3D GEOVISUALIZATION TO FIND SUITABLE SITES FOR ERECTION OF MOBILE BASE TRANSCEIVER STATIONS

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ABSTRACT: The rapid growth of mobile communication requires efficient network planning of cellular mobile communication. The primary operations in the telecommunication network industry include network site identification and planning, signal strength measurements with coverage estimation for expansion of system. The efficiency of radio wave propagation system can be improved greatly with powerful capability of handling geospatial data through Remote Sensing and GIS techniques. Signal strength predicted by 3D Viewshed analysis are taken into account for factors like height of the terrain, building and tower to be erected. The variation in signal strength depends upon many factors, such as the type of obstacles: buildings, surfaces, trees, trunks, leaves, branches, their densities, and their heights relative to the antenna heights. When the signal strikes the surface of a building, it may be diffracted or absorbed. This is an important consideration in the coverage planning of a radio network. 3D Viewshed analysis can be utilized to formulate suitable plans and strategies for an effective telecom planning and development. In the age of rapid urbanization and cut throat competitive marketing, health aspect of humans is overruled. In the absence of efficient technical framework for installing Mobile Base Transceiver Stations, telecom companies exploit human health by exponentially installing more than the required number of BTS in order to amplify the signal gain so as to render hassle free mobile communication and improved data quality. This poses a radiation hazard in terms of physical and mental health for people living in close proximity of BTS. The case study is based around reducing the number of BTS through 3D GIS visualization, terrain analysis and using low transmittance power repeaters.

1. INTRODUCTION

As There are a total of 72361 mobile transceiver base stations in Uttar Pradesh out of which 110 are in Indirapuram and adjoining Ghaziabad only (Source : Telecom Regulatory Authority of India Report 2014). A cell phone transmits 1 to 2 Watt of power in the frequency range of 824 - 849 MHz (CDMA), 890 - 915 MHz (GSM900) and 1710 – 1780 MHz (GSM1800). A cell phone has a SAR rating. In USA, SAR limit for cell phones is 1.6W/Kg which is actually for 6 minutes per day usage (MoEF&CC, n.d.). It has a safety margin of 3 to 4, so a person should not use cell phone for more than 18 to 24 minutes per day. This information is not commonly known to the people in India, so crores of people use cell phones for more than an hour per day without realizing its associated health hazards.

Cell tower antennas transmit in the frequency range of 869 - 894 MHz (CDMA), 935 - 960 MHz (GSM900) and 1810 – 1880 MHz (GSM1800). Also, 3G has been deployed in a few cities, in which base station antenna transmits in the frequency range of 2110 – 2170 MHz. Mobile phone operators divide a region in large number of cells, and each cell is divided into number of sectors (Sujoy Kumar Guha, n.d.). The base stations are normally configured to transmit different signals into each of these sectors. In general, there may be three sectors with equal angular coverage of 120 degrees in the horizontal direction as this is a convenient way to divide a hexagonal cell. If number of users is distributed unevenly in the surrounding area, then the sectors may be uneven. These base stations are normally connected to directional antennas that are mounted on the roofs of buildings or on free-standing masts. The antennas may have electrical or mechanical down-tilt, so that the signals are directed towards ground level.

A base station and its transmitting power are designed in such a way that mobile phone should be able to transmit and receive enough signal for proper communication up to a few kilometers (Morakot Pilouk, n.d.). Majority of these towers are mounted near the residential and office buildings to provide good mobile phone coverage to the users. These cell towers transmit radiation 24x7, so people living within 10's of meters from the tower will receive 10,000 to 10,000,000 times stronger signal than required for mobile communication. In India, crores of people reside within these high radiation zones.

A GSM900 base station antenna transmits in the frequency range of 935 - 960 MHz. This frequency band of 25 MHz is divided into twenty sub-bands of 1.2 MHz, which are allocated to various operators. There may be several carrier frequencies (1 to 5) allotted to one operator with upper limit of 6.2 MHz bandwidth. Each carrier frequency may transmit 10 to 20W of power. So, one operator may transmit 50 to 100W of power and there may be 3-4 operators on the same roof top or tower, thereby total transmitted power may be 200 to 400W (Musliman, Rahman, & Coors, 2006). In addition, directional antennas are used, which typically may have a gain of around 17 dB (numeric value is 50), so effectively, several KW of power may be transmitted in the main beam direction.

