LAB 2: Planning Terrestrial Radio Networks

Lab Exercise Manual

Updated on February 2022

1 Introduction

In this lab, a simple GSM cellular network is introduced together with a wireless network planning tool, InfoVista CellPlanner, which is provided for our department by InfoVista.

The lab is expected to help students develop skills in the area of geographic information systems (GIS), site planning and coverage analysis.

The following section provides an overview of a GSM network, which will make it easier for you to follow various abbreviations and elements of a GSM network that you will encounter while using InfoVista CellPlanner. The actual lab exercises are in section 3.

2 Basics of a GSM network

A cellular GSM network is composed of several functional entities, whose functions and interfaces are specified below. Figure 1 shows the layout of a generic GSM network. The GSM network can be divided into three broad parts:

- The *Mobile Station* - is carried by the subscriber.
- The *Base Station Subsystem* - controls the radio link with the Mobile Station.
- The *Network Subsystem* - the main part of which is the Mobile services Switching Center (MSC), performs the switching of calls between the mobile users, and between mobile and fixed network users. Not shown here is the Operations and Maintenance Center, which oversees the proper operation and setup of the network.

The mobile station (MS) consists of the mobile equipment (the terminal) and a smart card called the Subscriber Identity Module (SIM). The SIM provides personal mobility, so that the user can have access to subscribed services irrespective of a specific terminal. The GSM terminal is uniquely identified by the International Mobile Equipment Identity (IMEI). The SIM card contains the International Mobile Subscriber Identity (IMSI) used to identify the subscriber to the system, a secret key for authentication, and other information. The IMEI and the IMSI are independent, thereby allowing personal mobility. The SIM card may be protected against unauthorized use by a password or personal identity number.

The Base Station Subsystem is composed of two parts, the Base Transceiver Station (BTS) and the Base Station Controller (BSC). The Base Transceiver Station houses the radio transceivers that define a cell and handles the radio link protocols with the Mobile Station. In a large urban area, there will potentially be a large number of BTSs deployed, thus the requirements for a BTS are ruggedness, reliability, portability, and minimum cost. The Base Station Controller manages the radio resources for one or more BTSs. It handles radio-channel setup, frequency hopping, and handovers. The BSC is the connection between the mobile station and the Mobile service Switching Center (MSC).

The central component of the Network Subsystem is the Mobile services Switching Center (MSC). It acts like a normal switching node of the PSTN or ISDN, and additionally provides all the functionality needed to handle a mobile subscriber, such as registration, authentication, location updating, handovers, and call routing to a roaming subscriber. These services are provided in conjunction with several functional entities, which together form the Network Subsystem. The MSC provides the connection to the fixed networks (such as the PSTN or ISDN). Signaling between functional entities in the Network Subsystem uses Signaling System Number 7 (SS7),

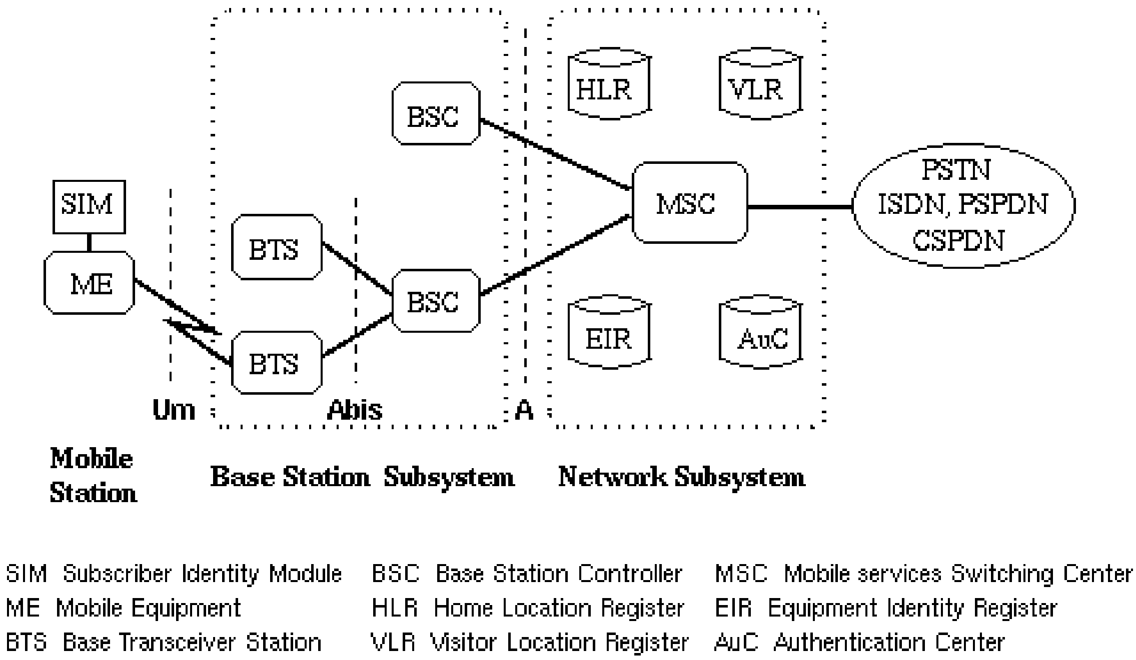


Figure 1: GSM Network Architecture

used for trunk signaling in ISDN and widely used in current public networks. The Home Location Register (HLR) and Visitor Location Register (VLR), together with the MSC, provide the call-routing and roaming capabilities of GSM.

The HLR contains all the administrative information of each subscriber registered in the corresponding GSM network, along with the current location of the mobile. The location of the mobile is typically in the form of the signaling address of the VLR associated with the mobile station. The actual routing procedure will be described later. There is logically one HLR per GSM network, although it may be implemented as a distributed database.

The Visitor Location Register (VLR) contains selected administrative information from the HLR, necessary for call control and provision of the subscribed services, for each mobile currently located in the geographical area controlled by the VLR. Although each functional entity can be implemented as an independent unit, all manufacturers of switching equipment to date implement the VLR together with the MSC, so that the geographical area controlled by the MSC corresponds to that controlled by the VLR, thus simplifying the signaling required. Note that the MSC contains no information about particular mobile stations, this information is stored in the location registers.

The other two registers are used for authentication and security purposes. The Equipment Identity Register (EIR) is a database that contains a list of all valid mobile equipment on the network, where each mobile station is identified by its International Mobile Equipment Identity (IMEI). An IMEI is marked as invalid if it has been reported stolen or is not approved. The Authentication Center (AuC) is a protected database that stores a copy of the secret key stored in each subscriber's SIM card, which is used for authentication and encryption over the radio channel.

