Smart Subsurface Investigation Tools for Smart Cities

Dr. Sanjay Rana, Director, PARSAN; sanjay@parsan.biz

Introduction

There is no universally accepted definition of a smart city. At In a country like India, in the imagination of any city dweller, the picture of a smart city contains a wish list of infrastructure and services that describes his or her level of aspiration. To meet the aspirations and needs of the citizens, urban planners ideally aim at developing the entire urban eco-system, which is represented by the four pillars of comprehensive development- institutional, physical, social and economic infrastructure. A smart city is a city that provides core infrastructure and gives a decent quality of life to its citizens, a clean and sustainable environment and application of ‘Smart’ Solutions. Assured water and electricity supply, sanitation and solid waste management, efficient urban mobility and public transport, robust IT connectivity, e-governance and citizen participation, safety and security of citizens, constitute core infrastructure elements of a smart city. Application of smart solutions is essence of smart city concepts.

Underground infrastructure constitute a major component of any city's infrastructure, with underground metro corridors, parking, utilities (water, gas, sewer, telecoms, electricity etc.). Underground infrastructure also remains one of the most neglected, unplanned, least regulated and rarely maintained component. Hidden under layers of smooth roads, swanky buildings, lush green parks and city's exterior, it fails to get the attention, unless some accident (pipe ruptures, sunk roads, etc.) brings it back in focus albeit for a short time.

A smart city can not be expected to function smartly without paying adequate attention to underground infrastructure. It is of utmost importance to have geospatial database of underground infrastructure, to evolve a system of maintenance & updating of this database regularly, and coordinated efforts of various stakeholders for smart utilisation of underground space.

Subsurface investigations are required to map existing underground infrastructure, to classify soil strata of cities, to assess effect of earthquakes in various parts of cities and link it to building standards, and for various such applications wherever an structure is to be erected. All these factors have a bearing on underground structure. Geophysical methods, due to their non-destructive nature, provide ideal solutions for smart subsurface investigations for smart cities.

Indian Experience

In Indian urban context, what is conceived as ‘smart’ does not remain ‘smart’ for a very long time. None of the commercial and residential complexes or areas developed post independence is smart anymore. The reason could be manifold and it is not possible to point any particular reason. But one major reason is our inability to develop more such complexes and areas fast enough. As a result, the existing ‘smart complexes” if they can be called so, are no longer smart. Speaking specifically of NCR, places like Nehru Place or Bhikaji Cama Place which were conceived for as smart business districts have metamorphosed into highly disorganized retail markets bursting at seams.
**Concept to Construction**

Till a few decades ago, only sewer lines, storm drains and water supply lines were underground. Later, power supply lines were also put underground. As the day passes, more and more utilities are going underground. As different agencies and departments are doing this underground utility laying without any coordination, there is no central database on underground utilities to refer to. Authentic information on layout and exact location of underground utilities is not available centrally with one single agency. As a result, every time a new utility is being laid underground, the user starts from the scratch as there is no reliable information source to turn to. As things stand today, the underground space available for laying of utilities is getting congested day by day. Most of the times, departments depend upon personal memory of staff who would have supervised the utility laying work. As a result, whatever little information is available is anecdotal and resides with a particular person. With the movement of that one person, due to transfer or superannuation, this information is lost.

Another issue which is of grave concern is covering of existing manhole and inspection covers. As a good engineering practice, manhole and inspection covers are required to be raised whenever the roads are re-laid. Most of the times, road laying work is done at night and there is no supervision by concerned agencies to ensure that manholes and inspection covers are raised to the new road level. Unscrupulous road contractors do not bother and take the easier option of covering the manholes and inspection covers with new layer of asphalt. So, by next day morning, there a nicely laid road where all traces of manholes and inspection covers are obliterated. Once a manhole gets covered by asphalt, it is very expensive and time consuming to locate and unearth them. The other extreme, of course, is a raised manhole cover which is of great risk to road users especially at night.

