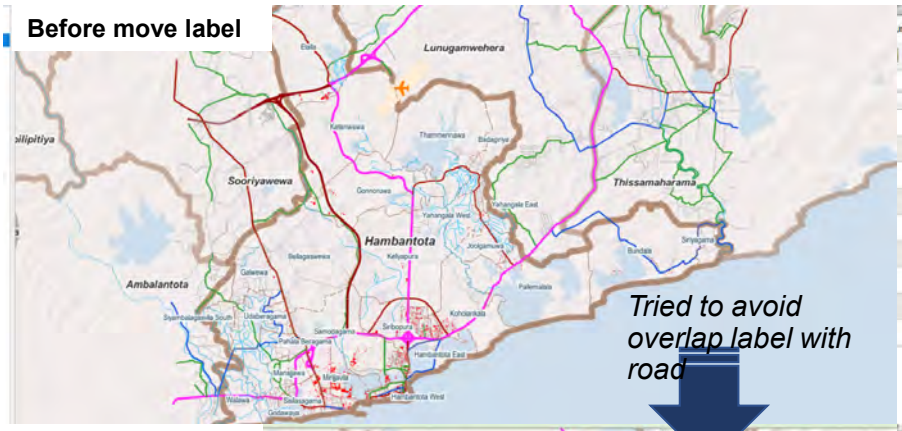


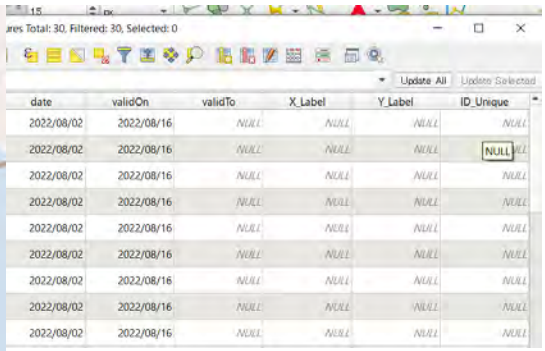


8. Layout Map with QGIS

Label Tool Bar: To move label location as you like

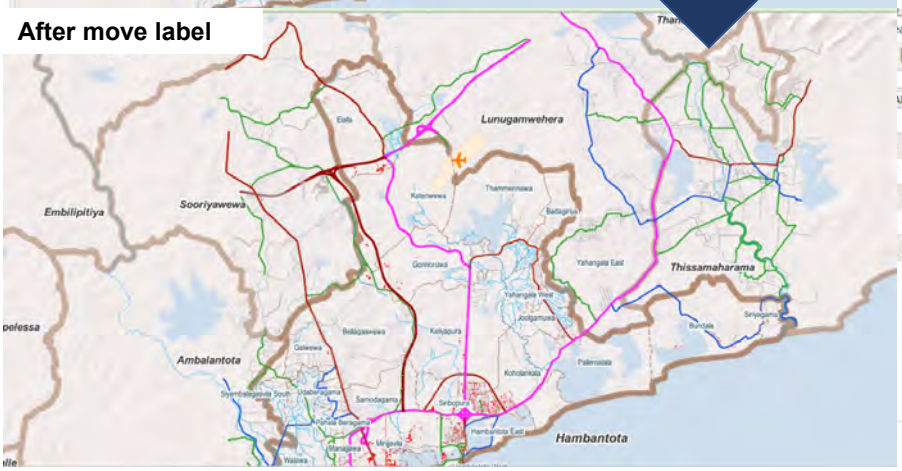
Before move label

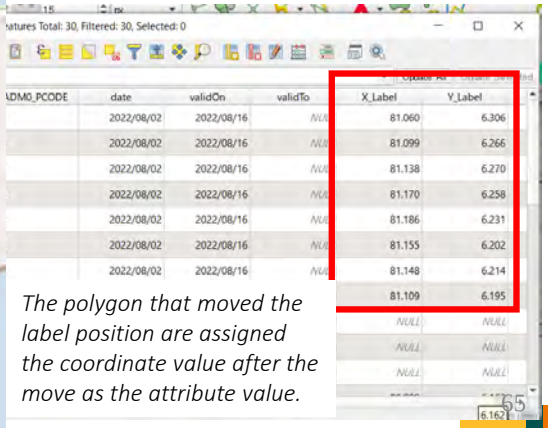




Tried to avoid overlap label with road

After move label



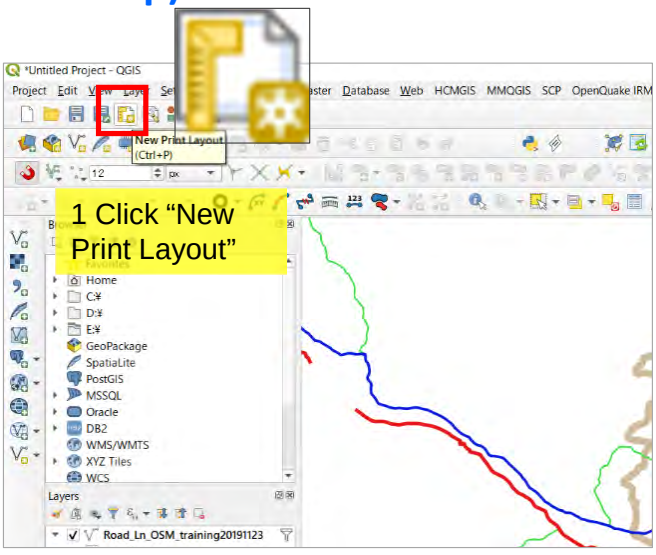


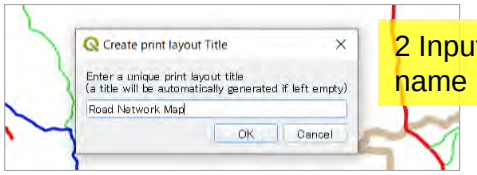
The polygon that moved the label position are assigned the coordinate value after the move as the attribute value.

Project on Capacity Development for Urban Planning

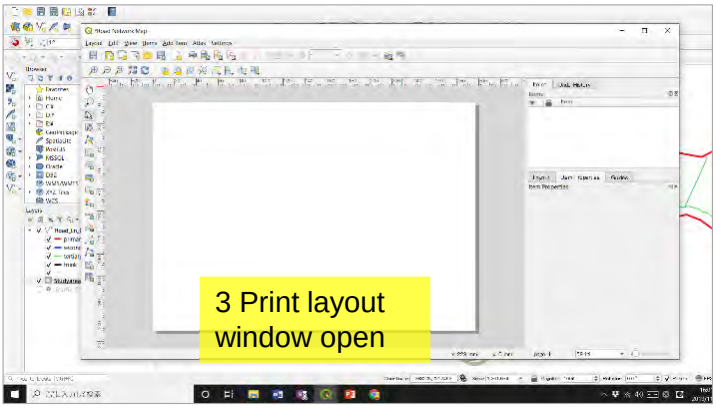
8. Layout Map with QGIS

Using “Print Layout” module (Similar function with Layout view in ArcMap)



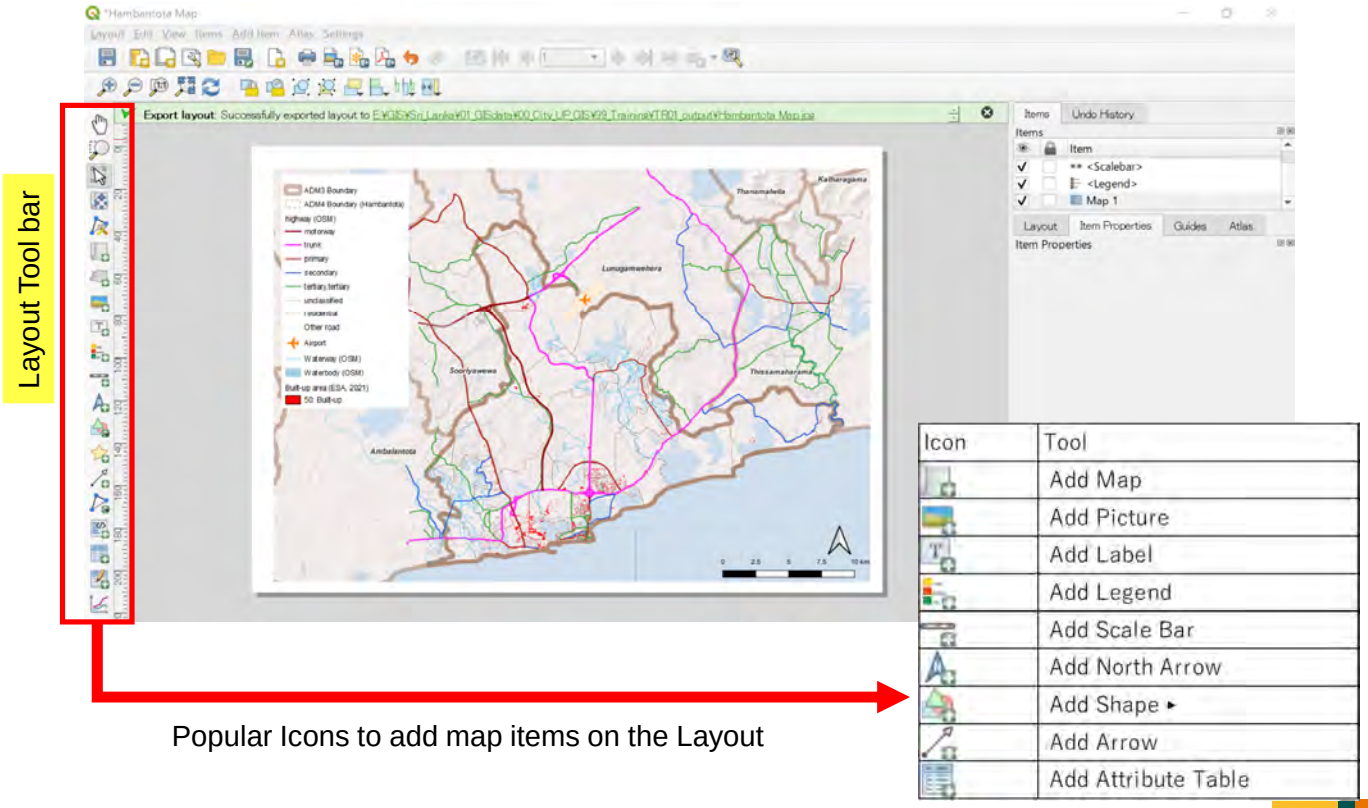


2 Input layout name



8. Layout Map with QGIS

Add Item on Layout

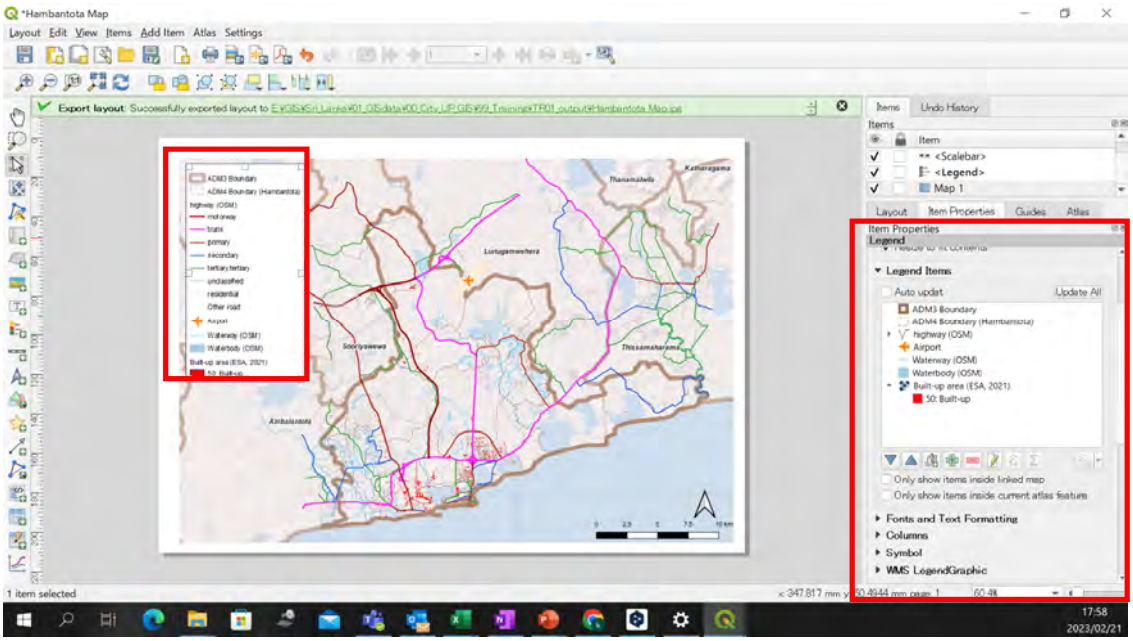


Popular Icons to add map items on the Layout

8. Layout Map with QGIS

Customize Layout Item

If you want to customize “Legend”, Click Legend, then Legend Item window will open.
You can customize the order of layers, font, etc.



Thank you!

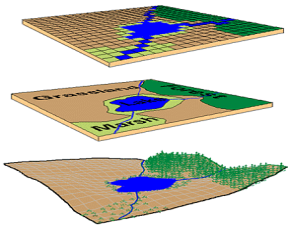
Project on Capacity Development for Urban Planning

PPT. No.3

Module LU3-2: Spatial Data Analysis by GIS

Introduction of Geographical Modeler in QGIS

The Project Capacity Development for Urban Planning






LU3-2: Introduction of Geographical Modeler in QGIS

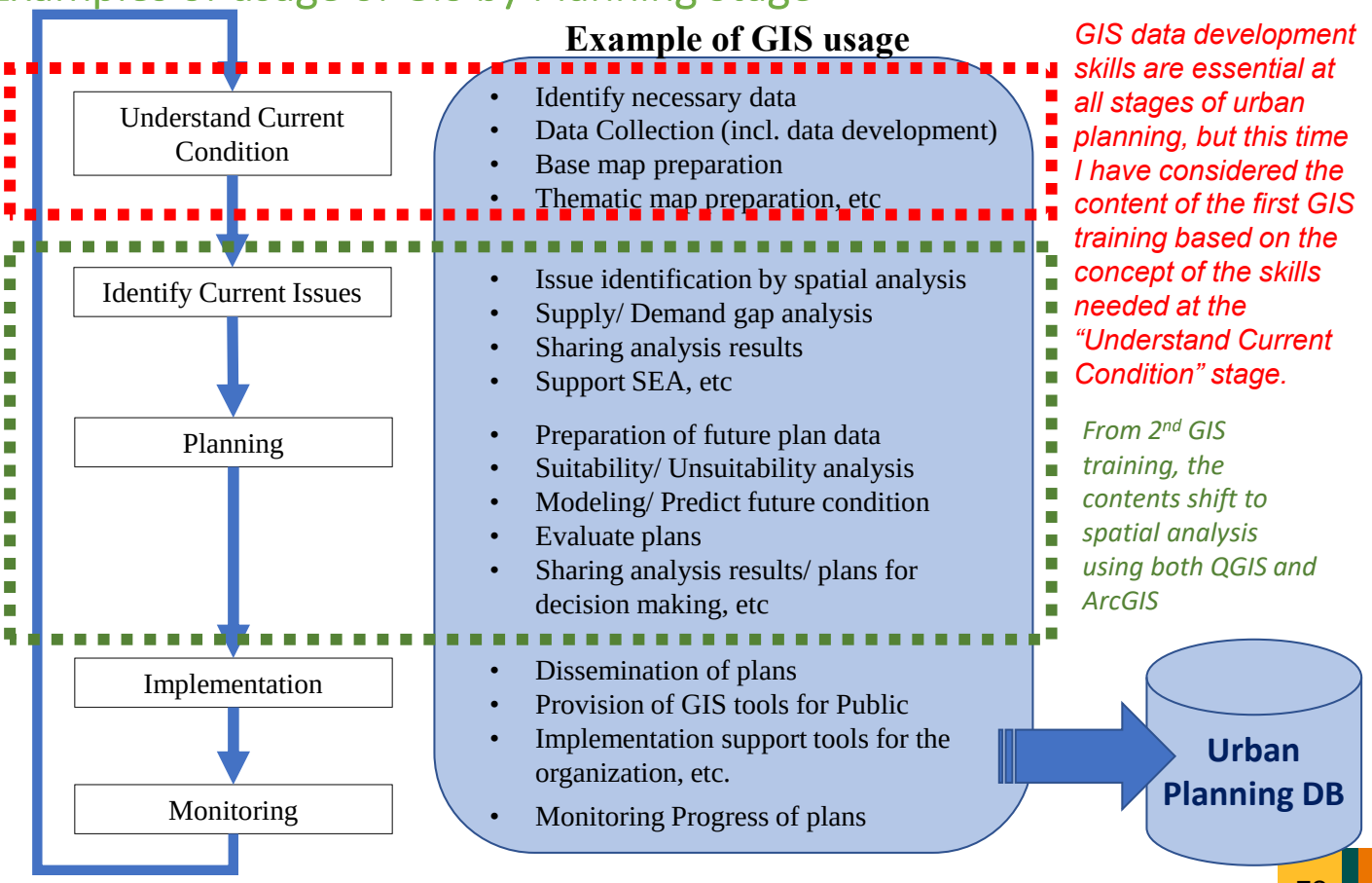
9 Mar. 2023

Outline of Module LU3: GIS

Major Theme		Training Title		Description	Tentative Training Course Plan	Indicator (Expected Outcome)	Required Time (Hour)
LU3	GIS	LU3-1	GIS and Spatial Data Construction	This module focuses on the method of spatial data construction, containing database schema concept, coding rules, data editing, error checking, and cleaning with Open source GIS software QGIS	(1) Lecture: GIS, QGIS general and Spatial Data Construction (2h) (2) Exercise (5h): Preparation of base map (incl. updating road network, administrative boundary, Data edit error check & cleaning, etc.)	[For Overall Goad, Project Purpose 1, Output 1] > GIS techniques are utilized in planning > Spatial data and Maps are organized and standardized > Spatial analysis ready vector data are prepared	7
		LU3-2	**Spatial Data Analysis by GIS**	**Several basic and advanced techniques of GIS is learnt for urban planning for both vector and raster analysis. The aim is to understand how GIS technology can be used to efficiently conduct analyses related to urban planning, including land use, environmental, and other possible analysis, etc.**	**(1) Lecture: Utilization of advanced GIS technics for planning (2h) (2) Exercise (5h) : 1) Network analysis (Shortest path, service coverage), 2) Raster analysis (Observation of land cover change)**	**[For Overall Goad, Project Purpose 1, Output 1] > GIS techniques are utilized in planning > Open data are utilized in the planning process**	**7**

Outline of Module LU3: GIS

Examples of usage of GIS by Planning Stage



GIS data development skills are essential at all stages of urban planning, but this time I have considered the content of the first GIS training based on the concept of the skills needed at the "Understand Current Condition" stage.

From 2nd GIS training, the contents shift to spatial analysis using both QGIS and ArcGIS

Project on Capacity Development for Urban Planning

1. Overview of Geographical Modeler in QGIS

1. Overview of Geographical Modeler in QGIS

Data processing is one of the main tasks of GIS. GIS software has many tools, both proprietary or open source, available for data processing. The data processing workflow typically requires several steps. These steps are connected to each other in a sequence of steps from input to output.
Therefore, all processing steps can be placed and connected in a model. In this session, we will show you how to create a model builder in QGIS called a ***graphical modeler.***

The advantage of utilizing Graphical Modeler is that the workflow of the GIS analysis can be recorded.

While it is difficult to utilize the spatial analysis model directly in other projects, at least the workflow can be referenced, eliminating the need to think through the workflow from scratch.

2. General Steps to Prepare Geographical Model

General steps to prepare a geographical model in QGIS using the Graphical Modeler:

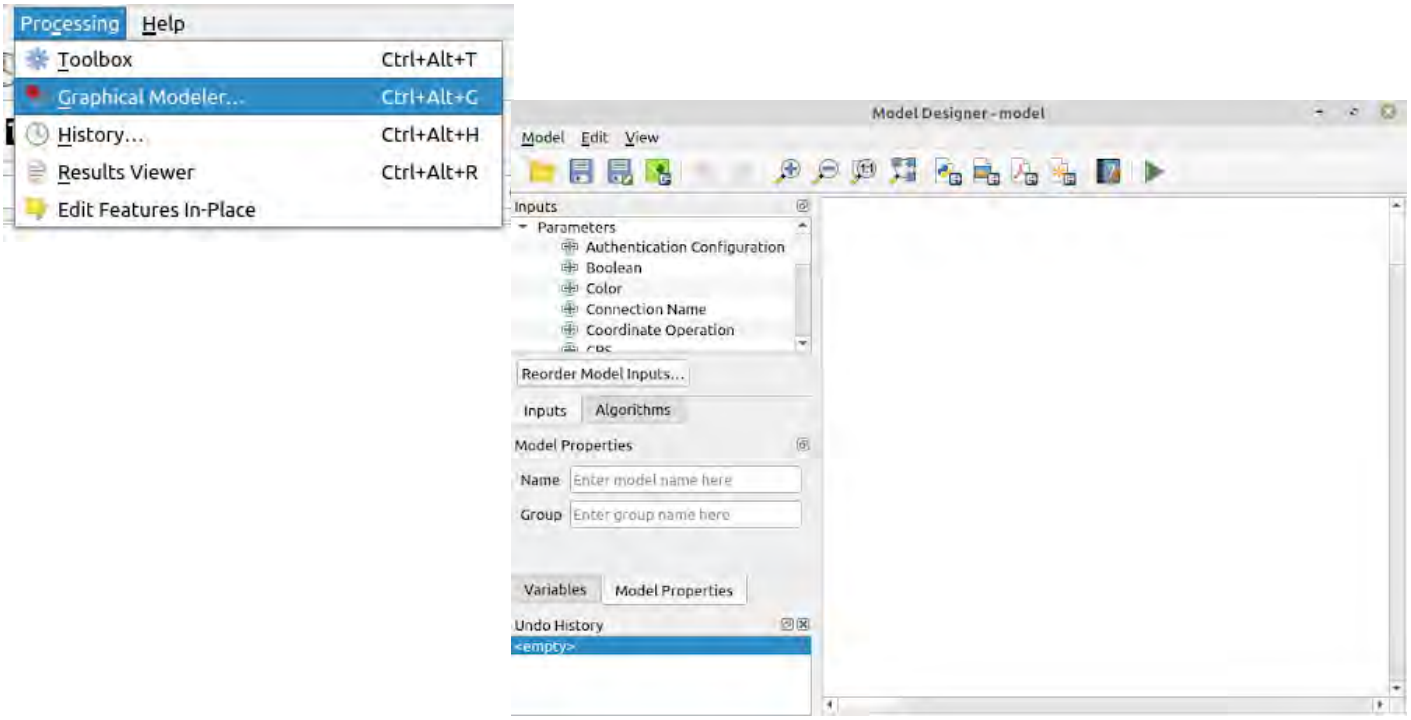
1. Open QGIS and go to the Processing Toolbox. Click on the **"Graphical Modeler"** icon.
2. In the Graphical Modeler interface, click on the **"New Model"** button to create a new model.
3. **Give the model a name** by double-clicking on the "Model name" box and typing in a name.
4. In the Processing Toolbox**, select and drag the processing algorithms** you want to include in your model to the model canvas. You can search for algorithms by name using the search bar at the top of the Processing Toolbox.
5. **Connect the processing algorithms** by clicking on the output of one algorithm and dragging the cursor to the input of another algorithm. Repeat this process until all algorithms are connected in the correct order.
6. **Define the inputs and outputs** for your model by adding parameters to your algorithms. To do this, right-click on an algorithm and select "Add Input" or "Add Output". Then, give each parameter a name and select the appropriate data type.
7. **Save your model** by clicking on the "Save" icon in the Graphical Modeler toolbar. Choose a location to save your model file and give it a name.
8. To **test your model**, go back to the main QGIS window and select the model from the Processing Toolbox. Fill in the input parameters and run the model.

That's it! This is a basic process for creating a sample geographical model in QGIS using the Graphical Modeler. You can customize your model by adding more algorithms, parameters, and data types as needed.

2. General Steps to Prepare Geographical Model

Open QGIS and go to the Processing Toolbox. Click on the **"Graphical Modeler"** icon.

To start a model in QGIS, you have to open a graphical modeler window from Processing menu then select Graphical Modeler. An empty graphical modeler window will be opened.



Project on Capacity Development for Urban Planning

Thank you!

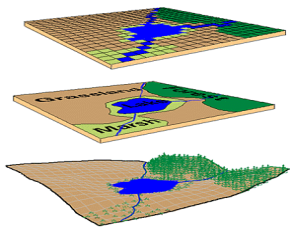
PPT. No.4

Module LU3-2: Spatial Data Analysis by GIS

Example of GIS usage in Planning Activities

Project on Capacity Development for Urban Planning

The Project Capacity Development for Urban Planning






LU3-1 & LU3-2: Example of GIS usage in Planning Activities

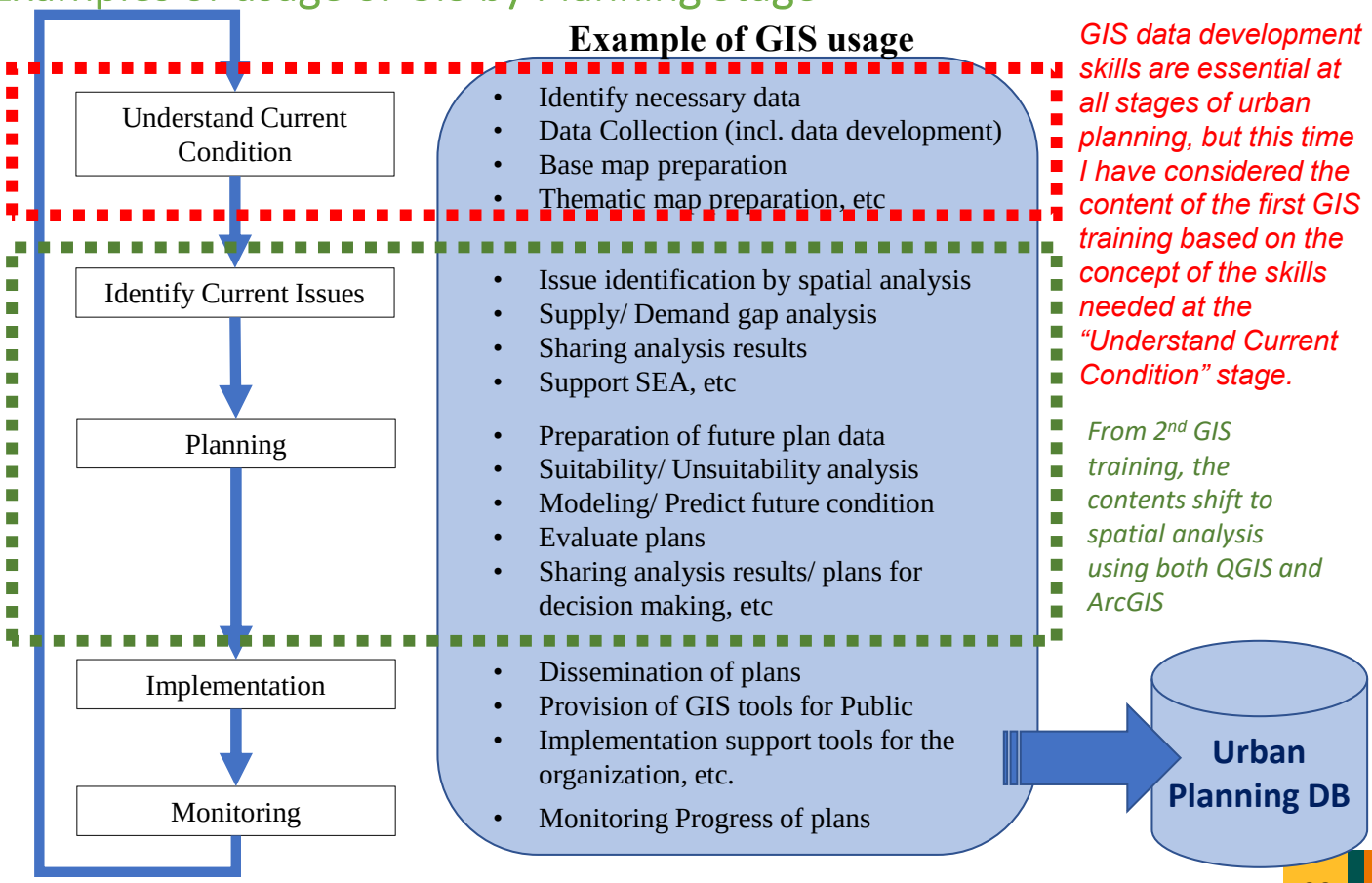
9 Mar. 2023

Outline of Module LU3: GIS

Major Theme		Training Title		Description	Tentative Training Course Plan	Indicator (Expected Outcome)
LU3	GIS	LU3-1	GIS and Spatial Data Construction	This module focuses on the method of spatial data construction, containing database schema concept, coding rules, data editing, error checking, and cleaning with Open source GIS software QGIS	(1) Lecture: GIS, QGIS general and Spatial Data Construction (2h) (2) Exercise (5h): Preparation of base map (incl. updating road network, administrative boundary, Data edit error check & cleaning, etc.)	[For Overall Goad, Project Purpose 1, Output 1] > GIS techniques are utilized in planning > Spatial data and Maps are organized and standardized > Spatial analysis ready vector data are prepared
		LU3-2	**Spatial Data Analysis by GIS**	Several basic and advanced techniques of GIS is learnt for urban planning for both vector and raster analysis. The aim is to understand how GIS technology can be used to efficiently conduct analyses related to urban planning, including land use, environmental, and other possible analysis, etc.	(1) Lecture: Utilization of advanced GIS technics for planning (2h) (2) Exercise (5h) : 1) Network analysis (Shortest path, service coverage), 2) Raster analysis (Observation of land cover change)	[For Overall Goad, Project Purpose 1, Output 1] > GIS techniques are utilized in planning > Open data are utilized in the planning process

Outline of Module LU3: GIS

Examples of usage of GIS by Planning Stage



GIS data development skills are essential at all stages of urban planning, but this time I have considered the content of the first GIS training based on the concept of the skills needed at the "Understand Current Condition" stage.

From 2nd GIS training, the contents shift to spatial analysis using both QGIS and ArcGIS

Example 1:
Development Potential Analysis
<Raster Model>

0. Example from Jakarta Metropolitan Area

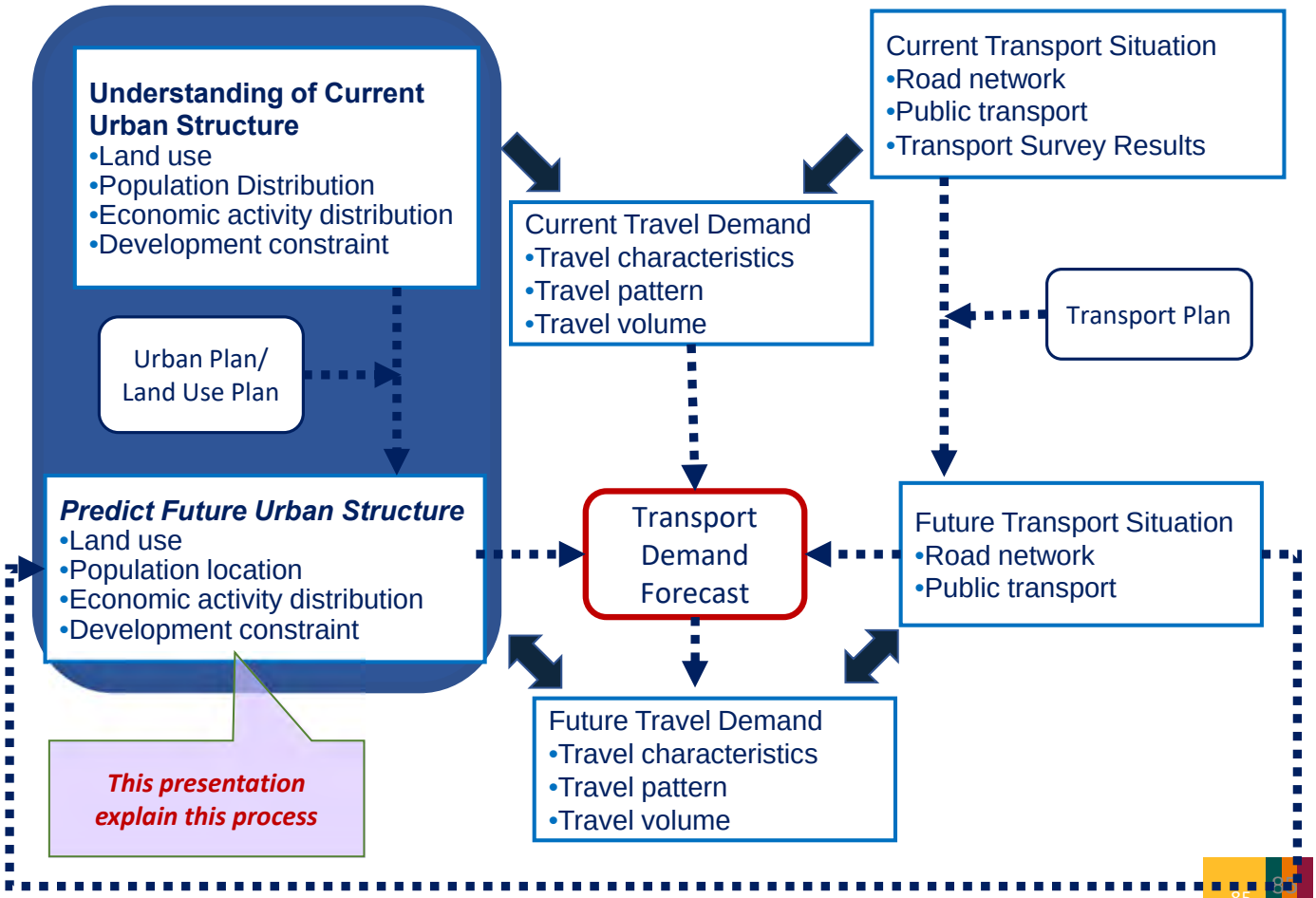
Development Potential Analysis for Future Population Distribution

Population Distribution Using Development Potential with GIS Techniques & MS Excel for Transport Demand Forecast Model

1. General Concept of Transport Demand Forecast
2. Utilization of GIS Techniques for Transport Planning
3. Objectives of Population Distribution
4. Overview of Population Distribution
5. **Development Constraint Analysis**
6. **Development Advantage Analysis (Base Year)**
7. **Development Potential Analysis (Base Year)**
8. Future Potential Analysis and Estimate Target year population

*In this analysis, **the development potential score** was calculated by subtracting the result **score of the development promotion analysis** from the result **score of the development constraint analysis**.*

0. Example from Jakarta Metropolitan Area



1. Outline of the Analysis

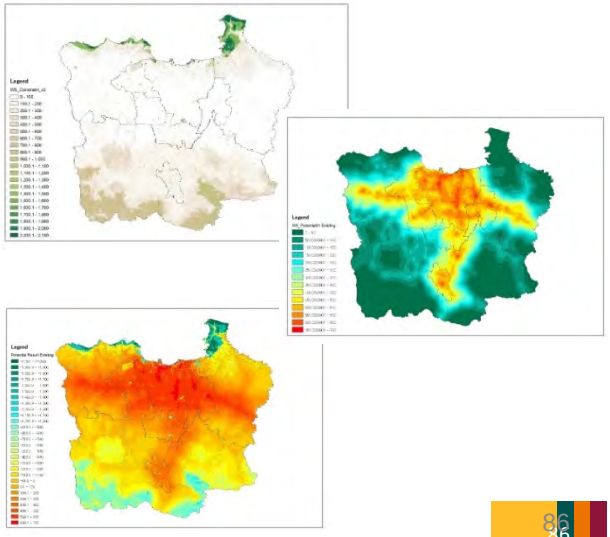
Objectives of Population Distribution

Preparation of Input parameter (SE indicators) for Transport Demand Forecast Model through *Development Potential Analysis*.

- To Identify current characteristics (=trend) of “Where people are tend to live/ work in the Study area?”, Population, Land use, Accessibility (road, railway station, Urban centers, etc.) and other various data are analyzed
- Future population distribution estimates based on current characteristics with collected Government policy/ Developments plans

This Development Potential Analysis aims to

- Identify Characteristics of Urban Structure in the Study area (Understand Current Situation)
- Assess Level of Suitability/ Unsuitability of Urban Development
- Predict Future Urban Structure
- Assess Proposed Transport Network



1. Outline of the Analysis

Overview of Population Distribution: Development Potential Analysis

Purpose

- Distribute Target Year Population by Traffic Analysis Zone (This will be input for Transport Demand Forecast Model) through Development potential analysis

※ *SE framework is not covered in this presentation*

Why it is necessary?

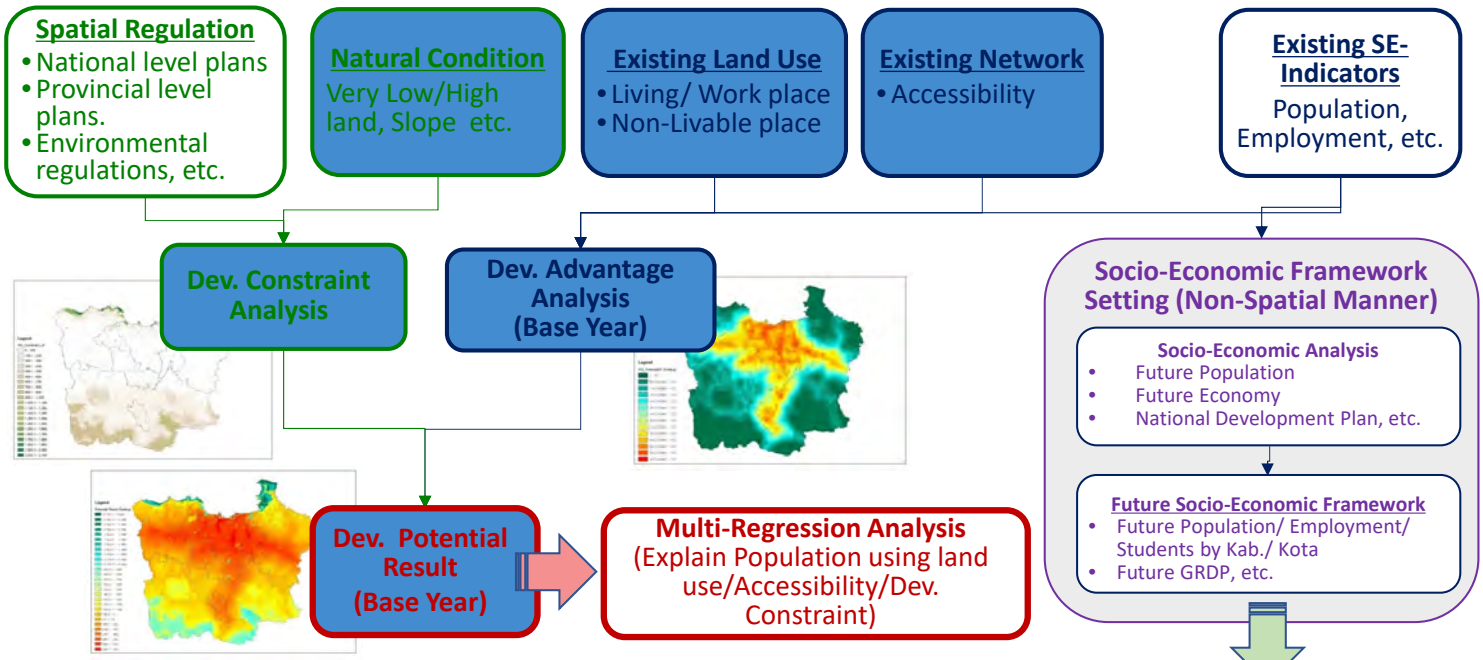
- Target Year Population is given by SE Framework Analysis.
- It is necessary to distribute these Framework data by TAZ for Transport Demand Forecast Model

Basic Idea

- Base year population is available by village level
- Identify relationship between "base year population by village" and "land use/Accessibility/Development Constraint" use GIS techniques (multi criteria analysis) & Multi-regression Analysis
- Use same methodology of current condition , predict target year population distribution considering future transport network, future development plans
- Development constraint areas use both Base year and Target Year

Project on Capacity Development for Urban Planning

2. Overview of Analysis : Base Year



Dev. Potential Analysis (Base year)
Re-production of JABODETABEK Population Distribution:

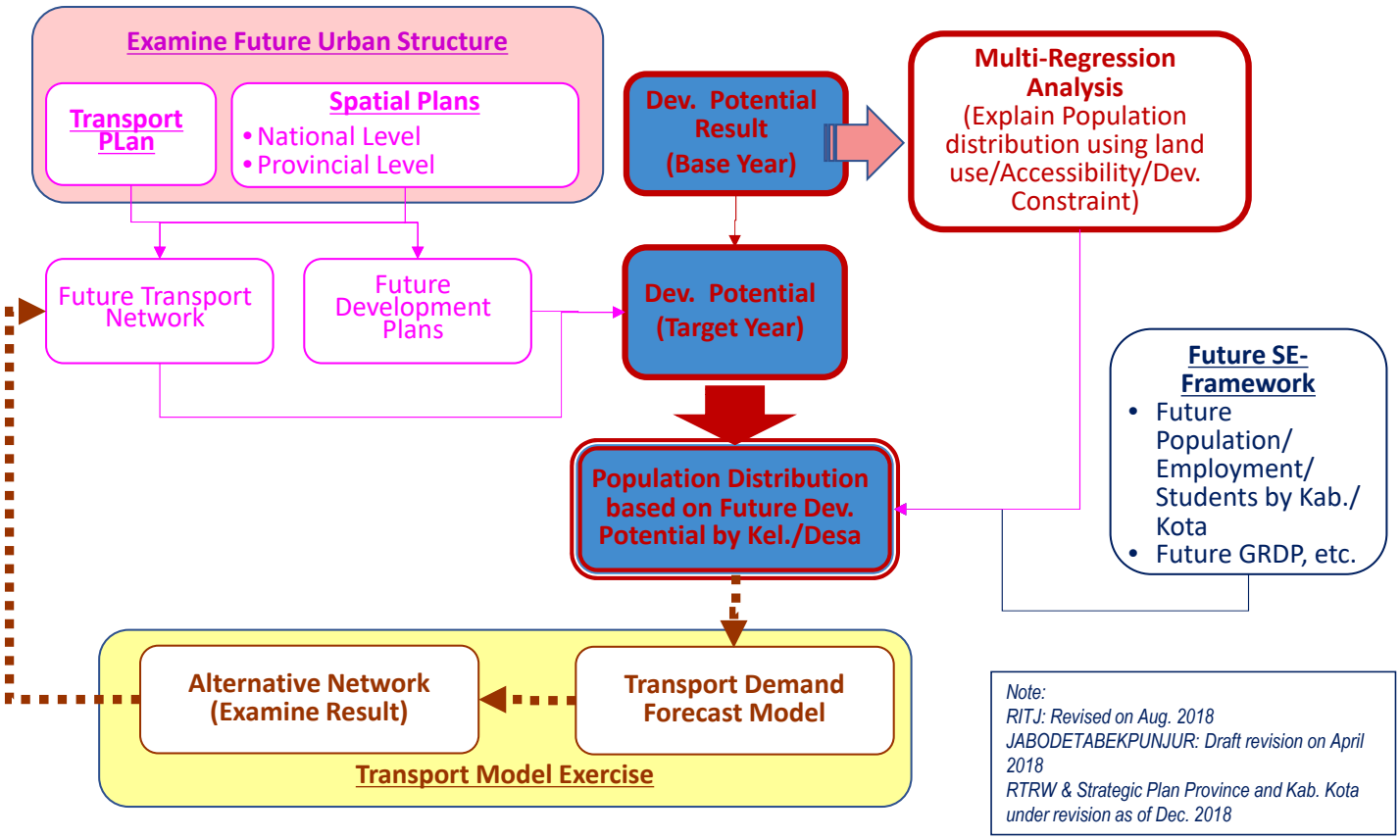
- Explain Base-year population distribution in Quantitatively & Spatially using land use, accessibility to transport and development constraint ***using Multi-Regression Analysis***
- Identify "which factor(s) affects higher/ lower density areas?"

⇒ Based on this results, predict future pop. distribution

- Framework sets by Level 3 Administrative unit
- Necessary to distribute by TAZ using *"Future Development Potential"*

Note:
RITJ: Revised on Aug. 2018
JABODETABEKPUNJUR: Draft revision on April 2018
RTRW & Strategic Plan Province and Kab. Kota under revision as of Dec. 2018

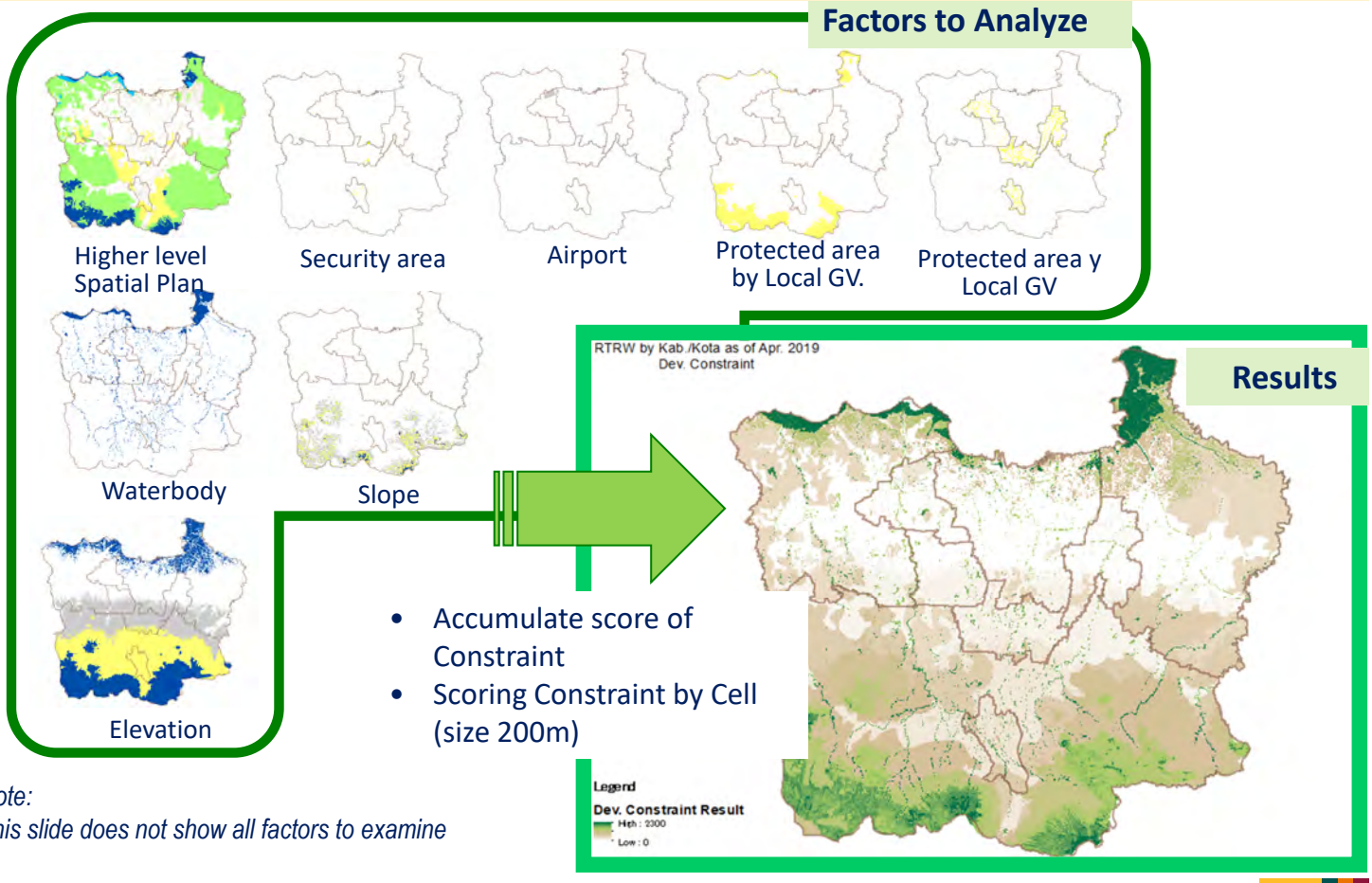
3. Overview of Analysis: Target Year



Note:
RITJ: Revised on Aug. 2018
JABODETABEKPUNJUR: Draft revision on April 2018
RTRW & Strategic Plan Province and Kab. Kota under revision as of Dec. 2018

Project on Capacity Development for Urban Planning

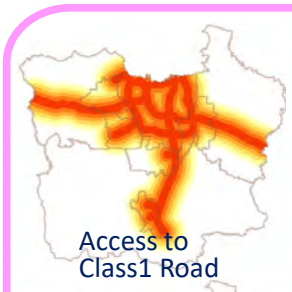
4. Development Constraint Analysis



Note:
This slide does not show all factors to examine

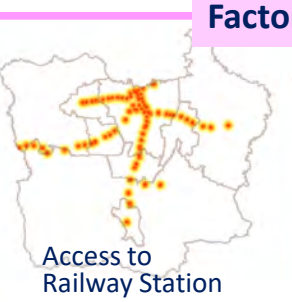
5. Development Advantage Analysis

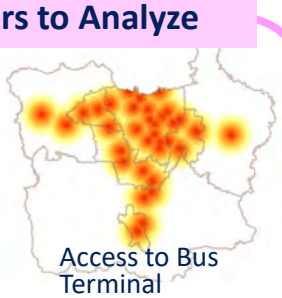
Factors to Analyze

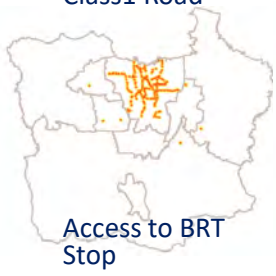

Access to Class1 Road


Access to Class2 Road


Access to Class3 Road


Access to Railway Station

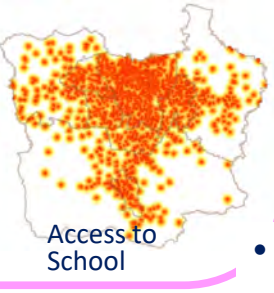

Access to Bus Terminal


Access to BRT Stop

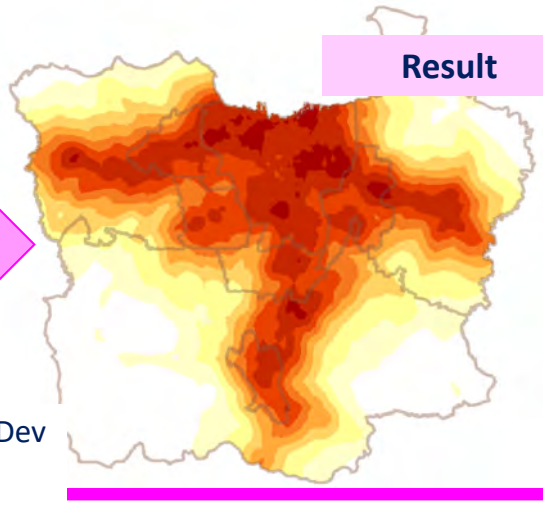

Access to City Center


Access to Market


Access to Industrial Zone


Access to School

Result

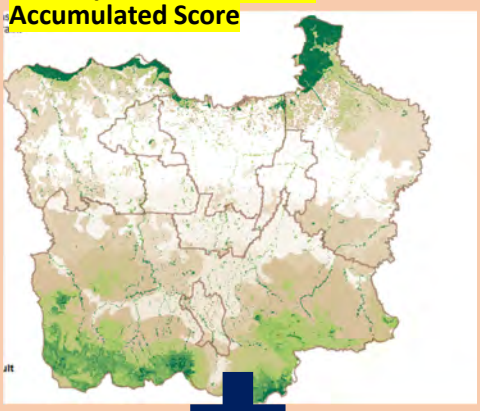


Note:
This slide does not show all factors to examine

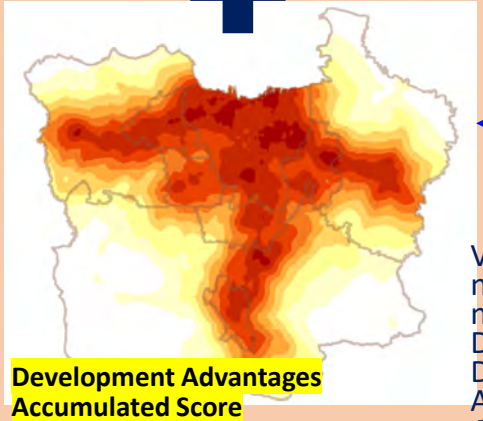
- Accumulate score of Dev Advantage
- Scoring Dev. Advantage (Cell size 200m)

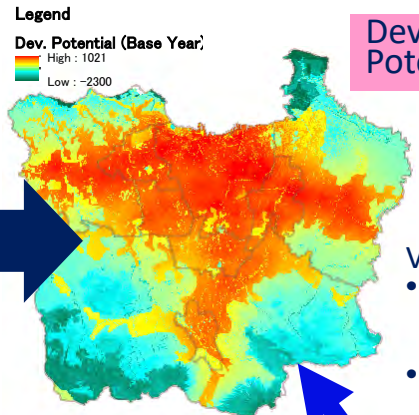
6. Development Potential Base Year: Identify Factors to Explain Population Distribution

Development Constraints Accumulated Score



Development Advantages Accumulated Score

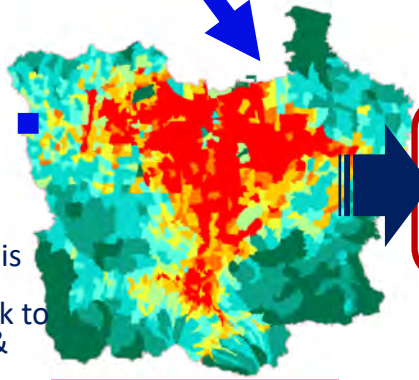




Development Potential (Base Year)

Validate with Actual Population

- Whether high population density areas are high potential areas or not?
- Identify factors to include Multi-regression Analysis



Multi-Regression Analysis
(Explain Population using land use/Accessibility/Dev. Constraint)

After validation, go to Multi-regression analysis

Validation result is not good, it is necessary to back to Dev. Constraint & Dev. Potential Analysis (Modify/ Add factors)

Population 2018

7. Development Potential Base Year: Multi-Regrresion Analysis

Result of Development Potential Analysis

- Identify factors (Explanatory variables) to explain base year population other than land use data

Multi-Regression Analysis (using MS Excel, not GIS software)

- To model relationship among factors and get regression equation (Estimate dependency of each factors=Coefficients)

Population for each Village is explained as below, based on Multi Regression Analysis (Population by village is collected given from Statistical Bereau)

$$
\begin{aligned}
Pop_{i=} \\
&0.01401 \times Residential\ area + \\
&0.006821 \times Industry\ \&\ Warehouse + \\
&0.007292 \times Commercial, Education\ \&\ Pub.Facility\ area + \\
&0.005291 \times Agriculture\ area + \\
&0.005992 \times Swamp, River\ \&\ Pond\ area + \\
&0.006163 \times Bush\ \&\ Forest\ area + \\
&-0.00838 \times Dev.\ Constraint\ score\ (Natural\ Condition) + \\
&0.000404 \times Dev.Constraint\ score(Regulation) + \\
&0.002002 \times Access\ to\ JKT\ score + \\
&0.000957 \times Access\ to\ Pub.Transport\ score + \\
&2452.762 \times Access\ to\ Road\ score
\end{aligned}
$$

7. Development Potential Base Year: Multi-Regrresion Analysis

Result of Development Potential Analysis

- Identify factors (Explanatory variables) to explain base year population

Multi-Regression Analysis (using MS Excel, not GIS software)

- To model relationship among factors and get regression equation (Estimate dependency of each factors=Coefficients)

	Explanatory variables	Coefficients	t -value	P-value	R Square	Observation
Land use	Residential area	0.01401	15.19636	1.35E-48	0.831	1501
	Industry & Warehouse	0.006821	6.515418	9.89E-11		
	Commercial, Education & Pub. Facility	0.007292	3.391975	0.000712		
	Agriculture	0.005291	5.927388	3.82E-09		
	Swamp, River & Pond	0.005992	5.979235	2.8E-09		
	Bush & Forest	0.006163	6.392709	2.17E-10		
Dev. Constraint (Natural Condition)	Waterbody, Slope, Elevation	-0.00838	-8.77062	4.76E-18		
Dev. Constraint (Regulation)	Airport, Protected area, Low Capacity area, Technical Irrigation, Buffer for Protected area & Low capacity area, Security area	0.000404	1.956395	0.050605		
Accessibility	Access to JKT	0.002002	10.9289	8.46E-27		
	Access to Pub. Transport	0.000957	6.233614	5.92E-10		
	Access to Road	2452.762	11.65018	4.41E-30		

8. Future Potential Analysis and Estimate Target Year Population

Factors to be included for Target year development potential

- Based on Multi-Regression Analysis result (Base year), following factors are necessary to estimate to estimate Target year population by Village
- After estimate data by Village, summarized by TAZ

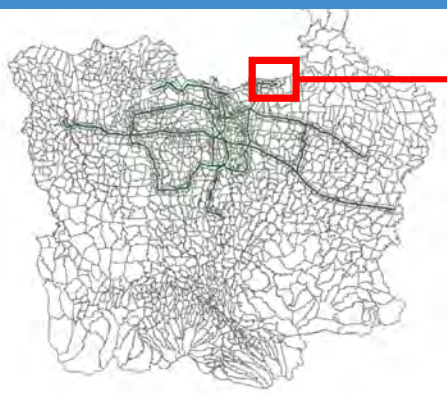
Category	Factors	Source
Natural Condition	Waterbody	Same as Base year
	Slope Condition	Same as Base year
	Very High/ Low land area	Same as Base year
Spatial Regulation	Airport	Same as Base year
	Protected area	Same as Base year
	Low capacity land	Same as Base year
	Technical irrigation area	Same as Base year
	Buffer area for Protected area/ Low Capacity land	Same as Base year
	Score of Development Constraint Analysis	Same as Base year
Accessibility	**Road Access (by Road class)**	**Target year road network**
	Access to JKT (Travel time to JKT (30/60/90min.), Distance to JKT)	**Target year road network**
	Access to Public Transport (Railway /Bus Terminal/ BRT/ MRT/ LRT/ Monorail)	**Target year public transport network**
Land use (Livable area)	**Residential area, Industrial area, Commercial, Education&Pub. Facility, Agriculture, Bush&Forest**	**Spatial Plan by Local GV (incl. New development areas, Planned large scale industrial development area**

8. Future Potential Analysis and Estimate Target Year Population

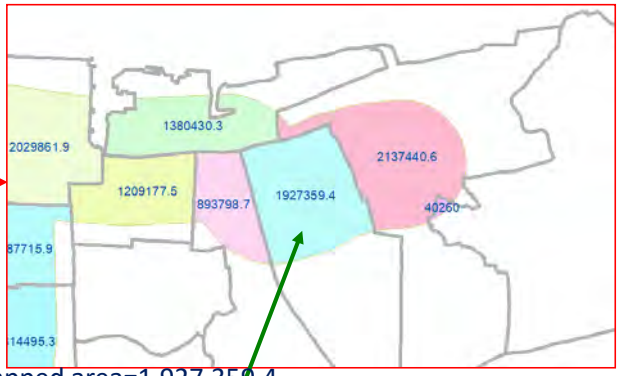
Preparation of data (factors) to be included for Target year

- Natural Condition and Regulation factors are same as base year data
- Prepare data based on Network data for Transport Demand Forecast Model and other Future plan data
- Calculate overlap areas of village and "Factors" (this area value will be "Score")

Sample: Calculation of overlap area: JUTPI MRT Network 2035



Planned MRT Network in Target year



Overlapped area=1,927,359.4
(This area value is "Score" of Future Public Transport)

Calculate 800 buffer area as influential area

Intersect "Village boundary" & 800m buffer area (Identify overlaped area)

Calculate these factors using same method

Accessibility	Road Access (by Road class)
	Access to JKT (Travel time to JKT (30/60/90min.), Distance to JKT)
	Access to Public Transport (Railway /Bus Terminal/ BRT/ MRT/ LRT/ Monorail)
Land use (Livable area)	Residential area, Industrial area, Commercial, Education&Pub. Facility, Agriculture, Bush&Forest

8. Future Potential Analysis and Estimate Target Year Population

Preparation data (factors) to be included for Target year development potential

- Natural Condition and Regulation factors are same as base year data
- Prepare data based on Transport Demand Forecast Model (Network data)
- Calculate overlap areas "Kel./Desa" and "Factors" within each Kel./Desa (this value will be "Score")

Example of Attributes data
This data will be inputs for Multi regression analysis to estimate Future population

IDVillage	Total area Village	Waterbody score	. . . . .	Protected area	Low Capacity area	. . . . .	Access to Road	Access to Pub. Transport	. . . . .	Livable area
3171010001	4110714.3	101123.3	. . . . .	258098.4	52809.1	. . . . .	4001350.8	2101350.8	. . . . .	3538902.1
3171010002	3322110	221133.4	. . . . .	112233.4	0	. . . . .	334455.6	1234.1	. . . . .	45678.9
. . . . .										

8. Future Potential Analysis and Estimate Target Year Population

Example of Attributes data
This data will be inputs for Multi regression analysis to estimate Future population

			Livable area (RTRW)	Access to JKT	Access to Public Transport	Access to Road	TOD influential area	GC influencial area	Planned large scale industry	Protected area	Loca capacity land	Technical Irrigation	Buffer for Protected area	Buffer for Low Capacity land	Security area	Dev. Constraint score
IDDESA	SMALLT RFZN	Area_SZ	Y35Res_TL_Res	Urban(JKT)_ACC	Pub_Transport ACC	Road_Acc	SC_Y35_P20_TOD	SC_Y35_P21_GC	P22NewDev	J_Prote	LowCp	TecIrri	BfProte	BfLowCp	Militar	Constra
3171010001	27	4110714.35	3289433.836	10670722.89	8144248.59	4.653552681	0.00000	0.00000	0	0.00000	499,818.96	0.00000	0.00000	0.00000	0.00000	0.00000
3171010002	28	3322110.675	4532397.209	11520469.78	10856160.3	3.305897263	0.00000	0.00000	0	0.00000	2,005,110.97	0.00000	0.00000	0.00000	0.00000	0.00000
3171010003	27	3647082.039	3481124.289	13993687.83	7294164.47	4.478072594	0.00000	0.00000	0	0.00000	1,640,479.75	0.00000	0.00000	0.00000	0.00000	0.00000
3171010004	27	5191589.074	4932762.506	8160411.755	10238091.1	3.71783798	0.00000	0.00000	0	0.00000	2,989,941.95	0.00000	0.00000	0.00000	0.00000	0.00000
3171010005	26	3155141.875	2917066.175	5679061.087	5975975.84	3.353107887	0.05204	0.00000	0	0.00000	1,252,248.68	0.00000	0.00000	0.00000	0.00000	0.00000
3171010006	26	3556907.629	3146454.058	7701932.934	5906990.97	4.876298156	0.07287	0.00000	0	0.00000	1,525,144.16	0.00000	0.00000	0.00000	0.00000	0.00000
3171020001	24	3840156.593	2835956.512	8965293.696	7394604.6	4.68785373	0.00000	0.00000	0	0.00000	260,786.92	0.00000	0.00000	0.00000	0.00000	0.00000
3171020002	24	4664562.609	2711025.857	8702862.236	9316601.5	4.41349854	0.07763	0.00000	0	0.00000	986,920.64	0.00000	0.00000	0.00000	0.00000	0.00000
3171020003	25	2720137.252	2633263.516	13071485.19	5240172.34	4.36534361	0.02908	0.00000	0	0.00000	2,368,390.79	0.00000	0.00000	0.00000	0.00000	0.00000
3171020004	25	1892846.896	1810361.51	10524690.8	3690945.2	5	0.00000	0.00000	0	0.00000	23,233.07	0.00000	0.00000	0.00000	0.00000	0.00000
3171020005	25	2567068.077	2464408.823	17610085.87	5044608.25	4.695987549	0.05468	0.00000	0	0.00000	219,197.04	0.00000	0.00000	0.00000	0.00000	0.00000
3171020006	15	2987463.483	2974819.434	5207890.879	5974927.44	4.369689562	0.00000	0.00000	0	0.00000	0.00	0.00000	0.00000	0.00000	0.00000	0.00000
3171020007	16	2886106.482	2220096.332	7562218.336	5323080.29	4.934275213	0.00000	0.00000	0	0.00000	0.00	0.00000	0.00000	0.00000	0.00000	0.00000
3171030001	12	4357064.799	4318172.692	13288396.99	8686696.7	4.218059826	0.22282	0.08292	0	0.00000	3,386.35	0.00000	0.00000	0.00000	0.00000	0.00000
3171030002	10	3508230.267	3345014.685	5742978.211	7006924.3	4.566119891	0.00000	0.00000	0	0.00000	1,407,092.95	0.00000	0.00000	0.00000	0.00000	0.00000
3171030003	9	5869846.354	5496964.974	6223799.982	11514819.1	4.828138959	0.00000	0.34248	0	0.00000	242,727.87	0.00000	0.00000	0.00000	0.00000	0.00000
3171030004	8	1599931.079	1286386.855	6305465.992	3199862.99	3.3363699	0.00000	0.14525	0	0.00000	0.00	0.00000	0.00000	0.00000	0.00000	0.00000
3171030005	11	2377983.116	2382428.485	8366934.194	4755966.63	3.394691489	0.00000	0.11358	0	0.00000	0.00	0.00000	0.00000	0.00000	0.00000	0.00000
3171040001	6	4428446.522	4312002.692	20367362.15	8806122.88	4.974362428	0.00001	0.00000	0	0.00000	0.00	0.00000	0.00000	0.00000	0.00000	0.00000
3171040002	6	1914326.07	1721266.478	8082543.643	3828652.14	5	0.00000	0.00000	0	0.00000	0.00	0.00000	0.00000	0.00000	0.00000	0.00000
3171040003	5	2073458.405	1957945.311	7064115.612	4052716.24	4.76843135	0.00000	0.00000	0	0.00000	0.00	0.00000	0.00000	0.00000	0.00000	0.00000
3171040004	5	2101337.836	1985059.442	6678859.888	3729834.34	4.845353273	0.00000	0.00000	0	0.00000	0.00	0.00000	0.00000	0.00000	0.00000	0.00000
3171040005	5	2788599.451	2702911.924	11832882.13	5530189.81	4.974833282	0.00000	0.00000	0	0.00000	0.00	0.00000	0.00000	0.00000	0.00000	0.00000
3171050001	7	6789120.688	6525091.919	13200386.77	13310567.1	4.561860185	0.15287	0.02080	0	0.00000	0.00	0.00000	0.00000	0.00000	0.00000	0.00000
3171050002	4	2333504.187	1924496.453	6156096.113	4667009.37	4.444945792	0.00000	0.00000	0	0.00000	0.00	0.00000	0.00000	0.00000	0.00000	0.00000
3171050003	3	1962238.339	1858104.437	6546006.862	3918967.84	4.974473455	0.00000	0.00000	0	0.00000	0.00	0.00000	0.00000	0.00000	0.00000	0.00000

Use equation based on base year development potential, estimate Y35 population by Kel./Desa (Use same equation)

$$
\begin{aligned}
Pop_i = {} & 0.01401 \times Residential\ area + \\
& 0.006821 \times Industry\ \&\ Warehouse + \\
& 0.007292 \times Commercial, Education\ \&\ Pub.\ Facility\ area + \\
& 0.005291 \times Agriculture\ area + \\
& 0.005992 \times Swamp, River\ \&\ Pond\ area + \\
& 0.006163 \times Bush\ \&\ Forest\ area + \\
& -0.00838 \times Dev.\ Constraint\ score\ (Natural\ Condition) + \\
& 0.000404 \times Dev.Constraint\ score(Regulation) + \\
& 0.002002 \times Access\ to\ JKT\ score + \\
& 0.000957 \times Access\ to\ Pub.Transport\ score + \\
& 2452.762 \times Access\ to\ Road\ score
\end{aligned}
$$

Example 2:
Example of Urbanization Simulation
<Vector Model>

1. Advantages of Using GIS and Mesh Data

Advantage of Using Geographic Information System (GIS):

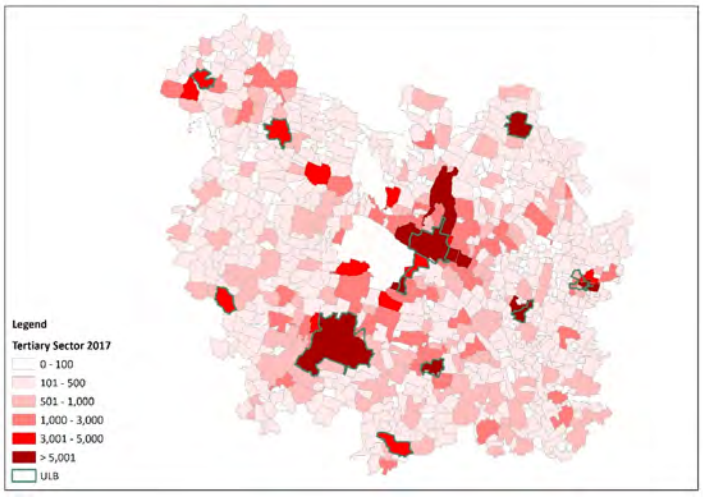
- A variety of information could be changed into spatially format and became visually
- Numerical data/information (e.g. Census data) could convert into GIS
- Accumulated data could overlay in spatial manner

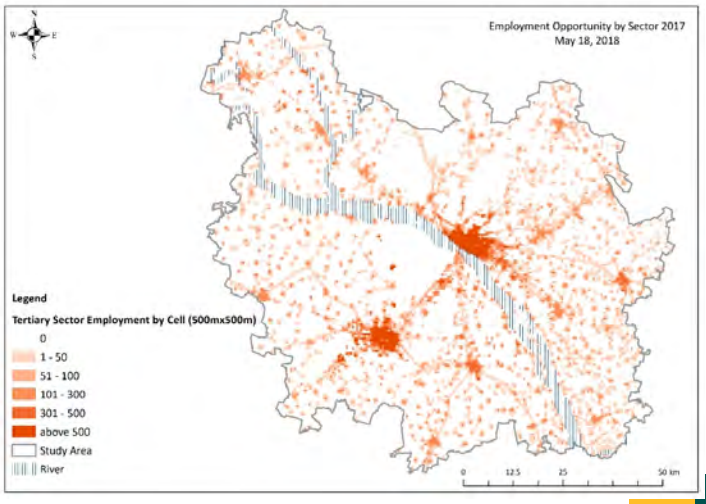
→ **Transport Model**

Advantage of Mesh Data Analysis:

- Mesh data analysis become accuracy compared to using administrative boundary
- The data could link to more specific area

* Smaller mesh data becoming large size file tends to be difficult to handle unless using high spec computer





Source: JICA Study Team

2. Objectives of Population/Employment Distribution by Using Land Use Data

APCR CTTS plans Comprehensive Transport by using Land Use data:

Land Use
- Living Place
- Working Place

⟷ Population & Employment ⟷ Number of Transport User ⟷ Transport Planning

Estimation of Existing Population/Employment Distribution for Transport Model (Base-Year):

- Estimation of the current population/employment allocation in spatial manner by using Existing Land Use

The result:

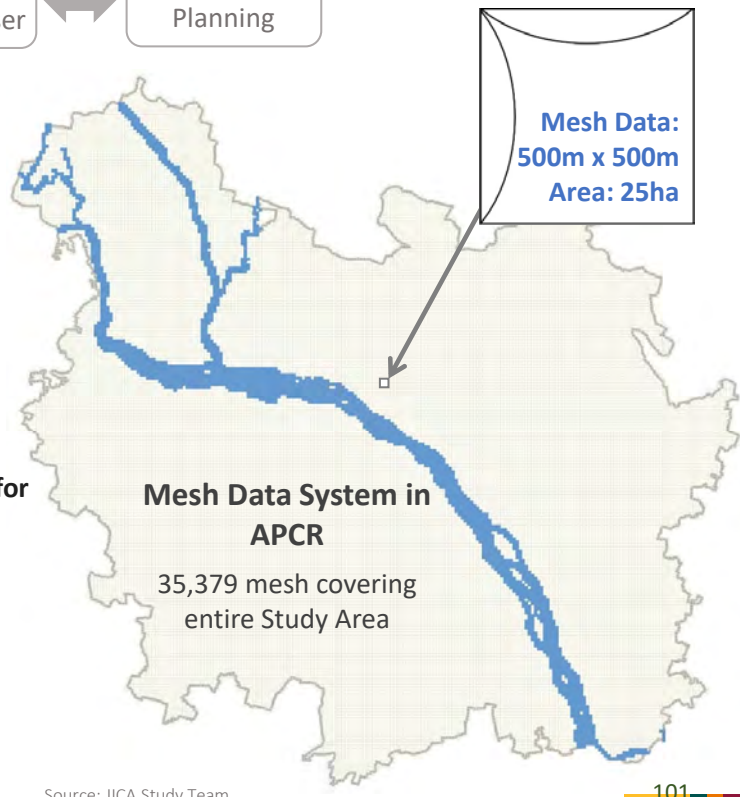
- Input to the Transport Model as base year data
- Recognizing the high/low dense area
- Understanding service coverage of transport facility

Estimation of Future Population/Employment Distribution for Transport Planning and Model (Future):

- Estimation of the future population/employment allocation in spatial manner by using urbanization model

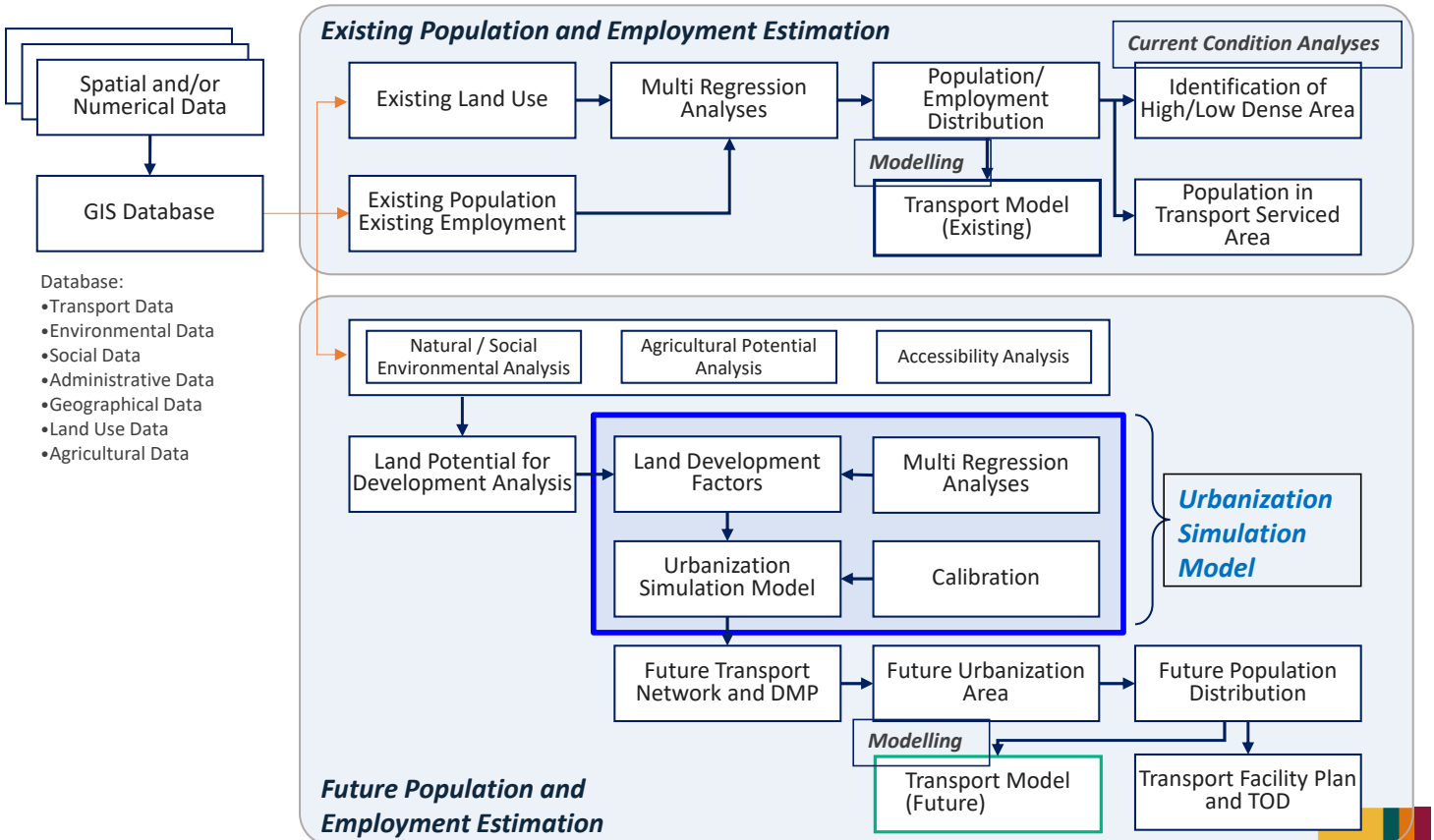
The result:

- Input to the Transport Model as target year data
- Transport facility and TOD planning



Source: JICA Study Team

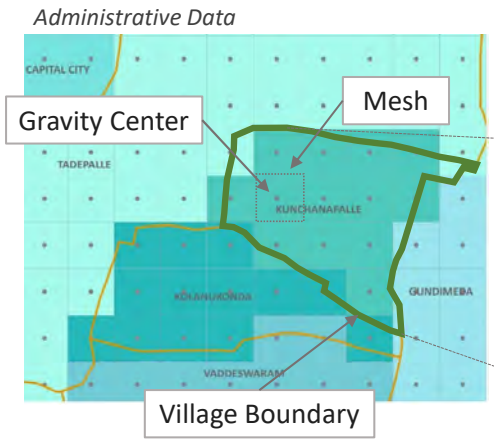
3. General Methodology of Population/Employment Distribution



Source: JICA Study Team

4. Brief Description of Attribute Data by Mesh

Attribute Data of Mesh:



Attribute Data of Administration is decided by Gravity Center of Mesh







Mesh has following Data

- Unique ID from 1 to 35,379
- Administrative Data (District, Mandal and Village)
- Status (Urban, Rural and Metropolitan Area)
- Land Use Data (Area by Category)
- Accessibility Data (Distance to Transport Facilities and Services)

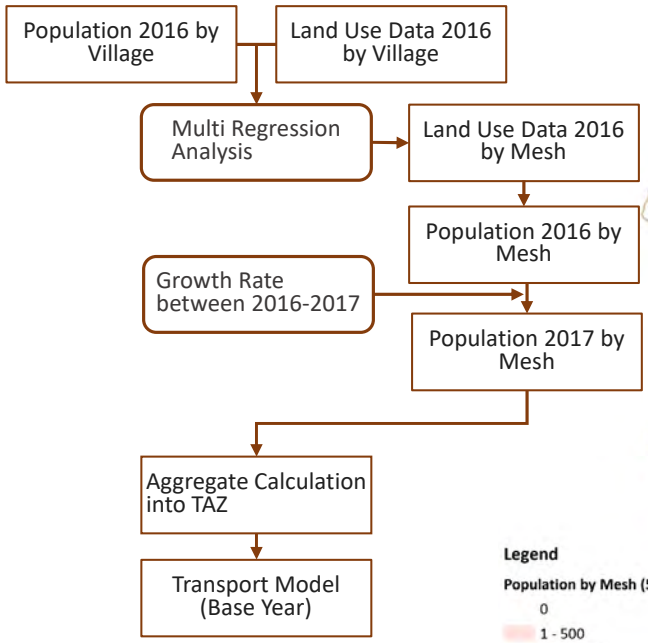
Example of Attribute Data by Mesh:

	Administrative Data					Land Use Data				Accessibility Data		
ID	Area	Village	Mandal	District	Status	LU_Res	LU_Com	LU_Ind	.....	MjRoad	Dis_BS	.....
30	25.0	Nandur	Ponnur	Guntur	Rural	0.51	0.00	0.11	.....	YES	800	.....
						Residence (ha)	Commercial (ha)	Industry (ha)		Major Road	Distance of Bus Stop (m)	

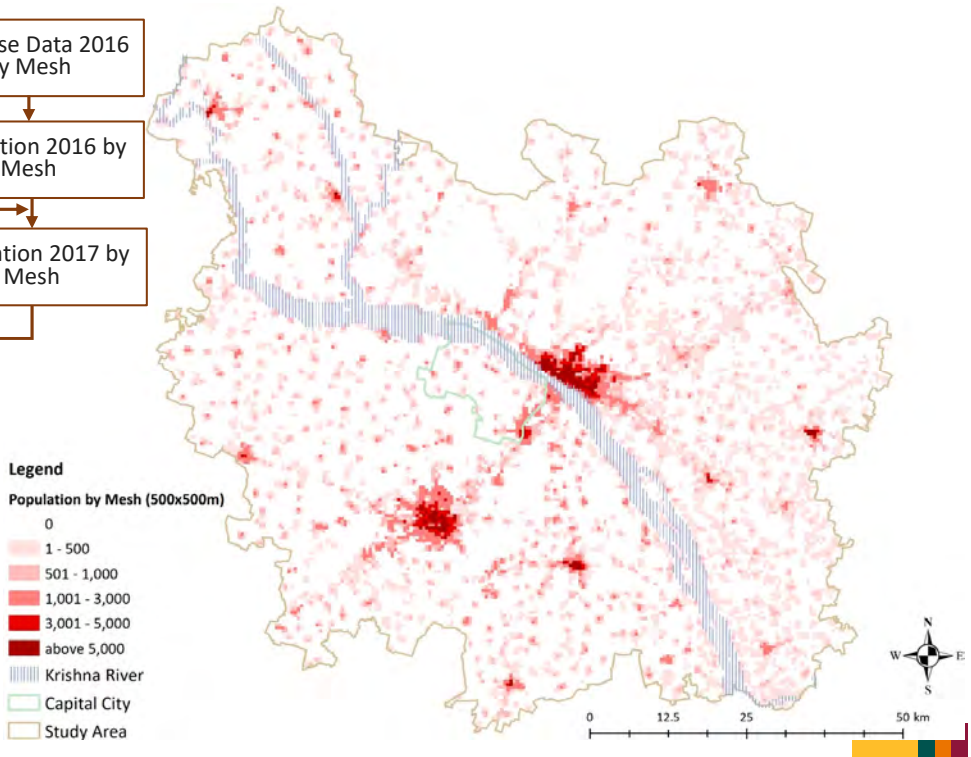
Source: JICA Study Team

5. Existing Population/Employment Distribution: Estimate Base year Population

Detailed Flow of Population Distribution :



Population Distribution Pattern 2017 :



6. Existing Population/Employment Distribution: Multi Regression Analysis

Summary Output of Multi Regression Analysis based on Land Use and Population:

Regression Statistics	
Multiple R	0.996258068
R Square	0.992530138
Adjusted R Square	0.992466156
Standard Error	4283.891492
Observations	943

ANOVA

	df	SS	MS	F	Significance F
Regression	8	2,277,481,890,787	284,685,236,348	15,513	0
Residual	934	17,140,512,382	18,351,726		
Total	942	2,294,622,403,169			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95%	Upper 95%
Intercept	333.8888	215.3984	1.5501	0.1215	-88.8321	756.6097	-88.8321	756.6097
Agriculture	-1.7524	0.3680	-4.7617	0.0000	-2.4746	-1.0302	-2.4746	-1.0302
Commercial	416.0552	57.2599	7.2661	0.0000	303.6821	528.4282	303.6821	528.4282
Mix Use (Urban)	5,023.1875	85.2898	58.8955	0.0000	4,855.8056	5,190.5694	4,855.8056	5,190.5694
Residential (Urban)	79.4974	5.8441	13.6029	0.0000	68.0282	90.9665	68.0282	90.9665
Residential (Rural)	52.8281	6.1414	8.6020	0.0000	40.7756	64.8806	40.7756	64.8806
[illegible]	[illegible]	[illegible]	[illegible]	0.0000	87.5180	161.1989	87.5180	161.1989
[illegible]	[illegible]	[illegible]	[illegible]	0.0000	54.6617	76.6477	54.6617	76.6477
Waterbody	-4.3819	1.0224	-4.2860	0.0000	-6.3884	-2.3755	-6.3884	-2.3755

Equation of Population

Intercept + Land Use × Coefficients = Population

Project on Capacity Development for Urban Planning

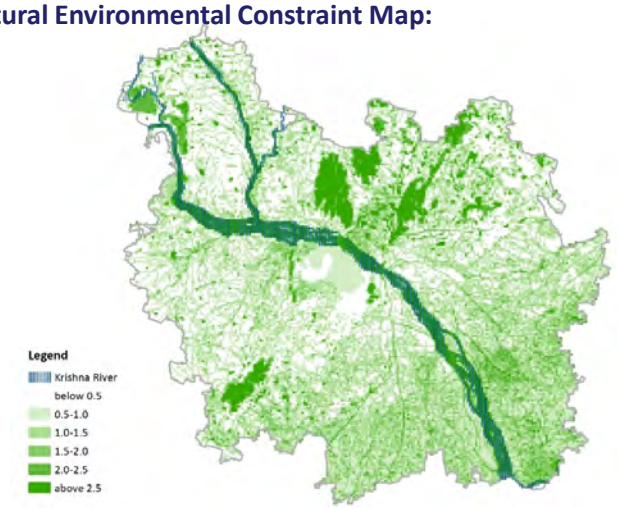
7. Future Population/Employment Distribution (1) : Existing Condition

Understanding the Development Constraint Area

Detailed Flow to Prepare the Map by Theme:

Data prepared by mesh → Converted 0 to1 Scoring System → Accumulated by mesh

Natural Environmental Constraint Map:



Guideline by MOUD

- Eco-sensitive zone (reserved forest area)
- Natural hazard zone (hurricane and flood occurred area)
- Slope above 45 degree

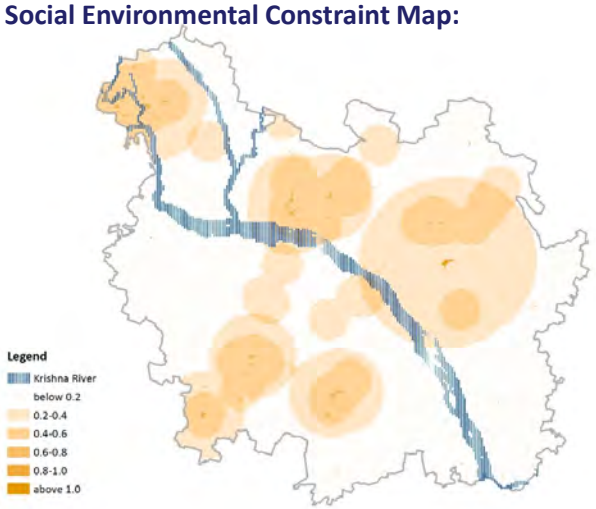
Coastal Regulation

- 100m from river bank

Land Use

- Waterbody and Berm

Social Environmental Constraint Map:



Guideline by MOUD

- Height control within 20km radius of airport
- 25 to 50km buffer between industrial zone and major settlement
- 5km buffer from small mining (<25ha) area and 10km from large
- 100m buffer from "Protected Area" and 200m from "Regulated Area"

Land Use

- Cemetery
- Airport
- Religious area

Source: Urban And Regional Development Plans Formulation and Implementation (Urdpfi) Guidelines

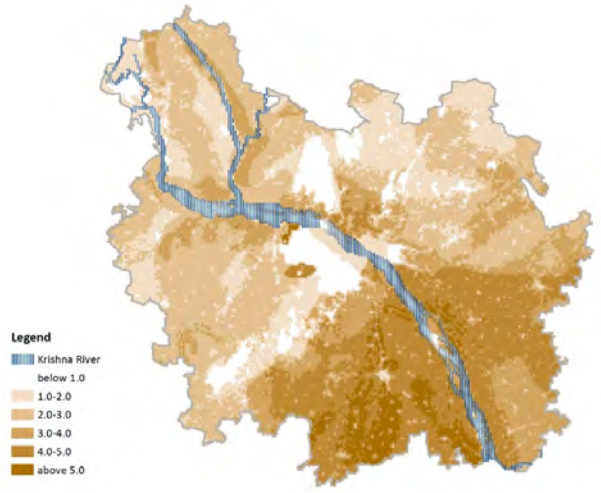
8. Future Population/Employment Distribution (2) : Existing Condition

Understanding the Productive and Potential Area

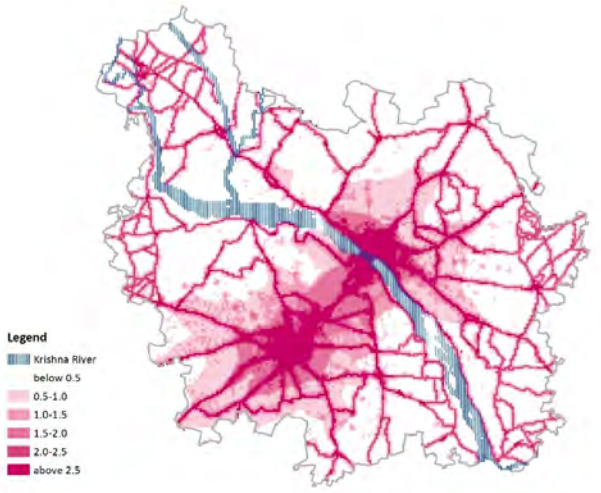
Detailed Flow to Prepare the Map by Theme:

Data prepared by mesh → Converted 0 to1 Scoring System → Accumulated by mesh

Productive Area Map:



High Accessible Area Map:



Agricultural Product

- Product volume of major crops (rice, chill, maize, pulse, sugar and cotton)
- Agricultural intensity

Soil and Irrigation

- Alluvial soil (better soil for agriculture defined by FAO)
- Well irrigated area

Accessibility to Road and Public Transport

- 0 to 1,000m distance from major roads
- 0 to 100m distance from minor roads
- 0 to 45 minutes walking distance from bus stops
- 0 to 30 minutes walking distance from major junction station and 0 to 15 minutes from other railway stations

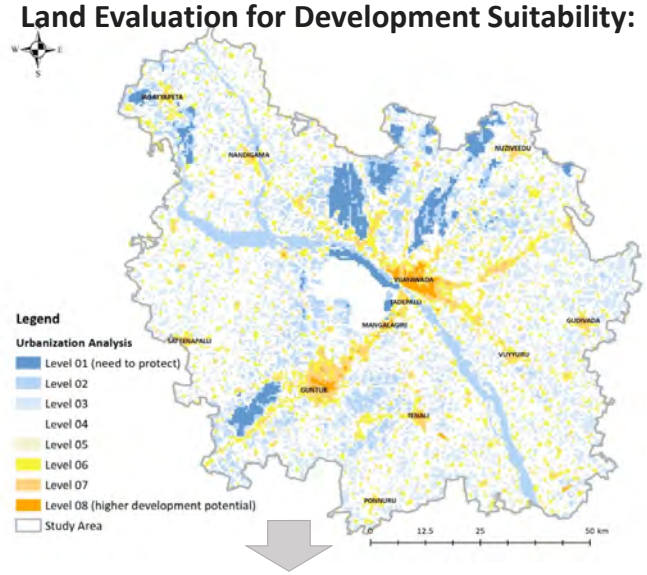
Accessibility to Major Service Centers

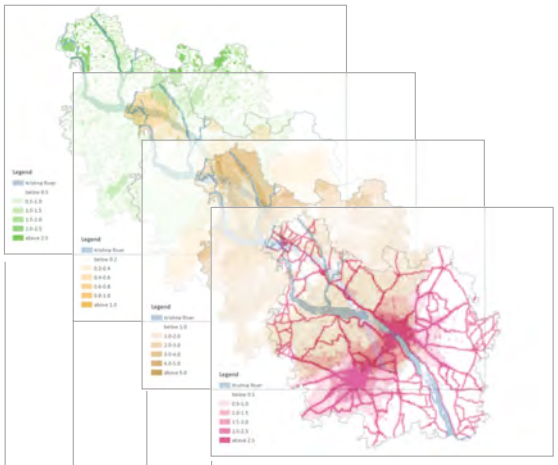
- 0 to 90 minutes driving distance from Vijayawada and Guntur

Source: Census 2011, Land and Plant Nutrition Management Service Land and Water Development 2005, FAO

9. Future Population/Employment Distribution : Urbanization Simulation Model

Land Evaluation for Development Suitability:





- Major and minor roads buffer
- Accessibility to bus stops
- Accessibility to railway station

- Good productivity
- Appropriate soil
- Well irrigated

- Height control area
- Buffer from mining, industry and social protected area
- Cemetery, religious and airport

- Reserved forest and water body
- Steep slope
- Disaster prone area

Analysis:

Accumulated Data by Mesh → Built Up Area → Multi Regression Analyses

Urbanization Simulation Formula:

Built Up Area = Factor × Land Use Accessibility

Negative Factor

- Waterbody
- Berm
- Reserved Forest
- Slope
- Flood Prone Area
- Agricultura land
- Mine
- Airport

Positive Factor

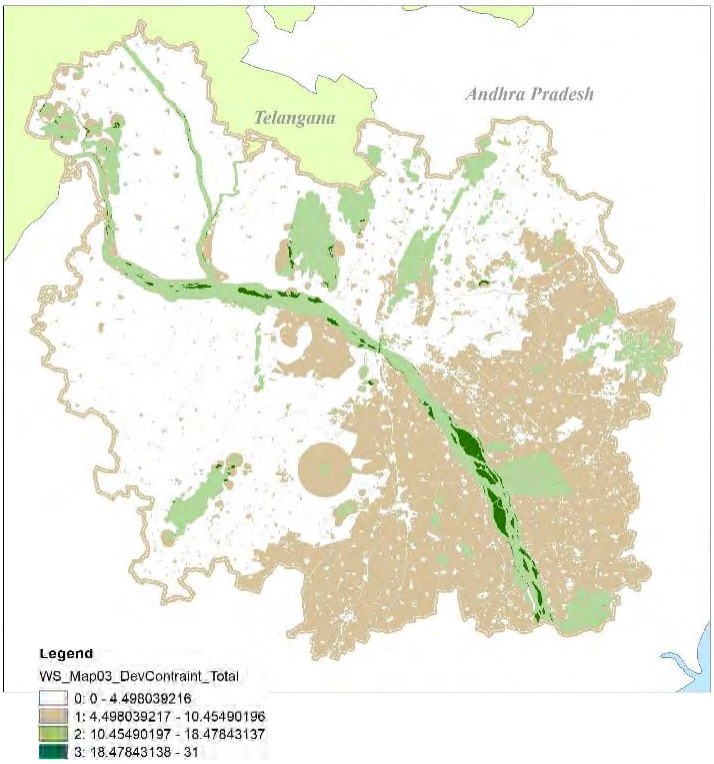
- Major and Minor Road Accessibility
- Bus Stop Accessibility
- Railway Station Accessibility
- Total Area of Road

Example :
Example as Assessment Tool for SEA

1. GIS as Supporting tool for SEA

In this example shows how to apply GIS in SEA as supporting tool.