2.1 Radio link aspects

The International Telecommunication Union (ITU), which manages the international allocation of radio spectrum (among many other functions), allocated the bands 890-915 MHz for the *uplink* (mobile to base station) and 935-960 MHz for the *downlink* (base station to mobile) for mobile networks in Europe.

Since radio spectrum is a limited resource shared by all users, a method must be devised to divide up the bandwidth among as many users as possible. The method chosen by GSM is a combination of Time- and Frequency-Division Multiple Access (TDMA/FDMA). The FDMA part involves the division by frequency of the (maximum) 25 MHz bandwidth into 124 carrier frequencies spaced 200 kHz apart. One or more carrier frequencies are assigned to each base station. Each of these carrier frequencies is then divided in time, using a TDMA scheme. The

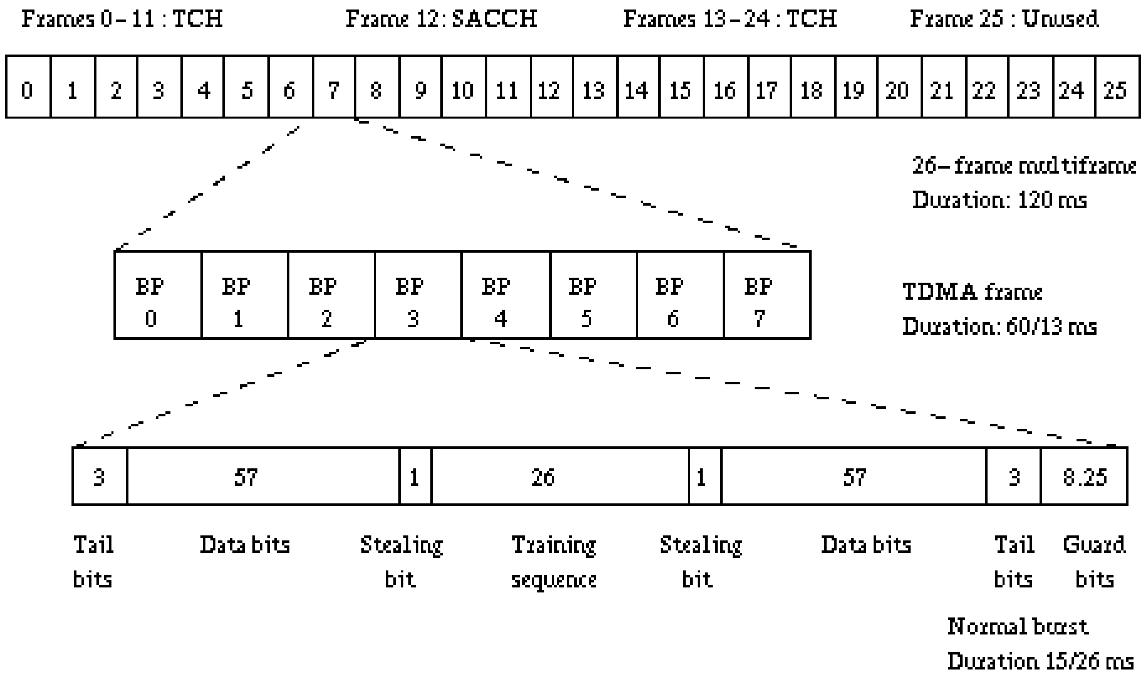


Figure 2: Organization of bursts, TDMA frames, and multiframes for speech and data Control channels

fundamental unit of time in this TDMA scheme is called a *burst period* and it lasts 15/26 ms (or approx. 0.577 ms). Eight burst periods are grouped into a TDMA frame (120/26 ms, or approx. 4.615 ms), which forms the basic unit for the definition of logical channels. One physical channel is one burst period per TDMA frame.

Channels are defined by the number and position of their corresponding burst periods. Channels can be divided into *dedicated channels*, which are allocated to one mobile station, and *common channels*, which may be used by all mobile stations while they are in idle mode or dedicated mode.

A *traffic channel* (TCH) is a dedicated channel used to carry speech and data traffic. Traffic channels are defined using a 26-frame multiframe, or group of 26 TDMA frames. The length of a 26-frame multiframe is 120 ms, which is how the length of a burst period is defined (120 ms divided by 26 frames divided by 8 burst periods per frame). Out of the 26 frames, 24 are used for traffic, 1 is used for the Slow Associated Control Channel (SACCH) and 1 is currently unused (see Figure 2). The TCHs for the uplink and downlink are separated in time by 3 burst periods, so that the mobile station does not have to transmit and receive simultaneously, thus simplifying the electronics.

Common channels can be accessed both by idle mode and dedicated mode mobiles. The common channels are used by idle mode mobiles to exchange the signaling information required to change to dedicated mode. Mobiles already in dedicated mode use the common channels to monitor the surrounding base stations for handover and other information. The common channels are defined within a 51-frame multiframe, so that dedicated mobiles using the 26-frame multiframe TCH structure can still monitor control channels. The common channels include:

- *Broadcast Control Channel* (BCCH): Continually broadcasts information on the down-link including base station identity, frequency allocations, and frequency-hopping sequences.

- *Frequency Correction Channel* (FCCH) and Synchronisation Channel (SCH): Used to synchronize the mobile to the time-slot structure of a cell by defining the boundaries of burst periods, and the time slot numbering. Every cell in a GSM network broadcasts exactly one FCCH and one SCH, which are by definition on time slot number 0 (within a TDMA frame).

- *Random Access Channel* (RACH): Slotted Aloha channel used by the mobile to request access to the network.

- *Paging Channel* (PCH): Used to alert the mobile station of an incoming call.

- *Access Grant Channel* (AGCH): Used to allocate an SDCCH to a mobile for signaling (in order to obtain a dedicated channel), following a request on the RACH.

3 Lab Work

Before you start working on the lab exercises, make sure that you have the correct lab file to work on. Follow the steps below for help.

1. Download the data file for this lab from *Canvas Lab2 section* and save it on a folder. Overwrite the existing file if necessary.
2. To start CellPlanner, go to the Start menu → All Programs → Mentum → Mentum CellPlanner 10.1.0 → Mentum CellPlanner. The main window will appear.
3. From the menu select File → Open and open the file WNMM_lab.n101 which you have saved on the same folder in the previous step.
4. Follow the steps in Appendix B to load map layers in the program. Make sure all layers are added. Make also sure that each map is added only once.

