Use of GIS and GPS in Construction Management and Infrastructure Projects: A Review

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***Abstract*: *As we know this is the era of technology and information technology. Information technology is taking place in every sector. In past few decades many software and technologies were arrived which are very helpful to analysis, designing, planning and executing of work. Every sector is improving day by day by implementation of information technology. Construction sector is major sector in developing countries. Information technology, robotics and advanced software are taking place in construction industry. These advancements are improving the quality of work, proper execution of work, project management and deep planning of project. A space technology is very helpful to engineering sectors such as Mining, Land explorations, Watershed management, Forecasting and topographical survey. Global Positioning System (GPS) is one of the space technologies which is combination of satellite which is very useful now a days for exploring many fields of science and technology. Geographical Information System (GIS) is a program which is work based on thinking machine like computer, super computer and laptop. GIS is prepared for various functions like to capture, analyze, interpret and store data. Data has been transmitted from navigation systems such as GPS. After management of data at different level it make the information available for users and use. GIS is very helpful in City planning, Zoning, Transportation system planning, Land use, Building modeling, Mapping, Survey, Facility management, Infrastructure planning etc. Now a day use of GIS with building planning and modeling software is trending which is very effective for construction management and infrastructure. For smart city planning in India many GIS application are used which may leads to proper planning of city. The study shows a how GIS and GPS works in construction industry as well as in civil engineering and application of GIS & GPS in Construction management and infrastructure projects were discussed.*

***Keywords*: Construction, GIS, GPS, Infrastructure, Management, Planning**

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I. INTRODUCTION

A. GPS (Global positioning system)

GPS spelled as Global Positioning System. As name itself suggest global means earthly, positioning means exact location and system means arrangement in systematic manner. It gives exact bull eye location on surface of earth with great accuracy. It gives exact location on surface of earth with great accuracy. It's possible simply because of an enormous network of satellites that are created surrounding orbit of earth in space and which transfer information on ground. It had been invented and developed by US military in the year 1960. Further revolution are made and today GPS is part of our daily life.

B. Working of GPS

GPS is works in fraction of time, to capture information about location of any point there are minimum 4 GPS satellites are requires. All satellites relay information about position and the latest capturing time to the GPS receiver at the fixed time interval in form of signal. A signal transmitted is intercepted by receiver devices. These signals are radio signals. Radio signal travels with the speed of light. A time taken by whole process of transmission of signal from GPS satellites to receiving receivers gives distance between GPS and receivers. Once the signal receives to receiver devices from minimum 3 GPS satellites, the receiver then gives points of location by trilateration process. Three sets of GPS satellites gives two-dimensional position such as latitude and longitude on the map and minimum 4 GPS satellites requires to finding three-dimensional position such as latitude, longitude, and altitude. Here Fig. 1 shown below is showing concept of GPS with satellites and receivers.

C. Application of GPS

1) Road Transport
2) Aviation
3) Shipping & Rail Transport
4) Science
5) Security
6) Heavy Vehicle Guidance

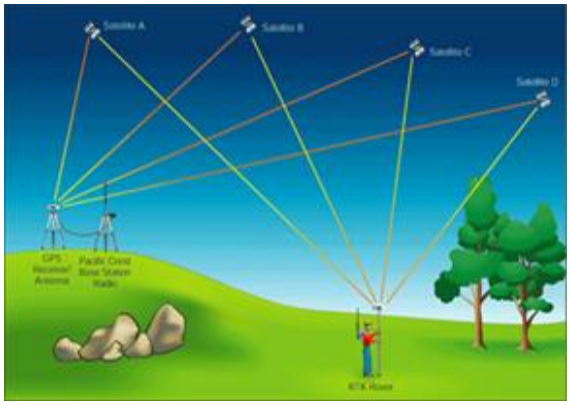

Fig. 1. Working of GPS.

7) Surveying, Mapping and Geophysics
8) Telecommunications
9) Financial Services

D. GIS (Geographical information system)

GIS spelled as Geographical Information System. There is difference between GPS and GIS but it's most common mistaken to consider similar. GIS is program that is prepared for capturing of data, analysis of data, interpretation of data and storing of data. GIS system developed in Canada in the Year 1960. Further it is developed and first desktop version was created in 1986 which enables for computer users. GIS can be used for various purposes like capturing movement of people, land use, city growth and spread of virus on map by interpretation. GIS makes the information more meaningful which are collected from GPS. GIS opens up many gates for almost every sector. Without GIS, GPS would not be worked to its maximum capacity in terms of applications. Here Fig. 2. Shown below is showing working concept of GIS in layer.