In this case, GIS was used to spatially layout the location or areas that need special attention in developing infrastructure. For the assessment of plan, two sets of maps; Strategic Environment Assets and Strategic Regional Environment Constraints were integrated to prepare a strategic environment sensitive area map.



Consolidated Strategic Environment Sensitive Area Map

1. GIS as Supporting tool for SEA

Utilization of GIS for SEA Activities

GIS is considered to be useful tool for assessing the cumulative impact of plans and a series of projects in a particular area, such as transportation planning and land use planning. Using GIS, as a method of avoiding environmentally sensitive areas, it is possible to show environmentally important or sensitive areas as map, and it is also possible to store environmental information of these areas in a GIS database.

Step		Activities	Utilization of GIS in CTTS
1	Scoping	• Review relevant policies and guidelines to identify outside factors and confirm their implications	No
		• Review and collect baseline information and identify key issues (Baseline Review)	Yes
2	Establishing Assessment Framework	• Develop SEA objective and indicators to assess policies and plans	No
		• Develop SEA assessment tools to assess the plan	Yes
3	Policy Level SEA	• Assessment of regional transportation policy to confirm consistencies between SEA objectives	No
		• Revision of regional policy, as required	No
4	Plan Level SEA	• Development of alternative scenarios	No
		• Assessment of alternatives by predicting impacts and assist in the refinement of the plan	Yes
5	Evaluation / Recommendation	• Evaluation of the final plan against SEA objectives	Yes
		• Recommendation of mitigation measures to ensure adverse effects will be reduced	No
		• Recommendation of monitoring plan to monitor the environment and social performance	No

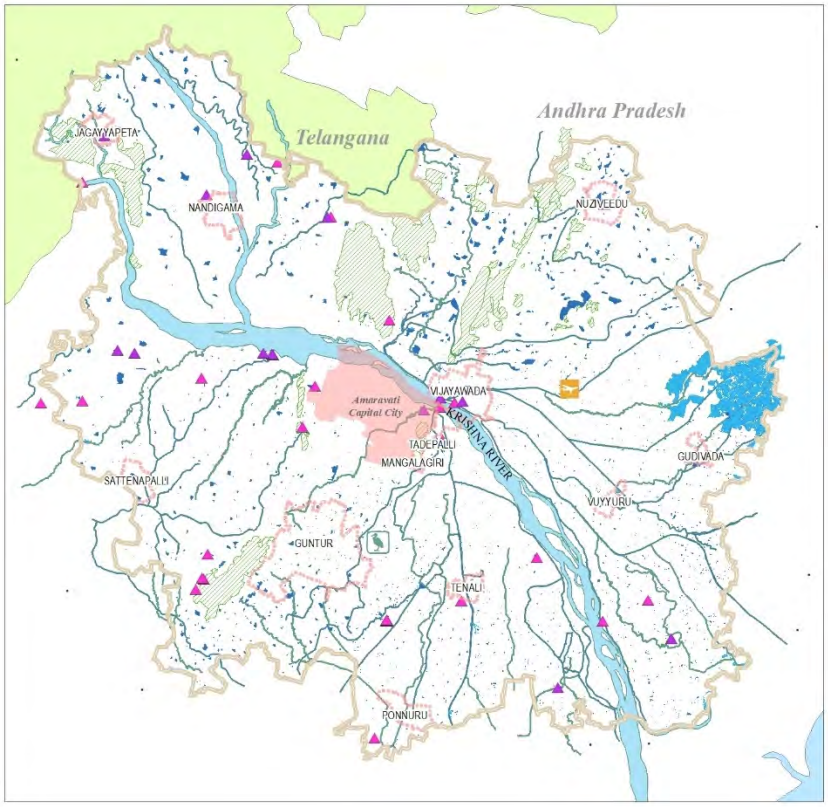
2. Baseline Review: Current Condition Map Preparation for SEA

Baseline Review with GIS

No.	Assessment Criteria (data)	Name of Baseline Assessment Result Map
1	• Reserved Forest • Waterbody (incl. Aquaculture) • Waterbody buffer • National Protected Monuments • State Protected Monuments	**Distribution of strategic environment assets**
2	• Flood inundation area • Cyclone prone • Steep slope area • Power plant location • Mega Industry area • Industrial area • Ash pond	**Distribution of regional environment constraint**
3	• CO2 emission	**Pollution level**
4	• Distribution of low income group	**Income level group distribution**
5	• Accessibility to public service	**Access to/from District/ Tertiary hospital**
6	• Accessibility to public transport	**Access to/from Bus stop** **Access to/from Railway Station** **No. of bus services per day by village**

2. Baseline Review: Current Condition Map Preparation for SEA

Distribution of strategic environment assets

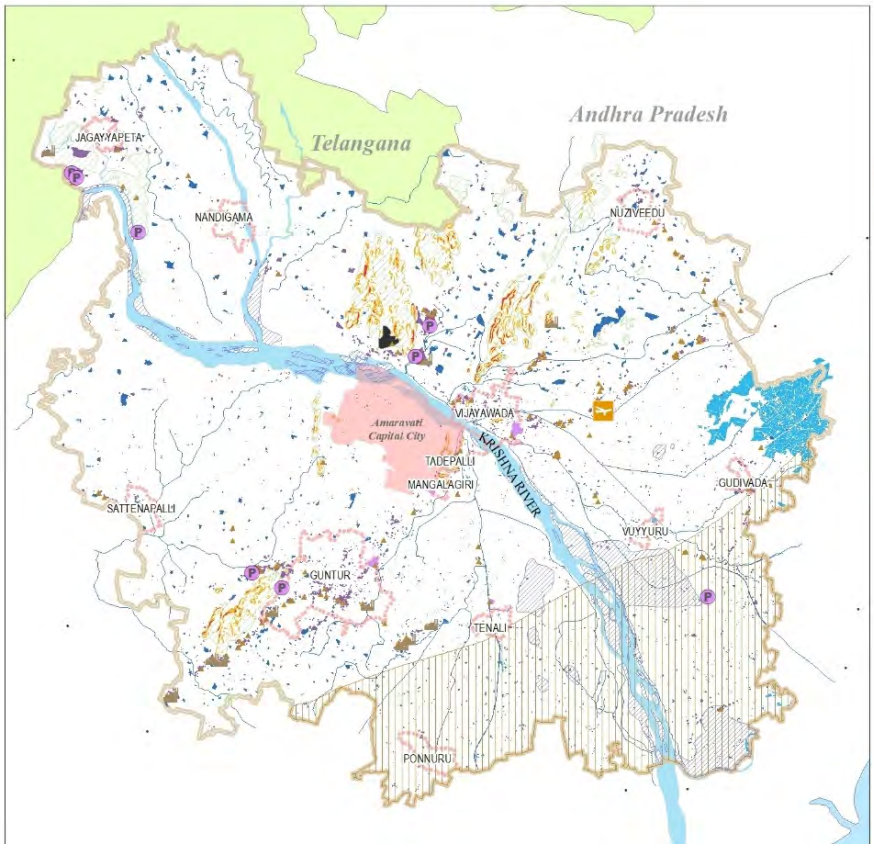


Legend

- Capital City Boundary
- APCR Boundary
- ULB
- National Proteted Monument
- State Protected Monument
- Bird Sanctuary
- Reserved Forest
- Aquaculture
- Pond
- Buffer (Pond, 30m)
- Krishuna River
- Canal
- Buffer (River: 100m)

2. Baseline Review: Current Condition Map Preparation for SEA

Distribution of regional environment constraint



Legend

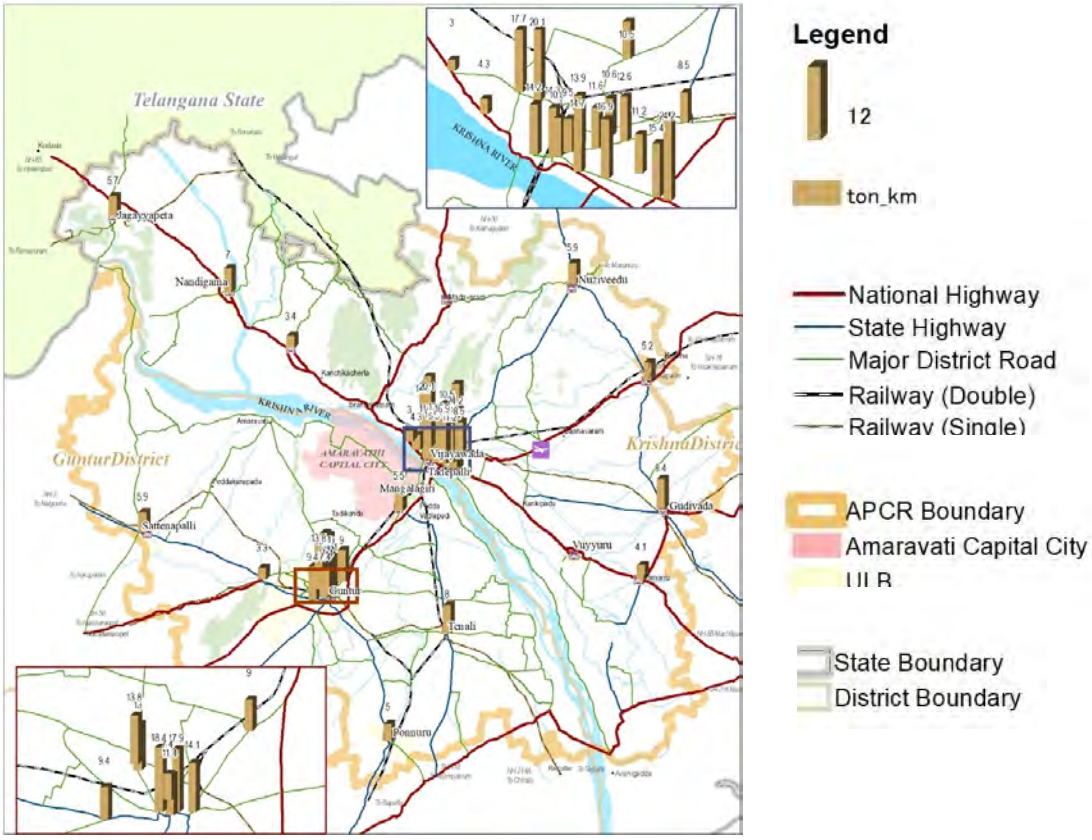
- Flood Inundation area
- Cyclone prone (Very High Risk Zone)

Slope (degree)

- 0 - 20
- 21 - 30
- 31 - 51
- Reserved Forest
- Powerplant
- Mega Industries (emp>1000)
- Major Industrial site
- Industrial area
- Autonagar
- Ash Pond
- APCR Boundary
- Capital City Boundary
- ULB

2. Baseline Review: Current Condition Map Preparation for SEA

Pollution level

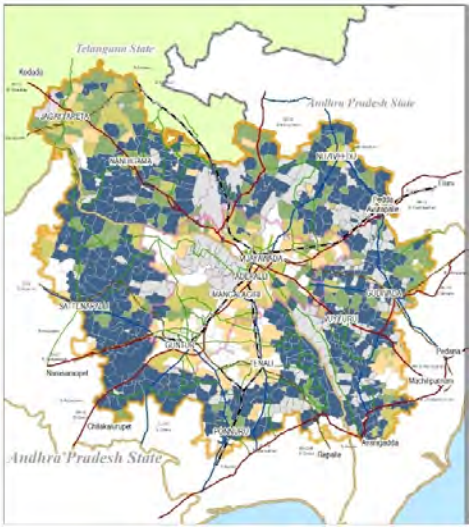


Project on Capacity Development for Urban Planning

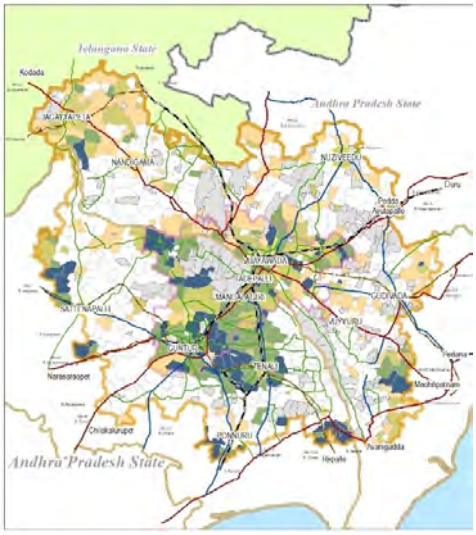
2. Baseline Review: Current Condition Map Preparation for SEA

Income level group distribution

Low income G.

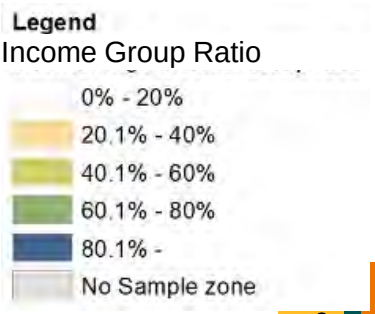


Medium income G.



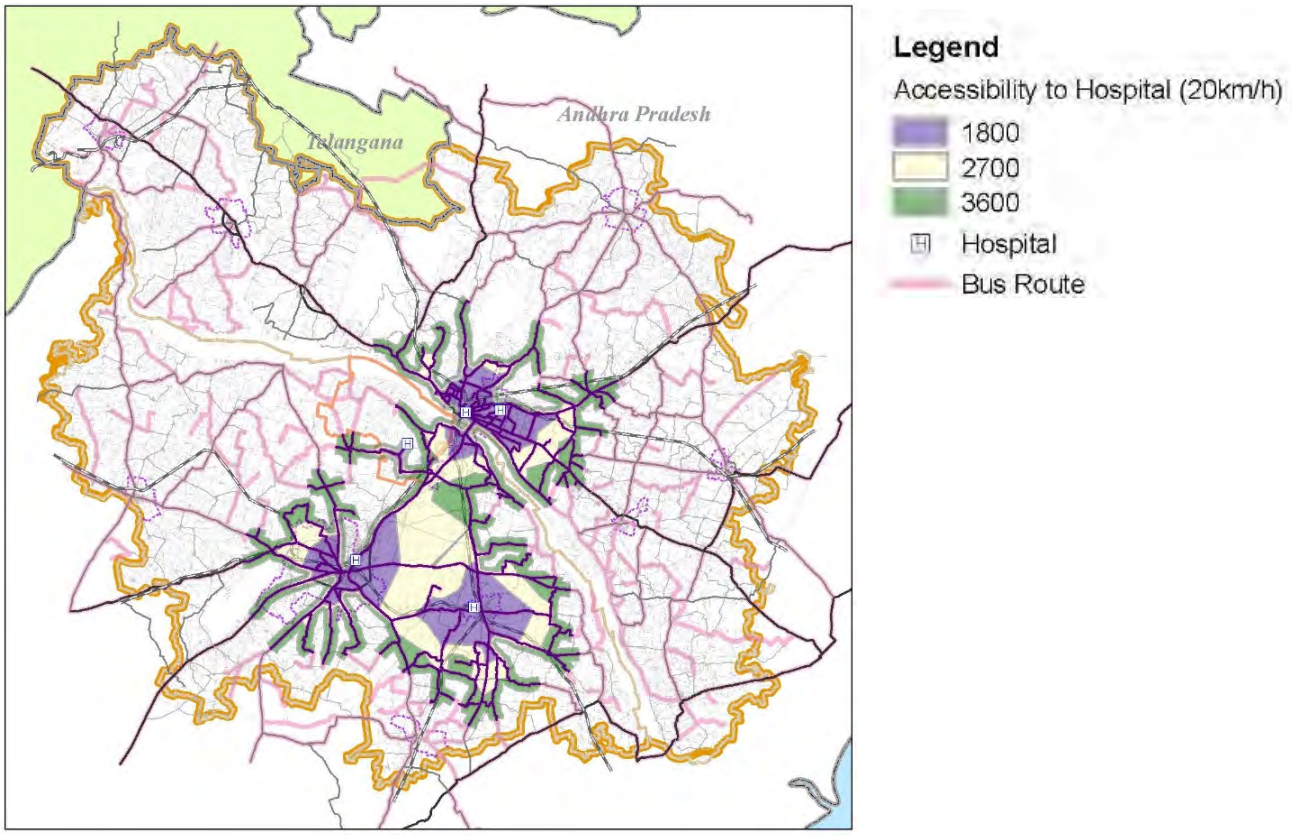
High income G.





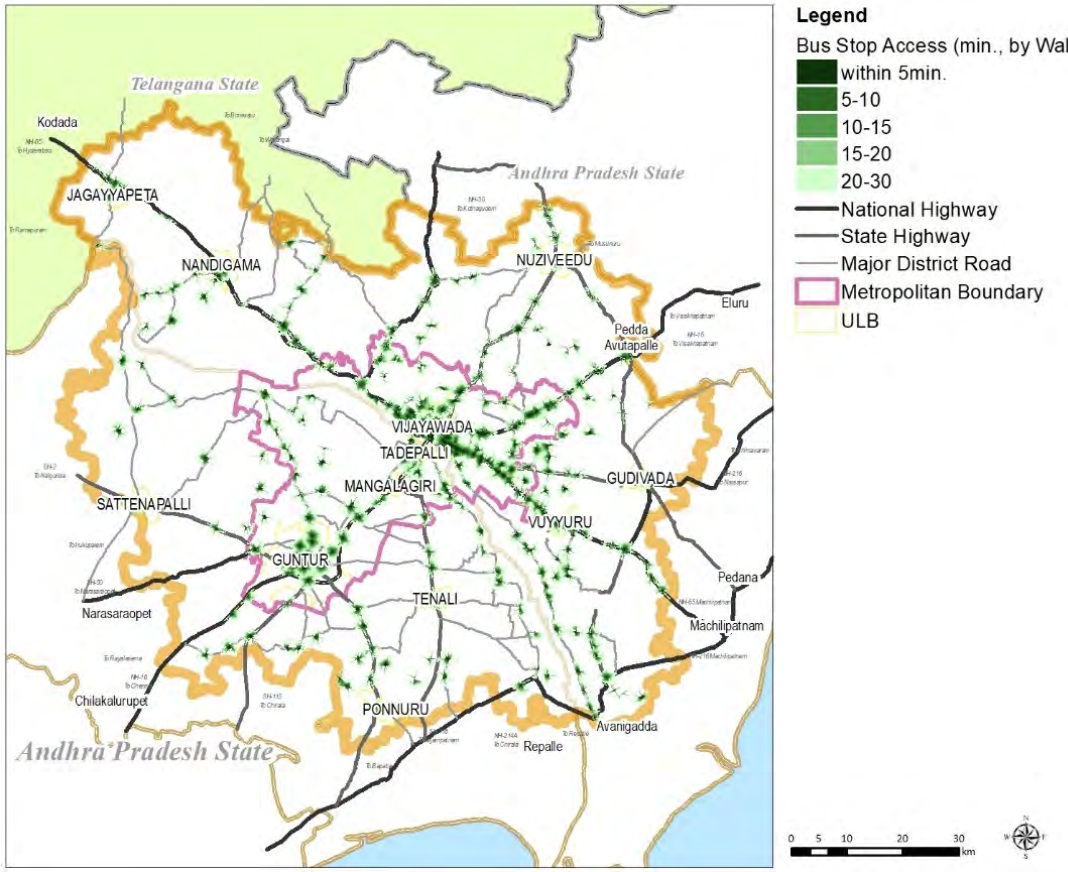
2. Baseline Review: Current Condition Map Preparation for SEA

Access to/from District/ Tertiary hospital



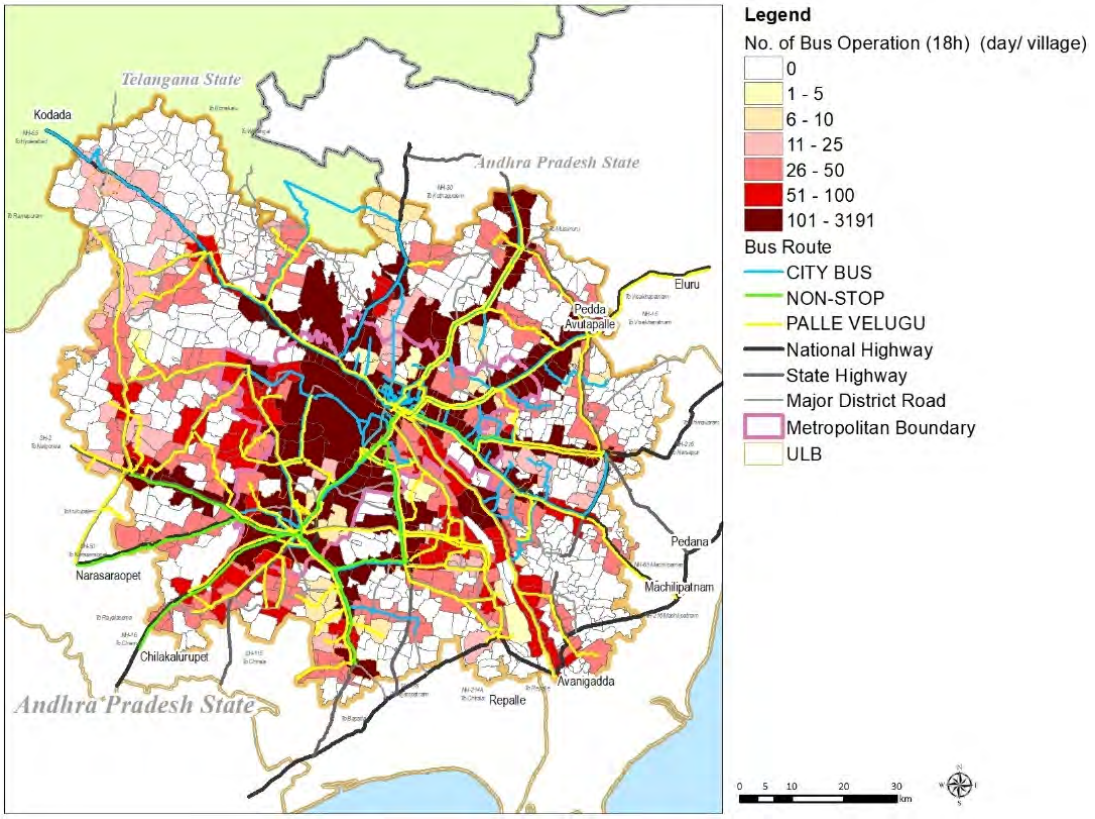
2. Baseline Review: Current Condition Map Preparation for SEA

Access to/from Bus stop



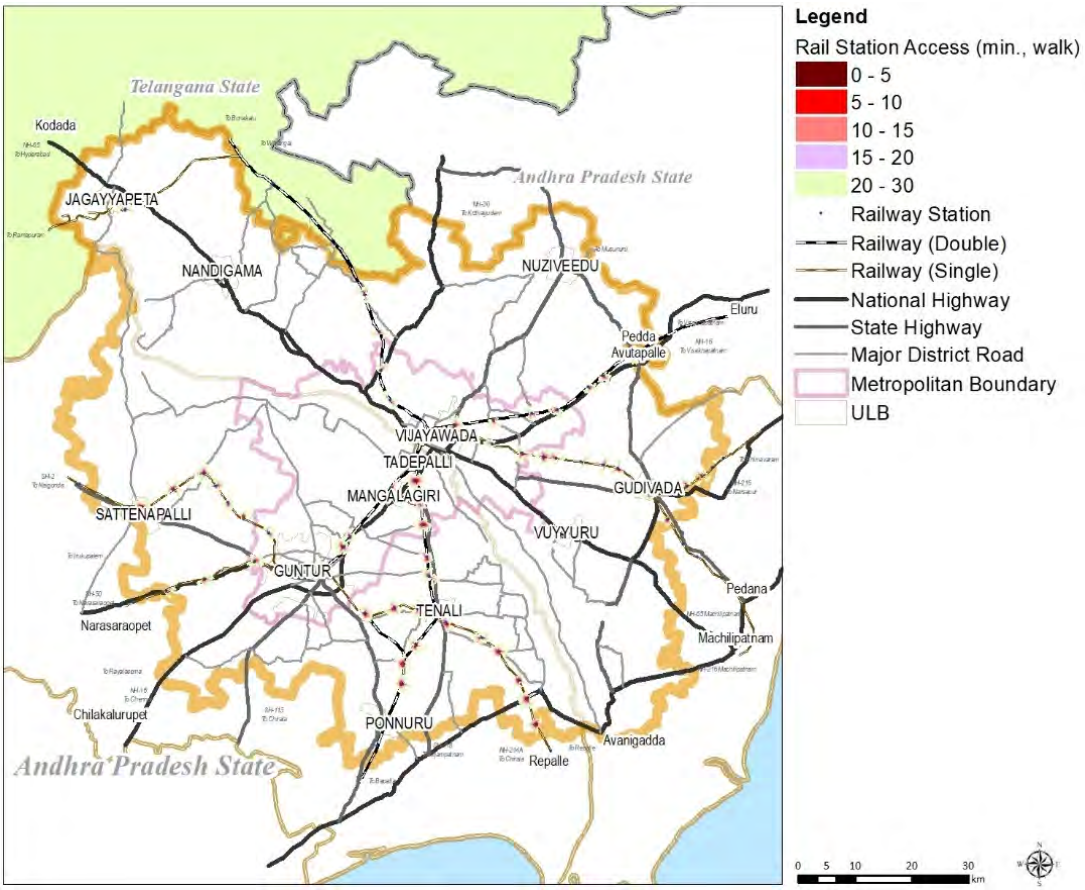
2. Baseline Review: Current Condition Map Preparation for SEA

No. of bus services per day by village



2. Baseline Review: Current Condition Map Preparation for SEA

Access to/from Railway Station



3. Spatial Multi Criteria Analysis (SCMA) for SEA

Concept of SMCA

Multi-criteria analysis is a method used to facilitate the consideration of multiple criteria in many fields and it is used to logically evaluate and compare multiple criteria.

SMCA is a GIS-based MCA, and the advantage of an application of SMCA is most of issues need to face in spatial planning are geographic nature and recently various data with geographic information are available in many fields. In addition, SMCA can evaluate alternatives using multiple criteria to support the selection among alternatives from various aspects. In SEA activity of this Project, SMCA is adopted following the baseline review. Based on identified multiple criteria by baseline review, a relative scoring system sets to each criteria to evaluate in a standardized manner. As a final step of SMCA, all of scored criteria are aggregated spatially and the result was visualized to support decision making easier.

In this SMCA, following steps are adopted;

1) Identification of Criteria and Structured (this is done by Baseline review in SEA activity)
2) Preparation of relative scoring System (all criteria can be evaluated within the same numerical range)
3) Perform spatial analysis to calculate the score by criteria
4) Integrate scores to be the analysis result

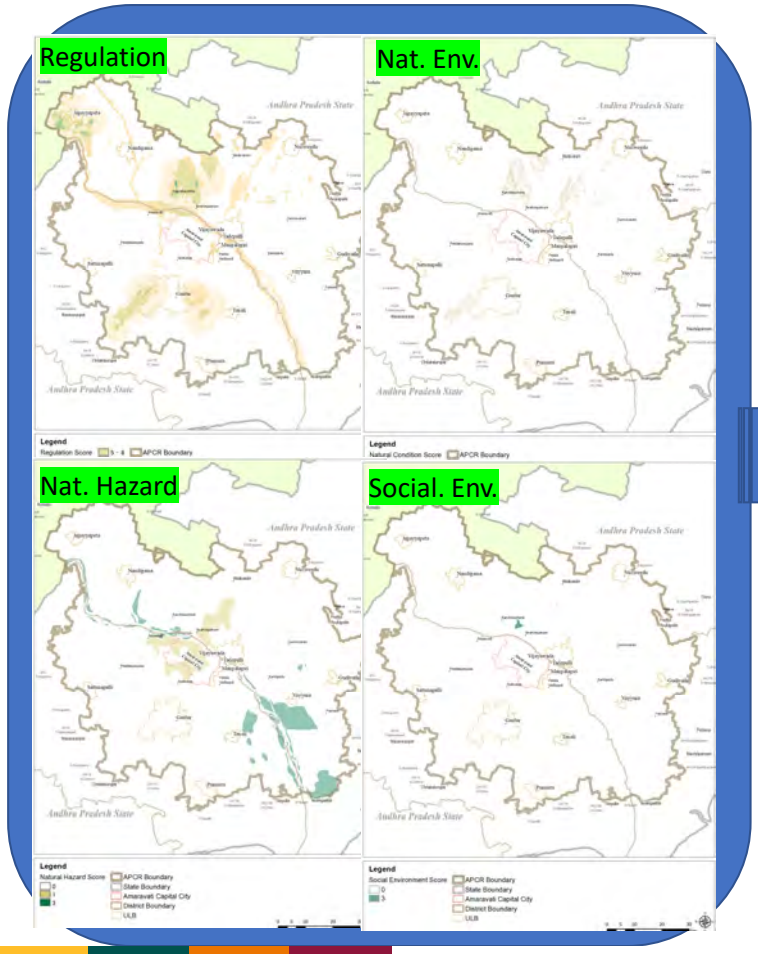
Project on Capacity Development for Urban Planning

3. Spatial Multi Criteria Analysis (SCMA) for SEA

Results Map	Assessment Category	Criteria	Level of Constraints (Score)				Remarks
			0	1	2	3	
Strategic Environment Constraint Map	Regulation	Reserved Forest	-	-	-	Exact location	
		Bird Sanctuary	-	-	5km	1km	
		River and Waterbody	-	-	-	100m buffer	
		Archeological site	-	-	200m buffer	100m buffer	
		Mining and quarrying site (< 25ha)	-	5km	-	500m	＜25ha (source: land use)
		Mining and quarrying site (> 25ha)	-	10km	-	1km	＞25ha (source: land use)
	Natural Environment	Slope condition	<10 degree	10-20 degree	20-30 degree	>30 degree	
		Elevation	0-400m	-	over 400m	less than 0m	
	Natural Hazard	Flood	-	Flood prone area w/ measures		Flood prone area w/o measures	
	Social Environment	Graveyard	-	-	-	Exact location	
		Ash pond	-	-	-	Exact location	

0: No constraints
1: Slight constraints
2: Development is allowed under certain condition
3: Must avoid

3. Spatial Multi Criteria Analysis (SCMA) for SEA



Strategic Environment Constraint Map with Score



Project on Capacity Development for Urban Planning

3. Spatial Multi Criteria Analysis (SCMA) for SEA

Following parameters and classification prepared by SEA expert, analyzed with GIS

Results Map	Assessment Category	Criteria	Level of Constraints (Score)				Remarks
			0	1	2	3	
Productive Land	Productive Land	Soil type	Other soil type	-	Black soil	Alluvial soil	
		Ground water level	＞20	8 to 20	3 to 8	＜3	meter
		GVA	＜6000	6000-12000	120000-24000	＞24000	Lakh Rs.
		Crop intensity	No data	<1.14	1.14-1.16	>1.16	Max 2.04 (Threshold: Natural Break)
		Irrigated Agriculture	0-0.21	0.22-0.43	0.44-0.67	0.68-0.86	% of Irrigated area (Threshold: Natural Break)
		Aquaculture	-	-	-	Exact location	

Note: Level of Constraint (Score)
0: No constraints
1: Slight constraints
2: Development is allowed under certain condition
3: Must avoid

3. Spatial Multi Criteria Analysis (SCMA) for SEA

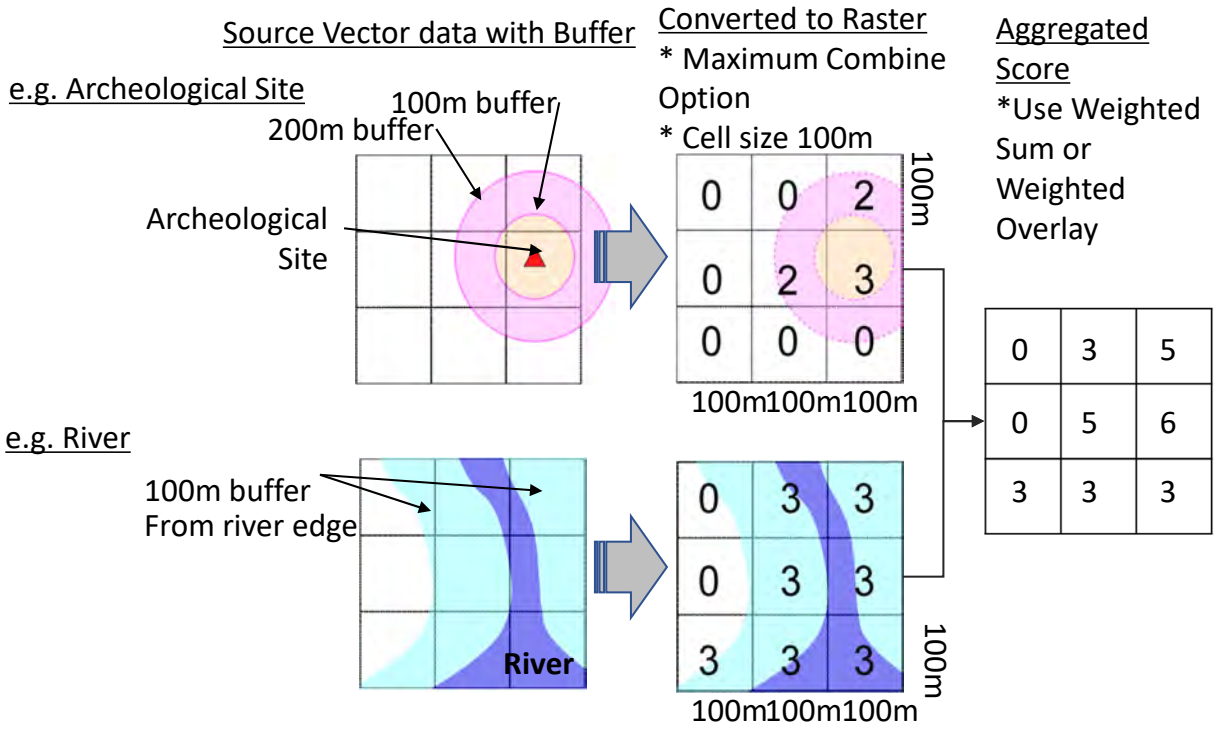
Productive Land Map with Score



Project on Capacity Development for Urban Planning

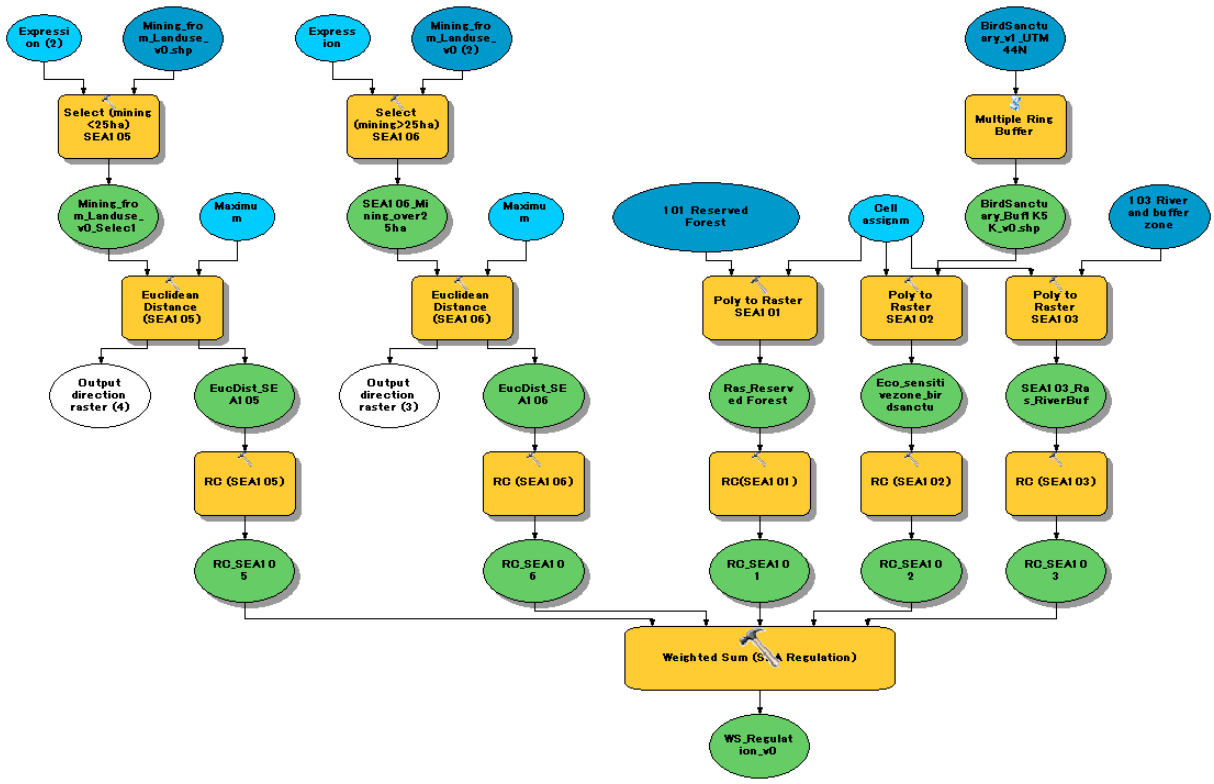
3. Spatial Multi Criteria Analysis (SCMA) for SEA

In this SMCA, ArcGIS Spatial analyst extension utilized and all of vector data is converted to raster data in 100m cell size.



3. Spatial Multi Criteria Analysis (SCMA) for SEA

Using “Model builder” in ArcMap, the SMCA for the Project ware performed.



4. Other Analysis for SEA

In addressing issues of accessibility to Public Transport, Time distance (30/60/90 min.) from major 3 centers are analyzed with ArcGIS Network Analyst extension to evaluate future public transport plans.

Overlaying the future population distribution data described previously, the population to be covered by public transportation in the future was estimated.

This analysis can evaluate planning alternatives with quantitative manner.



Thank you!

Project on Capacity Development for Urban Planning

PPT. No.5

Module LU3-1: GIS and Spatial Data Construction
Module LU3-2: Spatial Data Analysis by GIS

Basic Data Set for Urban Planning & Standardization of Data

Project on Capacity Development for Urban Planning in Sri Lanka

Basic Data Set for Urban Planning & Standardization of Data (esp. Land use)

17 Oct. 2023

Basic Data Set for Urban Planning: Discussion Point

Background:

- Implementation of urban planning activities as a pilot project in Tangalle
- A base map is needed in the early stages of the planning phase
- Need to **identify and collect data** necessary for base map
- The data required for the base map should **be the basic GIS data set** needed for future urban planning activities in various cities to be conducted by UDA.
- Standardization of attribute information is important for efficient planning activities

Discussion Points:

1. **Preparation of Basic Dataset for Tangalle Urban Plan**

- Identify necessary data to be included in the base map of Tangalle
- Source of each identified data for base map
- Identify necessary attribute information for each necessary GIS data

2. **Standardization of "Land use category"**

- For efficient planning activities, it is necessary to standardize the land use category

Request to URC/UDA after this session

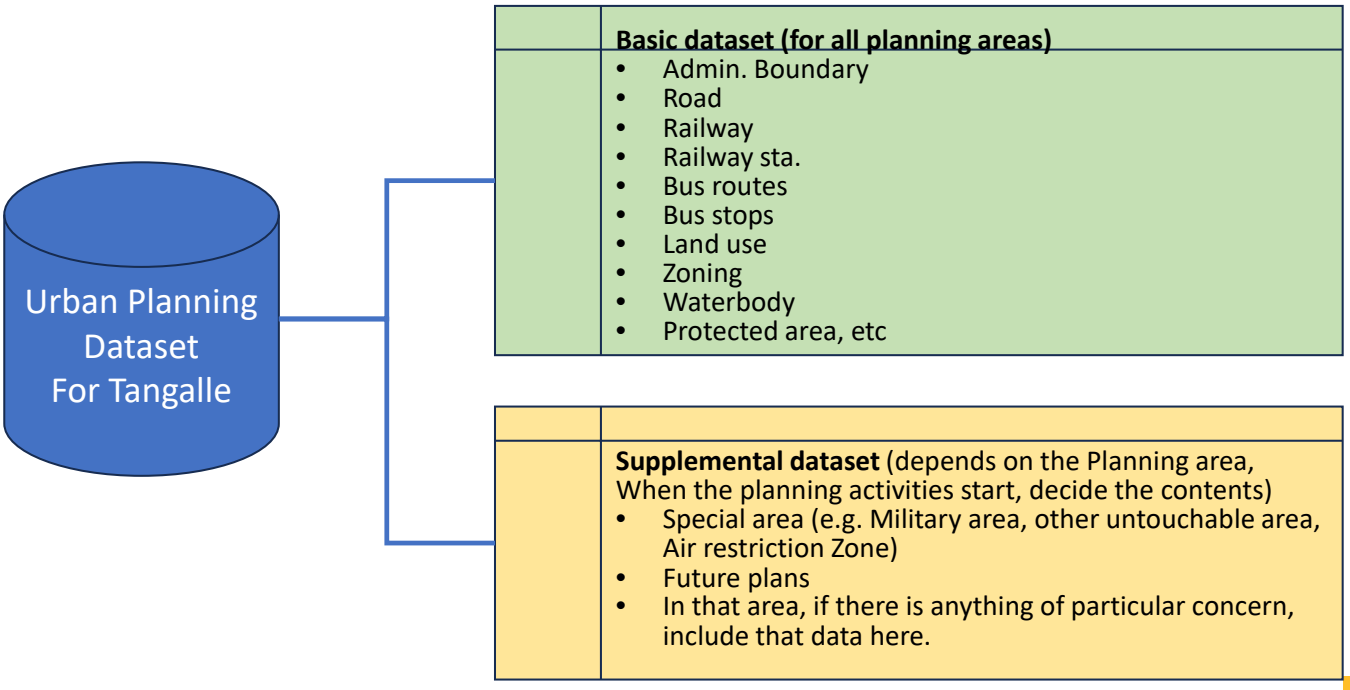
1. Please prepare the table of the necessary GIS data set as a draft version (with Data source, Data year)
2. Check the availability of necessary GIS data with associated information such as data year
3. Please prepare a draft standard land use category table with definition & sample photos (based on satellite imagery)

Basic Data Set for Urban Planning: Discussion Point

Discussion Point 1

Preparation of Basic Dataset for Tangalle Urban Plan

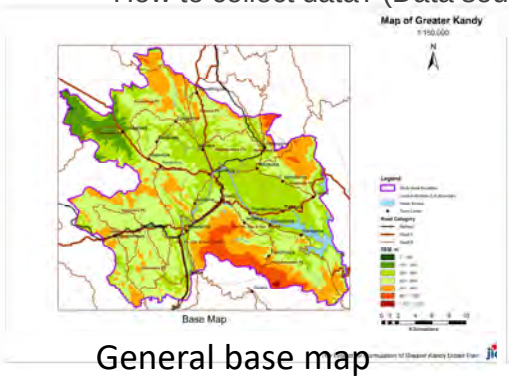
- Identify necessary data to be included in the base map of Tangalle
- Source of each identified data for base map
- Identify necessary attribute information for each necessary GIS data



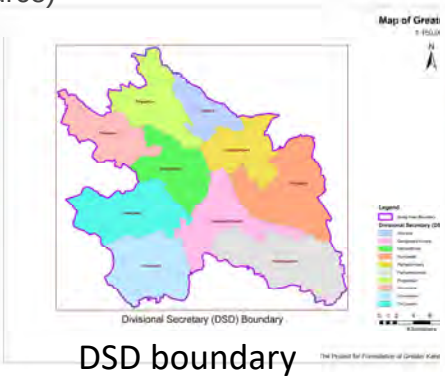
Basic Data Set for Urban Planning: Sample Base Map of Kandy

Sample Base maps for Kandy (1):

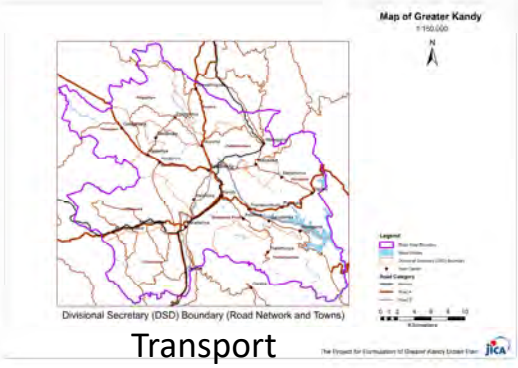
- There are various base maps are prepared by the theme
- Do we need all?/ Do we need to add more data?
- How to collect data? (Data source)



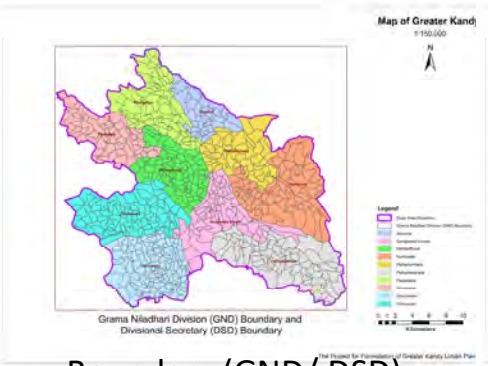
General base map



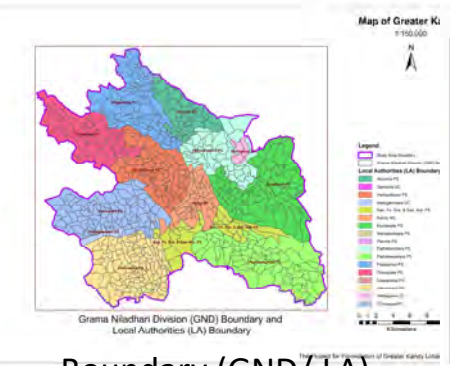
DSD boundary



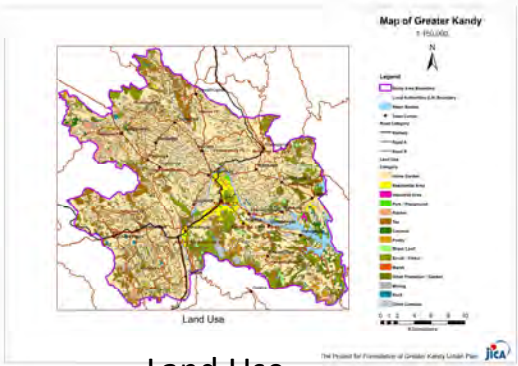
Transport



Boundary (GND/ DSD)



Boundary (GND/ LA)

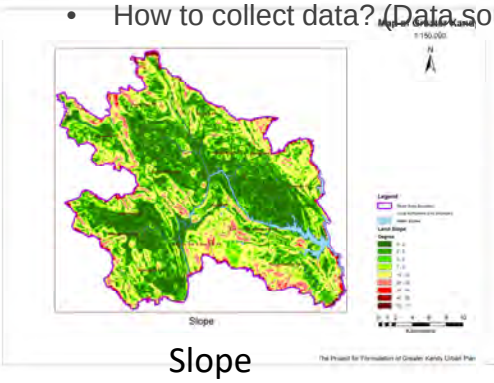


Land Use

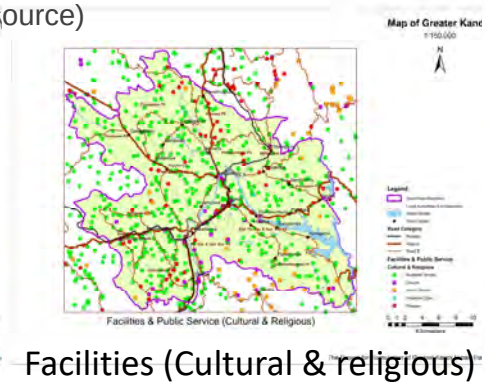
Basic Data Set for Urban Planning: Sample Base Map of Kandy

Sample Base maps for Kandy (2):

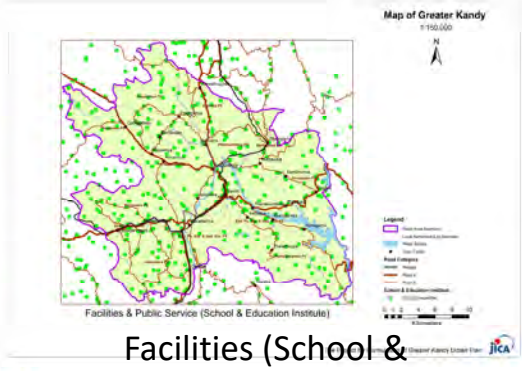
- There are various base maps are prepared by the theme
- Do we need all?/ Do we need to add more data?
- How to collect data? (Data source)



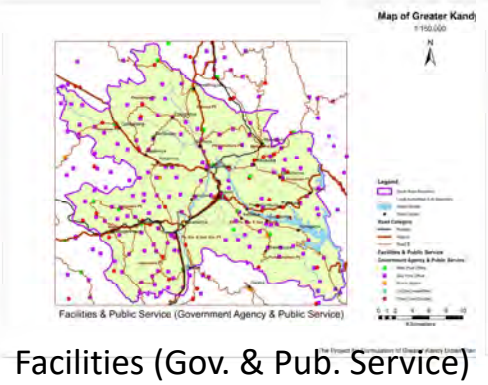
Slope



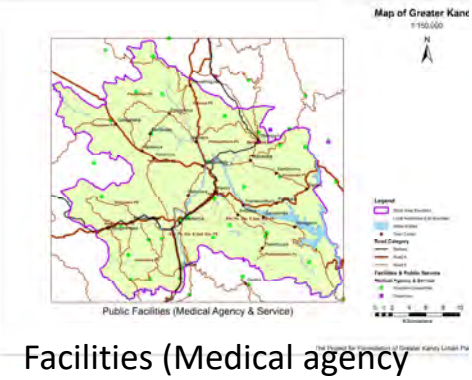
Facilities (Cultural & religious)



Facilities (School & Educational Institute)



Facilities (Gov. & Pub. Service)



Facilities (Medical agency & service)



Historical Heritage

Basic Data Set for Urban Planning: What kinds of Data are necessary?

Basic GIS Dataset for Urban Planning

1. Request URC/UDA to prepare Basic dataset table (Sample below)
2. After data collection, need to check topological errors before analysis
3. Need to check data year.
4. If necessary, need to update

Category	Data	Necessary Attributes	Source	Note
Administrative boundary	DS	Name, Code, Population		Latest boundary with population
	DSD	Name, Code, Population		Latest boundary with population
	GND	Name, Code, Population		Latest boundary with population
	Province	Name, Code		
Other boundaries	Panning area boundary			
	SEZ boundary			

Basic Data Set for Urban Planning: What kinds of Data are necessary?

Category	Data	Necessary Attributes	Source	Note
Natural Condition	Water body	Type (River, Channel, etc.)		
		Inland water (e.g. Lake, pond)		
	Elevation			
Land use	Existing land use	Land use category		Need to discuss standard land use category
	Future land use	Land use category		
	Land cover	Land cover category		
Zoning	Zoning	Zoning name, Zoning code, Description		

Project on Capacity Development for Urban Planning

Basic Data Set for Urban Planning: What kinds of Data are necessary?

Category	Data	Necessary Attributes	Source	Note
Transport	Road	Road category by administrator		
		Road category by function		
	Railway	Status (Operational, suspended, under construction, etc.)		
	Railway station	Name		
	Bus route	Name, Route No.		
	Bus stop	Name		
	Bus terminal	Name, Type (inter city/ intra city, etc.)		
	Airport	Name, Type (International, Domestic, Military, etc.)		
	Sea port	Name, Type		

Basic Data Set for Urban Planning: What kinds of Data are necessary?

Category	Data	Necessary Attributes	Source	Note
Facilities	Cultural facilities	Name, Category		
	Religious facilities	Type		
	School & other education	Type		
	Gov. & Pub. services			
	Medical institutes			
	Historical heritage			
Development Constraint	Protected area	Type		National/ Provincial level
	International protected/ conservation protocols	Type		e.g. “World heritage”, Ramsar wetland
	National Parks			

Project on Capacity Development for Urban Planning

Basic Data Set for Urban Planning: What kinds of Data are necessary?

Category	Data	Necessary Attributes	Source	Note
Disaster Management	Flood prone			
	Landslide prone			
Building	Building footprint			Some part of Sri Lanka, MS has already produced without attribute info.

Standardization Land Use Category: Current Situation

Discussion Point 2

Standardization of "Land use category"

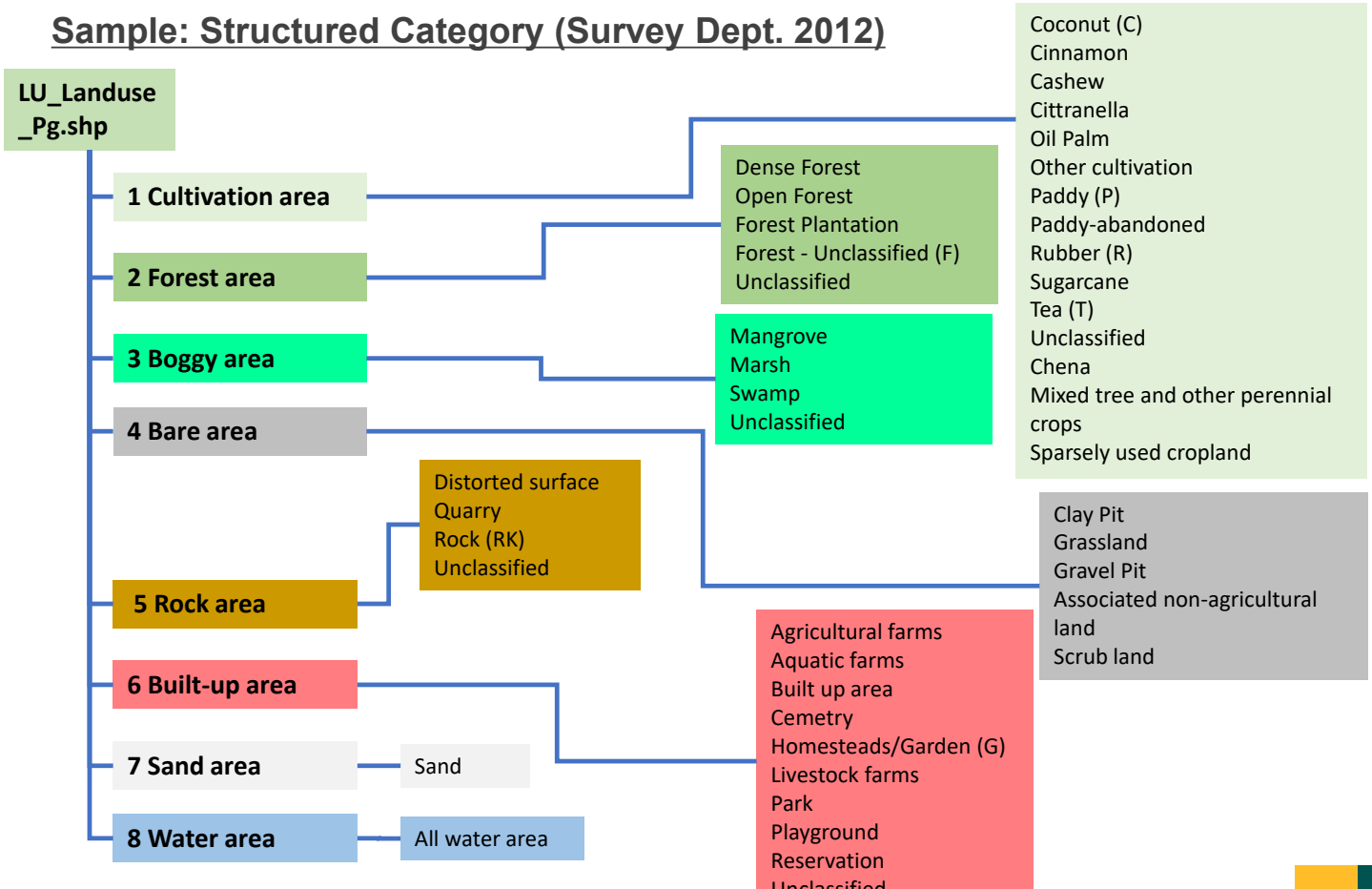
- For efficient planning activities, it is necessary to standardize the land use category

Kaduwela		Mahiyanganaya	
OID	Main_Use	OID	Main_Use
0	Abandoned Paddy	0	Abandoned Paddy
1	Agricultural Land	1	Agriculture Land
2	Bank & Allied	2	Bank & Allied
		3	Bare Land
3	Cemetry	4	Cemetry
4	Coconut	5	Coconut
5	Com/Resi		
6	Commercial	6	Commercial
		7	Defence
7	Educational	8	Educational
8	Fill Lands		
9	Forest	9	Forest
10	Health	10	Health
11	Home Garden	11	Home Garden
12	Industrial	12	Industrial
13	Institutional	13	Institutional
14	Land Sale		
15	Local Authority Roads	14	Local Authority Road
16	Marshy	15	Marshy
17	Mixed Cultivation		
		16	Minor Road
18	Open Space	17	Open Space
		18	Other Plantation
19	Other Roads	19	Other Road
20	Outer Circular Roads		

Kaduwela		Mahiyanganaya	
OID	Main_Use	OID	Main_Use
21	Paddy	20	Paddy
22	Park & Play Ground		
		21	Quarry
23	PRDA Roads		
24	RDA Roads	22	RDA Road
		23	Recreational
25	Religious	24	Religious
26	Reservation	25	Reservation
27	Residential	26	Residential
28	Rock	27	Rock
29	Rubber		
30	Scrub	28	Scrub
31	Socio-Cultural	29	Socio Cultural
32	Sports & Amusement	30	Sport & Amousement
33	Stores & Ware House		
34	Tourism	31	Tourism
35	Transportation	32	Transportation
		33	Unclassify
36	Under Construction		
		34	Undeclared Forest
37	Utility	35	Utility
38	Vacant Lands	36	Vacant Land
39	Vehical Park		
		37	Vegetation
40	Water Body	38	Water Body

Standardization of Land Use Category: Sample Category

Sample: Structured Category (Survey Dept. 2012)



Standardization of Land Use Category: URC/UDA L/U Category

Preparation of Land Use Category Table

- Identify suitable land use category for urban planning
- Need full coordination between planners and GIS Div. (How to categorize?)
- To standardize "Visual image interpretation", it is important to prepare "Land use interpretation guideline ***with sample satellite image***"

Sample Land use category table

Level 1 Name	Level 1 code	Level 2 Name	Level 2 code	Source	Definition
Built up area	10	Residential area	1	XXXXX	XXXX
Built up area	10	Commercial	2	XXXX	XXXXX
Built up area	10	Industrial	3	XXXX	
Built up area	10	Mix (res. & Comm.)	4	XXX	
Built up area	10	Mix (res. & Indust.)	5	XXX	
. . . .					

Standardization of Land Use Category: URC/UDA L/U Category

Preparation of Land Use Category Guideline

- Clear definition will standardize visual interpretation by GIS Div.
- Definition should be proposed by Planners and examine the definition is reasonable or not (Planners & GIS Div)
- Residential, Commercial, Industrial and Mix use areas are normally difficult to interpret with satellite imagery. How to deal with this issue?

Sample (Proposal): Land use category definition document for the Guideline

Level 1 Name	Level 1 code	Level 2 Name	Level 2 code	Source	Definition
Built up area	10	Residential area	1	XXXXX	More than XX% of land are occupied by residential building





Thank you very mush

ありがとうございます

Project on Capacity Development for Urban Planning

PPT. No.6

Module LU3-2: Spatial Data Analysis by GIS

Network Analysis with ArcMap

Project on Capacity Development for Urban Planning in Sri Lanka

Network Analysis with ArcMap

19 Sep. 2023

Network Analysis: Goal of the Session

Goal of the Session:

1. Understand the Difference of Network Analysis between ArcMap and QGIS
2. Understand the Outline of Network Analysis
3. Understand the basic workflow of Network analysis
4. Understand the methodology of building Network Dataset with ArcMap
5. Understand how to access Network Analyst tools
6. Understand the typical Network Analysis Process (Exercise)
   - Shortest Path
   - Service Area Analysis

1. Understand the Difference of Network Analysis between ArcMap and QGIS

ArcGIS (ArcMap)	QGIS
• Need to have Network analyst extension • Need to build "Network Dataset" • To build network data set, "Network Analyst" license is necessary • If you can get detailed information about road such as traffic regulation, it allow you to analyze in detail	• Various network analysis tools are available as default install • Various network analysis plugins are available, too • In order to use some plug-ins, there is a need to obtain tokens and a limit on the amount of data to be analyzed
• Need to build **Network Data Set** based on road network data for Analysis	• **Use road network data as it is for analysis**
• Allow to build Multimodal network	• No function for multimodal network (as of now)





Both software allow us to analyze followings

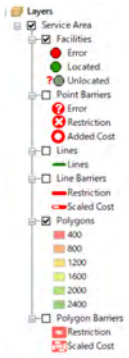
- Shortest pass
- Service area (Isochrones)
- Solving salesman issue
- OD-Matrix

2. Understand the Outline of Network Analysis

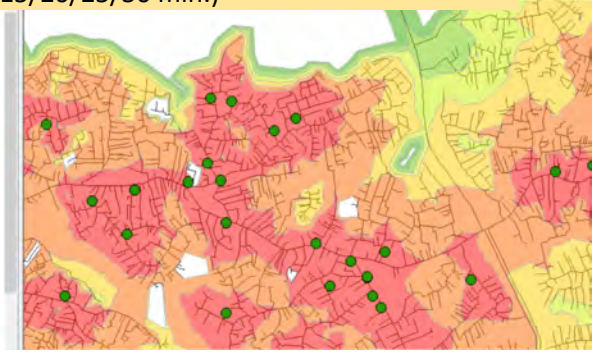
What you can do with Network Analysis?

What is the fastest way(route) to get from location "A" to "B"?

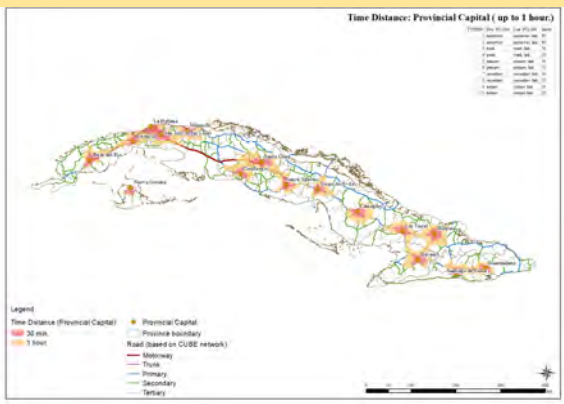


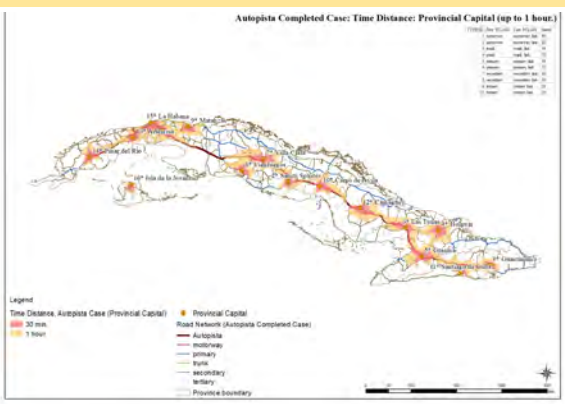


Walking distance coverage from medical centers (5/10/15/20/25/30 min.)



Predict (or examine) Future Accessibility and No. of population can get a benefit? (What if, the planned highway build?)





2. Understand the Outline of Network Analysis: Terminology

Terminology	Description
Transportation network	Transportation networks—like street, pedestrian, and railroad networks—can allow travel on edges in both directions. The agent on the network—for instance, a truck driver traveling on roads—is generally free to decide the direction of traversal as well as the destination.
Source features	Source features are the line and point features used to create a network dataset. They can be thought of as the physical network, which doesn't have topology embedded within the features. The network dataset can be thought of as the logical network, which does embed the topological relationships needed to perform network analyses.
Network dataset	The network dataset is a collection of interconnected network elements (edges, junctions, and turns) that model undirected flow. Its most common application is in modeling road networks. Any network analysis with the ArcGIS Network Analyst extension requires a network dataset, which is a logical network. You might wonder why a network dataset is necessary if you already have a line feature class that looks like a network. The reason is that line features don't inherently know what they are connected to, but network elements do. When a network analysis is performed, the solver needs to quickly scan a multitude of network elements to figure out which paths it can take to reach a destination. If it had to reference simple line features, it would need to perform time-consuming spatial operations for every line it inspected; the process would be too slow. Furthermore, setting up complex connectivity schemes would be difficult—if not impossible—to define with line features alone. Alternatively, when the solver scans a network dataset, the elements can provide accurate information without slowing the solver down as much.
Network elements	Network datasets are made up of edges, junctions, and turns; these components are generically referred to as network elements.

Source: https://desktop.arcgis.com/en/arcmap/latest/extensions/network-analyst/essential-network-analyst-vocabulary.htm

2. Understand the Outline of Network Analysis : Terminology

Terminology	Description
Network attributes	Network attributes hold information about the network dataset. There are four kinds: **Cost**—Penalizes traversal over an element. At least one cost attribute is required. **Descriptor**—Contains general information; it is often used to store values that are referenced by other network attributes to calculate their values. **Hierarchy**—Stratifies a network mainly for the purpose of solving network analyses quicker. **Restriction**—Typically prohibits certain movements on network elements but can also avoid or even prefer elements. Prohibiting elements allows you to model one-way streets, illegal turns, weight limits, and so on. Avoiding elements with a restriction attribute means Network Analyst will try to detour around the restricted elements, but only if doing so isn't too costly or if traveling on the restricted element isn't required. (The element may have to be traversed, at least partially, if a stop or other network location is located on it.) Restriction attributes can even be configured so that some elements are preferred over others, which makes it possible to model designated truck routes, for example.
Network cost or impedance	**Network cost** and **impedance** refer to the same concept. Whenever an agent traverses a network element, it is charged some amount, which is the network cost. For example, a path from one city to another might have a network "cost" of 45 miles. Network cost can be anything you choose but typically is distance or travel time. To be used in a network analysis, a network dataset must have at least one cost attribute because network analyses always optimize some cost. For instance, a route analysis finds the least-cost path between two or more points. In some cases, even more than one cost attribute is required.

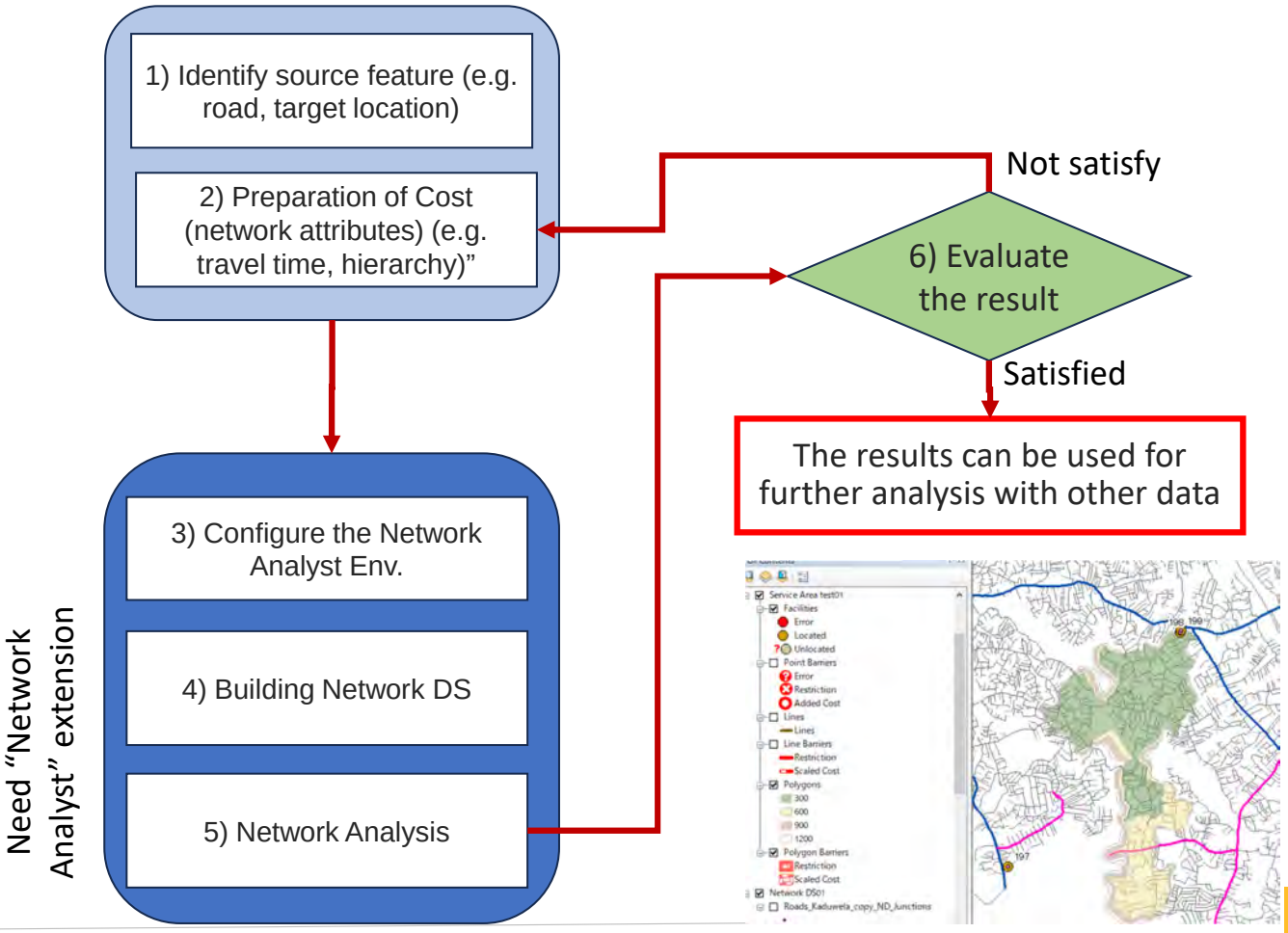
Source: https://desktop.arcgis.com/en/arcmap/latest/extensions/network-analyst/essential-network-analyst-vocabulary.htm

2. Understand the Outline of Network Analysis : Terminology

Terminology	Description
Evaluators	After you add a network attribute to a network dataset, the attribute values need to be calculated. Evaluators serve this function. There are many evaluators for each network attribute. A network attribute has a unique evaluator for each network element (junctions, edges, and turns) and each of their source feature classes. Moreover, there are two evaluators for each edge source feature class: one for the from-to side of edges and another for the to-from side. For example, if a cost attribute is added to a network dataset made from a streets feature class and a turns feature class, there can be an evaluator that calculates the cost attribute values for each of the following: System junctions, Turns, The from-to side of streets, The to-from side of streets If more source features are added to the network, more evaluators would be necessary to calculate costs for their corresponding network elements. There are various kinds of evaluators, such as constant evaluators that assign a single value to all elements in the group and field evaluators that can pull values from source features and assign them to their corresponding network elements
Network analysis layer	Network analysis layers, or analysis layers for short, can be thought of as a framework for setting up and solving a network problem. For instance, a route analysis layer is created when you choose to solve a route (least-cost path) problem in ArcMap. It is automatically associated with the active network dataset. Also, the analysis layer has properties that let you further define the problem, such as a property that lets you specify whether the stops should be optimally sequenced or visited in the order they are listed. Network analysis layers also contain a set of network analysis classes that are predefined for the network problem type: route analysis layers contain network analysis classes for stops, routes, and the various barriers; origin-destination analysis layers contain origins, destinations, lines, and barriers. The analysis classes in turn hold the input data you provide and the output data provided by the solve operation.

Source: https://desktop.arcgis.com/en/arcmap/latest/extensions/network-analyst/essential-network-analyst-vocabulary.htm

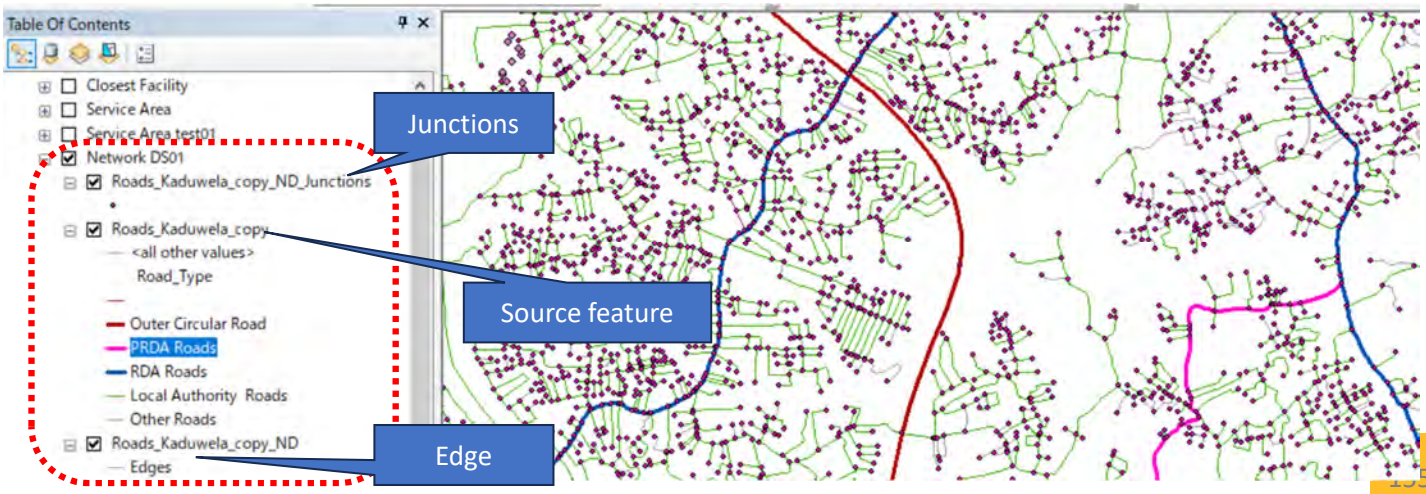
3. Basic Workflow of Network Analysis (1): Overall Work flow



3. Basic Workflow of Network Analysis (2): Preparation of Network Datasets

Network datasets are made of network elements. Network elements are generated from the source features used to create the network dataset. The geometry of the source features helps establish connectivity. In addition, network elements have attributes that control navigation over the network.

1. **Identify source feature** to use for the analysis (e.g. road, railway, railway station, etc)
   - *Clean line data is essential for the network analysis (if line connectivity is not properly edited, the area will not be analyzed)*
   - *Understand contents of attributes whether "Cost (impedance)" field(s) is available or not*
2. **Preparation of "Cost/ Impedance" in the source features (travel time, hierarchy, restrictions, etc.)**
   - *Add the new field to store "Cost", and calculate it in the field*
3. **Build "Network dataset"**
4. If the network dataset is required to be update/modified, the user must "build" the network dataset before analize.



Project on Capacity Development for Urban Planning

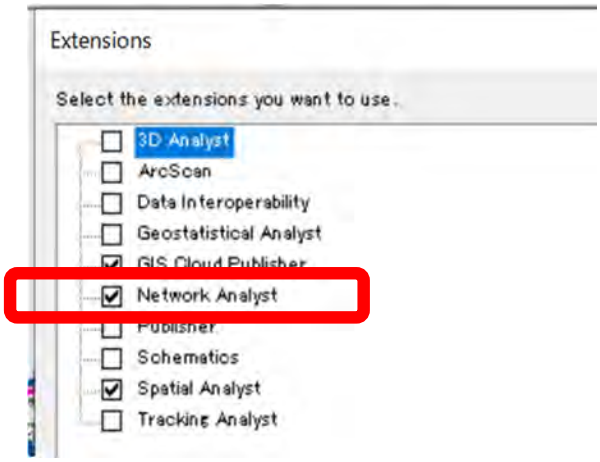
3. Basic Workflow of Network Analysis (3): Analysis Options

Most common types of network analysis for urban planning

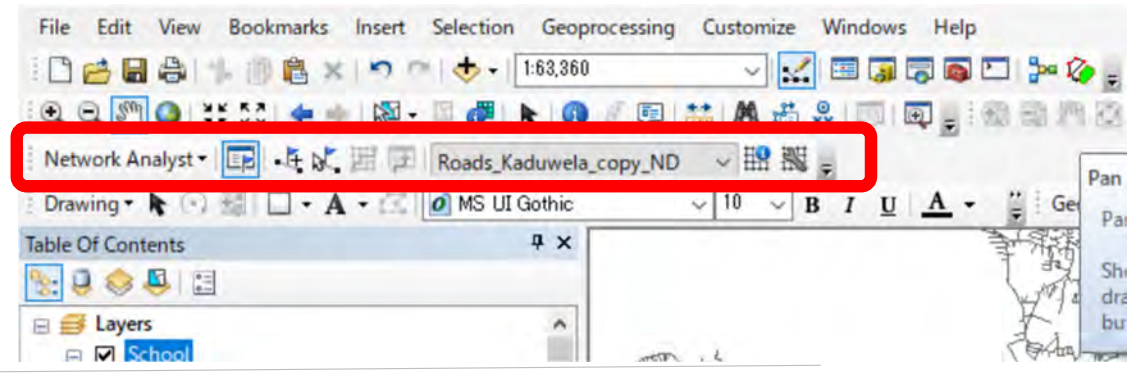
1	**Route (Point-to-point analysis)**	A point-to-point analysis is the most common routing problem. It consists of a set of points to find the most optimal route based on specific criteria.	**Find Nearest** – Where is the closest destination? It finds the nearest destination based on a starting point with multiple potential destinations.
			Shortest Distance – What's the fastest route? This analysis accumulates all distances, as you travel out from one point to the other. Then, it finds the route with the least distance.
			Fastest route – Which route takes the least amount of time? This network analysis takes into account speed limits, road classification, and other costs to determine the least travel time.
2	**Service Coverage (Finding Coverage)**	Isochrone (Iso area) correspond to the distance that can be reached within a specific amount of distance/ time.	Isochrone are different from buffers because it takes into account a street network. Buffers can cross waterbodies but drive-time areas can only cross water when there's a bridge.