! Please read through the instructions carefully. At the end of this lab you will submit a report in which you explain your results to some of the tasks. The tasks whose results should be in your report are marked with a note "Include this task's results in the report". For each of those marked tasks, take a screenshot of your simulation results[1], and also write a short paragraph which explains the steps you followed and the results you obtained. It may be a good idea to open a Word document now to save your notes and screenshots as you progress through the exercises. Upload your reports in PDF format to the Canvas under the Assignments/Lab2.

3.1 Displaying the map

In InfoVista CellPlanner each map has several layers of information. In this exercise you will get acquainted with the information contained in the different layers: elevation (height of land above sea level), vectors (railroads, streets), land use (forest, open land, buildings), etc. For more information about layers, see the appendix at the end of this document.

Start by displaying the *Map Legend*: View → Legend. Examine the information presented in the legend by double-clicking the items in the legend window.

Task 1 Display one by one all the map layers. To do this right-click on the map and then select Show/Hide Layer. Also check the map legend to see if there is any additional information for the layers that you are viewing; you need to double-click on the layer names in the legend in order to display the details. Try to display high resolution image of the Gamla Stan (Old City) area where streets and images of buildings can be seen from above. After observing layers, zoom out and turn back to the original map screen with all layers visible.

[1]You can search Snipping Tool in Windows and and then you can copy paste it in a Word document.

Task 2 Use the *Line of Sight* tool for showing the visibility pattern at site GSM900-11. To use this tool select $\boxed{\text{Map} \rightarrow \text{Line-of-Sight}}$ from the menu and click on any point on the map. Tip: To locate a site on the map you can use $\boxed{\text{Utilities} \rightarrow \text{Site explorer}}$, then right-click on the site name and select *Locate in map*. The LOS tool receives three input parameters (transmitter height, mobile height and radius) to calculate the line-of-sight pattern at the point you click the pointer on the map. Therefore note that these values are not automatically retrieved from the site configuration. Also keep in mind that in order to use line-of-sight tool you need to have the elevation layer visible.

Task 3 **Include this task's results in the report.** Assume that you are investigating a microwave link between sites GSM900-07 and GSM900-11. First, plot the terrain height profile and measure the distance between base stations GSM900-07 and GSM900-11. To do this, select $\boxed{\text{Map} \rightarrow \text{Terrain profile}}$ from the menu and then draw a line between these two sites by dragging the mouse on the map. Note that, in order to use the terrain profile tool, you need to have the elevation layer visible. After plotting the terrain profile, click on *Properties* to change transmitter's frequency to 23GHz, which is an appropriate frequency for microwave links. Observe the impact of frequency on the Fresnel zone radius. Repeat this task after you also make the *Land Use* layer visible and explain the impact of the land features on obstruction or clearance of the path between the two sites. In your report, include the screenshots of both terrain profile plots (with and without Landuse layer) and give your answers to this task in a paragraph. A small note about the user interface: If you did not notice any difference in the terrain profile tool's window after you have made the land use layer visible, close the terrain profile tool's window, switch to another tool, e.g. line of sight tool, and then switch back to the terrain profile tool. You may need to do this because there is a small issue with the user interface that sometimes leads to the land use layer not being displayed in the terrain profile tool's window.

3.2 Introduction to site databases

Include this task's results in the report. Each site in your network is described by a number of parameters controlling the electrical and physical properties of that site, which you can find in *Site Explorer*. To view the *Site Explorer* select $\boxed{\text{Utilities} \rightarrow \text{Site Explorer}}$. Examine the GSM900-11 site. Find and write down the following data in your report:

- Height of the antennas above ground level.
- Antenna type
- Azimuth of each antenna
- Transmission power of each cell

3.3 Coverage Predictions

In this exercise you will inspect the coverage area of the network. First you will predict the coverage of the given network by running a simulation, and identify the areas with poor coverage. Then you will determine and report the cause of the lack of coverage in these areas. Finally you will provide a solution for the areas which are not in coverage. The areas not in coverage may also be called "outage".

Task 1 Go back to the default view for this exercise. First perform a *Pathloss Prediction* and then a *GSM Best Server* calculation. Both are available under the $\boxed{\text{Analysis}}$ menu. You can find a detailed description of how to perform these tasks in appendix A.

Task 2 Plot *Best Server Coverage (Composite)* by clicking the button $\boxed{\text{Analysis Results Plots}}$ on the left toolbox (alternatively press $\boxed{\text{CTRL-R}}$) and inspect the signal quality. Coverage is defined as a minimum received power level of -102 dBm for this exercise. By default, the result plots do not show any color for the regions where the minimum received power level is not met; therefore the outage regions will be rendered as transparent. To be sure about this threshold, double click on $\boxed{\text{BS Signal Strength(dBm)}}$ in the *Map Legend*. If you need to adjust the displayed signal levels, right-click on *BS Signal Strength(dBm)*, then choose $\boxed{\text{Edit}}$. However, the default settings should be adequate most of the time. When displaying analysis results, you may want to make elevation layer (and land-use layer) transparent by right-clicking the layer name in the *legend* and choosing $\boxed{\text{Edit}}$. Making these layers transparent will let you see the coverage/outage areas more clearly. Note that if you hide these layers instead of making them transparent then you will not be able to perform the simulations. **Include this task's results in the report.**

Task 3 Identify two of the regions which do not have coverage and explain the reason for the lack of coverage in these regions. There may be many different reasons to outage, and sometimes a combination of several reasons. For example, the signal may be blocked by the terrain (hills, valleys), the land features may attenuate the signal (trees, buildings), transmitter may not have a line-of-sight with the receiver, or the transmit power may be too low to begin with. Note that this list is not exhaustive; there may be other reasons for lack of coverage. Investigate each major outage location and identify the causes of outage. **Include this task's results in the report.**

Task 4 **Include this task's results in the report.** Try to change the settings (height, transmit power, antenna azimuth, etc.) for necessary sites in order to provide coverage in the *interest area*, which is delimited by a black line. (To view the *interest area* select $\boxed{\text{Map} \rightarrow \text{Area Editor}}$, click on the $\boxed{\text{Interest Area}}$ and then press $\boxed{\text{View}}$). Maximum allowed power for each transmitter is 43 dBm and maximum allowed antenna height is 50m. You're not allowed to create new sites to solve the exercise. Important note: Every time you change any site related settings (e.g. antenna height, azimuth, power, etc) you have to perform a new *Pathloss Prediction* and *Best Server analysis* for changes to take effect. After you have succeeded to provide coverage in the interest area, include a screenshot of the best server calculation (composite) plot in your report and explain the changes you made. Make sure to put the plot threshold to -102 dBm when you plot the best server coverage. In order to explain the changes you made, you can use a table like following in your report. You can refer to the outage areas by the closest location's name on the map. To see place names on the map make the text layer visible).