While laying the new utilities, the contractors should prepare ‘As Built Drawings’ (ABD) for future reference. Most of the times, laying of new utilities is an outsourced activity and attention is more on laying the utility and putting it into use as early as possible with complete disregard to preparation of ABDs for future reference.

So, putting all three problems together:

- No central repository for location of underground utilities.
- No single agency monitoring the laying of new utilities.
- Non-availability of ABDs
- Covering of manholes and inspection covers during laying of roads.

Putting all these three issues together, one is looking at a problem which is getting out of hand with every passing day.

This paper discusses various areas where geophysical investigations can provide a mechanism for mapping and continuous updating of underground utilities which be a starting step towards conceiving such smart solutions.
What is Geophysics?

As the name implies, geophysics involves the application of physical theories and measurements to discover the properties of the earth. The discipline dates to antiquity, mainly as a scientific approach to earthquake prediction (a problem still unsolved), but major progress began in the late 1500's with initial work in such areas as magnetism and gravity. Tremendous improvements in instrumentation in the early years of the 20th century generated rapid progress in geophysics and ultimately led, in the 1960's, to the theory of plate tectonics.

Plate tectonics, the study of the interior structure of the earth, and such related areas as global and regional processes are known collectively as solid earth geophysics. The sub-discipline known as exploration geophysics involves the use of geophysical theory and instrumentation to locate petroleum and other mineral sources. Unlike solid earth geophysics, exploration geophysics generally concentrates on finding lateral heterogeneities in a relatively small part of the earth’s crust.

Geophysics has dramatically increased man's ability to exploit natural resources. Human senses cannot quantify, or even detect many physical phenomena (e.g., magnetism). Humans cannot detect variations in the earth's gravitation field of one part per million, but modern gravity meters can (in fact, to 0.02 parts per million or better). Seismology, the primary method of petroleum exploration, requires exact timing and recording of very low-amplitude vibrators, vibrations (or shaking) that is far below that a human would sense.

Engineering Geophysics deals with the geophysical techniques that are relevant to ground investigations to determine structural nature of the subsurface for engineering projects.

Benefits & Limitations of Geophysics

Geophysical investigation is an indirect approach for investigation subsurface or structures. Various physical properties of subsurface like conductivity, hardness, presence of anomalies, dielectric properties, moisture content, density, interfaces etc., can be determined using various techniques like seismic refraction, seismic reflection, electrical imaging, ground penetrating radar, EM, VLF, borehole geophysics etc. It is even possible to determine dynamic modulus like shear modulus, bulk modulus, poisson's ratio etc., using geophysical techniques. Interpretation of geophysical survey data usually requires some prior knowledge of the underlying geological structure. For optimum interpretation of geophysical data it is important that adequate direct information is available, which can be provided by boreholes or trial pits.

Geophysical surveys can offer considerable time and financial savings compared to borehole investigations. At an early stage of site investigation, it may be beneficial to undertake a reconnaissance geophysical survey to identify areas which should be further investigated using invasive techniques i.e. areas where anomalies have been identified. Geophysics has the unique advantage of providing continuous profile of subsurface rather than discreet information provided by boreholes. This is critical in areas with complex geology and in urban projects like tunnels, excavation etc., where a small buried object (pipeline/ cable etc.) can lead to major challenges during execution. Geophysical surveys can be used effectively to determine the geological, hydro-
geological and geotechnical properties of the ground mass in which the engineering construction is taking place.

Using geophysical techniques to solve engineering problems has sometimes produced disappointing results, particularly when a method, which lacked the precision required in a particular site investigation has been used, or when an inappropriate method has been used. In most of the cases, these problems can be avoided by using services of an experienced geophysicist who has access to various geophysical techniques. In other cases, the geological conditions at the site have been found to be more complex than anticipated at the planning stage of the geophysical survey and hence interpretation of the geophysical data by the geophysicists has not yielded the information expected by the engineer. It is often advisable to undertake a feasibility study at the field site to assess the suitability of the proposed geophysical techniques for the investigation of the geological problem.