4. Building "Network Dataset" (1) : Configure Environment

1. If necessary, activate "Network Analyst" Extension ("Customize" - "Extensions")
2. Make sure "Network Analyst" window is on the screen



"Network analyst" window



4. Building "Network Dataset" (2): Prepare "Cost"

- *If your source data doesn't have travel time, one of the solution is estimate travel time. Following method is a one of solution to estimate travel time*

  1. Create a new field and input travel speed.
  2. Create a new field to store travel time
  3. Using the "Field calculator", calculate travel time of each line feature

- *Length can be a "Cost". But if you use length as a "Cost", you can analyze only service coverage with in XX m. Can't calculate within "XX min." or "XX hours".*

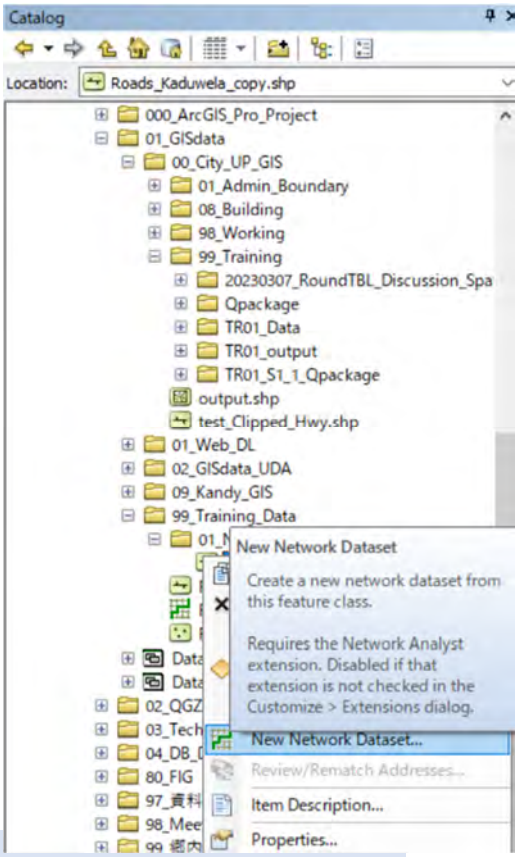
Table

Roads_Kaduwela_copy

FID	Shape	OBJECTID_1	Road_name	Shape_Leng	Road_Type	Road_Class	Z_Spd_kmh	Tra_Time01
7813	Polyline	7855		183.610067			0	0
7816	Polyline	7860		4.481459			0	0
7819	Polyline	7870		2.792229			0	0
7830	Polyline	7886		7.17851			0	0
0	Polyline	1		123.885831	Local Authority Roads		30	11.89304
1	Polyline	2		135.288524	Local Authority Roads		30	12.987698
2	Polyline	3		148.656886	Local Authority Roads		30	14.271061
3	Polyline	4		126.536005	Local Authority Roads		30	12.147456
4	Polyline	5		322.228006	Local Authority Roads		30	30.933889
5	Polyline	6		183.733047	Local Authority Roads		30	17.638372
7	Polyline	8		166.486463	Local Authority Roads		30	15.9827
8	Polyline	9		103.110178	Local Authority Roads		30	9.898577

4. Building “Network Dataset” (3): Build Network DS-1

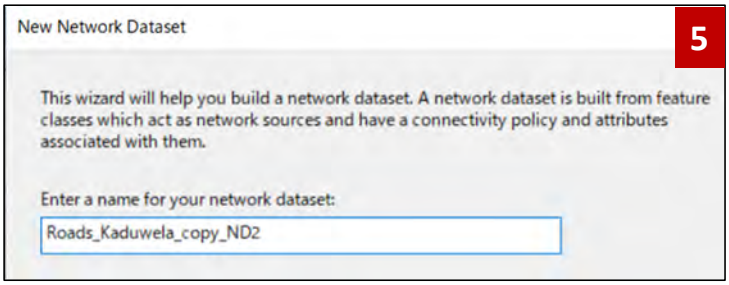
1. Open “Arc Catalog”
2. Create workspace for network analysis
3. Copy the source feature in the workspace and right click
4. Select “New Network Dataset”



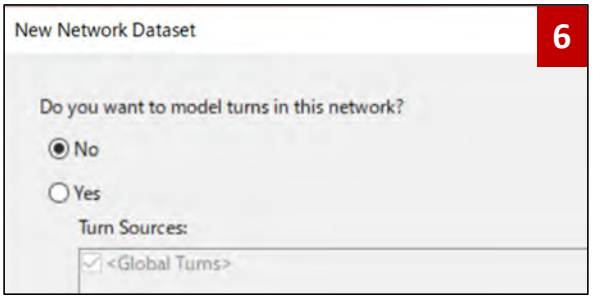
<Further detail can refer below>
https://desktop.arcgis.com/en/arcmap/latest/extensions/network-analyst/creating-a-network-dataset.htm

4. Building “Network Dataset” (3): Build Network DS-2

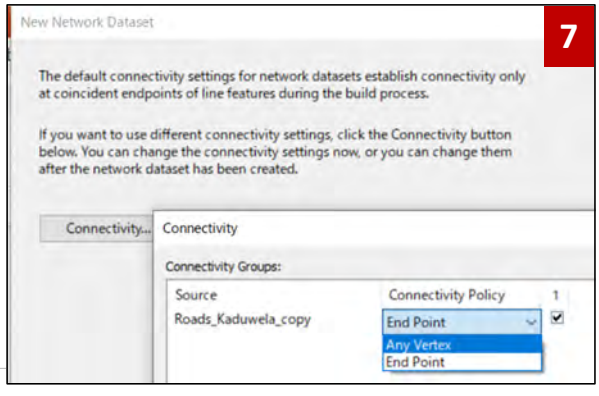
5. Input your network dataset name and click “Next”



6. “Turns” are not necessary to create a network dataset, so select “No”



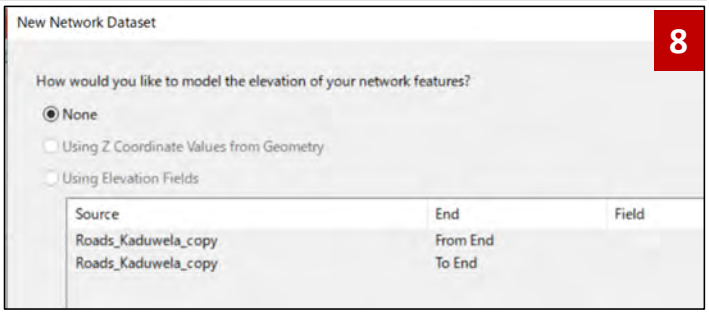
7. Set connectivity policy as “Any vertex”



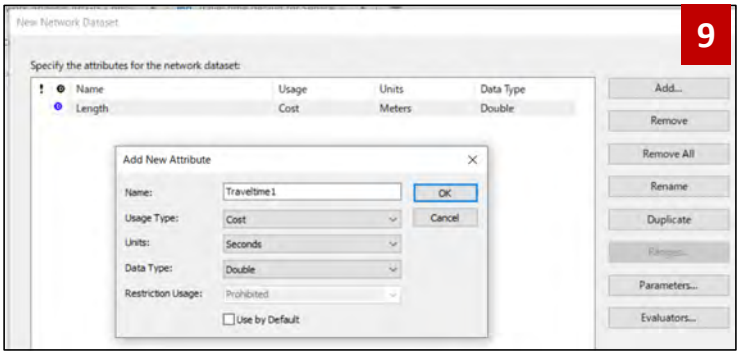
<Further detail can refer below>
https://desktop.arcgis.com/en/arcmap/latest/extensions/network-analyst/creating-a-network-dataset.htm

4. Building "Network Dataset" (3): Build Network DS-3

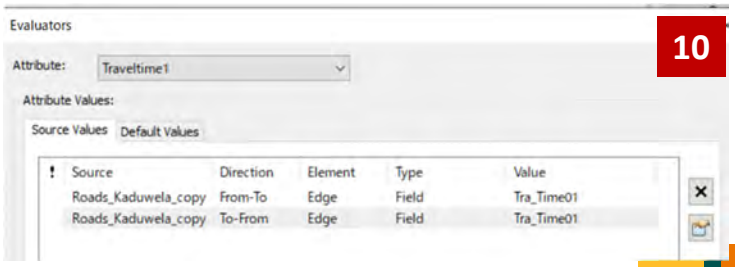
8. This Kaduwela road network data (source feature) doesn't have elevation, so select "None" (default)



9. Setting source attribute information. AS default, "Length" field is displayed. Your have already prepared "travel time" in the attribute table, so Add new attribute name as "traveltime1" & click "Evaluators

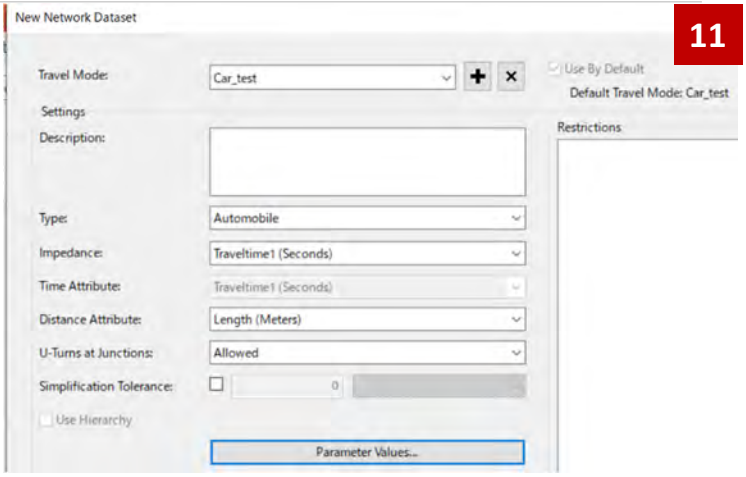


10. Change "Type" as "Field" and Change "Value" as "Tra_Time01" where you store travel time

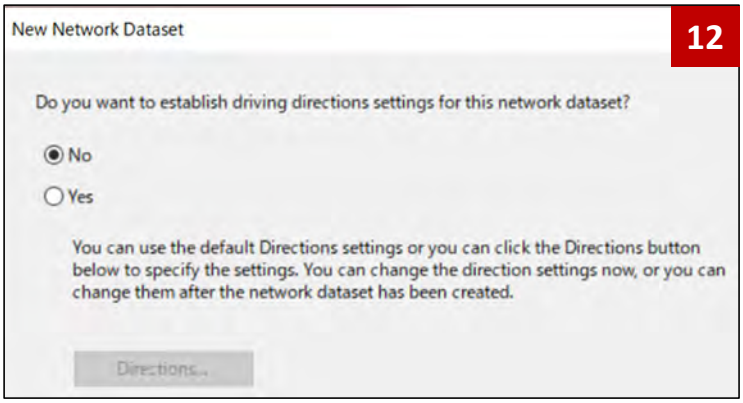


4. Building "Network Dataset" (3): Build Network DS-4

11. Input "Travel Mode" as you like and select "Traveltime1" as Impedance. You can leave as default in other options

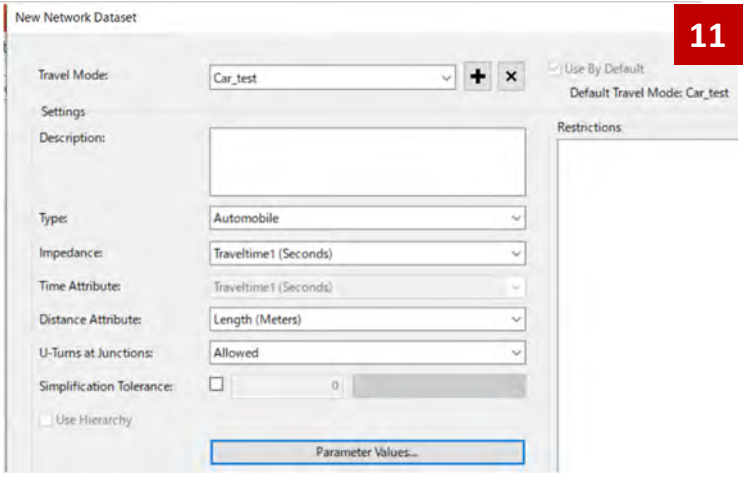


12. Setting driving direction as default. (We don't have such a detail info.)

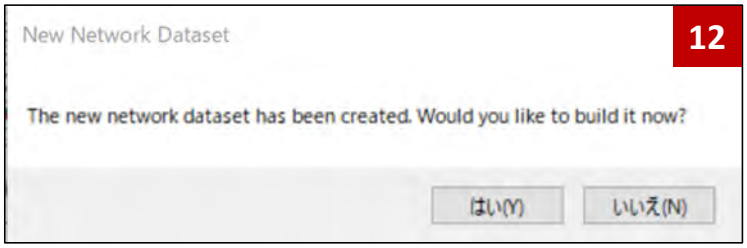


4. Building "Network Dataset" (3): Build Network DS-5

13. Input "Travel Mode" as you like and select "Traveltime1" as Impedance. You can leave as default in other options

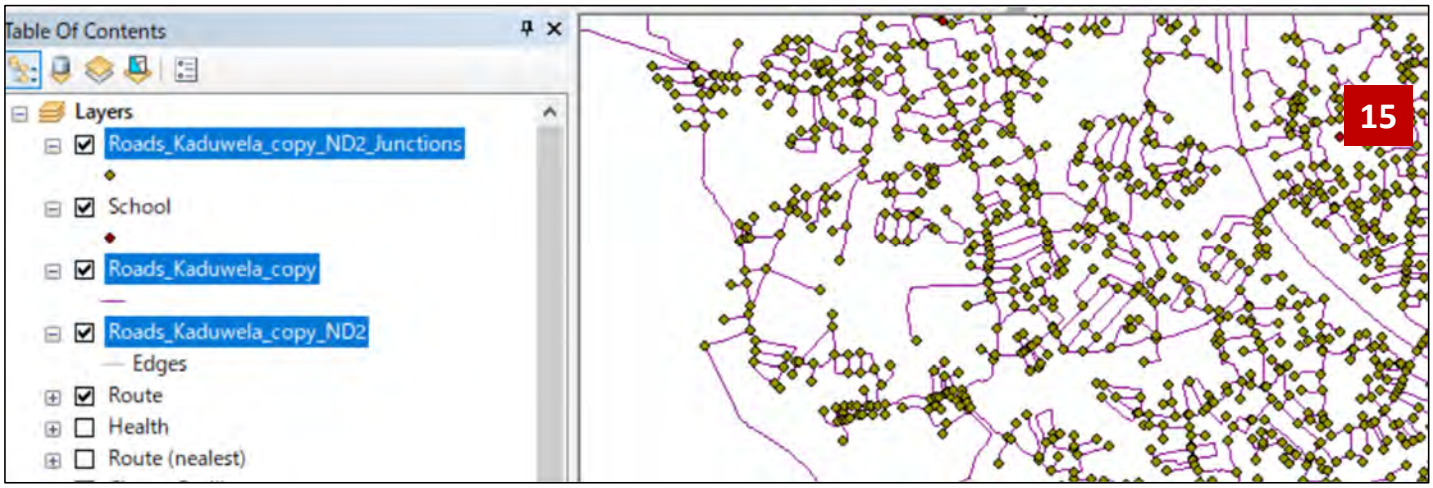


14. Check the summary of your setting and click OK. Then answer OK to build the network dataset.



4. Building "Network Dataset" (3): Build Network DS-6

15. You can see the network dataset on your screen

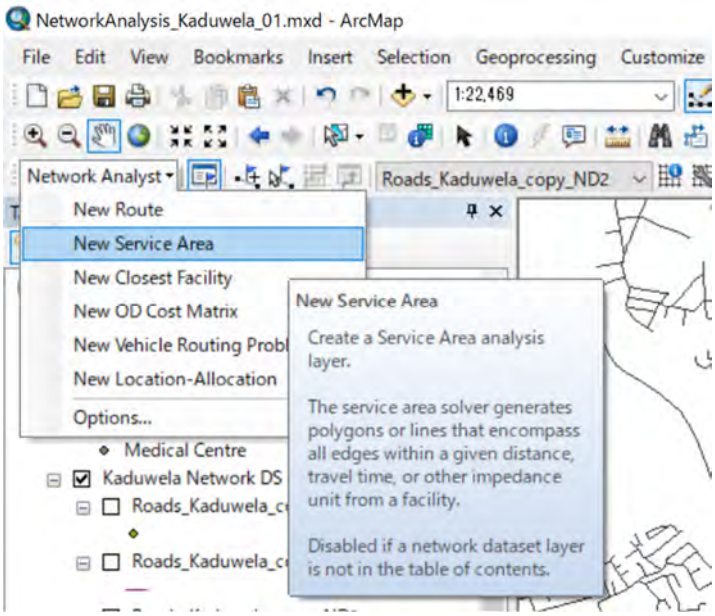


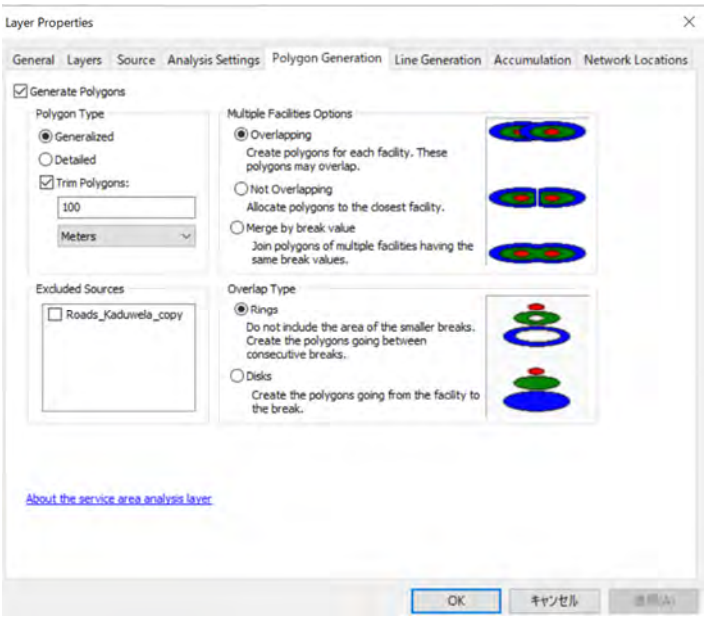
If road data connectivity is not correct, the junction (point) will not be generated

5. Understand how to access Network Analyst tools

To perform network analysis,

1. Select the analysis method from Network Analyst tool bar
2. Setting analysis options (Setting parameters are depends on the analysis method)





6. Understand the Typical Network Analysis Process (Exercise)

Exercise 1

- Analyze No. of Population within 15 min. service coverage area by walk from Medical Center

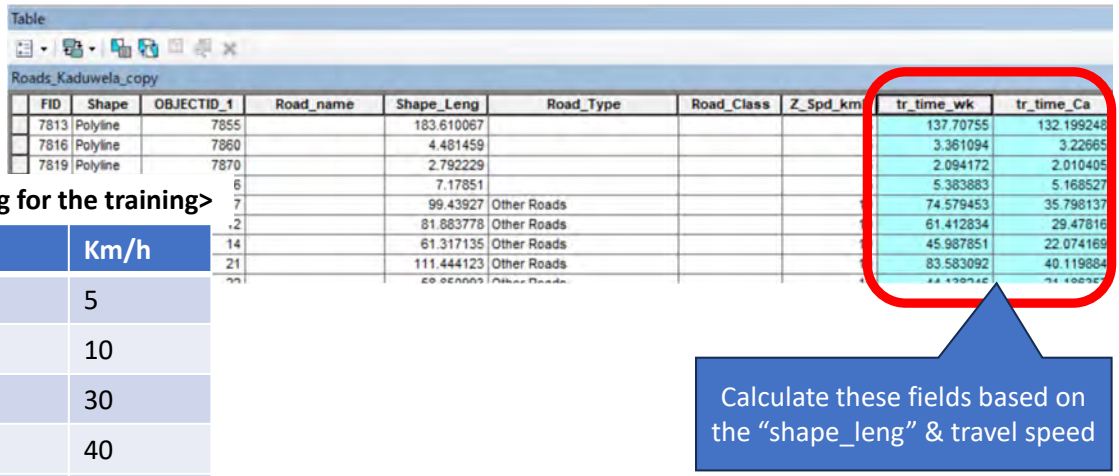
6. Understand the Typical Network Analysis Process 1 (Exercise)

Contents of Exercise

1. Preparation of Network DS

a. Preparation of Cost (impedance) field

- Preparation of **"tr_time_WK"** field as Cost (impedance) in the "seconds" for service coverage analysis ***by Walk*** option
  - *Assume Average walking speed as "80m/min."*
- Preparation of "**tr_time_Ca**" field as Cost (impedance) in the unit "seconds" for service coverage analysis ***by Vehicle*** option
  - *Setting travel speed based on Road_Type, refer the table on this slide*



<"Z_spd_kmh": Speed Setting for the training>

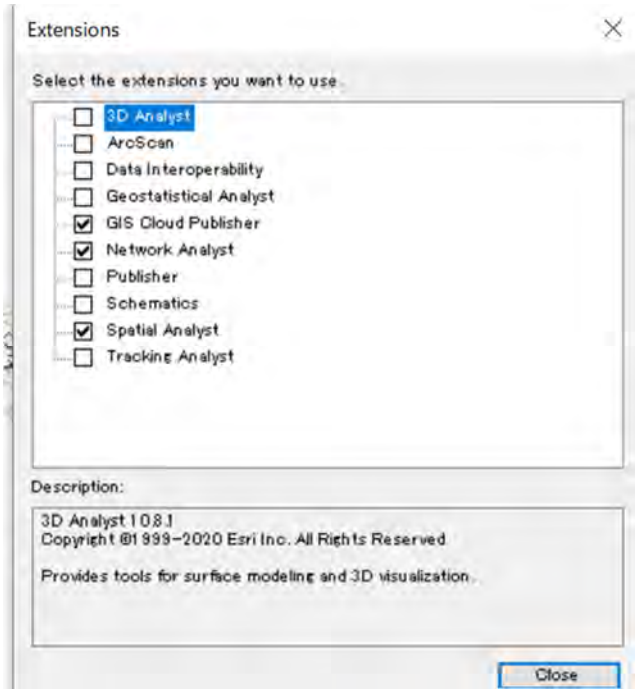
Road_Type	Km/h
No road type info	5
Other roads	10
Local Authority Roads	30
RDA Roads/ PRDA Roads	40
Outer Circular Road	60

6. Understand the Typical Network Analysis Process 2 (Exercise)

Contents of Exercise

2. Configure the Network Analyst Extension Environments

Before you can work with the ArcGIS Network Analyst extension in ArcMap, you must enable the extension. The same is true for ArcCatalog; thus, if you use Network Analyst with both ArcCatalog and ArcMap, you need to enable the extension twice. Enabling the extension does not cause relevant user interface components to appear automatically but enables the Network Analyst functionality and tools so that you can work with them.



A) Start either ArcMap or ArcCatalog.
   - *Start ArcMap by clicking Start > All Programs > ArcGIS > ArcMap.*
   - *Start ArcCatalog by clicking Start > All Programs > ArcGIS > ArcCatalog.*

B) Click Customize > Extensions.
   - *The Extensions dialog box opens.*

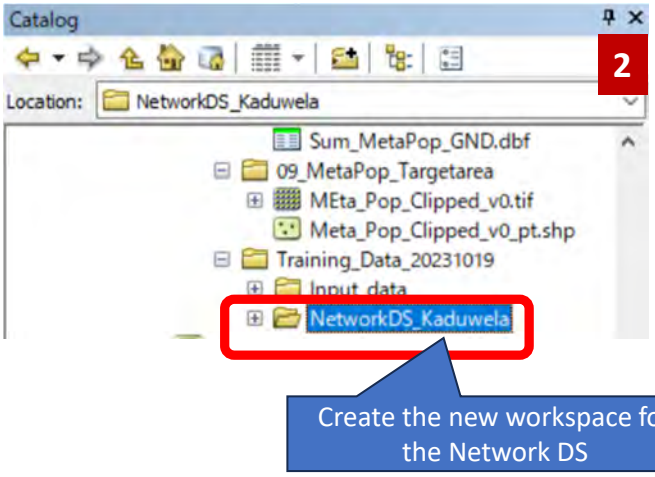
C) Check the Network Analyst check box.

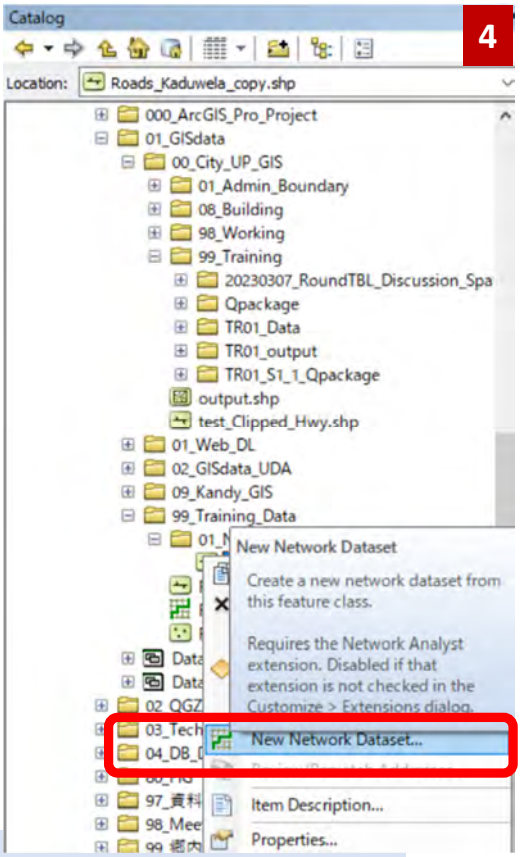
D) Click Close.

6. Understand the Typical Network Analysis Process 3 (Exercise)

3. Build Network Datasets - 1

1. Open “Arc Catalog”
2. Create workspace for network analysis
3. Copy the source feature in the workspace and right click
4. Select “New Network Dataset”



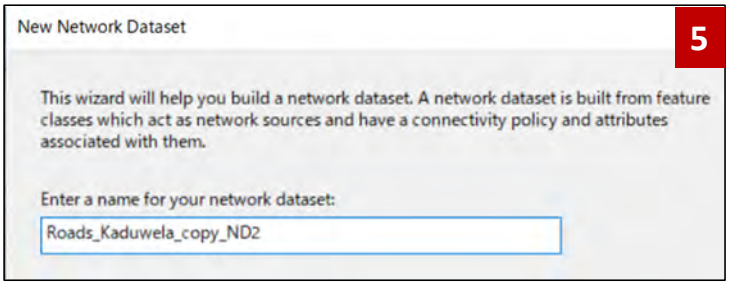


<Further detail can refer below>
https://desktop.arcgis.com/en/arcmap/latest/extensions/network-analyst/creating-a-network-dataset.htm

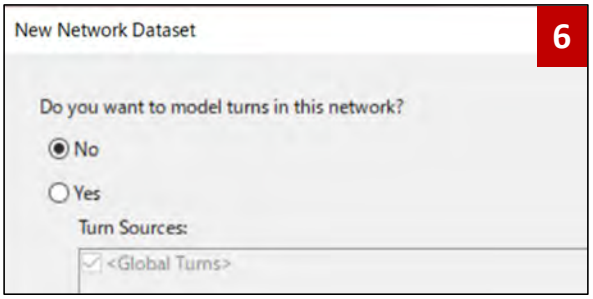
6. Understand the Typical Network Analysis Process 3 (Exercise)

3. Build Network Datasets - 2

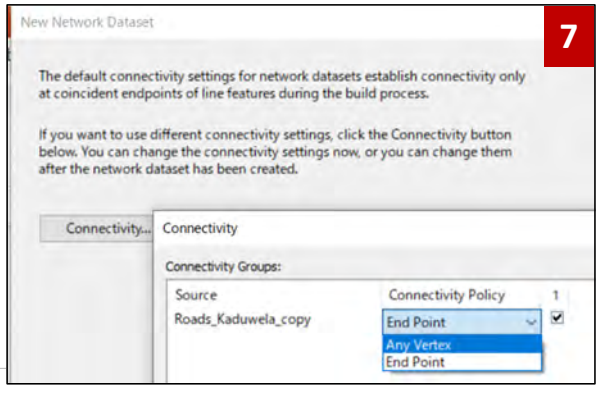
5. Input your network dataset name and click “Next”



6. “Turns” are not necessary to create a network dataset, so select “No”



7. Set connectivity policy as “Any vertex”

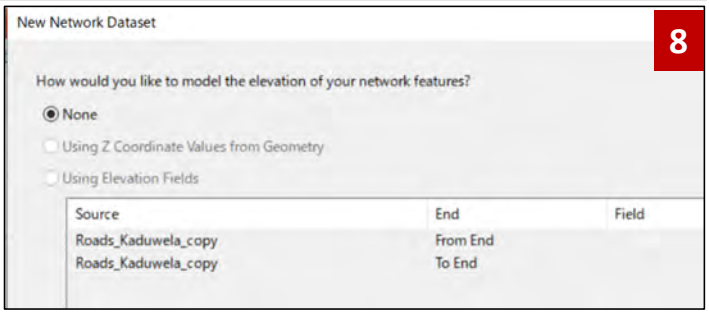


<Further detail can refer below>
https://desktop.arcgis.com/en/arcmap/latest/extensions/network-analyst/creating-a-network-dataset.htm

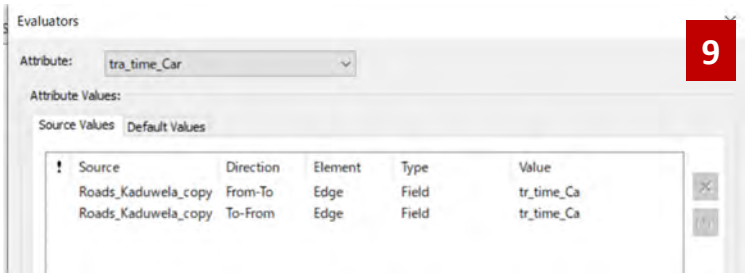
6. Understand the Typical Network Analysis Process 3 (Exercise)

3. Build Network Datasets - 3

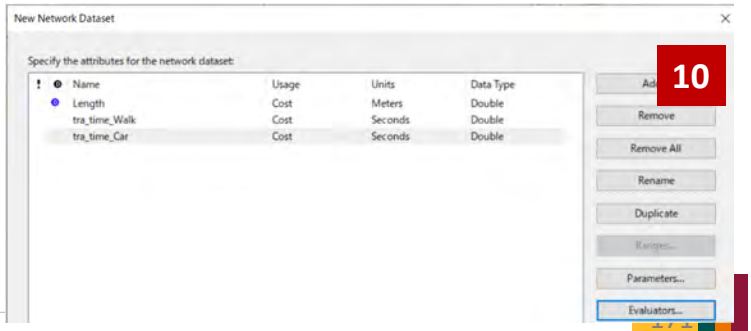
8. This Kaduwela road network data (source feature) doesn't have elevation, so select "None" (default)



9. Setting source attribute information. As default, "Length" field is displayed. Your have already prepared "travel time" in the attribute table, so Add new attribute name as "traveltime1" & click "Evaluators



10. Change "Type" as "Field" and Change "Value" as field name where you store travel time

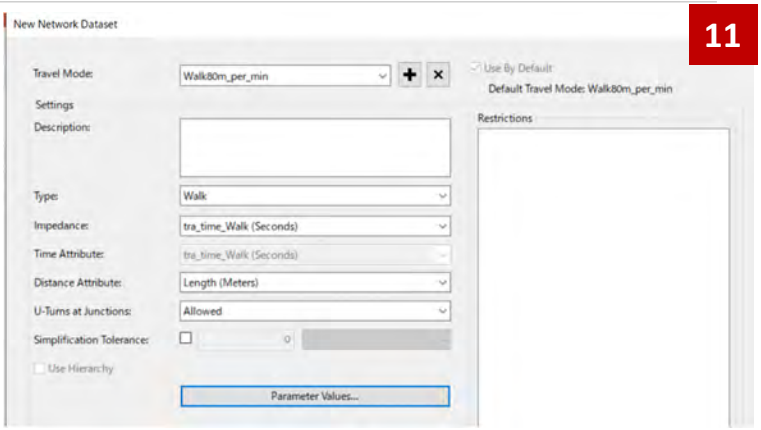


Project on Capacity Development for Urban Planning

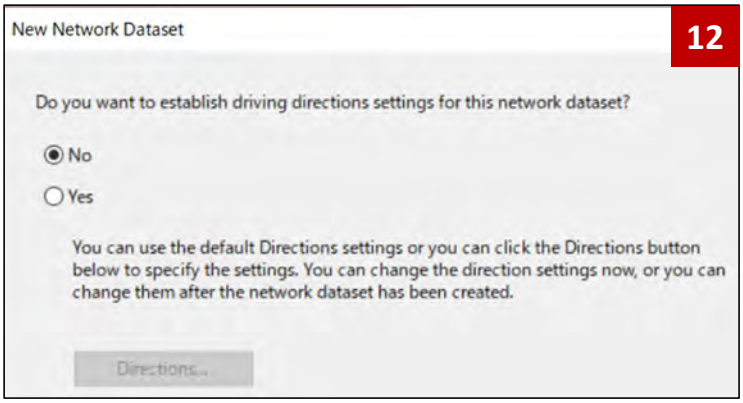
6. Understand the Typical Network Analysis Process 3 (Exercise)

3. Build Network Datasets - 4

11. Input "Travel Mode" as you like and select "Tra_time_WK" as Impedance. You can leave as default in other options



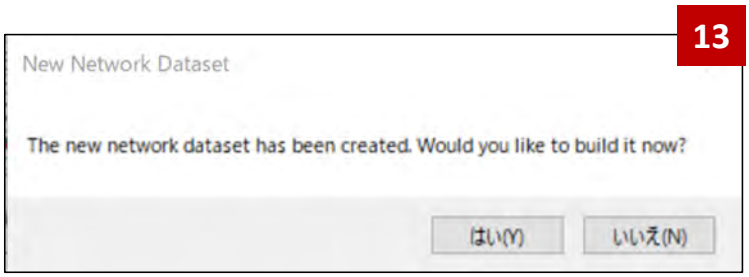
12. Setting driving direction as default. (We don't have such a detail info.)



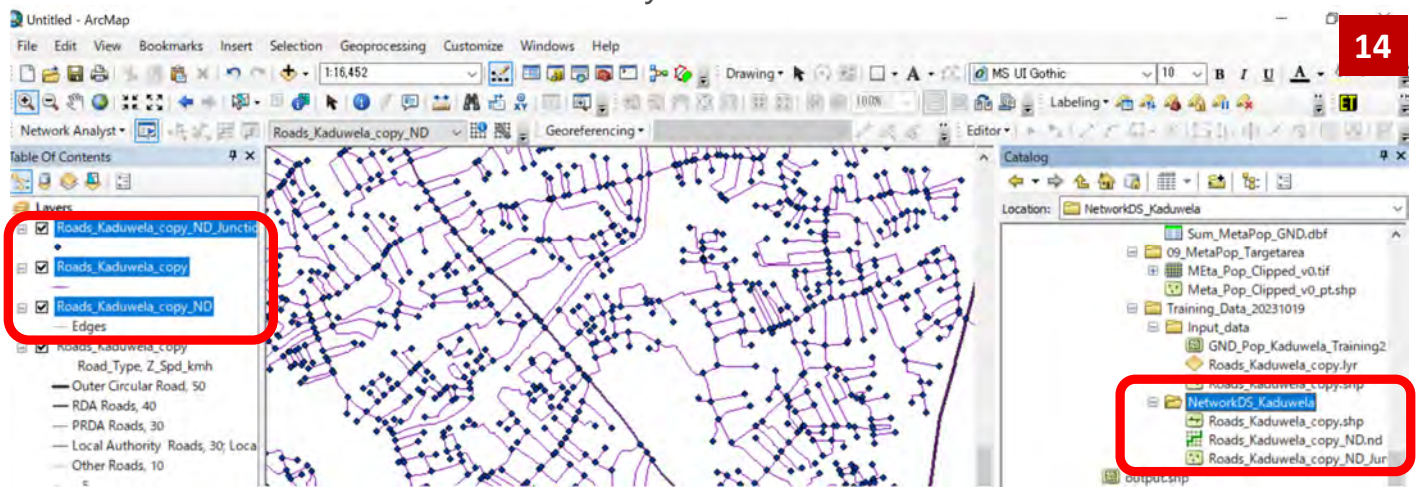
4. Building "Network Dataset" (3): Build Network DS-5

3. Build Network Datasets - 5

13. Check the summary of your setting and click OK. Then answer OK to build the network dataset.



14. You can see the network dataset on your screen



If road data connectivity is not correct, junctions (point) will not be generated

6. Understand the Typical Network Analysis Process 2 (Exercise)

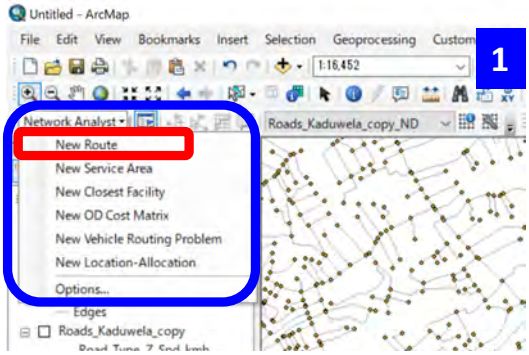
Contents of Exercise

4. Perform Network Analysis (1): Route Analysis - 1

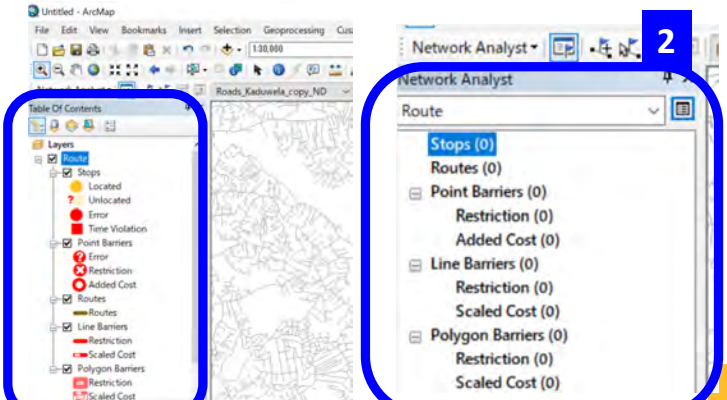
What you are going to do is…
Exercise 1 "Search shortest route between 2 point (by Walk)"

Network Analyst can find the best way to get from one location to another or to visit several locations. The locations can be specified interactively by placing points on the screen, entering an address, or using points in an existing feature class or feature layer. If you have more than two stops to visit, the best route can be determined for the order of locations as specified by the user. Alternatively, Network Analyst can determine the best sequence to visit the locations, which is known as solving the traveling salesman problem. (by ESRI)

1. Select Analysis Type



2. Analysis layers are open & Network Analyst Window open automatically



6. Understand the Typical Network Analysis Process 2 (Exercise)

Contents of Exercise

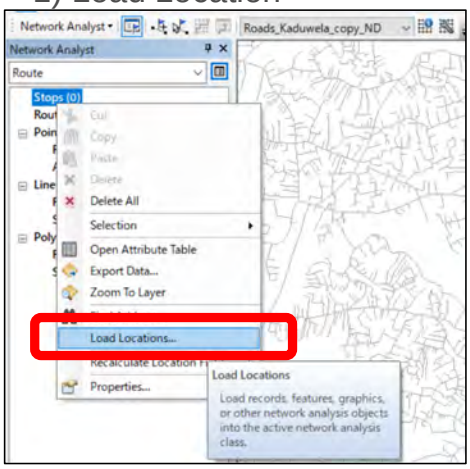
4. Perform Network Analysis (1): Route Analysis - 2

3. Preparation of “Stop”

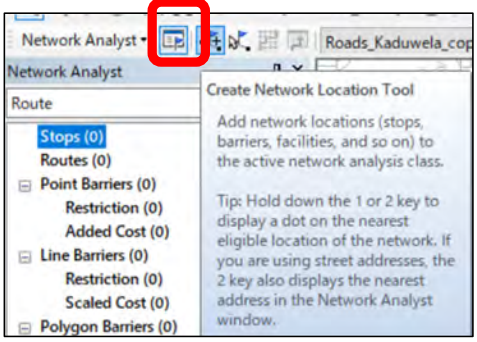
There are 2-way to set “Stop” for Route analysis

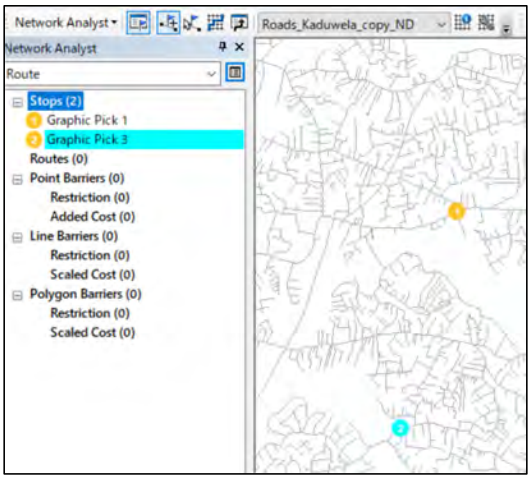
1) If you have GIS data, you can set “Stop” based on your data from “Load Location”
2) You can also input “Stop” location dynamically on your screen manually

1) Load Location



2) Input location points manually





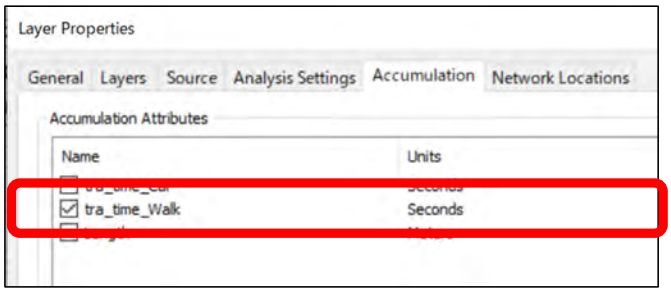
6. Understand the Typical Network Analysis Process 2 (Exercise)

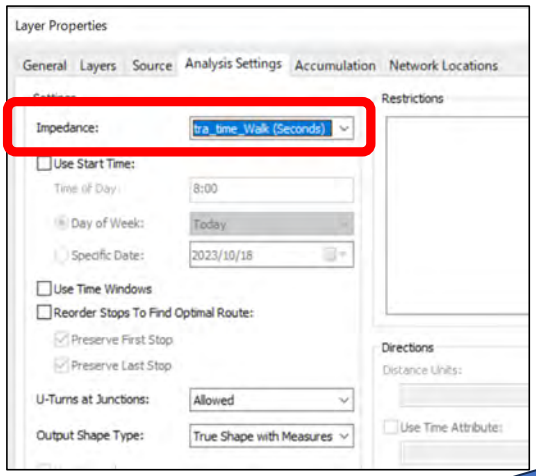
Contents of Exercise

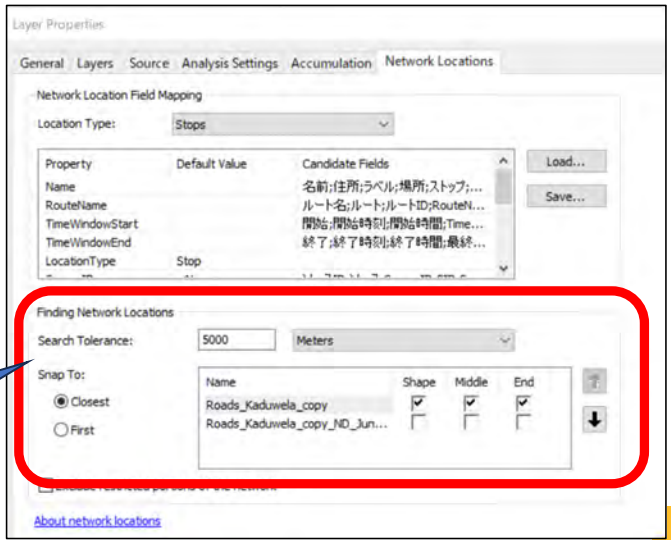
4. Perform Network Analysis (1): Route Analysis - 3

3. “Route” Layer Property Settings

- Analysis Setting
- Accumulation (If you need)
- Network Location







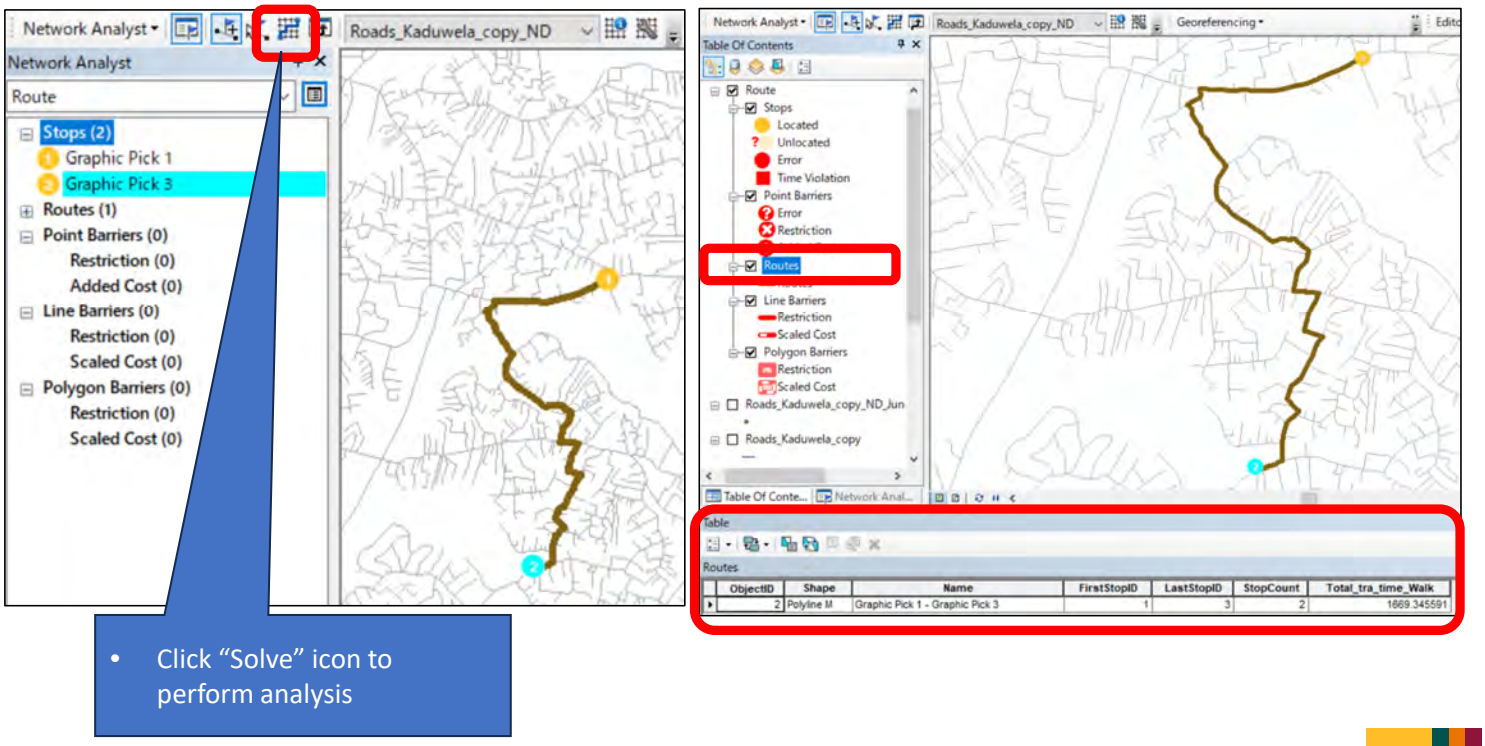
Setting…
- Search tolerance
- type of finding routes

6. Understand the Typical Network Analysis Process 2 (Exercise)

Contents of Exercise

4. Perform Network Analysis (1): Route Analysis - 3

4. Perform “Route” analysis



- Click “Solve” icon to perform analysis

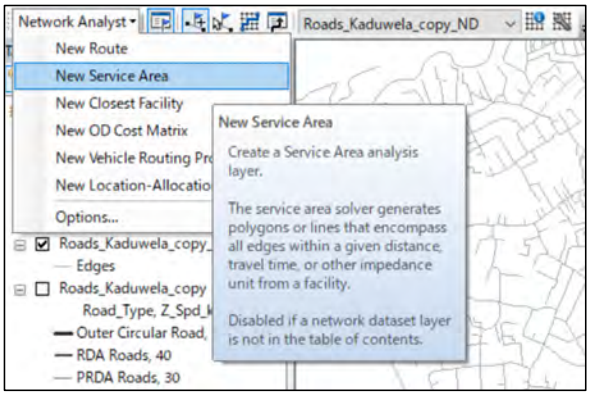
6. Understand the Typical Network Analysis Process 2 (Exercise)

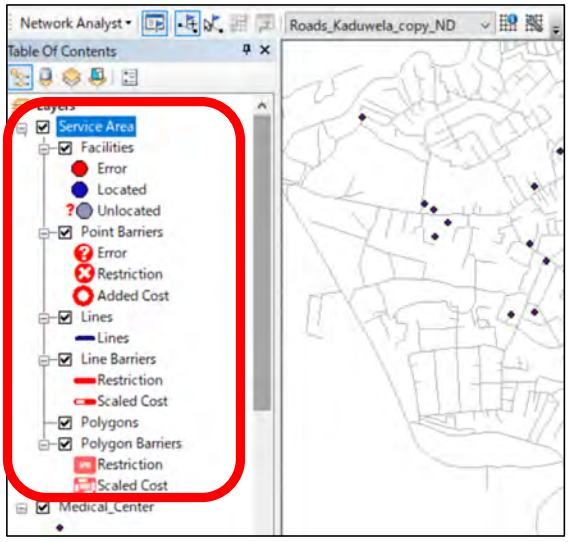
Contents of Exercise

4. Perform Network Analysis (2): Service Area Analysis - 1

Perform “Service area” analysis:
Calculate service area of 15, 30, 45, 60 min. From/to Medical Centers

1. Select Analysis Type: “Service Area”





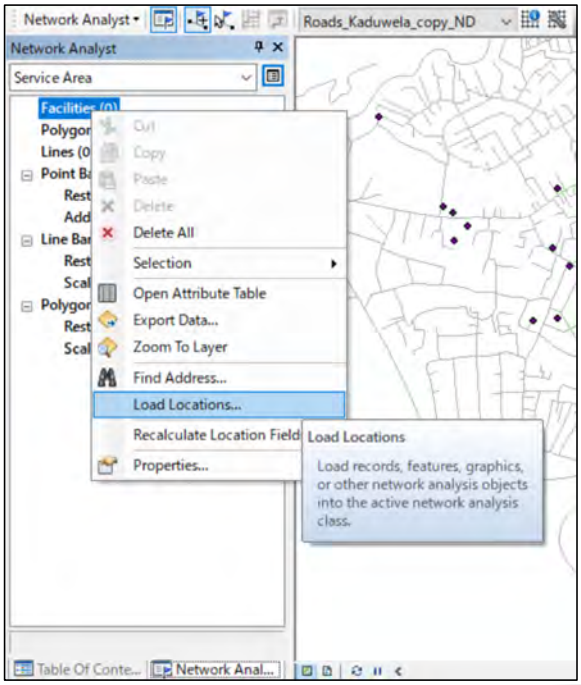
6. Understand the Typical Network Analysis Process 2 (Exercise)

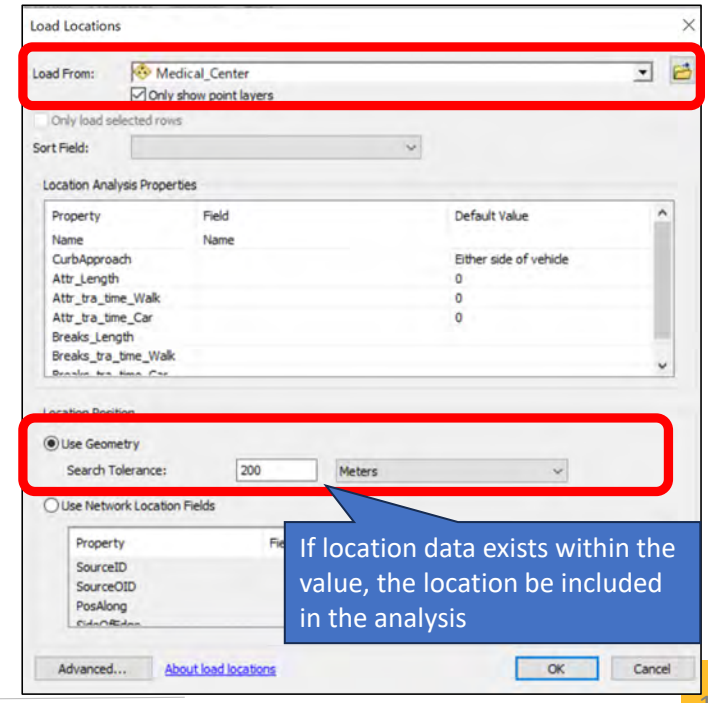
Contents of Exercise

4. Perform Network Analysis (2): Service Area Analysis - 2

Perform "Service area" analysis:
Calculate service area of 15, 30, 45, 60 min. From/to Medical Centers

2. Load (import) location of medical centers





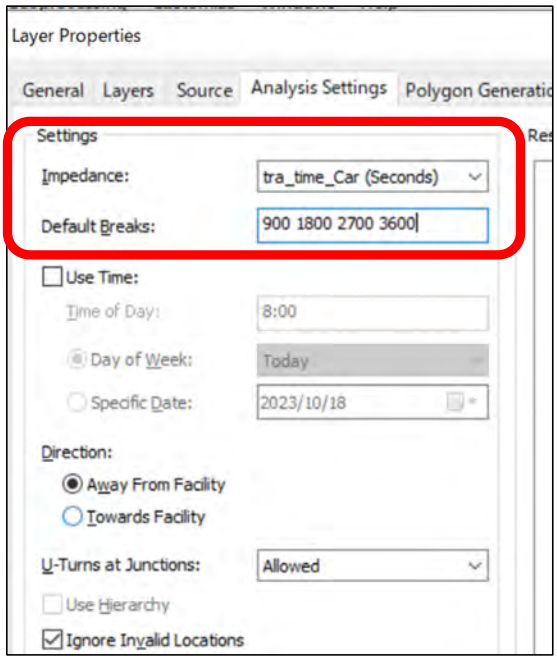
6. Understand the Typical Network Analysis Process 2 (Exercise)

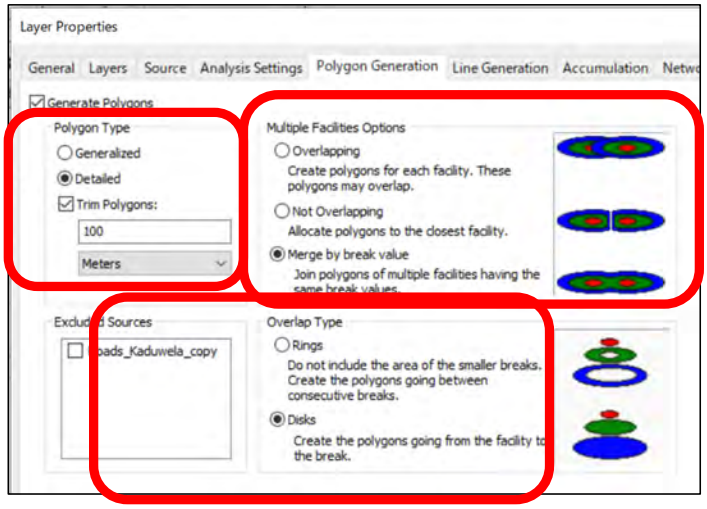
Contents of Exercise

4. Perform Network Analysis (2): Service Area Analysis - 3

Perform "Service area" analysis:
Calculate service area of 15, 30, 45, 60 min. From/to Medical Centers

3. Service Area Layer Settings (1)





6. Understand the Typical Network Analysis Process 2 (Exercise)

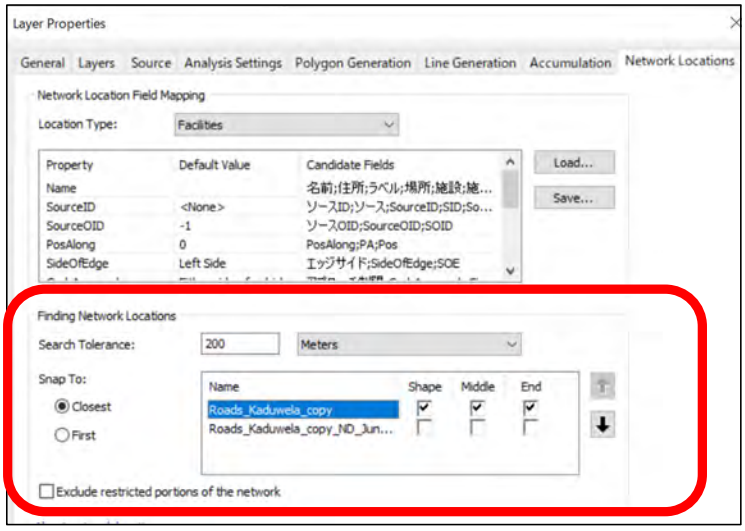
Contents of Exercise

4. Perform Network Analysis (2): Service Area Analysis - 3

Perform "Service area" analysis:
Calculate service area of 15, 30, 45, 60 min. From Medical Centers

3. Service Area Layer Settings (2)





Project on Capacity Development for Urban Planning

Thank you very mush

ありがとうございます

PPT. No.7

Module LU3-2: Spatial Data Analysis by GIS

ArcGIS Pro General

Project on Capacity Development for Urban Planning

Project on Capacity Development for Urban Planning in Sri Lanka

Migrating ArcMap to ArcGIS Pro

13 Aug. 2024

Migrating ArcMap to ArcGIS Pro: Objectives

Background:

- CITY-UP procured ArcGIS Pro with Spatial analyst extension and Network Analyst extension which is requested by URC/UDA
- ArcGIS Desktop is no longer sold, and any bugs will no longer be fixed (Many ArcMap users shift to QGIS too, QGIS trainings already done by City-UP)
- Most of geoprocessing tools in ArcMap are available in ArcGIS Pro (Tools that are not available in ArcGIS Pro is here: *https://pro.arcgis.com/en/pro-app/latest/tool-reference/appendices/unavailable-tools.htm*)
- An urban plan for Tangalle is currently being formulated. By using actual data from Tangalle in the training, the results of the analysis conducted in the training can be used in the urban planning of Tangalle.
- Various e-learning materials are available on Web about "How to use ArcGIS Pro", this training will focus on "How to utilize GIS techniques with ArcGIS pro for urban planning activities.

Ultimate Goal:

- Utilize spatial analysis knowledge of ArcGIS Pro with extensions for urban planning activities by URC/ UDA

To achieve the Ultimate Goal:

The objective of this training session are;

1. Understand differences between ArcMap and ArcGIS Pro
2. Understand How to import .MXD to ArcGIS Pro
3. Understand basic operation with ArcGIS Pro
4. 3D visualization without extension
5. Basic geoprocessing operations in ArcGIS Pro

There is a documentation for ArcMap users migrating to ArcGIS Pro here (by ESRI):
https://pro.arcgis.com/en/pro-app/latest/get-started/migrate-to-arcgis-pro.htm
https://www.esri.com/en-us/arcgis/products/arcgis-pro/resources/migrate

Migrating ArcMap to ArcGIS Pro: ArcMap vs. ArcGIS Pro

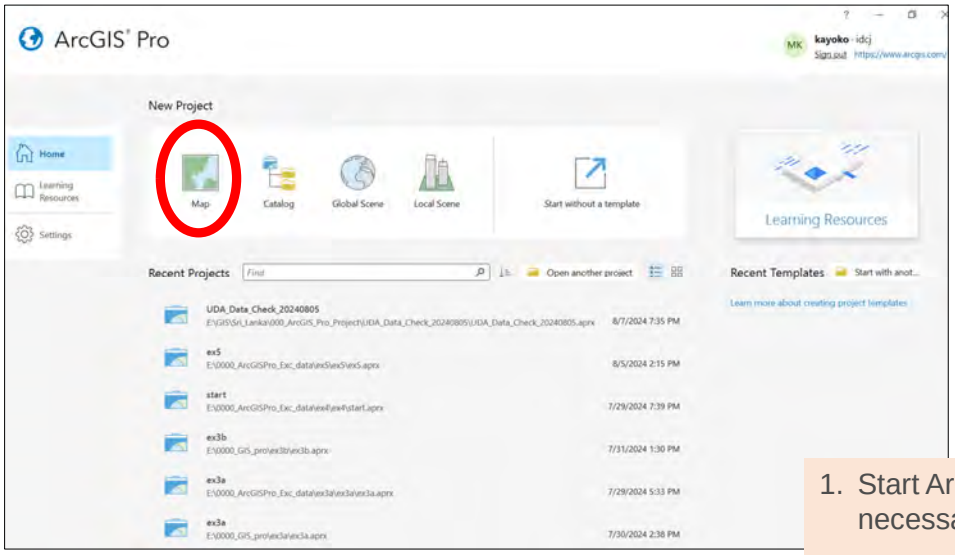
Major Differences between ArcMap vs. ArcGIS Pro

	ArcMap	ArcGIS Pro
Project file	.MXD	.aprx (Can import .mxd)
Interface	Many toolbars that must be manually be turned on or off	Contextual ribbons, like MS-Office apps
Editing session	Need to start / end editing session	Without start editing session, you can start data editing
Processing speed	Processing with only 32-bit even PC spec is 64bit	ArcGIS Pro is a 64-bit multi-threaded application
Tools	No longer add new tool	Most of tools in ArcMap are available and added more tools
Map creation	Available only 1 map canvas in the project	Multiple maps can prepare in 1 project
Map Layout	Available only 1 map layout in the project	Multiple layouts can create in 1 project
3D	ArcScene and ArcGlobe are stand-alone programs	3D integrated into the program

Migrating ArcMap to ArcGIS Pro: Create Project

Create a Project from default template (1)

When you start ArcGIS Pro, the start page appears. The start page has options to open a recent project or to create a project from a template. Templates define the starting state of the project. For example, the Map template creates a project that opens with a map view.



1. Start ArcGIS Pro and sign in if necessary.
2. On the start page, under **New Project**, click **Map**.

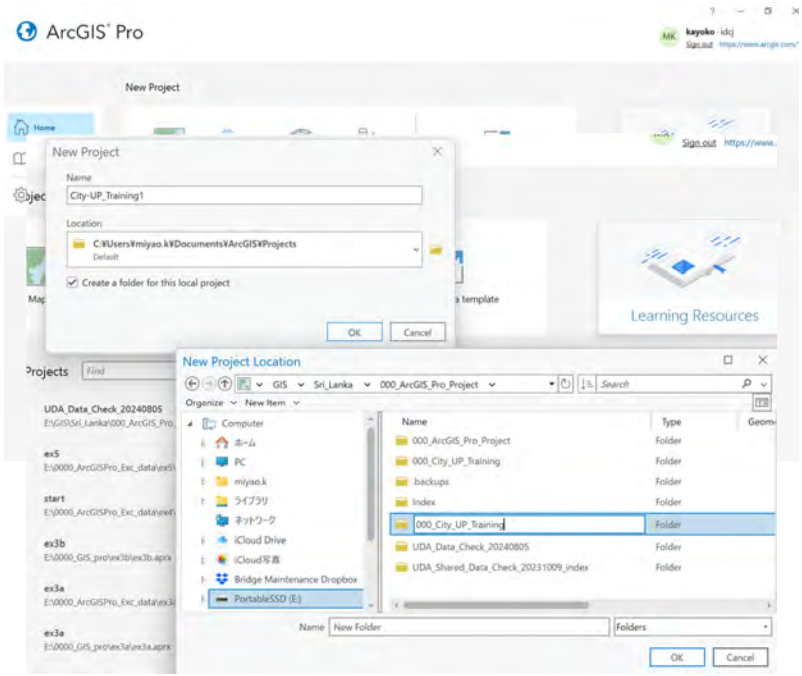
Source: https://pro.arcgis.com/en/pro-app/latest/get-started/create-a-project.htm

Project on Capacity Development for Urban Planning

Migrating ArcMap to ArcGIS Pro: Create Project

Create a Project from default template (2)

When you start ArcGIS Pro, the start page appears. The start page has options to open a recent project or to create a project from a template. Templates define the starting state of the project. For example, the Map template creates a project that opens with a map view.



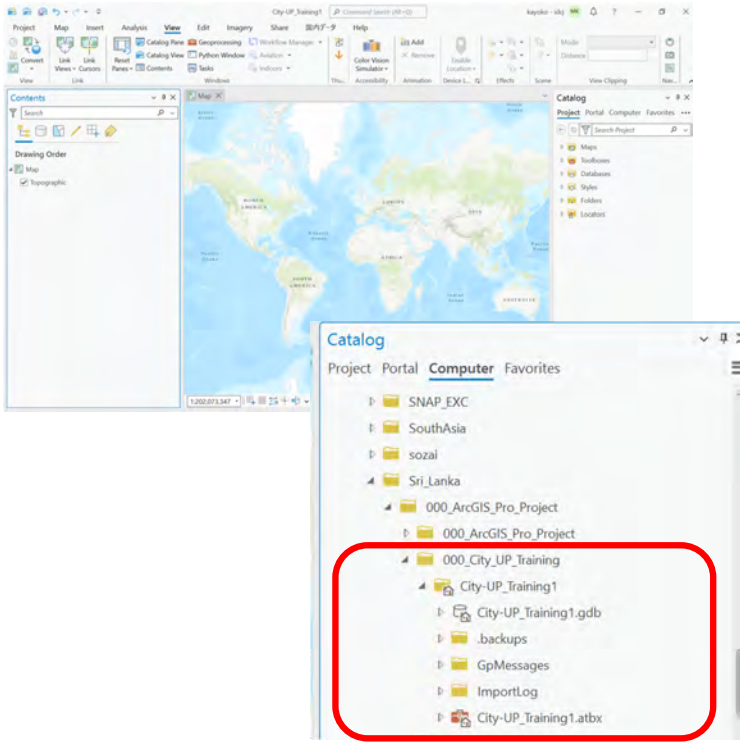
3. On the **New Project** dialog box, in the **Name** box, replace the default project name as you like. By default, projects are created in your ¥Users¥<username>¥Documents¥ArcGIS ¥Projects folder. To save a project to a different location, click Browse and browse to the folder you want.
4. The Create a folder for this project check box is checked by default. It is usually convenient to keep project files organized in a folder.

Source: https://pro.arcgis.com/en/pro-app/latest/get-started/create-a-project.htm

Migrating ArcMap to ArcGIS Pro: Create Project

Create a Project from default template (3)

The new project opens with a map view showing a topographic basemap.



5. The **Contents** and **Catalog** panes are open in most projects. Depending on your work in previous ArcGIS Pro sessions, other panes may be open as well. You'll set the pane state to the default for mapping.
6. On the ribbon, click the View tab. In the Windows group, click Reset Panes Reset Panes and click Reset Panes for Mapping (Default).
7. If you explore the folder you create, you can see geodatabase that automatically created by ArcGIS Pro with other default folders

Source: https://pro.arcgis.com/en/pro-app/latest/get-started/create-a-project.htm

Migrating ArcMap to ArcGIS Pro: Interface

Interface

In ArcGIS Pro, use ribbon tabs and panes, which dynamically update based on your context, to access functionality.



Component	Description	How this compares to ArcMap
Project tab 1	Provides access to application settings and other configurable properties.	This is comparable to the settings on the Customize menu: ArcMap Options, ArcCatalog Options, ArcGlobe Options, and ArcScene Options, respectively.
The ribbon 2	Organizes commands on a series of tabs.	These tabs are more context sensitive than the toolbars in ArcMap, and may change based on the state of the application.
The Command Search box 3	The Command Search box helps you find and open geoprocessing tools and run user interface commands. You can also access help topics related to your search terms.	This is comparable to the Search window in ArcMap in that you can find and open geoprocessing tools.
Contents pane 4	Displays items related to the active view, which may be a map, a scene, a layout, or a view of the catalog.	This is similar to the way ArcMap displays the contents of a document in the table of contents.
Table view 5	Views—such as the map, scene, and table views in this example—are the primary work areas in ArcGIS Pro.	Views are comparable to the data and layout views in ArcMap and the 3D view in ArcGlobe and ArcScene.
Catalog pane 6	The items in a project can be managed in the Catalog pane.	This is similar to the Catalog window in ArcMap.

Source: https://pro.arcgis.com/en/pro-app/latest/get-started/user-interface.html

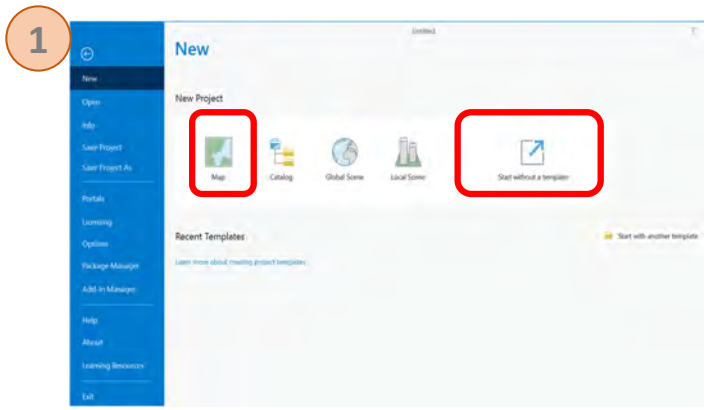
Migrating ArcMap to ArcGIS Pro: Import .MPK/.MXD

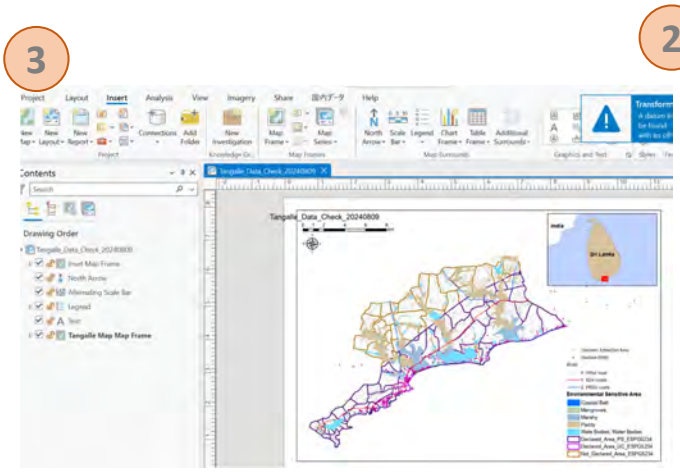
Import ArcMap document

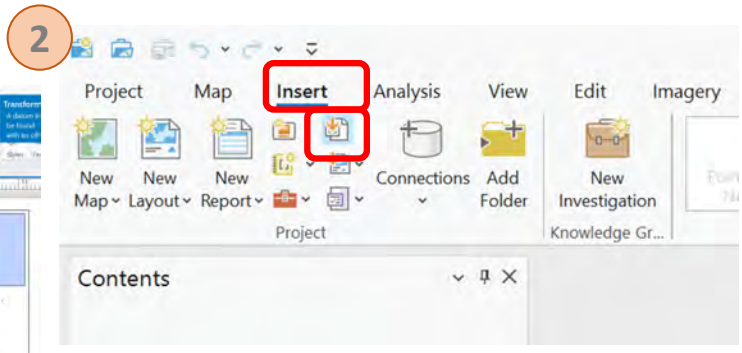
1. Select “Start without a template”or map to create the new project to import Arcmap document (.mxd/ .mpk)

2. Click “Import” tab – “import map” and navigate to the .MPK

3. You can open .MPK in ArcGIS Pro







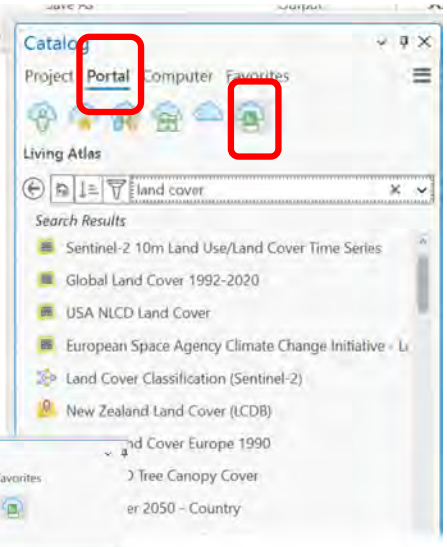
Migrating ArcMap to ArcGIS Pro: Utilize Online Resources

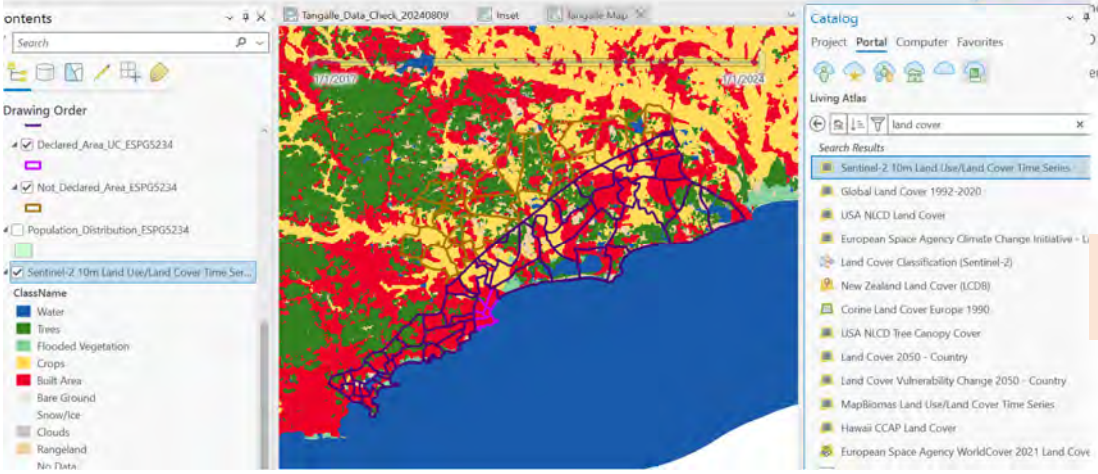
Living Atlas

The ArcGIS Living Atlas is a carefully selected, highly reliable collection of geographic information. This collection has been gathered from all over the world and continues to grow. This collection contains maps, apps, and data layers that can be used, adapted, and analyzed for your project.

But this is careful to use data in the living atlas, many of them are view only. If you want to sue for analysis/ export, need to check metadata/ properties of the data.

In addition to default basemap in ArcGIS Pro, this Living Atlas will be a one of alternatives of background image.



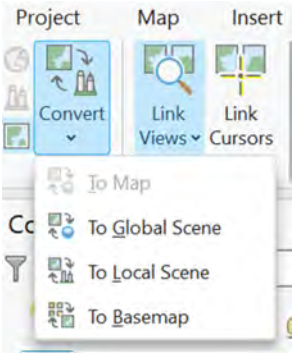


ArcGIS Living Atlas of the World

Migrating ArcMap to ArcGIS Pro: 3D Visualization

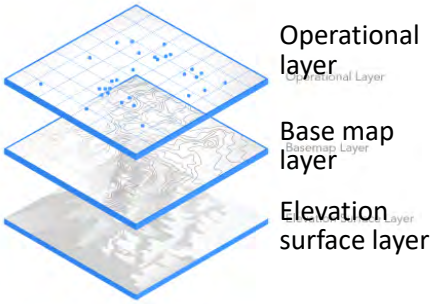
Convert 2D to 3D: Map to Scene

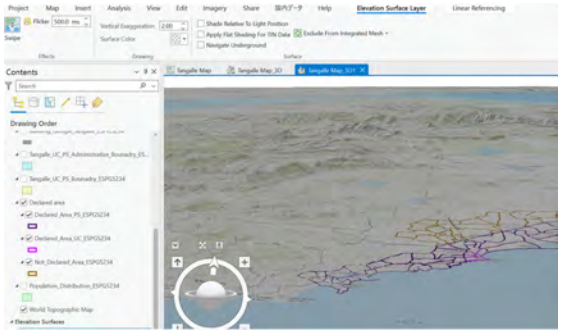
A scene allows you to visualize your data and analyze geographic information in an intuitive and interactive 3D environment. You can choose between a global or local scene to best display your data, such as airline flight patterns, campus facilities, or underground utilities.
In case of urban planning, basically use only “Local scene”.



Elevation Surface Layer

Once you create the scene, ArcGIS Pro automatically insert “Elevation Surface”. An elevation surface layer is a composite layer representing the ground surface or a custom surface. Elevation surface layers define the height values across the extent of a map or scene. Elevation surface layers contain one or more elevation source layers that contribute height values to the surface.





https://pro.arcgis.com/en/pro-app/latest/help/mapping/layer-properties/elevation-surface-layers.htm

Project on Capacity Development for Urban Planning

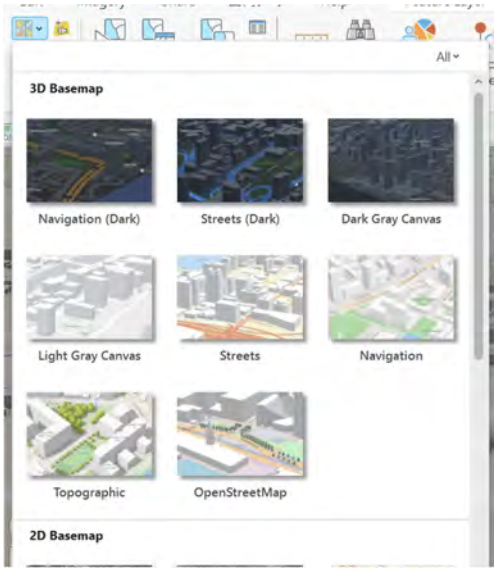
Migrating ArcMap to ArcGIS Pro: 3D Visualization

3D Base Map

3D Basemaps includes the following information products:

Item	Description	Minimum user type
3D Basemaps	An ArcGIS Pro project used by GIS analysts and mapping technicians to create and maintain a 3D basemap for their organization	GIS Professional, Advanced

https://doc.arcgis.com/en/arcgis-solutions/11.1/reference/introduction-to-3d-basemaps.htm

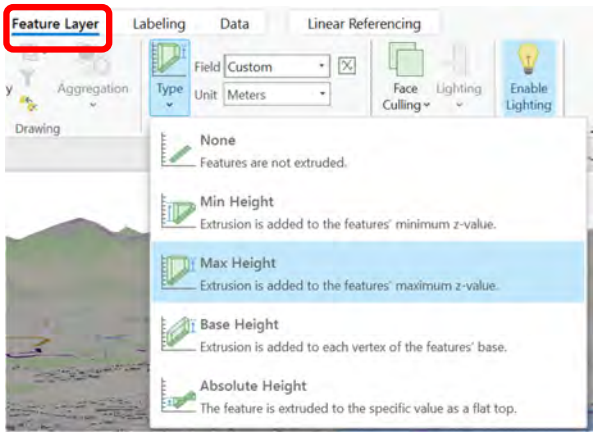




Migrating ArcMap to ArcGIS Pro: 3D Visualization

3D Extrusion

When you extrude a layer in the **2D Layers** category in the **Contents** pane, it is moved to the **3D Layers** category. You can only extrude a single layer at a time. If more than one layer is selected in the **Contents** pane, extrusion choices are unavailable. Extrusion is only available in scenes.



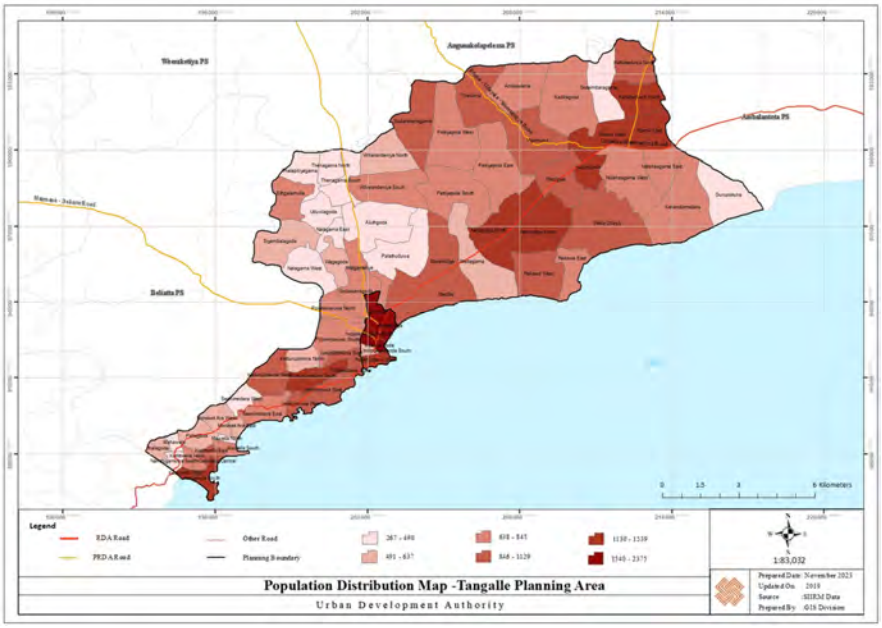


Project on Capacity Development for Urban Planning

Migrating ArcMap to ArcGIS Pro: 3D Visualization

3D Extrusion of Statistical data: Population

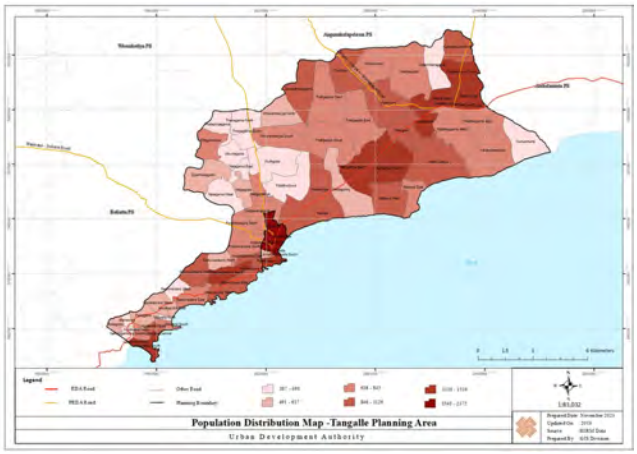
Before go to 3D visualization of population data, here is a question. This map has issue. What is the issue?

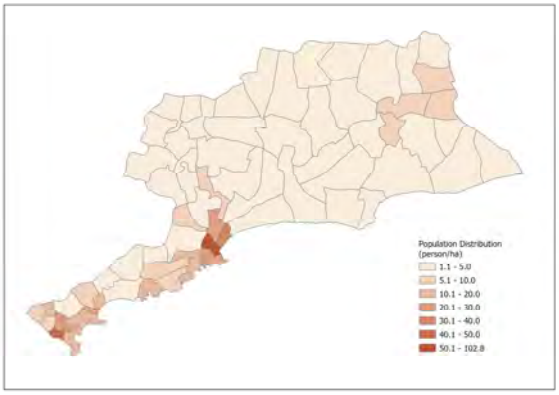


Migrating ArcMap to ArcGIS Pro: 3D Visualization

Population Density Map

Before go to 3D visualization of population data, here is a question. This map has issue. What is the issue?





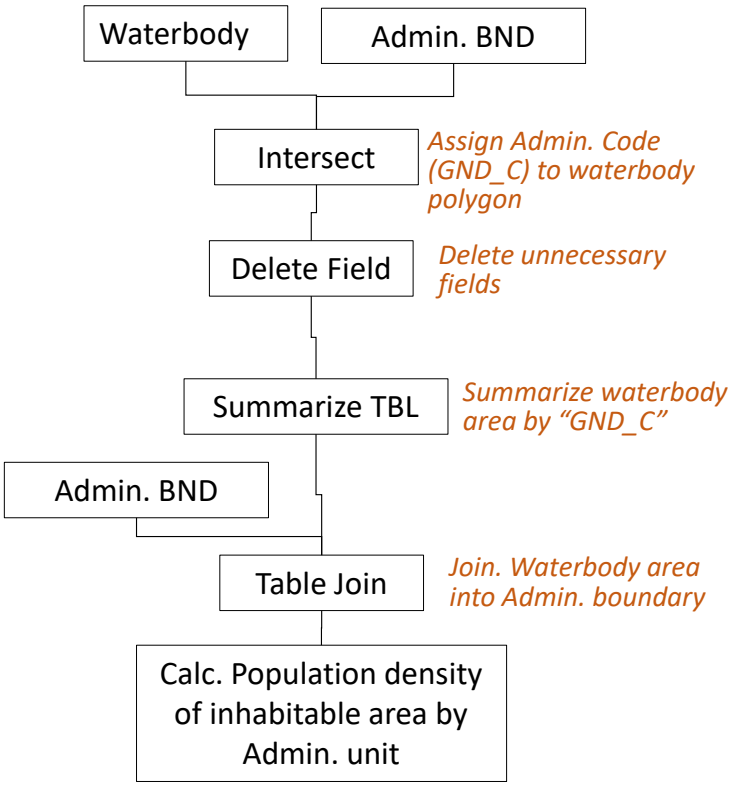
Presenting population values as they are often misleads map readers when compared to population density maps.
In addition, in urban planning or transportation planning, land area that cannot be inhabited, such as waterbody and military land, is often excluded from the area when calculating population density.

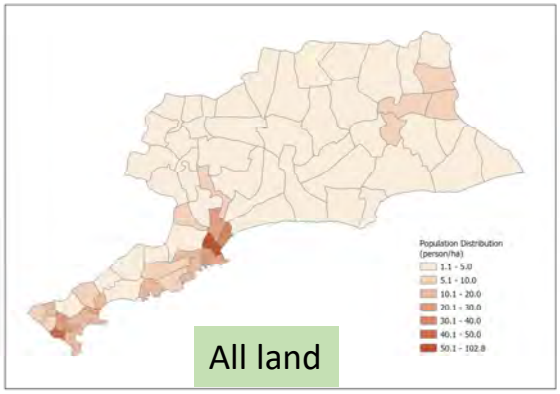
Project on Capacity Development for Urban Planning

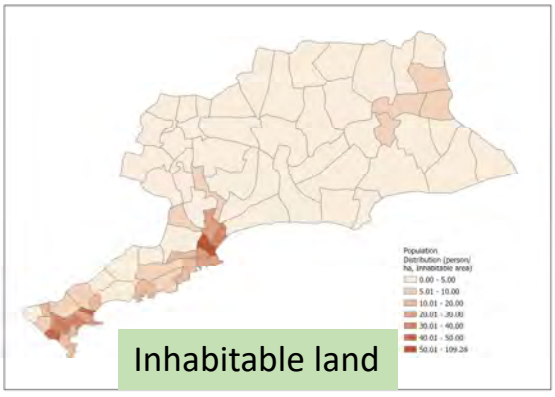
Migrating ArcMap to ArcGIS Pro: 3D Visualization

Population Density Map: Inhabitable land

How to calculate population density of inhabitable land?





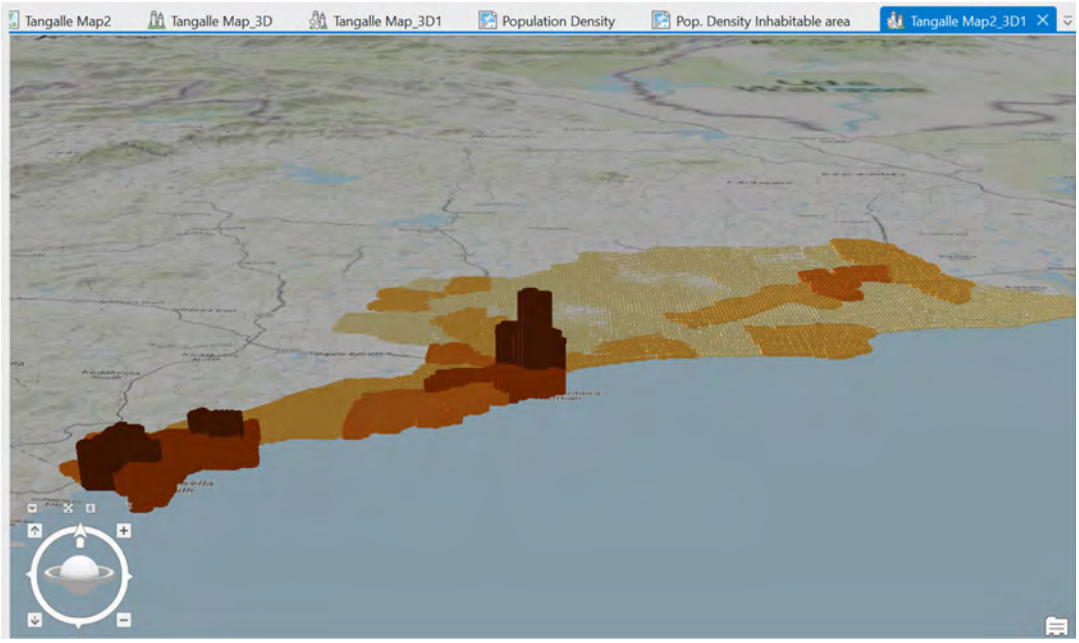


Migrating ArcMap to ArcGIS Pro: 3D Visualization

3D Population Distribution Map:

Not only surface, you can do 3D visualization of statistical data, such as population.

In the case of polygons, 3D extrusion may not be possible if the number of polygons is too large. In such cases, it is necessary to convert polygons to points and display them in 3D scene.

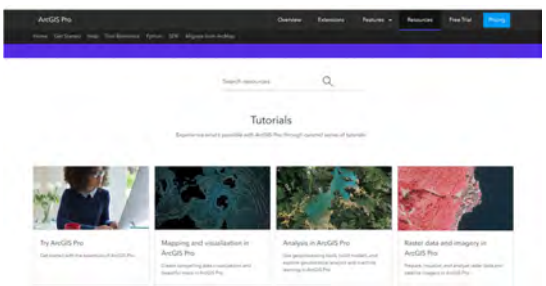


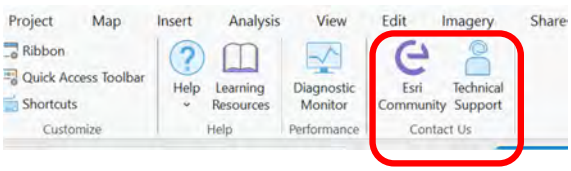
Migrating ArcMap to ArcGIS Pro: Self-Learning Materials

There are various self learning materials available on YouTube, ESRI website and on internet.

Popular self-learning materials are listed below.

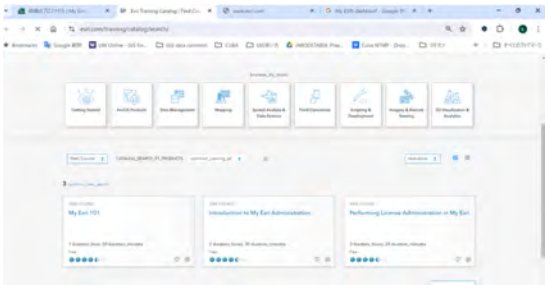
1. ESRI special site for ArcMap users to migrating ArcGIS Pro
https://www.esri.com/en-us/arcgis/products/arcgis-pro/resources/migrate
https://esrisingapore.com.sg/map-to-pro/introduction-to-arcgis-pro
2. ESRI resource site
https://www.esri.com/en-us/arcgis/products/arcgis-pro/resources
3. ESRI Community site
https://community.esri.com/t5/arcgis-pro/ct-p/arcgis-pro
4. ArcGIS Pro tutorial by Colby College
https://sites.google.com/colby.edu/mgimond-arcgis-pro/home





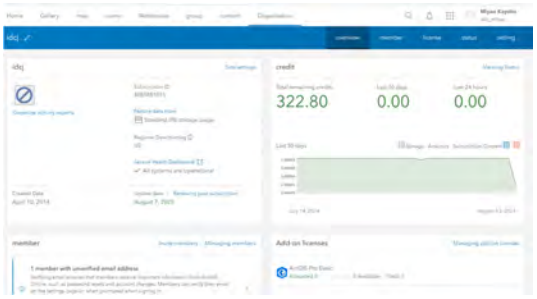
Migrating ArcMap to ArcGIS Pro: Self-Learning Materials

- Licensed user can ask question directory to ESRI through My ESRI.
- You can learn by yourself ESRI Training Website (Some of them are free of charge, but mostly maintenance subscription required)
- ESRI has YouTube Channel and various tutorial & Lectures videos are available
- Administrator of the Organization (UDA) should manage credit/ user/ license through My ESRI









Project on Capacity Development for Urban Planning

Thank you very mush

ありがとうございます

PPT. No.8

Module LU3-2: Spatial Data Analysis by GIS

ArcGIS Pro Spatial Analyst Extension

Project on Capacity Development for Urban Planning

Project on Capacity Development for Urban Planning in Sri Lanka

Spatial Analyst: Apply for Urban Planning Activities

14 Aug. 2024

Spatial Analyst Basic: Objectives

Ultimate Goal:

- Utilize spatial analysis knowledge of ArcGIS Pro with extensions for urban planning activities by URC/ UDA

To achieve the Ultimate Goal:

We will learn followings;

1. Understand Spatial Analyst in General (What you can do with Spatial Analyst)
2. Understand Interpolation & Surface Analysis
3. Understand conversion method from Vector to Raster
4. Understand Reclassification & Raster Overlay
5. Understand Sentinel -2 data collection and pre-process for Raster analysis
6. Understand Image Analysis

In this session, 2 case studies are included;
Case Study 1: Analyze Unsuitable Areas for Development
Case Study 2: Collect Sentinel-2 data and calculate NDVI with ArcGIS Pro

Spatial Analyst Basic: What Can You Do?

ArcGIS Spatial Analyst provides a broad range of powerful spatial modeling and analysis features. You can create, query, map, and analyze cell-based raster data; perform integrated raster/vector analysis; derive new information from existing data; query information across multiple data layers; and fully integrate cell-based raster data with traditional vector data sources.

ArcGIS Spatial Analyst provides a broad range of powerful spatial modeling and analysis features. You can create, query, map, and analyze cell-based raster data; perform integrated raster/vector analysis; derive new information from existing data; query information across multiple data layers; and fully integrate cell-based raster data with traditional vector data sources.

Examples of major usages:

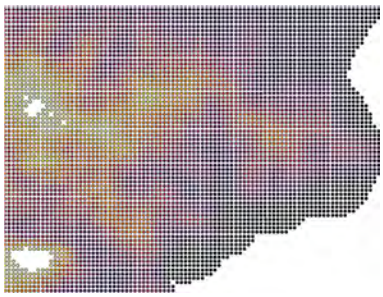
1. Derive new info. From existing data
2. Interpolate data
3. Find Suitable/ Unsuitable Location
4. Calculate various indicators (NDVI, NDWI, etc.)

Spatial Analyst Basic: What Can You Do?

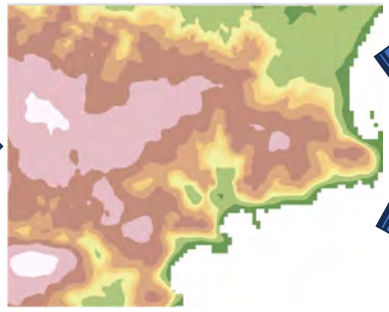
Examples of usage:

1. Derive new info. From existing data
2. Interpolate data

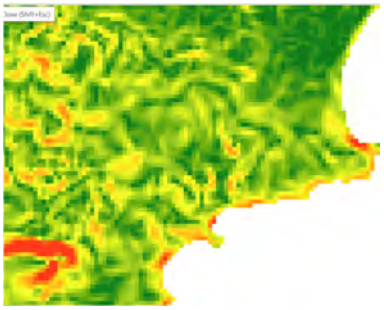
Elevation (Point)

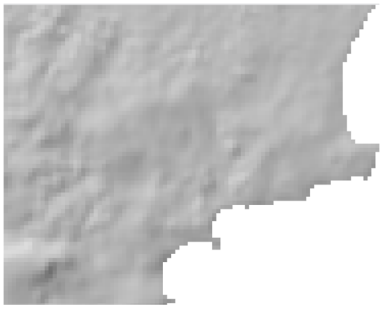


Interpolation (IDW)



Slope (%)





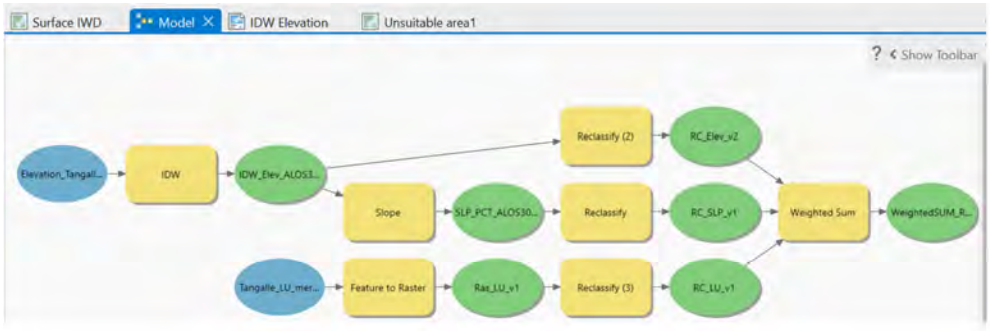
Hillshade

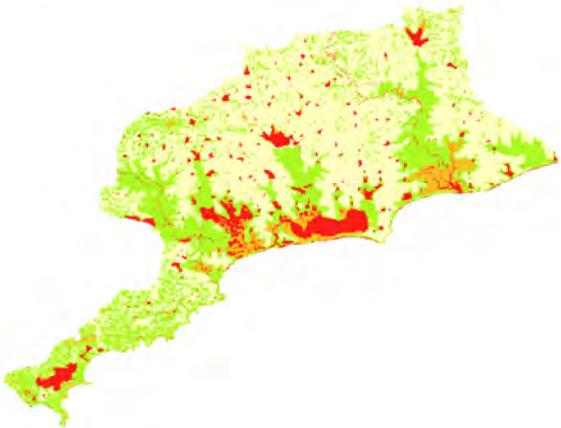
Project on Capacity Development for Urban Planning

Spatial Analyst Basic: What Can You Do?

Examples of usage:

3. Find Suitable/ Unsuitable Location





Spatial Analyst Basic: What Can You Do?

Examples of usage:

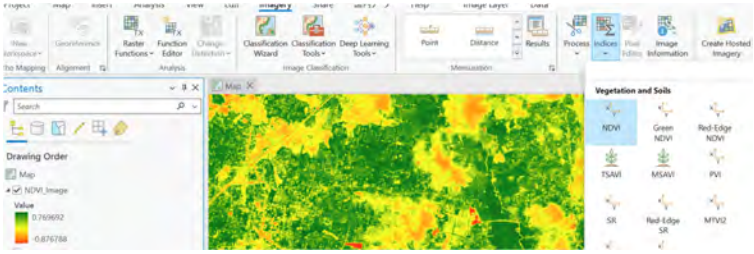
4. Calculate various indicators (remote sensing techniques)

(1) NDVI: Normalized Difference Vegetation Index

The well known and widely used NDVI is a simple, but effective index for quantifying green vegetation. It normalizes green leaf scattering in **Near Infra-red** wavelengths with chlorophyll absorption in **Red** wavelengths.