Place name	Reason for lack of coverage	The change you made to fix it
E.g. Barkarby	E.g. Hills blocking the signal from base GSM900-11A	E.g. Increased height of GSM900-11A to 40m.
...	...	...

Appendix A: A Short Guide to InfoVista CellPlanner

InfoVista CellPlanner is a mobile network planning software which is used to design and optimize mobile radio networks. It can be used for various complex tasks, including network dimensioning, traffic planning, site configuration and frequency planning. InfoVista CellPlanner supports GSM, WCDMA, LTE, and WiMAX technologies.

A.1 Map Layers

To select *Map Layers* use the $\boxed{\text{Map Properties}}$ button or right-click on the map and use $\boxed{\text{Show/Hide Layers}}$. More information about map layers in GeoBox format can be found in [1] section 9.

- **Elevation** Digital Elevation Models (DEM) are stored as two-dimensional matrices of grid cells. Each cell contains a value corresponding to an elevation value above mean sea-level for the surface area covered by the cell.
- **Image:** Image data can be satellite images, aerial photographs or scanned maps, stored as two-dimensional matrices, in GeoBox formatted dataset or in standard image format like TIFF.
- **Land Use:** Land use data is stored as two-dimensional matrices of grid cells. Each cell contains a value representing a land use category code for the surface area covered by the code.
- **Text:** This layer consists of text data such as area names and town names. The text data is stored as a line of text followed by the east and north coordinates of the item that the text describes.
- **Vector:** The vector layer contains points, lines and areas where each point or node is stored as a pair of coordinates, easting and northing. All kind of roads and railways are, for example, stored as vector data.
- **Network layer:** This layer contains network elements (BSs, BSCs, MSCs, etc.)

A.2 Analysis

Pathloss Prediction From the $\boxed{\text{Analysis}}$ menu, select $\boxed{\text{Calculate Pathloss}}$. Use filter *GSM*, so that all GSM sites will be considered for analysis. Choose a fixed resolution of 40 m (if you choose 20 m the simulations will be slow and create very large result files). Recalculate should be set to *Always*. Do not use puncturing. Press *Start*. Note that to obtain analysis results, you need to perform *best berver calculation* after *pathloss prediction*.

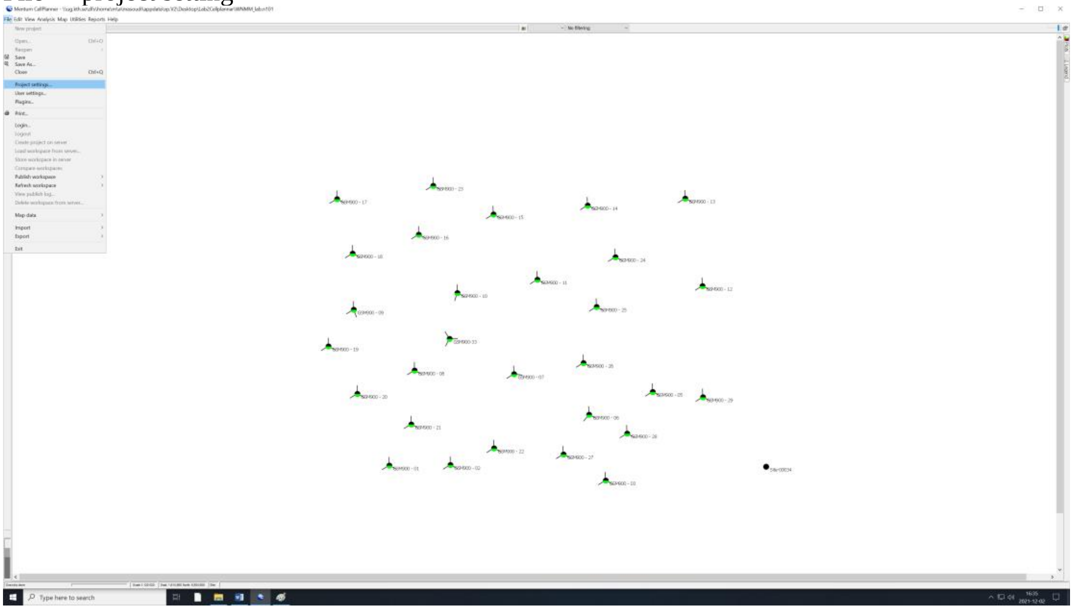
Best Server Calculation For each simulation bin (or pixel), CellPlanner determines which serving cell will be the most likely server of a mobile in that pixel. **Note that pathloss prediction must have been performed before the best server calculations.** From the menu select $\boxed{\text{Analysis} \rightarrow \text{GSM} \rightarrow \text{Calculate best server}}$. Select filter *GSM*. In *Traffic cases*, select *GSM bearer VOICE*. *Traffic cases* option performs the best server calculation for the combination of a given terminal type (Ericsson T68i in this exercise) and a GSM bearer. Set depth of the best server list to 1. Calculate a maximum pathloss of 200dB in your simulations, and 30 cells per bin. Disable *Calculate radio coverage for interference and probability calculations*. Click *Start*.

All results from the best server calculations can be accessed from the $\boxed{\text{Analysis results plots}}$ in the left toolbox or from the menu $\boxed{\text{Analysis} \rightarrow \text{Result Plots}}$.