Once the geophysical data has been obtained, it is possible to produce a model of the geological structure, which gives a realistic correlation with the data. The best overall model is obtained by using all the available geological information from boreholes and field mapping. Without this precise input, which includes knowledge of the fundamental physical properties of the geological material at the site, the model cannot be constrained in practical terms. There needs to be close collaboration between site geologists, engineers and geophysicists for the interpretation of the geophysical data.

**Use of Geophysics for Trenchless Projects**

The use of Geophysics in Trenchless projects has been maturing over the past few years. Major construction projects often use geophysics to image the subsurface along the proposed route to detect changes in soil and rock stratigraphy, locate buried utilities and map fracture zones. The ability of geophysics to mitigate risks associated with unexpected delays has often resulted in significant cost savings. A variety of complementary geophysical methods are employed on projects of this nature.

Advancement in technology for Trenchless projects is taking place at a rapid pace, and more sophisticated, advanced and costly drilling machines are available in market. The performance and productivity of these machines largely depends on the subsurface medium encountered, and most importantly a prior knowledge of subsurface properties, enabling right choice of machines, bits and tools.

Various techniques like Ground Penetrating Radar (for detection of buried utilities and shallow stratigraphy), Seismic Refraction (to map soil-bedrock interface and determine mechanical strength of subsurface), Electrical Tomography (to map water saturated zones, faults, fractures) and seismic reflection (deep investigations for faults, fractures, shears) are available to provide quick information on subsurface conditions. Use of these techniques ensures proper equipment selection, least down time for equipment, and a resultant saving on projects.

Hereunder are few examples of information derived prior to trenchless projects using geophysical methods:
Example-1- Detection of buried pipeline using ground penetrating radar

Example-2- Detection of boulders & water accumulation using electrical resistivity imaging

Example-3- Soil classification and bedrock depth using Seismic Refraction
Use of Geophysics for Detection & Mapping of Underground Utilities (SUE):

Most of Indian cities have an extremely complex network of utilities, typically characteristic of a developing country. The records on existing utilities underground are either simply non-existent or inaccurate. With ever-increasing use of trenchless technology, requiring precise information on underground utilities, techniques for non-destructive detection of such utilities are extremely important. Poor records, improper notification, and excavation errors contribute to often cause damage to subsurface utilities but such incidents are preventable. Subsurface Utility Engineering (SUE) is a discipline dedicated to the determination of the exact location of existing underground facilities. Use of SUE ensures that utilities are accurately picked up and plotted on site plans. This in turn reduces costs, delays, and public inconvenience. In addition, by eliminating the risk of utility breakage, the project will be safer for both construction personnel and the general public, hence reducing liability concerns. Subsurface Utility Engineering, or SUE is a new discipline that utilizes modern techniques to detect underground utilities in a total non-destructive manner. This process results in a digital map that will identify utilities within the project area.

Data collection for existing utilities consists of various steps, starting from quick reconnaissance to detailed investigations. These steps commonly designated as Quality Levels (QL) are:

**Historical Utility Records Research**

The data collection under this stage is aimed at obtaining basic information on possible locations, congestion and orientation of utilities. Such information is highly inadequate for use by trenchless contractor, but immensely useful for SUE contractor for deciding density and orientation of survey lines, selection of equipment, and planning of survey operations.

**Designation**

Designation is the process where by the approximate horizontal location of a utility is determined. Following a rough approximation of the general location of facilities provided by historical records research and visual site assessment, a number of geophysical technologies can be used for identifying the horizontal locations of various utilities.