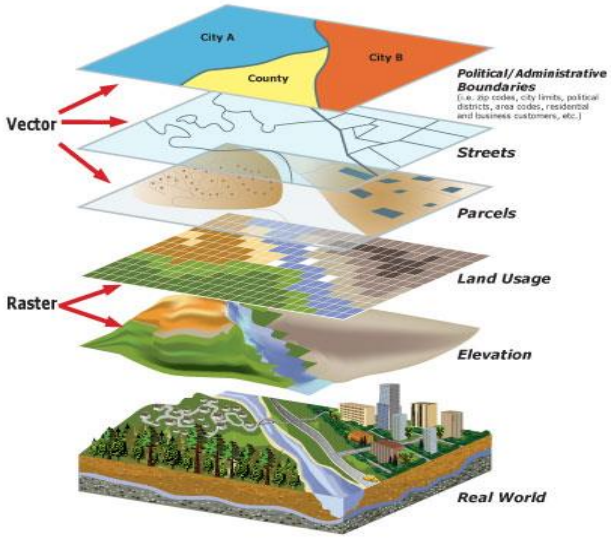

Fig. 2. Concept of GIS.

E. Working of GIS

GIS technology is combination of following process listed Map, Data, Analysis and Apps.

1) Maps: - Maps are best way for showing geographic content in diagrammatic manner. GIS maps can easily share and inbuilt in apps. It can accessible by everyone, everywhere.
2) Data: - GIS can combined many different types of data. Most GIS data are based on geographical information. The data can delivered in form of image, features and base maps. These data can linked with the spreadsheet and tables.
3) Analysis: - Spatial analysis allows users to evaluate, estimate, predict, interpret and give new perspectives, which can helpful to users in decision making.
4) Apps: - Apps are best way for using technologies in hand at anywhere and anytime. Apps gives real time experience of data at right time. It can accessible on your mobile phones, tablets, in web browsers and on desktops. Here Fig. 3 shown below is showing working of GIS with flow line.

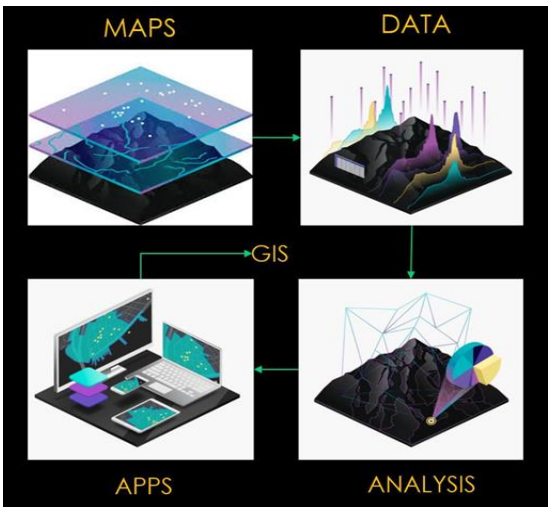

Fig. 3. Working of GIS

F. Application of GIS

1) Infrastructure Management
2) Land Fill Site Assortment
3) Urban Development and Town Planning
4) Site Analysis
5) Watershed Management
6) Better Management at a Reduced Cost
7) Provides All Geographic Information
8) Transportation Planning
9) Environmental Analysis
10) Provide Construction Requirements
11) Data Collection As-Built Surveying
12) Designing
13) CAD Integration
14) Model Application
15) Construction Management
16) 3D Renderings
17) Space Utilization

G. Need of study

As construction sector is growing day by day a new adoption of technology is required to complete the construction work with more good in quality, within budgets, W and as per planning. GIS is one of emerging technology in civil engineering but lack of vast knowledge of this field is in India in construction sector affects the implementation of facilities and project planning within developers, government and engineers.

Why study is required is shown in following points:-

1) For making awareness about technology and how it works to students and researchers.
2) How system is works in Construction management field for planning and implementation.
3) How it can help in infrastructure management and smart city planning.
4) How GIS helpful in scheduling and progress of work.

Until proper use of latest technology is not adopted by new comers engineers and developers then there are more gap will increase with developing world. There are huge knowledge and multi benefits of GIS in construction management and infrastructure development.

H. Objectives of study

Following objectives are major objectives of study:

1) For understanding of GIS concepts in Civil engineering and Infrastructure engineering.
2) For getting awareness of Software related to GIS.
3) For knowing how GIS can implemented to Construction management and Infrastructure management.
4) For making awareness regarding subject and technologies within students, research scholars and professionals.
   For understanding planning of building with GIS application with scheduling.