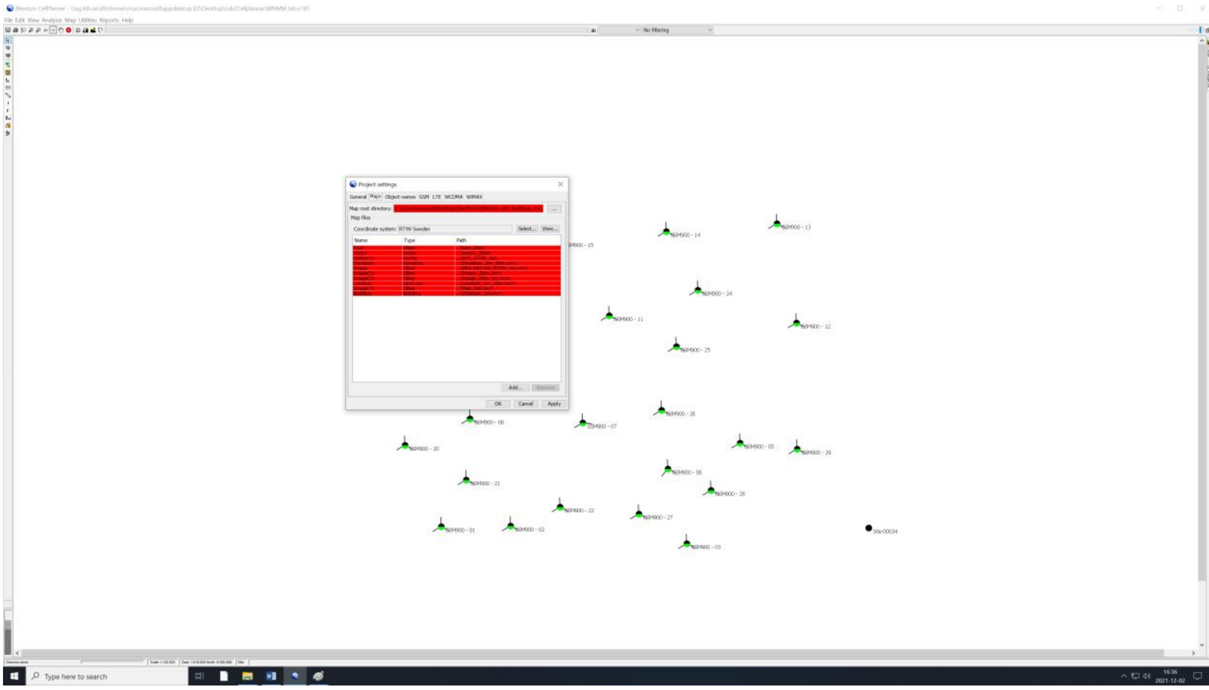
Appendix B: Steps to load the map to Mentum Cellplanner

1- Download the map from the provided link to your Desktop.
    a. Extract the map folder in your desktop.
    b. Within the extracted folder, there is a folder called TEMS_PROJECTS. If it is zipped, extract it into the same folder.
2- Open the Mentum Cellplanner app.
    a. File->open->
    b. Find the “WNMM_lab.n101” from the extracted folder in your desktop.
    c. You should see the loaded BSs similar to the following figure.

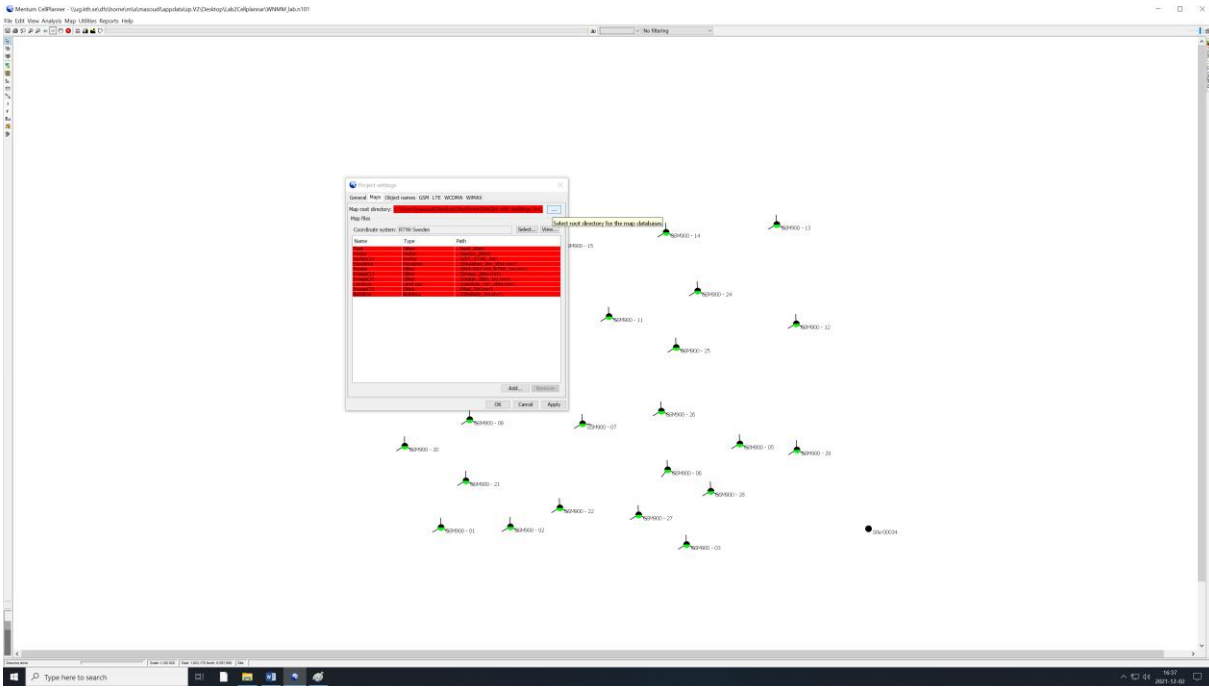
3- To load the map:
    a. File -> project setting