**Induction Utility Locators**

Induction utility locators operate by locating either a background signal or by locating a signal introduced into the utility line using a transmitter. There are three sources of background signals that can be located. A utility line can act like a radio antenna, transmitting electromagnetic signals that can be picked up by a receiver. AC power lines have a 50Hz signal associated with them. This signal occurs in all active AC power lines regardless of voltage. Utilities in close proximity to AC power lines or used as grounds may also have a 50Hz signal that can be located with a receiver. A signal can be indirectly induced onto a utility line by placing the transmitter above the line. Through a process of trial and error, the exact above position can be determined. A direct induced signal can be generated using an induction clamp. The inductor clamp induces a signal on specific utilities. This is the preferred method of tracing, where possible. By virtue of the closed loop, there is little chance of interference with the resulting signals. When access can be gained to
a conduit, a flexible insulated trace wire can be used. The resulting signal loop can be traced. This is very useful for non-metallic conduits. Finally, these signals can be located horizontally on the surface using a receiver. The receiver is moved across the estimated location of the utility line until the highest signal strength is achieved. This is the approximate horizontal location of the utility. The receiver is then rotated until minimal signal strength is achieved. This will give the approximate orientation of the utility. Vertical depth, however, derived from this equipment is subject to gross error.

**Ground Penetrating Radar**

Ground Penetrating Radar (GPR) is an electromagnetic method that detects interfaces between subsurface materials with differing dielectric constants (a term that describes an electrical parameter of a material). The GPR system consists of an antenna, which houses the transmitter and receiver; and a profiling recorder, which processes the received signal and produces a graphic display of the data. The transmitter radiates repetitive short-duration EM signals into the earth from an antenna moving across the ground surface. Electromagnetic waves are reflected back to the receiver by interfaces between materials with differing dielectric constants. The intensity of the reflected signal is a function of the contrast in the dielectric constant at the interface, the conductivity of the material through which the wave is travelling, and the frequency of the signal. Subsurface features which may cause such reflections are: 1) natural geologic conditions such as changes in sediment composition, bedding and cementation horizons, voids, and water content; or 2) man-introduced materials or changes to the subsurface such as soil backfill, buried debris, tanks, pipelines, and utilities. The profiling recorder receives the signal from the antennae and produces a continuous cross section of the subsurface interface reflections, referred to as reflectors.

Depth of investigation of the GPR signal is highly site specific, and is limited by signal attenuation (absorption) of the subsurface materials. Signal attenuation is dependent upon the electrical conductivity of the subsurface materials. Signal attenuation is greatest in materials with relatively high electrical conductivity such as clays and brackish groundwater, and lowest in relatively low conductivity materials such as unsaturated sand or rock. Maximum depth of investigation is also dependent on antennae frequency and generally increases with decreasing frequency; however, the ability to identify smaller features is diminished as frequency decreases.

Various GPR antennas used are internally shielded from aboveground interference sources. As a result, the GPR signal is minimally affected by nearby aboveground conductive objects such as metal fences, overhead power lines, and vehicles.

A GPR survey is performed by towing an antenna across the ground along predetermined transect lines. The antennae is either pulled by a person or towed behind a vehicle. Preliminary GPR transects are performed over random areas of the site to calibrate the GPR equipment and characterize overall site conditions. The
optimum time range settings are selected to provide the best combination of depth of investigation and data resolution for the subsurface conditions at the site. Ideally, the survey is performed along a preselected system of perpendicular or parallel transect lines. The configuration of the transect lines is designed based on the geometry and size of the target and the dimensions of the site. The start and end points of the transect lines and grid intersection points, or nodes, are marked on the ground with spray paint or survey flags. A grid system is used to increase the probability of crossing the short axis of a target providing a more definitive signature in the data. The location of the antenna along a transect line is electronically marked on the cross section at each grid intersection point to allow correlation of the data with actual ground locations. The location of the targets can be marked on the ground surface using spray paint or survey flags.