Mobile Tower is a triangular / cone shaped metal structure which is more than nine meter in height on which 3 or more antennas are fixed, the structural height may depend on whether it is fixed on land or on a building. Height of the Ground based towers varies from 30-200 meters however most of the towers are of 40 meters and roof-top towers vary from 9-30 meters. Mobile Tower Antennas are the source of radiation in a mobile tower. However, a telecom infrastructure consists of electronic (active) and non-electronic infrastructure.

• Electronic infrastructure includes base tower station, microwave radio equipment, switches, antennas, transceivers for signal processing and transmission.

• Non-electronic infrastructure includes tower, shelter, air-conditioning equipment, diesel electric generator, battery, electrical supply, technical premises.

For a good quality wireless communication, Mobile Tower Base Stations (MTBS) are an inevitable part of the telecom infrastructure system.

Mobile phone operators divide a region in large number of cells, and each cell is divided into number of sectors. The base stations are normally configured to transmit different signals into each of these sectors. In general, there may be three sectors with equal angular coverage of 120 degrees in the horizontal direction as this is a convenient way to divide a hexagonal cell. If number of users is distributed unevenly in the surrounding area, then the sectors may be uneven. These base stations are normally connected to directional antennas that are mounted on the roofs of buildings or on free-standing masts. The antennas may have electrical or mechanical down-tilt, so that the signals are directed towards ground level. Mobile Tower Antennas are the source of radiation in a mobile tower.

Mobile Tower is a triangular / cone shaped metal structure on which 3 or more antennas are fixed radiating electro-magnetic power, whereas Base Transceiver Stations (BTSs) are established at suitable locations, as per their Radio Frequency (RF) Network Planning for proper coverage of the area and for meeting capacity requirements. BTS also contain a number of radio transmitter and each of these has the same maximum output power. The outputs from the individual transmitters are then combined and fed via cables to the base station antenna, which is mounted at the top of a mast (or other suitable structure). With the growing population of India, the wireless communication density and its network has escalated at a rapid pace over the past few years. The statistics reveal that there are 867.8 million wireless subscribers in India at the end of March 2013 which account for nearly 96 % of the total telecom subscriptions. According to TRAI currently there are 5 lakh telecom towers and it is estimated that around One lakh additional towers would be required to cater the need of ONE billion mobile telephones by 2014. There are 12-14 telecom service providers catering to total projected wireless subscriber base all the over the country covering both GSM (Global System for Mobile Communications) and CDMA (Code Division Multiple Access) technologies.

With the growing population of India, the wireless communication density and its network has escalated at a rapid pace over the past few years. The statistics reveal that there are 900 million wireless subscribers in India at the end of March 2017 which account for nearly 98.3 % of the total telecom subscriptions. According to TRAI currently there are 5 lakh telecom towers and it is estimated that around 2 lakh additional towers would be required to cater the need of 1.5 billion mobile telephones by 2018. There are 12-14 telecom service providers catering to total projected wireless subscriber base all the over the country covering both GSM (Global System for Mobile Communications) and CDMA (Code Division Multiple Access) technologies (MoEF&CC, n.d.).

In India, we have adopted radiation norms given by ICNIRP guidelines of 1998 for safe power density of f/200, where frequency (f) is in MHz. Hence, for GSM900 transmitting band (935-960 MHz), power density is 4.7W/m2 and for GSM1800 transmitting band (1810-1880 MHz), it is 9.2W/m2. The ICNIRP guidelines clearly state that for simultaneous exposure to multiple frequency fields, the sum of all the radiation must be taken into consideration. However, in India, we have applied this limit to individual carrier, so the radiation level exceeds by several times than even prescribed by ICNIRP guidelines, depending upon the total number of transmitters in that area Some of the people (especially older people, house wives, small children) living near the towers are exposed to this radiation 24 hours a day. Unfortunately, ICNIRP has considered only the thermal effects of radiation, whereas scientist all over the world have found non-thermal effects of these radiations to have significant health effects and these non-thermal health effects occurs at levels much below these norms.

Building Biology Institute, Germany, provided following guidelines for exposure:

1. <0.1 µW/m2 (0.00001 µW/cm2) - no concern

2. 0.1 - 10 µW/m2 (0.00001 to 0.001 µW/cm2) - slight concern

3. 10 - 1000 µW/m2 (0.001 to 0.1 µW/cm2) - severe concern

4. > 1000 µW/m2 (> 0.1 µW/cm2) - extreme concern

Power densities should not exceed 100 µW/m2. EU Parliament (STOA 2001) recommends - 100 µW/m2. A power density of 9.2 W/m2 has been adopted in India as per the ICNIRP & EU recommendations 1998.

