

# Management of Underground Utility by using RS & GIS techniques: A Review

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**ABSTRACT:** Every local government's maximum activities estimated to be geographically based. For example plats, zoning, public work (street, water supply, sewer, garbage collection, land ownerships, and valuation.) RS and GIS techniques have an efficient adaption to manipulation of spatial and non-spatial data and provide decision support system to government dignitaries. Modelling of underground infrastructure is one of the most crucial among other government activities. RS and GIS are appropriate solution to such big challenging task. This paper presents overview of underground utility and their accession by using geo-technology to mapping, monitoring, modelling, measuring, and managing existing underground infrastructure. This paper also explores the technique implemented in the literature, which is used to convert infrastructure to smart infrastructure.

**KEYWORDS:** GIS, Remote Sensing, Geo-technology, Modelling, Underground Infrastructure, pipeline.

## I.INTRODUCTION

Advancements in technology, improvement in obtaining geotechnical data and development of new equipment have led to improvements in utility Designing, Mapping, Managing, Maintenance and installation work. Presently Geographical information system (GIS) is as a solution to the problem which was challenging in previous insoluble problem. Current easiness in using GIS tools against problem domain is the outcomes of tremendous development in the GIS [1]. There are several definitions of GIS in literature. A definition, which is implicit in particular way may not implied on another aspect. Defining GIS varies accordingly discipline variation, Because GIS is interdisciplinary concept. The reason behind difficulty of defining GIS are many different way of defining and classifying object & subject [2]. Environmental science Research Institute [ESRI] define Geographic information system (GIS) as "an organized collection of computer hardware, software, geographic data, and personnel designed to efficiently capture, store, update, manipulate, analyse, and display all forms of geo-referenced information." With the Association of Remote sensing [RS] the progress of GIS is to be unrelenting, Because RS allows us to deal with remote Geographical data. Environmental science Research Institute defines Remote sensing [RS] as "Collecting and interpreting information about the environment and the surface of the earth from a distance, primarily by sensing radiation that is naturally emitted or reflected by the earth's surface or from the atmosphere, or by sensing signals transmitted from a device and reflected back to it".

In the infancy of GIS and RS it was difficult to know about underground infrastructure, without excavation. As these technologies grown up we made such impossible things to possible things, as like as doctors can scan whole human body for diagnosis and cure of the disease with the help of instrumentation [3]. Managing underground utility consists of detecting leakage [4], design optimal route [6], Implementing SCADA system, Implementing GIS-based DSS [5]. There are numerous technique involved in each phases of managing utility. Managing and using technique may vary according to the location of study area and type of utility [1].

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## 1.1 UNDERGROUND UTILITY

This paper emphasizes on those underground utility, which are identified as a pipeline structure. For example water supply pipeline, oil pipeline and gas pipeline. The step to install such utility under the ground:

- a) Dig a trench,
- b) Lay the pipe in trench
- c) Fill the trench back in.

It's very difficult to estimate structure below the ground. To get know pipeline physically we have to excavate ground where pipeline is located, but this is not possible for whole system. This is very expensive and time consuming task to find correct location of pipeline. In the management point of view we must be able to locate location regarding problem (leakage in system), optimize route of pipeline, monitoring system, and measuring utility. RS & GIS is the Answer to the question asked by such type of utility.

## 1.2 TYPE OF UTILITY

Underground Utility mostly called as pipeline infrastructure

### 1.2.1 DRINKING WATER PIPELINE

Potable water is right of every human being on the globe; water already on globe such as water in pond, water in sea, water in River is not drinkable, we as a human being cannot drink such water directly because of impurity of such water, which may be reason of several disease. To make this non-drinkable water to drinkable and to distribute water at adequate pressure we have a system called drinking water system. Drinking water system is a system which manages whole regularity of water to be potable and provides continuous supply of potable water at adequate pressure up to the consumer's tap. The distribution system is the final barrier before delivery to the consumer's tap. Even when the water leaving the treatment plant is of the highest quality, if precautions are not taken its quality can seriously deteriorate. In extreme cases, dangerous contamination can occur. To avoid such hazard we must have sophisticated system that can manage purity and suitable distribution of water. Entire Utility is an expensive but long life. System is composed of pipes, valve, hydrant, storage tanks, pumping station etc. as majority of pipes this system Entirely Identified as pipeline network [7]. Efficient management of such system provides reliable and efficient service to the consumer, which is the objective of recently announced smart city's project by government of India [8].