Non-Destructive Air-Vacuum Excavation

This information provides the highest level of accuracy presently available. It involves “locating”, the use of non-destructive digging equipment to expose buried utilities at critical points. When surveyed and mapped, precise plan and profile information is available for use in making final design decisions. The use of nondestructive digging equipment, particularly vacuum excavation, eliminates damage to underground utility facilities traditionally caused by backhoes. By knowing exactly where a utility is positioned in three dimensions, the designer can often make small adjustments in design elevations or horizontal locations and avoid the need to relocate utilities. Additional information, such as the composition, condition, and size of the underground utility, soil contamination, pavement thickness, etc., also assists the designer and the utility owner in making important decisions.

Non-destructive Air-Vacuum Excavation is used to determine the exact horizontal and vertical location of facilities. The process involves removing the surface material over approximately a 1’ x 1’ area at the electronically determined approximate horizontal location produced during the designation stage. The air-vacuum process proceeds with the simultaneous action of compressed air-jets to loosen soil and vacuum extraction of the resulting debris.

This process ensures the integrity of the utility line during the excavation process, as no hammers, blades, or heavy mechanical equipment comes into contact with the utility line. This eliminates the risk of damage to utilities and personnel. The process continues until the utility is uncovered. Normally, the following information (if applicable) is recorded for each vacuum excavation: the utility type, material, size, depth, condition, location (x, y, z), orientation, roadway section materials and depths, soil type and water table.

Air-Vacuum Excavation can also be used at a proposed boring location to excavate below the "utility window" which is usually eight feet. This reduces the risk to utilities during the initial drilling process. Soil samples can be taken during the air-vacuum excavation process. Frequently, contaminants move along utility line trenches. Air-vacuum excavation can be used to obtain soil samples adjacent to utility lines without risking damage.
Data Management

Equipped with this EXACT information, the Data Management aspect of SUE can begin. These four categories of invaluable information can be utilized to provide extremely accurate subsurface "photographs" for designers. The unique blending of all four of these distinct procedures produces the most exact CADD map possible. After concluding the air-vacuum stage, the exact utility data is then translated into a computer generated three-dimensional map. This computer-generated map then becomes a critical weapon for the designer, allowing for exact instructions for excavation. The sum total of benefits to the client when SUE is utilized is the virtual elimination of utility breaks and work stoppages, cost overruns, safety hazards, adverse publicity, and the ensured health and safety of the general public all related to subsurface utility breaks.

When all of these procedures are blended together and applied, a clear and exact visual representation of the position of underground utilities in an area of excavation is produced. Each of these tools, applied independently, offers a limited and only partial representation of the subsurface utilities. The benefits derived from the application of these procedures are maximized when each is fully utilized to complement another tool.

The two-fold end result of performing a complete SUE survey is:

- A precise subsurface map that eliminates utility breaks, safety hazards or claims, and public outcry, and
- Confidence to provide the client or owner with the best product while reducing design cost and compressing schedules.

Example SUE Map (SUM- Subsurface Utility Map):
Innovative Geophysical Methods for Pipeline Leakage Detection

There are innovative techniques for leak detection using sophisticated geophysical instruments, which can be applied to locate and pinpoint leaks in most of the cases. The details of the techniques are as under:

Leak detection is done by using sophisticated noise level monitoring technique. The technique involves use of extremely sensitive devices called Geophones along the route of the pipeline. The geophone or sensor is connected to the monitoring and data storage facility where the data is recorded and displayed.

A geophone is a small, cheap instrument for measuring ground motion. There are many variants for different applications which are designed for earthquakes, machine vibrations, oil exploration, mining, etc. Most of the models have a coil hanging from a spring in the center of magnets. When the case is moved up and down the mass tends to stay stationary due to inertia and induces small currents into the coil as it moves through the magnetic field. It measures velocity of coil. This induced current is used to move a stylus or is directly recorded for analysis.