At many places, cell phone towers are mounted on the roof top of residential /commercial buildings. Even though antenna radiates less power vertically down but the distance between the antenna and top floor is usually a few meters, so the radiation level in the top two floors remain very high. From Table 2, power density at R = 3m is equal to 8,840,000 µW/m2 in the main beam. In the vertically down direction, radiation is approximately 20-22 dB less and the roof may provide attenuation of 6 to 10 dB depending on the construction (implying 1/1000th power), implying radiation density of 8,840 µW/m2, which is still very high.

Interphone study in 2010 mentions that excessive use of mobile phones has doubled to quadrupled brain tumor risk. However, they claim that for an average user, increase in cancer cases is not significant but they have taken an average user as a person who uses cell phone for 2 hours/month. In India, many people use cell phones for 1 to 2 hours per day. Re-evaluation of the Interphone study by a group of eminent scientist has found that the risk of affected people is significantly higher than reported. Interphone Study excluded children from the study. Children are at higher risk from exposures to carcinogens than adults and today very large population of children are using cell phones and also many of them sleep with the cell phones beneath their pillows every night without realizing the health hazards.

Table 1: Base Station Types

Base Station Types	Typical Coverage Radius	Typical Use
Femtocell	10 m	Home or office use
Domestic Repeater	100 m	Home, office or factory use
Picocell	200 m	High rise building, hotel or car park use
Microcell	1 – 2 km	Shopping centers, transport hubs, mine sites, city block
Macrocell	5-32 km	Suburban, city and rural use
Macrocell–Extended Reach	50-150 km using extender cell technology	Suburban and rural use

Power density P_d at a distance R is given by:

$$P_d = \frac{P_t \times G_t}{4\Pi R^2}$$

Equation :1

where, P_t = Transmitter power in Watts,
G_t = Gain of transmitting antenna,
R = Distance from the antenna in meters.

For P_t = 20 W, G_t = 17 dB = 50, P_d for various values of R is given in Table 2.

Table 2: Values of P_d

Distance R (m)	P_d (W/m^2)	P_d (μW/m^2)
1	79.6	79600000
3	8.84	8840000
5	3.18	3180000
10	0.796	796000
50	0.0318	31800
100	0.008	7960
500	0.000318	318

2. OBJECTIVES

- To create and visualize 3D model of Indirapuram, Ghaziabad.
- To perform 3D Viewshed Analysis in order to find suitable sites for installing minimum number of mobile communication towers with enhanced coverage

3. STUDY AREA

The study area is confined to Indirapuram, Ghaziabad district.in Uttar Pradesh. It is also a part of National Capital Region sector of North India extending at 77.3714^0 E and 28.6415^0 N. It lies in west part of Uttar Pradesh. The area is known for high rise buildings and dense telecommunication network. It is shown in Figure 1.

4. DATASETS

3D models of several buildings in the area have been designed in Sketchup Pro 2017. Indirapuram is a sector of Ghaziabad (U.P) as well as a part of National Capital Region. The apartment complexes were designed on Sketchup and images were overlaid onto the structures using Layout. Raster image of same area is added through Geo-location service of Sketchup so as to provide a reference where corresponding 3D models are to be laid.

5. SOFTWARES

(i) Google Earth – to visualize the areas of interest and validate the models built on Sketchup