### 1.2.2 WASTEWATER PIPELINE

Wastewater pipeline is another one underground infrastructure that manages regulation of wastewater; Wastewater is sewage, storm water, and water that have been used for various purposes around the community. Unless properly treated, wastewater can harm public health and the environment. Most communities generate wastewater from both residential and non-residential sources.

#### I.2.2.1 RESIDENTIAL WASTEWATER

Although the word sewage usually brings toilets to mind, it actually is used to describe all types of wastewater generated from every room in a house. There are two types of domestic sewage:

- [1] Blackwater—wastewater from toilets, and
- [2] Graywater—wastewater from all sources except toilets.

Blackwater and graywater have different characteristics, but both contain pollutants and disease-causing agents that require treatment.

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## 1.2.2.2 NON-RESIDENTIAL WASTEWATER

Non-residential wastewater in small communities is generated by such diverse sources as offices, businesses, department stores, restaurants, schools, hospitals, farms, manufacturers, and other commercial, industrial, and institutional entities. Wastewater treatment is the task of civil engineering, but how pipeline should be routed so that other existing infrastructure could not face the problem of “cross bore” and manage utility is such way that we can keep aware from harm to environment, is the task of technology. Lots of work has been done in literature mostly on pipeline management. These works can be implemented on wastewater pipeline as implemented on other underground utility [9].

## 1.2.3 OIL PIPELINE

To get crude oil from well and various final product from refinery, pipeline is used for the purpose of transportation. This goes to be very chip in economic context although such linear and long network occupies large geographical area because of specific sources of oil. Due to coverage of large land there would be problem in operation. GIS is used to identify problem and Decision making system and take suitable step for the management of system [10].

## 1.2.4 GAS PIPELINE

Gas pipeline consist of pipe, valves, compressor, metering stations, regulator stations, delivery stations, holder, and fabricated assemblies, as same extent similar to the other pipeline infrastructure the goal of this system is to provide gas to customer without adverse effects on employees, the public, customer or the environments. Existing system faces problems of allocating resources for appropriate activity that will result in improvement safely and a reduction in number of incidents. As the development in GIS we can have set of tools to model gas pipeline, which is been implemented in literature, so that we can achieve our goal to manage integrity of pipeline and process is going on, until we get efficient model to manage pipeline [10].

## II. PIPELINE ROUTE PLANNING AND GIS

Optimum Pipeline route design offers reduction in cost and energy consumption, which is need of smart society, smart environment and beneficial in economic point of view. RS & GIS is efficient tools to such type of routing. During last decade lots of works have been done to determine optimum pipeline routing i.e. deterministic techniques, stochastic techniques implemented using GIS in literature. 3D spatial data model can also be used in GIS for visualization of optimum layout design of pipeline. Technological review on pipeline suggests that the methodology is still at exploratory stage [26].

## III. FIVE M'S OF APPLIED GIS

This paper reports a review on the study done in literature for the accessing underground Utilities with respective of Five M's of GIS such as Mapping, Measuring, Modelling, Monitoring, and Managing.

Mapping is process of bounding object in a particular relation. Traditional output-perhaps the least powerful output. And maps are source of input data too (data capture). Measuring is the Extracting distance information from data. i.e., stream length from location A to location B. Modelling is assembling the data housed in the hardware in an organized and analytical manner in the software for 'knowledge' extraction. Monitoring in GIS is gone to be unrelenting with the help of Remote Sensing device, Accessing data spatially and temporally. Managing includes Creation, deletion, storage, organization, updating and achieving data.

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## IV.LITERATURE REVIEW

Prior to use of computer technology pipeline operator manually capture data on alignment sheets. User had to match each sheet to the adjustment sheet collectively served as a bible for the engineers & technician who managed the pipeline. Operators detailed events, accidents, repairs, and inspection along the pipe. In 1980's many pipeline operator converted their existing alignment sheets to CAD system, but it was not perfect solution for the problem. Again search continue for the appropriate solution. As computer technology becomes powerful, varieties of strategies rises to handle spatial data. GIS is new interdisciplinary field built out of the use and theory of GIS. GIS is built upon knowledge from Geography, cartography, computer science, information system, Mathematics.

With the help of growing GIS & RS lots of works have been done in literature on the pipeline issues. Quoting all research work date wise is out of the scope, only some of them noted in such review paper.

Five M's of Applied GIS helps to arrange review of techniques used for pipeline optimization.