The value range of the NDVI **is -1 to 1**. Negative values of NDVI (values approaching -1) correspond to water. Values close to zero (-0.1 to 0.1) generally correspond to barren areas of rock, sand, or snow. Low, positive values represent shrub and grassland (approximately 0.2 to 0.4), while high values indicate temperate and tropical rainforests (values approaching 1). It is a good proxy for live green vegetation; see for details.

Basic Formula "NDVI"	(NIR-RED) / (NIR+RED)
Sentinel 2	(B8-B4) / (B8+B4)
Landsat 8	(B5-B4) / (B5+B4)



https://custom-scripts.sentinel-hub.com/custom-scripts/sentinel-2/ndvi/

Project on Capacity Development for Urban Planning

Spatial Analyst Basic: What Can You Do?

Examples of usage:

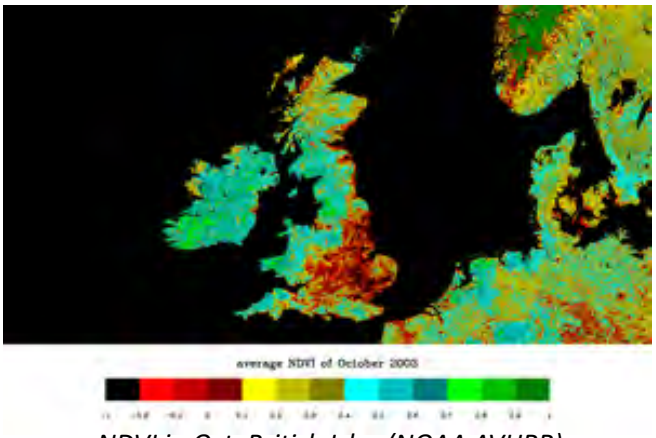
4. Calculate various indicators (remote sensing techniques)

(1) NDVI: Normalized Difference Vegetation Index

The well known and widely used NDVI is a simple, but effective index for quantifying green vegetation. It normalizes green leaf scattering in **Near Infra-red** wavelengths with chlorophyll absorption in **Red** wavelengths.

Interpretation of the value

The value range of the NDVI **is -1 to 1**. **Negative values of NDVI (values approaching -1) correspond to water**. Values close to zero (-0.1 to 0.1) generally correspond to barren areas of rock, sand, or snow. Low, positive values represent shrub and grassland (approximately 0.2 to 0.4), while high values indicate temperate and tropical rainforests (values approaching 1). It is a good proxy for live green vegetation



NDVI in Oct. British Isles (NOAA AVHRR)

Basic Formula "NDVI"	(NIR-RED) / (NIR+RED)
Sentinel 2	(B8-B4) / (B8+B4)
Landsat 8	(B5-B4) / (B5+B4)

https://custom-scripts.sentinel-hub.com/custom-scripts/sentinel-2/ndvi/

Spatial Analyst Basic: What Can You Do?

Examples of usage:

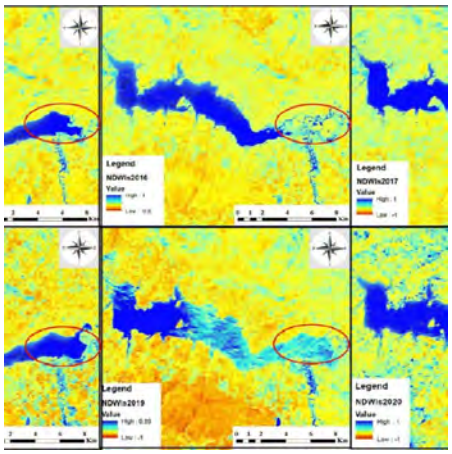
4. Calculate various indicators

(2) NDWI: Normalized Difference Water Index

The NDWI is used to monitor changes related to water content in water bodies. As water bodies strongly absorb light in visible to infrared electromagnetic spectrum, NDWI uses **green** and **near infrared** bands to **highlight water bodies**. It **is sensitive to built-up land and can result in over-estimation of water bodies**. The index was proposed by McFeeters, 1996.

Basic Formula "NDWI"	(Green-NIR) / (Green+NIR)
Sentinel 2	(B3-B8) / (B3+B8)
Landsat 8	(B3-B5) / (B3+B5)

https://custom-scripts.sentinel-hub.com/custom-scripts/sentinel-2/ndwi/



Interpretation of the value

Visual or digital interpretation of the output image/raster:
-1 to 0: Bright surface with no vegetation or water content
More than 1: represent water content
For the second variant of the NDWI, another threshold can also be found in that avoids creating false alarms in urban areas:
< 0.3: Non-water
>= 0.3: Water

**** It is important to evaluate the results with actual condition!***

Spatial Analyst Basic:

Case Study 1: Analyze Unsuitable Areas for Development

Analyze unsuitable areas utilize various Spatial Analyst geoprocessing tools

Spatial Analyst Basic: Case Study 1 - Analyze Unsuitable area

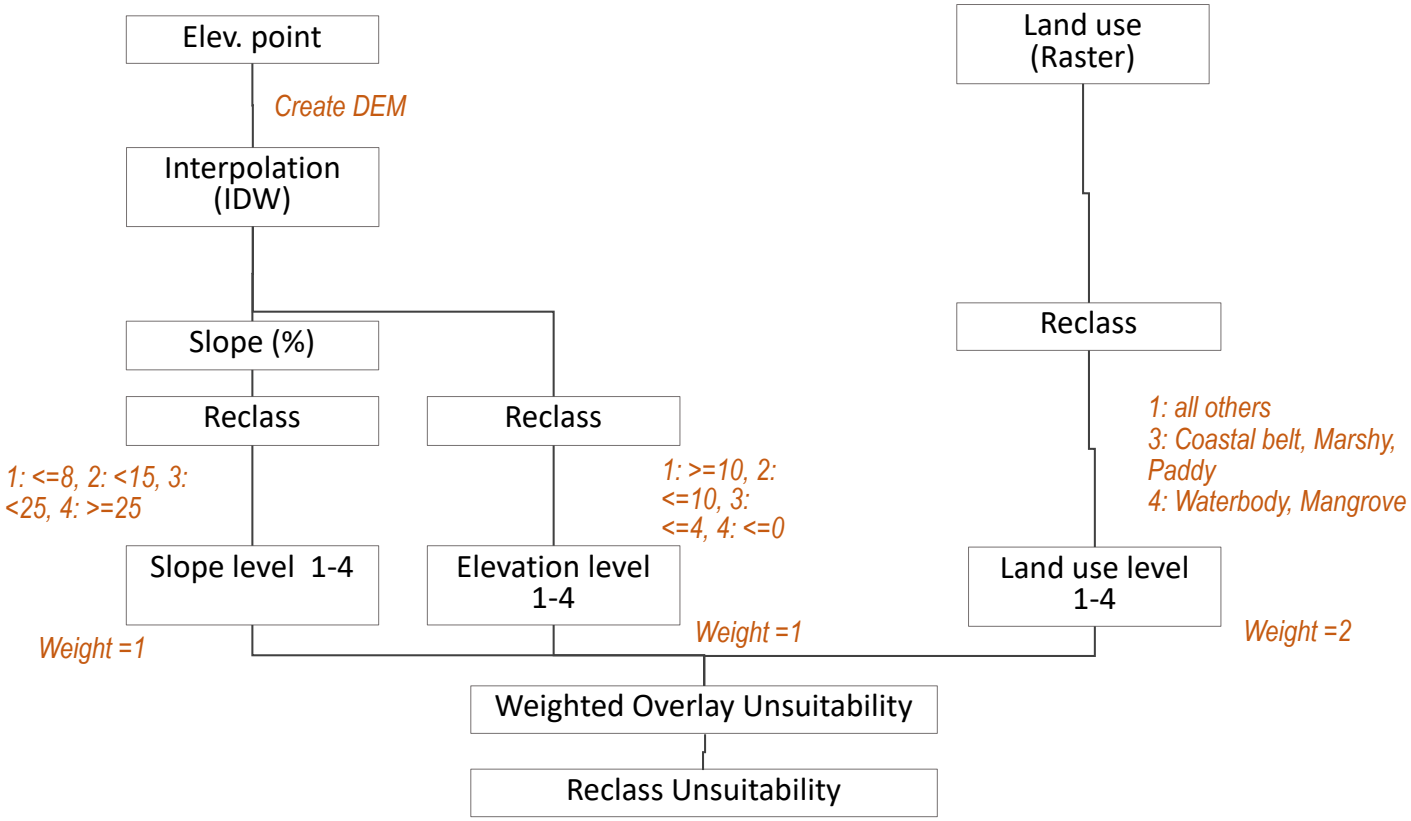
Analyze Unsuitable Area for Urban Development

In this case study, we will classify the land in the Tangalle area into four levels of development unsuitability.

	Very Unsuitable	Unsuitable	Not unsuitable	Suitable for development
	4	3	2	1
Elevation	Less than 0	0 – 4m	4-10m	More than 10m
Slope condition	More than 25%	Less than 25%	Less than 15%	Less than 8%
Land use	Water body, mangrove	Coastal belt, Marshy, Paddy	NIL	All other land use categories

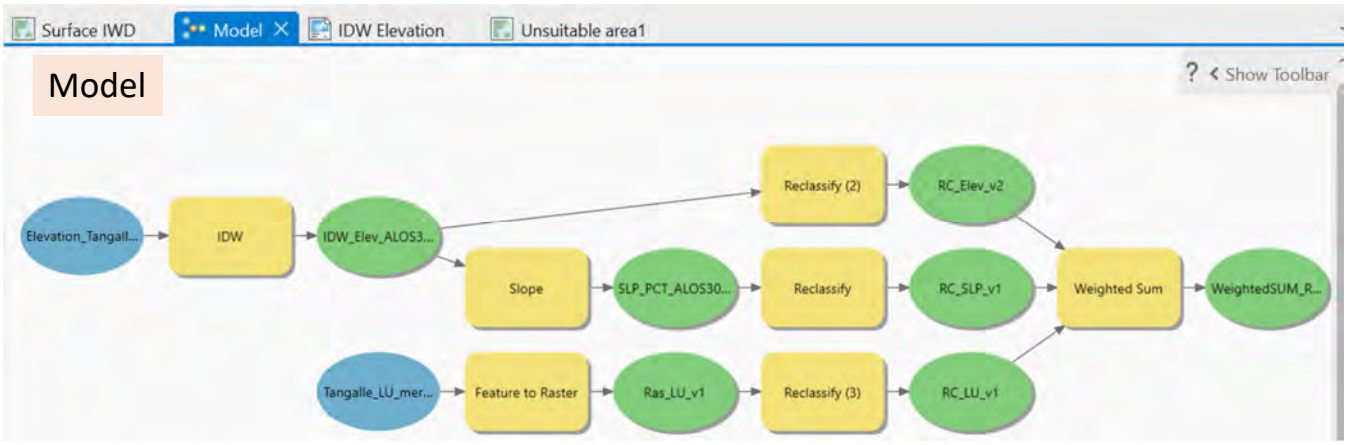
※ *In actual urban planning work, it is important to know which data to analyze and at what threshold to evaluate the data. Finalizing the analysis is done through repeated trial and error, in consultation with experts in each sector.*

Spatial Analyst Basic: Case Study 1 - Analyze unsuitable areas

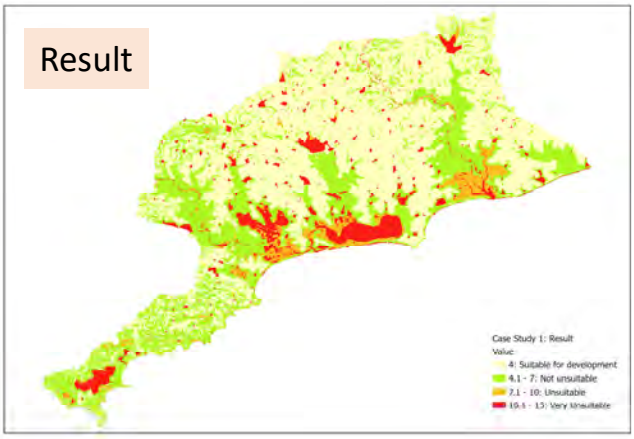


4	3	2	1
Very Unsuitable	Unsuitable	Not Suitable	Suitable for Development

Spatial Analyst Basic: Case Study 1 - Analyze unsuitable areas



Model



Result

Spatial Analyst Basic:

Case Study 2: Collect Open data & Calculate NDVI

Collect Sentinel-2 data and calculate NDVI with ArcGIS Pro

Spatial Analyst Basic: Case Study 2

Tips: Info. About "Sentinel 2"

Sentinel Mission

Sentinel data is satellite data acquired by ESA. There are number of missions that are encompassed within Sentinel data. To date the most common are Sentinel 1 ,2 and 3.

Sentinel 1	Synthetic Aperture Radar (SAR), penetrates clouds & can be used at night
Sentinel 2	**Passive Multispectral (high resolution, 10-60m, 13 bands)**
Sentinel 3	Global scale focus on land water & atmosphere

There are 3 levels of Sentinel products "Level1b", "Level1C" & "Level2A". In this session, we will use most popular level "**Level2A**".

Level1B	top of atmosphere radiances in sensor geometry
Level1C	top of atmosphere reflectance in cartographic geometry
Level2A	**Atmospherically corrected surface reflectance in cartographic geometry (most processed level)**

Source:sentinel-2_user_handbook (esa.int)

Project on Capacity Development for Urban Planning

Spatial Analyst Basic: Case Study 2

Tips: Info. About "Sentinel 2"

Sentinel 2: NDVI	**(B8-B4) / (B8+B4)**

Sentinel 2: 13 bands

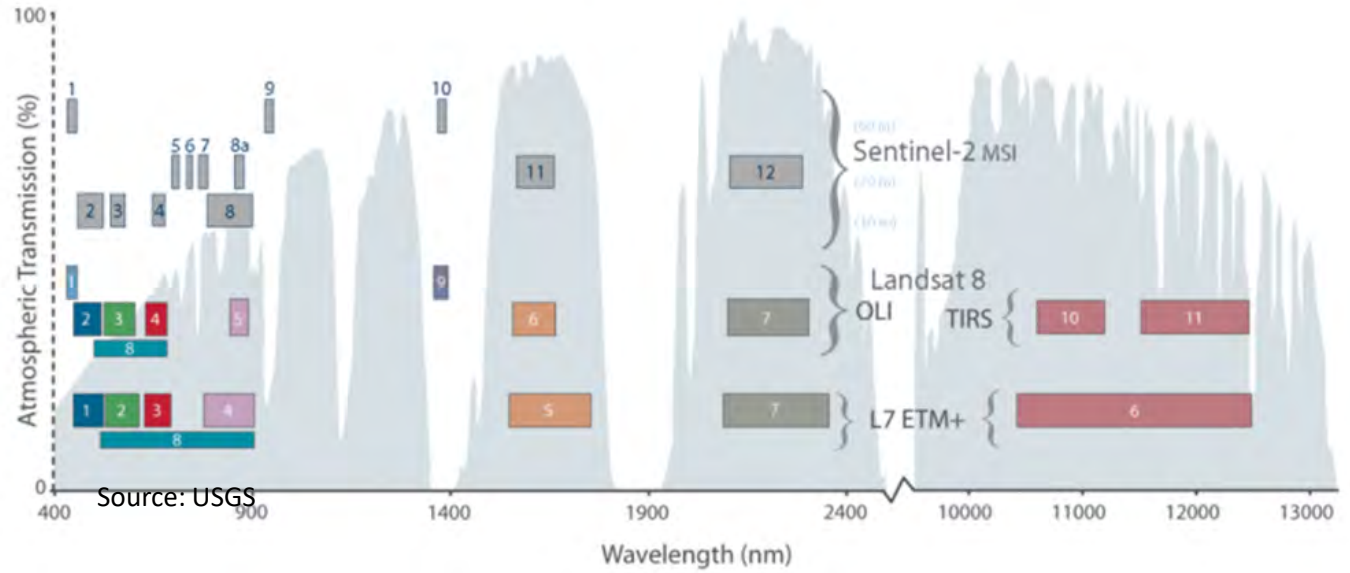
Band	Resolution	Central Wavelength	Description	Usage
B1	60 m	443 nm	Ultra Blue (Coastal and Aerosol)	Atmospheric correction, can panetrate into water and is sensitive to clouds, smoke and haze
B2	10 m	490 nm	Blue	Sensitive to vegetation aerosol scattering
B3	10 m	560 nm	Green	Sensitive to chlorophyll in vegetation
B4	**10 m**	**665 nm**	**Red**	**Built environment, Geologic feature**
B5	20 m	705 nm	Visible and Near Infrared (VNIR)	vegetation red edge, plant health, crop monitoring
B6	20 m	740 nm	Visible and Near Infrared (VNIR)	vegetation red edge, plant health, crop monitoring
B7	20 m	783 nm	Visible and Near Infrared (VNIR)	vegetation red edge, determine water and vegetation
B8	**10 m**	**842 nm**	**Visible and Near Infrared (VNIR)**	**NIR, determine water and vegetation**
B8a	20 m	865 nm	Visible and Near Infrared (VNIR)	vegetation red edge, determine water and vegetation
B9	60 m	940 nm	Short Wave Infrared (SWIR)	water vapor, land/ water boundary
B10	60 m	1375 nm	Short Wave Infrared (SWIR)	coastal aerosol band- cirrus clouds
B11	20 m	1610 nm	Short Wave Infrared (SWIR)	vegetation health and water content
B12	20 m	2190 nm	Short Wave Infrared (SWIR)	water content, mineral composition in rocks and soil, burn scars

Spatial Analyst Basic: Case Study 2

Tips: Info. About "Sentinel 2"

Sentinel 2 & Landsat spectral bands

Basic Formula "NDVI"	(NIR-RED) / (NIR+RED)
Sentinel 2	(B8-B4) / (B8+B4)
Landsat 8	(B5-B4) / (B5+B4)



Source: USGS

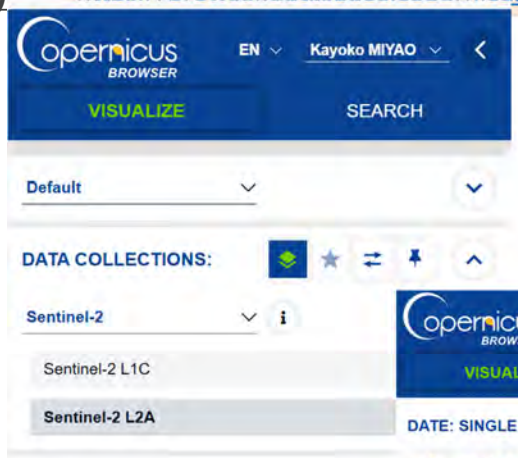
Project on Capacity Development for Urban Planning

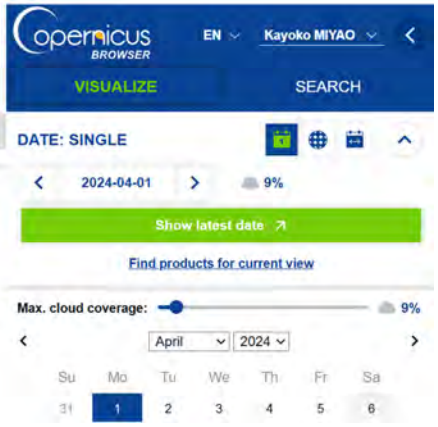
Spatial Analyst Basic: Case Study 2

How to Access Sentinel Data? (1)

https://browser.dataspace.copernicus.eu/

- Access to Copernicus browser (need to register & Login)
- Go to AOI (Area of Interest)
- On "Visualize" tab
  - ✓ Under "Data Collections" section: Select "Sentinel-2", "Sentinel-2 L2A"
  - ✓ Expand "Date": select date and customize the cloud cover ratio
  - ✓ "Find products for current view"





- "Download product": You will get ".zip"

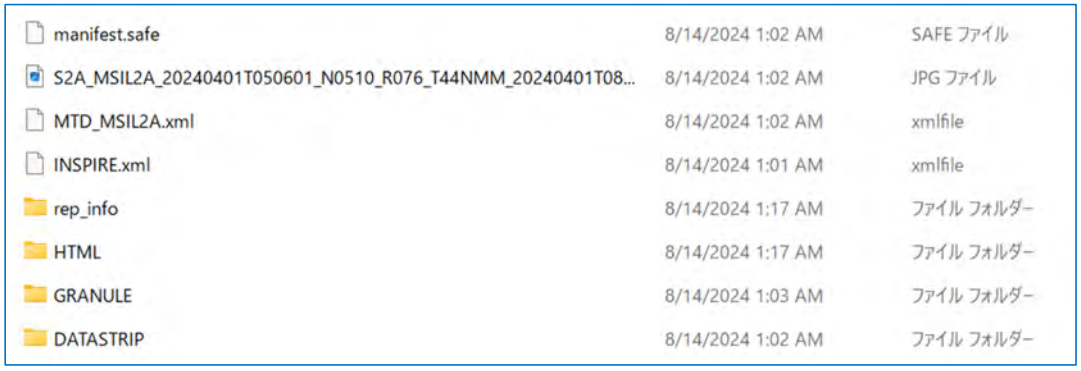


For detail process to download data you can refer here (YouTube)
https://www.youtube.com/watch?v=qUwZVPLjoAY

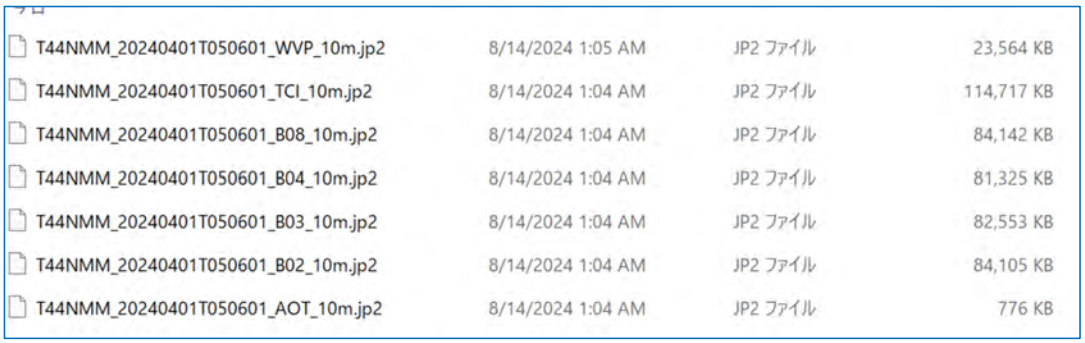
Spatial Analyst Basic: Case Study 2

How to Access Sentinel Data? (2): Download data





- *Image data is in "Granule"*
- *Image format is "jpeg2000"*
- *"MTS_MSIL2A.xml" includes the data about bands*

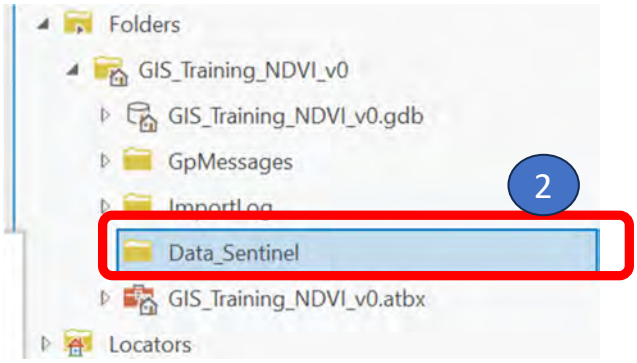


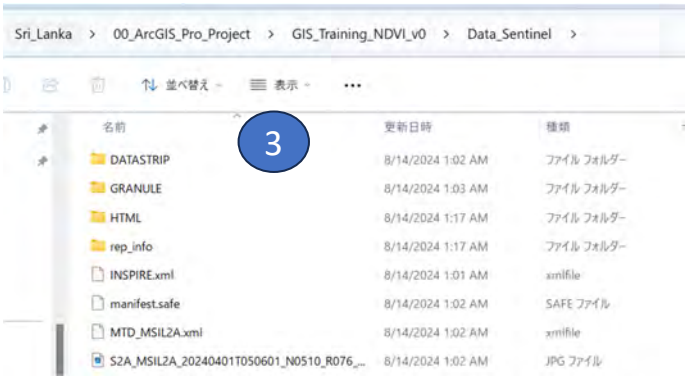
Project on Capacity Development for Urban Planning

Spatial Analyst Basic: Case Study 2

Load Data into ArcGIS Pro

1. Open New Project with ArcGIS Pro
2. Create New folder "Data_Sentinel" under the Project folder
3. Use File explore copy all downloaded data into "Data Sentinel"

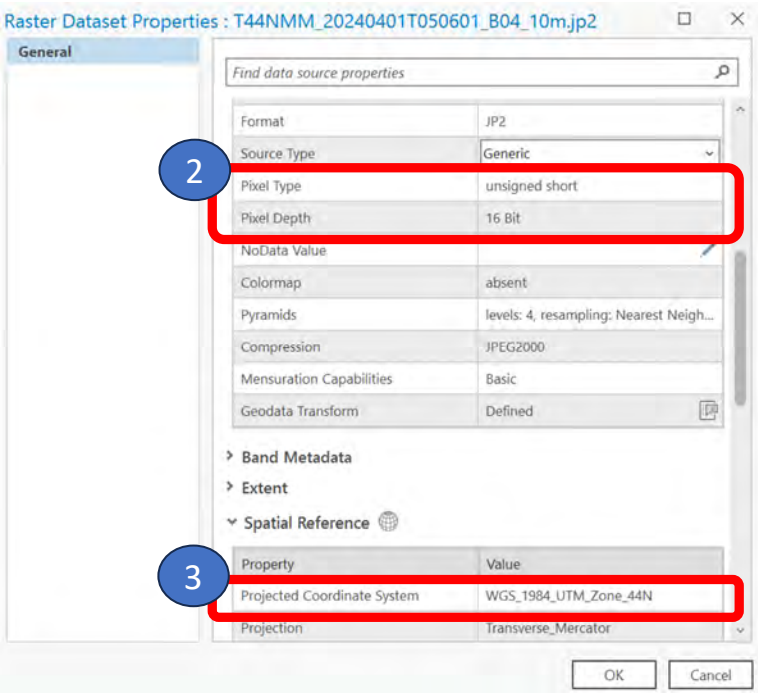




Spatial Analyst Basic: Case Study 2

Explore data information

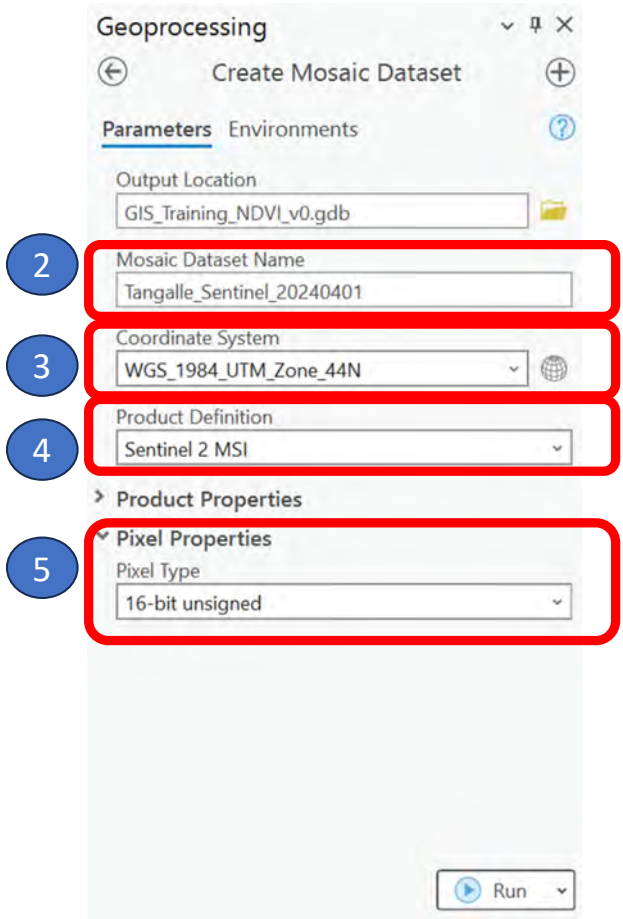
1. Select B4 or B8 and open Properties
2. Check “Pixel Type” & “Pixel Depth”
3. Check “Spatial Reference” & “Coordinate system”



Spatial Analyst Basic: Case Study 2

Create Mosaic Dataset

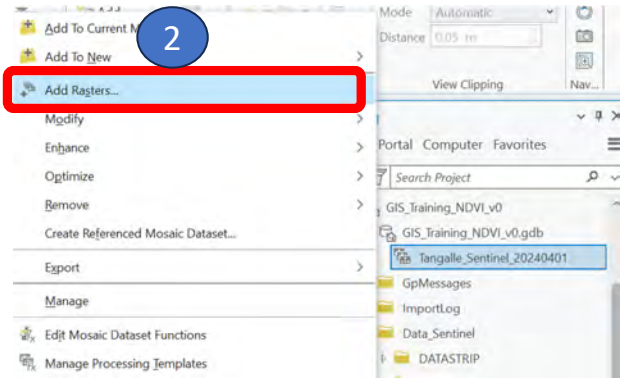
1. Right-Click home Geodatabase – “New” – “Mosaic dataset”
2. Input mosaic dataset name
3. Select Coordinate system
4. Set Product definition
5. Set Pixel type

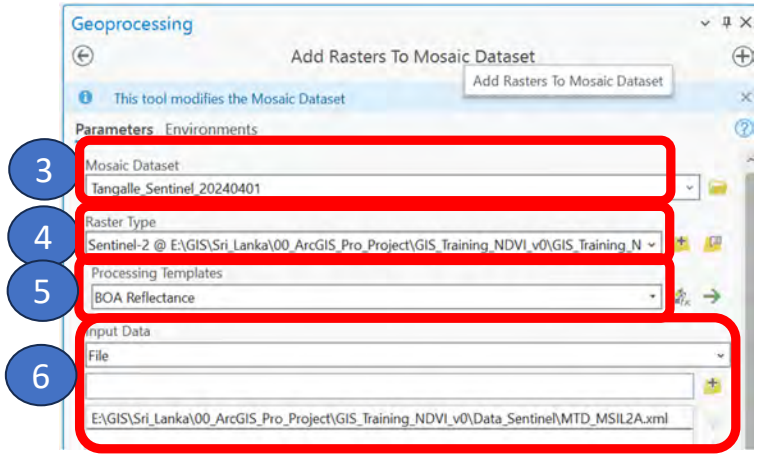


Spatial Analyst Basic: Case Study 2

Sentinel 2 data into ArcGIS Pro

1. Right-Click the created mosaic dataset in home .GDB
2. Click “Add Rasters”
3. Make sure “Mosaic dataset” set as the created data folder that stored downloaded Sentinel data
4. “Raster type” default (Sentinel-2)
5. “Processing Template “BOA Reflectance” to bring in all bands
6. Input Data “MTD_MSIL2A.xml” (include the data about bonds)
7. Check “Calculate Statistics” & “Build Raster Pyramids”





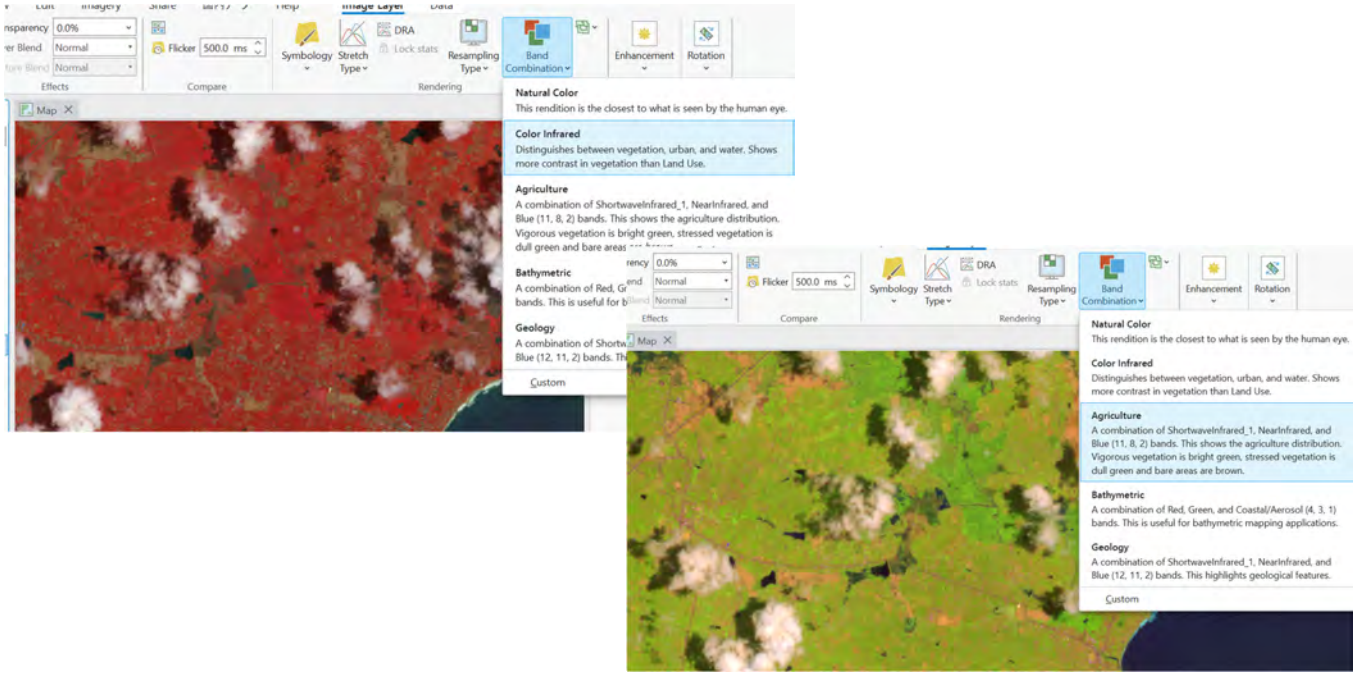


Project on Capacity Development for Urban Planning

Spatial Analyst Basic: Case Study 2

Calculate NDVI and more (1)

1. “Zoom to Layer” to focus AOI and you can see processed true color imagery
2. Select “Image” in Contents pane –Band Combination, you can change band combination (Color infrared: all vegetation show in bright red

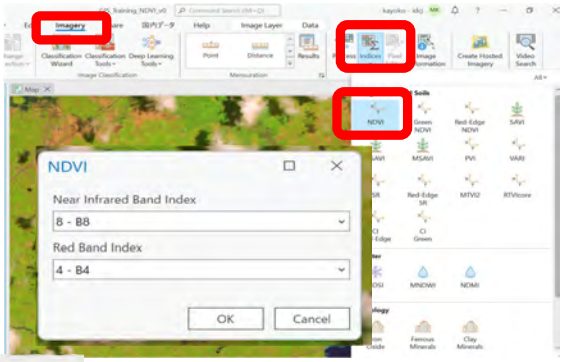


Spatial Analyst Basic: Case Study 2

Calculate NDVI and more (2)

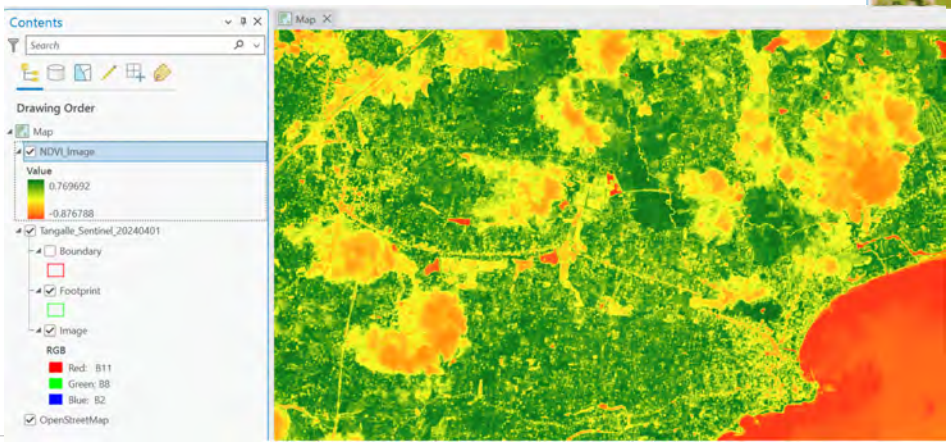
Basic Formula "NDVI"	**(NIR-RED) / (NIR+RED)**
Sentinel 2	**(B8-B4) / (B8+B4)**

1. "Imagery" –"Indices" – "NDVI"
2. Set band combination "NIR" as B8, "Red" as B4



Interpretation of NDVI value

The value range of the NDVI ***is -1 to 1. Negative values of NDVI (values approaching -1) correspond to water****. Values close to zero (-0.1 to 0.1) generally correspond to barren areas of rock, sand, or snow. Low, positive values represent shrub and grassland (approximately 0.2 to 0.4), while high values indicate temperate and tropical rainforests (values approaching 1). It is a good proxy for live green vegetation*



Project on Capacity Development for Urban Planning

Thank you very mush

ありがとうございます

PPT. No.9

Module LU3-2: Spatial Data Analysis by GIS

ArcGIS Pro Network Analyst Extension

Project on Capacity Development for Urban Planning

Project on Capacity Development for Urban Planning in Sri Lanka

Network Analyst: Network Analysis Basic/ Utilize Service Area Analysis

20 Aug. 2024

Network Analyst Basic: Objectives

Ultimate Goal:

- Utilize spatial analysis knowledge of ArcGIS Pro with extensions for urban planning activities by URC/ UDA

To achieve the Ultimate Goal:

We will learn followings;

1. Understand Network Analyst in General
   - Understand Network Analysis in General
   - Understand Network Analyst Toolbox
2. Understand Typical Usage of Network Analyst in Urban Planning: Example of Service Area Analysis (Case Study)
3. Building Network DS

In this session, a case studies is included;
Case Study: Calculate population within 15, 30, 45, 60 minutes drivetime from Tangalle central areas

Network Analyst Basic:

1. Understand Network Analyst in General

Network Analyst Basic: What Can You Do by License Level?

You can perform some tasks that are related to the ArcGIS Network Analyst extension without the extension license; however, to have access to all of its functionality, the license must be enabled for the extension.

With Network Analyst	**Standard**	**Can use all analysis tools** **Can edit/ build network dataset**
	Basic	Can use all analysis tools Can't update (modify) network dataset
Without Network Analyst	Any License level	View properties of network datasets. View network dataset layers, including any associated traffic feeds. View network analysis layers. Change properties of network analysis layers.

Source: Licensing and the ArcGIS Network Analyst extension—ArcGIS Pro | Documentation

Why did CITY-UP procure ArcGIS Network Analyst extension at the Standard license rather than the Basic license ?

URC/UDA is the entity in charge of urban planning, and therefore needs to analyze not only the current condition, but also its own network that reflects the future road plan. To build your own Network Dataset for use in Network Analyst, you will need a Standard license. Standard license is required to build your own Network Dataset for use with Network Analyst.

Network Analyst Basic: Types of Network Data for Network Analyst

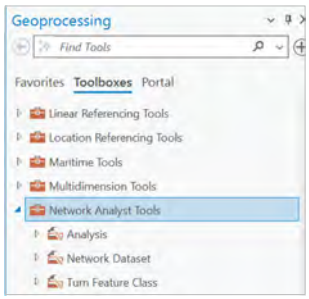
Road Network Data	Description	Extension	Credit Consumption
ArcGIS Online (https://www.arcgis.com)	Road network data provided by ArcGIS Online. It contains information on roads in most parts of the world, but please note that the accuracy may vary from country to country or region to region. The data can be used in an environment with an Internet connection. You can analyze with only existing road network.	Not Necessary	YES
Own Network Dataset	The road network data used in network analysis is created in the form of "network datasets". If you have the Network Analyst extension, you can create your own network datasets in ArcMap/ ArcGIS Pro You can include your future road plans	Network Analyst	NO

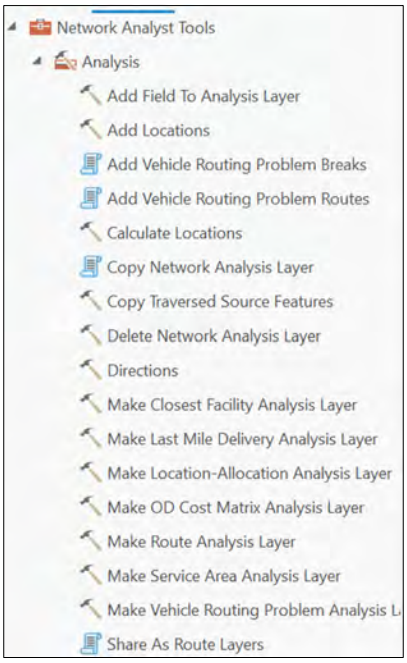
Network Analyst Basic: Network Analyst Toolbox

There are 2-way to access network analyst tools:

1: From Geoprocessing window

2: From “Analysis” Tab – “Workflow” – “Network analysis”





Toolsets	Description
Analysis	The Analysis toolset contains tools used to perform analysis when using the ArcGIS Network Analyst extension. The toolset contains a variety of tools, including tools to create a network analysis layer and set its analysis properties for each solver provided with Network Analyst, tools to add network analysis objects to one or more network analysis classes, a tool to solve an analysis, and a tool to generate driving directions.
Network Dataset	The Network Dataset toolset contains tools used to perform network dataset maintenance tasks such as building and dissolving network datasets.
Turn Feature Class	The Turn Feature Class toolset contains tools used to build and edit turn data. The tools in the toolset allow you to create new turn feature classes, convert existing ArcView GIS or ArcInfo Workstation turn tables to turn feature classes, and maintain the integrity of existing turn features based on their geometry or an alternate ID field in cases when the reference source features are updated.

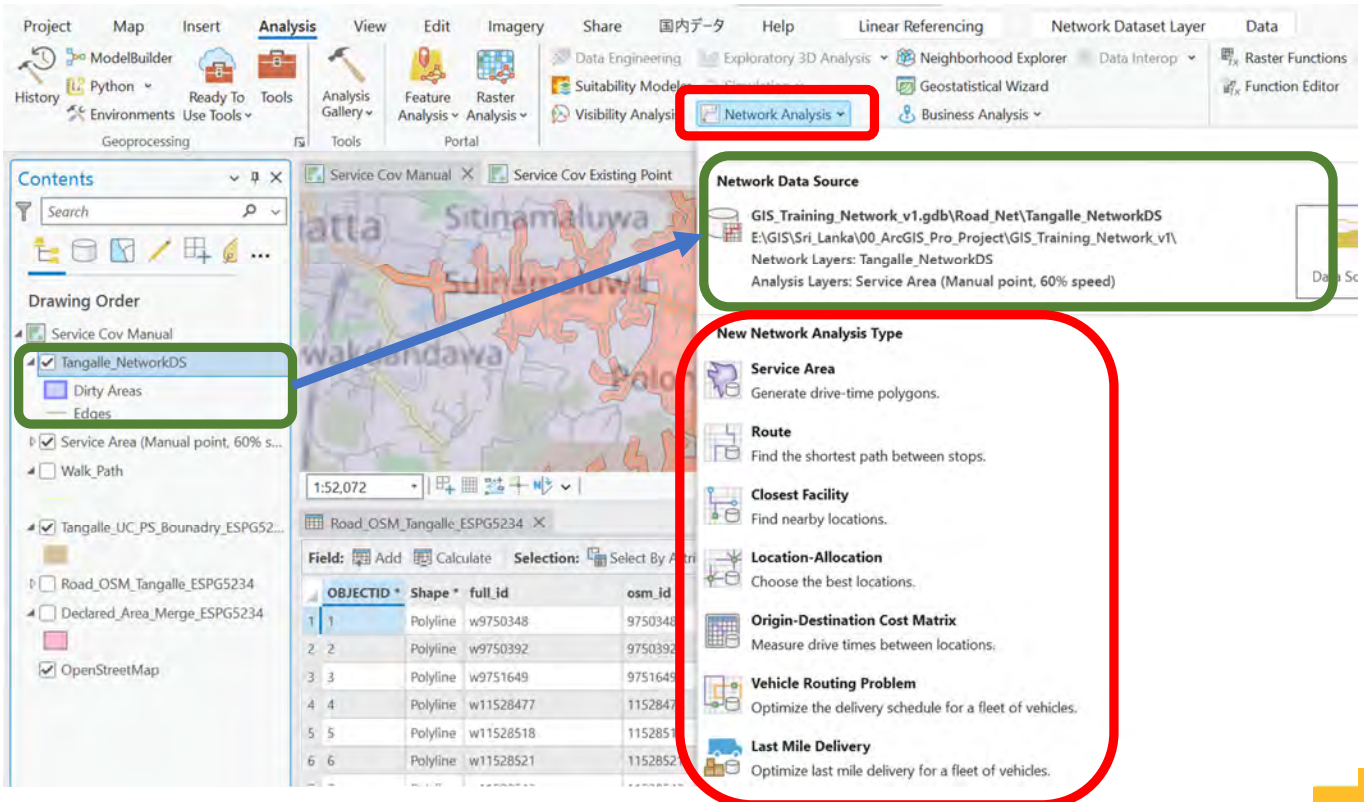
Project on Capacity Development for Urban Planning

Network Analyst Basic: Network Analyst Toolbox

There are 2-way to access network analyst tools:

1: From Geoprocessing window

2: From “Analysis” Tab – “Workflow” – “Network analysis”

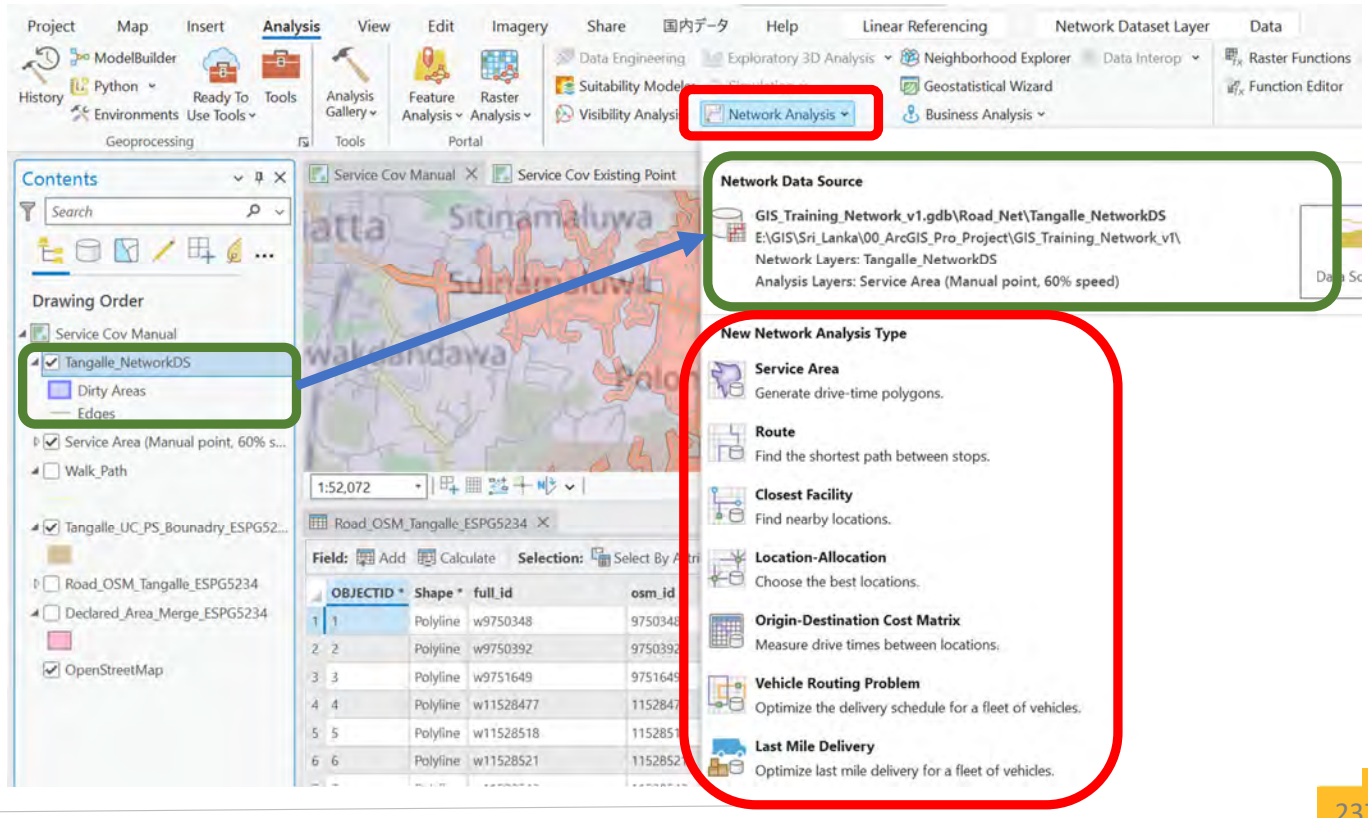


Network Analyst Basic: Network Analyst Toolbox

There are 2-way to access network analyst tools:

1: From Geoprocessing window

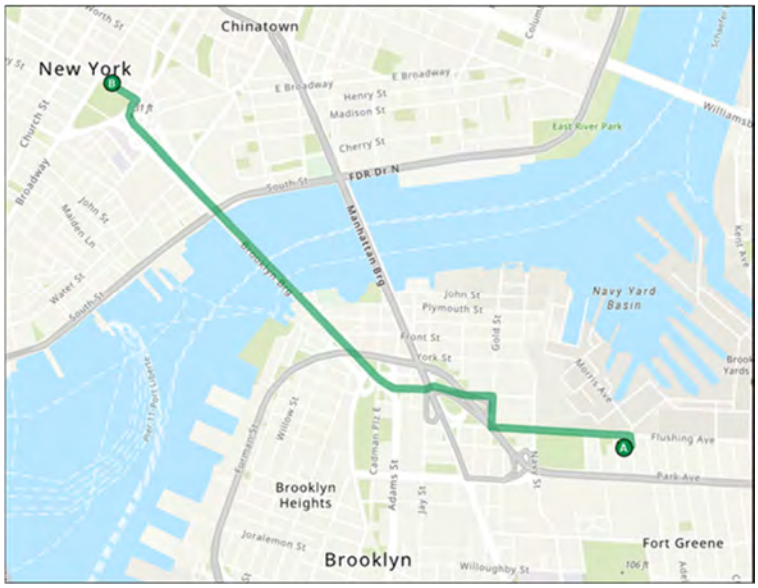
2: From "Analysis" Tab – "Workflow" – "Network analysis"



Project on Capacity Development for Urban Planning

Network Analyst Basic: Network Analyst Toolbox

Sample of Network Analysis: Shortest Path



What is the quickest way to get from point A to point B?

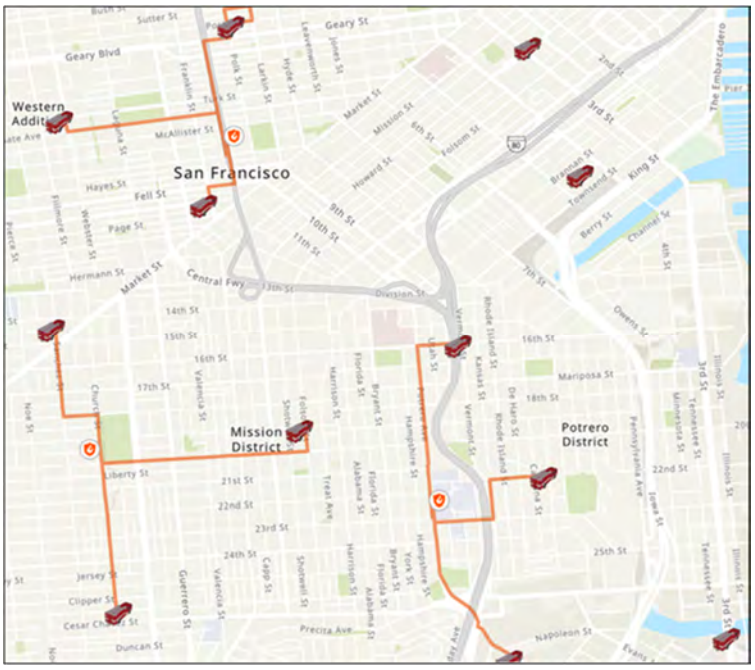
Or

What route is the minimum length of travel ?

Source: What is the ArcGIS Network Analyst extension?—ArcGIS Pro | Documentation

Network Analyst Basic: Network Analyst Toolbox

Sample of Network Analysis: Closest Facilities



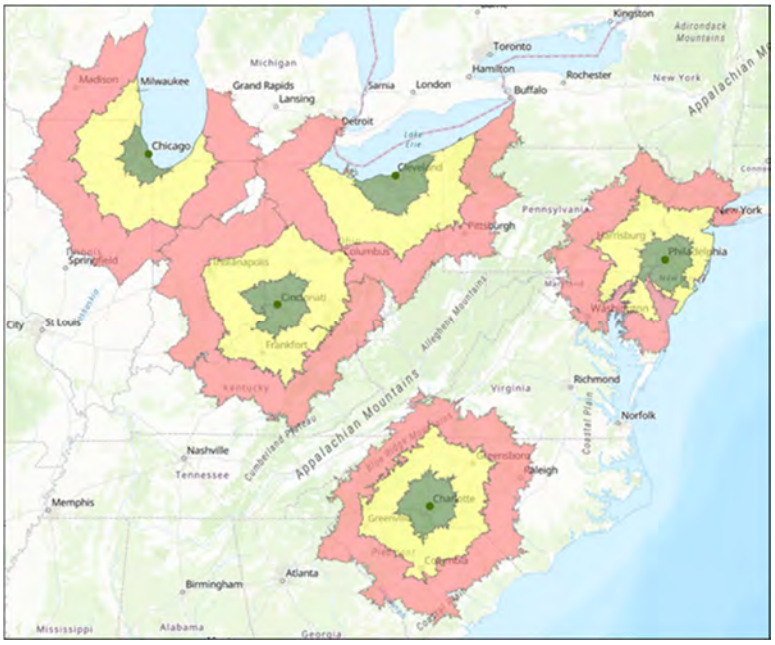
Find one or more facilities closest to an incident based on travel time, distance, or other cost and outputs the best route, chosen facility, and driving directions between the incident and the facility.

Source: What is the ArcGIS Network Analyst extension?—ArcGIS Pro | Documentation

Project on Capacity Development for Urban Planning

Network Analyst Basic: Network Analyst Toolbox

Sample of Network Analysis: Service Area



This Service area analysis is very popular for urban planning. WE can evaluate future plans using this analysis.

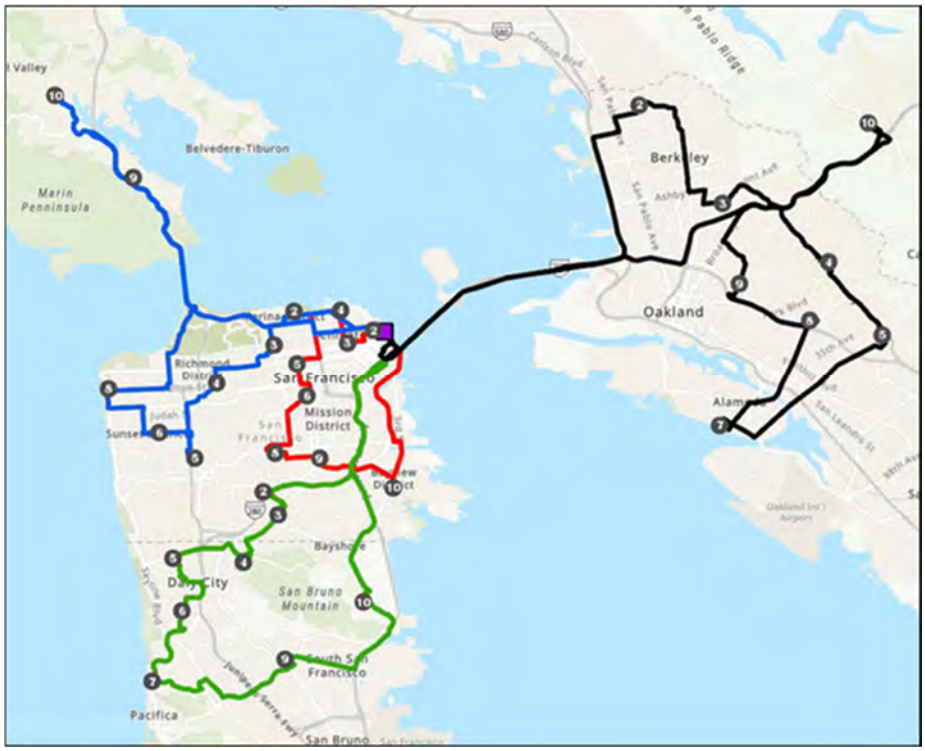
What market areas does the business cover?

The green points represent warehouses in various cities, and the polygons represent their market areas, which are divided into three rings. The surrounding green polygons can be reached by trucks within one hour; yellow, within two hours; and red, within three hours.

Source: What is the ArcGIS Network Analyst extension?—ArcGIS Pro | Documentation

Network Analyst Basic: Network Analyst Toolbox

Sample of Network Analysis: Vehicle Routing Problem



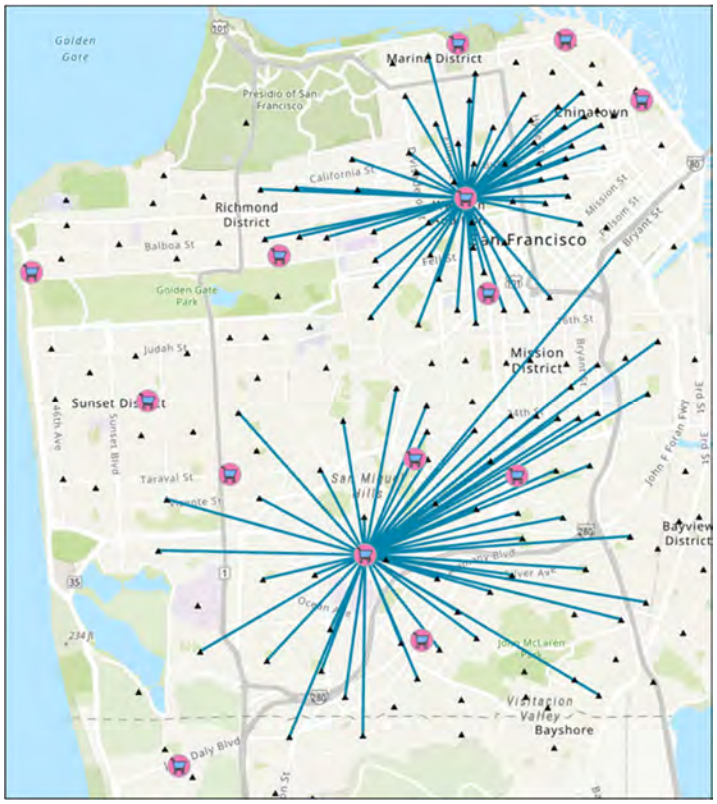
- How can we route our fleet of delivery vehicles to minimize overall transportation costs and improve customer service?
- Food delivery trucks at a distribution center are assigned grocery stores and directions to the stores that minimize transportation costs. Vehicle capacities, lunch breaks, and maximum travel time constraints are included in the analysis.

Source: What is the ArcGIS Network Analyst extension?—ArcGIS Pro | Documentation

Project on Capacity Development for Urban Planning

Network Analyst Basic: Network Analyst Toolbox

Sample of Network Analysis: Location-Alocation

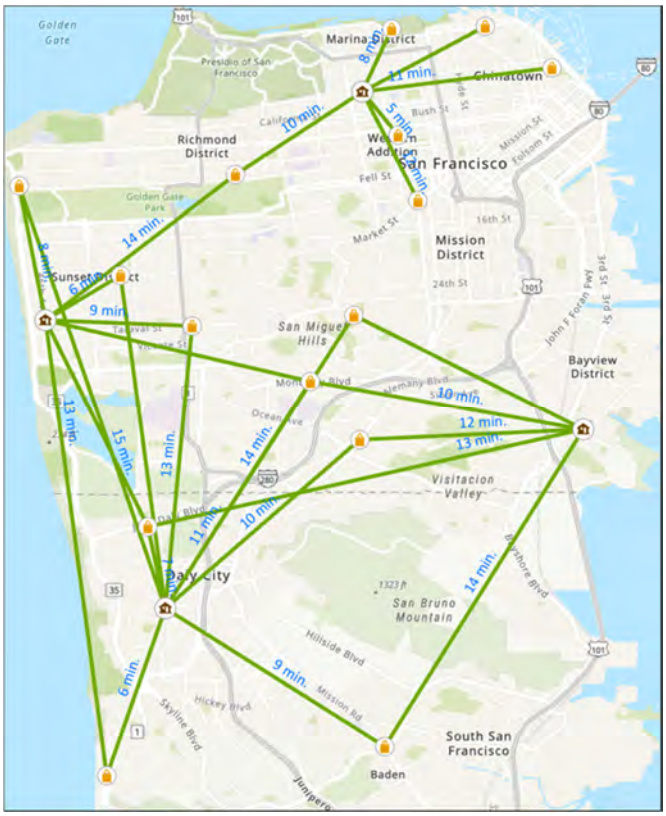


- Where should we open a new branch of our business to maximize market share?
- Location-allocation can be used to find the best locations from a set of input locations. In the above example, the tool evaluated the locations that meet the business needs for the establishment of new stores and identified the locations that capture the most demand from the overall market area.

Source: What is the ArcGIS Network Analyst extension?—ArcGIS Pro | Documentation

Network Analyst Basic: Network Analyst Toolbox

Sample of Network Analysis: OD cost matrix



Source: What is the ArcGIS Network Analyst extension?—ArcGIS Pro | Documentation

- The origin-destination cost matrix analysis calculates the least-cost network paths from origins to destinations. It outputs line features that link origins to destinations. Each line feature stores the total network cost of the trip as an attribute value. Analysts often take the attribute table and use it as input for linear programming applications.

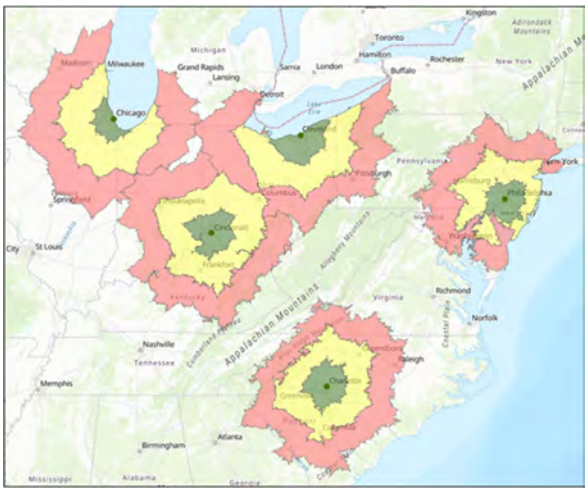
Network Analyst Basic:

2. Understand Typical Usage of Network Analyst in Urban Planning: Example of Service Area Analysis (Case Study)

Network Analyst Basic: Perform Network Analysis

Service Area Analysis: Outline of Service Area Analysis

- Make a service area network analysis layer and sets its analysis properties.
- A service area analysis layer is useful in determining the area of accessibility within a given cutoff cost from a facility location.
- The layer can be created using a local network dataset or a routing service hosted online or in a portal.
- After creating the analysis layer, you can add network analysis objects to it using the Add Locations tool, solve the analysis using the Solve (or RUN) tool.

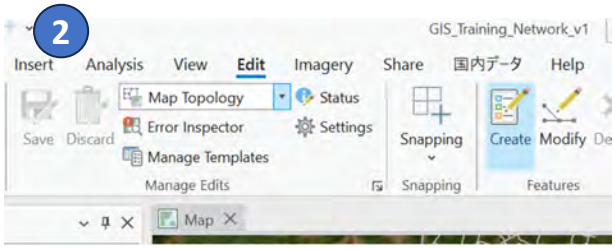


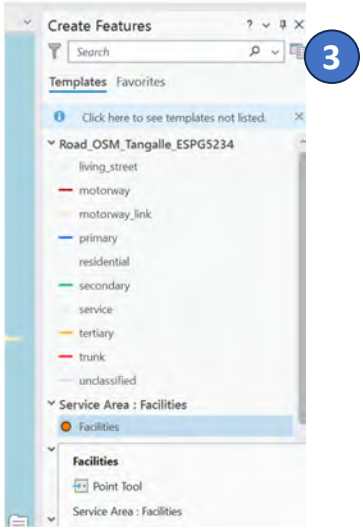
Network Analyst Basic: Perform Network Analysis

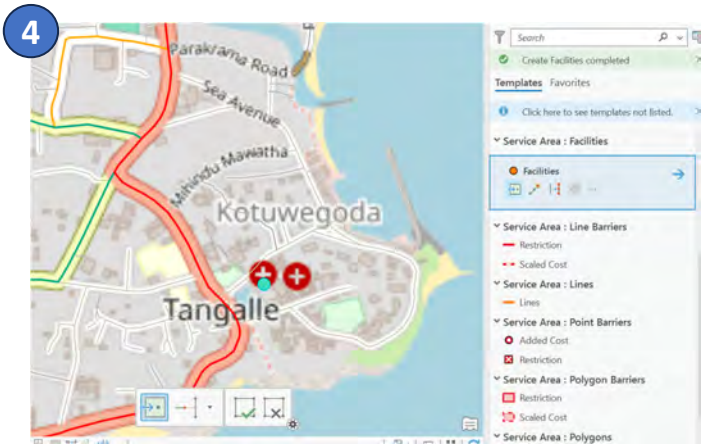
Network Analysis 1: Service Area (1) with manually input facilities

Analyze 15/ 30/ 45/ 60 min drive time areas from city center of Tangalle

1. From “Analysis” Tab – “Workflow” – “Network analysis”-”Service Area” (to create Service area layer)
2. Edit – “Create” in “Features group”
3. Select “Service area : Facilities”
4. Input the point
5. “Edit” Tab – “Save in Manage Edits”





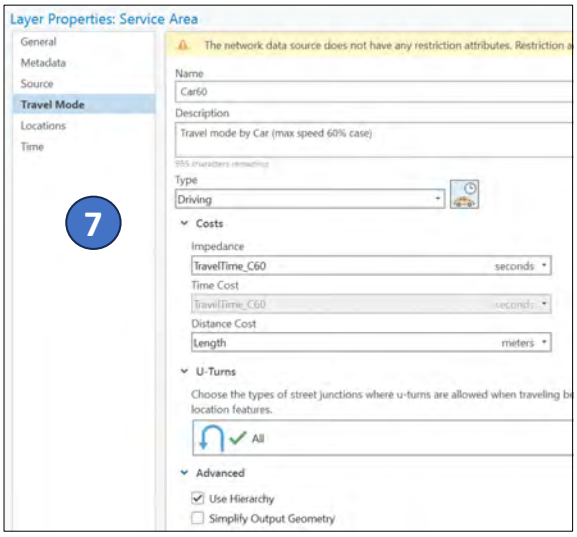


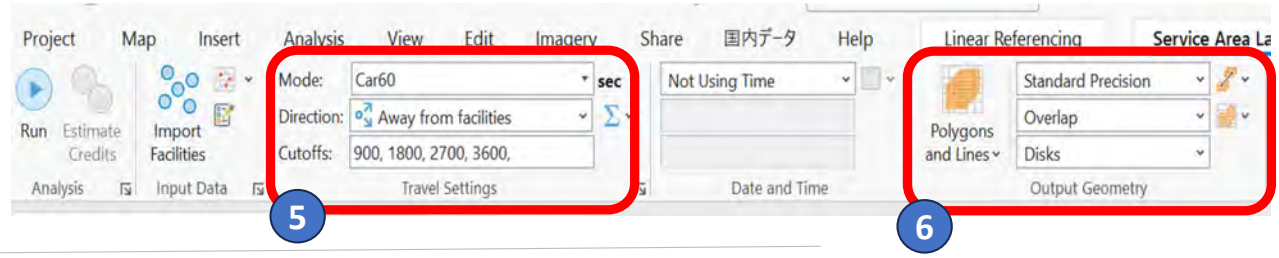
Network Analyst Basic: Perform Network Analysis

Network Analysis 1: Service Area (1) with manually input facilities

Analyze 15/ 30/ 45/ 60 min drive time areas from city center of Tangalle

5. Service Area Layer – Travel Setting: Setting analysis parameters
6. Service Area Layer – Output Geometry: Setting output data parameters
7. Contents window – Right click “Service Area” - Properties, modify parameters, if necessary
8. Click “Run” to perform analysis





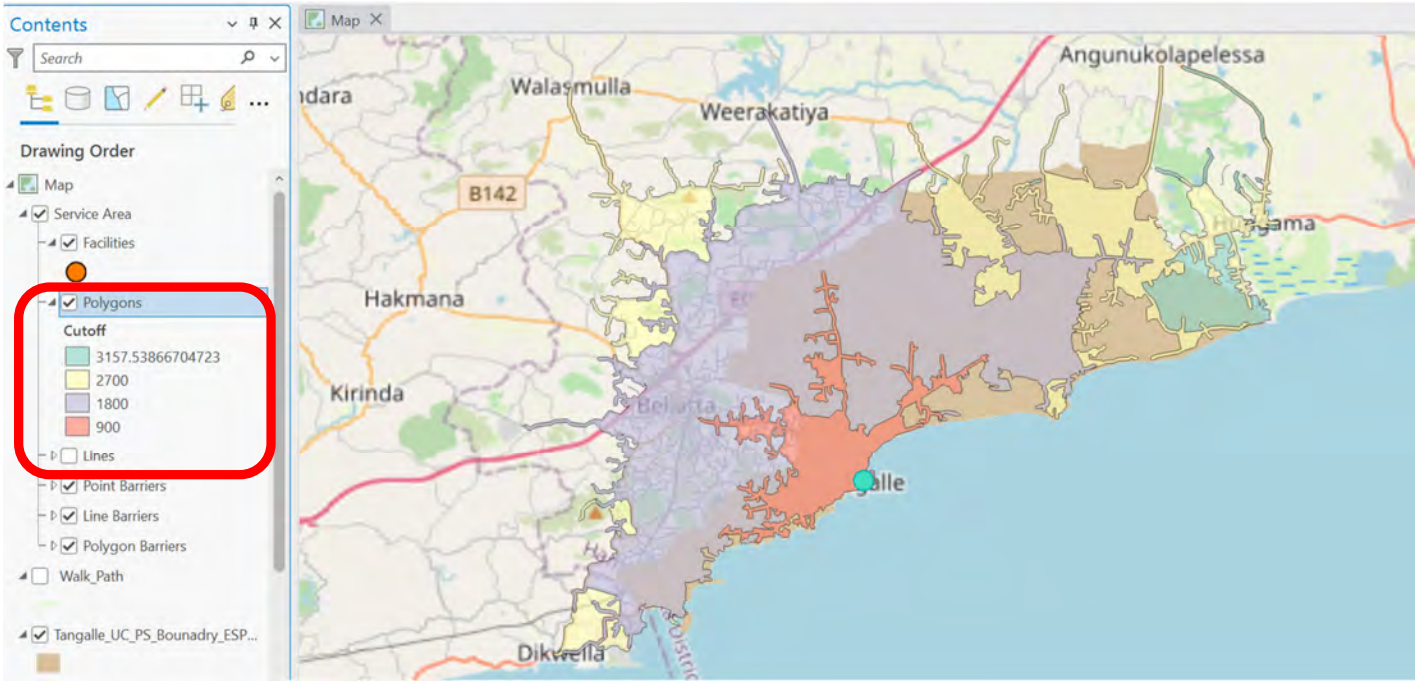
Project on Capacity Development for Urban Planning

Network Analyst Basic: Perform Network Analysis

Network Analysis 1: Service Area (1) with manually input facilities

Analyze 15/ 30/ 45/ 60 min drive time areas from city center of Tangalle

The result polygons (and/ or lines) are created as virtual layer. If you want the result as permanent data, need to export to feature class.



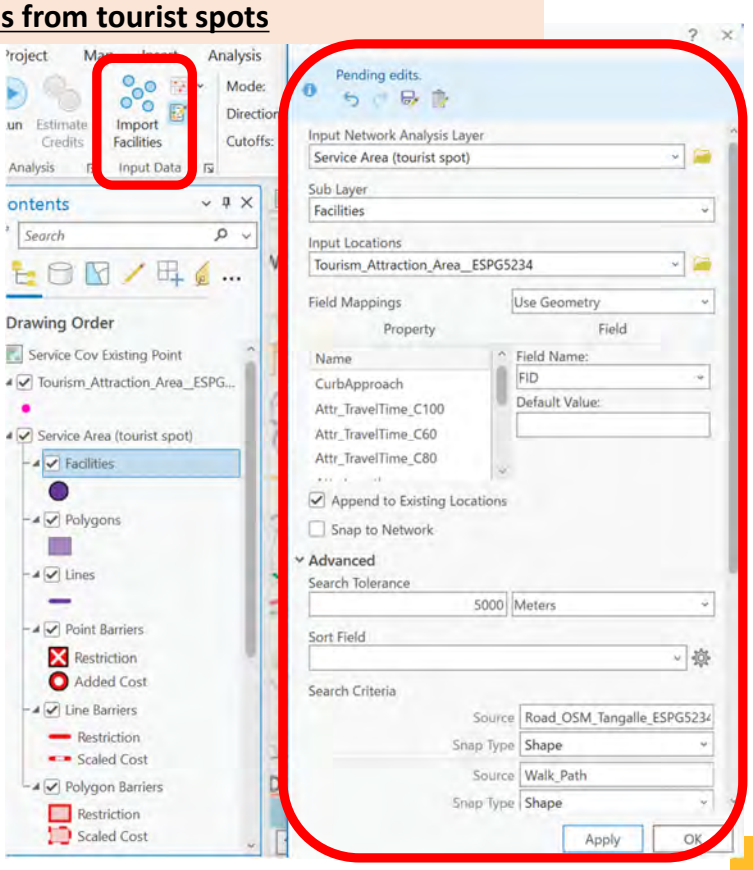
Network Analyst Basic: Perform Network Analysis

Network Analysis 1: Service Area (2) with existing point data as facilities

Analyze 15/ 30/ 45/ 60 min drive time areas from tourist spots

1. From “Analysis” Tab – “Workflow” – “Network analysis”-”Service Area” to create service area layer
2. Input data group – Import facilities, set parameters (Do not forget to set search tolerance! Because most of spots are not touch to roads)





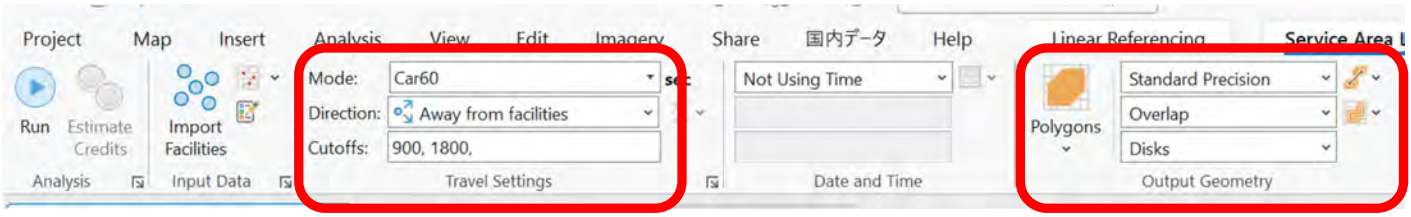
Project on Capacity Development for Urban Planning

Network Analyst Basic: Perform Network Analysis

Network Analysis 1: Service Area (2) with existing point data as facilities

Analyze 15/30 min. drive time areas from tourist spots

3. Service Area Layer – Travel Setting: Setting analysis parameters
4. Service Area Layer – Output Geometry: Setting output data parameters
5. Contents window – Right click “Service Area” - Properties, modify parameters, if necessary
6. Click “Run” to perform analysis

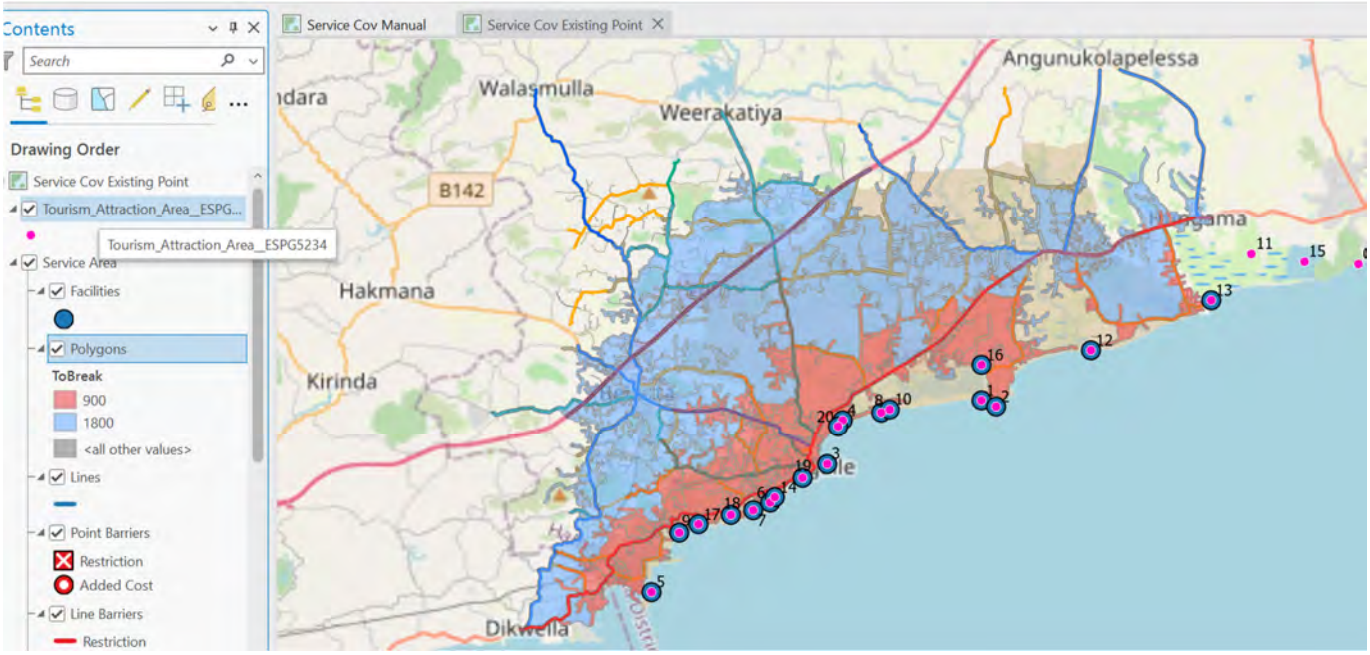


Network Analyst Basic: Perform Network Analysis

Network Analysis 1: Service Area (2) with existing point data as facilities

Analyze 15/30 min. drive time areas from tourist spots

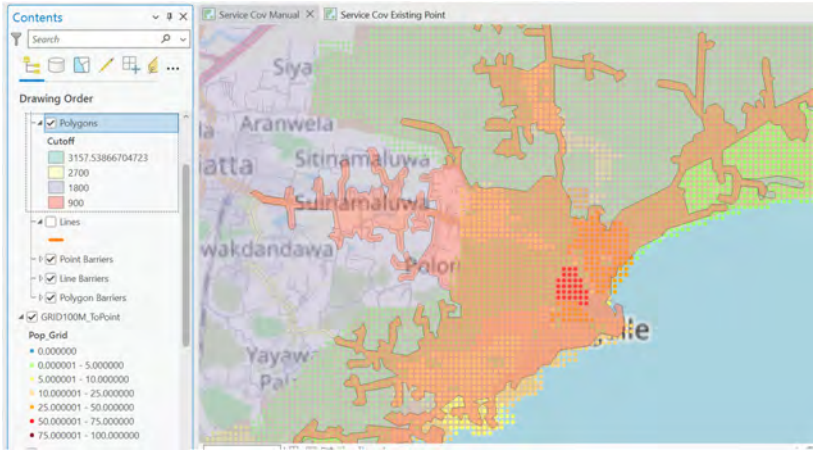
Better to delete facilities located outside of analysis extent to reduce analysis time



Network Analyst Basic: Perform Network Analysis

How to evaluate the results？ (How to utilize the result polygon?)

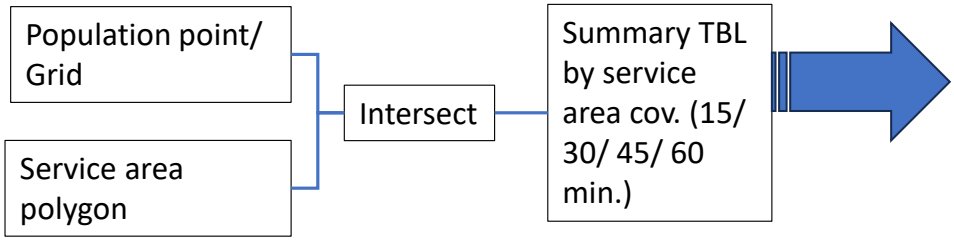
e.g. Overlay with population grid/ points to estimate population covered.





*Population data (point): Created from grided population (30m*30m) used in the City-UP GIS training on 13th Aug. 2024*

You can simulate covered population using service area analysis result polygon. If you have future population projection with future road network, you can compare both results.
This is typical usage of network analyst in urban planning



Service area Cov. From Tangalle City center	Covered Population
15 min. area	XXXX
30 min. area	XXXX
45 min. area	XXXX
60 min. area	XXXX

Network Analyst Basic: Perform Network Analysis

Other Network Analysis Tools

Analysis Tool	Description
Closest facility	The closest facility solver measures the cost of traveling between incidents and facilities and determines which are nearest to one other. When finding closest facilities, you can specify how many to find and whether the direction of travel is toward or away from them. The closest facility solver displays the best routes between incidents and facilities, reports their travel costs, and returns driving directions.
Route	The route solver can be used to find the best way to get from one location to another or to visit several locations. The best route can be the quickest route for a given time of day considering the traffic conditions applicable during that time, or it can be the shortest route that minimizes the travel distance. The route solver can also find the best route that visits each stop during permitted time windows you specify. If you have more than two stops to visit, the best route can be determined for the fixed order of locations you specify

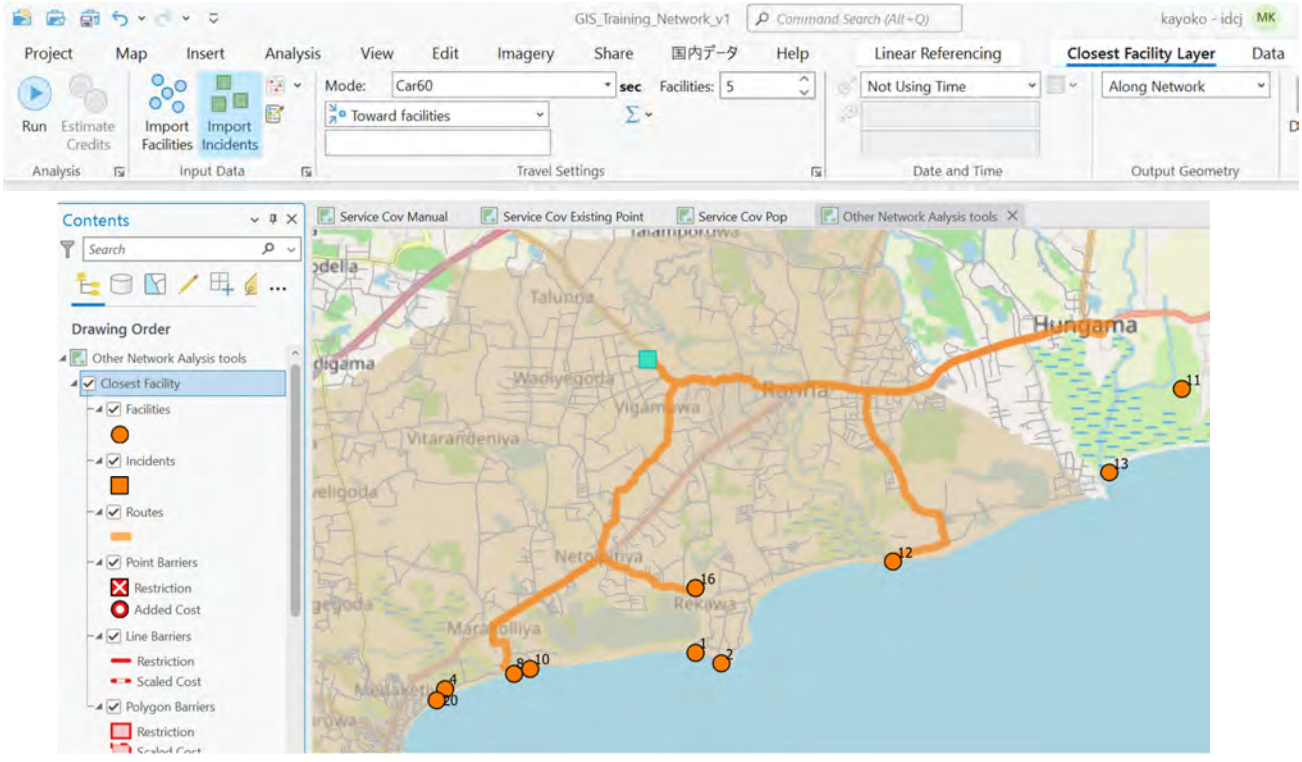
There are other network analysis tools are available. But it is not directly related to Urban Planning activities. Most useful analysis tool is “Service area”.
If you interested in all tools in Network Analyst extension,, refer below;
Network Analyst solvers—ArcGIS Pro | Documentation

Project on Capacity Development for Urban Planning

Network Analyst Basic: Perform Network Analysis

Other Network Analysis Tools

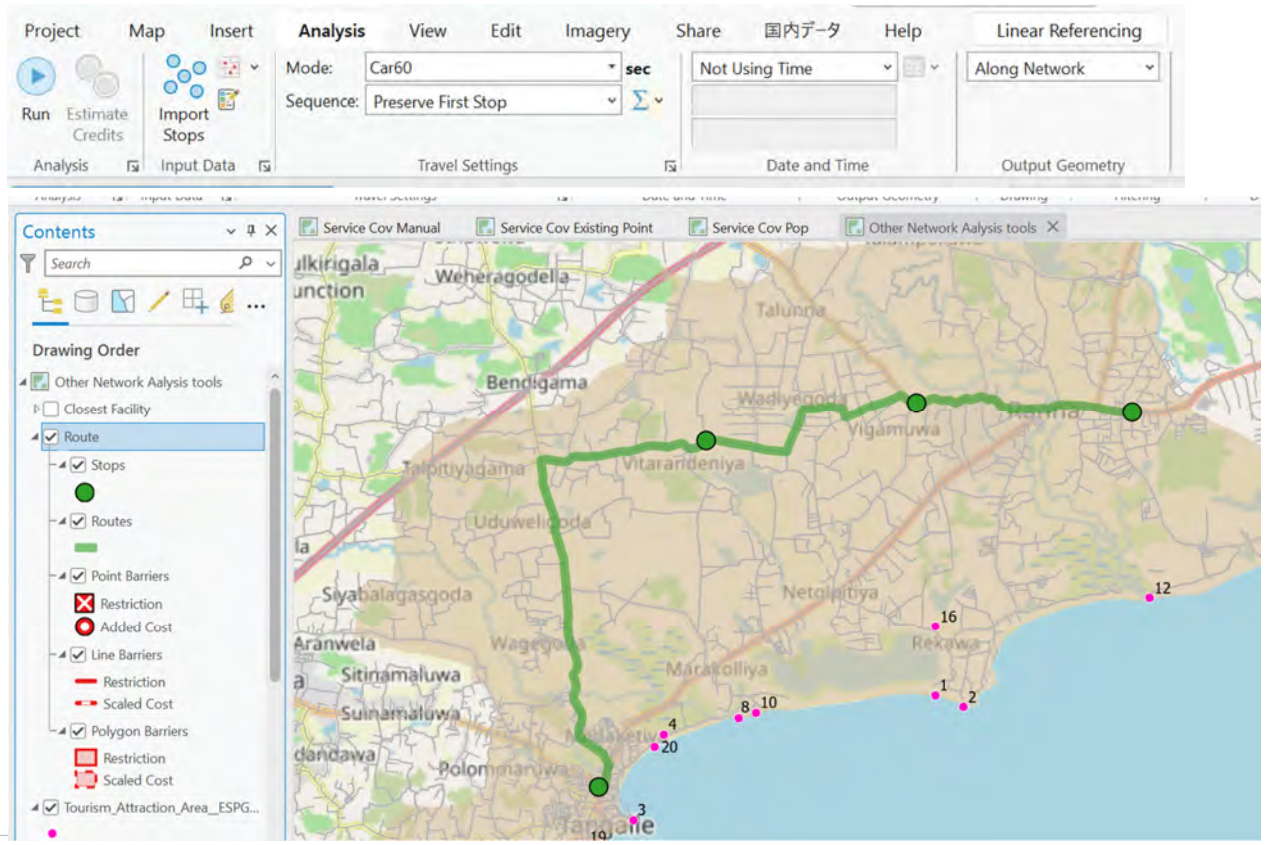
Closest Facilities Analysis



Network Analyst Basic: Perform Network Analysis

Other Network Analysis Tools

Route analysis



Network Analyst Basic:

3. Building Network DS

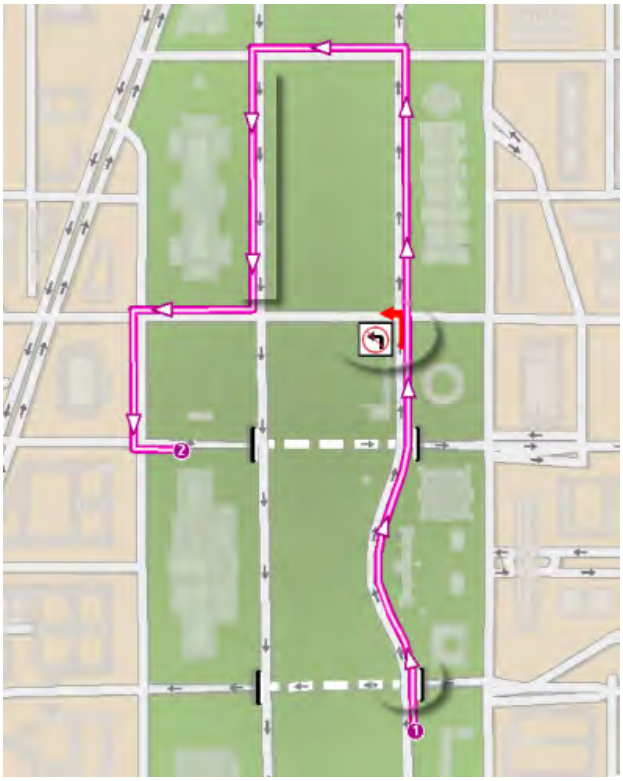
Network Analyst Basic: Network DS

Basic Steps to Create Network:

1. Find centerline road network without topological errors
2. Create necessary fields for Network Analysis (e.g. length, travel time, hierarchy, etc.)
3. Create New file geodatabase
4. Create New feature dataset
5. Import the road network feature class (single) into the created feature dataset
6. Create network dataset
7. Setting parameters in the Properties windows
8. Build Network DS

Network Analyst Basic: Network DS

What is a Network Dataset? (It is not same as "Road network layer")



Network datasets are well suited to model transportation networks. They are created from source features, which can include simple features (lines and points) and turns, and they store the connectivity of the source features. **When you perform a network analysis, it is always done on a network dataset.**

The graphic highlights that one-way streets, turn restrictions, and overpasses/tunnels can be modeled. The analyses that are performed on the network, such as the route from stop 1 to stop 2, respect these and other network dataset properties.