(ii) Sketchup Pro 2017 – to build 3D models of high rise buildings

(iii)Terra Explorer Pro 7.0 – to calculate 3D viewsheds and signal coverage

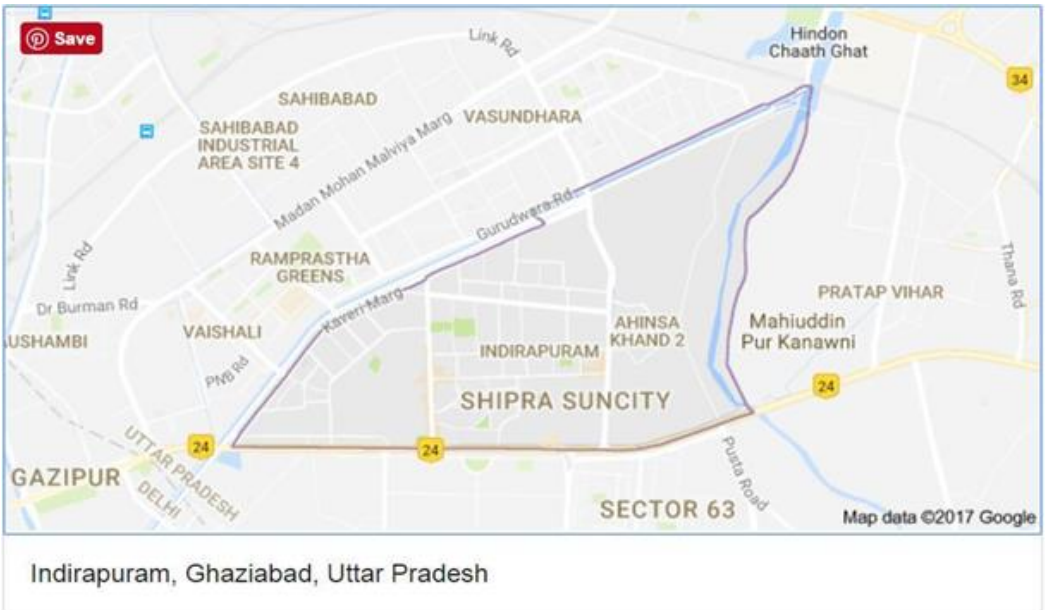
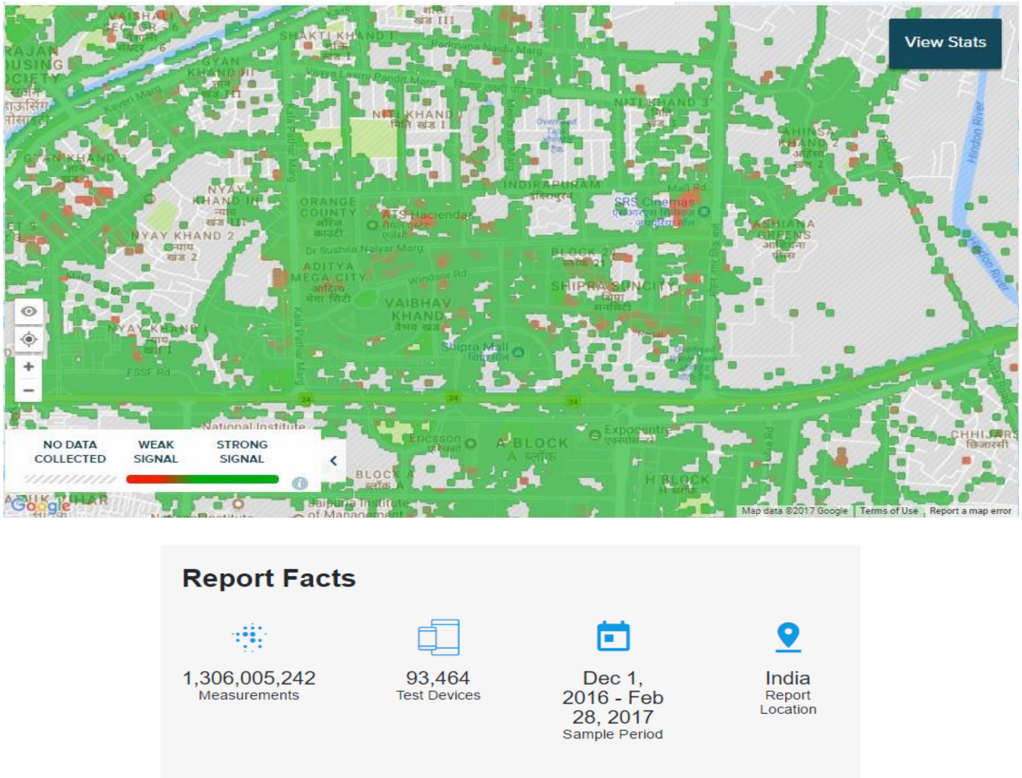


Figure 1: Study Area- Indirapuram, Ghaziabad



Source : www.opensignal.com

Figure 2: Telecommunication Density in Indirapuram

6. METHODOLOGY

The first step of methodology deals with the site selection after which 3D models are imported from Sketchup Warehouse. Then the raster of entire interest area is mosaiced using Sketchup and 3D models are created and laid over the corresponding latitudes, longitudes on the raster. After that the DEM layer of the study area is extracted and classified based on elevation in ArcGIS software. The DEM layer is converted in Google Earth to find the elevated areas suitable for tower erection. Line of Sight analysis is done followed by Viewshed Analysis in Terra Explorer PRO. The suitable sites are obtained in the output.