### 4.1 MAPPING TECHNIQUES

Pipeline as an underground utility is cumbersome during mapping. Object to map should at least seen by eyes. Mapping is process of bounding object in a particular relation, unobserved quantity can also be mapped with the help of special statistical tool. In underground utility such as pipeline is an unobserved object as we could not able see it easily and could not predict how pipeline under the ground is laying. Our objective is not to identify how pipeline lying under the ground. We are planning to how it should be, in correlation with existing one. That is reason that we should know existing pipeline system. And we should able to apply management condition on the system. Mapping of underground utility consist of high resolution geo-physical tools such as EMI, GPR, GPS. These Three techniques are used to mapping underground pipeline.

#### 4.1.1 ELECTROMAGNETIC INDUCTION TECHNIQUE

These typically involve deployment of a fixed frequency electromagnetic field to induce the flow of secondary electromagnetic field on subsurface conductors. As this system are passed over a conductive target (i.e. steel pipe, cable), and data is recorded. These data spatially referenced by concurrent capture of GPS data. These data are digital logged and can be downloaded for the plotting Database [11].

#### 4.1.2 GROUND PENETRATING RADAR

EMI is ok for conductive target but what if target is non-conductive. For this GPR is available. Radar is similar in principle of seismic and sonar technique. Radar produces short duration high frequency (10-1000MHz) of electromagnetic energy, which is transmitted through ground. The reflected signal detected amplified by receiver and digitized for processing [11].

#### 4.1.3 CCTV FIELD INSPECTOR

CCTV camera travel inside the pipe sending location details to GPS receiver and GIS database. It also has electromagnetic hardware sonde to detect junction of the pipe. The project in Lexington, Kentucky incorporate combined technologies of electromagnetic sonde, lateral robotic camera, GIS mapping software, & GPS collection device [12].

### 4.2 MEASURING TECHNIQUES

#### 4.2.1 PHOTOGRAMMETRY

Collecting spatial information by survey crew is time consuming and may be inaccurate. The use of photography in surveying and mapping to ascertain measurement between object. Photogrammetry is the method consists of

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construction of 3-D model of exposed underground utility. The geo-referenced coordinate stored. Absolute coordinate derived from the model. And Graphical user interface is used to retrieve and update GIS Database for 3D visualization [16].

## 4.3 MODELLING TECHNIQUES

Decorate the system with its necessary component and representing system in efficient manner. The techniques used in literature for modelling is huge array. Modelling underground pipeline comprises 3D modelling and Hydraulic modelling.

### 4.3.1 3D MODELLING

Testing framework is developed to test different strategy for 3D scene modelling of underground pipeline system. The criteria of framework were.

- Number of scene graph node
- Number of triangle & vertices on the scene
- Needed transformation
- Appearance option

Spatial oracle is used to store data of pipeline and X3DOM/X3D used to generate 3D model of study area [13].

### 4.3.2 HYDRAULIC MODELLING

Hydraulic model is mathematical model of water/sewer/storm system and used to analyse system's behaviour. EPANET is one of the hydraulic modelling tools used to integrate all sensor used for decision support system will help to reduction in the water losses. Computer based control on technical component of system fulfill by EPANET, which is a computer program [24]. Development of hydraulic model depends on the need at a time. Creating hydraulic model of water distribution system provide a graphics and mathematical representative of its hydraulic behaviour. The simulation of hydraulic behaviour involves solution to non-linear equation for example, hazen-william equation, darcy-weibach and manning equation [20].

## 4.4 MONITORING TECHNIQUES

Detection of water loss by installing wireless sensor networks (WSN) with acquisition data from sensing technologies such as moisture, sound, pressure sensor. These sensors interconnected with WSN. Soil volumetric water content is measured by Decagon MDA300 mica (data acquisition board), water flow is measured by deploying KENT V100 (PSM) meters, pressure transducer from HONEYWELL, and ZONESCAN-800 is used for leak noise detection [22].

Monitoring pipeline networks may be divided in two components such operator monitoring system and remote sensing data monitoring system. Integration of two systems makes easily monitoring of pipeline network [17]. High resolution of data Imagery such as SPOT7, IKONOS 1m and LIDAR, RADAR, SAR also available [28]. Conditions rating of pipeline have been recognized by using artificial neural networks (ANN) with having input pipe type, pipe size, age, breakage rate, hazen-williams factor, excavation depth, soil type [14].