If you set various information of roads, the result shall be more realistic.(but it will be very time-consuming work to prepare it)

Source: What is a network dataset?—ArcGIS Pro | Documentation

Network Analyst Basic: Network DS

Create necessary fields for Network DS

Based on downloaded OSM road, add multiple fields to prepare network DS.
Travel time will be “cost” or “impedance” to analyze service area.
As a case study, we will prepare travel time with “100% max speed”, “70% of max speed” and “60% of max speed” fields. (max speed refer OSM data, if OSM data not have max speed, max speed set as “10km/h”, because most of data is living street)

Field name	Description
Car_SPD100	Max speed value based on downloaded OSM data. In case, original OSM data doesn’t have max speed, set as 10km/h
Car_SPD80	Based on “WK_SPD100”, calculates 70% value
Car_SPD60	Based on “WK_SPD100”, calculates 60% value
TraTM_C100	Travel time of the link (max speed 100% case) *e.g. (!Length_m! /(!Car_SPD100!*1000)) *3600*
TraTM_C80	Travel time of the link (max speed 70% case)
TraTM_C60	Travel time of the link (max speed 60% case)
Length_m	Length of the link (unit=meter)
Hierarchy	Hierarchy of road by type (smaller number is higher hierarchy) e.g. 1: Motorway, motorway link, 2: Trunk, primary, secondary, tertiary, 3: residential, 4: all othes
WLK_SPD	4km/h
TraTM_WLK	Travel time of the link (max speed 60% case)

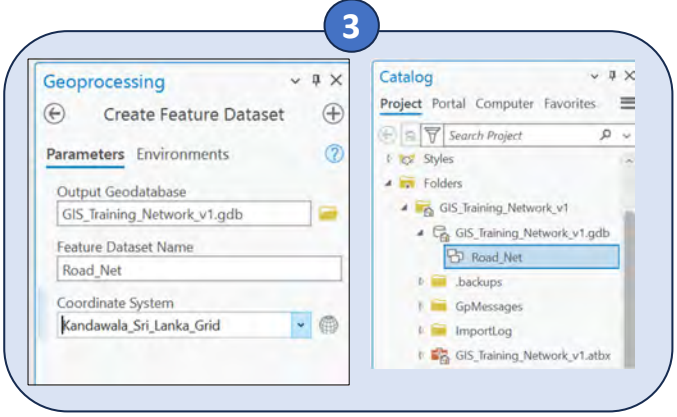
Network Analyst Basic: Network DS

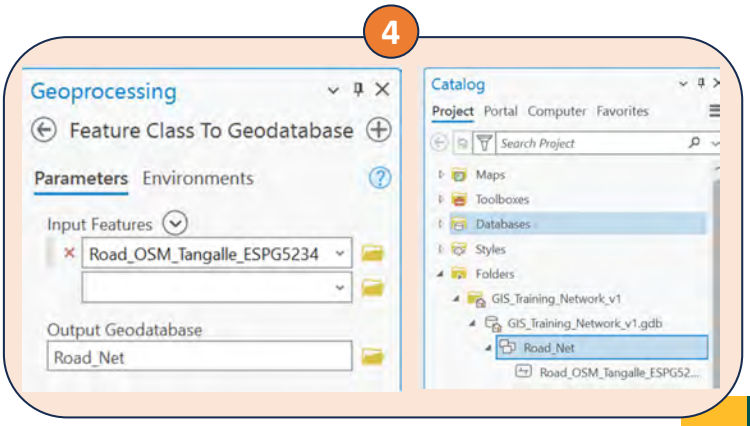
Basic Process to Create Network DS (1)

We are going to create Network DS of Tangalle area with 2 network source

- Tangalle road (both car & walk available)
- Walkable path (can’t access by car)

1. Find centerline road network without topological errors
2. Create necessary fields for Network Analysis (necessary fields are differ by analysis tool in network analyst tools)
3. Create feature dataset where the network dataset will be created. The feature dataset should contain the source feature classes that will participate in the network dataset.
4. Import source road feature class into the created feature dataset



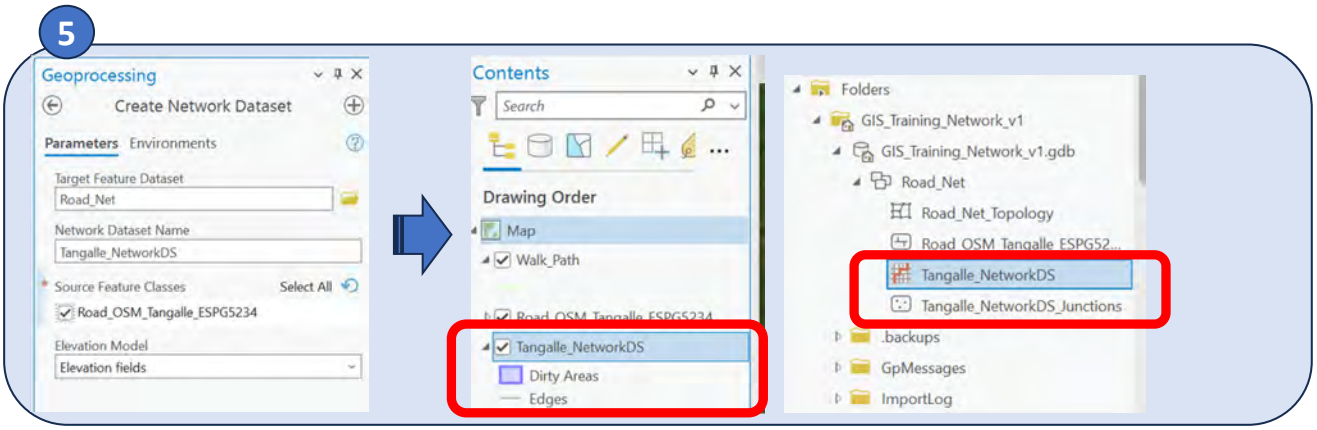


Network Analyst Basic: Network DS

Basic Process to Create Network DS (2)

5. Geoprocessing tool – Network Analyst tool – Create Network Dataset
6. Remove the created network DS to modify network DS properties (Network dataset properties cannot be edited while the network dataset layer is in the map. You must remove the layer from the map to proceed)

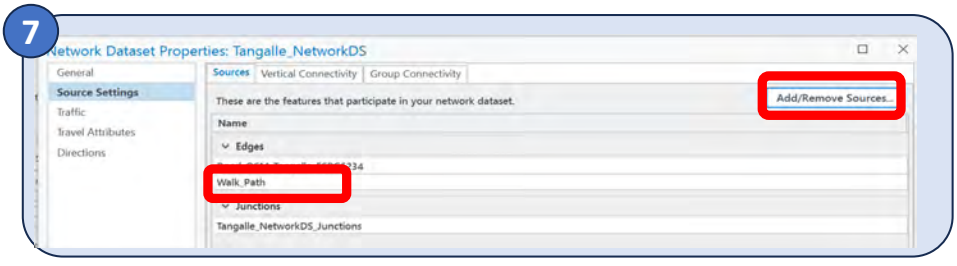
Next, add "walk path" as additional source of the network and edit "cost" and others to analyze the network

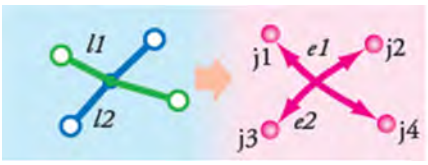


Network Analyst Basic: Network DS

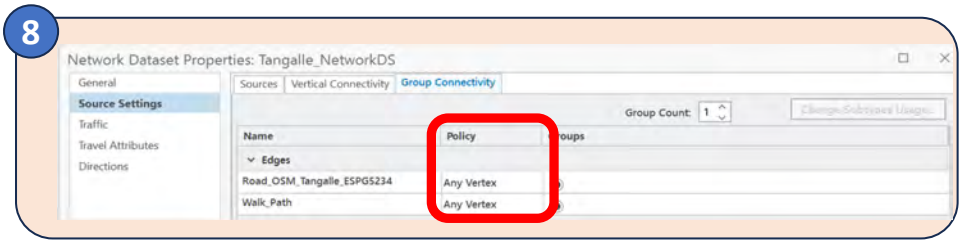
Basic Process to Create Network DS (3): Add network source & Set Connectivity

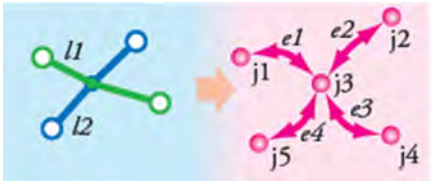
7. Remove the created network DS to modify network DS properties (Network dataset properties cannot be edited while the network dataset layer is in the map. You must remove the layer from the map to proceed)
8. Source Setting – Group Connectivity: Select "Any Vertex" as Policy column (you can turn at all intersection)





End point connectivity





any vertex connectivity

Network Analyst Basic: Network DS

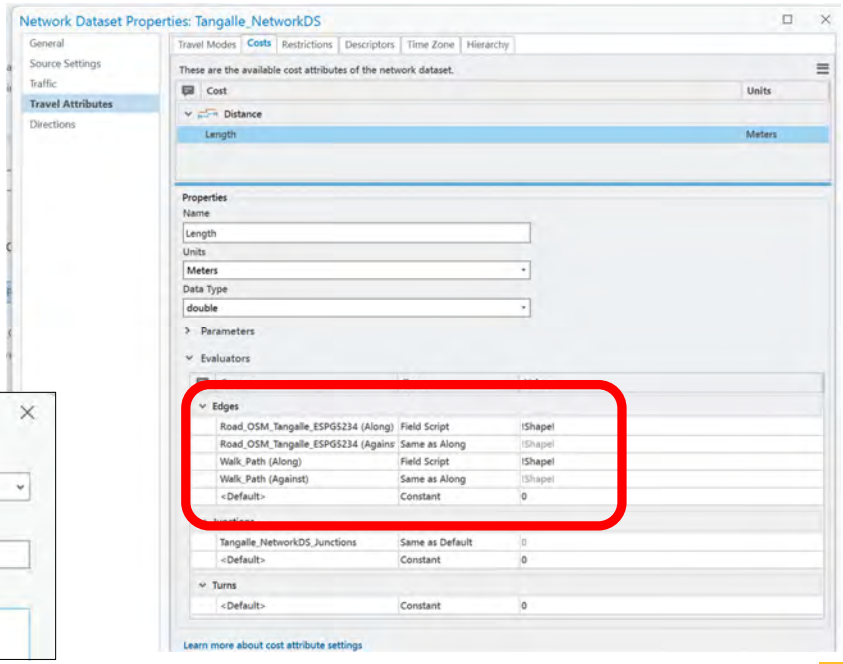
Basic Process to Create Network DS (4): Add cost (or Impedance)

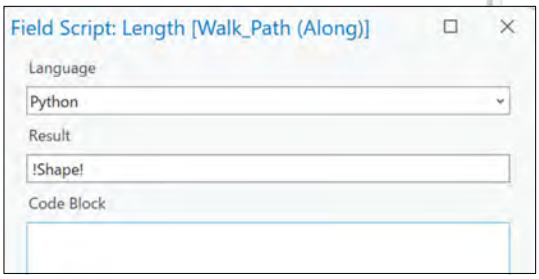
Network analysis often involves the minimization of a cost (also known as impedance) during the calculation of a path. As a next step, you will be adding cost attributes to the network dataset. A cost attribute is used to model an impedance on the network dataset. These attributes are apportionable along an edge; that is, they are divided proportionately along the length of an edge.

Cost: Length (default cost)

Click “Travel Attribute” – “Cost”

!Shape! Means “use the Shape field in the Field Script evaluator to return the geodesic length of the line feature in the units of the network attribute





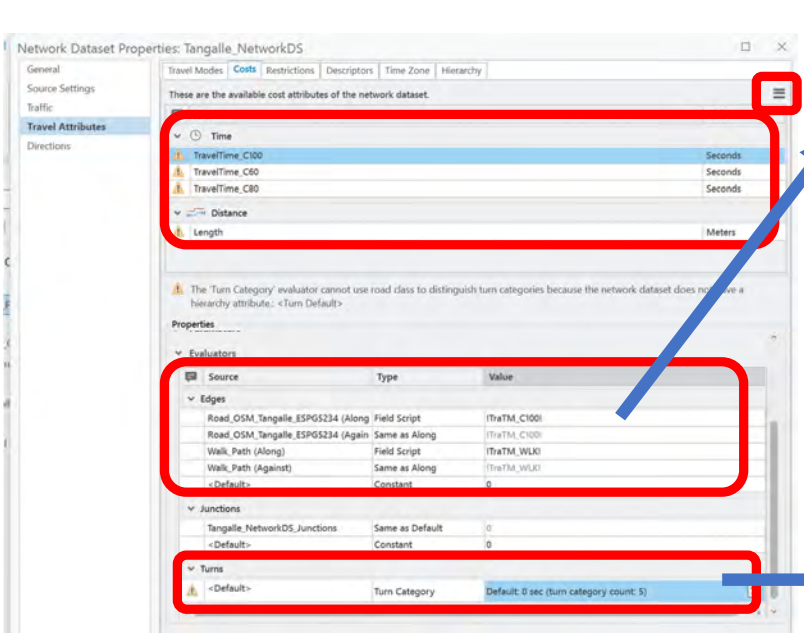
Network Analyst Basic: Network DS

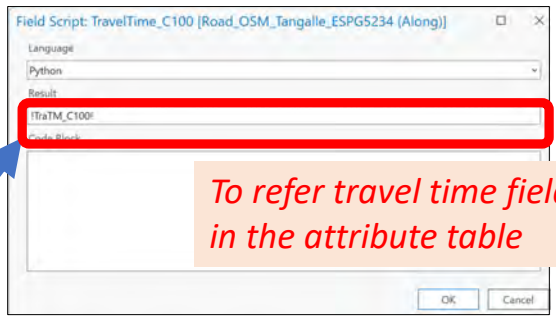
Basic Process to Create Network DS (5): Add cost (or Impedance)

Cost: Assign “Travel time” as cost and set “turn” evaluator

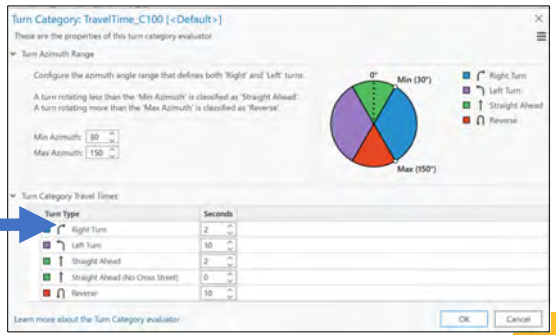
Click “Travel Attribute” – “Cost”- “New” : click upper right corner 

To modify “turns”, you can modify extra time when perform turn





To refer travel time field in the attribute table



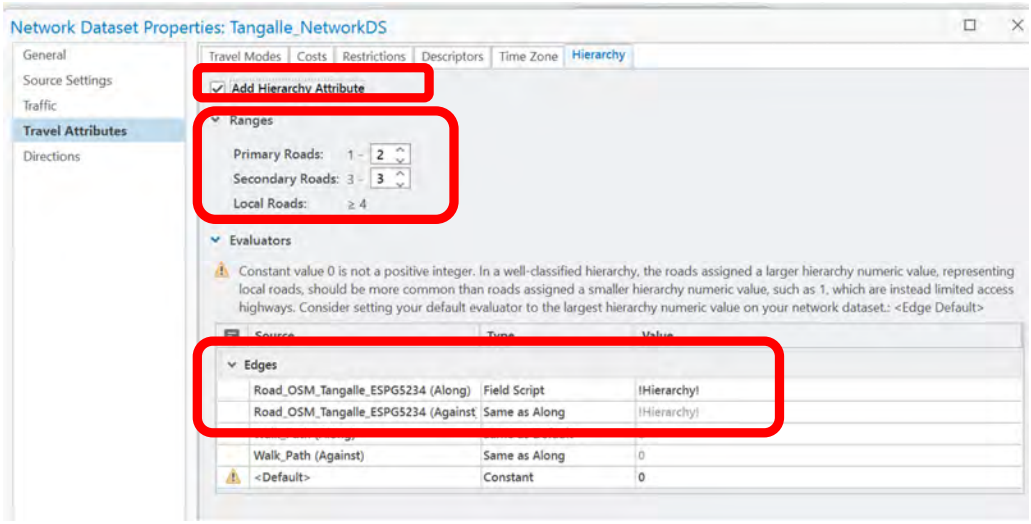
Network Analyst Basic: Network DS

Basic Process to Create Network DS (6): Assign Hierarchy

Assign Hierarchy: Hierarchy is the order or rank assigned to network elements. Once a hierarchy attribute is present, you can choose whether to use or ignore it when solving a network analysis.

Hierarchy of the road data ("Hierarchy" field in this sample road data)

1: Motorway, motorway link
2: Trunk, primary, secondary, tertiary } *Set as "Primary"*
3: residential → *Set as "Secondary"*
4: all others → *Set as "Local roads"*

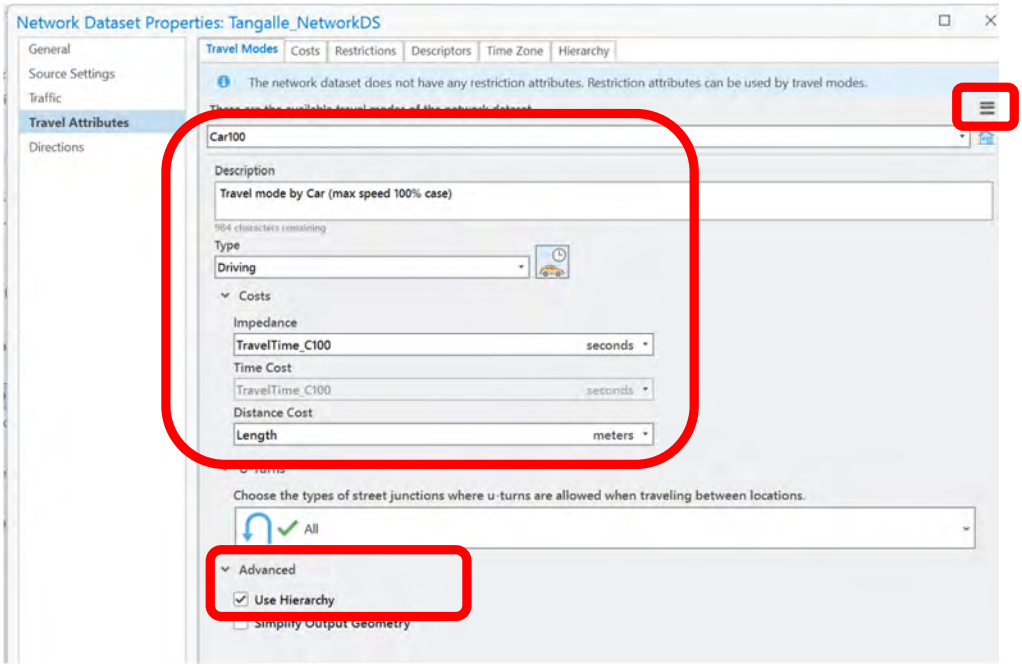


Project on Capacity Development for Urban Planning

Network Analyst Basic: Network DS

Basic Process to Create Network DS (7): Set Travel modes

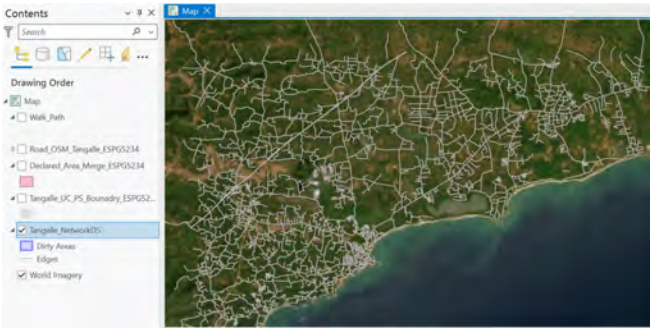
A travel mode is essentially a template consisting of a long list of travel settings that define the physical characteristics of a vehicle or pedestrian. These characteristics are considered when performing network analysis to define how the vehicle or pedestrian travels and where it can go.



Network Analyst Basic: Network DS

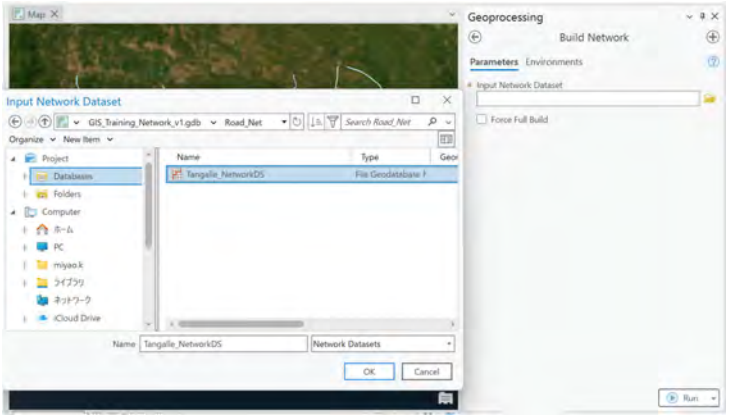
Basic Process to Create Network DS (8): Build Network

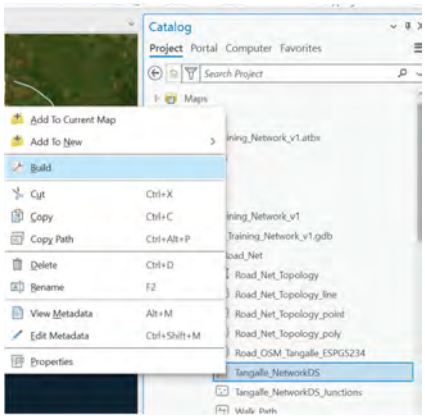
Once complete all necessary network settings, the next step is “Build network”
Building the network creates and updates the network edges, ensuring that it has the most current information from the source features.



To access “Build network” there are 2-way

1. Geoprocessing – search “Build network”
2. Right click the network DS in the catalog pane, select “Build”





Project on Capacity Development for Urban Planning

Thank you very mush

ありがとうございます

PPT. No.10

Module LU3-2: Spatial Data Analysis by GIS

Road Density Analysis

Project on Capacity Development for Urban Planning

Training Session for GIS

Road Density Analysis

JICA Expert Team
20 March 2025

0. Outline

Contents of Training

Contents of Training

1. **Introduction**
Purpose of Road Density Analysis

2. Process of Analysis
Case Study at Battaramulla
⇒ Road Density Analysis

3. Further Evaluation
Road Density Analysis with Land Cover, Population

4. Way Forwards
Further Analysis

1. Introduction

Purpose of Road Density Analysis

Purpose of Road Density Analysis

- **Road density analysis** helps **assess the distribution** and **concentration** of **road networks** within a given area, which can be useful for urban planning, transportation studies, environmental analysis, and more.
- Road density could evaluate the **significance characteristic of various areas**. This can provide insights into:
  - Improving infrastructure
  - Ensuring safety
  - Managing resources effectively
  - Traffic Management and Congestion Reduction
  - Emergency Services and Disaster Response
  - Transportation and Accessibility Analysis
  - Environmental Impact Assessment
  - Economic and Social Development
  - Tourism and Recreational Development

1. Introduction

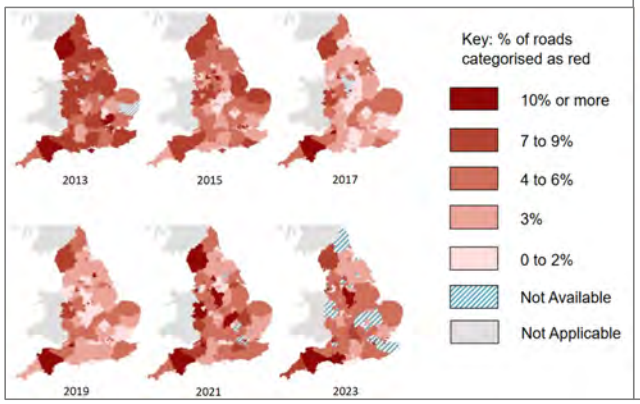
Purpose of Road Density Analysis

Example of Road Density Classification

Road density description class	Road density (m/ha)
Very high	> 40
High	30-40
Moderate	20-30
Low	< 30

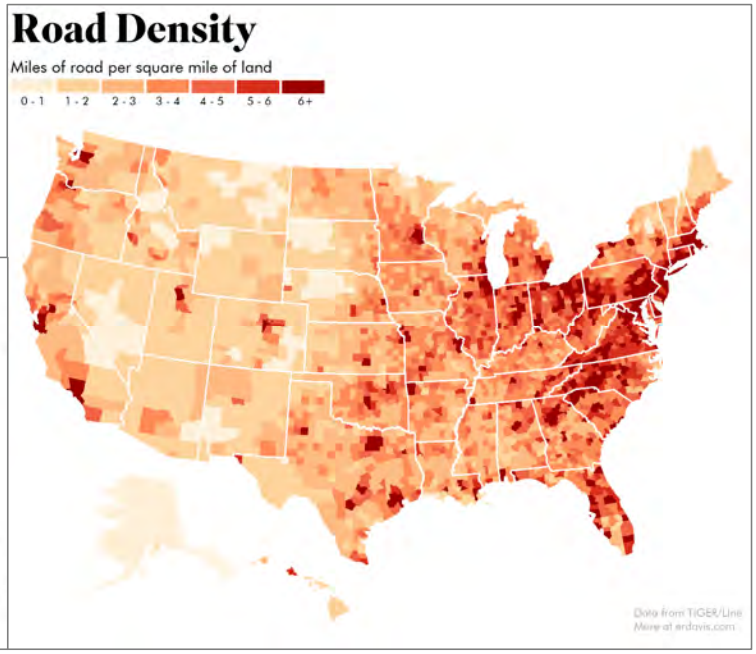
Source: https://www.researchgate.net/figure/The-scale-of-road-density-class-used-in-the-study_tbl1_41891891 [accessed 17 Mar 2025]

Understand the Urbanization



Source: https://www.gov.uk/government/statistics/road-conditions-in-england-to-march-2023/road-conditions-in-england-to-march-2023

Understand the Concentration of Development



2. Process of Analysis

Case Study at Battaramulla (Road Density)

Case Study at Battaramulla (Road Density)

Step 1: Data Preparation

Tools:

- QGIS

Necessary Data:

- Road Line Data (Reprojected-Battaramulla-Road.shp)
- Area Boundary (Reprojected-Battaramulla-Boundary.shp)

Condition:

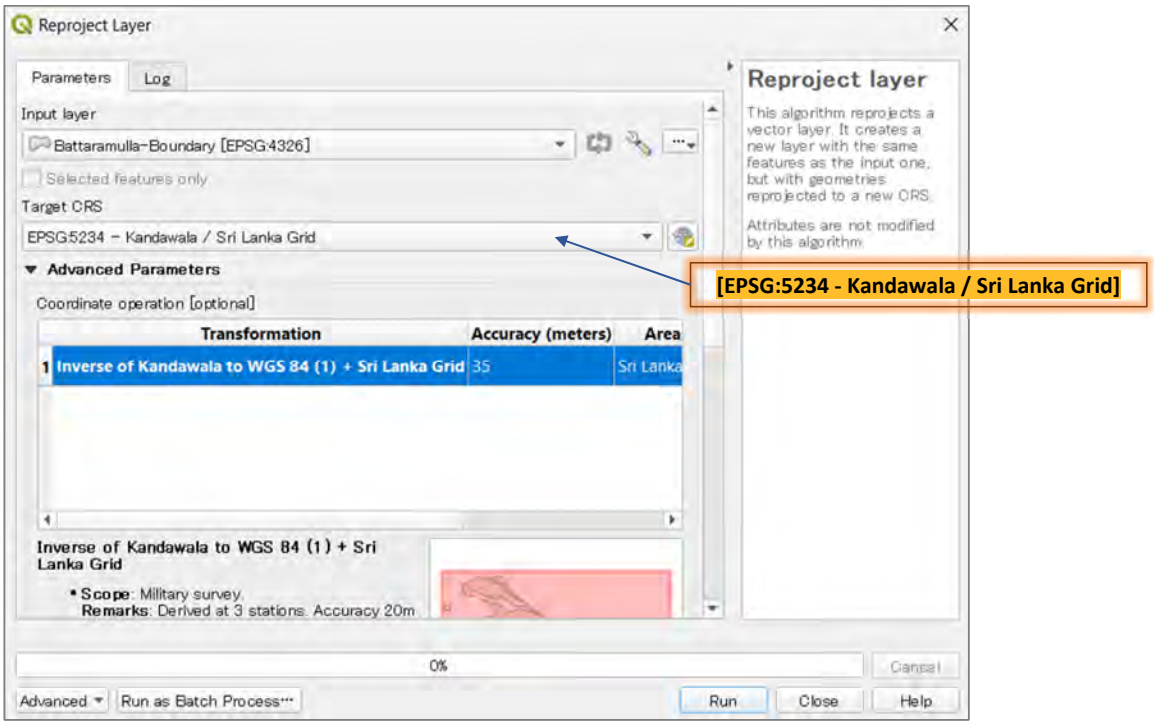
1. All data files are projected to [EPSG:5234 - Kandawala / Sri Lanka Grid]
2. All Road Lines are [Dissolved] in one attribute

Project on Capacity Development for Urban Planning
2. Process of Analysis

Case Study at Battaramulla (Road Density)

Step 1: Data Preparation

- **Use Processing Tools > [Reproject Layer] to Project all data files to [EPSG:5234 - Kandawala / Sri Lanka Grid]**

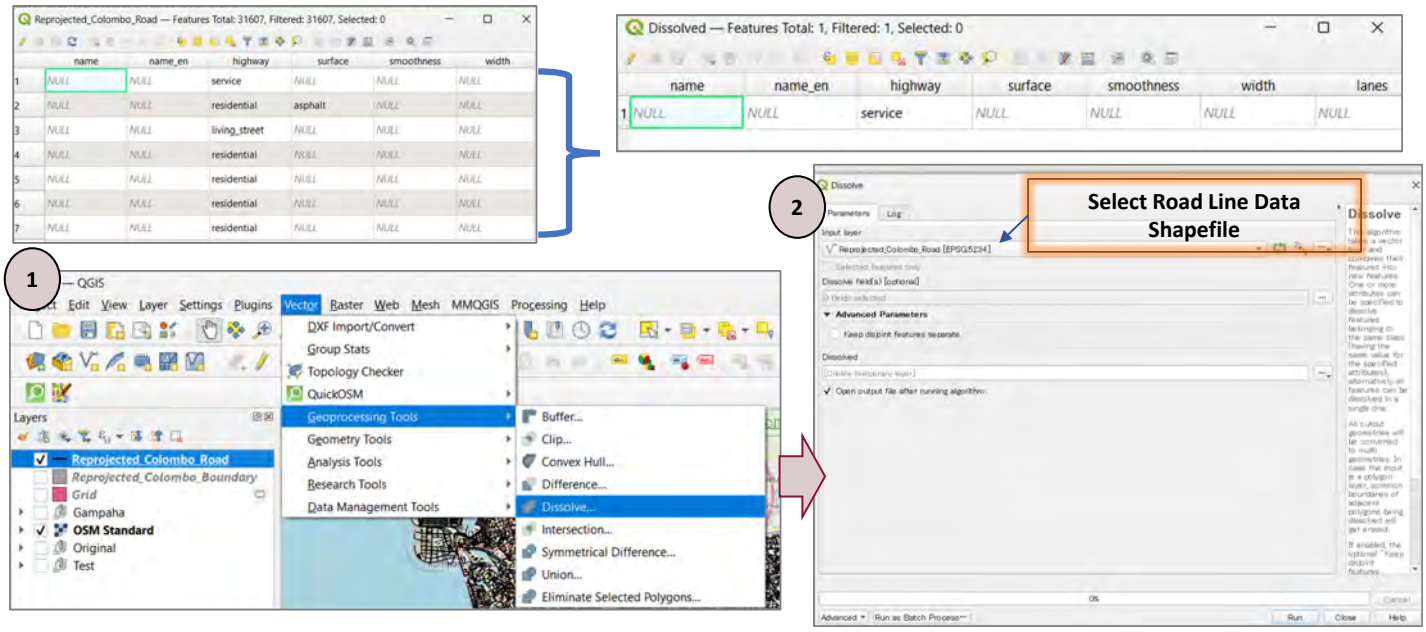


2. Process of Analysis

Case Study at Battaramulla (Road Density)

Step 1: Data Preparation

- Use **Vector > Geoprocessing Tools > [Dissolve]** to dissolve Road Line Data in **ONE** attribute

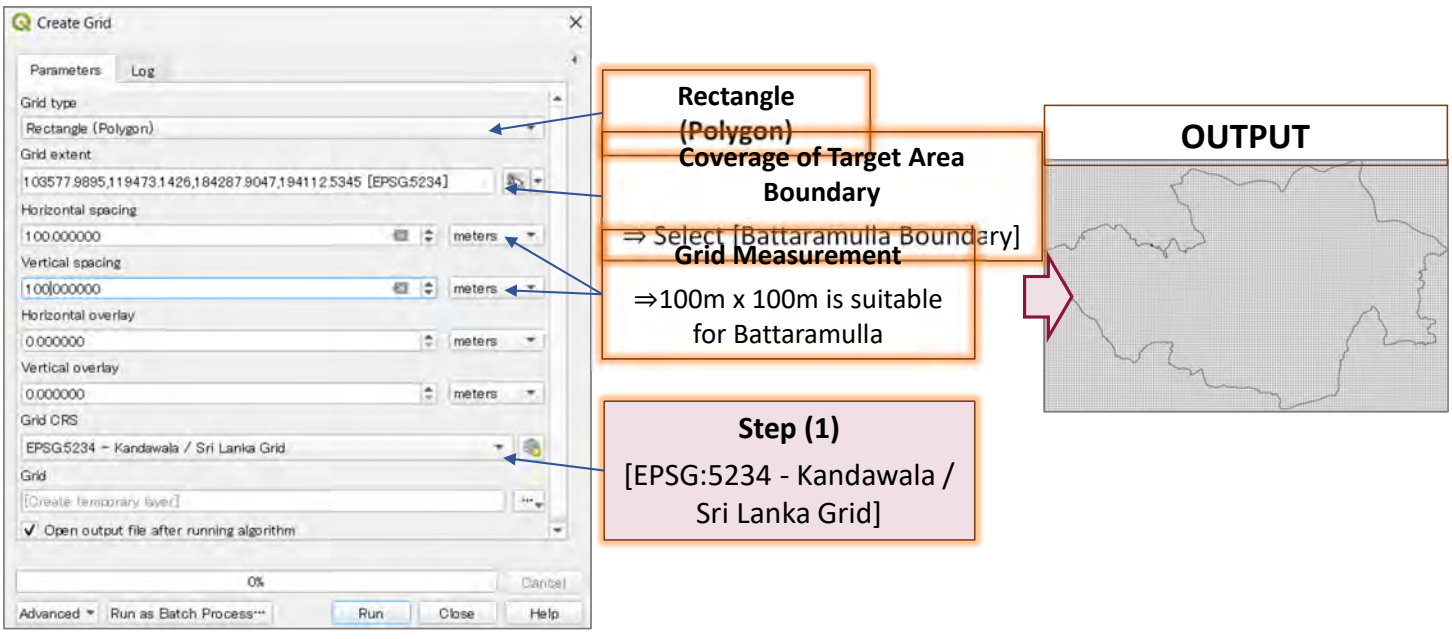


2. Process of Analysis

Case Study at Battaramulla (Road Density)

Step 2: Data Analysis

- Use **Vector > Research Tools > [Create Grid]** to create grid as a base for the road line

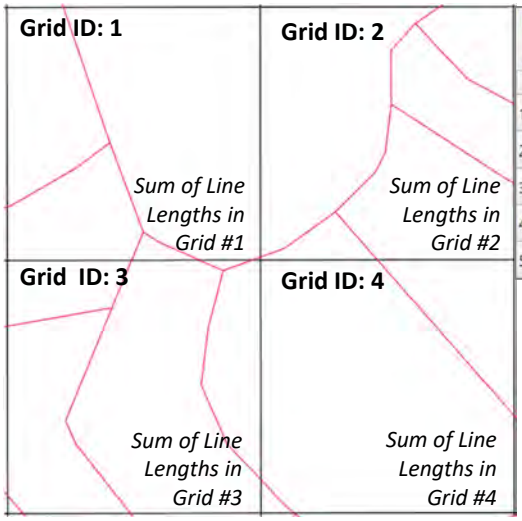


2. Process of Analysis

Case Study at Battaramulla (Road Density)

Step 2: Data Analysis

- Use Vector > Analysis Tools > [Sum Line Lengths] to get the sum of the length of all polylines within the certain polygon



Reprojected-Battaramulla-SumLineLengths — Features Total: 9147, Filtered: 9147, Selected: 1

	id	left	top	right	bottom	LENGTH	COUNT
1	27510	103905.723199...	190522.006699...	104005.723199...	190422.006699...	109.292626166...	1.00000000000...
2	26330	103505.723199...	190522.006699...	103605.723199...	190422.006699...	0	0
3	26331	103505.723199...	190422.006699...	103605.723199999999993085	006699...	7.45380395118...	1.00000000000...
4	26624	103605.723199...	190622.006699...	103705.723199...	190522.006699...	0	0
5	26625	103605.723199...	190522.006699...	103705.723199...	190422.006699...	0	0



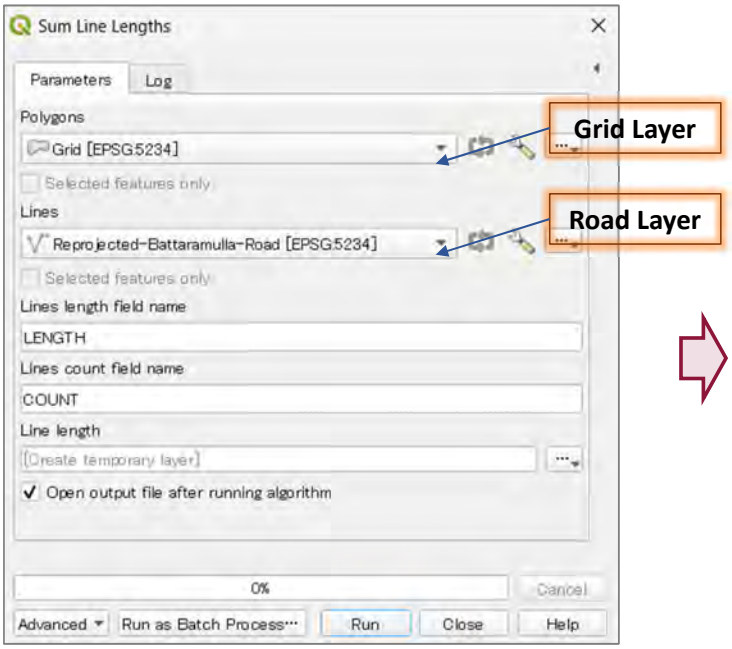
Project on Capacity Development for Urban Planning

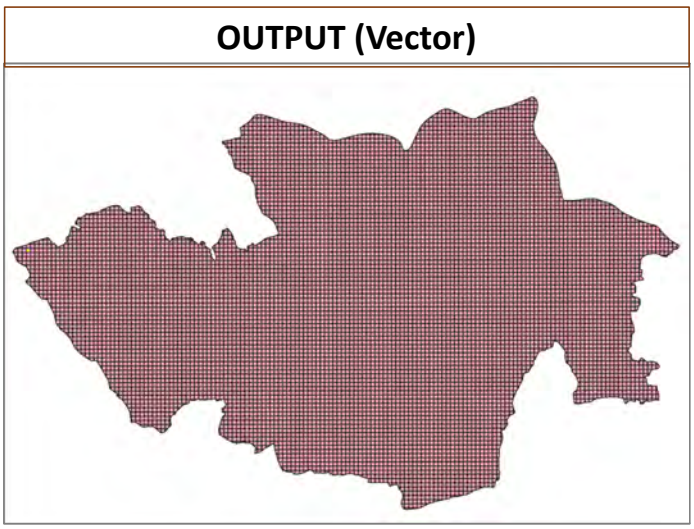
2. Process of Analysis

Case Study at Battaramulla (Road Density)

Step 2: Data Analysis

- Use Vector > Analysis Tools > [Sum Line Lengths] to get the sum of the length of all polylines within the certain area



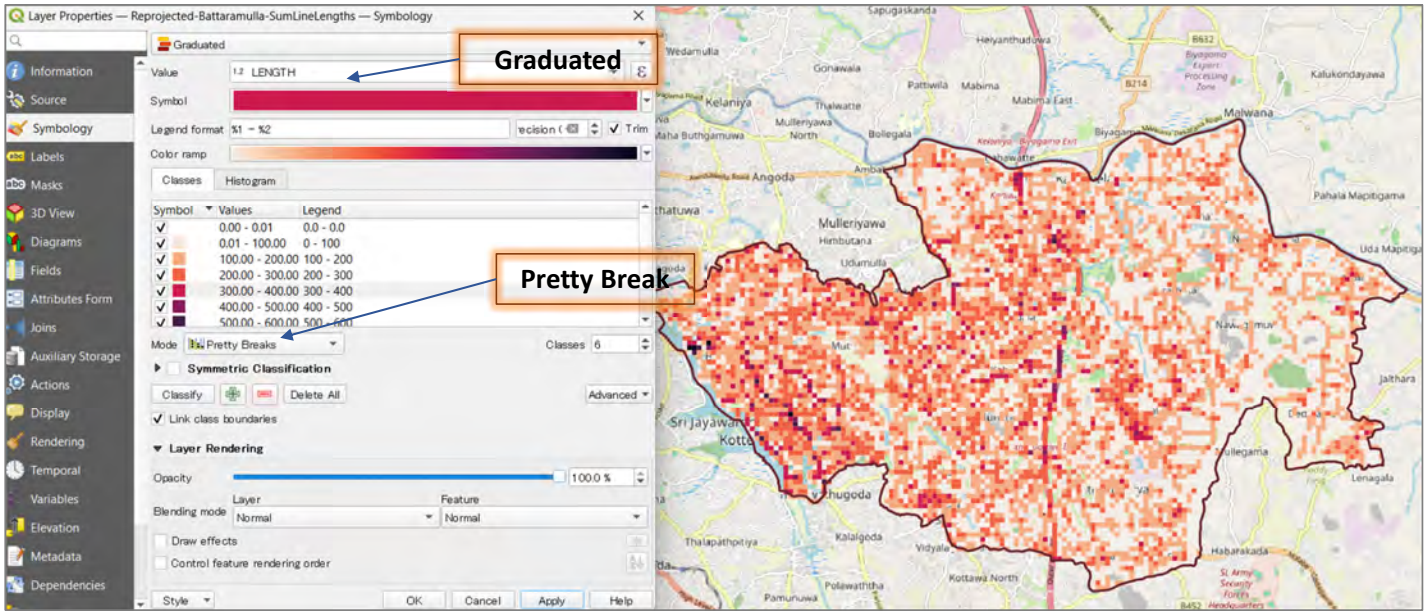


2. Process of Analysis

Case Study at Battaramulla (Road Density)

Step 3: Result Visualization

- Use Layer Properties > [Symbology] to visualize the analysis result

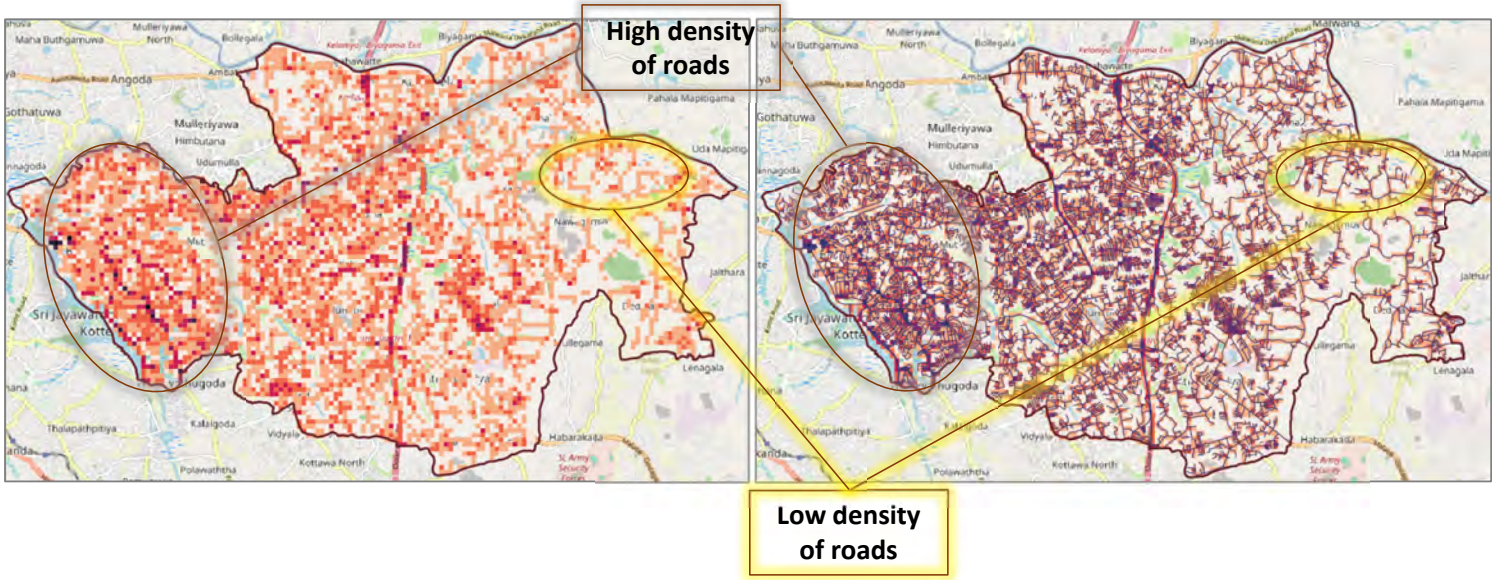


2. Process of Analysis

Case Study at Battaramulla (Road Density)

Step 4: Result Evaluation

- Observe and overlay the road lines on Sum Line Lengths analysis map



Road Density = Total lengths of road in the area (each grid polygon) of 100mx100m

3. Further Evaluation

Application on Land Cover, Population

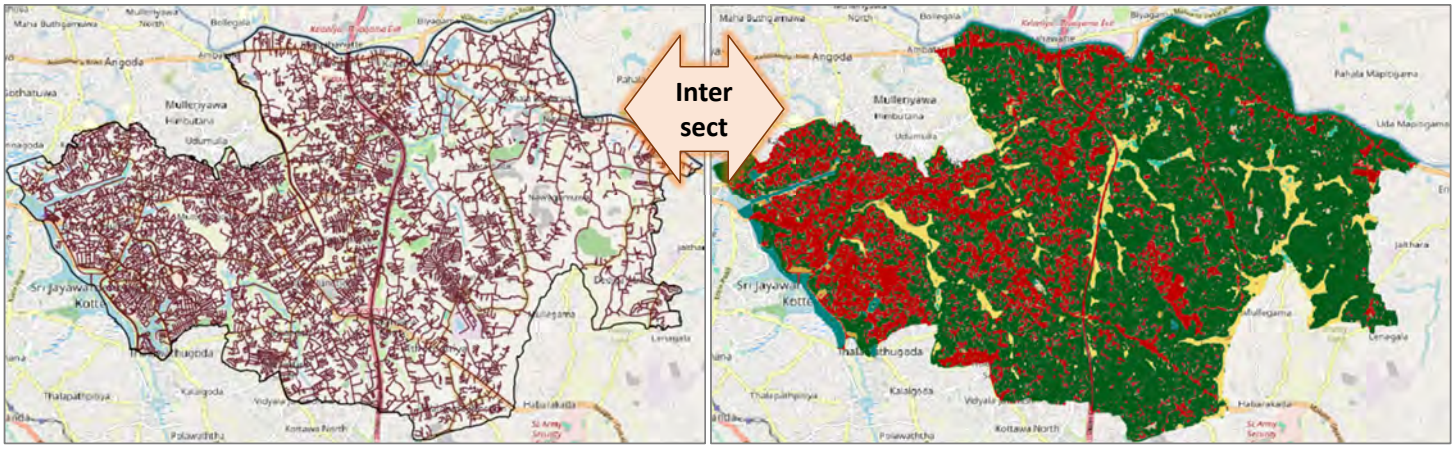
Application on Land Cover

Road Density x Land Cover ⇒ Urban Planning Consideration

- **Use Vector >Geoprocessing Tools > [Intersection] to overlap two layers and get the Cross Statistic from both layers**

E.g.: What is the total lengths of roads for each land cover categories?

Necessary Data:



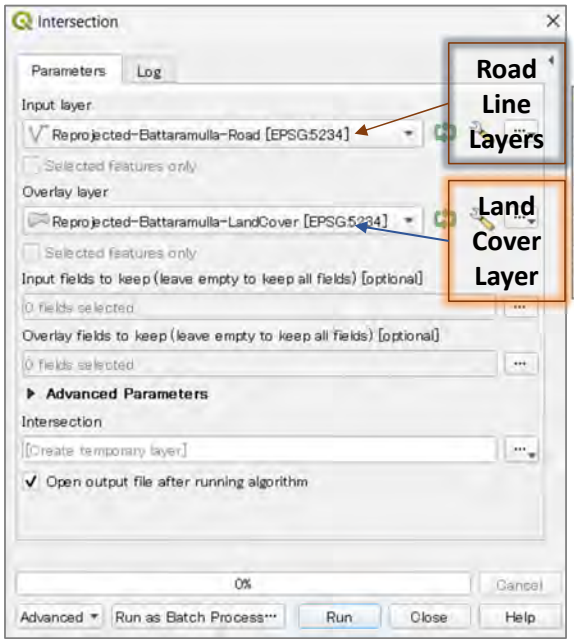
1. Data of Road Line (Vector)

2. Land Cover (Vector)
(Reprojected-Battaramulla-LandCover.shp)

Application on Land Cover

Road Density x Land Cover ⇒ Urban Planning Consideration

- **Use Vector >Geoprocessing Tools > [Intersection] to overlap two layers and get the Cross Statistic from both layers**



Sum Line Lengths (Road Density) Layers

Land Cover Layer

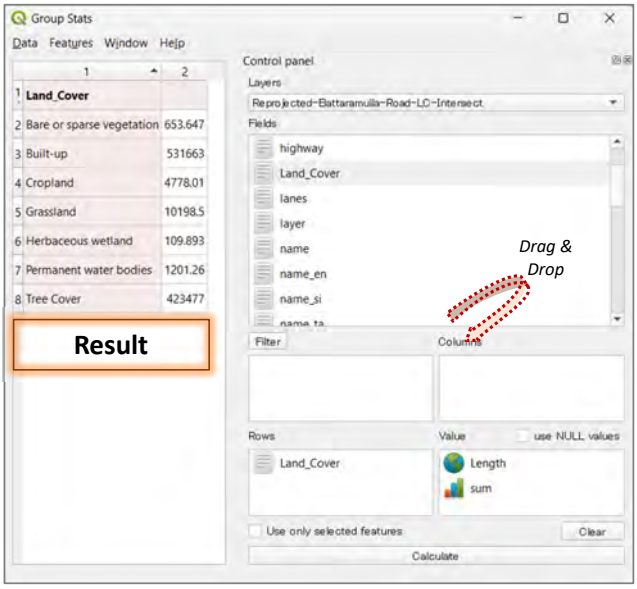
Reprojected-Battaramulla-Road-LC-Intersect — Features Total: 13604, Filtered: 13604, Selected: 0

	name	highway	surface	width	lanes	layer	osm_id	osm_type	fid	DN	Land_Cover
1	NULL	residential	NULL	NULL	NULL	NULL	311539711	ways_line	8122	50	Built-up
2	NULL	residential	NULL	NULL	NULL	NULL	311539711	ways_line	8145	50	Built-up
3	NULL	residential	NULL	NULL	NULL	NULL	311539711	ways_line	8251	50	Built-up
4	NULL	residential	NULL	NULL	NULL	NULL	311539711	ways_line	8291	50	Built-up
5	NULL	residential	NULL	NULL	NULL	NULL	311539711	ways_line	8524	10	Tree Cover

Application on Land Cover

Road Density x Land Cover ⇒ Urban Planning Consideration

- **Install Plugin [Group Stats]**
- **Use Vector > [Group Stats] to obtain cross statistic result**

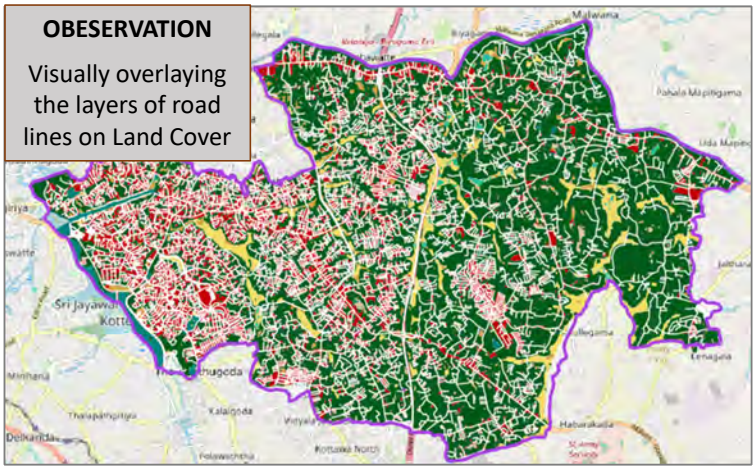


OUTPUT

Land Cover	Total Road Lengths (m)
Tree Cover	423,477
Grassland	10,198
Cropland	4,778
Built-up	531,663
Bare or sparse vegetation	654
Permanent water bodies	1,201
Herbaceous wetland	110
Total	**972,081**

OBESERVATION

Visually overlaying the layers of road lines on Land Cover

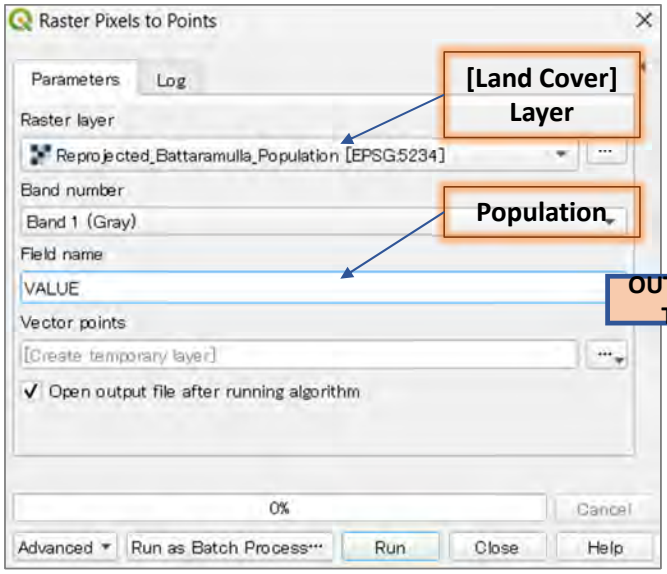


3. Further Evaluation

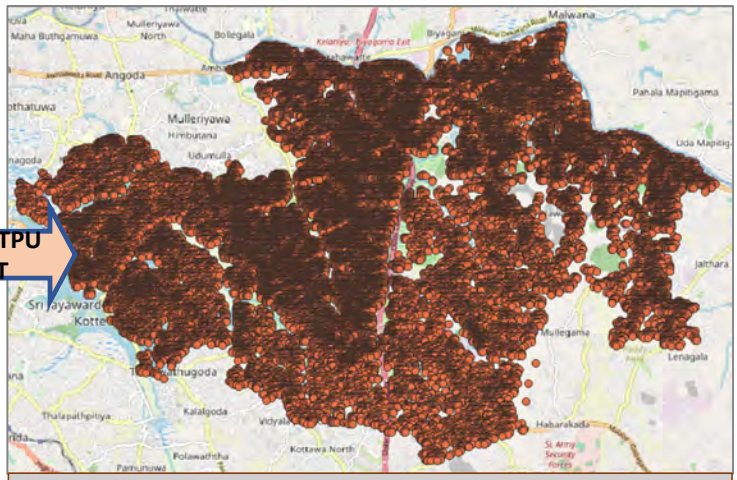
Application on Population Distribution

Road Density x Population Density

- Use Processing Tools > [Raster Pixels To Points] to change the visualize the raster data to vector point data



OUTPUT



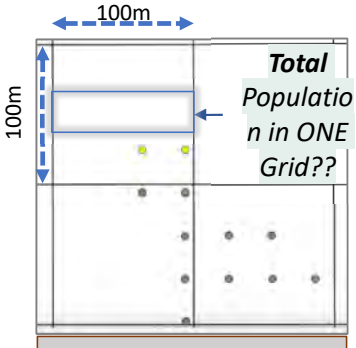
Every Points contains **certain number of population**

3. Further Evaluation

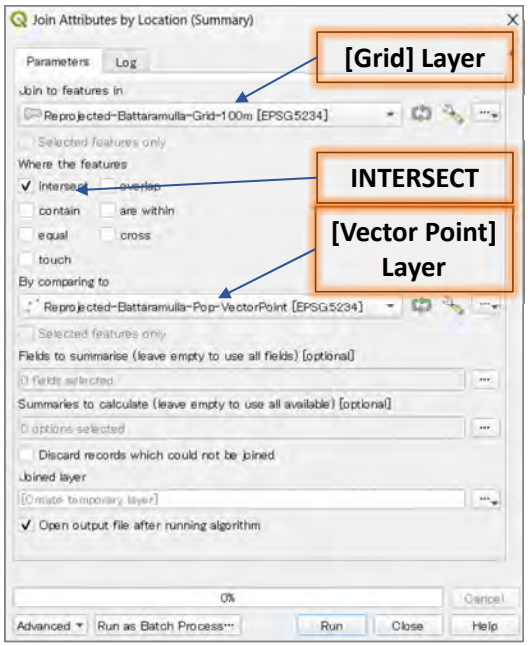
Application on Population Distribution

Road Density x Population Density

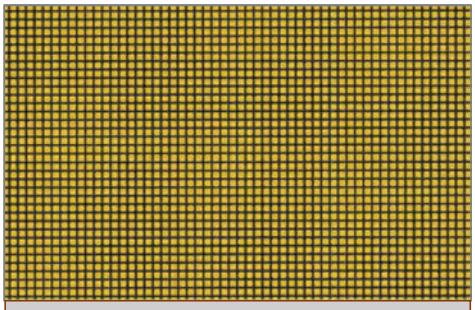
- Use Processing Tools > [Join Attributes by Location (summary)] to SUM the Population on each Grid 100mx100m



Overlay Population Point on Grid 100mx100m



OUTPUT



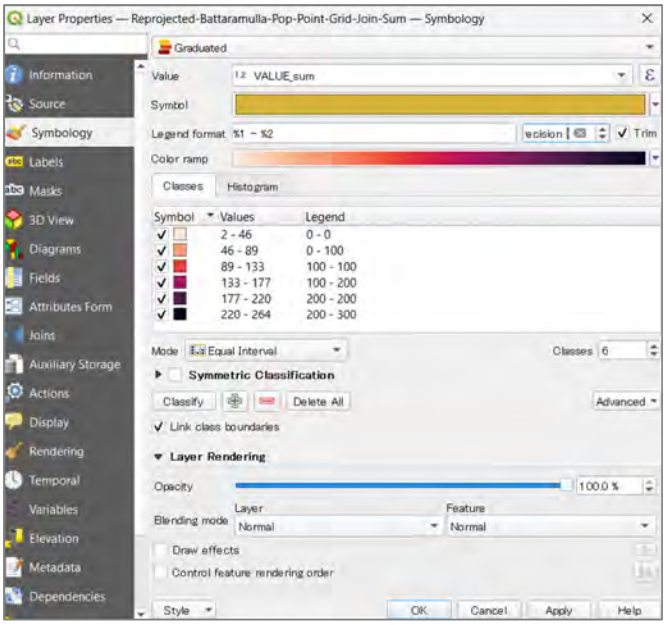
Every Grid contains **TOTAL number of population**

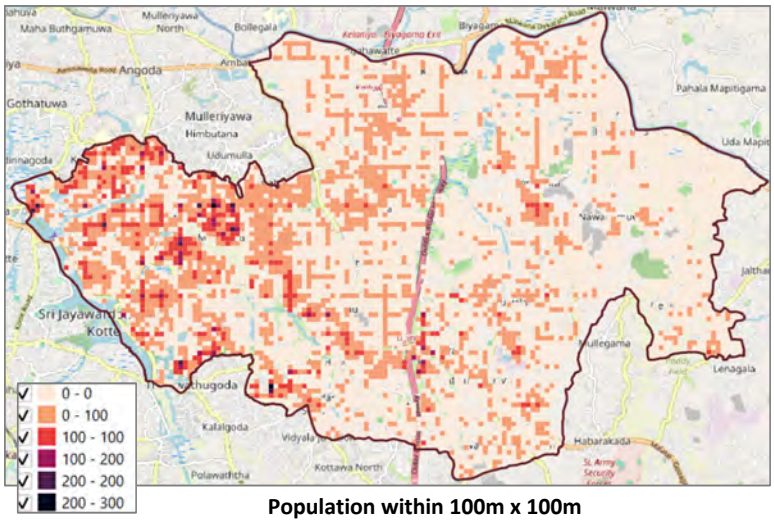
3. Further Evaluation

Application on Population Distribution

Road Density x Population Density

- Use Layer Properties > [Symbology] to visualize the population density





Population within 100m x 100m

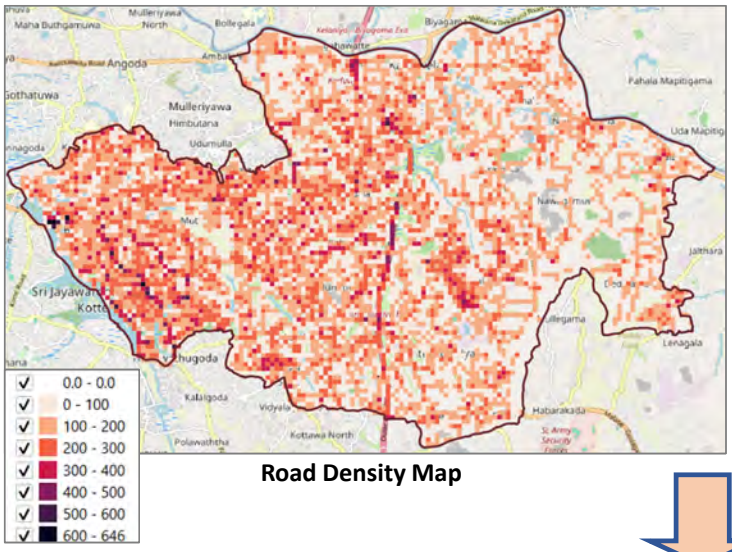
Project on Capacity Development for Urban Planning

3. Further Evaluation

Application on Population Distribution

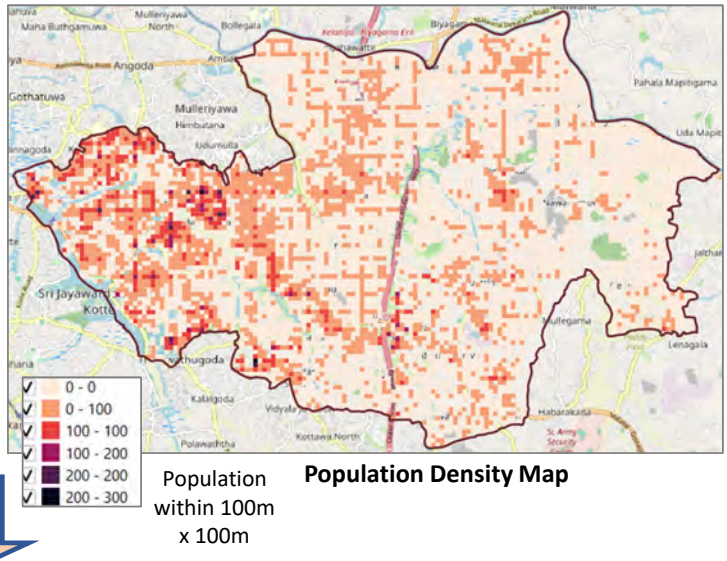
Road Density x Population Density

- OBSERVATION: Compare Road Density and Population Density within every Grid 100mx100m



Road Density Map

Road Length within 100m x 100m



Population within 100m x 100m

Population Density Map

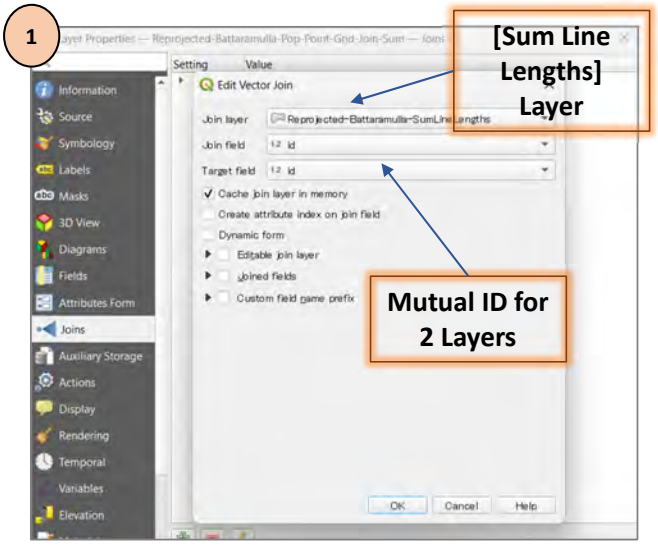
EVALUATION: Find Road Lengths per Population within every Grid 100mx100m

3. Further Evaluation

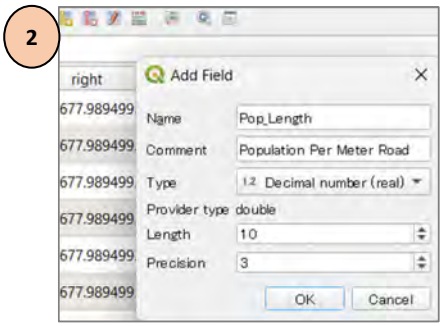
Application on Population Distribution

Road Density x Population Density

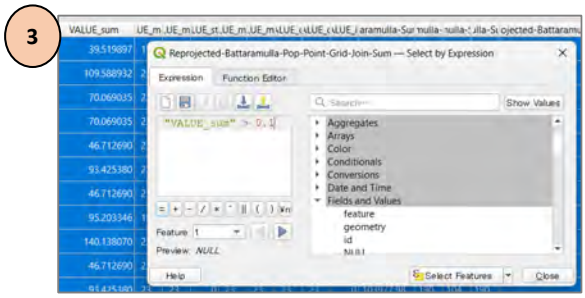
1) Use Layer Properties> [Joins] to join the layers of Road Lengths and Population within every 100m x 100m area



2) Add Field to for the result of Population by Road Lengths



3) Search for the field [Value_SUM] (Population) more than 0.1

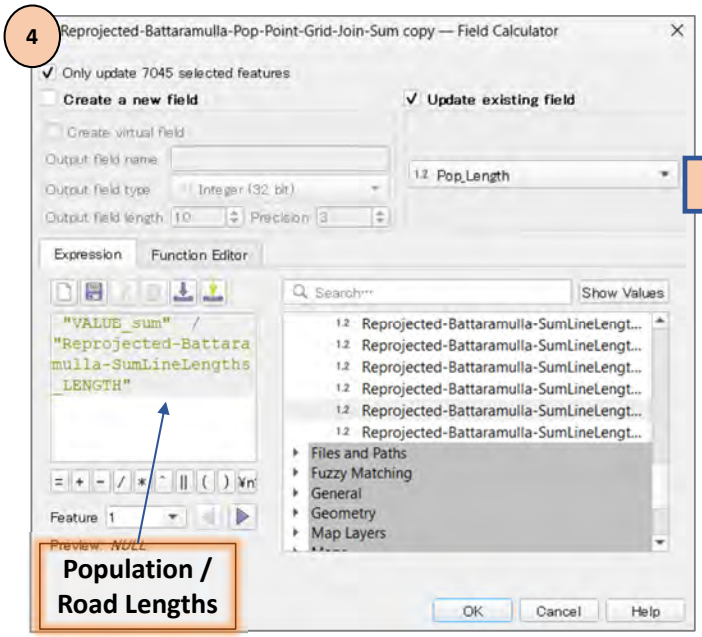


3. Further Evaluation

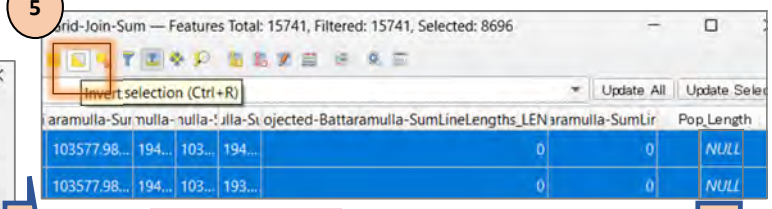
Application on Population Distribution

Road Density x Population Density

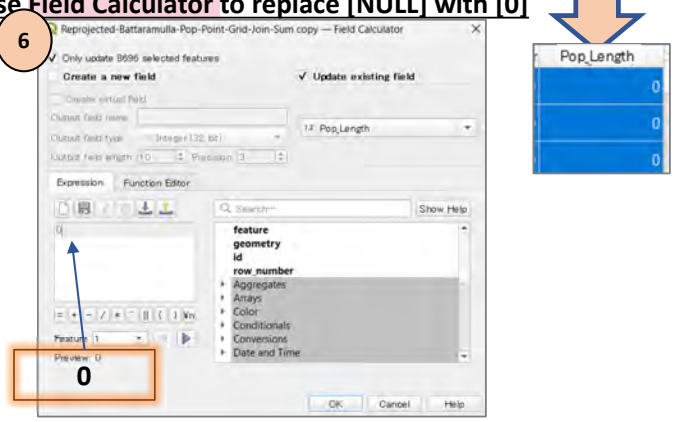
4) Use Field Calculator to calculate the Population Per Road Lengths within every 100m x 100m area



5) Use Invert Selection for the field [Pop_Length] (Population) with [NULL]



6) Use Field Calculator to replace [NULL] with [0]

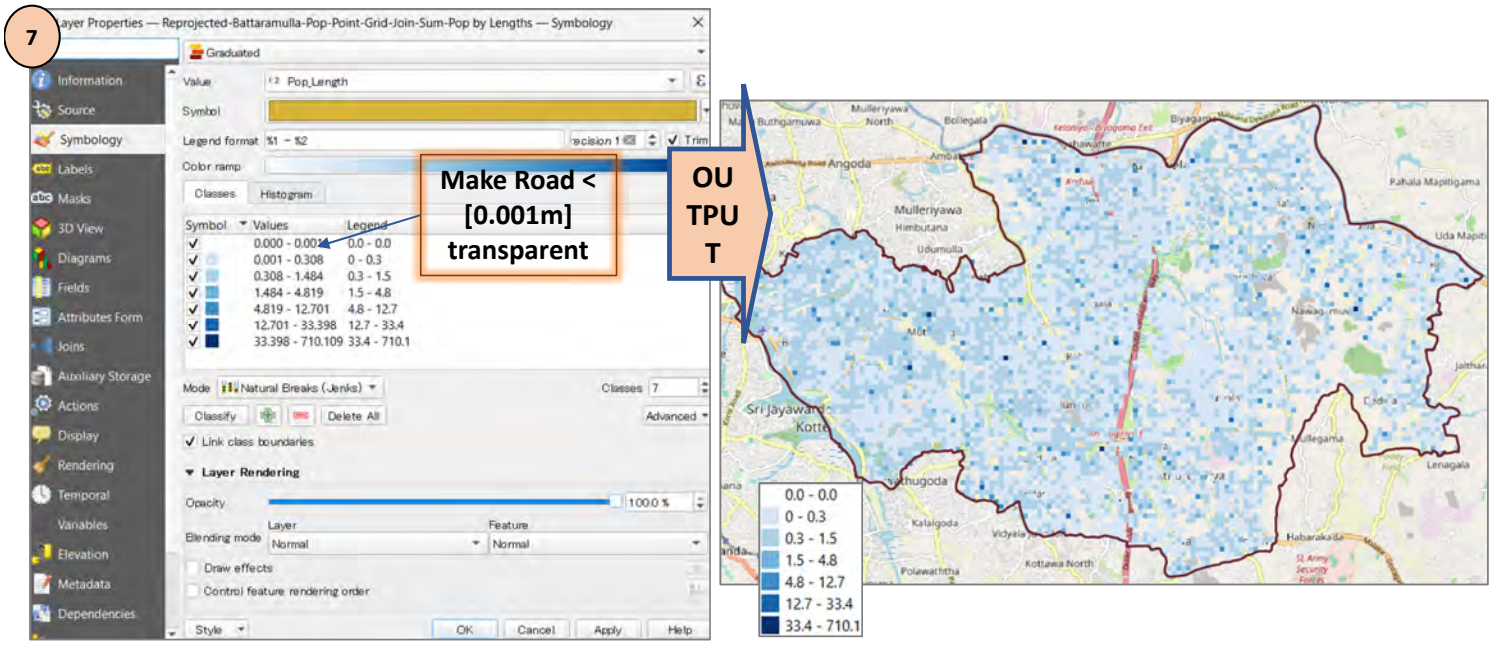


3. Further Evaluation

Application on Population Distribution

Road Density x Population Density

7) Use Layer Properties > [Symbology] to visualize the Population Per Road Lengths



3. Way Forwards

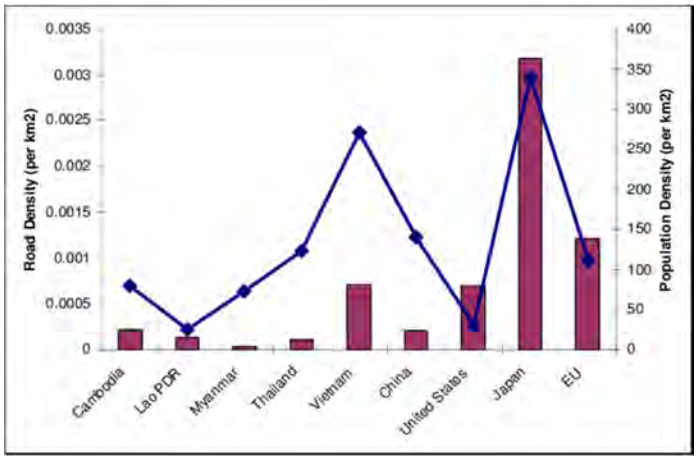
Further Studies

4. Way Forwards

Further Analysis

- Road Density x Population Density

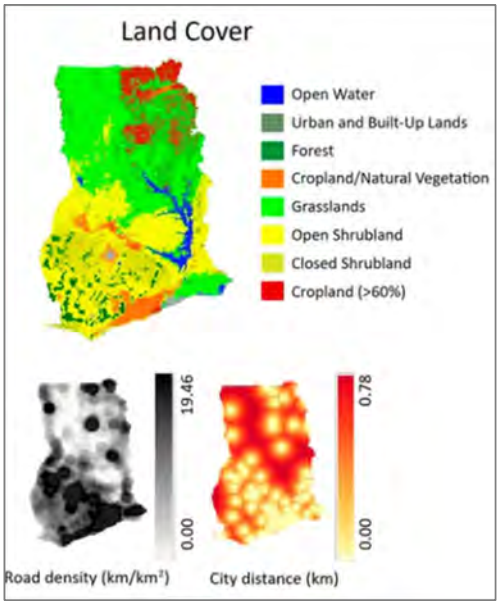
⇒ Traffic Capacity and Demand Analysis, Urban Planning



Source: https://www.researchgate.net/figure/Road-vs-population-density_fig1_46449241

- Road Density x Land Cover

⇒ Urban Planning Consideration



Source: https://www.frontiersin.org/journals/environmental-science/articles/10.3389/fenvs.2021.729266/full

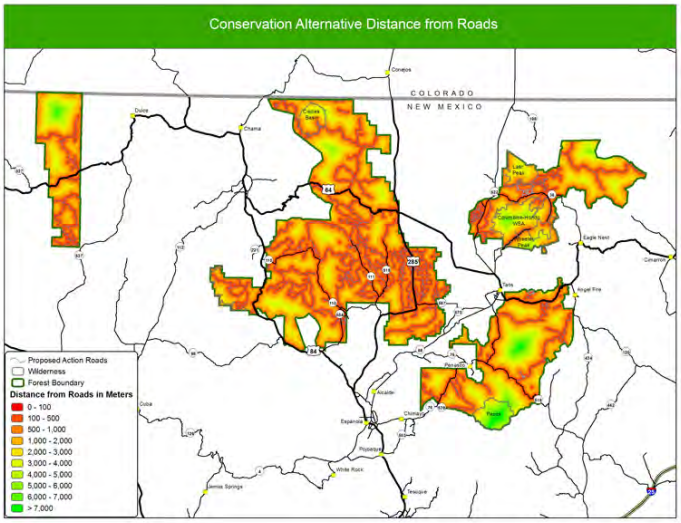
Project on Capacity Development for Urban Planning

4. Way Forwards

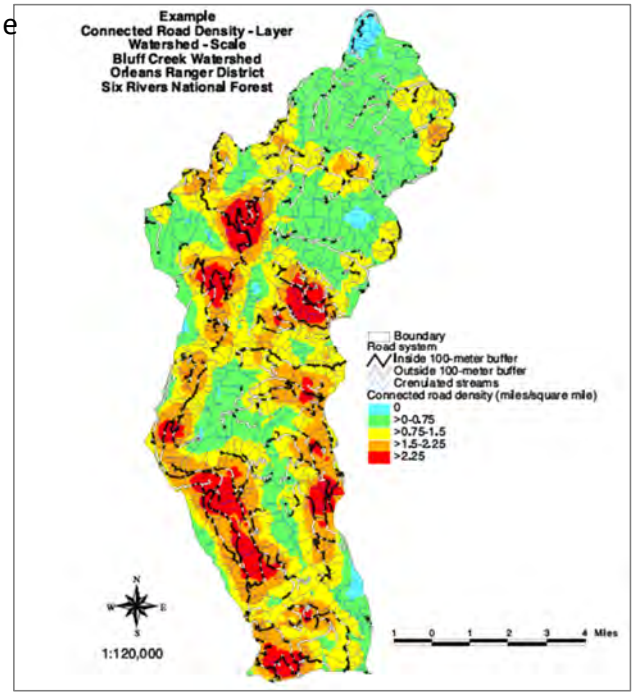
Further Analysis

- Road Density x Forest / DEM / Hazard / Flood/ Landslide

⇒ Natural Disaster Prevention & Protection



Source: https://www.biologicaldiversity.org/publications/maps/highlighted_maps/Carson_National_Forest_roads.html

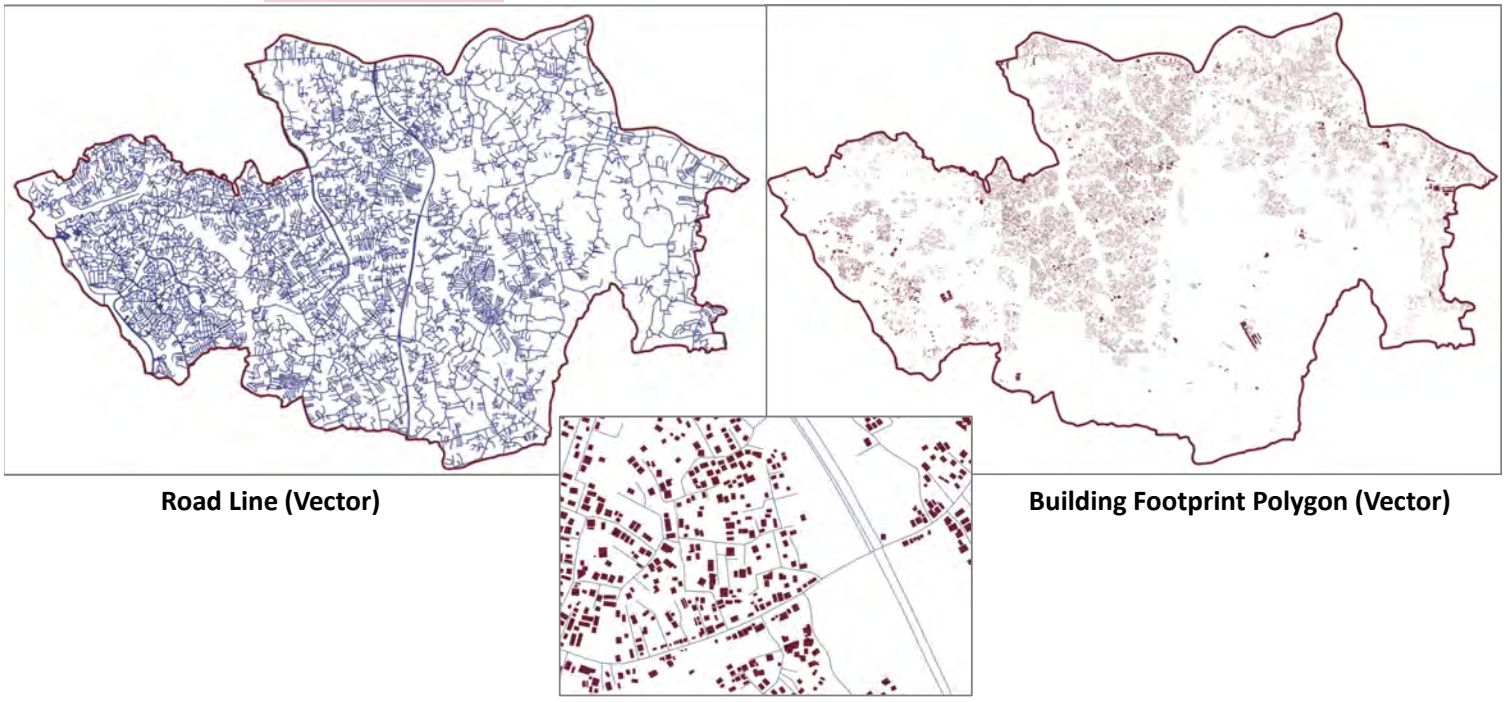


Source: https://www.fs.usda.gov/eng/road_mgt/appendix2/app2-g.pdf

4. Way Forwards

Further Analysis

Road Density x Building Density ⇒ How?



Road Line (Vector)

Building Footprint Polygon (Vector)

Project on Capacity Development for Urban Planning

PPT. No.11

Module LU3-2: Spatial Data Analysis by GIS

Urban Area estimation

Project on Capacity Development for Urban Planning in Sri Lanka

Urban Areas Estimation with Various Data

21 Mar. 2025

Training Outline

Ultimate Goal:

- Understand various usage of GIS techniques for Buttaramulla Guide Plan

To achieve the Ultimate Goal:

We will learn followings;

<Part 1: 30 min>
- Understand various sources to be as an urbanized area estimation
- Useful Open data

<Part 2: 30 min>
- 3D visualization with building footprint data
- Utilization of 3D Base map

<Part 3: 1h – 1.5h>
- Accessibility analysis (Service area analysis) with Network Analyst

Various GIS techniques will present today.
*But all those analysis require **spatial analysis ready** GIS data.*
When you analyze data, it is necessary to check the data is good enough quality for your analysis or not.

Part 1
Various Sources for Urban Areas Estimation

Various Sources for Urban Areas Estimation

1. Land use: Data by UDA

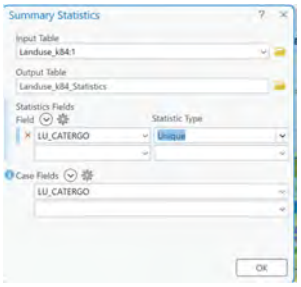
Categorize land use data in to "Urban" or "Rural"

<Non-urban>

LU_CATERGO	FG_Urban	FREQUENCY
Agriculture Land	2	40
Cemetry	2	13
Coconut	2	263
Forest	2	2
Marshy	2	144
Open Area	2	80
Other Plantation	2	65
Paddy	2	199
Plantation	2	1
Reservation	2	49
Rock	2	1
Rubber	2	201
Scrub	2	17
Up Rotted Rubber	2	3
Vacant Lands	2	972
Water Bodies	2	79

<Urban>

LU_CATERGO	FG_Urban	FREQUENCY
Bank & Allied	1	84
Com/Resi	1	66
Commercial	1	2987
Educational	1	256
Fill Lands	1	13
Health	1	127
Home Stead	1	107
Industrial	1	169
Institutional	1	109
Local Authority Roads	1	4494
Main Road	1	34
Mixed Lands	1	112
Other Roads	1	2686
Outer Circular Roads	1	2
Park & Play Ground	1	18
Play Ground	1	2
PRDA Roads	1	5
Private Roads	1	15
Recreational	1	2
Religious	1	170
Residential	1	3269
Socio-Cultural	1	69
Sports & Leisure	1	24
Stores & Ware House	1	42
Tourism	1	52
Transportation	1	7
Under Construction	1	972
Utility	1	49

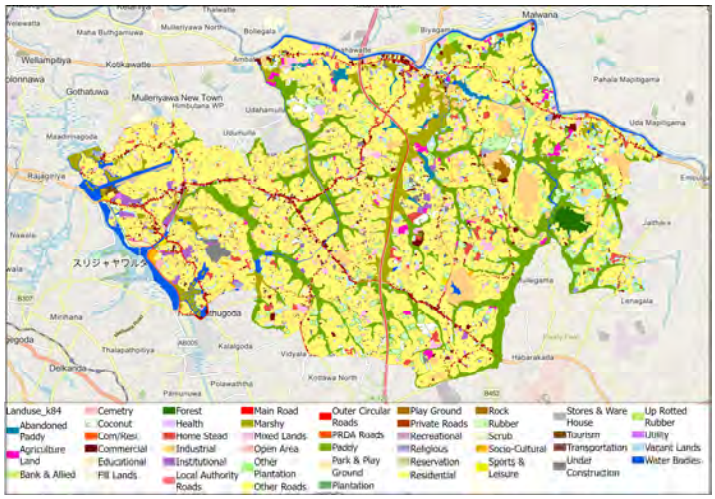


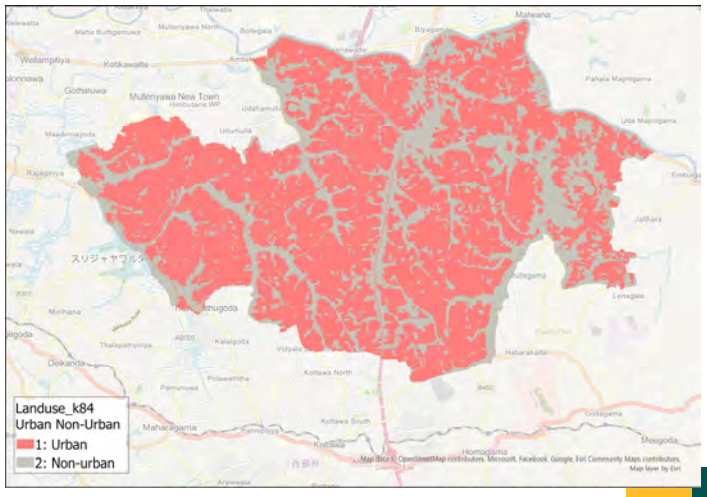
Various Sources for Urban Areas Estimation

1. Land use Categorize land use data in to “Urban” or “Rural”

- Based on Land use data with Urban area category, almost 70% of area is urban
- It fully rely on accuracy & definition of land use data

	Type	Area (ha)	%
1	Urban	6,042.8	68.8%
2	Non-Urban	2,744.1	31.2%



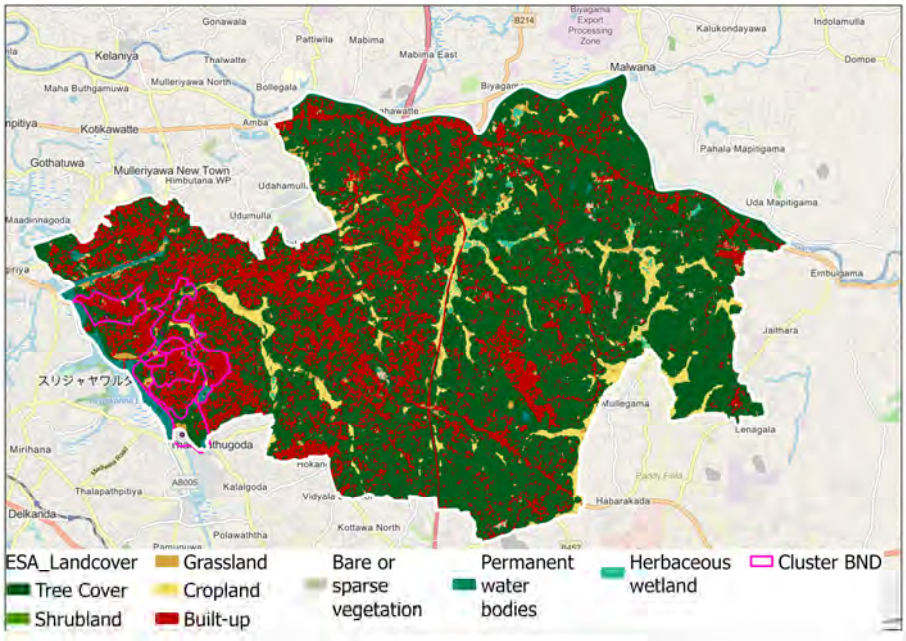


Project on Capacity Development for Urban Planning

Various Sources for Urban Areas Estimation

2. Land cover: by ESA 2021 (10m resolution)

- Based on Sentinel 1 & 2 data, this data provides a baseline global land cover
- Data includes 11 land cover classes at 10m resolution, one of class is “built-up”
- With ArcGIS Pro, you can access vis Living Atlas
- You can extract particular area of this raster data with “Extract by Mask” Tools in ArcGIS Pro



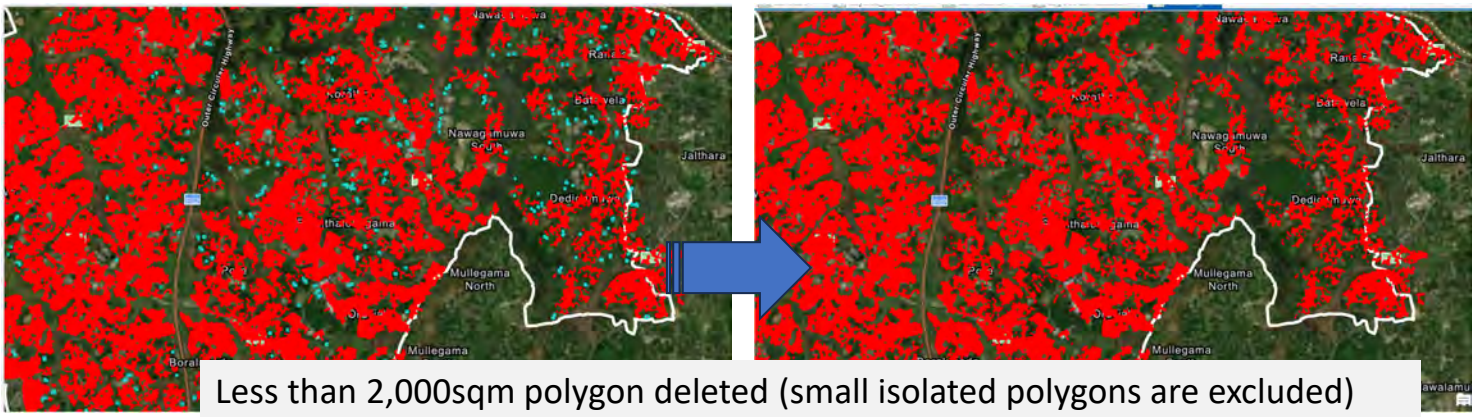
ClassName	
Tree Cover	64.1%
Shrubland	0.0%
Grassland	2.3%
Cropland	4.7%
Built-up	26.1%
Bare or sparse vegetation	0.3%
Permanent water bodies	2.0%
Herbaceous wetland	0.5%
	100.0%

The table above was prepared from the attribute table of this raster data.