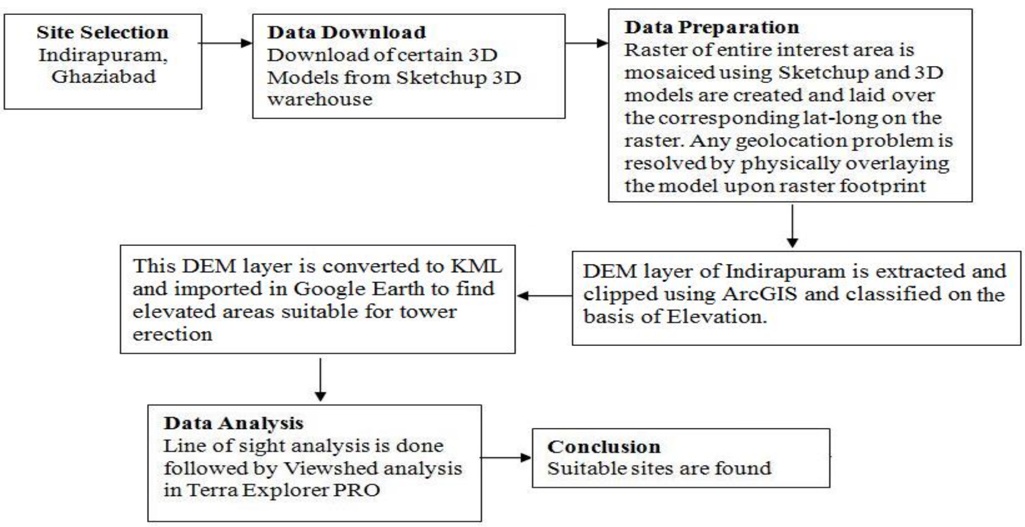


Figure: 3. Methodology

7. RESULTS AND DISCUSSIONS

The Elevation profile of the study area as shown in Figure 4 was extracted through DEM layer and clipped using ArcGIS. The areas depicted in red have a topographical advantage of highest elevation whereas the areas depicted in cyan have lowest elevation. This elevation profiling is done as a prerequisite for surveying before MTBS are erected.

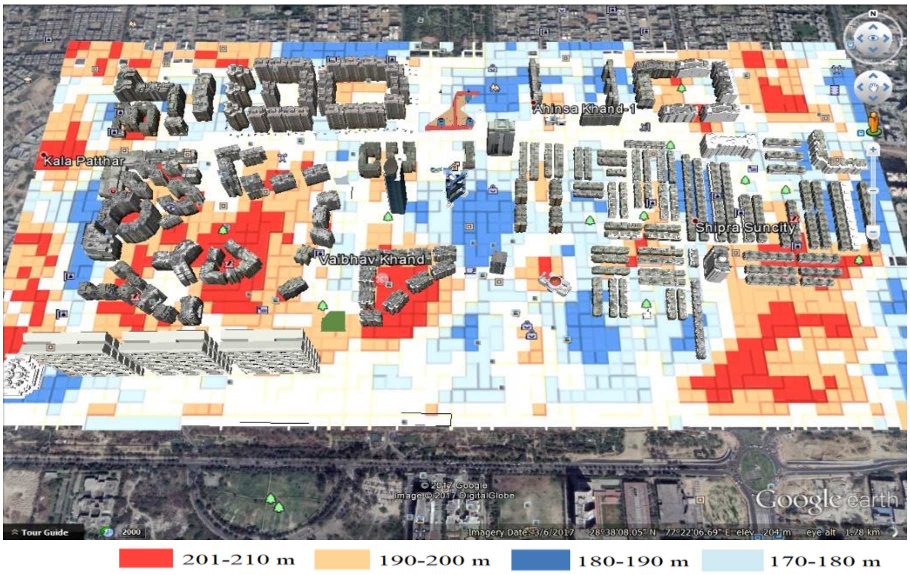


Figure 4: Elevation in the Study Area

On the basis of terrain height and building height, MBTS ranging between 10 m to 30 m are erected in order to have maximum signal coverage in first bounce off the apartment complexes and roads. The areas depicted in red receive signals after multiple bounce. The sites are chosen considering the Picocell base station and keeping aerial distances of at least 200m between the site of erection and the apartment complexes in the line of sight.