The Geophone water leak detector accurately locates underground leaks, both water and steam, eliminating costly and time-consuming excavation. It is extremely sensitive to vibration caused by water leaks under hard surfaces like asphalt and concrete. Many industrial plants, water departments, and municipalities are successfully using the Geophone to pinpoint underground water leaks.

With the advancement in technology, the modern system sends the data from geophones to seismograph where data can be recorded and displayed in real time.
Use of such systems also allow a much bigger layout, using 24 channels (geophones) covering 120-240 meters of length simultaneously. The results from all the 24 geophones are displayed giving the operator a full view of the background natural noise and abnormal noise created due to leakage.

Noise Level Display

Geophone Layout along the pipeline

The modern system also has digital signal enhancement and filtering capabilities, to concentrate on the anomalies and filter the background noise. The system also allows minimum noise profiling.
Other than the above, GPR is also used to pick difficult leaks, having little or no acoustic noise associated due to soil conditions/pipe condition/backfill conditions.

*High amplitude reflections from saturated layer top*

*Strong amplitude from water saturated layer top*

*Loss of signal due to increased conductivity caused by water saturation*
Smart Subsurface Investigation Tools

Ground Penetrating Radar

Ground Penetrating Radar, also known as Georadar or GPR, uses Radar technology to obtain a continuous profile of the subsurface, as described in earlier section.

The Georadar is of immense application in areas requiring high-resolution information of relatively shallow subsurface. Depth of penetration of radar signal depends on the frequency used and material properties.

The application areas of GPR technology include:

- Detection of underground utilities- Pipes, cables (metallic and non-metallic)
- Soil-bedrock interface, shallow geological investigations
- Mining Development
- Mineral Exploration
- Water Table determination
- Glaciology
- Archaeology & Forensics
- Cavities & Voids (Structures- Dams, Bridges, Weirs, Barrages etc.)
- Ground Contaminants (Environment)
- Road Investigations (Layer thickness, Subsidence)

Advantages:

- Rapid ground coverage afforded by towing the antennae either by hand or from a vehicle.
- High lateral resolution of targets, even for larger surveys.
- The instant graphic display offered by most GPR systems allows on-site interpretation.

Limitations:

- Data acquisition may be slow over difficult terrain.
- Depth of penetration is limited in materials with high electrical conductivities like clays.

Seismic Surveys

Seismic technique is one of the most developed geophysical techniques, providing vital information on subsurface, crucial for most of the engineering projects. Seismic Refraction surveys are routinely carried out for assessment of subsurface conditions prior to engineering projects.
The seismic refraction method is based on the measurement of the travel time of seismic waves refracted at the interfaces between layers of different velocities. The seismic energy is generated at the shot point using a source (hammer, weight drop, explosive). The energy radiates from the shot point, and first arrivals are detected using geophones. The first arrivals can be direct arrivals or refracted arrivals, on different geophones, depending on velocities and thickness of subsurface layers. The time-distance curve is used to determine velocities and thickness of various subsurface layers.

The velocity depends on elasticity and density of material through which the energy is travelling, and hence provides information on the material strength, and helps in classification of the material.

The seismic refraction surveys are used to determine:

- Bedrock profile, rock quality and depth.
- Thickness of overburden
- Fractures and weak zones
- Topography of ground water
- Rippability assessment in mines
- Slope stability studies
- Pipeline route studies

**Electrical Surveys**

The electrical methods, used for measurement of subsurface resistivity, involve passing an electrical current into the ground using two electrodes, and measuring resultant potential using two potential electrodes. Resistivity sounding involves gradually increasing the spacing between the current and/or potential electrodes to obtain deeper penetration. Under profiling, the electrode spacing is kept constant and the entire arrangement is moved along profile lines, to obtain lateral variation in subsurface resistivity.