Various Sources for Urban Areas Estimation

3. Building footprint: by UDA (Year unknown)

- Assuming areas where building footprint concentrates are urban areas
- It is depends on data accuracy of building footprint
- Use both outside buffer & inside buffer to clustering building footprint (To exclude isolated structures (small polygons) from urban areas)
- Buffer size should determine with ground condition (try & error process)



Less than 2,000sqm polygon deleted (small isolated polygons are excluded)

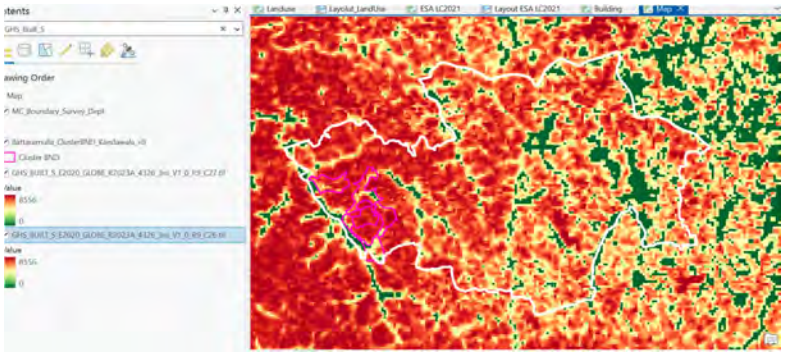
	Type	Area (ha)	%
1	Urban	4,145 ha	32.3%
2	Non-Urban	8,673 ha	67.7%

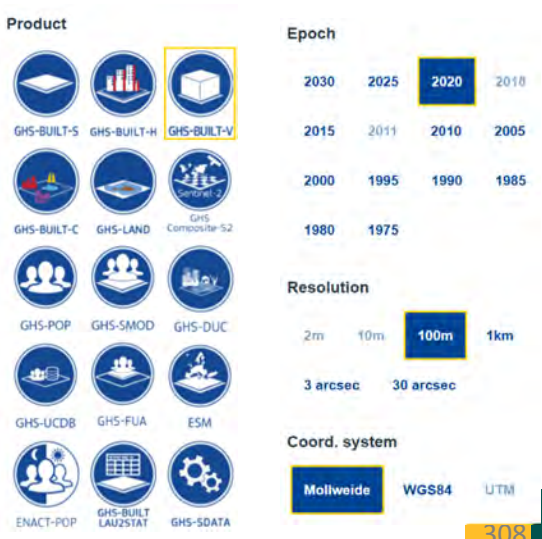
Project on Capacity Development for Urban Planning

Various Sources for Urban Areas Estimation

4. GHSL: Global Human Settlement Layer (by European Commission, Copernicus Project)

- Open and free data and tools for assessing the human presence on the planet
- One of key dataset is **Built-up-S/H/V** which indicate built-up areas. The data reports about the total built-up volume and the built-up volume allocated to dominant nonresidential (NRES) uses (chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://human-settlement.emergency.copernicus.eu/documents/GHSL_Data_Package_2023.pdf?t=1727170839)
- Base year is 2018 (10m), and 1975 – 2030 (100m) analytical data are available
- If you don't have any source to identify urban area, this data will help you





GHS-Built-S: Built-up Surface
Cell value is between 1- 10000, the value correspond to ratio of built-up surface (e.g. 7500=75% surface is built up)

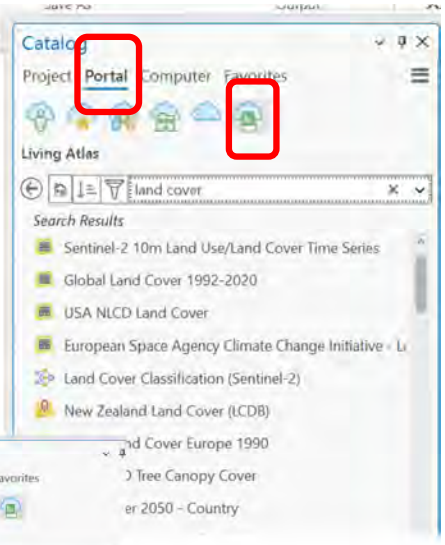
Something more (review from last year training)

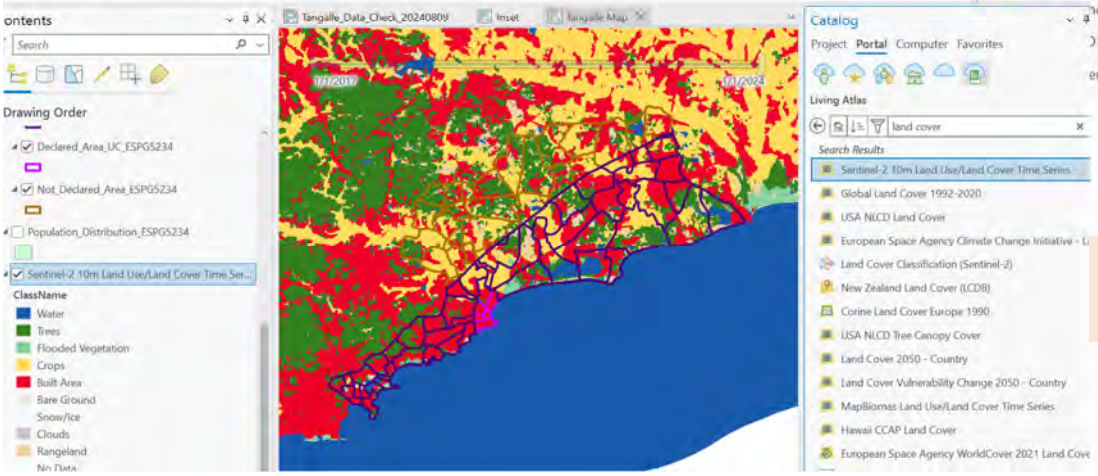
Living Atlas

The ArcGIS Living Atlas is a carefully selected, highly reliable collection of geographic information. This collection has been gathered from all over the world and continues to grow. This collection contains maps, apps, and data layers that can be used, adapted, and analyzed for your project.

But this is careful to use data in the living atlas, many of them are view only. If you want to sue for analysis/ export, need to check metadata/ properties of the data.

In addition to default basemap in ArcGIS Pro, this Living Atlas will be a one of alternatives of background image.





[ArcGIS Living Atlas of the World]

Project on Capacity Development for Urban Planning

Thank you very mush

ありがとうございます

PPT. No.12

Module LU3-2: Spatial Data Analysis by GIS

3D Visualization

Project on Capacity Development for Urban Planning

Project on Capacity Development for Urban Planning in Sri Lanka

3D Visualization with ArcGIS

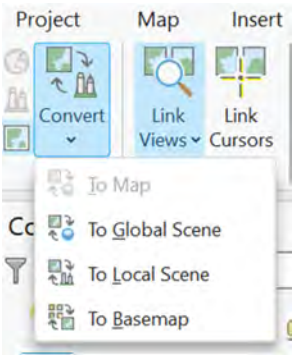
21 Mar. 2025

Part 2
3D Visualization with ArcGIS Pro

3D Visualization: Review

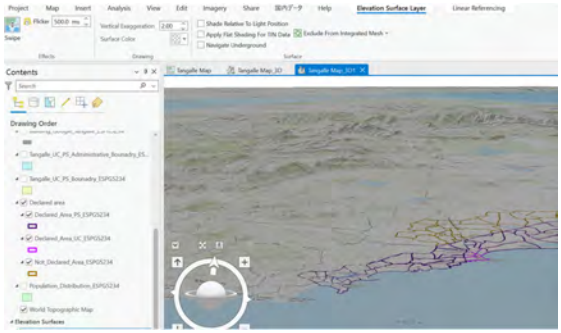
Convert 2D to 3D: Map to Scene

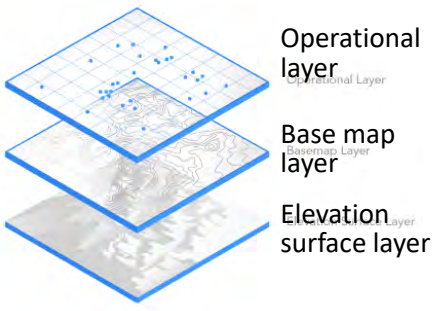
A scene allows you to visualize your data and analyze geographic information in an intuitive and interactive 3D environment. You can choose between a global or local scene to best display your data, such as airline flight patterns, campus facilities, or underground utilities.
In case of urban planning, basically use only “Local scene”.



Elevation Surface Layer

Once you create the scene, ArcGIS Pro automatically insert “Elevation Surface”. An elevation surface layer is a composite layer representing the ground surface or a custom surface. Elevation surface layers define the height values across the extent of a map or scene. Elevation surface layers contain one or more elevation source layers that contribute height values to the surface.



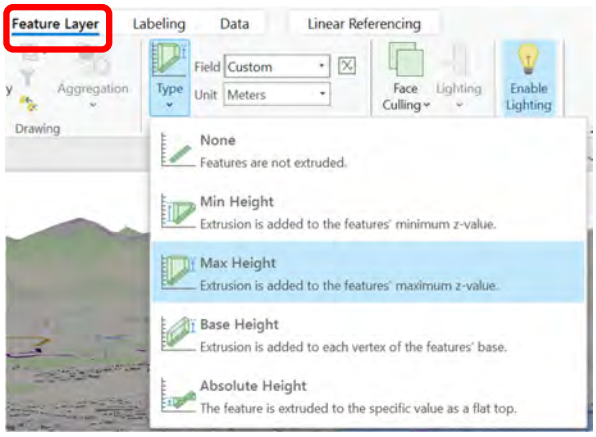


https://pro.arcgis.com/en/pro-app/latest/help/mapping/layer-properties/elevation-surface-layers.htm

3D Visualization: Review

2D map to 3D Seane

When you extrude a layer in the **2D Layers** category in the **Contents** pane, it is moved to the **3D Layers** category. You can only extrude a single layer at a time. If more than one layer is selected in the **Contents** pane, extrusion choices are unavailable. Extrusion is only available in scenes.





Project on Capacity Development for Urban Planning

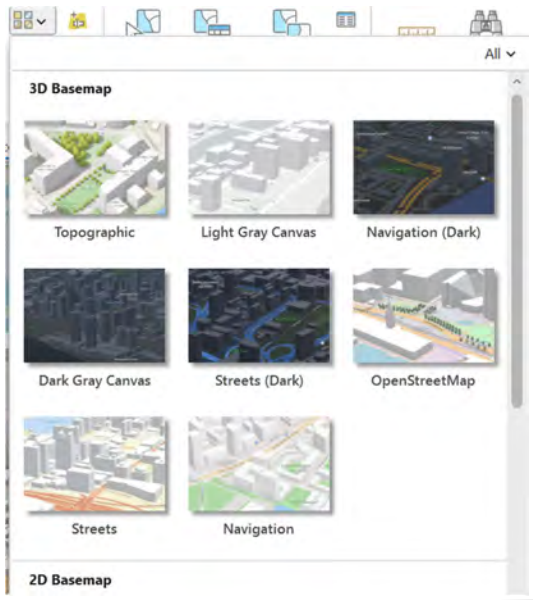
3D Visualization: Review

3D Bae map

3D base maps are available when you working on 3D Scene.

Item	Description	Minimum user type
3D Basemaps	An ArcGIS Pro project used by GIS analysts and technicians to create and maintain a 3D basemap for their organization	GIS Professional, Advanced

https://doc.arcgis.com/en/arcgis-solutions/11.1/reference/introduction-to-3d-basemaps.htm





3D base map using OSM

3D Visualization: Review

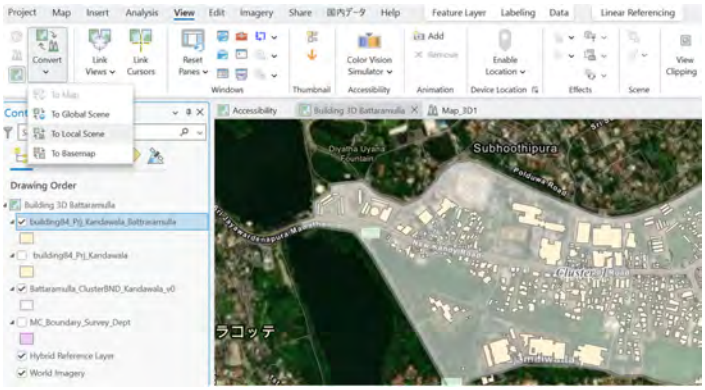
2D map to 3D Seane: Battaramulla Cluster 1 area

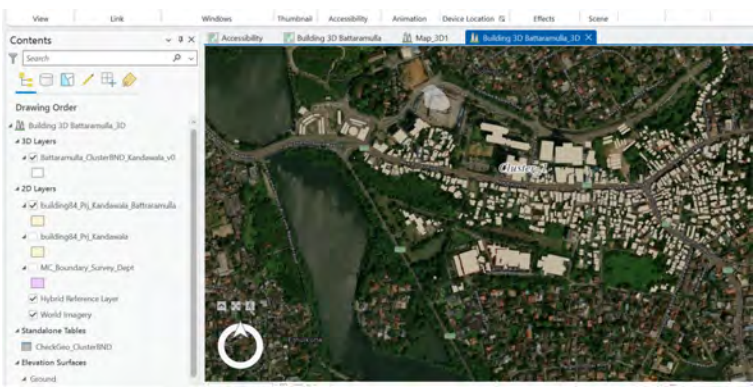
0. Preparation

- Make sure CRS
- Make sure the data would like to extrude has height information in the attribute table (This time data only has No. of Floors, so in this exercise, it is assumed that 1 floor = 3 m)
- Hight information field must prepared in numeric field

1. "View"-"VConvert to 2D map to 3D scene

- "View"-"Convert" select "To local scene"
- New 3D map tab is automatically open





Elevation layer automatically added by ArcGIS online

Project on Capacity Development for Urban Planning

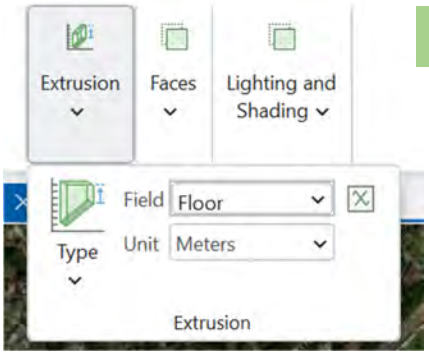
3D Visualization: Review

2D map to 3D Seane: Battaramulla Cluster 1 area

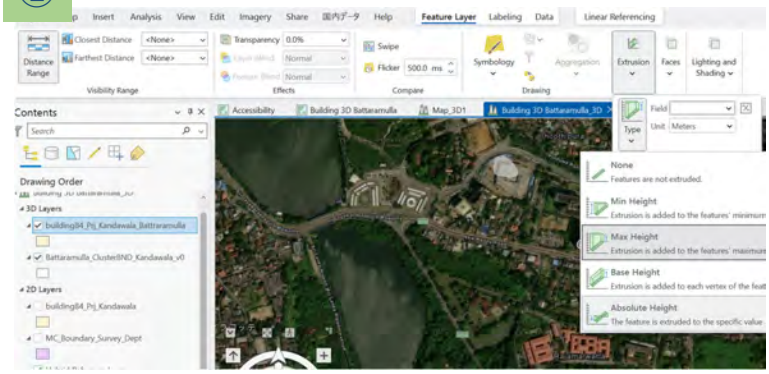
2. Extrude building footprints

① "Feature layer"- "Extrusion" – "Type" – "Max height"
② Set height info: select "Floor" field in the Field column, unit is "meter"
③ Assuming 1-floor is 3m for this training, open "expression builder" and input formular "**[Floor]*3**" (in case of VBScript)

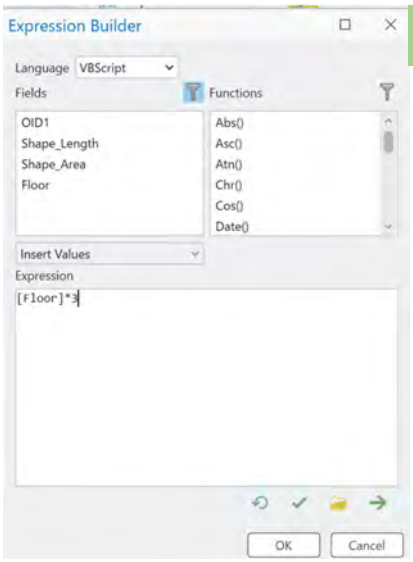
②



①



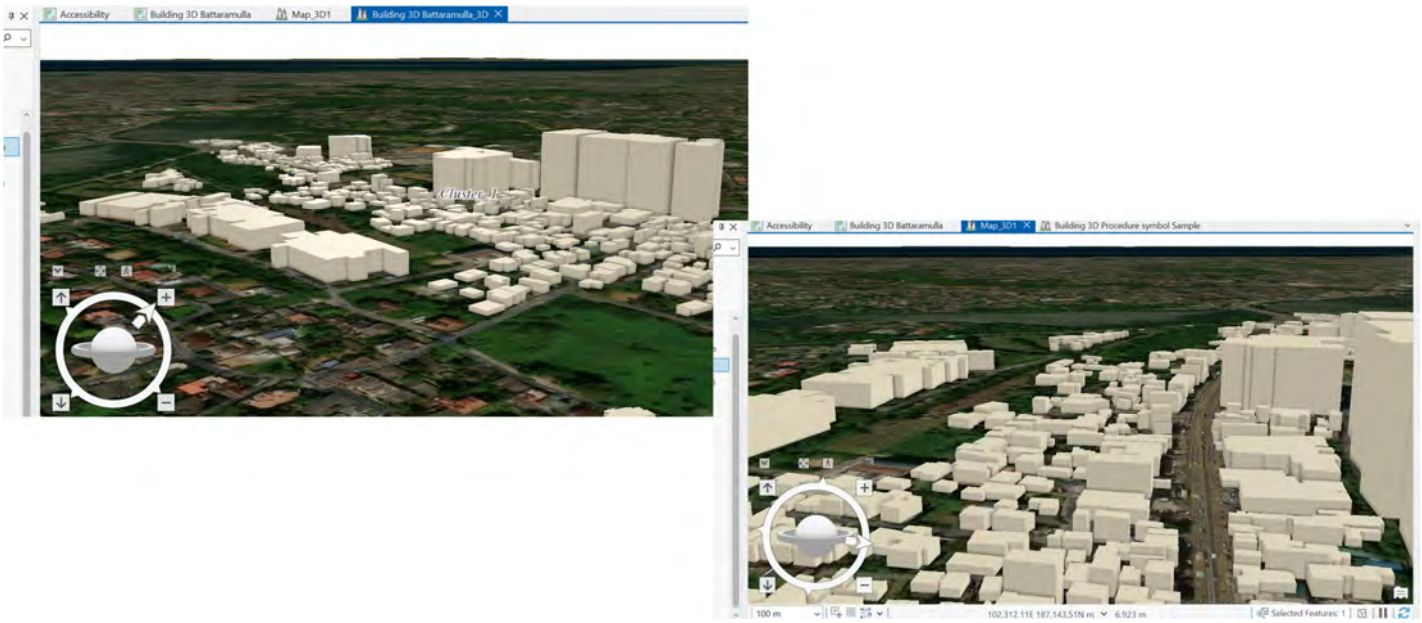
③



3D Visualization: Review

2D map to 3D Seane: Battaramulla Cluster 1 area

3. 3D visualization (1)

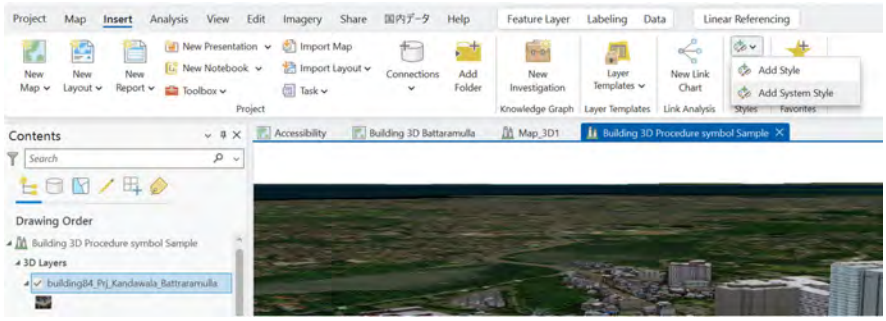


3D Visualization: Procedural Symbols

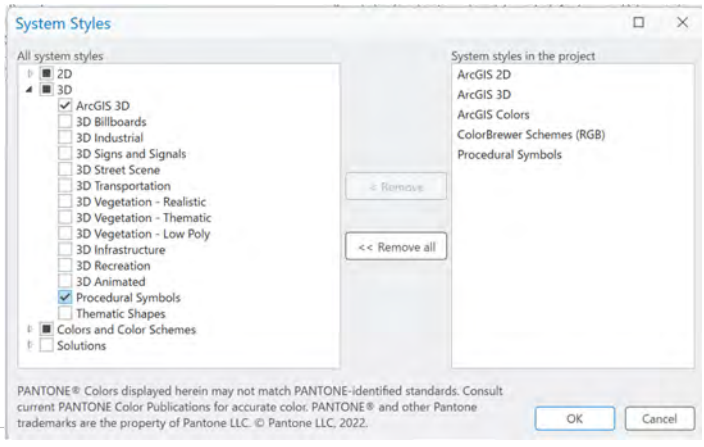
2D map to 3D Seane: Battaramulla Cluster 1 area

4. 3D visualization with Procedural Symbols (1): Utilize preset symbol to 3D Polygon

① Insert – Add System Style



② Select “Procedural Symbols”

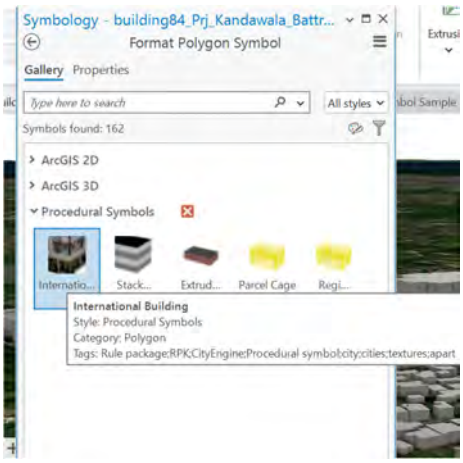


3D Visualization: Procedural Symbols

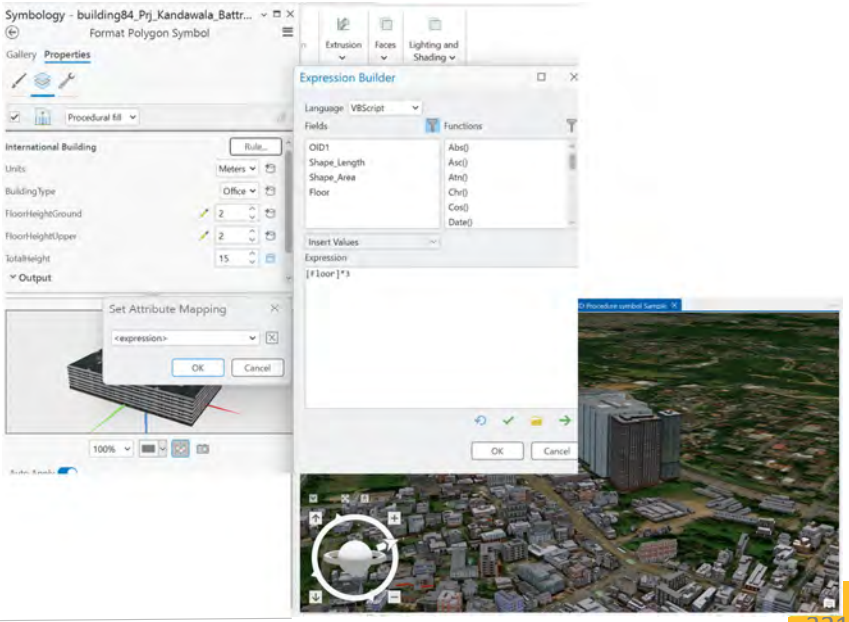
2D map to 3D Seane: Battaramulla Cluster 1 area

4. 3D visualization with Procedural Symbols (2): Utilize preset symbol to 3D Polygon

③ Symbology – Gallery - Procedural Symbol- International Building



④ Symbology – Properties: Set parameters



Project on Capacity Development for Urban Planning

3D Visualization: Procedural Symbols

2D map to 3D Seane: Battaramulla Cluster 1 area

4. 3D visualization with Procedural Symbols (3): Utilize preset symbol to 3D Polygon

⑤ 3D Building with procedural symbols (International building)



You can utilize other rule packages to produce procedural symbols from here: https://www.arcgis.com/home/search.html?restrict=false&sortField=relevance&sortOrder=desc&searchTerm=rule+package#content

Thank you very mush

ありがとうございます

Project on Capacity Development for Urban Planning

PPT. No.13

Module LU3-2: Spatial Data Analysis by GIS

Accessibility Analysis

Project on Capacity Development for Urban Planning in Sri Lanka

Accessibility Analysis

21 Mar. 2025

Network Analyst Basic:

Part 3
Accessibility Analysis with Network Analyst Extension

Network Analyst Review: What Can You Do by License Level?

You can perform some tasks that are related to the ArcGIS Network Analyst extension without the extension license; however, to have access to all of its functionality, the license must be enabled for the extension.

With Network Analyst	Standard	Can use all analysis tools Can edit/ build network dataset
	Basic	Can use all analysis tools Can't update (modify) network dataset
Without Network Analyst	Any License level	View properties of network datasets. View network dataset layers, including any associated traffic feeds. View network analysis layers. Change properties of network analysis layers.

Source: Licensing and the ArcGIS Network Analyst extension—ArcGIS Pro | Documentation

Why did CITY-UP procure ArcGIS Network Analyst extension at the Standard license rather than the Basic license ?

URC/UDA is the entity in charge of urban planning, and therefore needs to analyze not only the current condition, but also its own network that reflects the future road plan. To build your own Network Dataset for use in Network Analyst, you will need a Standard license. Standard license is required to build your own Network Dataset for use with Network Analyst.

Network Analyst Review: Types of Network Data for Network Analyst

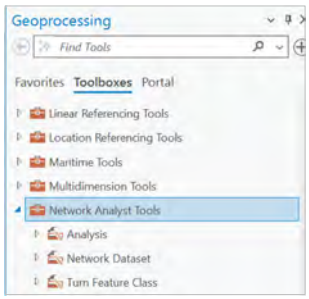
Road Network Data	Description	Extension	Credit Consumption
ArcGIS Online (https://www.arcgis.com)	Road network data provided by ArcGIS Online. It contains information on roads in most parts of the world, but please note that the accuracy may vary from country to country or region to region. The data can be used in an environment with an Internet connection. You can analyze with only existing road network.	Not Necessary	YES
Own Network Dataset	The road network data used in network analysis is created in the form of "network datasets". If you have the Network Analyst extension, you can create your own network datasets in ArcMap/ ArcGIS Pro You can include your future road plans	Network Analyst	NO

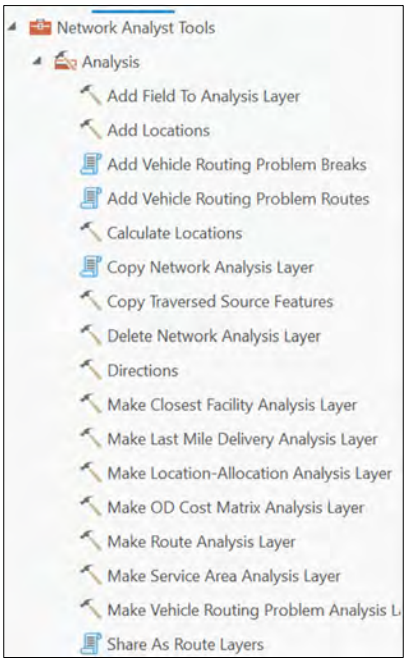
Network Analyst Review: Network Analyst Toolbox

There are 2-way to access network analyst tools:

1: From Geoprocessing window

2: From “Analysis” Tab – “Workflow” – “Network analysis”





Toolsets	Description
Analysis	The Analysis toolset contains tools used to perform analysis when using the ArcGIS Network Analyst extension. The toolset contains a variety of tools, including tools to create a network analysis layer and set its analysis properties for each solver provided with Network Analyst, tools to add network analysis objects to one or more network analysis classes, a tool to solve an analysis, and a tool to generate driving directions.
Network Dataset	The Network Dataset toolset contains tools used to perform network dataset maintenance tasks such as building and dissolving network datasets.
Turn Feature Class	The Turn Feature Class toolset contains tools used to build and edit turn data. The tools in the toolset allow you to create new turn feature classes, convert existing ArcView GIS or ArcInfo Workstation turn tables to turn feature classes, and maintain the integrity of existing turn features based on their geometry or an alternate ID field in cases when the reference source features are updated.

Network Analyst : Review of Building Network DS

Create Network DS : Review (Today we don’t build Network DS)

1. Make sure source road data is correct CRS
2. Preparation of “”cost” fields such as length, speed, travel time, etc.
3. Create Feature Dataset (Set correct CRS)
4. Import source road data into created feature dataset
5. “Create Network Dataset” tool
6. Remove created Network dataset from TOC
7. Setting parameters into Network dataset (e.g. travel attribute, hierarchy)
8. Build network

KADU_R84_Road_Kandawala

Field: Add Calculate Selection: Select By Attributes Switch

	Shape_Leng	RD_BL	PRD_WTH	New_Road	Name	Car_SPD	Wrk_SPD	TraTM_Car	TraTM_Wrk	Hierarch
1	67.315089	0	0			5	4	48.4669	60.5836	3
2	23.127904	0	0			5	4	16.6521	20.8151	3
3	311.625998	0	0			10	4	112.1854	280.4634	2
4	84.19779	0	0			5	4	60.6224	75.778	3
5	67.836682	0	0			5	4	48.8424	61.053	3
6	113.97067	0	0			5	4	82.0589	102.5736	3
7	123.885427	0	0			10	4	44.5988	111.4969	2
8	135.28818	0	0			10	4	48.7037	121.7594	2
9	148.65647	0	0			10	4	53.5163	133.7908	2
10	126.535627	0	0			10	4	45.5528	113.8821	2

Network Analyst : Case Study

<Your Mission>

You need to propose the location of LRT station to considering coverage population both by Car & by Walk

Result

Service coverage population table of proposed LRT stations

What you need to do

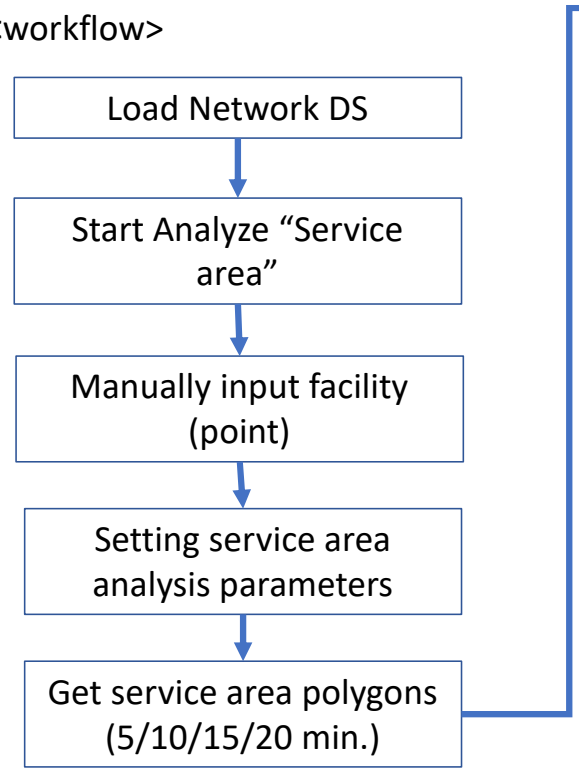
1. Set Alternative location(s) of Proposed LRT Station.
2. Analize service area from each station (5min., 10min., 15min., 20 min.) by Car/ by Walk
3. Analyze service coverage population per service coverage by Car/ by Walk
4. Identify the location of proposed LRT station that has most coverage population by Car/ by Walk

<Expected output>

Location: Proposed Station Alternative 1		
	by car	by Walk
5 min. area pop.	XXXXX	XXXXX
10 min. area pop.	XXXXX	XXXXX
15 min. area pop.	XXXXX	XXXXX
20 min. area pop.	XXXXX	XXXXX

Network Analyst : Case Study

<workflow>



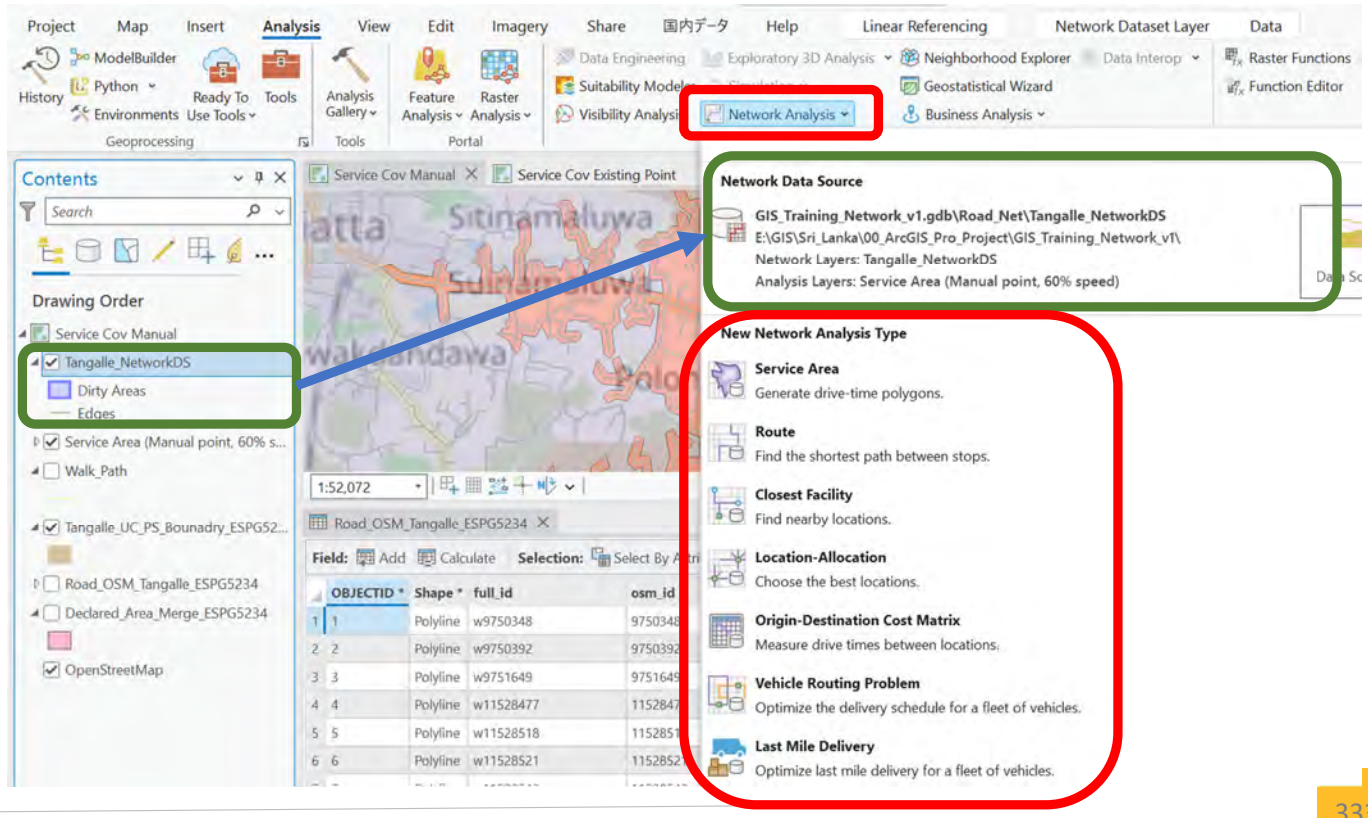
Location: Proposed Station Alternative 1		
	by car	by Walk
5 min. area pop.	XXXXX	XXXXX
10 min. area pop.	XXXXX	XXXXX
15 min. area pop.	XXXXX	XXXXX
20 min. area pop.	XXXXX	XXXXX

Network Analyst review: Network Analyst Toolbox

There are 2-way to access network analyst tools:

1: From Geoprocessing window

2: From "Analysis" Tab – "Workflow" – "Network analysis"

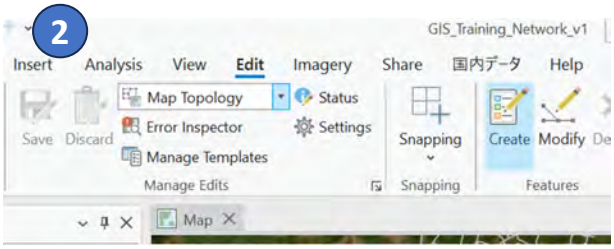


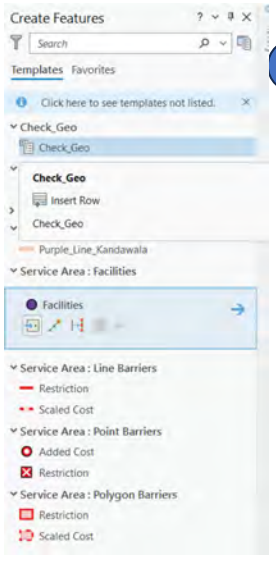
Network Analyst Basic: Perform Network Analysis

Network Analysis : Service Area (manually input facilities)

Analyze 5/ 10/ 15/ 20 min drive time areas from proposed LRT stations

1. From "Analysis" Tab – "Workflow" – "Network analysis"-"Service Area" (to create Service area layer)
2. Edit – "Create" in "Features group"
3. Select "Service area : Facilities"
4. Input the point
5. "Edit" Tab – "Save in Manage Edits"





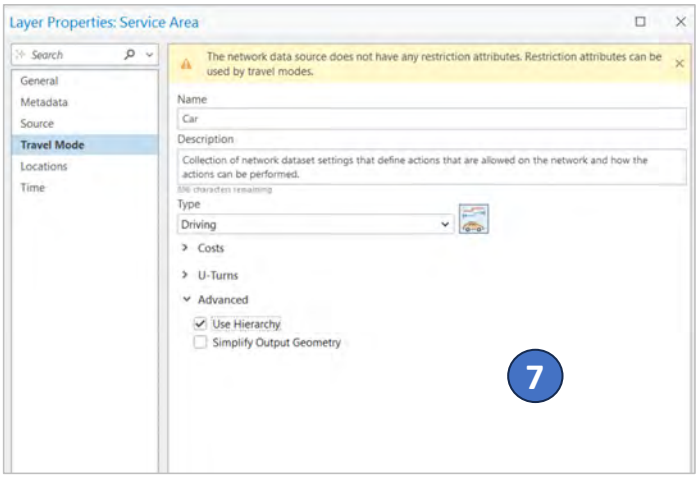


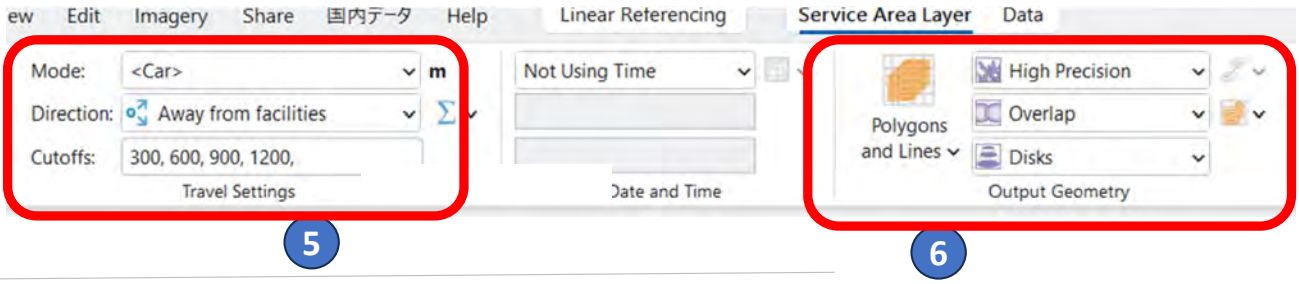
Network Analyst Basic: Perform Network Analysis

Network Analysis : Service Area (with manually input facilities)

Analyze 5/ 10/ 15/ 20 min drive time areas from proposed LRT stations

5. Service Area Layer – Travel Setting: Setting analysis parameters
6. Service Area Layer – Output Geometry: Setting output data parameters
7. Contents window – Right click “Service Area” - Properties, modify parameters, if necessary
8. Click “Run” to perform analysis



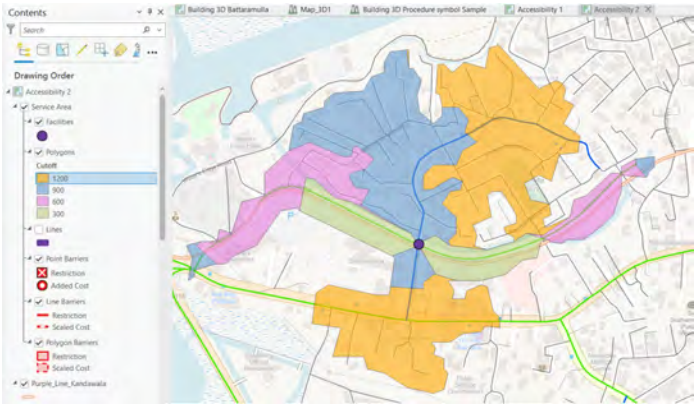


Project on Capacity Development for Urban Planning

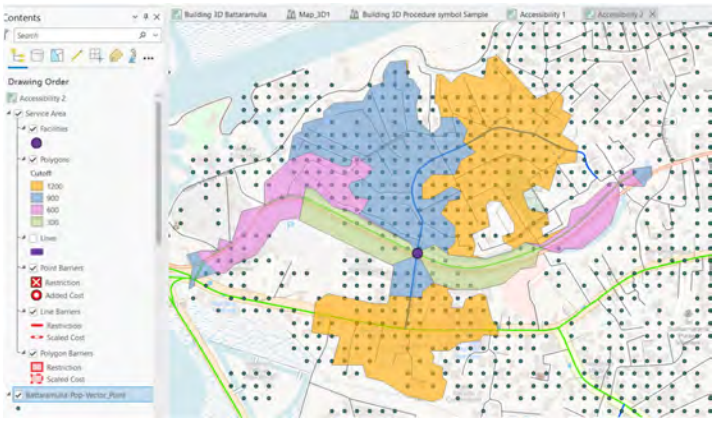
Network Analyst Basic: Perform Network Analysis

Network Analysis : Service Area (with manually input facilities)

Analyze 5/ 10/ 15/ 20 min drive time areas from proposed LRT stations



Result polygons:
5/10/15/20 min.



Result polygons 5/10/15/20 min.
with Population points

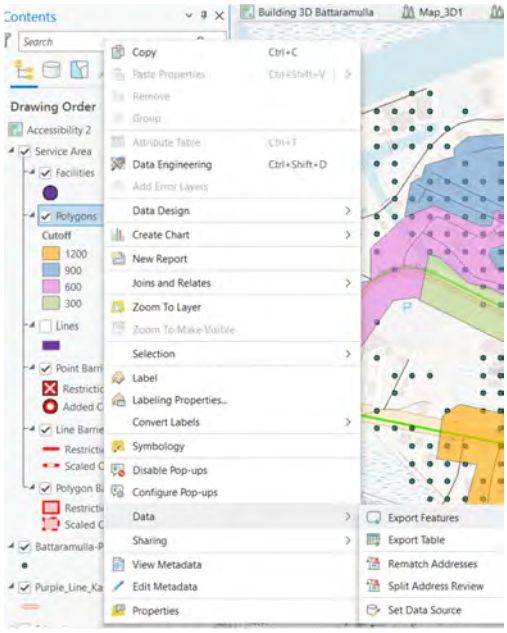
Overlay “Result Polygon” and “population points, then you can calculate coverage population

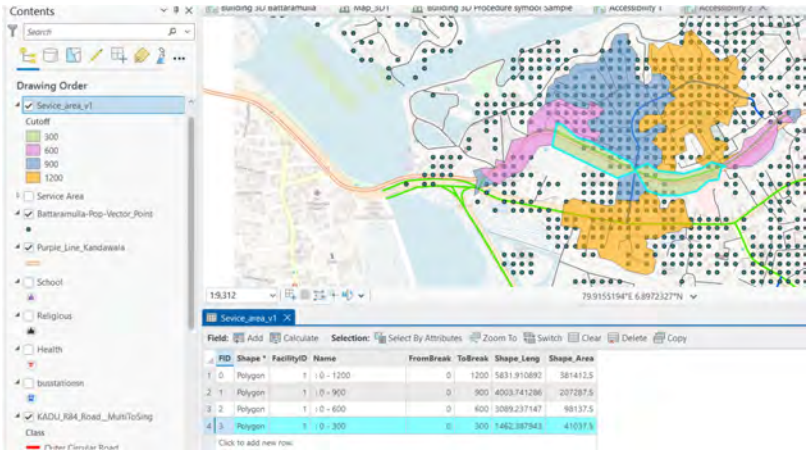
Network Analyst Basic: Perform Network Analysis

Network Analysis : Service Area (with manually input facilities)

Calculates 5/ 10/ 15/ 20 min drive time areas population

1. Export service coverage polygon





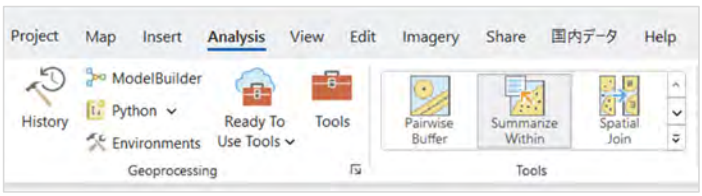
Project on Capacity Development for Urban Planning

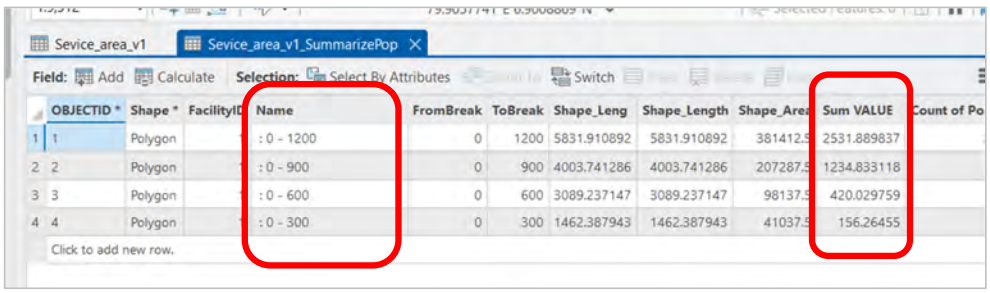
Network Analyst Basic: Perform Network Analysis

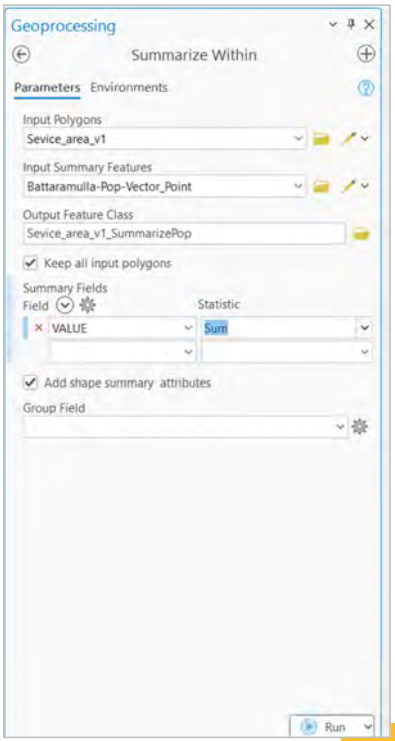
Network Analysis : Service Area (with manually input facilities)

Calculates 5/ 10/ 15/ 20 min drive time areas population

2. Calculate population by Service Cov.: Tool “Summarize Within” (Analysis – Tools)







Please calculate both “by Car” & “by Walk” to complete output table

Network Analyst Basic: Perform Network Analysis

Network Analysis : Service Area (with manually input facilities)

Calculates 5/ 10/ 15/ 20 min drive time areas population

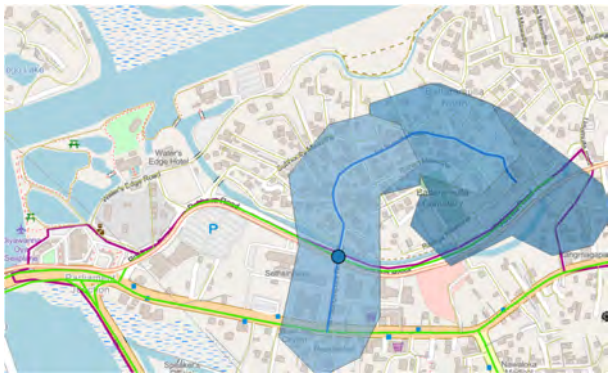
3. Create Table with MS Excel
- It is possible to copy & paste from attribute table of the result of "Summarize within"
- Analyze "by Walk" case and complete the analysis result table

Location: Proposed Station Alternative 1		
	by car	by Walk
5 min. area pop.	156.26	XXXXX
10 min. area pop.	420.03	XXXXX
15 min. area pop.	1,234.83	XXXXX
20 min. area pop.	2,531.89	XXXXX

Network Analyst : If you get strange result

If you get strange result : Review/ Examine Network data and Source data and clean errors!

1. If the analysis result is strange, most likely the source data has geometry or topological errors
2. To receive good quality analysis result, it is necessary to have good quality (= analysis ready) GIS data



Sample strange result:
Despite calculate 5/10/15/20 min. service coverage from blue point. But the service coverage was calculated only along the blue line.



All lines must be separated at intersections. But this line doesn't separate at intersection



Lines are not correctly connected

Thank you very mush

ありがとうございます

Training Manual (Technical Manuals)

PC1: How To Use Mentimeter

How to Use Mentimeter

March 2025

Prepared by JICA Expert Team
For Urban Development Authority

TABLE OF CONTENTS

PART 1. WHAT IS MENTIMETER? 1
1.1 What can we do with Mentimeter? 1
1.2 Differences in Plans 1
PART 2. CREATE SLIDES 2
2.1 Create an account 2
2.2 Launch “New Menti” 3
2.3 Select the type of slide 3
PART 3. INTERACTIVE QUESTIONS 5
3.1 Multiple Choice 5
3.2 Word Cloud 6
3.3 Open Ended 6
3.4 Scales 7
3.5 Ranking 8
3.6 Q and A 8
3.7 Guess The Number 9
3.8 100 Points 9
3.9 2 x 2 Grid 10
3.10 Pin on Image 10
PART 4. CONTENT SLIDES 11
4.1 Heading 11
4.2 Paragraph 11
4.3 Bullets 12
4.4 Image 12
4.5 Video 12
4.6 Big 13
4.7 Quote 13
4.8 Number 13
4.9 Instructions 14
PART 5. TECHNIQUES FOR SMOOTH MEETING OPERATION 15
5.1 Start timer 15
5.2 Show joining instruction 15
5.3 Hide responces 15
PART 6. CONDUCT AN ONLINE SURVEY 17
6.1 Purpose of the online survey 17
6.2 Online survey methodology 17
PART 7. USE THE RESULTS FOR PLANNING 19

LIST OF FIGURES

Figure 1.2.1: Price list 1
Figure 2.1.1: Web site home page 2
Figure 2.1.2: Web site sign-up page 2
Figure 2.2.1: Home page after logging in 3
Figure 2.3.1: Slide creation page 3
Figure 2.3.2: Slide types 4
Figure 3.1.1: Sample responses to Multiple Choice 5
Figure 3.1.2: Various layouts of Multiple Choice 5
Figure 3.2.1: Sample responses to Word Cloud 6
Figure 3.3.1: Sample responses to Open Ended 6
Figure 3.4.1: Sample responses to Scales (Bar chart) 7
Figure 3.4.2: Sample responses to Scales (Spider chart) 7
Figure 3.5.1: Sample responses to Ranking 8
Figure 3.6.1: Sample responses to Q and A 8
Figure 3.7.1: Sample responses to Guess The Number 9
Figure 3.8.1: Sample responses to 100 Points 9
Figure 3.9.1: Sample responses to 2 x 2 Grid 10
Figure 3.10.1: Sample responses to Pin on Image 10
Figure 4.1.1: Entry example of Heading 11
Figure 4.2.1: Entry example of Paragraph 11
Figure 4.3.1: Entry example of Bullets 12
Figure 4.4.1: Entry example of Image 12
Figure 4.5.1: Entry example of Video 12
Figure 4.6.1: Entry example of Big Text 13
Figure 4.7.1: Entry example of Quote 13
Figure 4.8.1: Entry example of Number 13
Figure 4.9.1: Entry example of Instructions 14
Figure 5.3.1: Major commands that can be used while displaying Menti 15
Figure 5.3.2: All commands that can be used while displaying Menti 16
Figure 6.2.1: Example of a poster 18
Figure 6.2.1: Download page 19
Figure 6.2.2: Workflow from opinion gathering to reflection of plan content 19

Part 1. WHAT IS MENTIMETER?

1.1 What can we do with Mentimeter?

Mentimeter is a service that allows the opinions of meeting participants to be collected and aggregated in real time. Participants' opinions are immediately reflected on the host's presentation screen, and can be edited and published on the Web, so they can be used not only on PCs, but also on tablets, smartphones, and other devices.

PowerPoint and Keynote are applications in which the presenter speaks one-sidedly while showing pre-determined slides. Mentimeter, on the other hand, is an interactive application that allows meeting participants to answer a survey via smartphone or tablet during the presentation and immediately reflect the results.

1.2 Differences in Plans

Mentimeter has four plans: a free version and a paid version (Basic, Pro, and Enterprise). The differences in what these four types can do are shown on the official website below.

https://www.mentimeter.com/plans

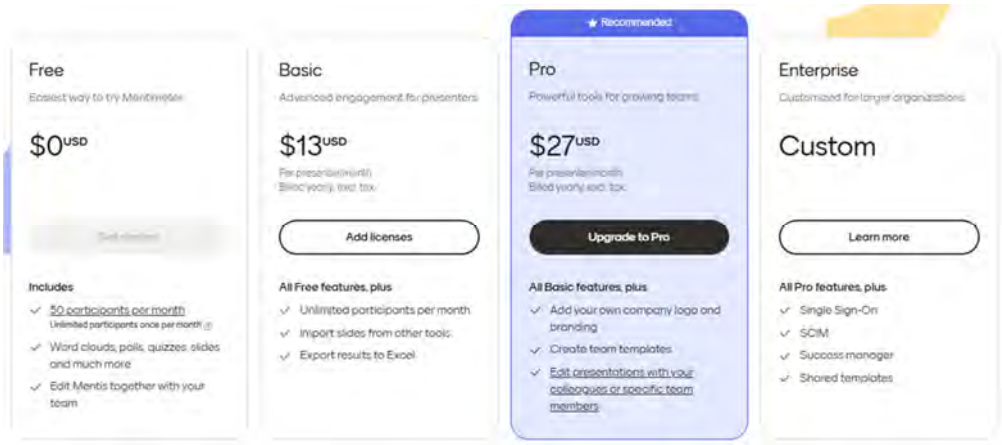


Figure 1.2.1: Price list

The major differences between the free and paid versions are as follows. In the Pro and higher versions, it allows.

1. The free version allows only two question slides per presentation. On the other hand, the paid version allows any number of question slides per presentation.
2. The free version can only output response results in PDF format, but the paid version can output them in Excel format, shortening the data input process after the meeting. It can also output a summary of the data, making data processing easy.

While more features are added in the Pro and higher versions, surveys and interviews conducted during the CITY-UP project led to the conclusion that the features of the Basic version would be sufficient for stakeholder meetings conducted by the UDA.

Part 2. CREATE SLIDES

2.1 Create an account

Connect to the official Web site of mentimeter at the following URL

https://www.mentimeter.com/

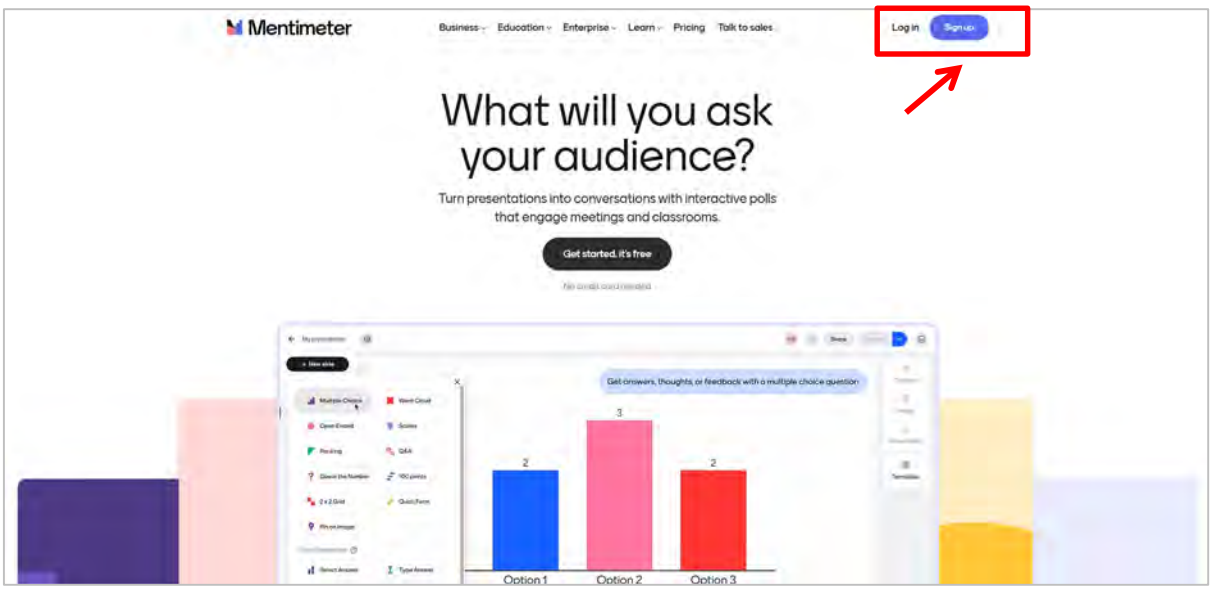


Figure 2.1.1: Web site home page

Sign up and select any plan by linking your existing service account or creating Mentimeter account. As mentioned above, the Free Plan is limited to two quizzes per presentation, so the Basic Plan is preferred as a minimum for smooth meeting operations.

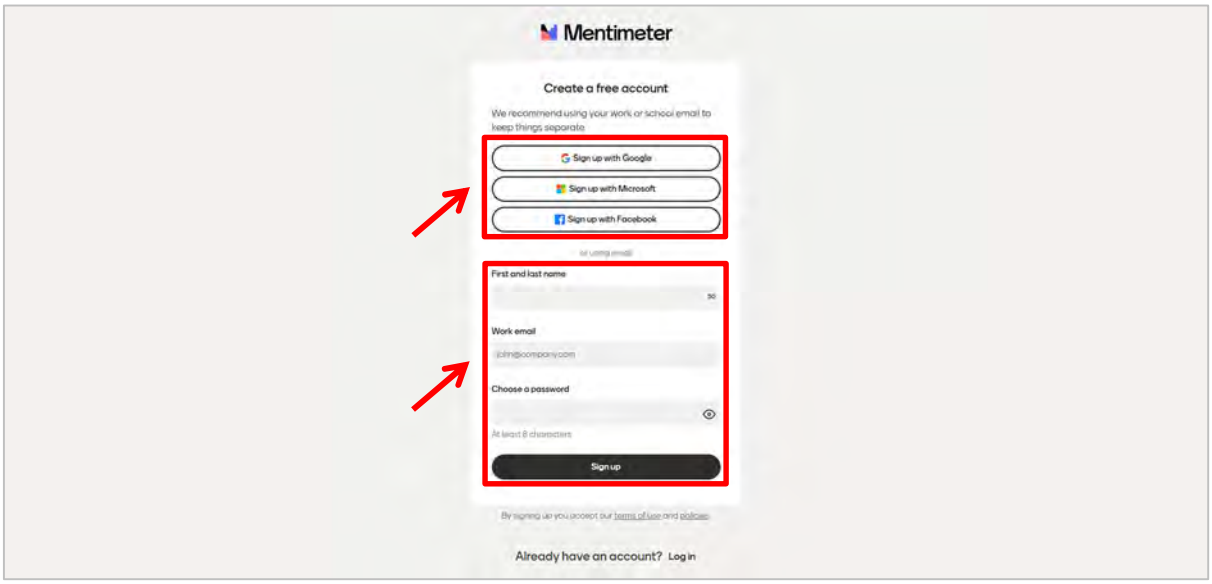


Figure 2.1.2: Web site sign-up page

2.2 Launch “New Menti”

After logging in, you will see the following page and click “New Menti” Menti is like a file in PowerPoint, and you can create multiple slides in a Menti. Menti, unlike PowerPoint, are all stored in the cloud.

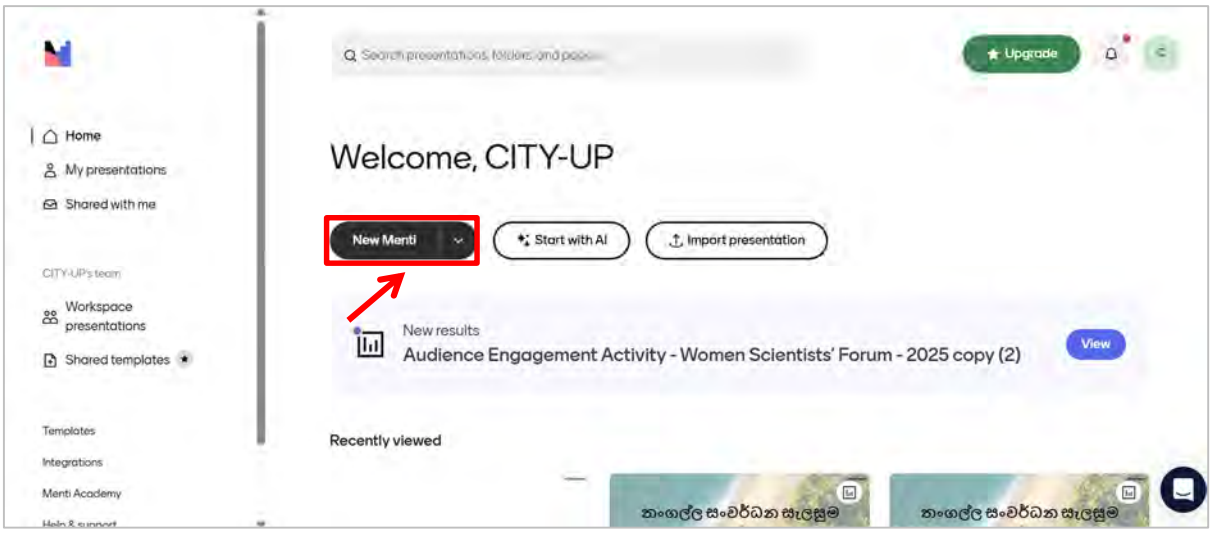


Figure 2.2.1: Home page after logging in

2.3 Select the type of slide

Click on “Untitled presentation” and give the presentation a name of your choice. Click “+New slide” and select the slide format that best suits your purpose.

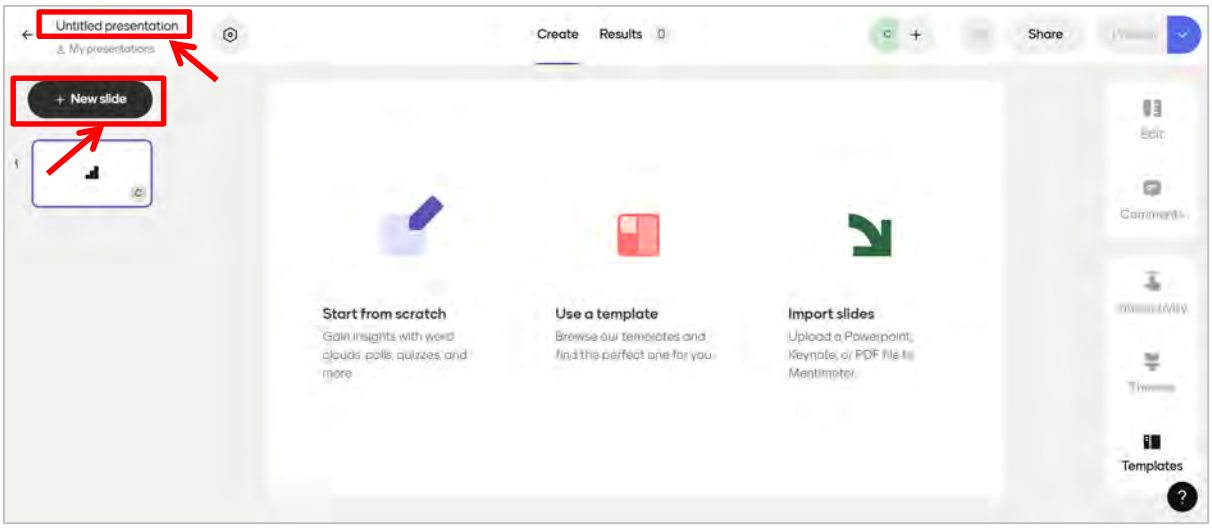


Figure 2.3.1: Slide creation page

As of March 2025, when this manual was prepared, there were 23 Slide types, and Slide types can be broadly divided into the following three categories. The next section describes the outline of “Interactive questions” and “Content slides”.

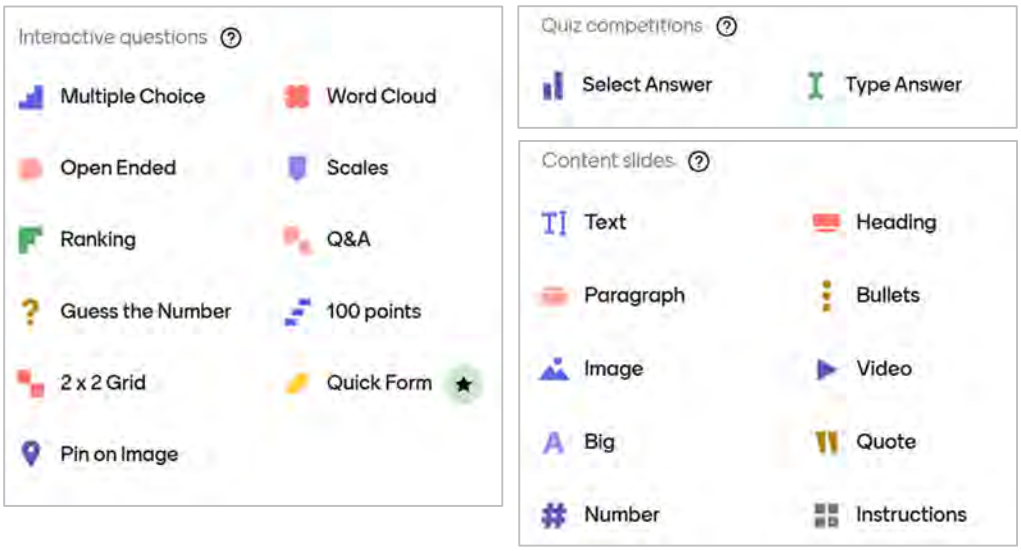


Figure 2.3.2: Slide types

Part 3. INTERACTIVE QUESTIONS

3.1 Multiple Choice

The presenter prepares the choices in advance. Participants select one or more options. The results of the choices are displayed in a graph. Any number of choices can be added. In addition to bar graphs, doughnut, pie, and dot graphs can be used in the layout settings.

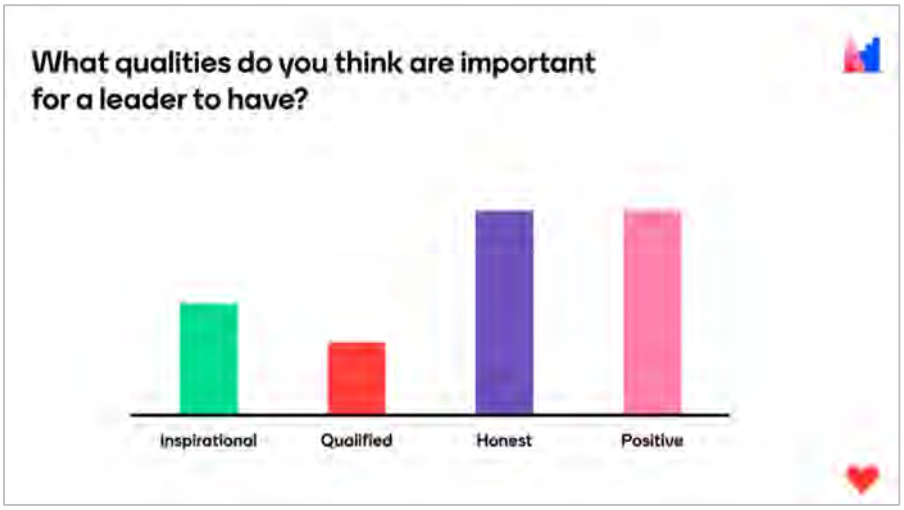


Figure 3.1.1: Sample responses to Multiple Choice

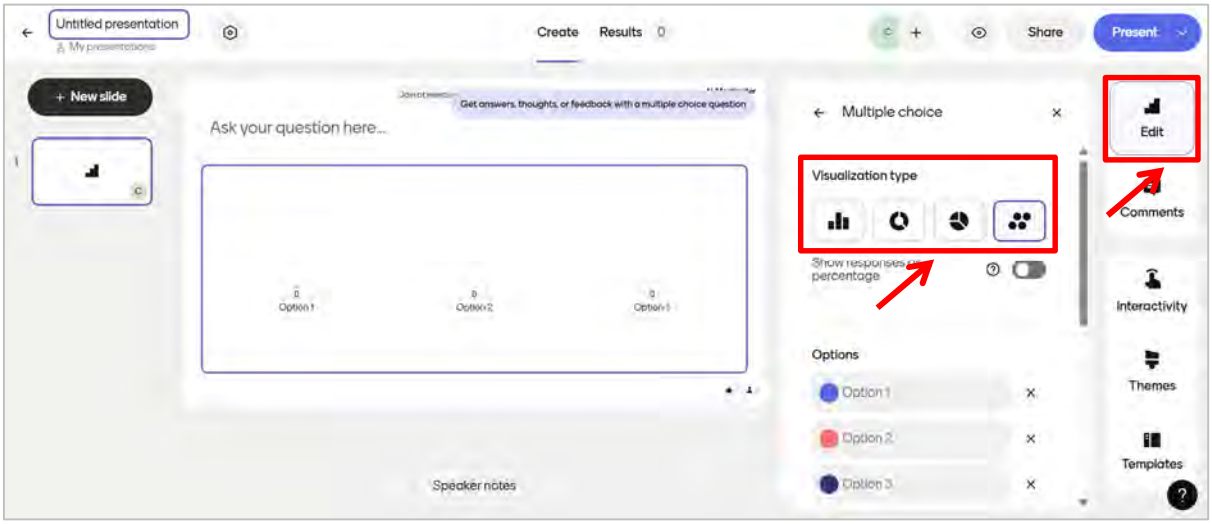


Figure 3.1.2: Various layouts of Multiple Choice

3.2 Word Cloud

The presenter does not prepare choices in advance. Participants respond with any short word choice. The most frequent response results are placed in a larger font size and in the center of the Cloud. By specifying a maximum number of words when asking participants to respond, it is easier to get a sense of the results. For example, it prevents respondent A from sending a one-word response and respondent B from sending a five-word response.



Figure 3.2.1: Sample responses to Word Cloud

3.3 Open Ended

The presenter does not prepare options in advance. Participants can send questions and opinions in short sentences. The presenter accepts those questions and opinions and responds verbally in real time. It is not a topic that requires discussion, but is expected to be used to resolve simple questions before entering into a discussion.

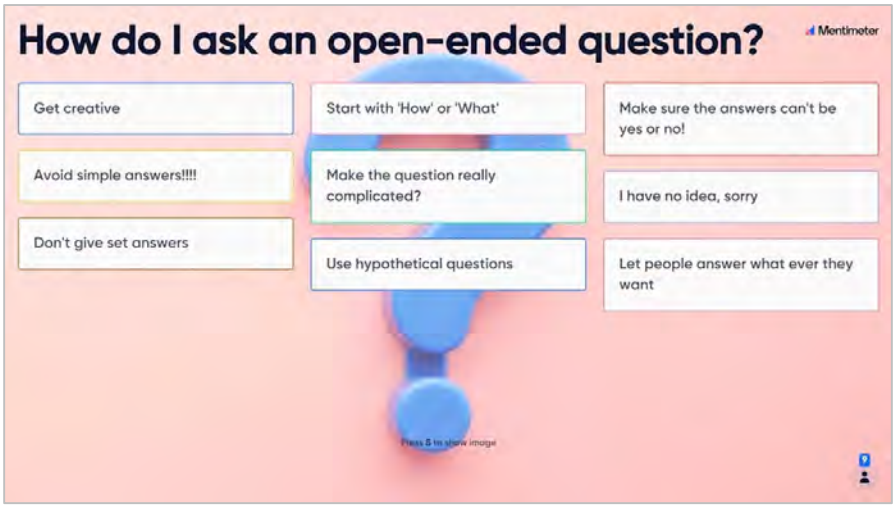


Figure 3.3.1: Sample responses to Open Ended

3.4 Scales

The presenter prepares the choices in advance. Participants respond to the choices with numerical values for their satisfaction, preferences, etc. The layout can be set up to use a spider chart as well as a bar chart.

In the case of a bar chart, the number represents the average of the responses, and the distribution of the individual responses is indicated by a slope diagram behind the number.

In the case of the spider chart, the distribution of responses is not shown, but it is possible to highlight what are the highly rated options and what are the disadvantages. (However, the distribution of responses can be temporarily displayed by hovering the mouse over the dots that indicate numerical values.)

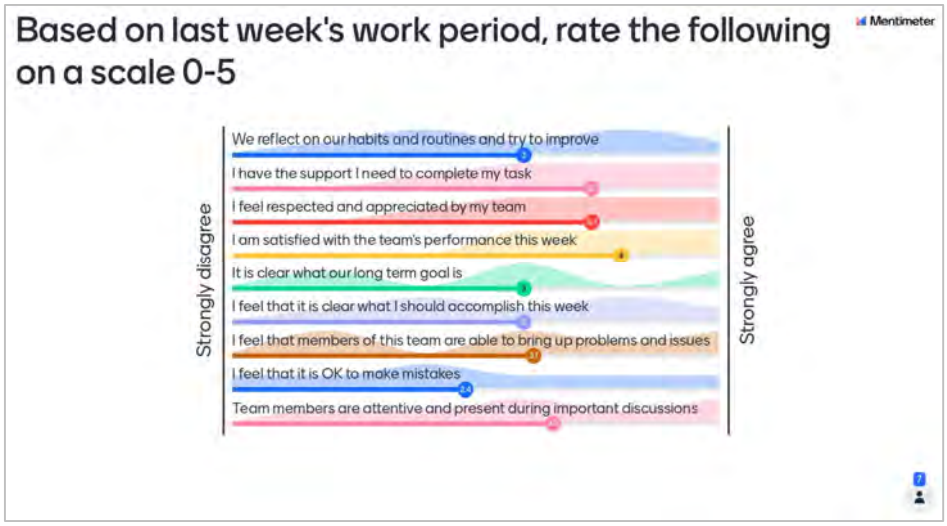


Figure 3.4.1: Sample responses to Scales (Bar chart)

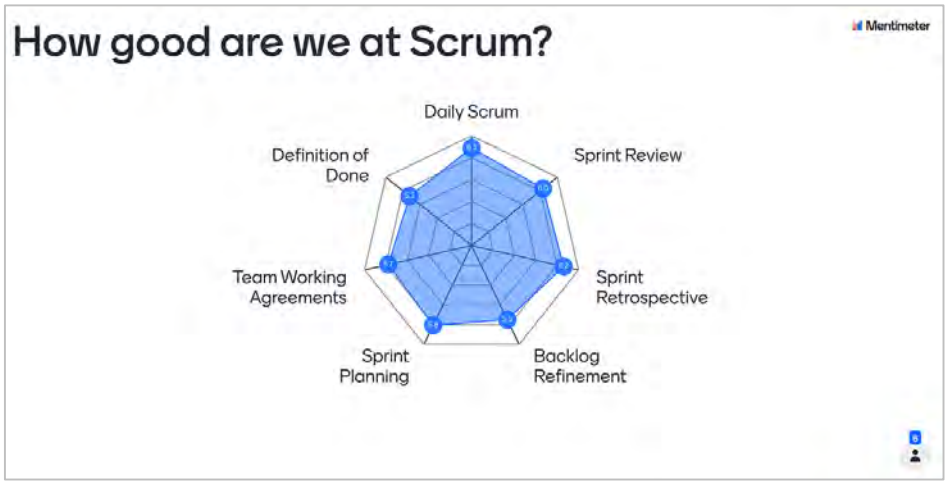


Figure 3.4.2: Sample responses to Scales (Spider chart)

3.5 Ranking

The presenter prepares the choices in advance. Participants rank the choices. The results of the responses are shown in a bar graph. By showing clear priorities, it is possible to narrow down the discussion by cutting out unimportant options from the large number of choices.

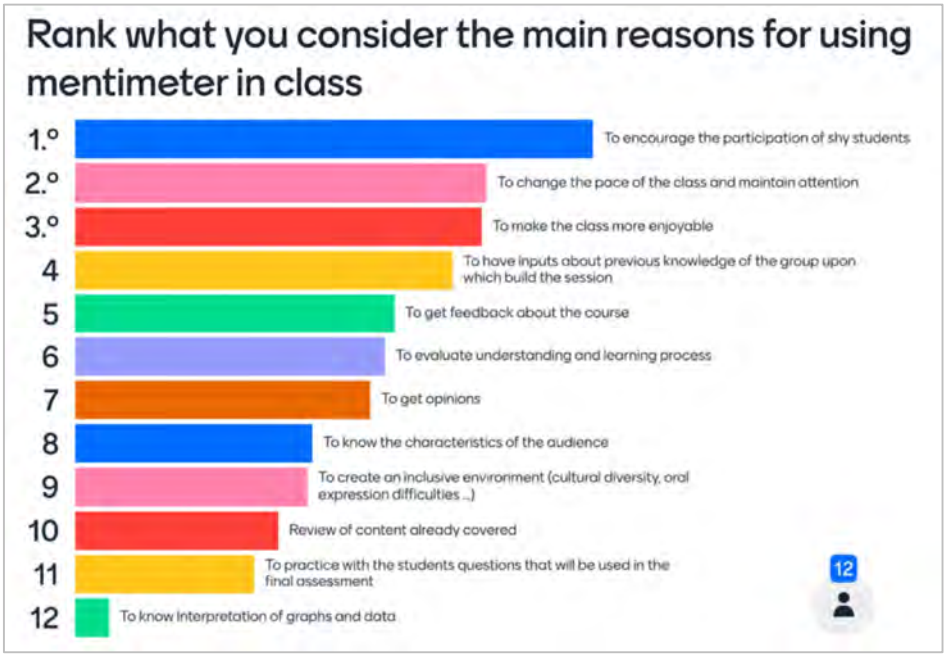


Figure 3.5.1: Sample responses to Ranking

3.6 Q and A

The presenter accepts questions from participants. The questions submitted can be viewed on other participants' smartphones and tablets and a Good button can be pressed; depending on the number of Goods, the presenter will verbally respond to the question; Open Ended lists many questions and opinions, while Q and A highlights the questions that have received the most attention (=Many "Good").

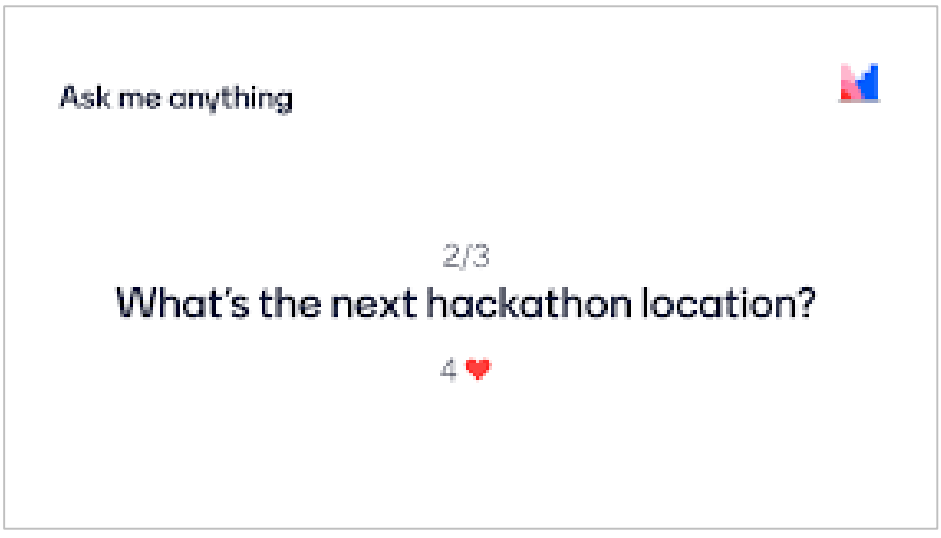


Figure 3.6.1: Sample responses to Q and A

3.7 Guess The Number

Participants select their responses along a numerical scale. Responses are highlighted along with the number of responses for each option. This is effective when specific numerical values such as calculations, statistics, prices, dates, etc. are to be collected as responses.

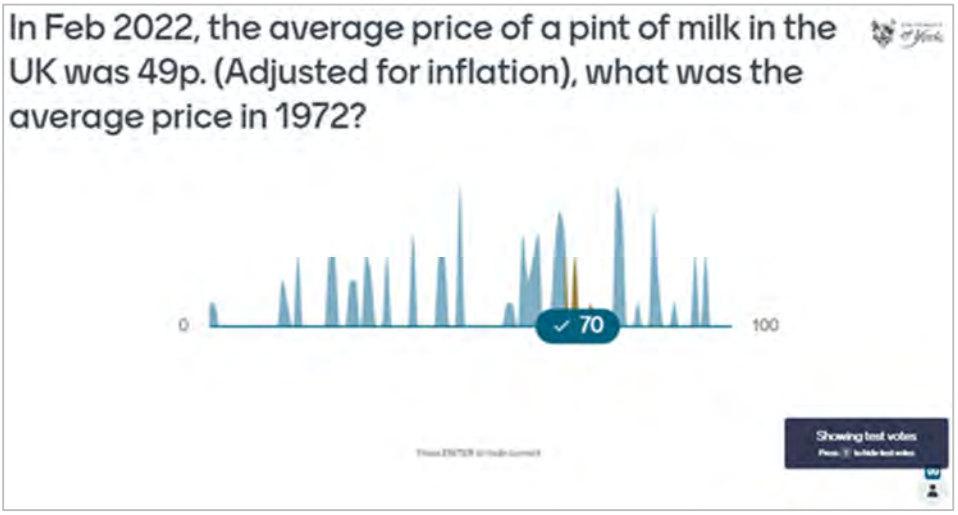


Figure 3.7.1: Sample responses to Guess The Number

3.8 100 Points

The presenter prepares the choices in advance. Participants can allocate their 100 points to the given choices in any proportion they like. Unlike the "Ranking" Form, the responses can be weighted, so that it is not just a ranking of the options, but also how much priority each option has. However, if there are many respondents who have the same priority (=same point allocation) for all options, it may be difficult to rank the options.

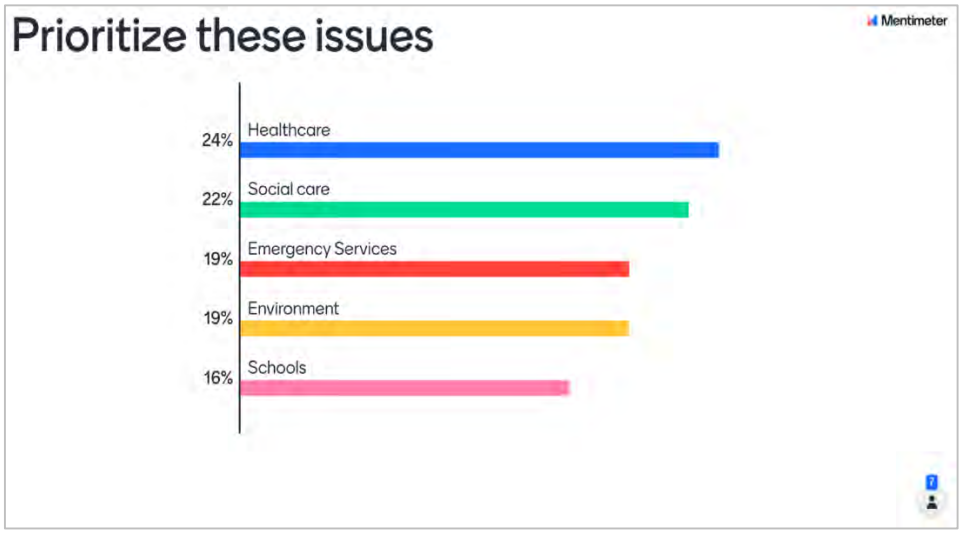


Figure 3.8.1: Sample responses to 100 Points

3.9 2 x 2 Grid

The presenter prepares the choices in advance. The 2 x 2 grid allows for evaluating the choices along two separate axes and showing the relationship between the choices. The results of the responses are plotted on the x-axis for scale 1 and on the y-axis for scale 2, with the coordinates for each choice representing the average response. The results can be evaluated in conjunction with indicators other than priority, e.g., social impact, financial burden, etc., to obtain a certain degree of realistic results. Moving the mouse over a response displays the distribution of responses for each individual (up to 50 responses).

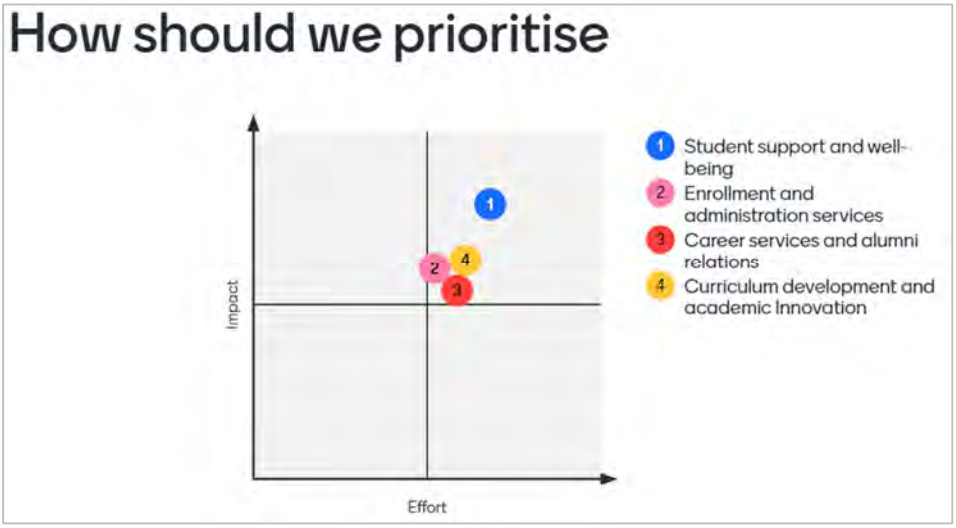


Figure 3.9.1: Sample responses to 2 x 2 Grid

3.10 Pin on Image

The Pin on Image allows respondents to add pins on the map and label the images. This provides an intuitive understanding of which areas of the target city have challenges and/or advantages. It can also be a good source of information for an actual visit to the site after the stakeholder meeting.



Figure 3.10.1: Sample responses to Pin on Image

Part 4. CONTENT SLIDES

Content Slides are used to effectively convey the explanatory parts before and after the questions. They can transform a stakeholder meeting from a mere briefing session with a single font and font size to a speech session that appeals to the audience by utilizing dialogue, numbers, images, and video.

However, in order to use Menti, which includes various types of Content Slides, you will need to practice multiple times after completing Menti. If you cannot take the time to practice, it is recommended that you use only Content Slides that are easy to handle, such as the “Heading” Form, “Paragraph” Form, and “Bullets” Form.

4.1 Heading

This is used to make the headline stand out and briefly explain the short content.



Figure 4.1.1: Entry example of Heading

4.2 Paragraph

This is used to explain the lengthy content along with the headings.



Figure 4.2.1: Entry example of Paragraph

4.3 Bullets

This is used with headings to provide bulleted explanations, which can be shown one at a time or all at once.