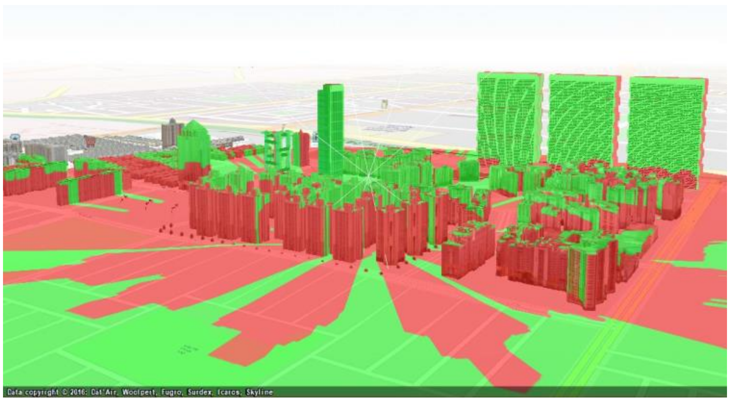


Figure 5: 3D Viewshed of Signal Coverage –ATS Greens Apartment Building

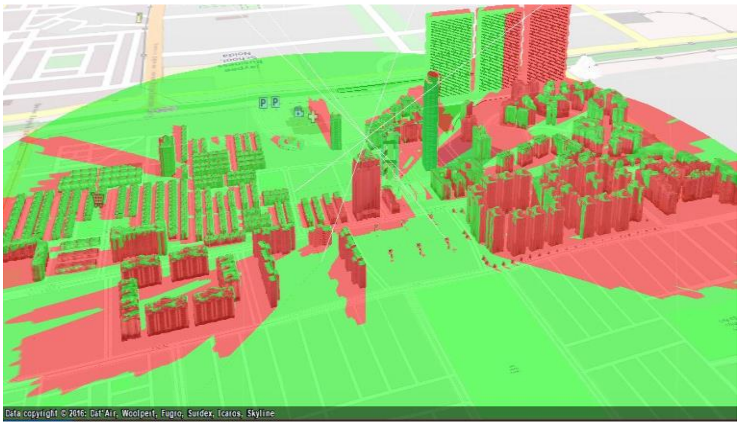


Figure 6: 3D Viewshed of Signal Coverage - Corporate Tower

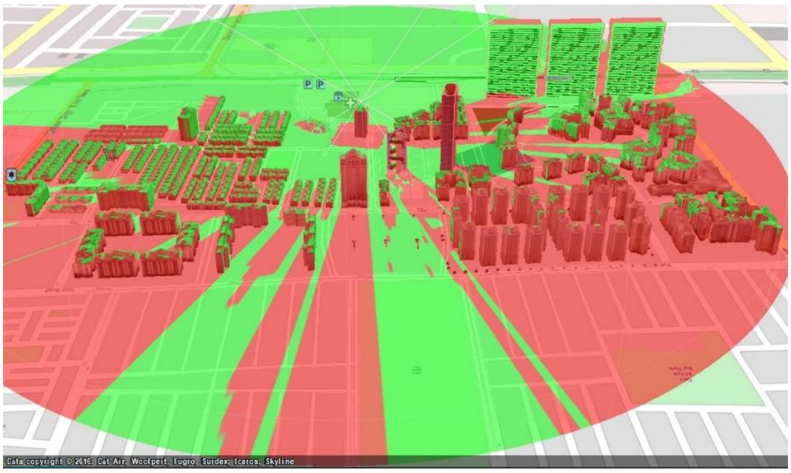


Figure 7: 3D Viewshed Of Signal Coverage - Credit Suisse Building

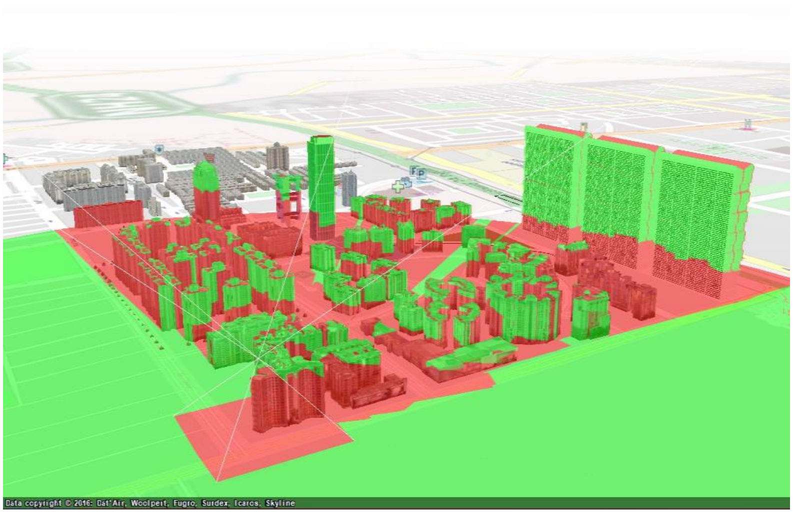


Figure 8: 3D Viewshed Of Signal Coverage - GC Grande Apartment Building