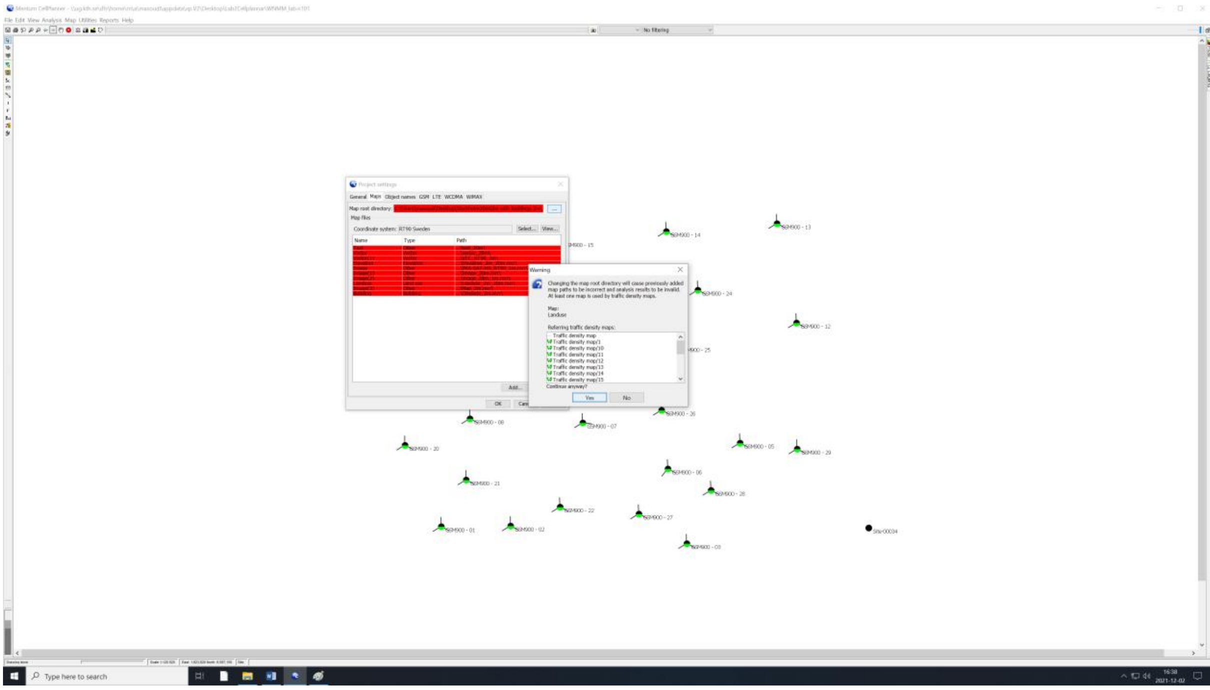
b. On the top, choose the Map tab



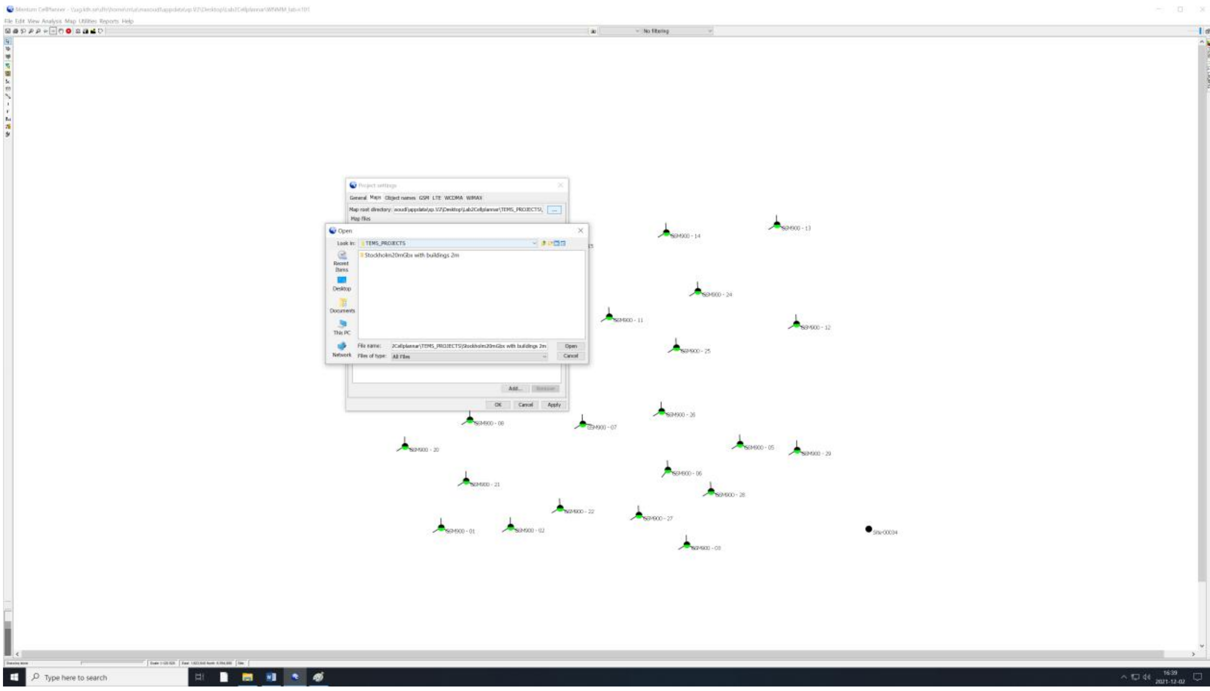
c. Click on the button with … to choose the map directory



d. Click on yes



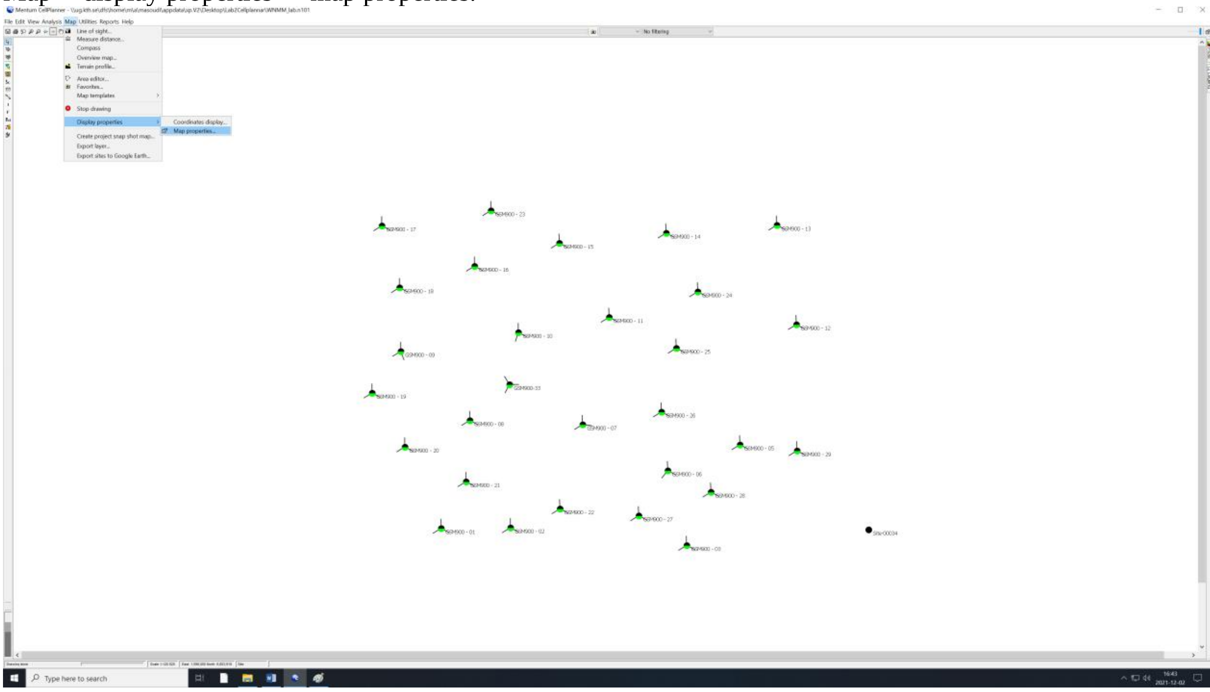
e. Then find the TEMS_PROJECTS ->Stockholm20mGbx with buildings 2m