Electrical resistivity techniques are based on the principle that the resistivity varied depending on the material encountered. Resistivity can then be used to identify different geological units by their electrical properties. If a material’s resistivity value drops it could mean that the rock is water saturated and one can expect to find fractured bedrock. The variation in resistivity will correspond to a geological variation along a investigated line. By calibrating the resistivity results with known geologic materials on site, valuable geotechnical information can be obtained for the site. This type of survey becomes interesting in determining the weathered bedrock layers and the presence of sand/ moraine under the clay. It also corroborates the information from the refraction results for better geological interpretation.

2D resistivity imaging uses an array of electrodes connected by multicore cable to provide a linear depth profile of the variation in resistivity both along the survey line and with depth. The acquisition system consists of two units connected to a laptop computer. One unit is a resistivity meter which injects the electrical current into the ground and measures the voltage between the electrodes. The
other unit is a control switch box which selects both the injection electrode pair and the potential electrode pair for each data point.

The data are presented as pseudo-section in which the spatial distribution of the electric properties of the investigated material can be qualified. To qualify the data, a modeling routine is applied to the dataset according to the Zohdy method. This new section can be correlated to a depth section since the Zohdy method computes from the datapoint a series of continuous vertical electrical profiles.

The Electrical surveys of used in civil engineering, water resources, mining and environmental projects to:

- Determine the underground water resources
- Bedrock quality and depth measurements
- Mineral prospecting
- Dam structure analysis
- Landfill
- Contamination source detection

**Seismic Tomography**

Borehole seismic tomography is used to derive an image of seismic velocity between two or more boreholes by measuring travel time between source and receivers along various raypaths. The technique is used for detailed and targeted evaluation of material. One hole is used as source hole, and for wave generated at various depths in this hole; travel times are measured at number of receivers in the other hole, also known as receiver hole. This yields a network of overlapping ray paths, which are used in computations to create a velocity image, also known as tomogram. The tomogram helps identifying anomalous zones, which are visible as velocity contrasts. The technique allows determination of material property for each cell.

The application areas of seismic tomography are:

- Identification of features like fault zones and voids.
- Mapping of loose zones, sinkholes, anomalous zones in structures like dams.
- Detailed study of old foundations

**Micro-Gravity**

All matter exerts a gravitational field in direct proportion to its mass. Dense earth materials will exert a stronger localized gravitational field than less dense ones and this can be measured using extremely sensitive gravity meters. These instruments are essentially highly sophisticated spring balances. A simplified gravimeter design consists of a precisely measured mass suspended by a spring. Locating the instrument above higher density material causes the downward component of the local gravitational field \( g \) to increase and the spring extends under the additional force. The
relative increase in is determined through measurement of spring extension. In engineering and environmental applications, it is more usual to use the micro-gravity technique to locate the absence of material due to buried voids, mine shafts and wells. In these situations the mass deficiency results in shortening of the spring due to a relative and very localized decrease in ‘g’. Data are acquired on a grid at intervals designed to ensure detection of targets at the desired resolution (0.5 m-1 m spacing for a 2 m buried mineshaft). It is vital that the position of every data point acquired is surveyed accurately and that short-term changes in the gravitational field of the Earth (known as drift) are monitored throughout the survey period.

The application areas of micro gravity in urban projects are:

- Identification of natural voids and cavities.
- Detection of voids created due to water leakage from pipelines

CONCLUSIONS

Smart cities need smart solutions and a fresh re-look at the way, underground space is utilized and managed. The first step towards this would be to know the situation as of now. Various geophysical techniques exist to provide continuous information of subsurface conditions in totally non-destructive manner to accurately plan activities in projects. This information make the operations safe eliminating and minimizing chances of damages to equipment and existing infrastructure. Different methods provide information on different physical properties, and a combination of techniques should ideally be used to get a unique result. There is also an urgent need to institutionalize mapping and updating record of underground utilities before we embark on our journey towards creating smart cities. Geophysical techniques offer most economical methods to achieve this goal. For more information on any of these aspects author may be reached at sanjay@parsan.biz