Figure 9: 3D Viewshed of Signal Coverage - Palm Jumeirah Building

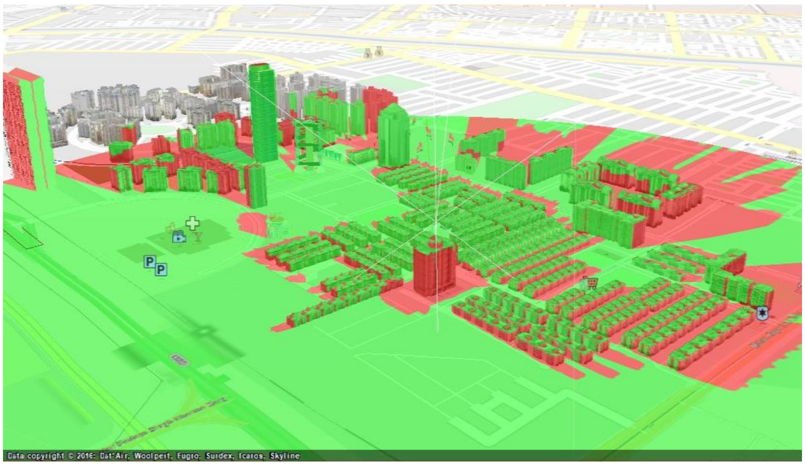


Figure 10: 3D Viewshed of Signal Coverage - Regalia Heights (Shipra Sun City)

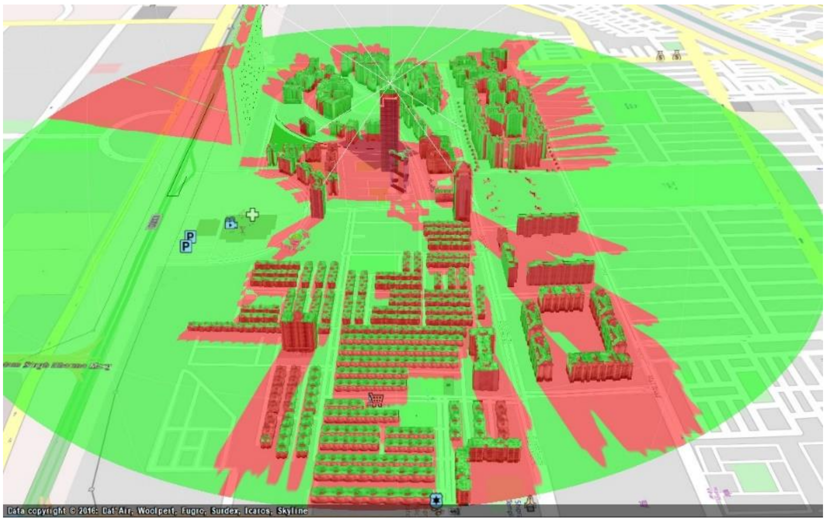


Figure 11: 3D Viewshed of Signal Coverage - Royale (Shipra Sun City)

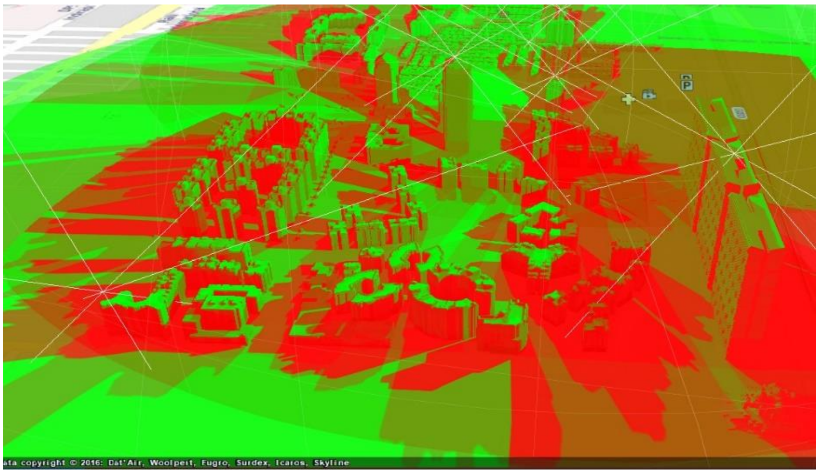


Figure 12: 3D Viewshed of Complete Signal Coverage over Indirapuram (North Facing)