## 4.5 MANAGING TECHNIQUES

As the title of this review is "management of underground utility", technique used to manage underground pipeline should be at the center. Optimization of pipeline comes under management issues. Lots of research has been done in literature on managing pipeline for route optimization. Finding shortest Route of pipeline has the similar characteristic as the finding shortest route of road. Hence the algorithm used to optimize road network can also be

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consider for underground pipeline for finding shortest path. Three fastest algorithm for real road networks, these are graph growth algorithm, Dijkstra with approximate bucket, and Dijkstra with double bucket [18]. Zhan evaluate 15 algorithms for real road network, was the extension of cherkassky's evaluation with excluding of two algorithms for acyclic graph. Again Zhan compare these two evaluation that is cherkassky (1993) and Zhan & Noon (1996). And suggest that best performing implementation solving the one-to-all shortest path is pallottino's graph growth algorithm and for one-to-some Dijkstra algorithm. They recommended two flavor of dijkstra implementation depends upon arc length of the network. First is Dijkstra with approximate bucket (DKA) and second is Dijkstra with Double bucket (DKD) [18]. Although fastest algorithm recognized by the research work done by Zhan and Noon, problem of large graph motivate to evaluate efficiently the collection of shortest path queries on massive graph [34]. efficient optimization algorithm Shuffled Complex Evolution (SCE) in conjunction with EPANET, because SCE searches in all direction and based on Nelder & Mead complex search technique and EPANET can handle steady state and extended period of simulation of water distribution system [20]. Volkan YILDRIM underlined the disadvantage of classical method in which only slope data of linear engineering structure considered and suggest new approach of using raster network analysis in which multi-criteria evaluation is universally applicable for GIS based route optimization [15]. Nonis has showed that the AHP approach is suitable in Indian scenario to optimize pipeline. Analytical Hierarchical process (AHP) is quantitative method for ranking decision making alternatives by developing numerical score to rank. Weighting scheme fed to the GIS and get result for optimum route of pipeline [24] [27]. Effectiveness of (AHP) again presented by VILDRIM with the implementation of NABUCCO project in which he considered techniques, economy, environmental, sociological should examined as whole in route determination process [25] [26] [28]. Genetic algorithm used to optimization of pipeline route. And concluded that Genetic algorithm is reliable solution to optimization problem [21]. Genetic algorithm on three isolated networks

- Sewer network
- Treatment plant network
- Whole system

To optimize them, and make use of MATLAB with GATOOL toolbox, which provide a convenient environment for GA [9]. One more research has break down optimization problem into two sub problem 1) ascertain the edge-weight 2) obtain N shortest path. Dijkstra algorithm was used to optimize design of the pipeline network [19]. Mathematical model was applied to simplify the procession of pipeline route selection, condition rating of hydraulic model [23]. Multi-criteria decision making tools can be categorized in two categories.

- 1) MADM (Multi attribute decision model)
- 2) MODM. (Multi Objective decision model)

GIS-MADM Integration has potential to enhance group decision making process. But not all MADM techniques can be properly integrated with common GIS software. Therefore there are the scopes for the future research. [24] [32].

Probability based model incorporated with the dynamic programming lead to development of intelligent system pipeline management. Computer vision technique is used to feed input to the predictive model [33]. Weighting scheme applied to factors affecting such as environment, construction, security to estimate the construction cost by incorporating multi-criteria evaluation and least cost path analysis [30]. Implementation cost of an algorithm is been underlined. Differential evolution (DE) algorithm in MATLAB & connection with EPANET for hydraulic calculation. Such a complete methodologies result of investigation compare with absolute optimization by Mixed Integer linear programming (MILP) [29].

## V.CONCLUSION

This paper attempts to present overview of underground utility and summarize some of them as a paradigm found in literature. As per literature this can be concluded that huge work has been done in every aspect of mapping & managing underground utility, still process is going on because of the limitation of Geo-physical Tools, and Advancement in computer science and Application. Optimum pipeline routing of underground utility make's huge saving in project cost then other management issues. As seen in literature lots of research has been done on modelling optimum routing pipeline of under study infrastructure. Shortest path algorithm such as prims, Bell-man ford, Dijkstra, evolutionary

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algorithms such as Differential evaluation, Genetic Algorithm, has been implemented in literature. The Opportunity is open for research work to implement algorithm explored in literature, compare them or fuse them and select one of them as a best tools for selecting optimum route of pipeline infrastructure.

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