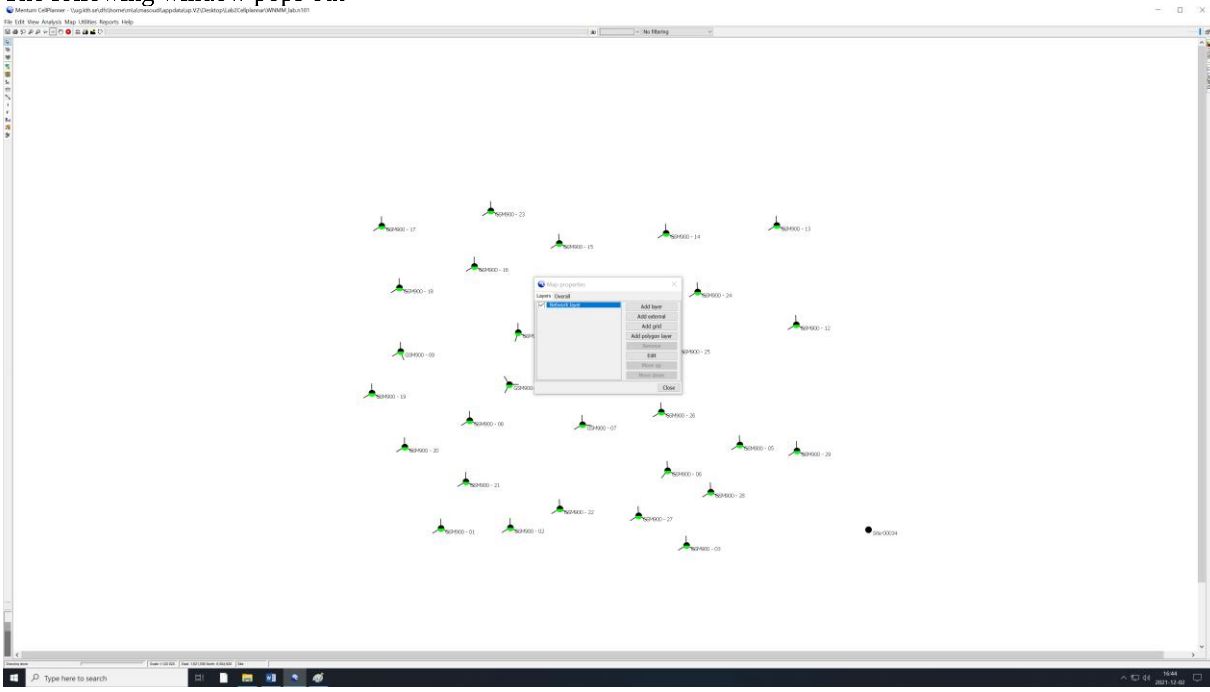
f. Choose Stockholm20mGbx with buildings 2m and click on Open
g. Click on Apply and Ok.

4- Now maps are configured to the software. In order to load it to your project:

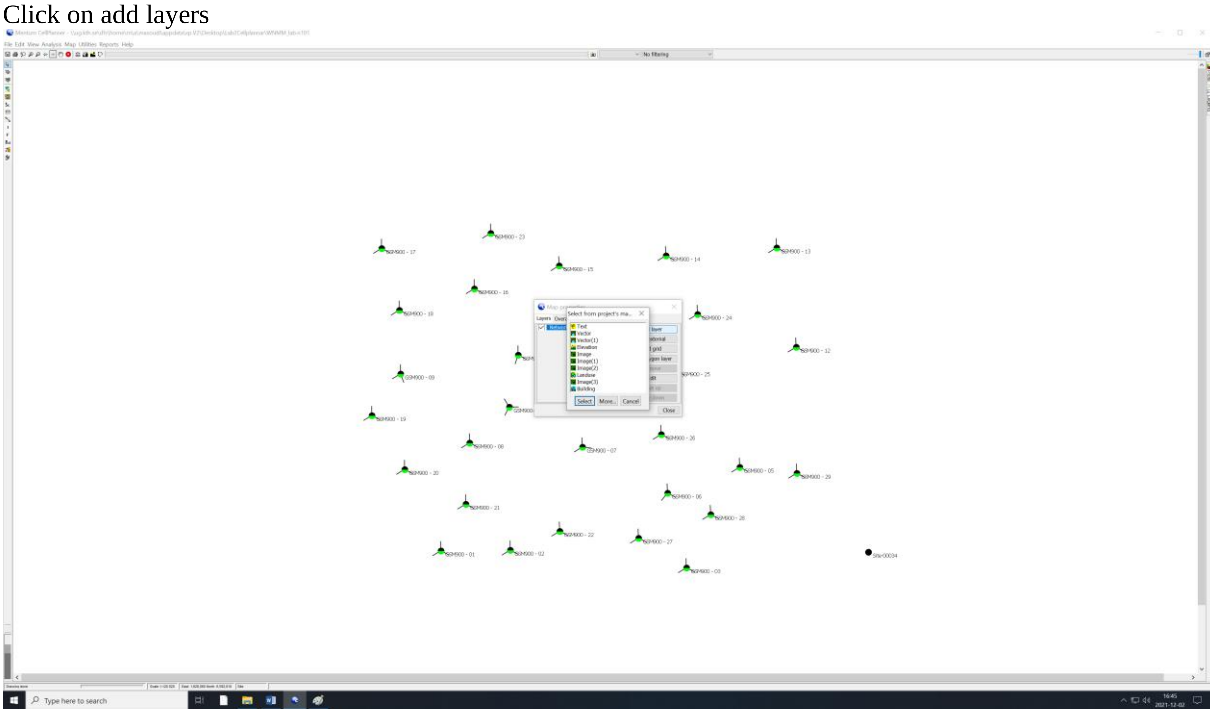
a. Map-> display properties -> map properties.