8. CONCLUSION

The area depicted in green shows the coverage of mobile signals before first signal bounce-off from concrete structures which makes the encircled site suitable for mobile tower establishment. The area shown in red shows the area where the signals reach after first and multiple bounce. In this way, the no. of mobile communication towers can be reduced by analyzing the maximum viewshed area covered under the line of sight of a tower

The 3D capabilities of computers are largely restricted in several hardware aspects (e.g. dedicated 3D hardware chip, floating point calculations are done by the software, hardware division circuits for integer division are missing, large amounts of texture cannot be processed due to memory restriction and slow processing speed). Besides, the algorithms have to be adapted for the low-resolution screens of mobile devices which provide limited color and shading options. Terra Explorer Pro can display at maximum 5 viewsheds. Beyond this, the viewshed layer cannot be selected and moreover, visualizing more than one viewshed challenges the processing capability of the graphic renderer and makes the system slow. The addresses displayed in Google Earth are calculated on approximation basis. At several times, the models imported from Sketchup 3D warehouse posed georeferencing problems and got layered onto other buildings in the vicinity when imported in Sketchup. This problem was resolved by adding and mosaicing the raster layer of the area in Sketchup and then creating/implanting 3D models onto that. The RF modelling softwares are not available as open source which is the biggest challenge for signal mapping. Only hypothesis is prepared and have been worked upon.

The current guidelines adopted in India are 1998 WHO approved International Commission on Non Ionizing Radiation Protection norms which allow 4.7 Watt/m^2 (940 MHz) to 9.2 watt/ m^2 (1840 MHz). The safe limit for maximum radiation density is 1000 $\mu W/m^2$ for outdoor RF exposure and 100 $\mu W/m^2$ for indoor, cumulative RF exposure. Transmitted power from each cell tower must be immediately reduced to maximum 1 to 2W, which will protect health of the people from harmful effects of cell tower radiation. It will also protect birds, animals, plants, trees and environment. The reduced transmitted power may create signal problem to the people living near the edge of the circle in the beginning. This problem can be overcome using multiple domestic repeaters where the viewshed is shown in red.

The results of this research could be of great assistance in the field of telecommunication, ranging from tower erection to signal optimization. Policy-makers are expected to follow the research outcomes and create action plans for the affected regions

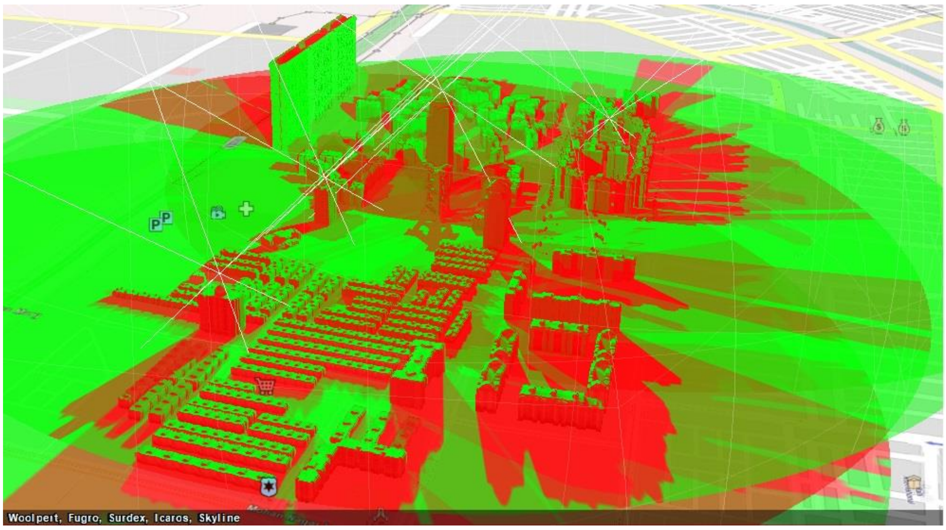


Figure 13: Total Area Coverage under 5 Viewsheds

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