Figure 4.3.1: Entry example of Bullets

4.4 Image

This is used when you want to present a certain message in an impressive way with a photograph.



Figure 4.4.1: Entry example of Image

4.5 Video

This is used when you want to present a certain message in an impressive way with a video. The presenter first uploads the video to YouTube and then copies and pastes the YouTube URL into Mentimeter's slide.



Figure 4.5.1: Entry example of Video

4.6 Big

This is used when you want to present a certain message in an impressive way with a text.



Figure 4.6.1: Entry example of Big Text

4.7 Quote

This is used to quote someone famous.



Figure 4.7.1: Entry example of Quote

4.8 Number

This is used when you want to show the numbers in an impressive way. It has an animation effect that counts up from a slightly previous number.

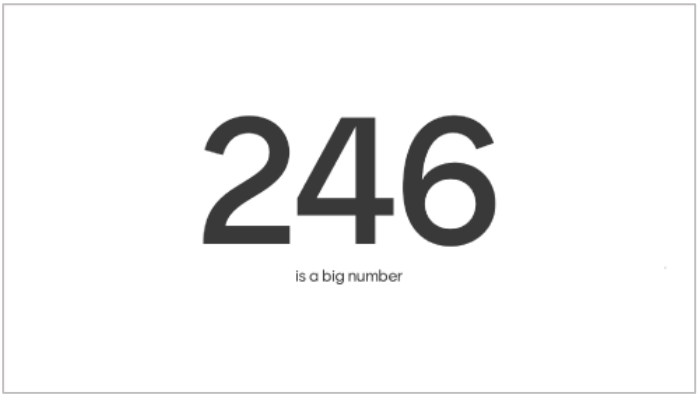


Figure 4.8.1: Entry example of Number

4.9 Instructions

The slides are designed to allow attendees to participate in the Mentimeter slides. Participants can be navigated by taking a picture of the QR code with their smartphone camera.



Figure 4.9.1: Entry example of Instructions

Part 5. Techniques for Smooth Meeting Operation

While Menti is shown to the participants, the following commands can be used to facilitate the meeting

5.1 Start timer

The remaining time is added with each click of each command. For example, if you want to set the response time to 2.5 minutes, click twice on 1 minute and once on 30 seconds.

5.2 Show joining instruction

The QR Code can be displayed whenever you want it to appear without using the “Instructions” Form. Basically, we want participants to think about their opinions and comments in a focused state, so it is important to get their attention using the “Instructions” Form, but if some participants close the response screen during the stakeholder meeting, the QR code can be displayed again using this command.

5.3 Hide responces

A great feature of Mentimeter is the ability to share the results of responses with participants in a timely manner, however, if there is a possibility that participants may change their opinions because of their surroundings, the results can be hidden until the responses are all available.

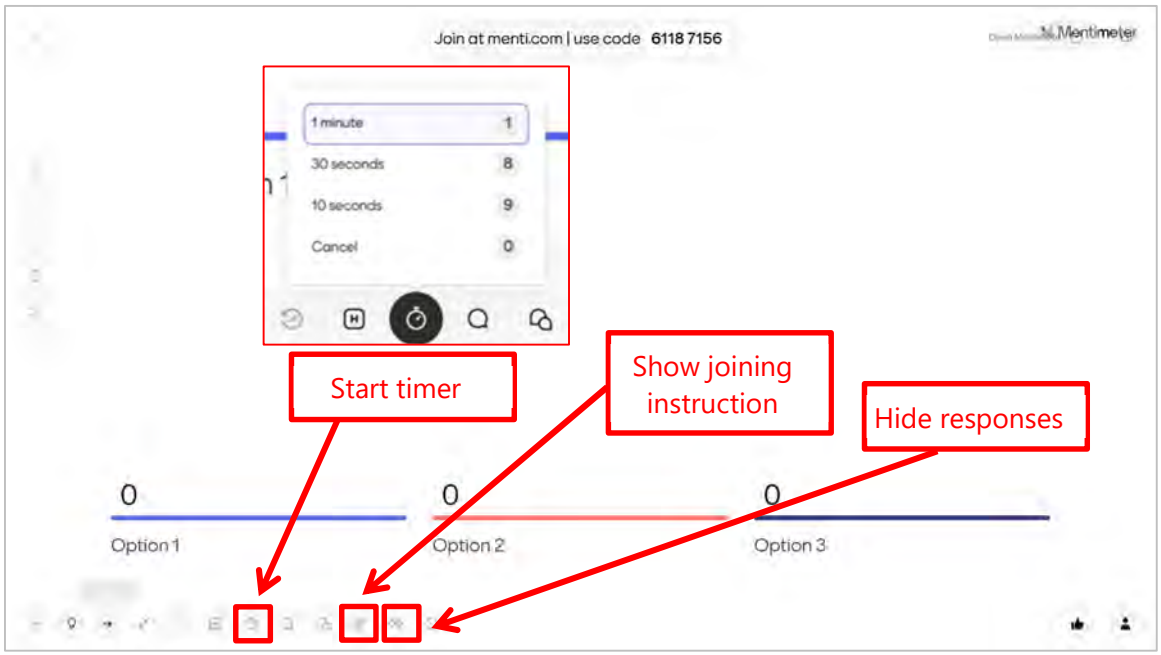


Figure 5.3.1: Major commands that can be used while displaying Menti

Various other commands are also available by clicking on the following keys

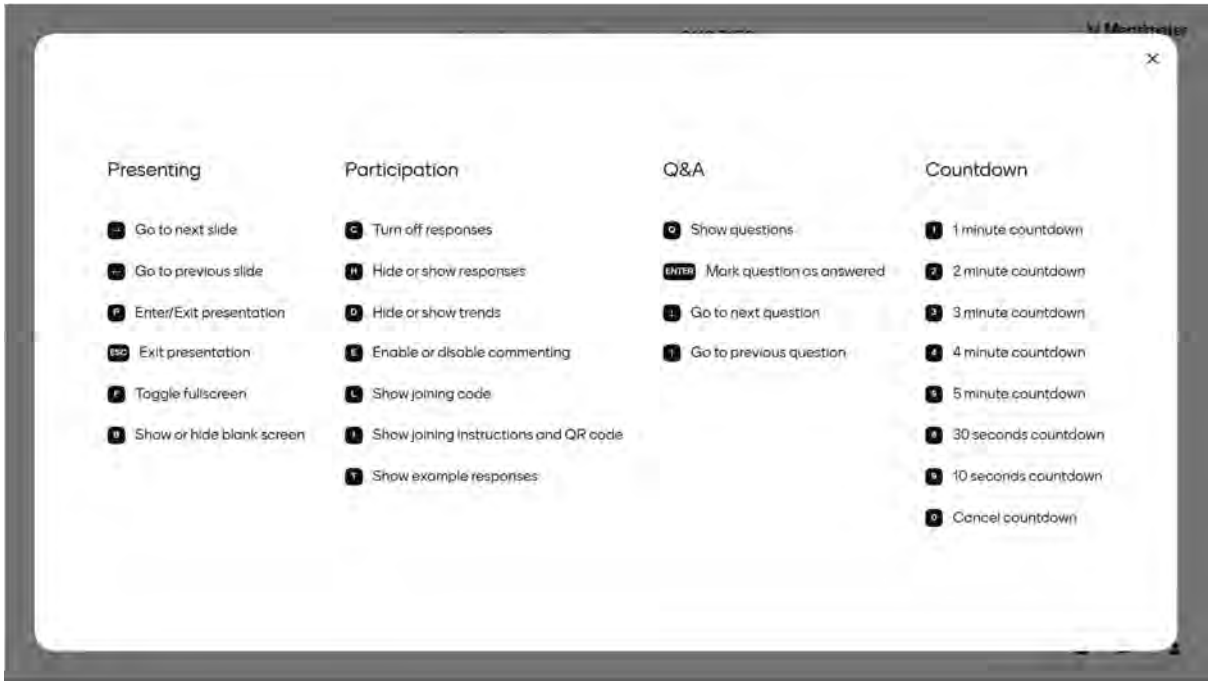


Figure 5.3.2: All commands that can be used while displaying Menti

Part 6. CONDUCT AN ONLINE SURVEY

6.1 Purpose of the online survey

In addition to stakeholder meetings, Mentimeter can also be used to conduct online surveys. Possible objectives of conducting an online survey follows.

1: To collect the opinions of potential participants who were unable to attend the stakeholder meeting before and/or after the meeting to improve the completeness of the collected opinions.

2: To collect the opinions of those not invited to the stakeholder meeting (i.e., the general public) to expand the scope of opinions collected.

3: To obtain reference material for considering the choices that should be made available in the questions that will be asked at the stakeholder meeting.

6.2 Online survey methodology

To conduct the online survey efficiently, it is necessary to disseminate QR codes to people to access the survey form.

1: UDA's website

2: Mass media such as TV commercials and news programs

3: Social media such as Instagram and Facebook

4: Posters and leaflets at places where people gather, such as train stations, bus stops, plazas, parks, etc.

An example of a poster is shown below.

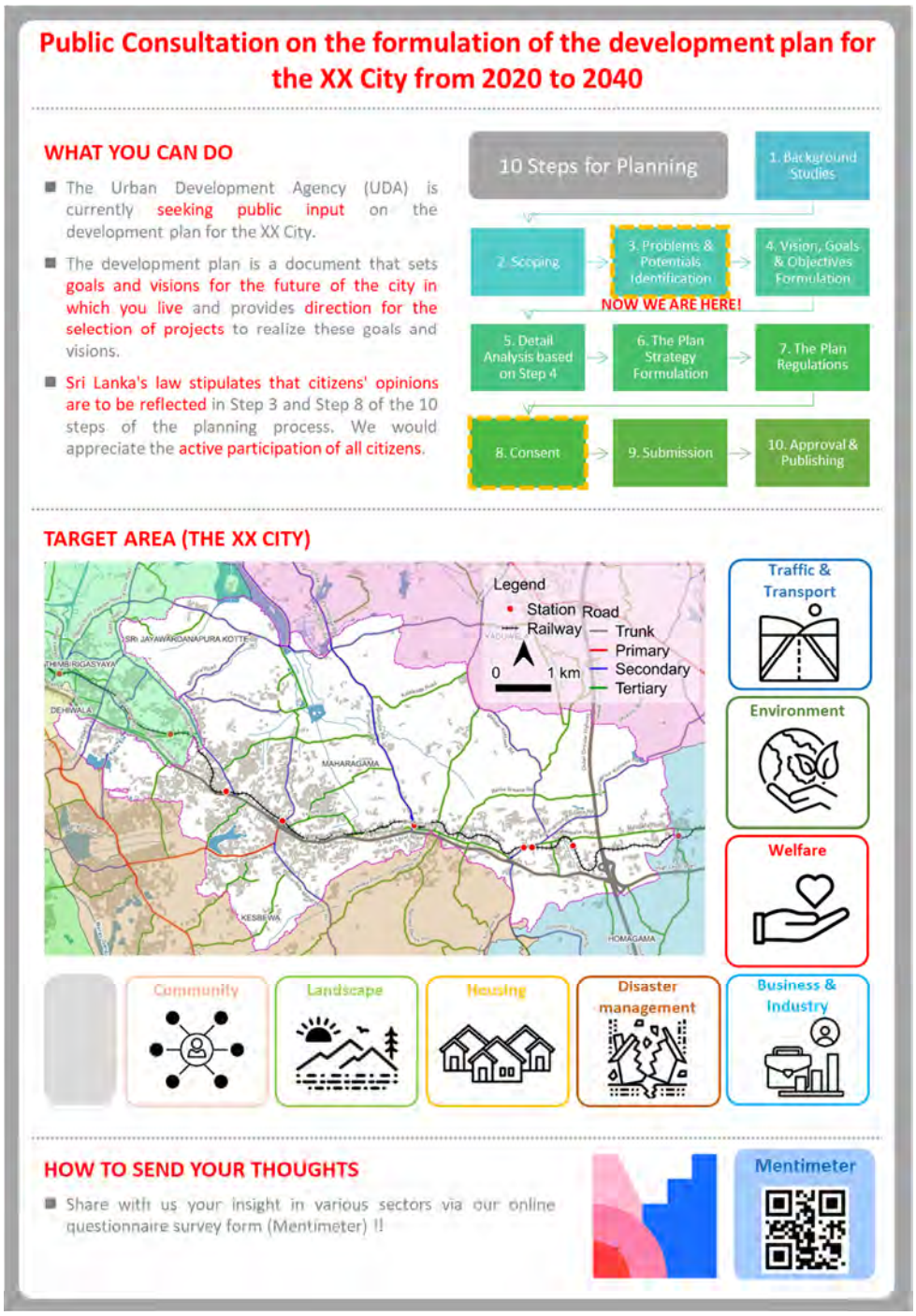


Figure 6.2.1: Example of a poster

After collecting opinions through the online survey for a certain period of time, the collected opinions should be tabulated in a simple manner and the results should be shared externally in the same manner as when the QR codes are disseminated.

At this time, if time allows, it would be desirable to present a policy and schedule for how the results of the tabulation will be reflected in the planning process. Knowing how the collected opinions will be used will motivate the respondents to participate in the next stage of the participation process.

In addition, understanding potential issues in advance will help eliminate bottlenecks and prevent delays when implementing the plan.

Part 7. Use The Results For Planning

The slides can only be downloaded in PDF format, though the results obtained with Mentimeter can be downloaded in Excel format, as shown in the figure below.

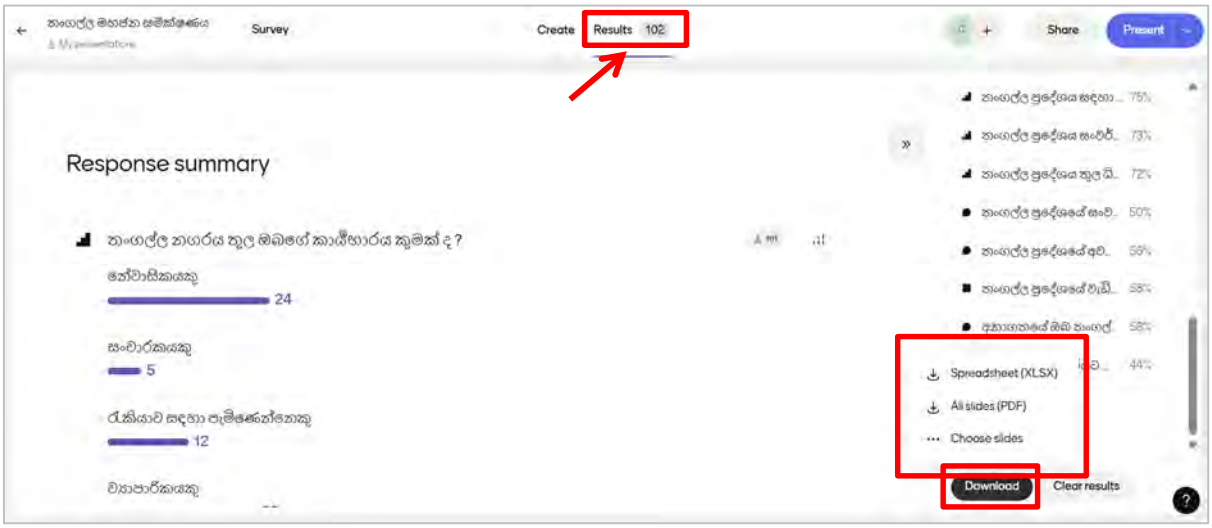


Figure 6.2.1: Download page

The simple tabulated results are already graphed, but if you like to cross-tabulate multiple results or fine-tune the presentation of the graph, you can process the data on the downloaded Excel file. UDA can then use the processed data for planning and consensus building.

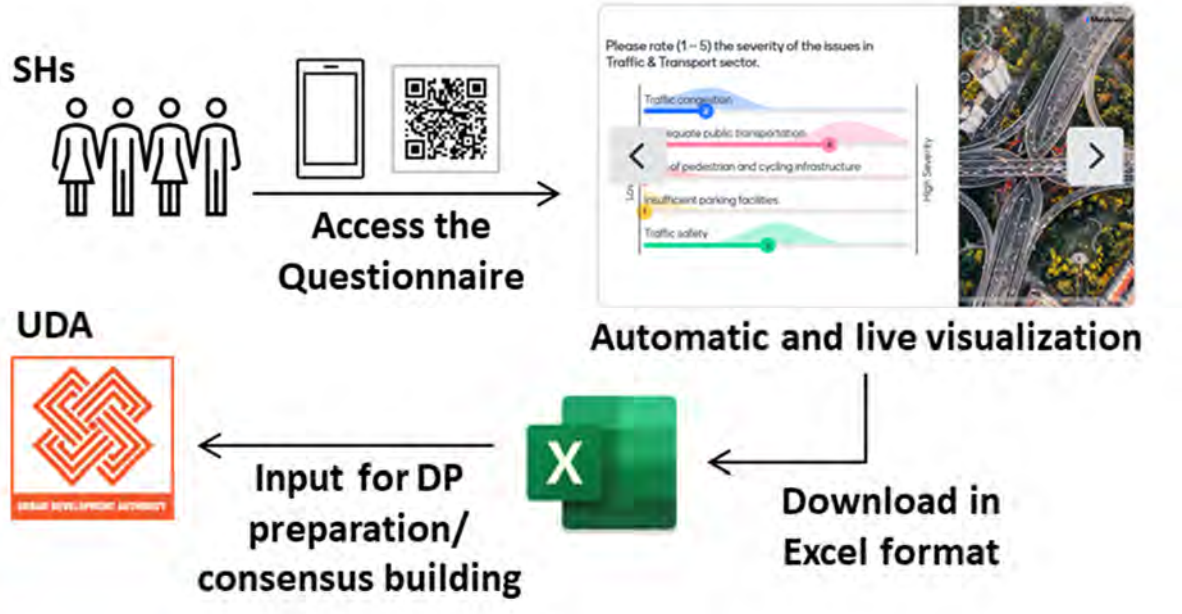


Figure 6.2.2: Workflow from opinion gathering to reflection of plan content

----Nothing follows----

Training Manual (Technical Manuals)

UD2: Technical Manual for Advanced Technology (2D/3D/DX)

CITY – UP

Urban Development

ToT Project

[Advanced Technology (2D/3D/DX)]

Prepared by ERECTRUS

For Urban Development Authority

TABLE OF CONTENTS

PART 1. INTRO TO METAVERSE: 1

1.1 Metaverse Intersects with Urban Planning 1

1.3 AUTODESK 3DS MAX 4

1.4 Modeling Techniques 6

1.5 Texturing and Materials 11

1.6 Export scene from 3Ds max to Blender 16

1.7 Integration with Other Software 17

1.8 Export scene from Blender to Spatial (Metaverse) 23

PART 2. SKETCH TO 3D MODEL BY AI 34

2.1 Project Urban Development Data 34

2.2 Prompting 37

2.3 Sketch to Image 37

2.4 Image to 3D Model 40

2.5 LIDAR Scan | Light Detection and Ranging Scan 42

2.6 POLYCAM 44

2.7 AR | Augmented Reality 50

2.8 AR by SketchUp 54

PART 3. APPENDIX 57

Part 1. INTRO TO METAVERSE:

1.1 Metaverse Intersects with Urban Planning

- Virtual Urban Spaces: As the metaverse becomes more developed, it is likely that virtual urban spaces will become a more important component. These virtual spaces can be used for a range of activities, such as virtual conferences, online shopping, and socializing with friends.
- Digital Twins: A digital twin is a virtual replica of a physical object or space. In the context of urban planning, a digital twin can be used to create a virtual model of a city or neighborhood. This can help urban planners and designers to test different scenarios and make more informed decisions about the design of the built environment.
- Mixed-Use Development: The metaverse has the potential to bring together a range of activities in a single virtual space. This means that mixed-use development can be explored in new ways, such as incorporating virtual workspaces, virtual entertainment venues, and virtual shopping centers.
- Smart City Integration: As the metaverse develops, it is likely that it will become more integrated with smart city technology. This can include things like sensor networks, autonomous vehicles, and energy management systems. Urban planners and designers can explore how these technologies can be integrated into virtual urban spaces to create more sustainable and livable cities.
- Collaborative Design: The metaverse provides a new platform for collaborative design and planning. Urban planners, architects, designers, and other stakeholders can work together in a virtual space to explore different design scenarios and create more inclusive and sustainable urban environments.

1.2 Introduction to Autocad , 3D MAX and Blender

- start from planning by Autocad and making the model by 3d software (such as 3d max and blender) and shipping the model to Metaverse by Spatial platform.
- -For Autocad and 3ds max you need to download and use it trial for 30 days after that you need to buy it , and Blender it's a open source it free for everyone and Spatial it's free as well ,but you can subscription for pro version there are many feature more than a free version

- -And Spatial platform is use for uploading the 3d model to be the verse which have a requirement , the sizing of the model cannot over 100 mb , so we should do every model in the scene to be the Lowpolygon model

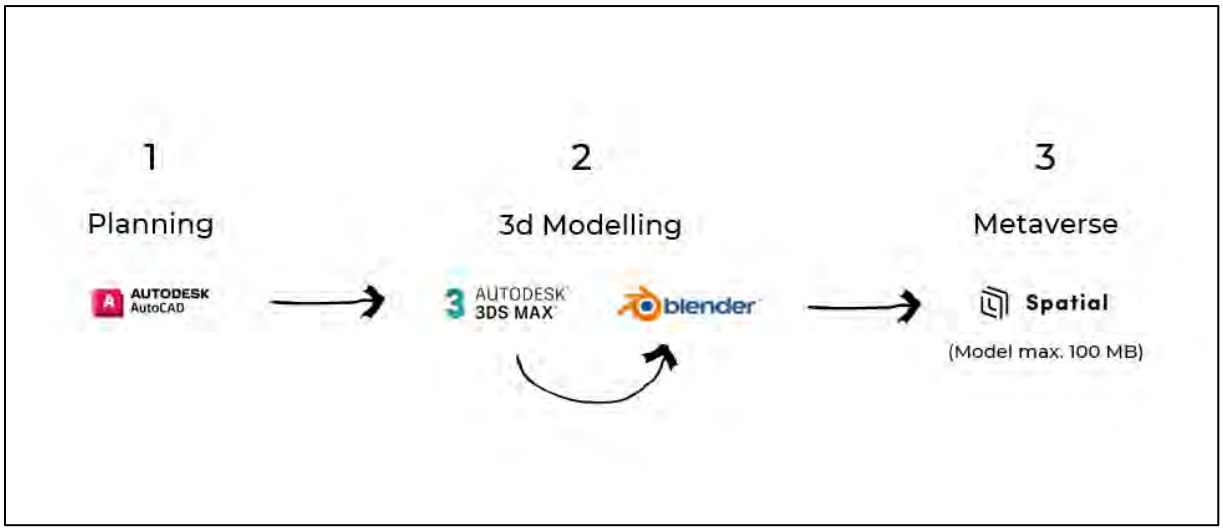


Figure 1.1.1: Creation step for Metaverse

Autocad or computer aid design is a drafting software which have 2d and 3d function

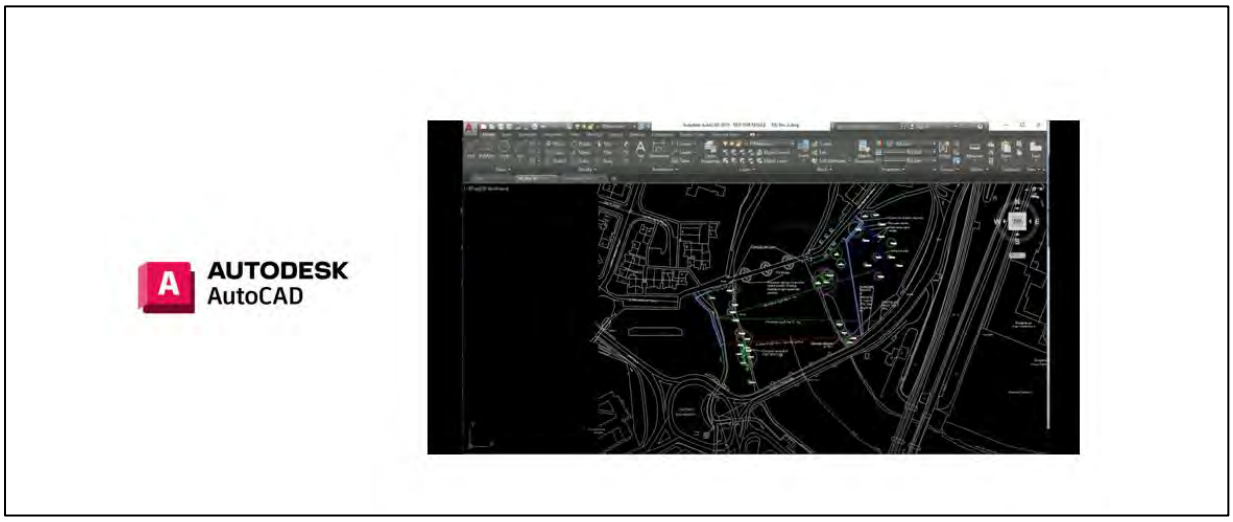


Figure 1.1.2: AUTODESK/AutoCAD

-Another one we will learn how to get the urban data from map by using **openstreetmap**

- -this is the window of OpenStreetMap , you will see the search box on the upper left , you can search the area what you want and export the data for free
- -when you get the data it's coming by the .OSM file , autocad cannot open this file , you need to convert that file to .DWG

- -There are about 3-4 ways to do that
- - for this course i will using **My geodata converter** , www.mygeodata.cloud/converter
- can convert and choose the data what you wants, for example , you want to use only building and road and tunnels.

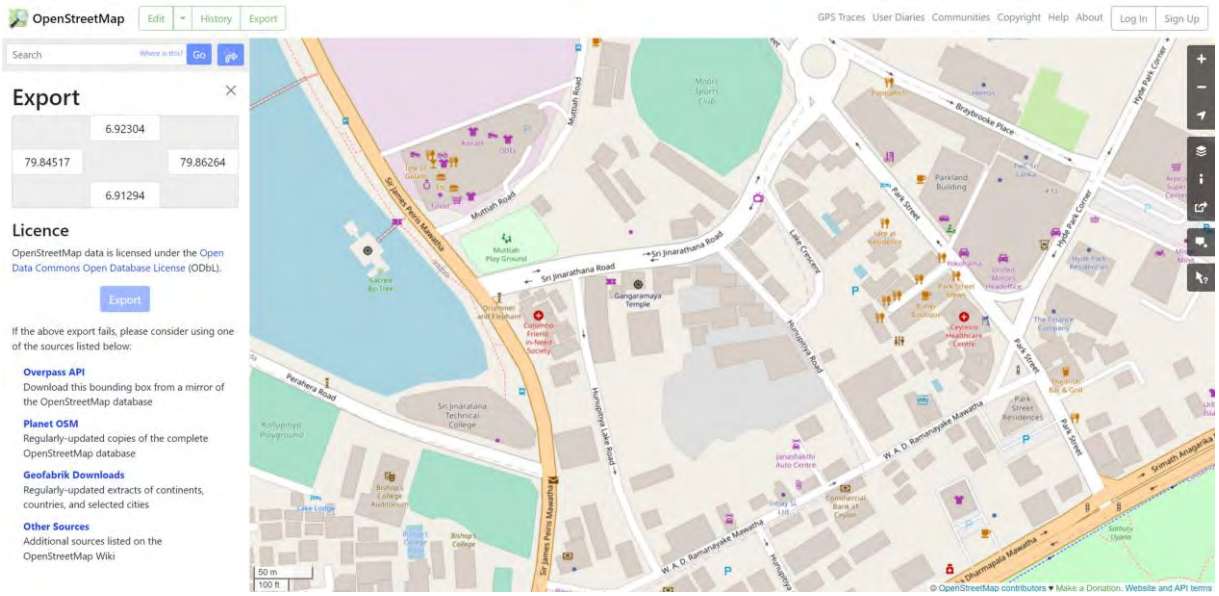


Figure 1.1.3: OpenStreeMap

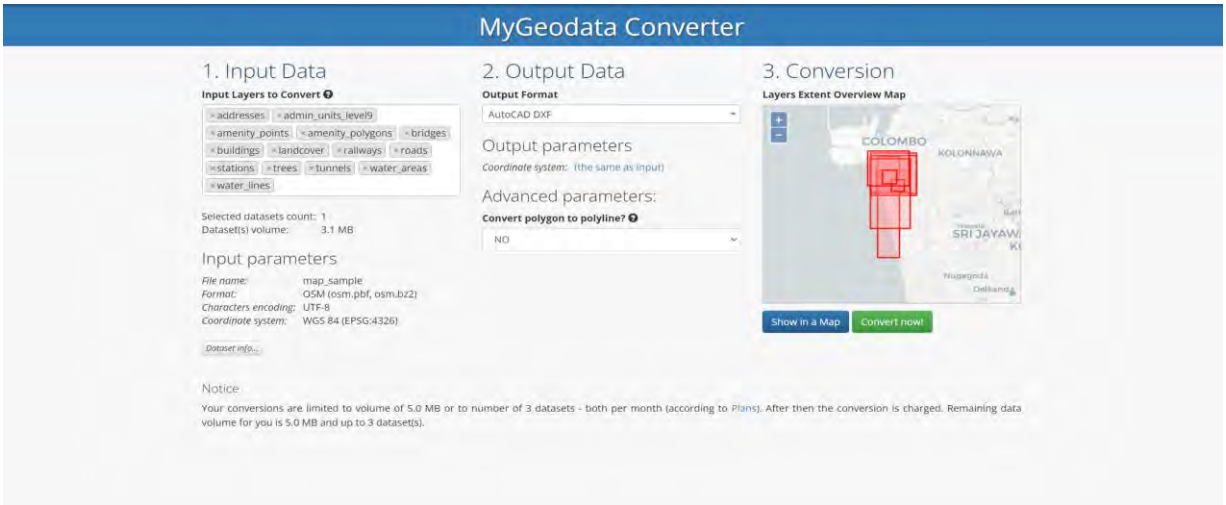


Figure 1.1.4: OpenStreeMap >> MyGeodata Converter

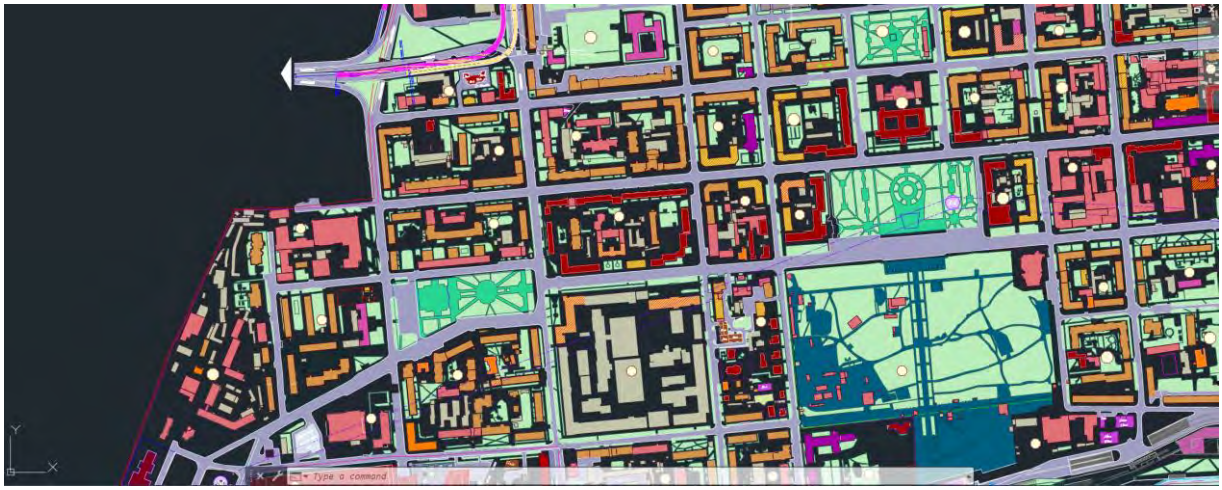


Figure 1.1.5: OpenStreeMap >> MyGeodata Converter

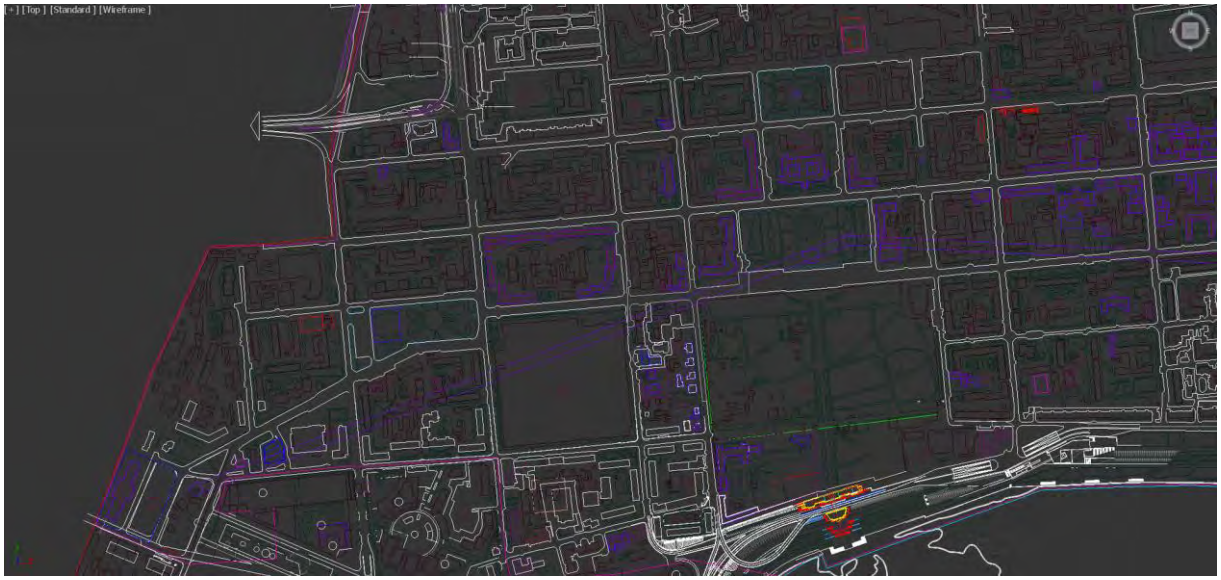


Figure 1.1.6: OpenStreeMap >> MyGeodata Converter

1.3 AUTODESK 3DS MAX

AUTODESK 3d max is the software for creating the 3d model which have a many function for architecture for example creating the building , creating the road , the traffic light pole something like that , there are like an instant tools to do that.

- - this lesson we going to learn not only how to create the 3d model but we have to know how to optimize the model that suite for metaverse also.

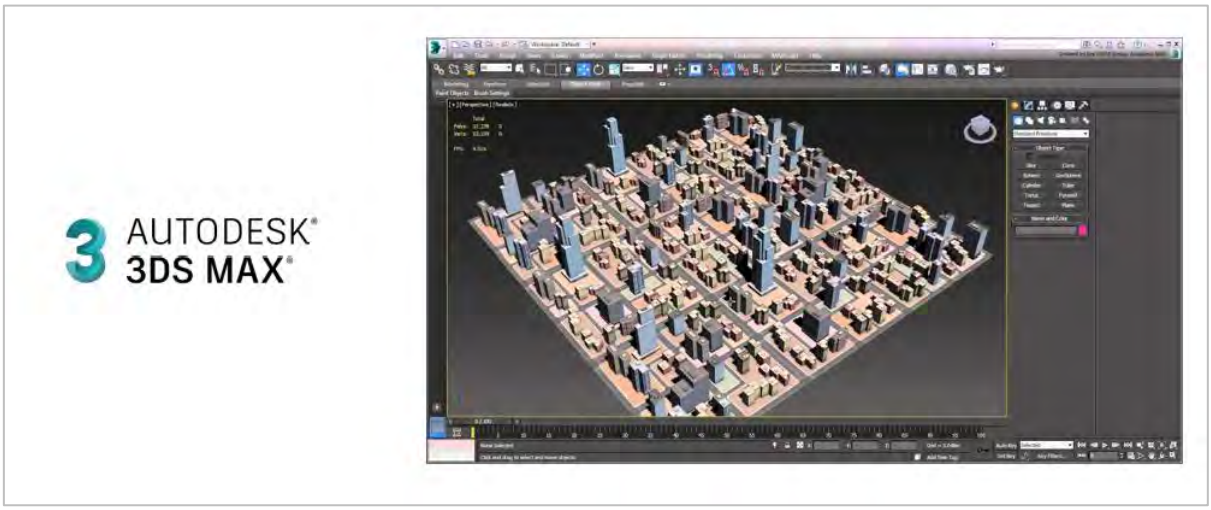


Figure 1.3.1: AUTODESK 3D MAX Program

1. **"viewport "** ,Normally the program gonna provide you the standard view
    - you will see the top view is on the above left , the front view is on the above right , the left view is on the below left and the last one the perspective view is on the below right
    - -for my opinion the standard view is ok for working , you just need to know how to control ,and change the view , basically
    - you can take some view quickly to the main view by using Alt+Q it's a shortcut
2. **"tools "**
    - standard format of tools for 3ds max was setting on the above tab and on the right tab , you can have almost of all of function by using this 2 position , for the next step we will focusing to the detail of each function.
3. **"how to control the model"** , move . scaling , rotating and how to move your view.
4. **" Axis "**
    - -Axis is a reference line ,
    - -The Vertical line is Axis Y
    - -The Horizontal line is Axis X and Z
    - -All of the tools in this program will reference by Axis name , you need to remember
    - -By the way if you another program , the axis is not the same , for example in Blender the vertical line is on Axis Z , and the Horizontal line is an Axis X and Y.

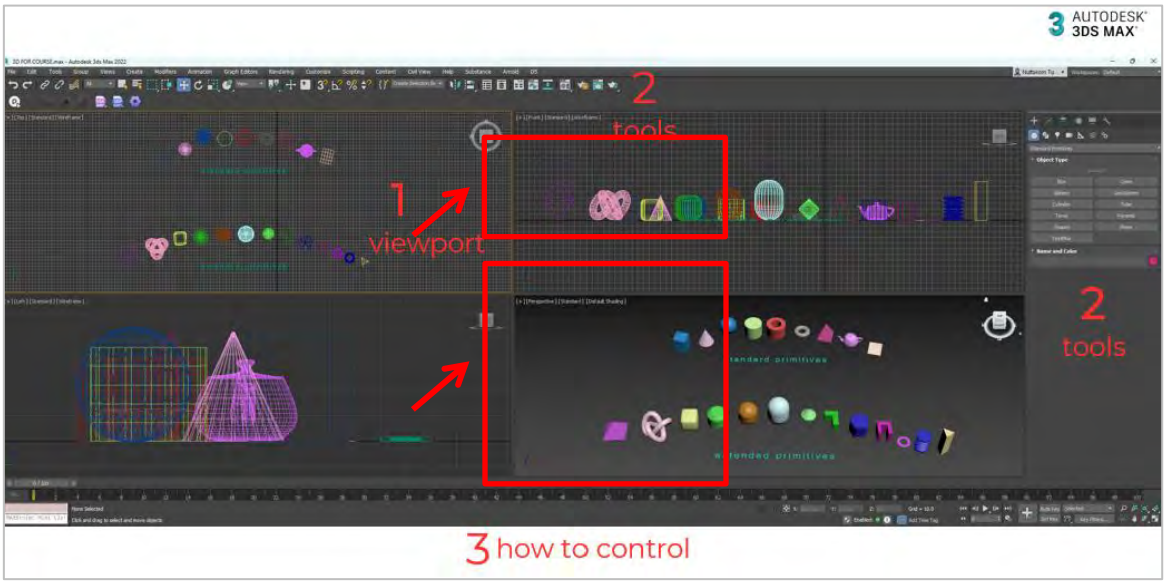


Figure 1.3.1: How to control 3D MAX

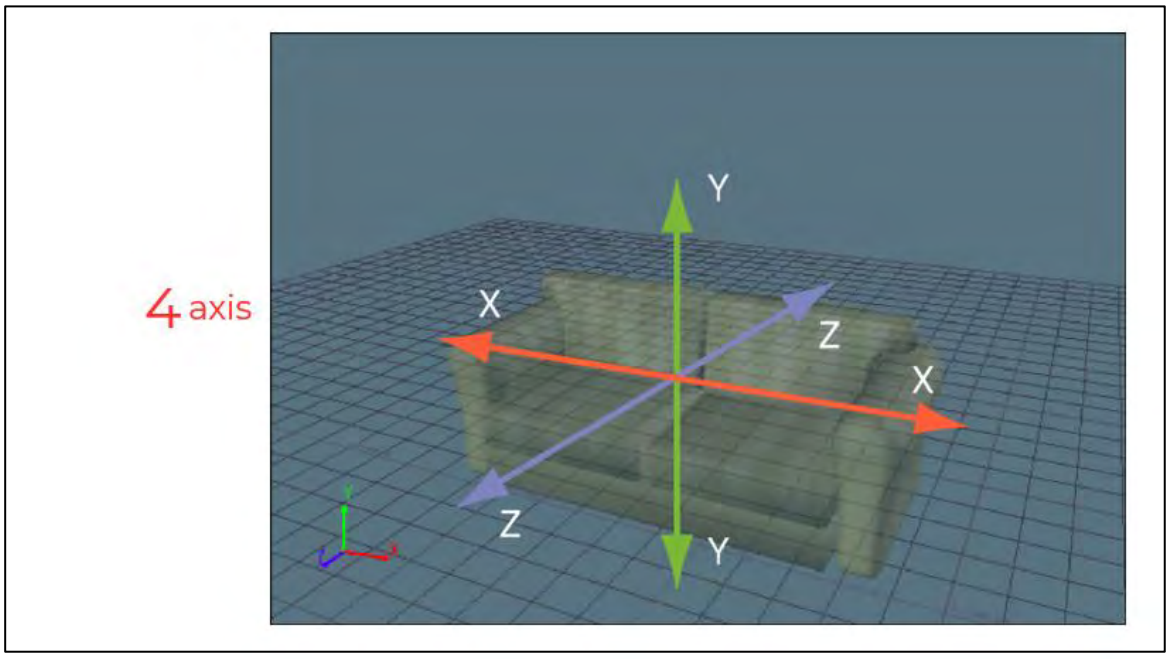


Figure 1.3.3: AXIS

1.4 Modeling Techniques

TOOLS to control the model . Example only basic tools , Actually there are many tools but most of that is not to use for this project .

- - Firstly , when open the program you need to set up the Unit that you have to use (see the upper right box)
- -choose ,and all of the model in that scene will be the same unit

- **Selection** , to select the model by use this 4 button ,
    - Select object , you just click this button you can select to model
    - Select by name , firstly you can set the name for each model when you created, and you can select it by name list
    - Shape for selection , you can choose the shape is suite for crop the object that you need.
    - Area select, when you select the object you can choose 2.
- -The Zoom is normal by wheel the button of your mouse
- -The move , the rotate and scale is 3 symbol , I'll show you how to control when we take a sample.
- -Redo and Undo , redo It's using when you want to back to the before step or moving forward after you already back but you don't want use redo.
- -Isolated , it's use for select the object which you want to do it alone and hide other else
- -Snap is use for making an alignment for your object or move one object to close to one object

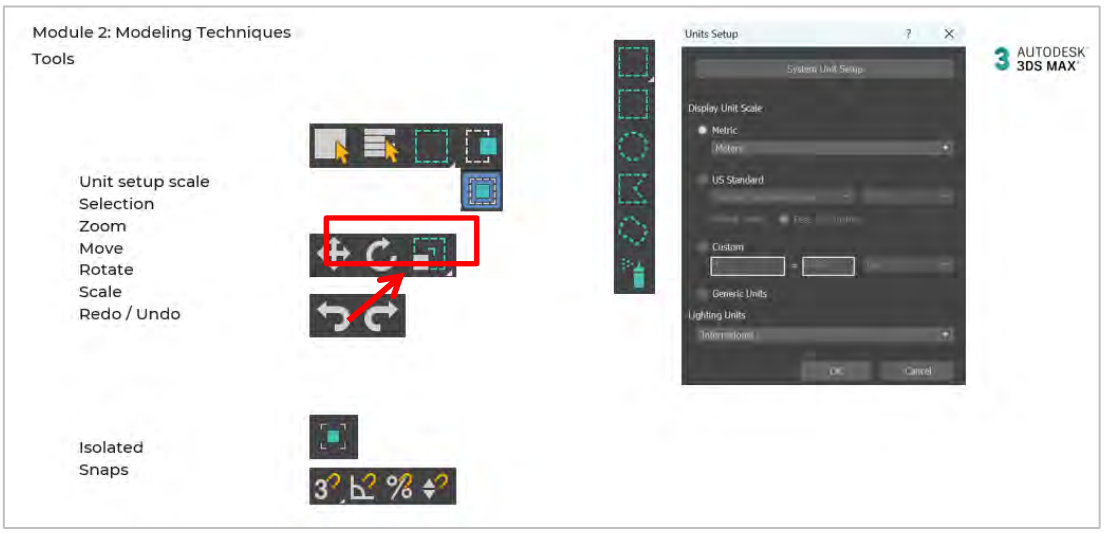


Figure 1.4.1: Tools of 3D MAX Program

CREATION is the Instant object which program provided you

- -you can easy to create and easy to adjust the sizing or the detail by each parameter.

- -First one is Spline , there are about 13 shape for ready to use , by the way you can do a different shape by using various type of line shape and connected it together. I'will show you later.
- -Next one is Standard and Extended Primitives , you can have a instant shape as you see , in easy step to create , the box , the sphere , the doughnut , the teapot , or and the fillet box , the capsule , or pyramid in easy way.

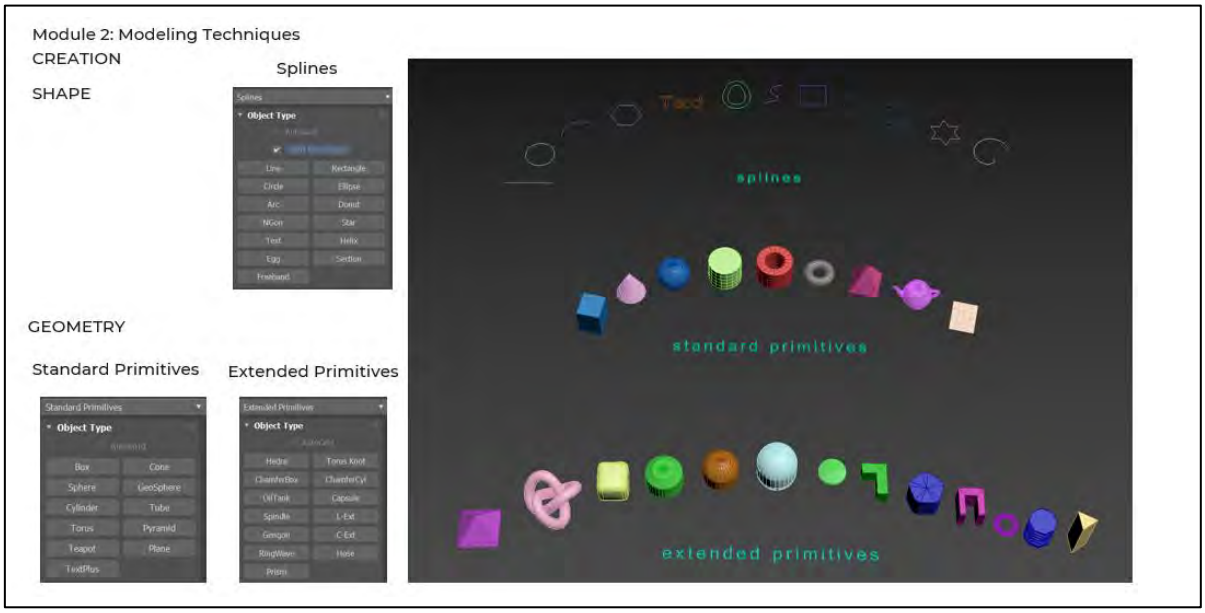


Figure 1.4.2: Creation the instant objects

MODIFY is when you get the object by using instant object or getting the spline from that .

- Extrude , when you created the line from instant or not you make it to be a mass by Extrude , I will show you the step later.
- Lathe , Lathe is feature for created the mass by marking the center of object and rotate them all , you just have an outline for using it.
- Array , Array is use for copy the object in several way , you can copy by straight or by circle. you can set the number of object that you want.
- Sweep , Sweep is use for created the object by using section line , there are about 10-11 instant shape providing you , mostly is in Architecture field , Such a pipe , a wide flange , and angle for example
- Shell , Shell is using when you want to make the thickness for your object , you can make it two way (inner and outer)

- Chamfer , normally it the same as fillet but you can adjust the amount of phase. If it too much it wille smoother , if it only phase it like a angle (see the picture)
- Spacing tool, Spacing tool is use for copy the object by moving to the line or the spline which you created.
- Mirror , It's use for mirror the object .

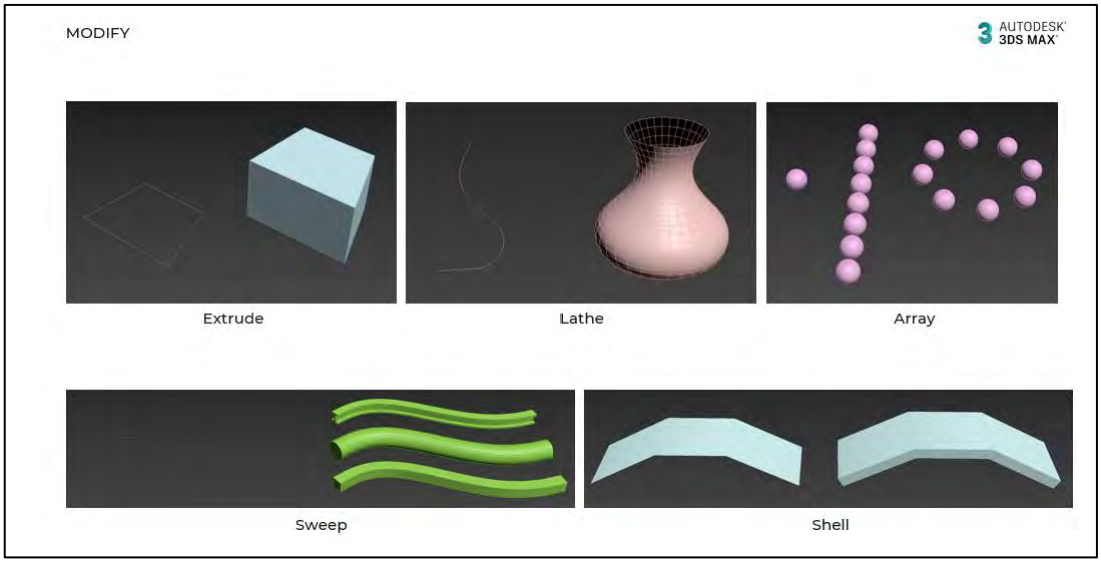


Figure 1.4.3: Modify

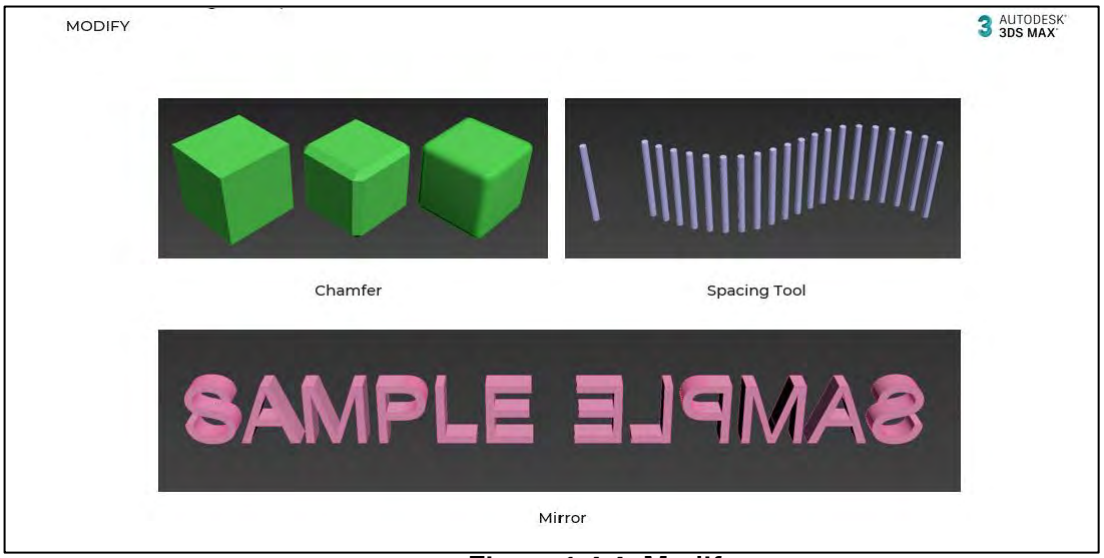


Figure 1.4.4: Modify

- ProBoolean , ProBoolean is like a tools for manage a cross area with object to and object.

- A instant stair tools, there are 4 option of the stair , for ready to use , ther straight shape , the L shape , the U shape ,and the spiral. you can adjust every detail in stair , the height , the amount of steps , the handrail and the overall sizing.
- Optimized tool, it's an important thing , when you guy already have an object , doing by yourself or by loading from 3d wearhouse , If there are many poly on an object , you need to reduce it by Optimized tool , -You will see the sub topic (Face thresh) the number provided by 4 , If you increase the number , the poly will reduce , on the other hand if you reduce the number the phase will increase. but you need to be careful for the shape of your model , this tool will reduce your face so sometime ,If you put the amount a lot , the shape may loose some of the details , see the picture.

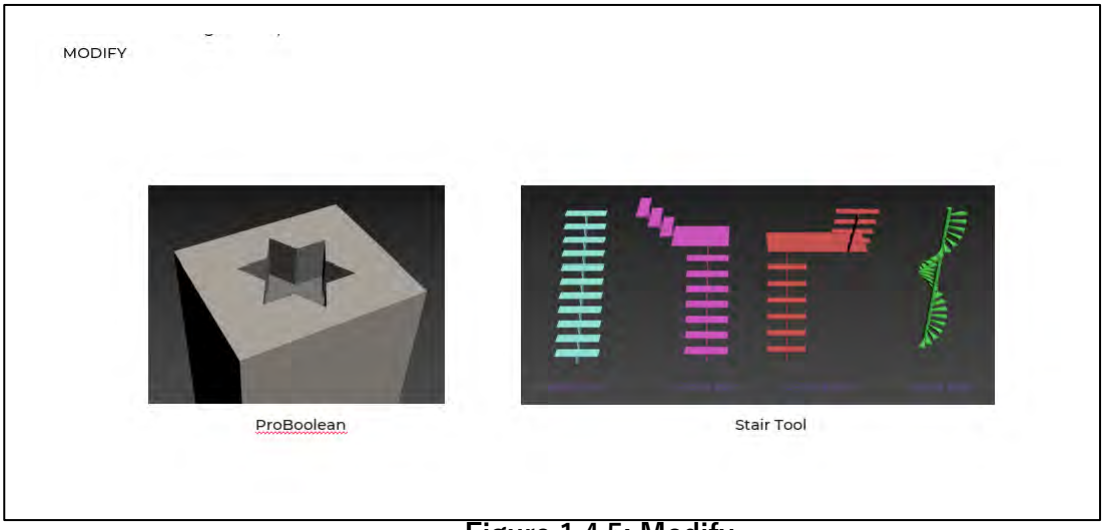


Figure 1.4.5: Modify

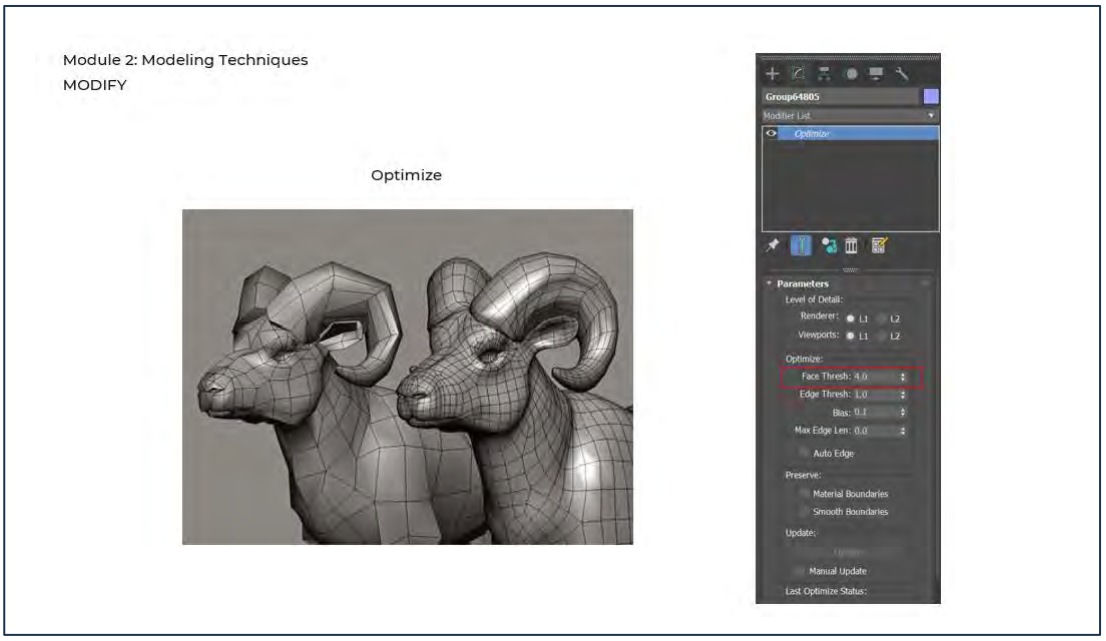


Figure 1.4.6: Modify

1.5 Texturing and Materials

Texture and material , when we get the model next step we put the material in it, by press M to open the Material editor.

- -For the material parameter there are many type of material , you can choose by click at Standard (Legacy) and choose another one.
- -This is the standard material which 3ds max provided you , but nowadays you can use like a outsource , render engine to created the material and render it output. It better than this one
- -More realistic , and the the speed per 1 picture is quite fast , such as corona render , D5 render something like that
- -the process is you select your model and choose the material in the slot which one and click the assign button .
- -you can make the name for you material in this slot.

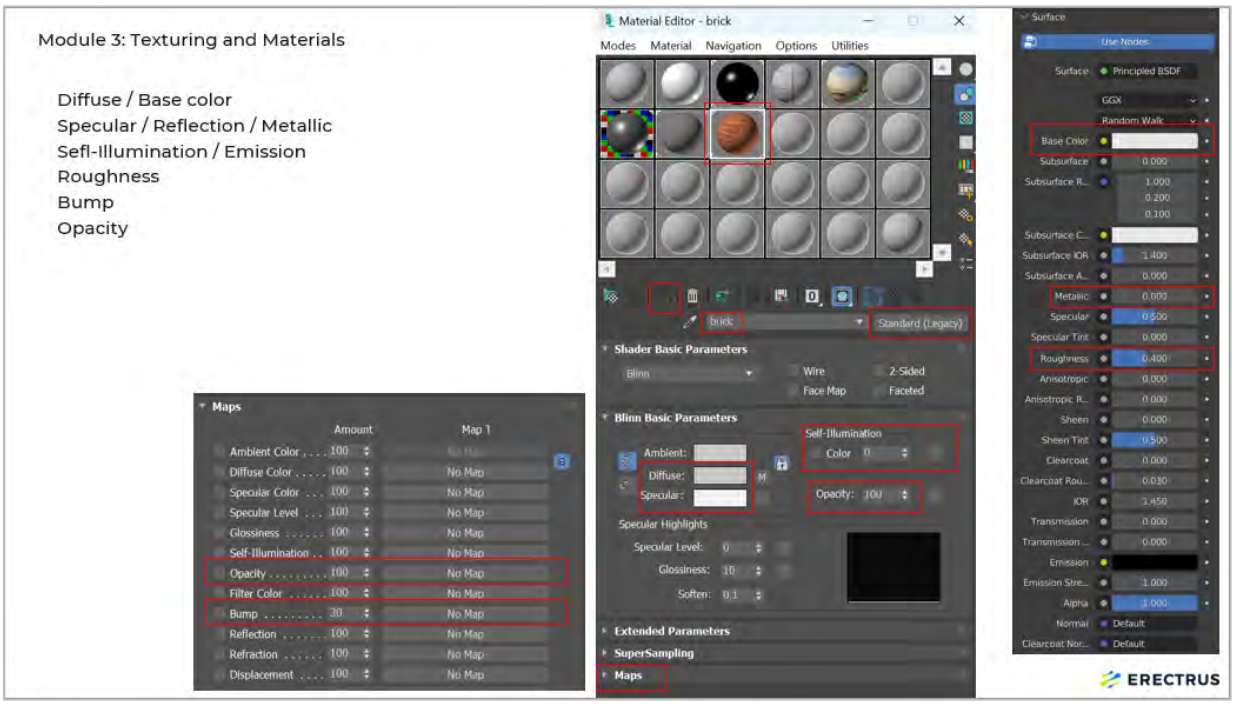


Figure 1.5.1: Material Editor

- Diffuse or base color is the same meaning but for other program may use other name , in 3ds max use diffuse , but in blender use base color , you see. It's use for input the color , or the picture image , on the surface of material. You can download a picture from internet and fill it in your model.

- Specular or reflection or metallic is the same as well , it's use for making the reflect on the surface of your object , you can think about the like a ceramic and fabric , the reflect is no the same
- Self-illumination or Emission , it's a illuminate by object self, how glow is it. It like to make the fluorescence material or bulb.
- Roughness , it's the sam definition of the name , how rough is it on you material , you can use together with the reflection.
- Bump, Bump is like a making the depth on the surface by using black and white picture to mapping. The white picture is going to be the ground level the black picture is like a groove , like deepness.

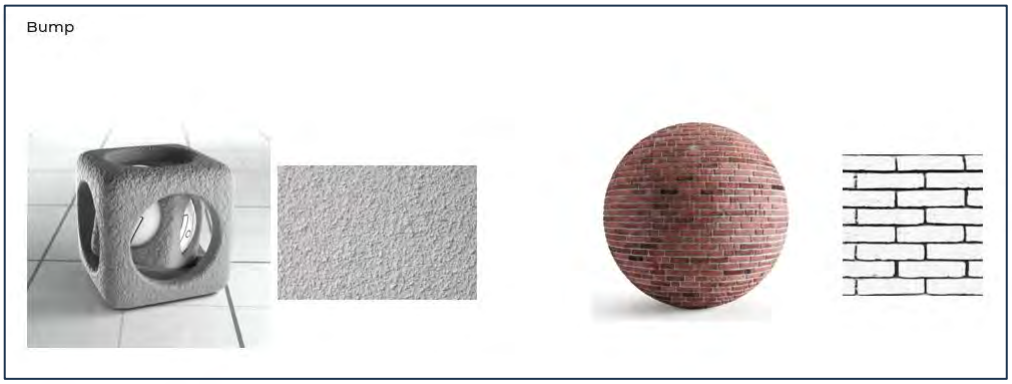


Figure 1.5.2: Material Editor (Bump)

- using only the black and white picture to created the texturing on the face , by noting to do on the real model. Just only mapping
- -white color is on ground level , and black color is deepness.
- Opacity mapping , you can use the mapping to created some object that look like you create the real model ,but it gonna be flat. It's like a plane
- -Normally I use it's for the model that too far or far away from your eye or the camera. It's quite good to be like a scene or background, cause we don't see how depth of the object.
- -you can map the black and white color on the material and it's going to be like this
- -it's the same process with bump , the white color is for appear texture, and the black color is for disappear.

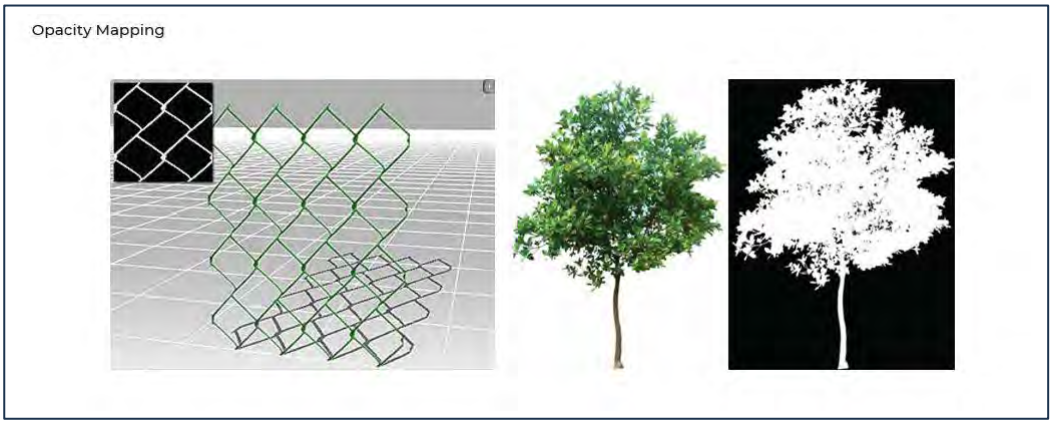


Figure 1.5.3: Material Editor (Opacity Mapping)

- The **UVW** map.
- -when you create the model and input the material finished , after that you need to use the uvw mapping to control your surface texture ,
- -There are about 7 difference type for mapping , but for the architecture filed we use only maybe 2 or 3 type ,which suite for the form of the object.
- -The step to use gonna be like this, firstly when you already input the material , you select your object , and looking for the UVW map in the modify topic , on right tab'
- -and then the parameter window will appeared like this ,
- -If your object have only 1 or 2 surface ,it's quite a flat one , you need to use the planar feature to map it, the planar will show the texture only front and back surface , and then you can adjust it to fit in you object.
- -It's the same way with other shape , If your model is like a box , or there are about 4 -6 surface , you need to use Box feature for mapping , and you can control the texture , to fit in you object completely.
- making the various texture in the same object,
- -When you finished to input the first material to the object , or finished UVW map ,then you need to convert the model to polygon , the parameter of UVW map will disappear , and then you need to selected the face what you want to input the new material , and go back to material editor and assign it. And you can convert it to poly again and do it the same to make a third material. or fourth or fifth , you can do what you want.
- And sometime I might not have to create the real detail on the model , I use mapping to create the environment of the scene.
- -and another good way , you will get the all of object that you need in the scene in low polygon .

- -The size of you is quite small.

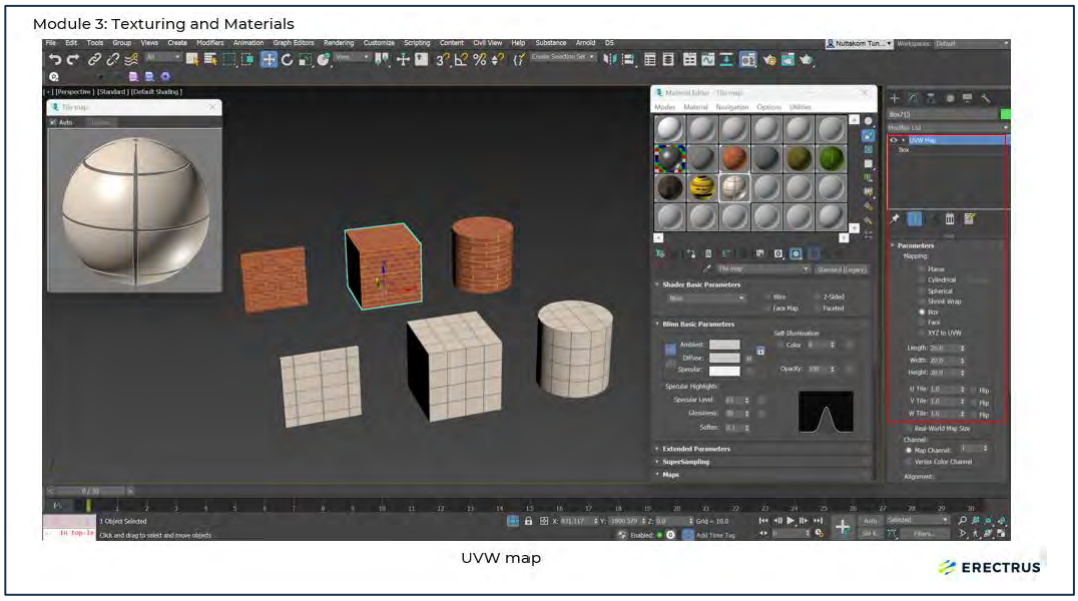


Figure 1.5.4: Material Editor (UVW map)

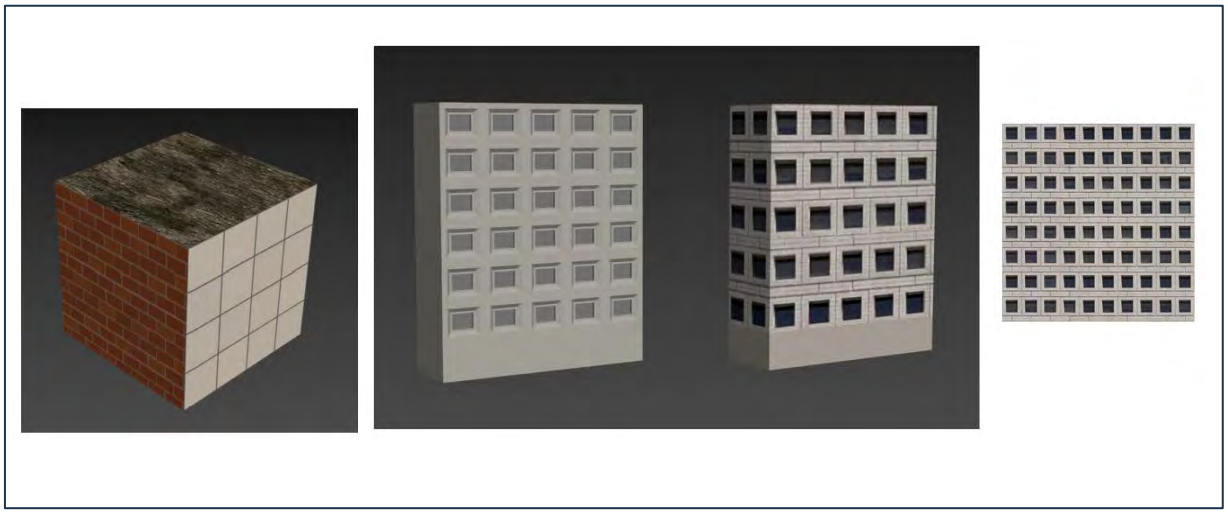


Figure 1.5.5: Material Editor (Mapping)

- something like this , the left one is 1000 poly and the right one is only 10 poly , this mean you can create the right one for a hundred building is equal with the left one.
- -but it suit for the environment , for the close up model you need to do the detail for it.

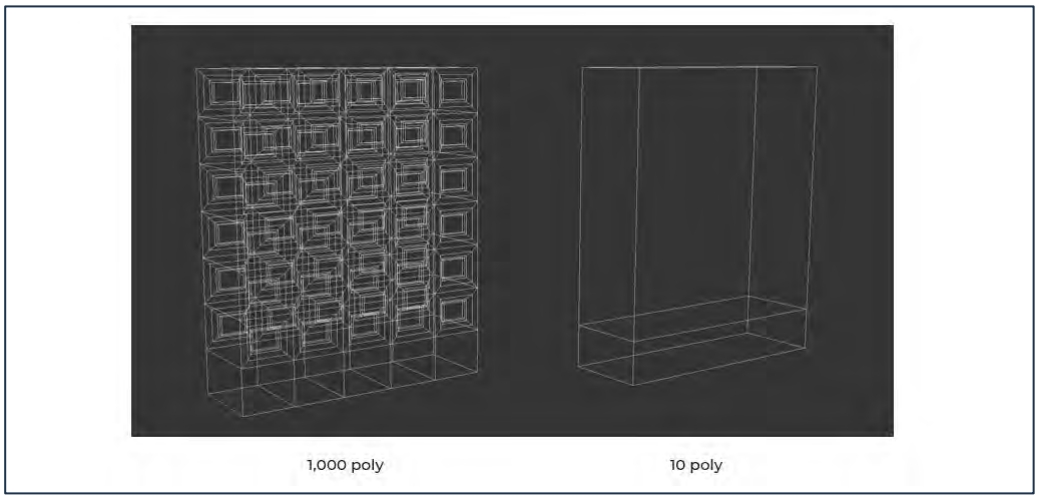


Figure 1.5.6: Material Editor (Mapping)

- Created some of object for urban
- -Actually, there are many way and many process how to created the object
- -Maybe you can start from Spline and make it like a mass by extrude and modify them later.
- -or maybe you can start form the box or cylinder and move the vertex to be the shape what you want. There are many way , it's depend to the form and the detail which you wants
- -But for my opinion , when you start everything form spline to plane and make it like a mass later , it's gonna be ok , your poly is not messed up , it will be clean and easy to adjust.



Figure 1.5.7: Material Editor (Modify)

1.6 Export scene from 3Ds max to Blender

Blender is a free software , it quite similar with 3d max , for creating the 3d model but there are many function is suit for character design , freeform object or an animation

- -but for this course blender will use to create the material and exporting the model to Metaverse , cause the spatial require the .GLB file , 3ds max cannot export that file
- -Actually you can create the model in this software , but for this urban project , I think 3ds max is better.
- -install this program , going to www.blender.org and download it , it's for free.

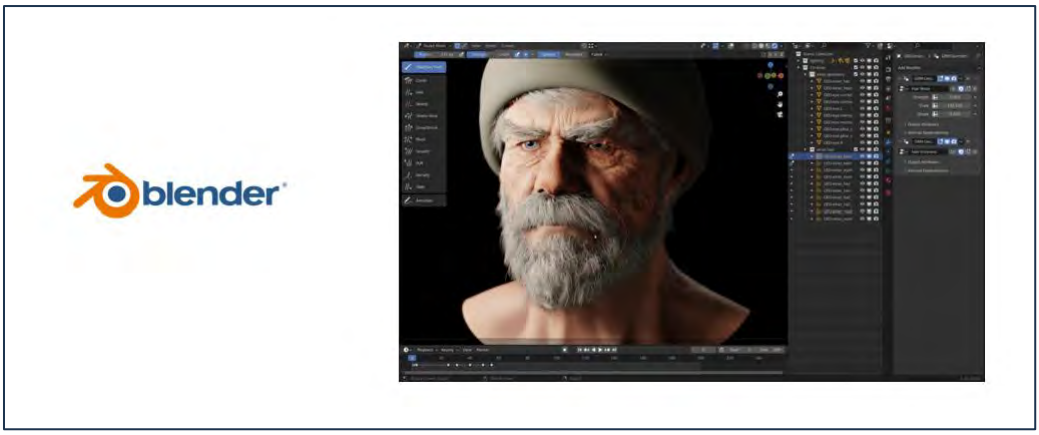


Figure 1.6.1: Blender Program

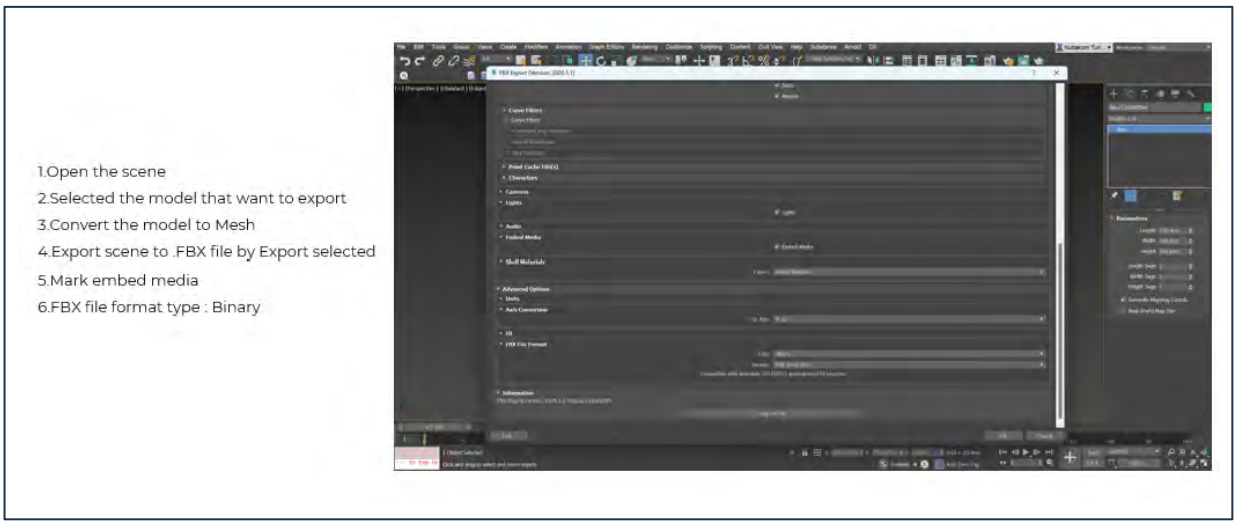


Figure 1.6.2: Opening 3Ds max scene(cavery) to export

- export the file from 3ds max , and import it in Blender
- -And then we gonna send this scene to Spatial platform ,you need to input a new material in Blender again ,because the Spatial platform is required the .GLB file , And Blender can open and export this file, so this mean that almost of you material in this scene will effected in Spatial environment.
- -Normally , I adjust only 4 parameter in this material slot , cause the scene of spatial ,they already provided and lock the lighting ,the image reflection and environment , it's like an instant scene that already beautiful , so some effected is not happened in spatial scene

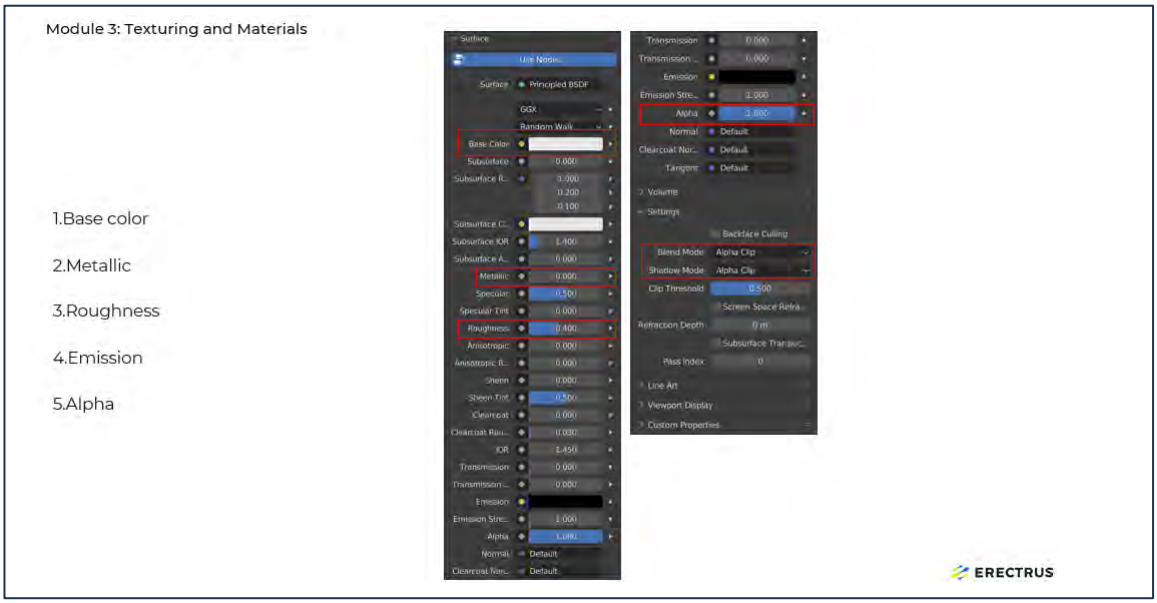


Figure 1.6.3: Import file to Blender

1.7 Integration with Other Software

The other technic of Blender Add-on ,which sometime may help you to do the scene for urban.

- **Blender GIS** , it's like a , we can import the GIS data from the google map to be like a 3d model , Maybe you guys can use this technique to fulfill or reference in your urban scene.
- -You will get the data like a Building ,Highway , railway something like that form the googlemap.
- **Blender MapModelImporter**.
- -This add-on quite difference with Blender GIS , The Blender GIS gonna provided a lot of data in GIS but you will only an object , you will not get the texture or the finishing of that.

- -But for BlenderMapsModelsImporter , it's like a you capturing the 3d scene form the google , you gonna get all of the object that you see in the scene.
- -the model , the material , all of that will appear in Blender.
- **Blender Buildify** , The Blender Buildify is a instane node for creating the building , this one is not an Add-on , you can create or change the parameter in that node to change the detail in your building ,
- -It's not mine , I didn't created this node but I think it's quite useful for your guy maybe for the future , so we talking about this technic also.

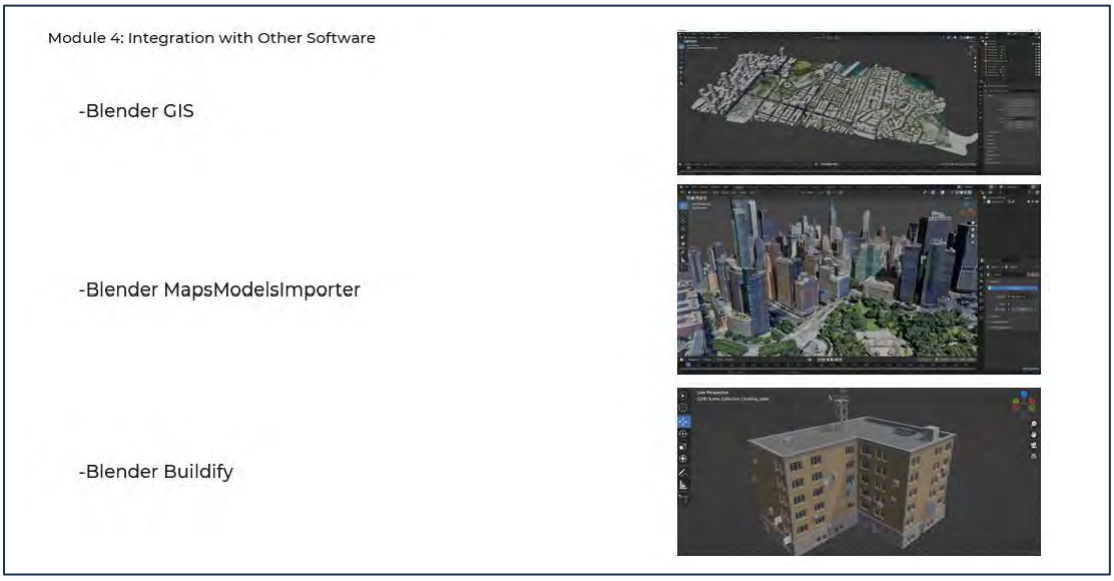


Figure 1.7.1: Integration with Other Software



Figure 1.7.2: Blender GIS (Add-on)

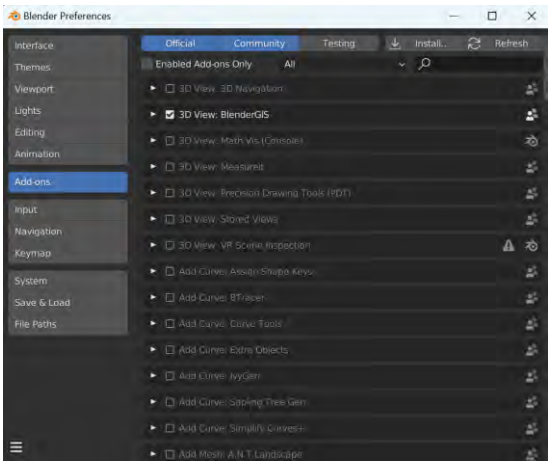


Figure 1.7.3: Blender GIS (Add-on) Installation

How to install Blender GIS (Add-on)

- 1.Download and Install Blender
- 2.Download Blender GIS master and install by this step
- Edit > Preferences > Add-ons>install > select zip file(BlenderGISmaster)
- > Mark on 3D View:BlenderGIS > the button(GIS)will appear

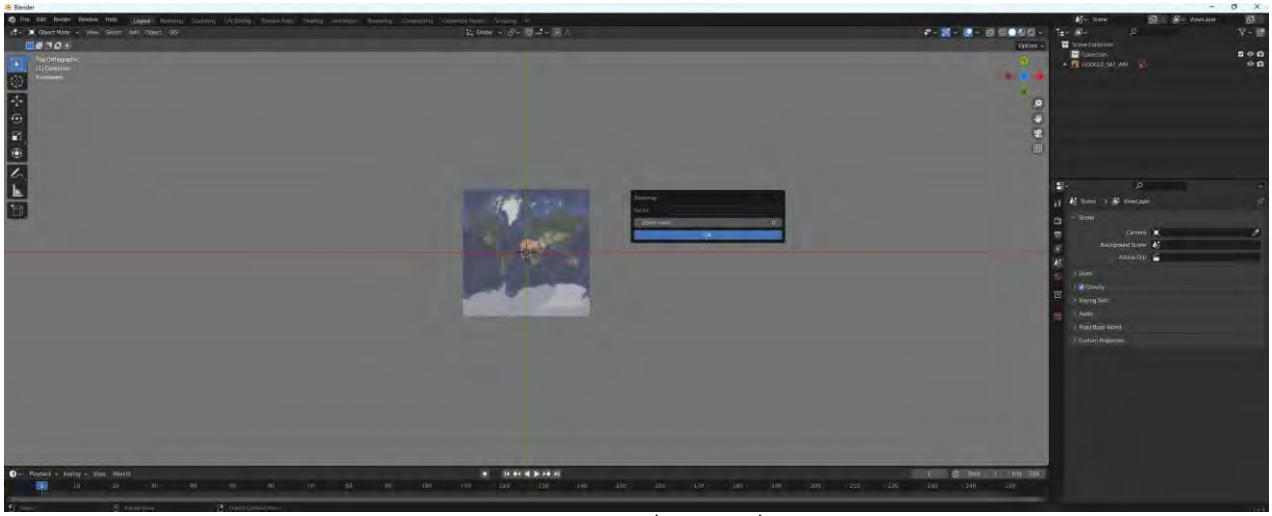


Figure 1.7.4: Blender GIS (Add-on) Base map

- -open GIS > Web geo data > base map
- -Press G to search the Location
- -Suggestion zooom level 16-18



Figure 1.7.5: Blender GIS (Add-on) Loaded

- -Press L to Lock the screen
- -scrolling the mouse to zoom in and out (the data will automatically loaded)
- -Press E to finish the scene

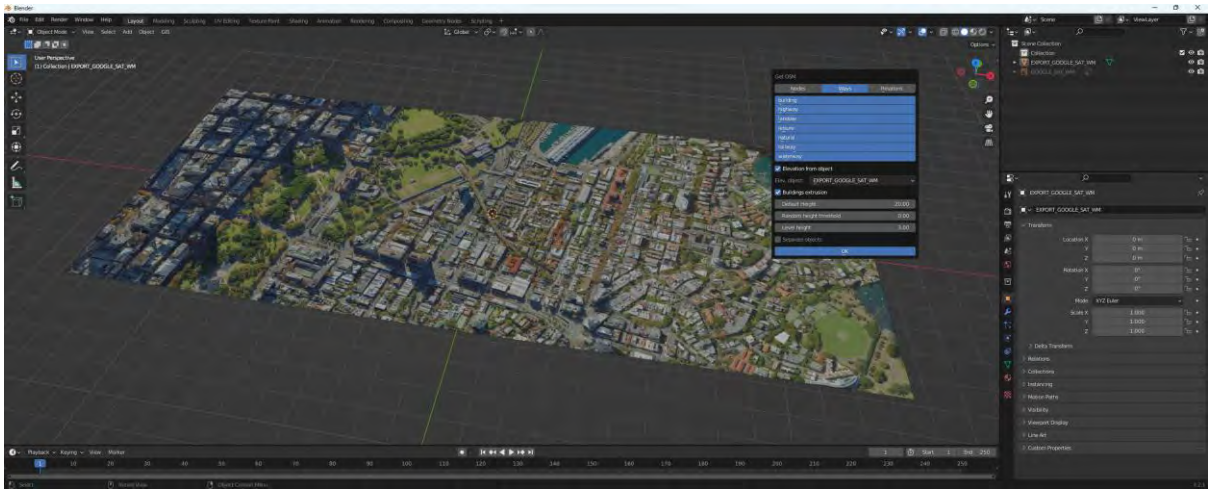


Figure 1.7.6: Blender GIS (Add-on) Get OSM

- -Back to the GIS and selected the '' Get OSM '' in Webgeodata
- -Choose Export_google_sat_wm
- -select all of data you need and don't forget to checking the box '' Elevation from object ''

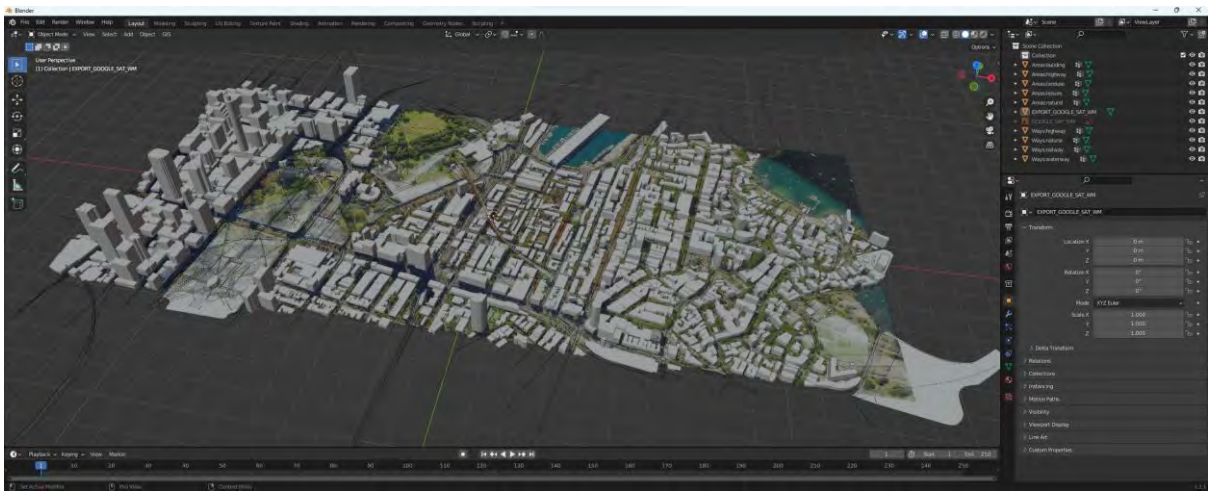


Figure 1.7.7: Blender GIS (Add-on) Data Import

Blender MapModelImporter.

- -This add-on quite difference from Blender GIS , The Blender GIS gonna provided a lot of data in GIS but you will only an object
- -But for BlenderMapsModelsImporter , it's like a you capturing the 3d scene form the google , you gonna get all of the object that you see in the scene.