b. The following window pops out

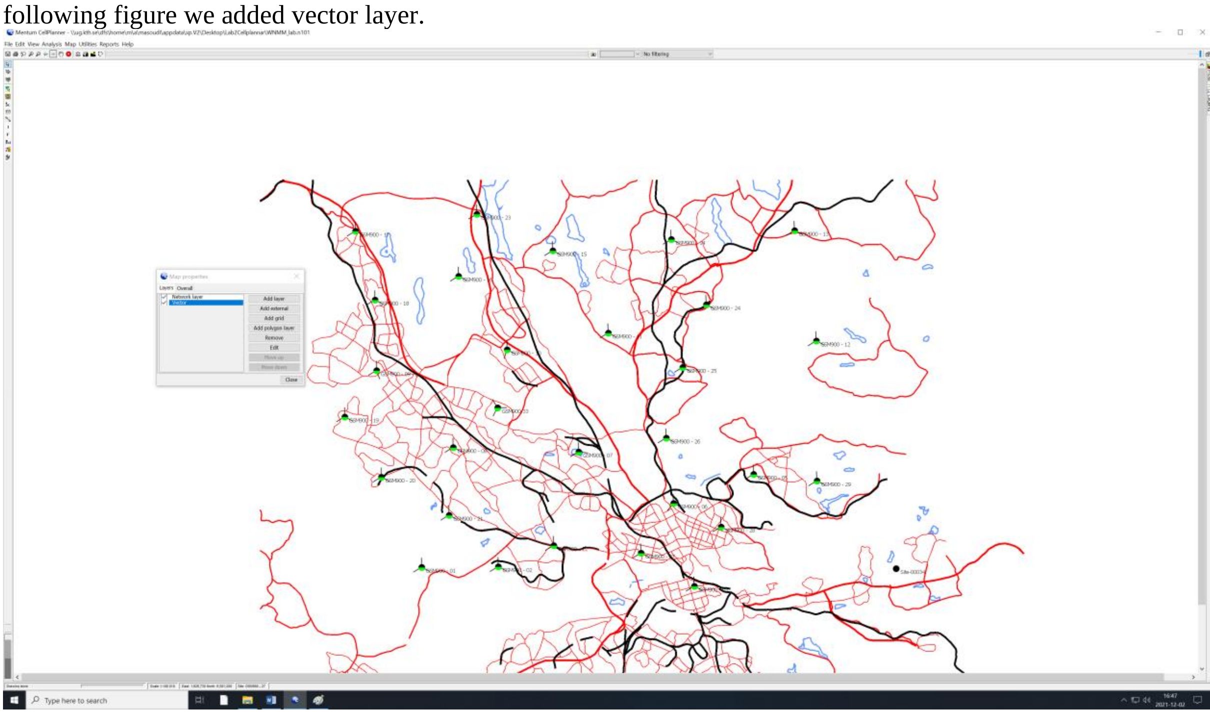


c. Click on add layers

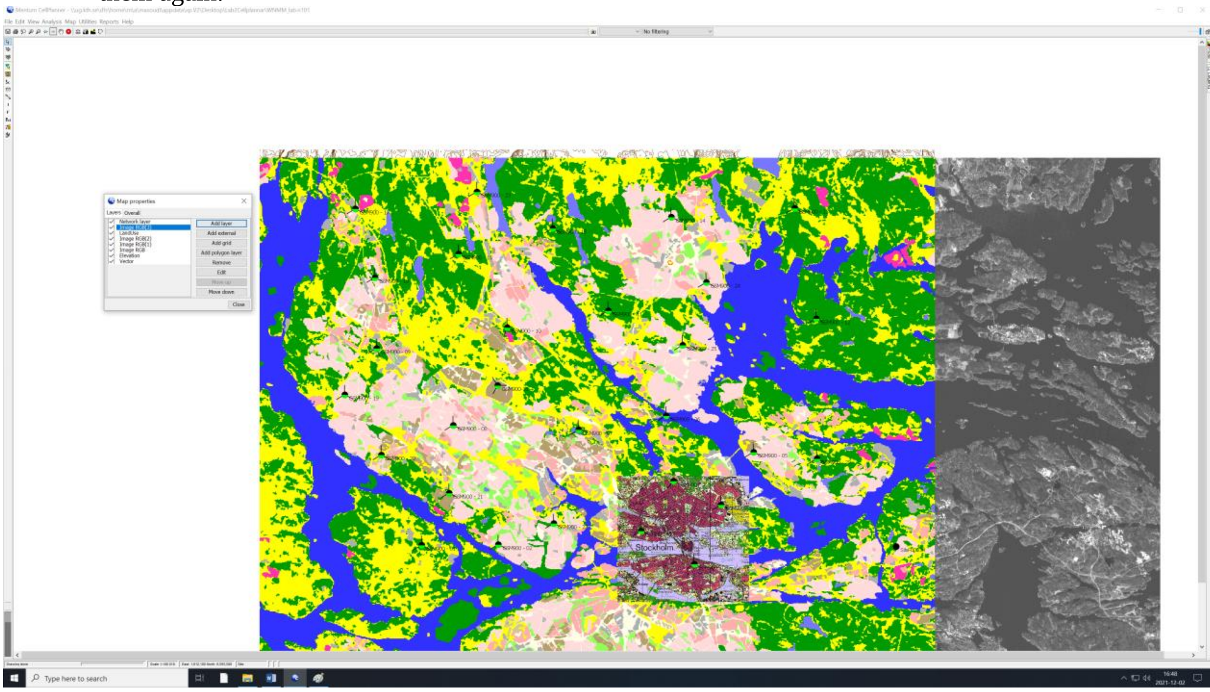


d. Add all of the displayed maps. You need to add them one by one.

e. Every time you add a layer, click on OK. The selected map should appear on the screen. In the following figure we added vector layer.



f. Make sure all layers are added. Make also sure that each map is added only once. Otherwise you may face memory problem.
   i. When you add a layer it will show up again as a new layer in the list. Don't choose them again.



5- Save the current project.

6- At any stage, if you face a problem that maps disappeared, you have to add the map layers again (step 4)

7- Now all maps, layers are added to the project and you are ready to start the lab.

8- During doing the lab, if it states that choose the favorite map or lab area, skip doing it. Because it may cause the maps to be disappeared. If it happened, don't worry just add the layers again or open the previously saved project.

REFERENCES

[1] Mentum CellPLanner 10.1.0 Common Features User Guide