Figure 1.7.8: Blender GIS MapModelsImporter (Add-on)

How to install Blender MapsModelsImporter (Add-on)

- 1.Download and Install MapModelsImporter (Version depend on Blender)
- 2.Download and Install Render DOC (Version depend on Blender)
- 3.Download and install google Chrome

Process

- 1.Going to C: >Program file or Program file(X86) > google > chrome > application >create shortcut
- 2.Put the new shortcut on desktop
- 3.Changing the name to : C:\Windows\System32\cmd.exe/c "SET RENDERDOC_HOOK_EGL=0 && START "" ^"C:\Program Files\Google\Chrome\Application\chrome.exe" --disable-gpu-sandbox --gpu-startup-dialog“
- (Don’t forget to change your root folder)
- 4. Open Chrome and check the number
- 5.Open Render DOC
- 6. In Render DOC go to : File>Inject into process
- 7.Fill the number that you get from your Chrome
- 8.Close the number tab ang use your Chrome going to Google map
- 9.Selected the area that your want in 3D view
- 10.Back to render DOC > Capture Frame(s) Immediately
- 11.Move around a little bit on 3d map
- 12.Save capture as on Render DOC (you will get the .rdc file)
- 13.back to Blender , Import google maps capture (.rdc)

Blender buildify is a node parameter tools , that provide you to make a model of building by adjust only the number on node.

- -So it quite simply and easy to adjust the model , I’m talking about this feature for show you guys the another way of process to created the object.
- -you can take a customized the shape , the amount of doors or windows by input only number. It’s like an instant tools.
- -and you can also add modifier to geometry nodes on your new plan shape to created this building

-may be it’s quite useful for making the building for the urban scene.

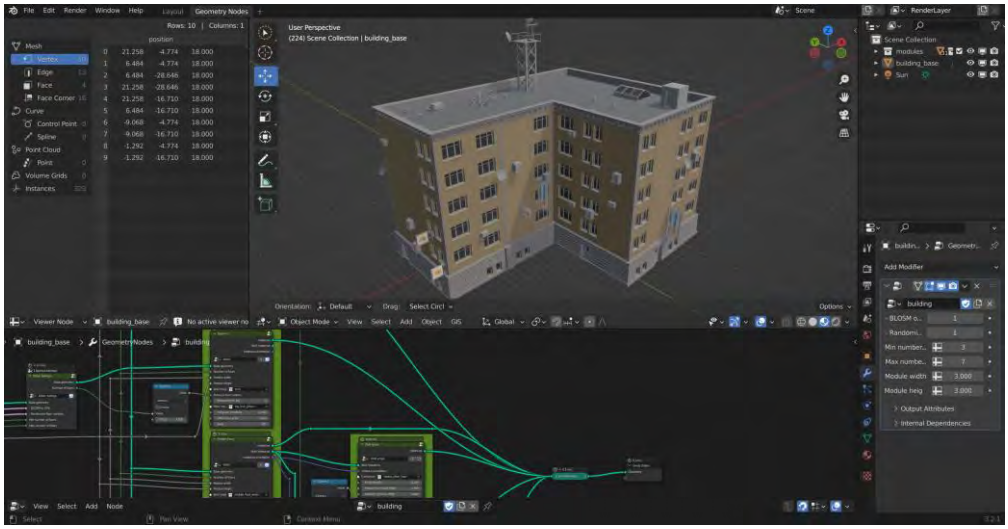


Figure 1.7.9: Blender Buildify

1.8 Export scene from Blender to Spatial (Metaverse)

- 1.Export scene to .GLB file
- 2.Use format glTF Binary (.GLB)
- 3.File can't be over 100 Mb
- (Spatial Limitation)

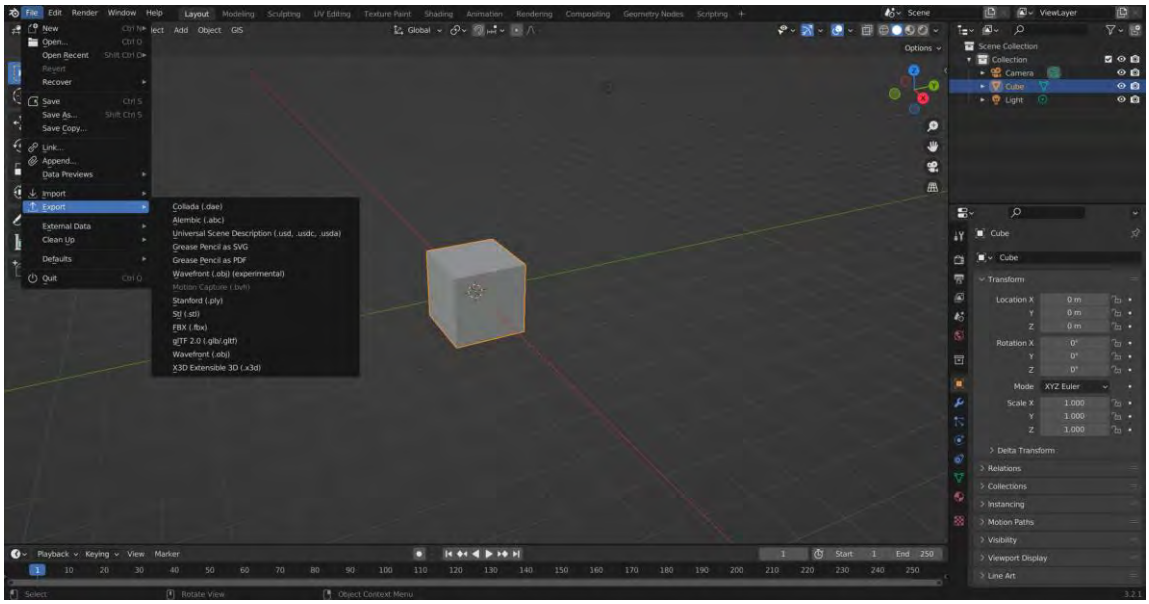


Figure 1.8.1: Sample Export the Cavery scene



Figure 1.8.2: Device Set Up

Device setting up

- -for this platform youcan use , actually all of device to access. Laptop and pc you need to access by website (www.spatial.io)
- -and for mobile , tablet , and VR headset , you need to access by the Application name Spatial.
- -When you access by website , or Application , the avatar controlling is quite difference.
- -by website you need to control by using the keyboard to move and using mouse to rotage your Avatar.
- -and by Application , you need to push button on the screen , 2 buttons to move and rotage your Avatar.
- -for my opinion , using this platform by website is quite easy for the first time.

How to created the account ,

- -Normally you can access by guest into the room , but you will cannot modify your avatar and it will be a simple one it's like a quickset.
- -and the next time when you access it again , you will lost all of your data. I mean the data from the last time.
- -there are 5 options to created the Account.
- -1. by google account

- -2. by metamask , metamask is a web3. wallet ,
- -3. by apple account
- -4. by Microsoft account
- -5. by using e-mail

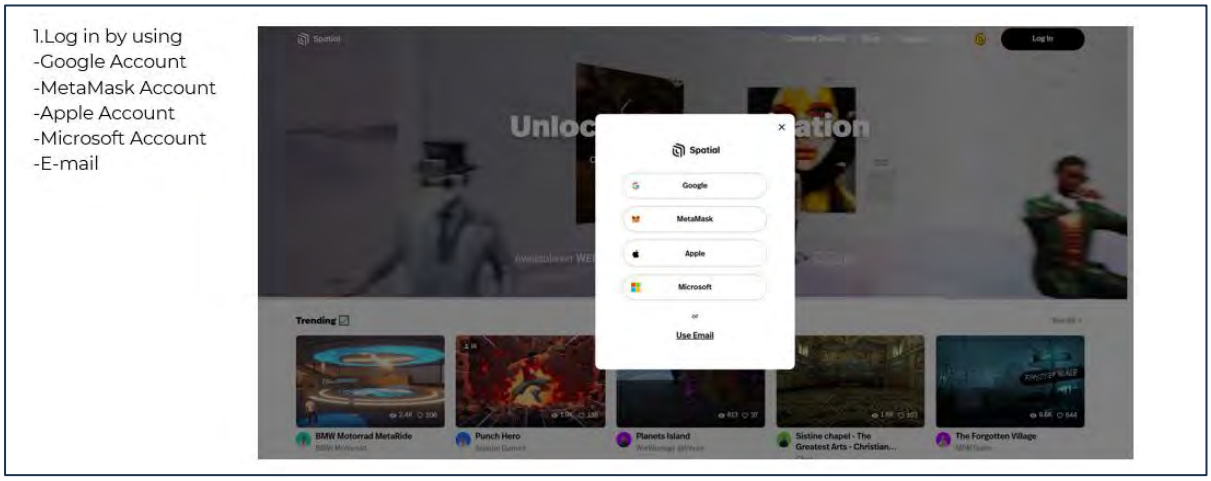


Figure 1.8.3: Spatial Log in



Figure 1.8.4: Customize Avatar in Spatial

- Customize Avatar
- -Ready Player Me
- -Realistic head

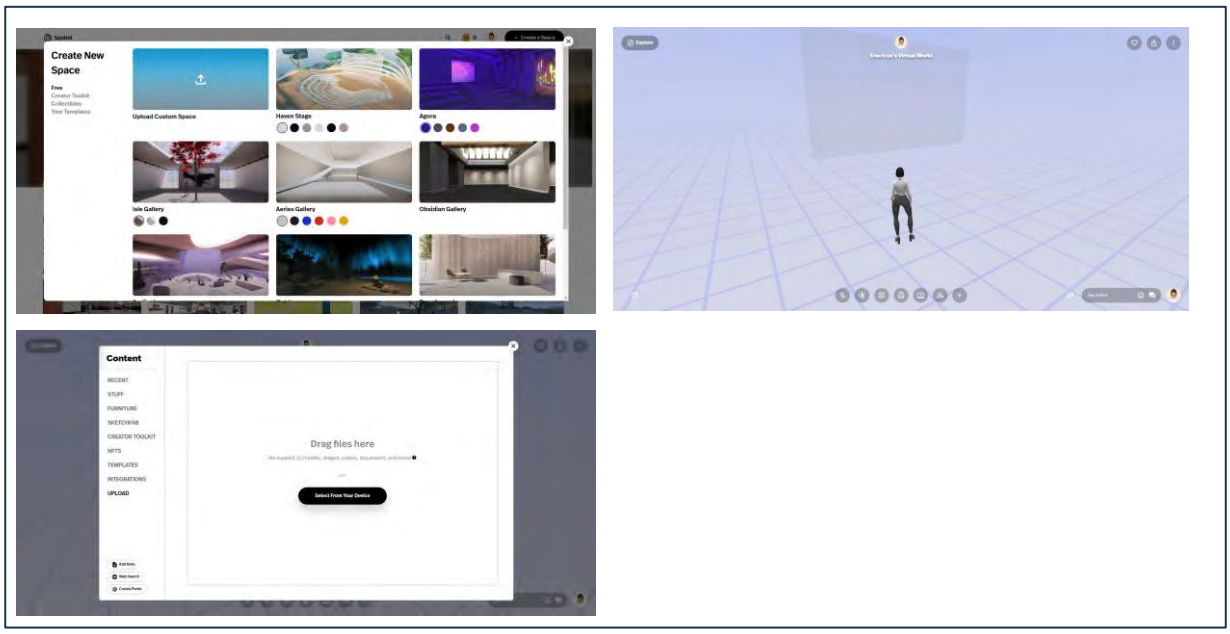
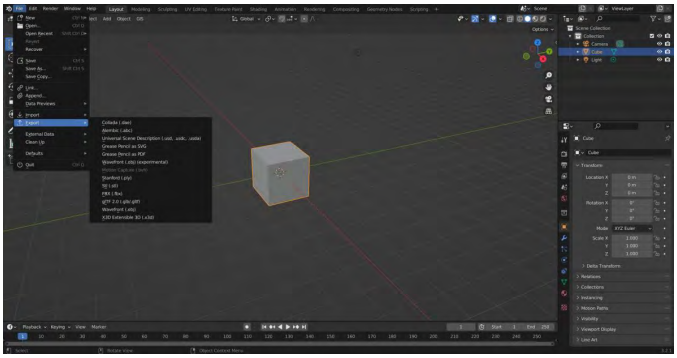


Figure 1.8.5: Create New Space in Spatial

Format	Maximum Size
3D Files - We recommend that you use a maximum texture size of 2048x2048.	
OBJ	100 MB
glTF	100 MB
GLB	100 MB
FBX	100 MB
DAE	60 MB
PCD	10 MB
Videos	
MP4	200 MB
MOV	200 MB
GIF	200 MB
Images	
PNG	10 MB
JPEG	10 MB
TIFF	10 MB
Documents	
PDF	100 MB
Microsoft Word .docx	100 MB
Microsoft Powerpoint .pptx	100 MB
Microsoft Excel .xlsx	100 MB





- choose Upload custom space , the window will show like this , (the empty scene) .
- The next one you need to drag and drop your .GLB file in here and your model will appear like this . (the small one)
- And then you need to selected on your model and choose ''set custom environment'' topic and choose environment again . And then your model will be the scene like this.
- You can also adjust the scale and positioning by choosing edit before finished its.



Figure 1.8.6: Custom Environment in Spatial

Scaling and Positioning object

- It mean if you complete to setting up your scene environment already and you need to add some more object , you can choose add content button or drag and drop you model into the window
- An then the tab will appear on the right . You can adjust the positioning , the rotation and scale by sliding the bar or input the number .
- -By the way, there is some trick if you export the model by Blender
- -Before you export from Blender you should moving your model to the center of 3 axis X , Y and Z like this pic. , It's super easy when you have to rotate or scale your model in Spatial , cause the Spatial will refer the axis to be the center of the model .
- -and the next trick , when you want to positioning your model in spatial , you can choose the object by click the left button on your mouse and hold it , and moving your avatar by using W A S D button on your keyboard , the object will following your avatar. It's like a you hold your model on your hand and carrying it .
- It's quite easy to setting up the positioning.

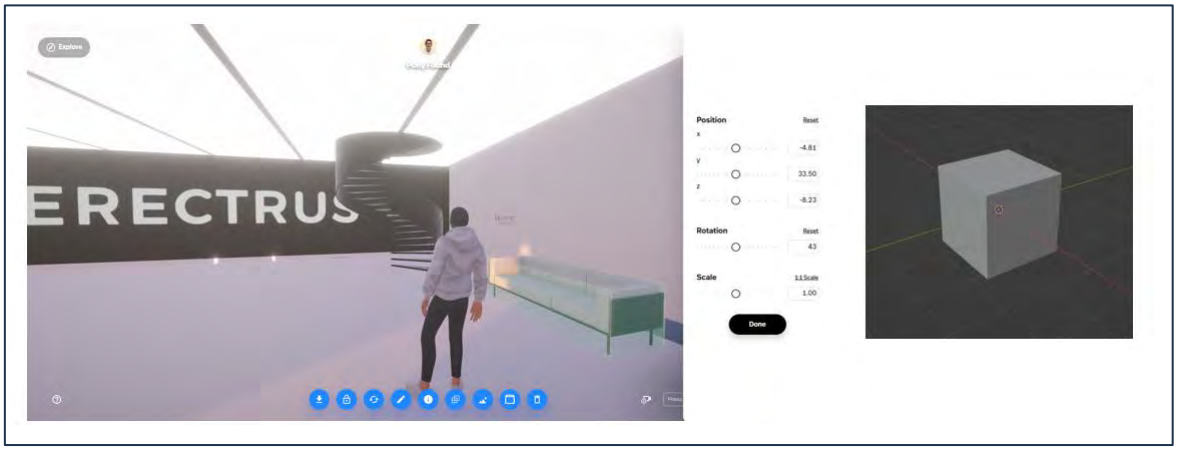


Figure 1.8.7: Scaling and Positioning in Spatial

How to setting up the skybox.

- What is the Skybox?
- -Skybox is a 360 degree orb
- It like a 360 degree image that was mapped into a sphere to use to be an environment in your scene
- You can also create your own Skybox by searching the view from the google map or download the 360 degree picture from internet

- OK for this topic I will show you how to create the skybox by searching the image from google map
- 1. You need to have a sphere to be a model for mapping 360 degree image
- -you can download this sphere from spatial website , or I will send you a link. into a massage box
- 2.You need to have a 360 degree image from google map , you have to download the software name ''Street view download 360'' , yes I will send you the link to download.
- 3.When you got the image by street view ,next one you have to convert the sphere and image to be a skybox file by using '' glb packer '' website , and don't forget to change the file name which you got to be ''texture''
- Then , you can drag and drop the file that you get from glb packer into your space and setting up this sphere to be a skybox . It finished , your space environment will change.



Figure 1.8.8: Create Skybox

'' How to uploading content & Supported file types ''

- Supported file type and limitation on Spatial
- - For 3d object , the file can't be over 100 Mb , you can choose about 6 type of file , but I recommended .GLB file
- -For Video , the file supported is .MP4 , .MOV and .GIF
- -For Image , the file supported is .PNG , .JPEG and . TIFF
- -And for the documents you can upload Microsoft file and Pdf by originally file , they will appear like a floating board , and you can also flip the page by click on the arrows
- The process is pretty simple , you can drag and drop the file which you want to upload to your window and adjust it , it's finished

Or you can click on ''Add content'' button and choose the content from the other source , such as from your Sketchfab account or from web search

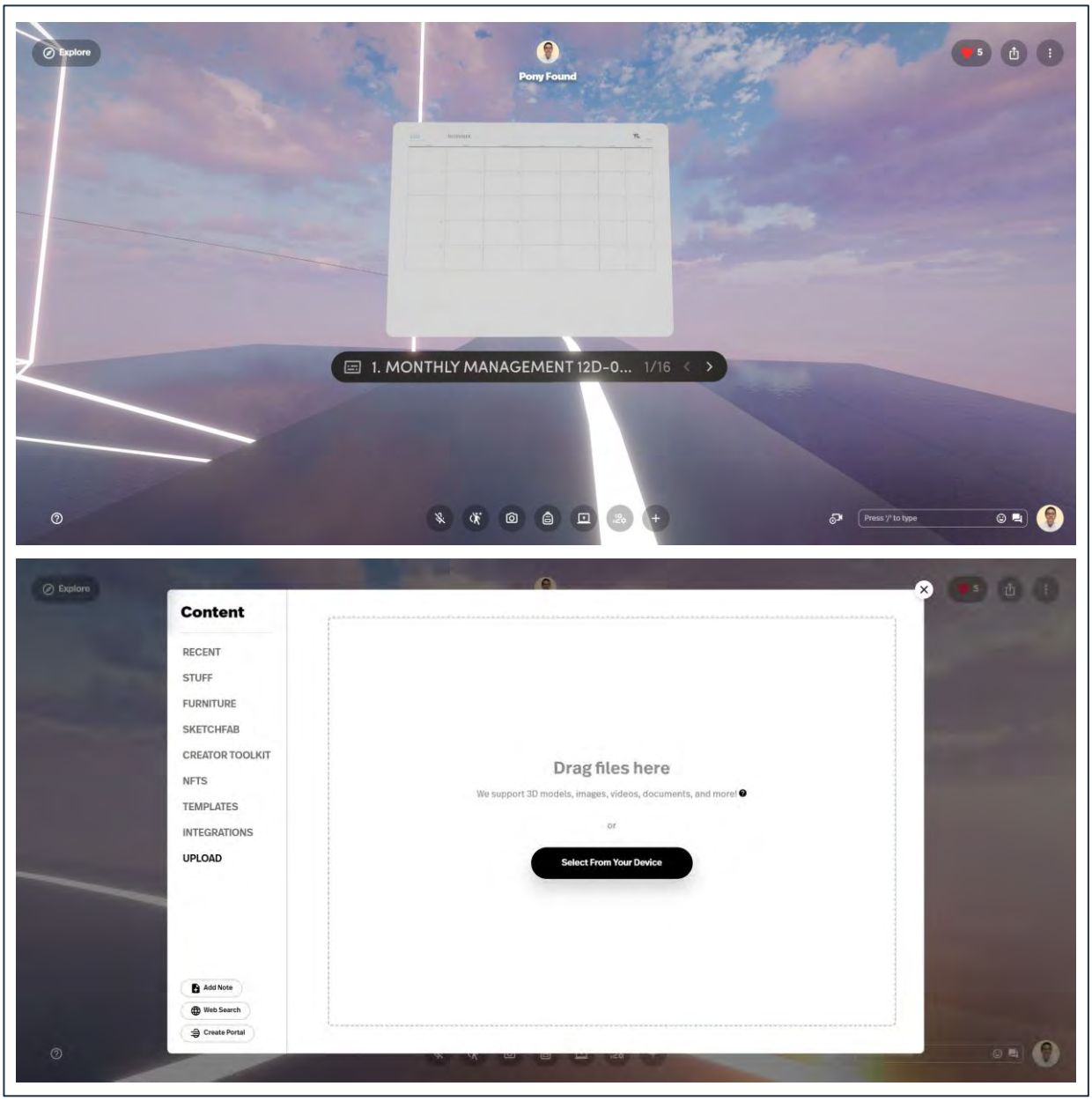


Figure 1.8.9: Uploading Content & Supported file types

Lidar scan.

- Lidar is stand for ''Light Detection and Ranging'' , is a remote sensing method used to examine the surface
- This function is only found on Spatial application , you can use by mobile phone or Ipad.
- You can Choose ''add content'' and Scan object

On the right picture I've scan my face to become like a 3d model

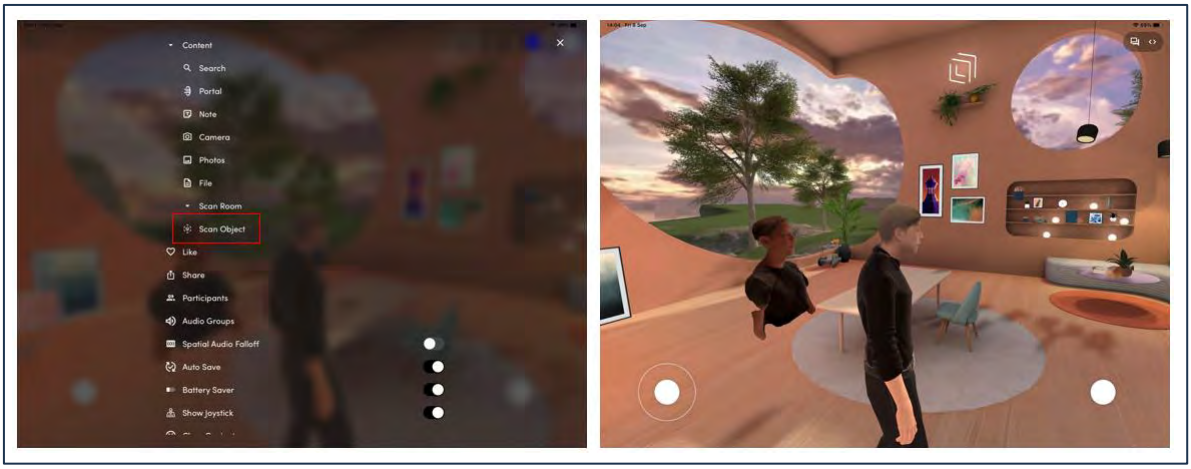


Figure 1.8.10: Lidar Scanning with Spatial's ios App

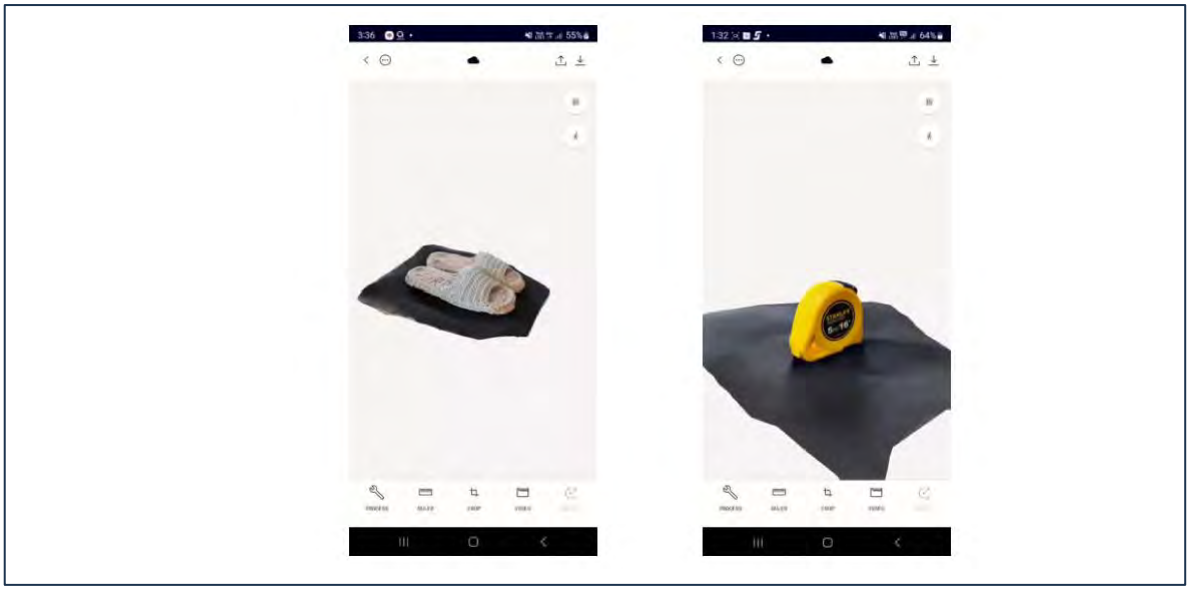


Figure 1.8.10: Lidar Scanning the Objects

Sketchfab integration

- Sketchfab is a 3D modeling platform website to publish, share, discover, buy and sell 3D model, VR and AR content.
- In spatial ,you can upload directly form Sketchfab when you finished logging in your account
- Not only the 3d model but also the environment and skybox as well .

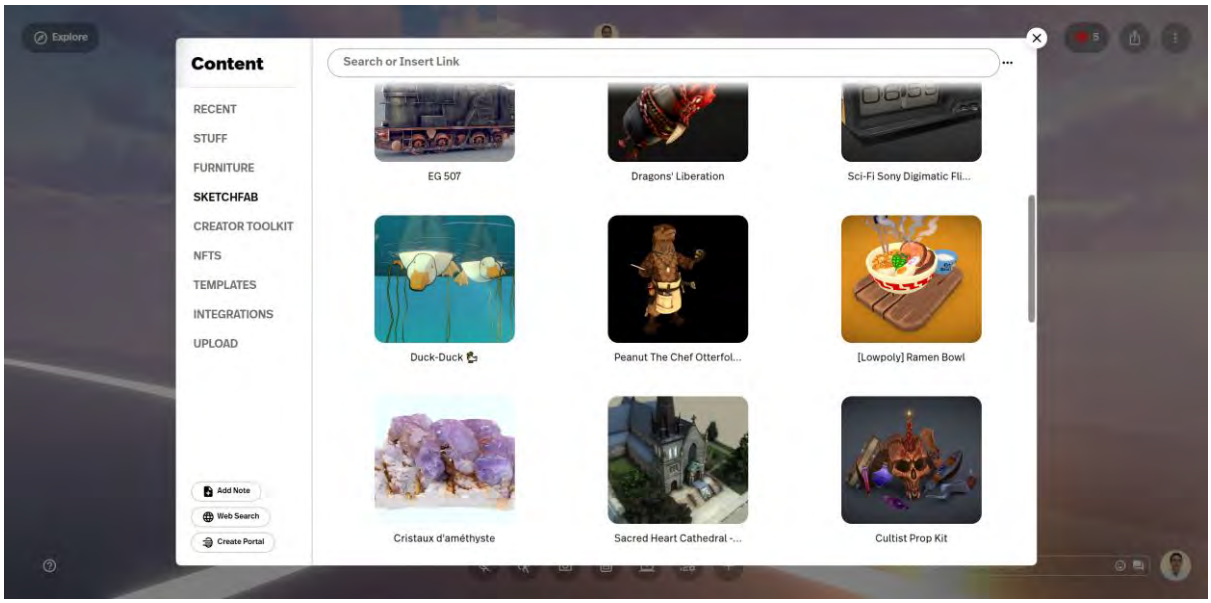


Figure 1.8.11: Sketchfab Integration

The web searcher

- Web searcher is like a search engine tools on spatial
- You can search the image and 3d model by typing in a searching box
- They will show an option for you.
- The process is click on '' Add content '' and then click on the web search topic .

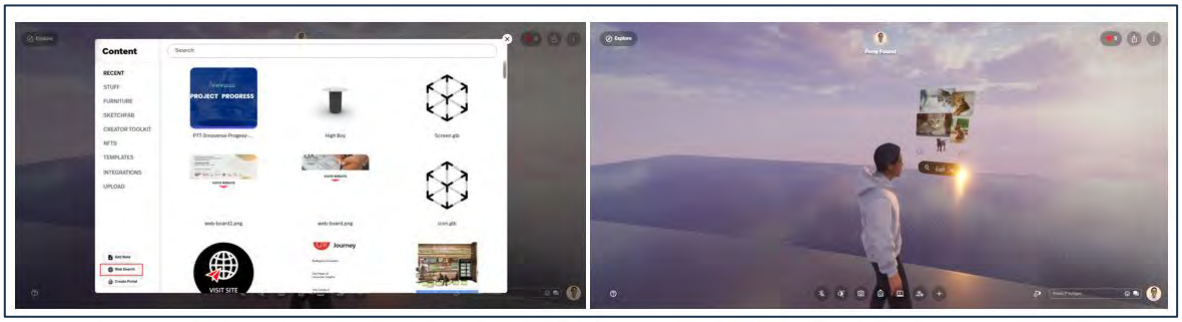


Figure 1.8.12: Web Search

Spatial Creator toolkit

- Spatial Creator toolkit is the one of features which let's your free to create your scene and condition , but you need to finished the scene pass through Unity software.
- Unity is a cross-platform game engine, for create a condition in your scene
- You need to create your scene from 3ds max or blender and export them by .FBX file , and import to unity to making a condition or scripting
- There are a many topic how to setup the condition provided on spatial website ,
- It's quite hard to doing this feature , you need to know how to using unity software , how to setting up order and result , It's like to making a little game in here
- But you will get the perfect scene in here , you can control the lighting , the real reflection on your object , the environment , adding some fog or some rain in here. For example
- I will show you some part of our space from SDK and , we will get into the space together , you can test to uploading , sharing some content and explore how to be the metaverse

And before we get into the space , I will show you this space scene in unity.

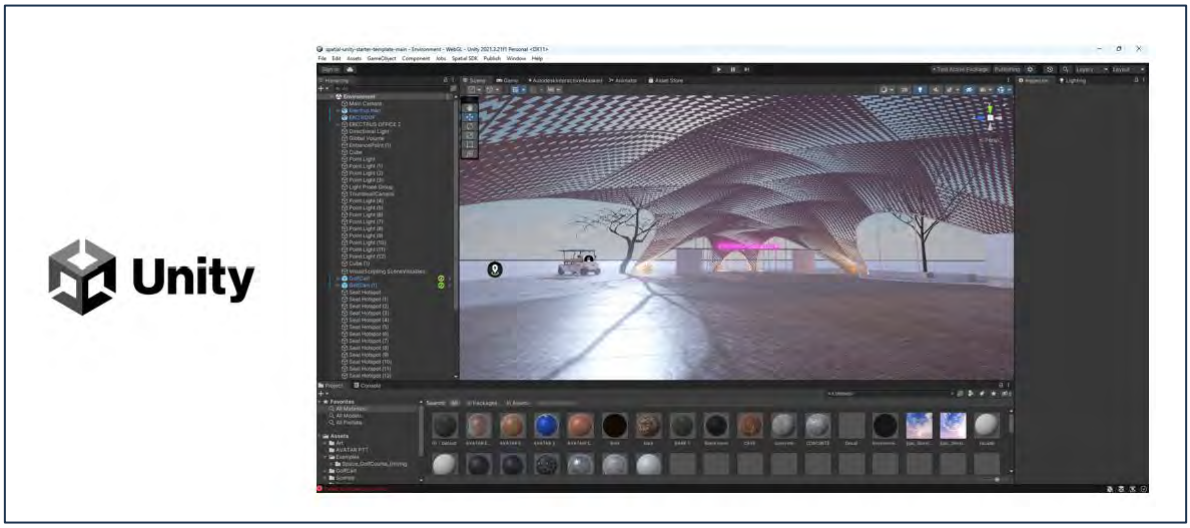


Figure 1.8.13: Spatial Creator Toolkit (Unity SDK)

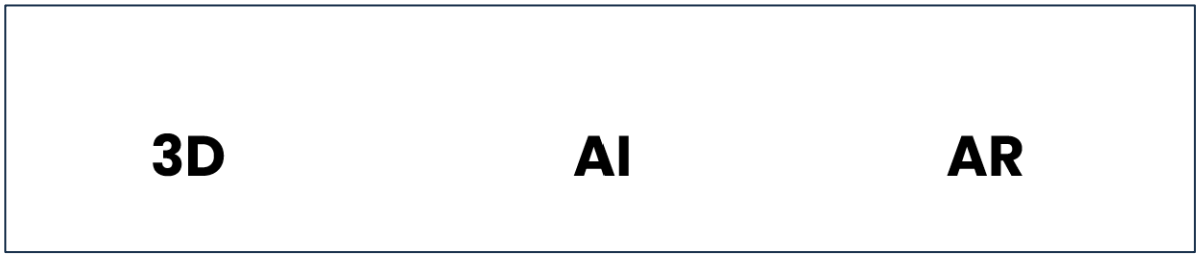


Figure 1.8.14: Summary of the Objective of the course

Part 1:

1. Preparing materials to be used for building our 3D models
2. Learning how to create 3D models from sketches using AI tools

Part 2:

3. Learning how LiDAR scanning works and how to scan objects using the Polycam app
4. Going out to do on-site LiDAR scans to capture the environment and generate 3D files of the surrounding area
5. Converting 3D models into AR for presenting projects in new and engaging formats
6. Creating QR codes to access the AR experience via mobile devices or tablets
7. Mapping AR models into real-world spaces using the SketchUp program

That's a rough overview of the topics we'll be covering. Some parts will be demonstrated for you, while others will require **hands-on participation** from all of you.



Figure 2.1.1: Based on the Site of the Project

Part 2. SKETCH TO 3D MODEL BY AI

2.1 Project Urban Development Data

- The project area is divided into four main building groups, with two roads cutting through the center, connecting to the main road and a bridge.



Figure 2.1.2: Project Area



Figure 2.1.3: Sketch Image Data

- this image as an example for our project. We will create an image using sketch lines and then generate a 3D model from the image.

How to Convert a Hand-Drawn Sketch into a 3D Model

1. The main process begins with sketching the model you want to create. The level of detail and material accuracy in the sketch is flexible because we will first use AI to transform the sketch into a realistic image.
2. The next step is to convert the AI-generated image into a 3D model file.
3. For this project, I will not go into too much detail on AI image prompting. Instead, I will present this as a workflow that can be used to complete the task.

4. Currently, there are many AI tools available for image prompting, each suited for different purposes. Since our project is architecture-focused, I have selected AI tools that are best suited for this type of work. Some of these tools offer free trials, while others require a paid subscription.

   AI Tools for Converting Sketches to Images:

   - **mnml.ai**
   - **Prome AI**
   - **Vizcom AI**

   You can also use other AI tools like **Midjourney** or **DALL-E** (from ChatGPT), but the three listed above are more specialized for architectural projects.

   AI Tools for Converting Images to 3D Models:

   - **Tripo AI**
   - **Meshy AI**
   - **Trellis AI**
   - **Vizcom AI**

   Vizcom AI is the only tool on this list that can both generate an image from a sketch and convert that image into a 3D model. However, extracting the 3D model file from Vizcom AI requires a paid subscription.



Figure 2.1.4: Sketch to Image to 3D Model

2.2 Prompting

The basic principles of prompting an image from a sketch are as follows: First, you need to upload the sketch image to the platform. Then, you need to input a prompt specifying the details of the image you want, prioritizing the prompt as follows:

1. **Subject**: The main topic or subject, which is what you want to depict. For example, in this case, it is "A modern high-rise office building."
2. **Description/Style**: This can vary and is not fixed. It describes what you want in the image, such as the materials of the building, the style of the building, and the surrounding landscape.
3. **Quality**: This includes the details of the image you want, such as the size and resolution. Some platforms may lock the image size, and if you want a larger image, you might need to pay.

Nowadays, you don't even have to write the prompt yourself. You can use AI to write it for you. In this example, I used Chat GPT to write the prompt for this building.



Figure 2.2.1: Sample of Prompting

2.3 Sketch to Image

- **mnml.ai**.
- uploaded the image and entered the previously written prompt, keeping all settings at their default values.
- The result is quite satisfying, but we can further adjust various settings or refine the prompt to better match our needs. For example, we can modify the **Geometries** settings

to make the design more **precise** or more **creative**. Additionally, we can use **negative prompts** to exclude unwanted elements from the generated image.

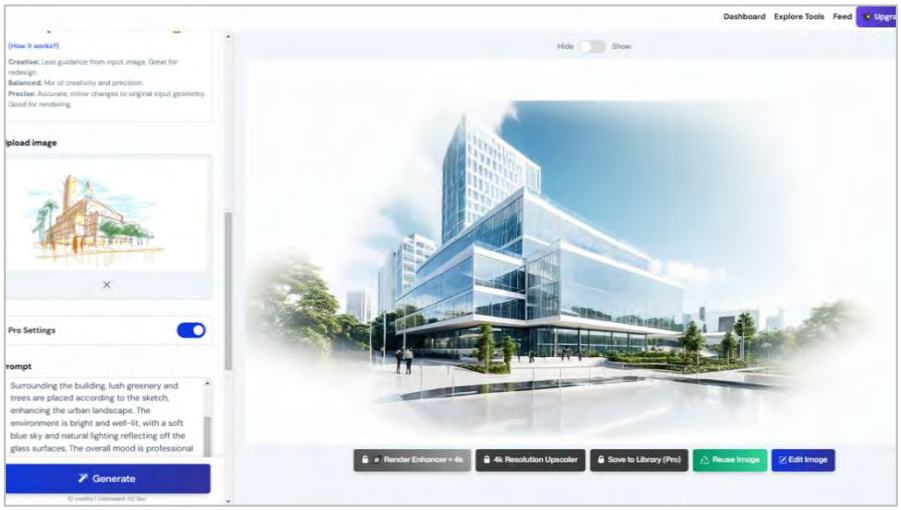


Figure 22.3.1: Uploading the Image

- **PromeAI.**
  I used the default settings and entered the same kind of prompt as before. The results are shown as three images for us to choose from. From what I can see, the first image came out with the wrong angle. The second and third images maintain the same perspective as the sketch, but the details are different.

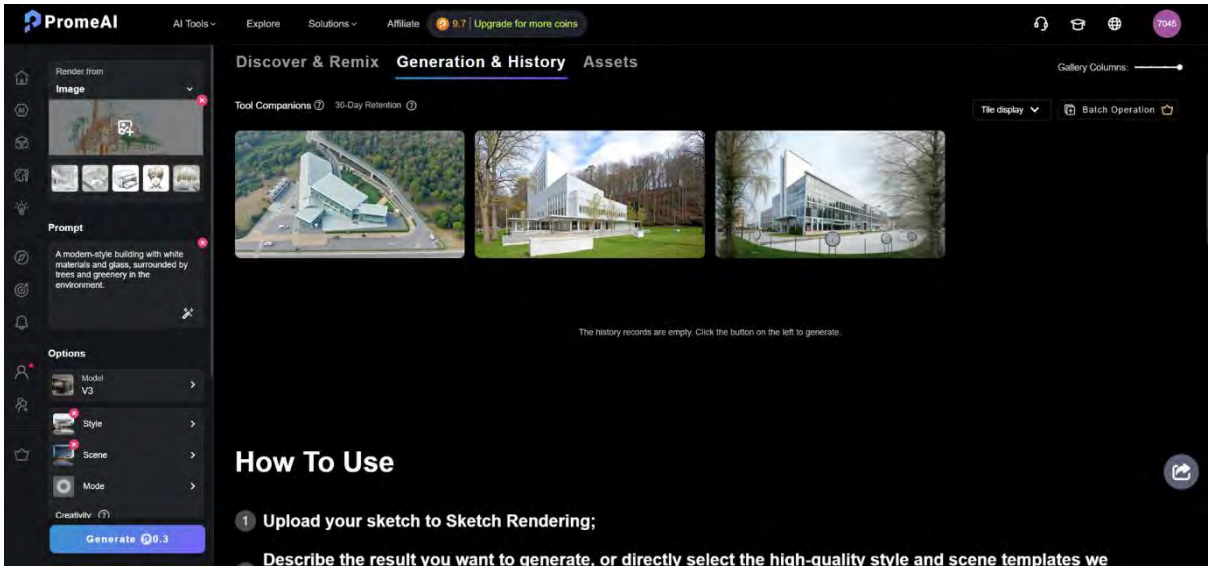


Figure 22.3.2: PromeAI



Figure 22.3.3: Download to PromeAI

the system only allows downloading in small sizes. If you look closely, the building shape in image 2 doesn't match the sketch, while image 3 is more similar. That said, it might be necessary to experiment with the prompt more to get the most accurate result.



Figure 22.3.4: Download to www.vizcom.ai

Vizcom.ai.

This platform allows you to generate an image from a sketch and even create a 3D file from that image. However, you can only download the image — to download the 3D file, you need to pay.

I uploaded the same sketch as before, but I adjusted the drawing setting from 100% down to

70%. If you leave it at 100%, the result will match the sketch exactly, both in color and linework.

2.4 Image to 3D Model

- creating 3D model files from images.
  The process isn't much different from generating an image from a sketch. We can upload the image created from a sketch directly into the platform we'll be using — we don't need to create any prompts. Most platforms will automatically calculate the details from the image.

Currently, platforms that generate 3D files from images still don't produce highly detailed 3D models. However, they are usable as architectural elements at an urban scale, primarily for distant or background views.



Figure 2.4.1: Tripo Platform

- **TripoAI**.
  I uploaded a single image that we previously generated from a prompt, and the system produced the result as shown here.
  The 3D model file created can be used at the **urban scale**, but if you want a model that's fully detailed — including accurate back and side views — the platform provides a function to upload multiple images from different angles. However, this feature is only available in the paid version. The details in that case will match the design much more closely.

- Once the file is generated, there's a **Download** button at the bottom left of the screen that lets you save the file to your computer in **.GLB** format.
  After you get the .GLB file, you can import it into **Blender** or **Spatial** for further use.

the **Vizcom AI** platform — the same one we used earlier to prompt images from sketches. You can click on the **layer** of the image you generated, and then click the **three-dot menu**, where you'll find an option to **Generate 3D**. A 3D preview will then pop up on the screen. After that, you'll be able to **export the 3D file** for use, but exporting the 3D file requires a **paid plan**.
You might want to test and adjust the result until it matches your desired outcome as closely as possible — then subscribed and export it.

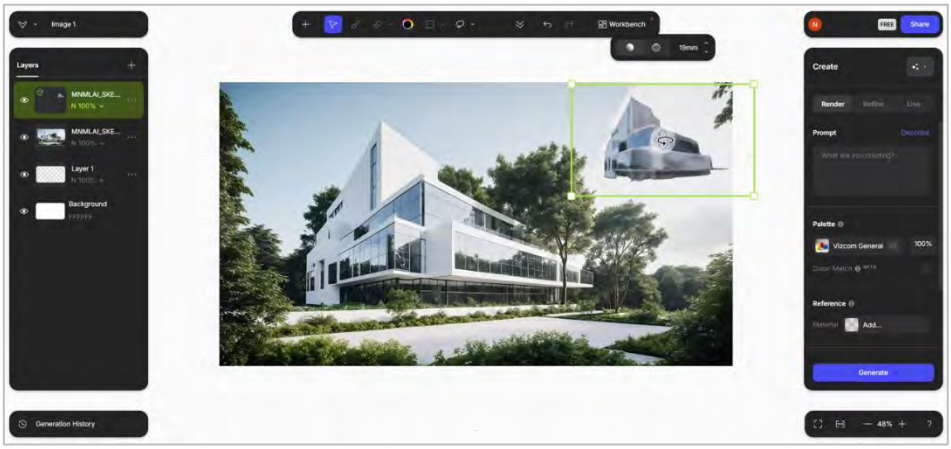


Figure 2.4.2: Sample Export 3D file to Vizcom

Trellis3D_AI.
Trellis3D is actually an **open-source platform**, meaning developers can take the code and further develop it. If you're interested, you can check it out on **GitHub** — feel free to download and try it out.

- That said, the platform also provides a web-based version that anyone can use directly. The interface is divided into three panels, as shown here.
- The **top-left panel** is where you upload your image.
- Once you click **Generate**, a preview of the 3D model will appear in the **top-right panel**.
- After the preview appears, click the **Extract GLB** button. The 3D model will then show up in the **bottom-right panel**.
- You can then click **Download GLB** to save the model and use it elsewhere — and that's it!

When it comes to **prompting images from sketches** and **generating 3D models** from those images, the results often won't be perfect on the first try.
It may take several attempts to get the desired outcome — as you get more familiar with prompting and with the tools or platforms you're using.

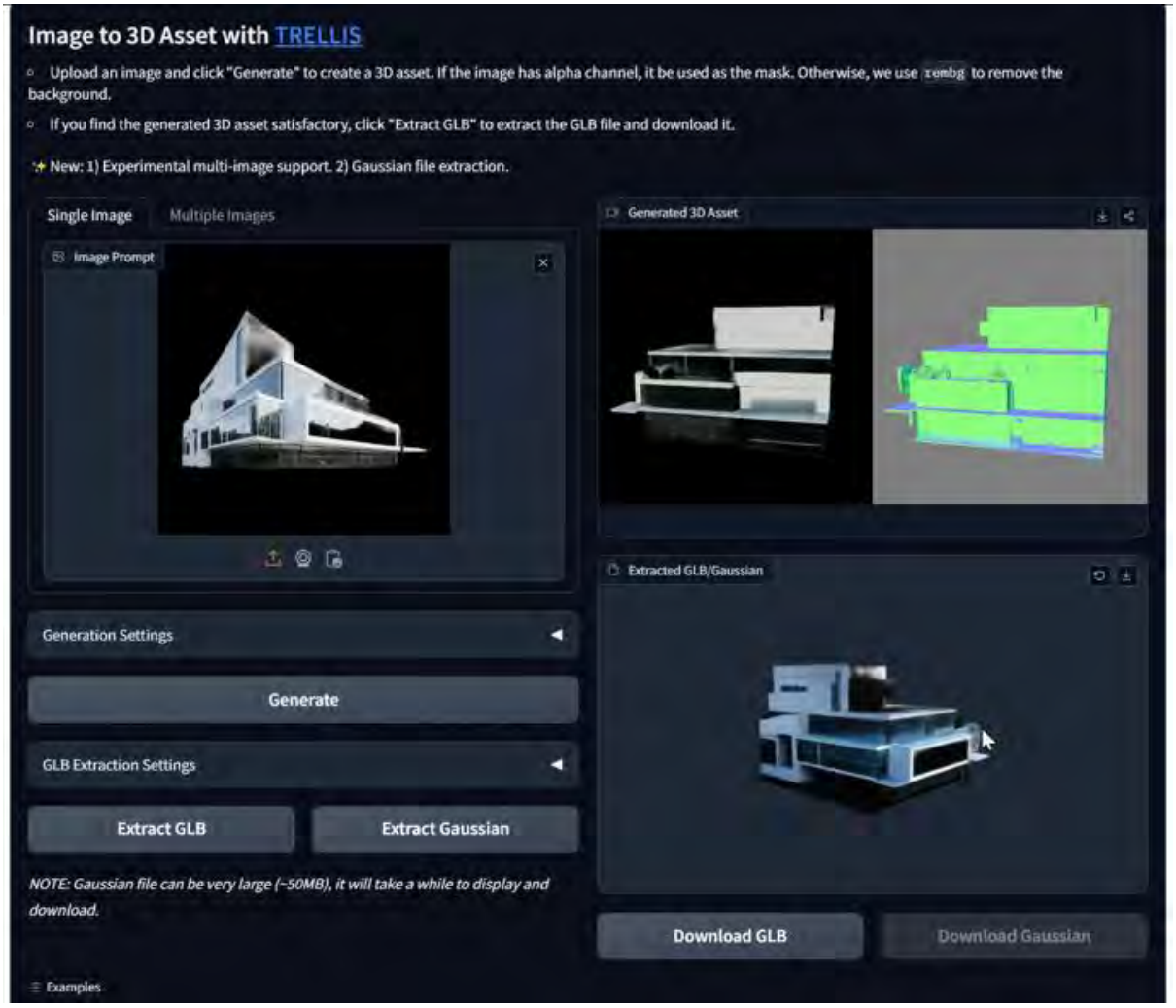


Figure 2.4.3: Sample Export 3D file to TRELLIS

2.5 LIDAR Scan | Light Detection and Ranging Scan

LiDAR stands for **Light Detection and Ranging Scan**.
It is a technology used to measure distances by shooting laser beams at an object or surface and then measuring the time it takes for the reflected light to return in order to calculate distance accurately.

How LiDAR scanning works:

1. Emit laser pulses
2. The laser hits an object and reflects back
3. A sensor detects the return signal
4. The system calculates distance based on the time of flight

   The farther the object, the longer it takes for the laser to bounce back — and the system uses that time to calculate the distance.

Data obtained from LiDAR:

- **Point Cloud Data**: Massive sets of 3D points (X, Y, Z) representing the shape and distance of objects
- Information about **height**, **depth**, and **density** of the object

Extremely precise **distance and location** data

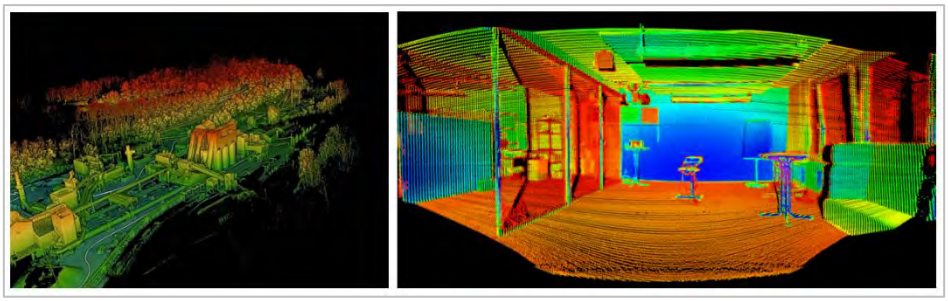


Figure 2.5.1: Point Cloud Data from LiDAR Scan

- **LiDAR** or **PHOTOGRAMMETRY** to scan surrounding buildings or environments to enhance and complete our design.
  If you remember from the previous class, we learned how to **import 3D models in point cloud format** directly from Google Maps by using a Add on in **Blender**.
- However, the **point cloud data for Colombo** hasn't been added to Google Maps yet, so we'll need to scan it ourselves.
- Normally, scanning with LiDAR typically produces **models with a high polygon count**, so we may need to **optimize or clean up the models** before use
- However, if you don't plan to deploy the project in the Metaverse, you can use the larger, high-resolution files directly and present the work as an **AR experience** or a **3D presentation** instead.



Figure 2.5.2: Photogrammetry

- **current LiDAR scanning systems** support a variety of devices, depending on the type of output needed.
  In this project, everyone will get hands-on experience with LiDAR scanning, so we've chosen to use **smartphones or tablets** for scanning, via an app called **Polycam**.
- We've already tested and compared several apps, and found that **Polycam** produces more **accurate model details** than others. Most importantly, **you can try it for free** before deciding whether to purchase the full version.
- So, please take a moment to **download the Polycam app** onto your mobile phone or tablet.



Figure 2.5.3: Variety of Devices for LiDAR scanning

2.6 POLYCAM

Polycam 3D Scanner & Editor.

And then when you get into it you can use third option to sign-up, by e-mail , google account or apple account.

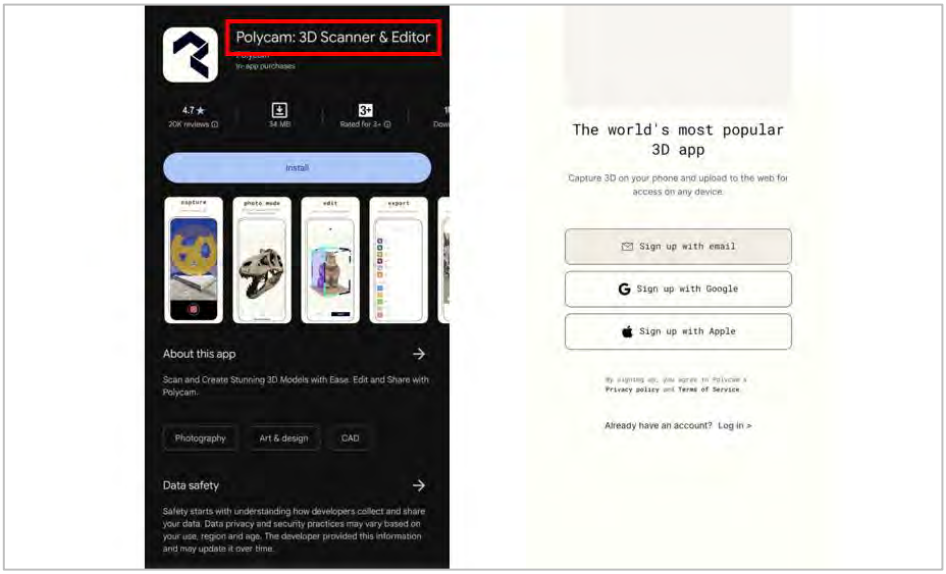


Figure 2.6.1: Polycam 3D Scanner & Editor

- get into the app the screen will appear the camera view first.
- The **interface of the Polycam app** on mobile devices and tablets is slightly different. Mobile is on the left and tablet is onth right
  you Just close it by tapping the cross **X** at the top right corner.
-
  After that, the screen will show a list of the files you've already captured.
  If you haven't scanned anything yet, you can start by tapping the **"+" button** at the top right corner.
- If I remember correctly, the app gives you some **free credits** to try scanning. After that, you'll need to **subscribe** to continue using it.
- To scan, go to the **"+" menu**. There are two scanning options:
- **Auto**: the camera automatically captures images as you move and pan the device.
- **Manual**: you need to tap the shutter button yourself for each shot.
- **How the app works:**
- You need to capture **at least 40 images** of the object you want to scan.
  Then, the app will **upload the data to the platform**, which will process and send the 3D file back to your device.
  The app will guide you through the steps with buttons for each stage.
- **Scanning tips:**
- Hold your device and **pan the camera steadily and slowly** , starting from the **top of the object** down to the bottom, and slowly rotate around the object.
  Repeat this process from all the necessary angles until you have full coverage.

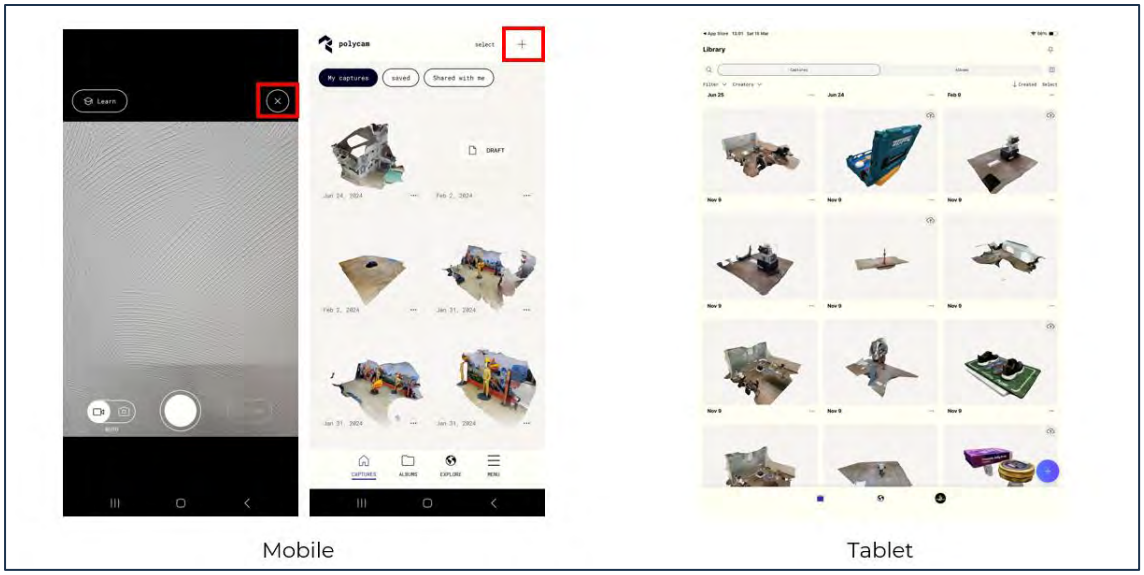


Figure 2.6.2: Polycam , How the app work.

For **ipad** device you can use option for scanning about 5 option.

- It's suite for each kind of type of object. Such Lidar , Floorplan , Object , space and 360 degree images.
  - an example of a scan I previously did — it's of an object roughly the height of a real person.
    Once you open the scanned file, you can **rotate**, **zoom in/out** to check if all the details of the object have been captured properly, or decide if you need to re-scan it.

The app also provides **editing tools** you can use before exporting, such as:

- **Crop**
- **Remesh**
- **Rotate**
- **Rescale**
- The scanned file will also include details such as:
- The **location** where the scan was done
- **File size**
- **Date and time** of the scan
- Total number of **vertices** in the model
- You can check this info by tapping the **three-dot menu** at the top left.
- If you look closely, you'll see that the scanned model includes some of the **background** behind the object. This isn't a problem — you can remove it **within the app** or delete it later using a **3D editing program** after exporting the file.

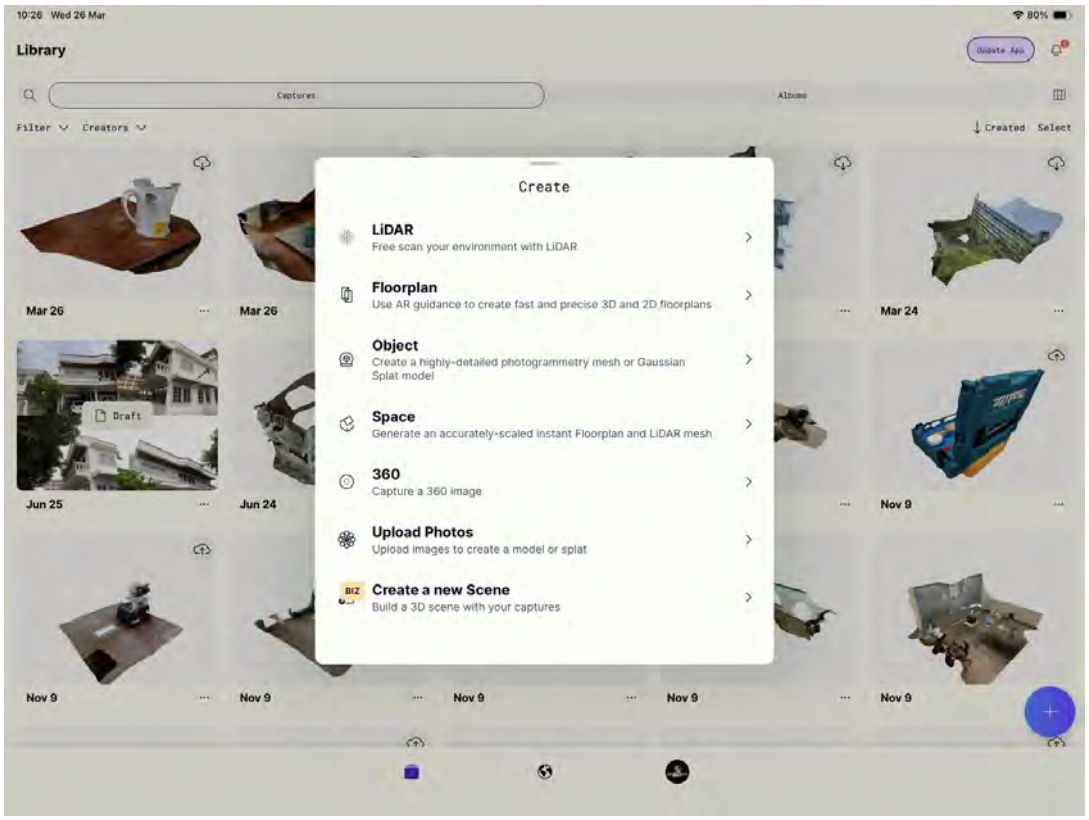


Figure 2.6.3: Polycam , App in ipad Device

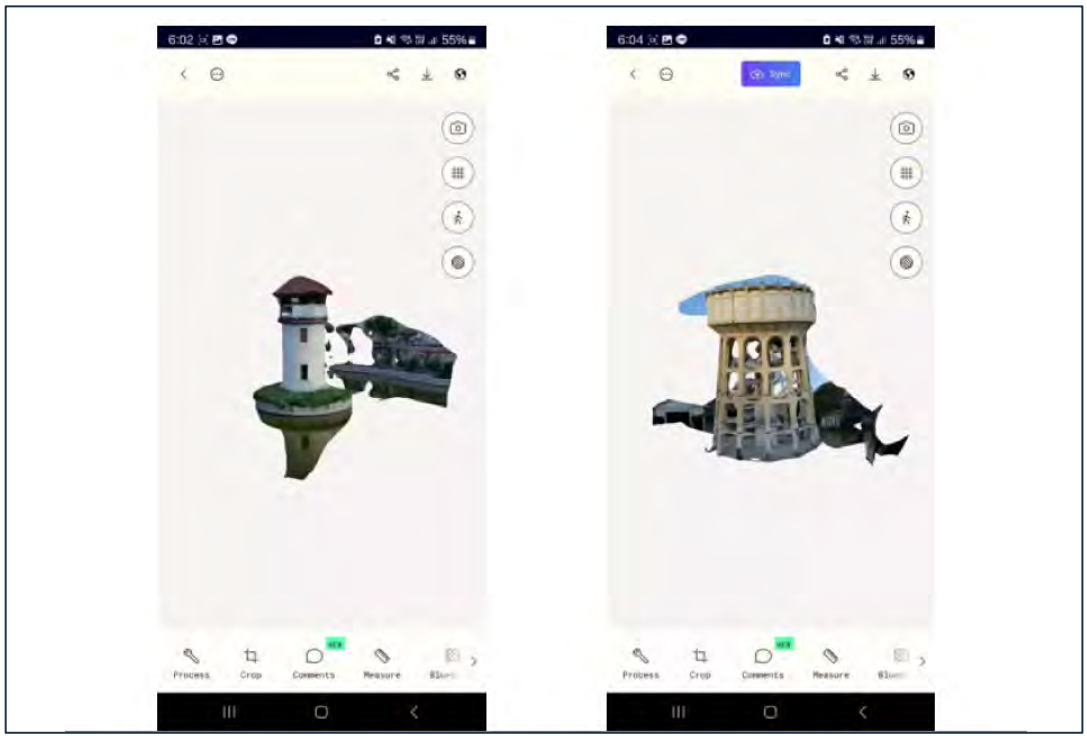


Figure 2.6.4: Example: Scanned for large building

- example I scanned — this time of an object **larger than a real person**, specifically a **tower building**.
- During the scan, I was only able to capture it from a **human-height perspective**, aiming the camera **upward**, and couldn't capture it from a **top-down angle**.
- As a result, the **upper part of the model** is not entirely accurate.
  However, the scanned file can still be **used as a base**, and you can later **add, refine, or remove parts** in your 3D modeling process as needed.



Figure 2.6.5: 3D file Formats available

- There are several **3D file formats** available for export,
  but in the **free version**, you can only export in **.GLTF format**.
  That format can still be **imported into Blender** without any issues.

- Start by **downloading the Polycam app** on your own device, then follow the steps we went through in the slides.
- Once we finish the indoor practice, we'll go outside and try **scanning an actual building** together.

- **scan the environment around the project site**.
  We'll capture nearby **buildings or key landmarks** to add into our **3D model**, helping the final presentation look more complete and realistic.
- The area inside the **yellow box** marks our **project site**.
  From what I've checked on the map, there are **two tall and visually prominent buildings** in the **red boxes**.
  If we include those in our project, it should really enhance the overall presentation.
- However, I think it would be best if we **scan the Department of Immigration building** — the view is clearer there, with no trees blocking the area we need to scan.
- **scan it by walking along the sidewalk on the opposite side**, following the **red arrows**.
  We'll start from one end of the building and walk along to the other end.
- In reality, this means we'll only be able to **capture one side** of the building. This is a **limitation of the location**, but we can always **adjust or complete the model later** in a 3D program



Figure 2.6.6: Planning to 3D scan large building

- Here is the model scanned the **Department of Immigration building.**
- But I have to edit the model file first by Blender.

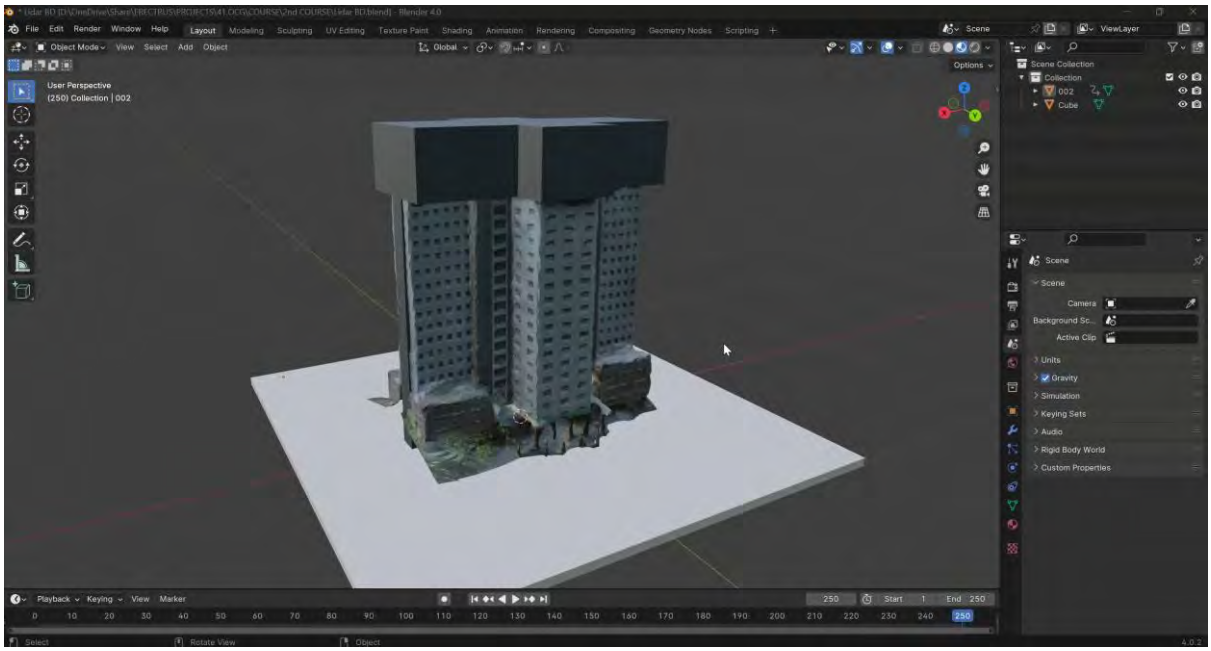


Figure 2.6.7: 3D Scan for Department of Immigration building

2.7 AR | Augmented Reality

Presenting Your Work Using AR

AR stands for **Augmented Reality**, a technology that overlays digital images, sounds, or information onto the real world through devices like smartphones, tablets, or AR glasses.

In this class, we'll create **AR files for our own projects** using a platform that generates a **QR code link**. You can save this QR code and **access it anytime later**.

Introduce **two AR workflow options** for this project:

1. The first method uses a **platform to generate your AR model**, which can be **accessed by scanning a QR code** on your mobile phone or tablet.
2. The second method may be more suitable for those who are already familiar with handling 3D files — by **opening the 3D model directly in the SketchUp application**.



Figure 2.7.1: AR (Augmented Reality) Technology

- **mywebar.com**.
  This platform allows users to **try out some features for free**.



- After signing up, **LET'S GET STARTED!!**
- Click the **GET STARTED(1)** button and **FILL IN THE REQUIRED INFORMATION(2)** (you can enter a general website like Facebook under the company website heading). When you're done, click the **SUBMIT(3)** button.



Figure 2.7.2: www.mywebar.com

- When you enter the Homepage, the main navigation will be on the **RIGHT HAND SIDE**, but in this project we will focus on the **MY PROJECT MENU.**

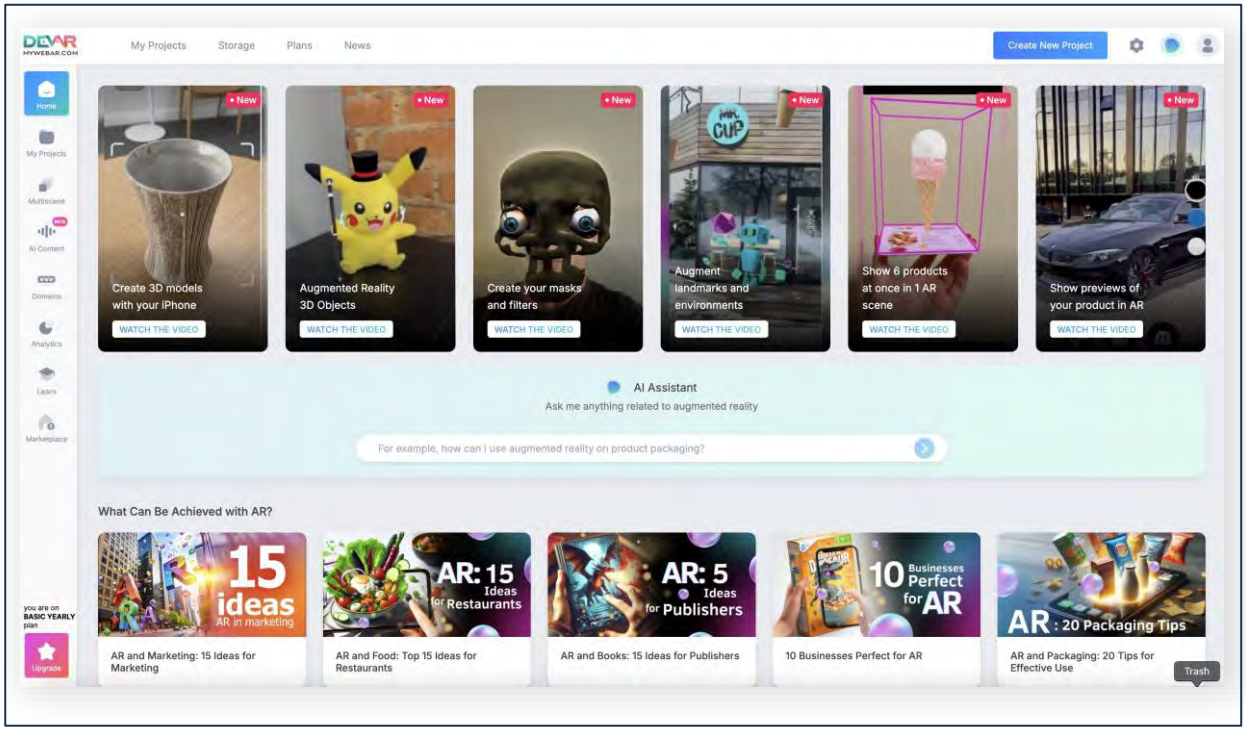


Figure 2.7.3: www.mywebar.com / my project menu

- When you enter My Project, click on **CREATE NEW PROJECT** to create a new project.
- When you create a new project, you can choose to add a variety of content including images, videos, audio, text, and lighting. But in this lesson, we will focus on **THE 3D MODEL.**
- Once you have selected to add the 3D model, you can choose to **UPLOAD A FILE** (1) or choose to **AI GENERATE (2)**. In this lesson we will focus on uploading files from your device first.
- After pressing upload file, wait for preview to see that the objects you uploaded are complete in the tool window.

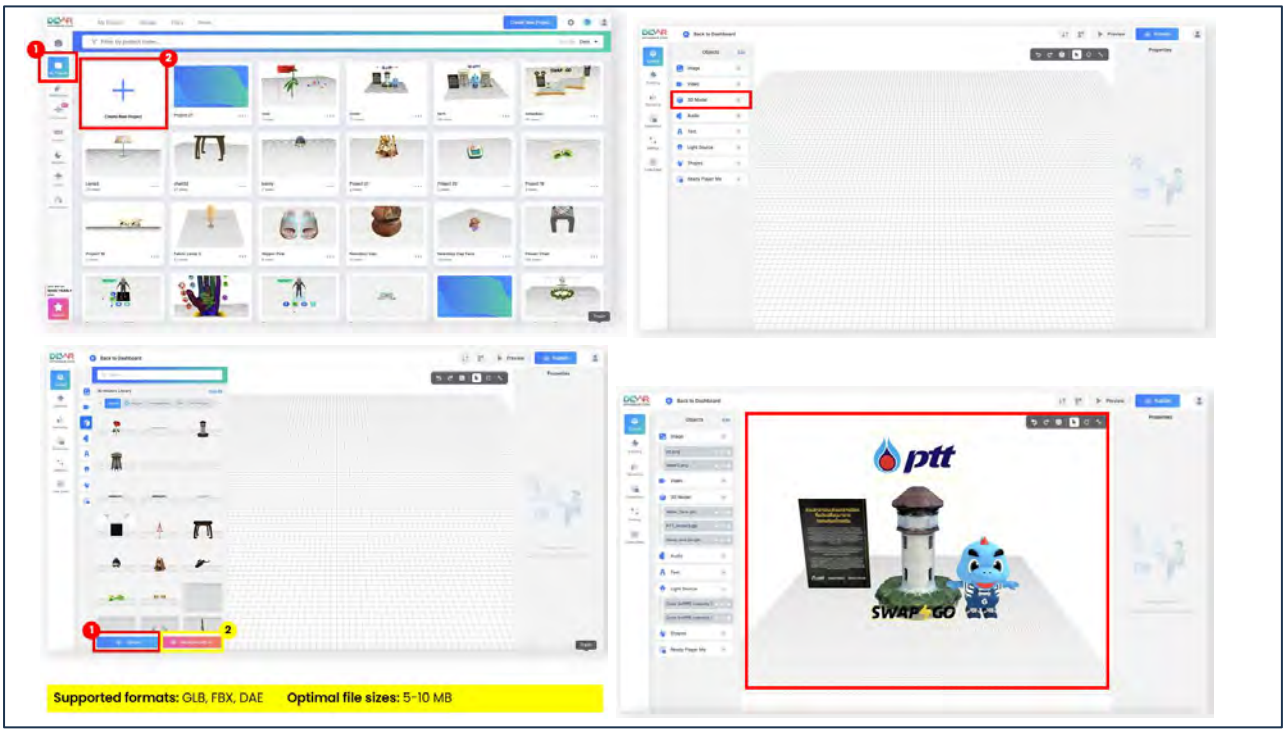


Figure 2.7.4: Add New 3D Model>Upload 3D>Preview

- You can **CLICK ON THE 3D OBJECTS(1)** to move their position as desired, and **SELECT OTHER DETAILS IN THE TOOLBOX ON THE RIGHT HAND(2)**.
- Setting steps are used to select the functions to be used in the **AR CONTENT PREVIEW**. Select the **SETTING MENU (1)** in the Advanced Setting box and **MAKE SURE YOU SET UP THE VARIOUS SECTIONS ACCORDING TO STEP (2).**
- Once the setup is done, press **THE PUBLISH BUTTON(1).**
- your 3D model is now ready for use in AR content.
- You can choose to **DOWNLOAD THE QR CODE IMAGE(2)** or **COPY THE LINK(3)** to forward it to play AR content.

Here are the steps to **Preview AR content:**

1. OPEN THE DEVICE YOU WILL BE USING, SCAN YOUR QR CODE OR CLICK ON A LINK.
2. PRESS THE LAUNCH BUTTON ON YOUR BROWSER.
3. SELECT AND TAP ON THE DESIRED AREA.
4. PRESS TO MOVE YOUR OBJECT.
5. USE TWO FINGERS TO SHRINK OR ENLARGE THE OBJECT.

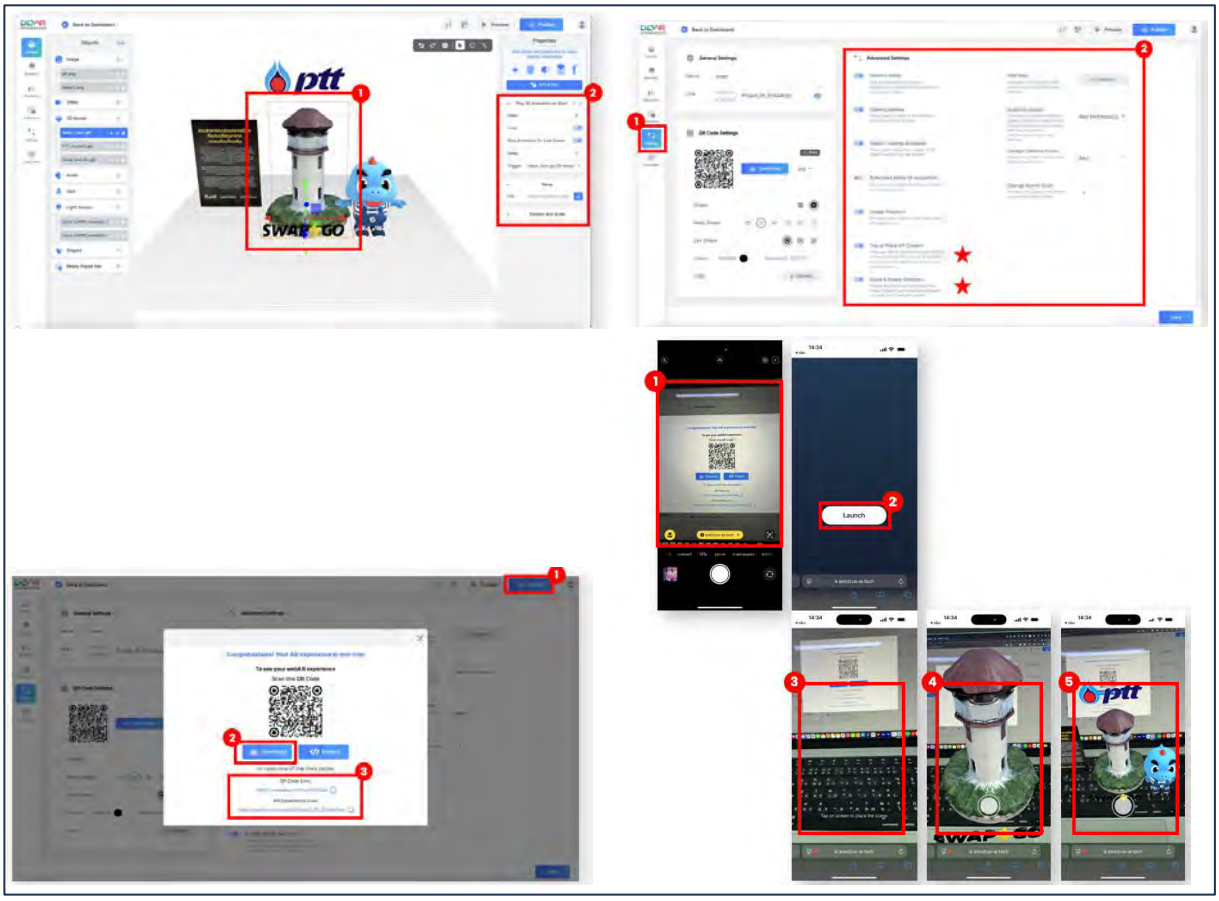
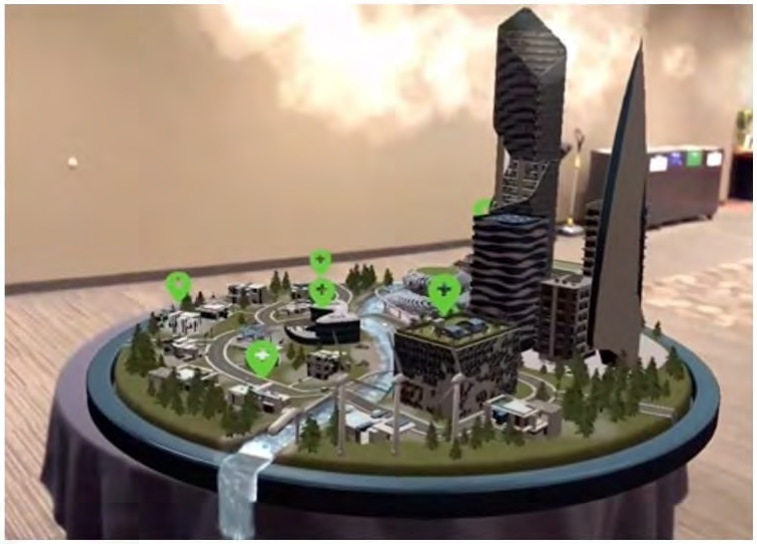


Figure 2.7.5: Step by step to Create AR content

2.8 AR by SketchUp



- **SketchUp**.
  SketchUp is a widely used program for creating **3D models**, especially popular in the field of architecture.
- What's interesting is that **SketchUp also has a mobile application version** that can display models in **AR** on tablets or smartphones.
- The core concept is to **project the 3D model you've built** in the program onto the **real-world environment**, allowing it to appear as a 3D object.
  Users can then **walk around it and view the design from all angles**.
- Start by **downloading the SketchUp application**, which is available **only on the Apple Store**.
  After that, open the app and **log in with your SketchUp account**.
- Your account will **sync your files**, and a screen like this will appear. Then, simply **select the file you want to present in AR**.

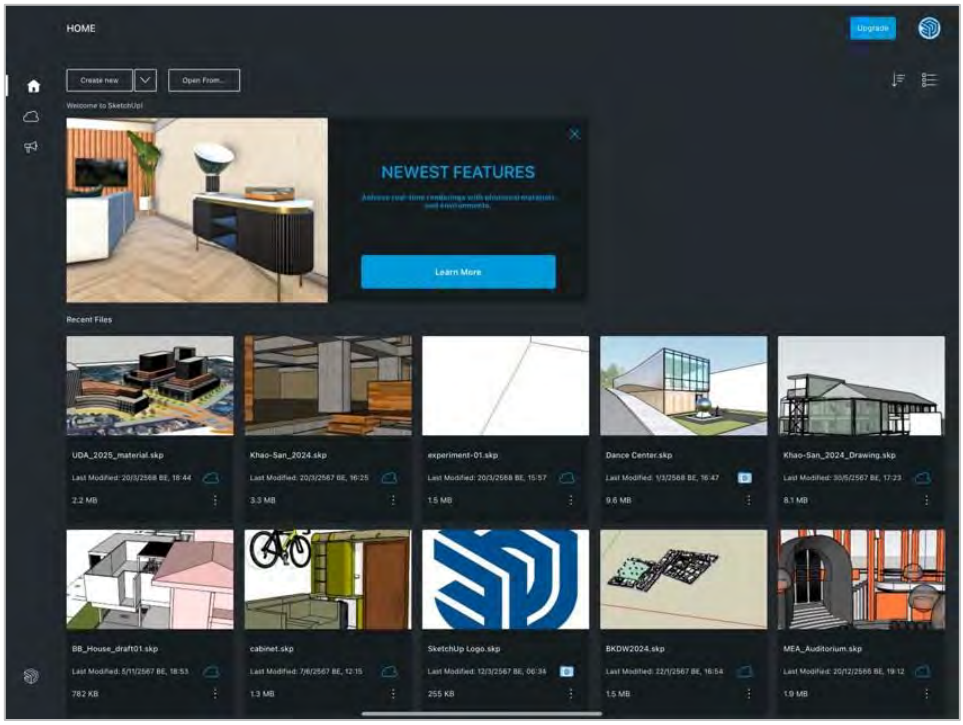


Figure 2.8.1: SketchUp log in

- open the file, the interface will look like this, with some basic tools available for use. Tap the **bottom-left button** to **switch the mode to AR**.



Figure 2.8.2: SketchUp AR tool

- **AR mode**, you can **move**, **rotate**, or **scale** your model to position it exactly where you want.
  After that, you can **walk around**, **raise**, or **tilt your device** to view the model from different angles — just like observing a real physical model.

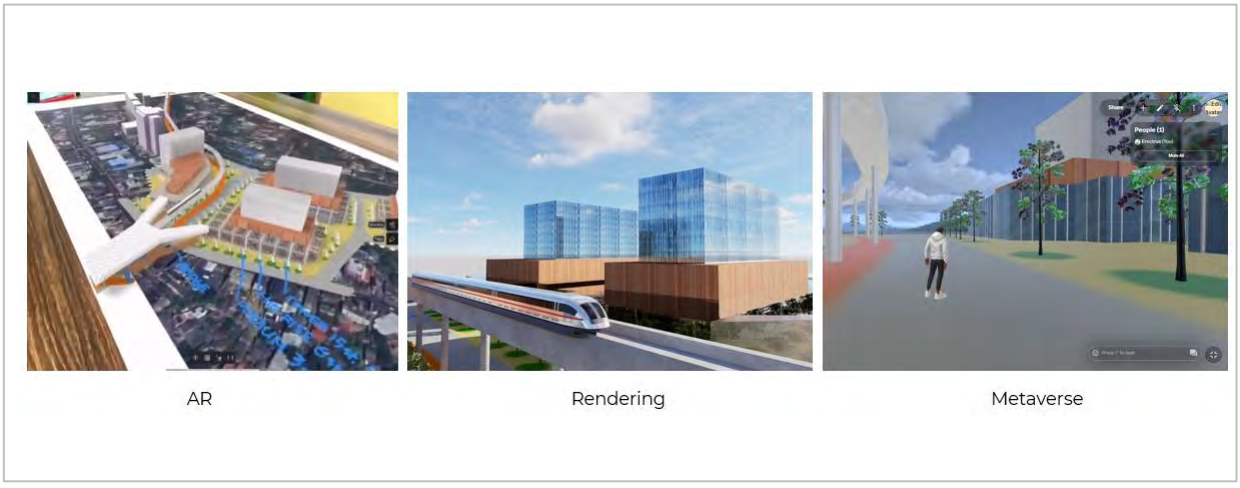


Figure 2.8.3: Advance Technology (3D/AR & Metaverse)

Part 3. APPENDIX



Figure 3.1: ToT Advanced Technology



Figure 3.2: ToT Advanced Technology

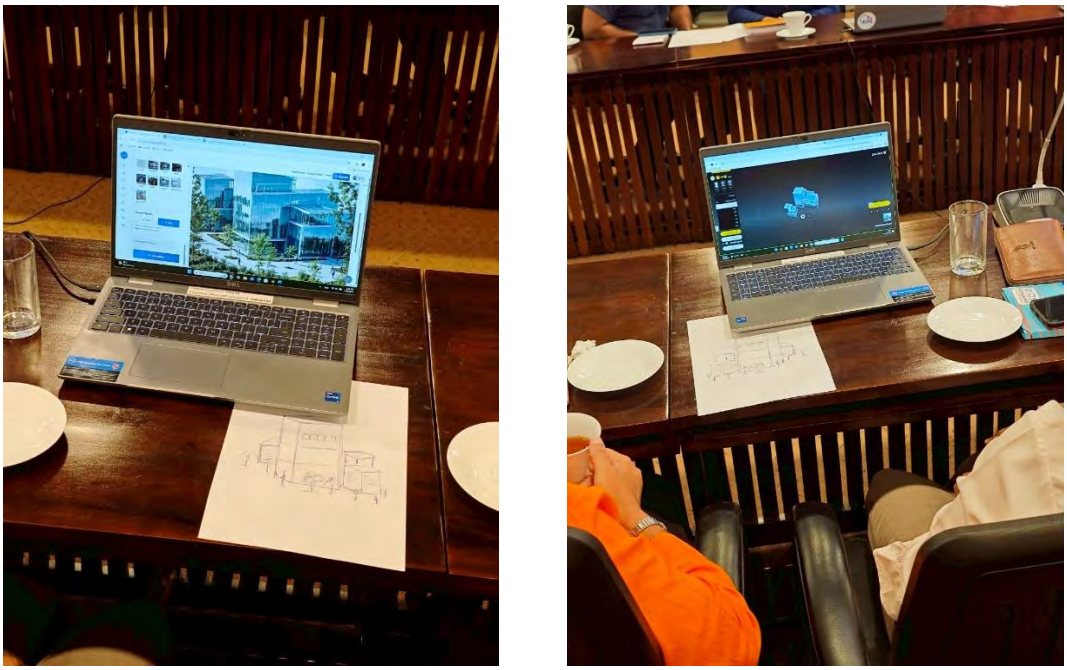


Figure 3.3: ToT Advanced Technology AI



Figure 3.4: ToT Advanced Technology



Figure 3.5: ToT Advanced Technology

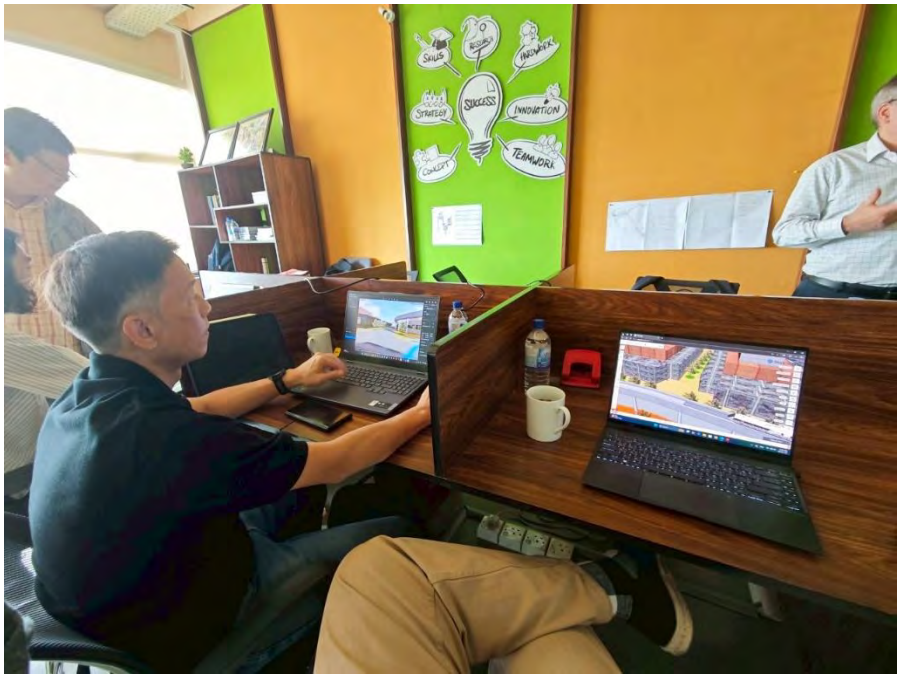


Figure 3.6: Prepare of ToT Advanced Technology