II. Literature Review

The review paper containing the work done by various authors and the outcomes of various research paper. Paper published in various national and international journals, Ph. D thesis, reports and books have been studied and their major outcomes are listed and mentioned here as below.

Nishant Arora et al. (2012) founded in his study that mobile GIS is very engineers friendly tool for quality managers and surveyors to collect, manage and store data during phase of construction. It can collects information in systematic manner and defined workflow. The stored information can be shared in real time. Mobile GIS can saves time, effort and money as compare to traditional method of quality assurance and quality control. It can reduce construction delay and better tool for decision making. [4]

Samarth Bhandari et al. (2013) explained in his work that integration of project schedule data with GIS system represents a 4 dimensional model. 4 dimensional model can be utilized for the visualization of project progress at different micro work packages and timeline. It can compare the actual progress of work with planned progress of work. The use of GIS in construction management vastly advantageous to the stakeholders, clients, project manager, site engineer and supervisor. The person who probably not knowing about building structure, unable to understand drawing, can easily understand the project status by a 4 dimensional models. It can beneficial in resource planning such as material management, labour management, equipment management and finance management. GIS can be tool for better decision making at various stage of project which save the cost and the time. [7]

S. Anbazhagan et al. (2014) showed in his work that the modern geoinformatics advancement had proved validity in mapping of existing facilities. The facility mapping provide area used by various infrastructure. Their output of work is more beneficial for planners, authorities, stakeholders, management, investors and engineers for any development activities such as construction of new building, expansion of road network, gardens, pipelines for water supply and underground connections, corridors etc. within the campus. [8]

Vihang V. Waghmare et al. (2015) given idea about use of GIS in water network, road planning, taxation etc. which can constructive to town authority for planning of various Town planning scheme and part to be developed in future. It is helpful in taxation of various properties and permission granting within the town. [6]

Nilesh B. Patil et al. (2016) illuminated knowledge about GIS is an emerging technique which can be effectively used for making optimum use of resources in day to day life; as such it is an essential tool for transforming the cities to Smart cities. Smart city have various overwhelming benefits for both, government and the citizens. The awareness and technical know- how about the GIS is important for its invariable use. [5]

A. Chaitanya Kumar et al. (2017) explained in his work that, the integration of Primavera software and GIS gives 4D model which provides the better visualization of the progress of projects. The chaining of drawings and scheduled activities helps in determining construction sequences and also investigating error that occur in project schedules. 4D GIS tool gives real time line. It helpful in decision making, scheduling, infrastructure facilities management and construction work commanding. But this method requires very careful planning of activities and proper linking with actual working drawing. [1]

S. Venkatraman et al. (2017) enlightened idea about applications of GIS and GPS in Civil Engineering. In Surveying, it helps in preventing data communication errors, eliminating the need for multiple flat files in desperate systems. In Construction, using GIS, all the data can be stored in a central location and it gives us the ability to make any necessary changes quickly and easily. In the field of Environmental Affairs like forest fire, one can use the forest fire simulation to predict and control the wildfire. Similarly

in the case of Tsunami, GIS is used for overlaying of satellite images incorporating natural resource data for effective analysis. With the help of GPS, accuracy of existing sewer system maps can be increased. Suitable areas for sewage disposals can be found and this prevents the contamination of fresh water, thereby providing health and safety for the environment. In Integrated Transportation, GIS-GPS plays a vital role in tracking out vehicles. It also helps in providing easier routes. In case of a Disaster, the most appropriate emergency response personnel such as rescue, fire, police, ambulance personnel to allow much quicker and more accurate response efforts and further reduce disaster impacts. [9]

Dadi Sanyasi Naidu et al. (2018) perspective given in his work that GIS and its different application could applicable in development of smart cities. For urban planning, city development plan, building planning, transportation system planning and understanding land use pattern, GIS is very fruitful to engineers. It gives real time maps with options of updating. Major point should kept in mind is GIS need expertise for accurate transmission data within system. [2]

A. Major finding from Literature

A following points are observed from studying the above literature, thesis and books related to subject matter.

1) GIS and GPS applications in civil engineering works.
2) Integration of GPS with CAD drawings.
3) Effective construction project management with help of GIS.
4) Infrastructure facility development plan with GIS.
5) Smart city planning according to nature of town.
6) Better decision making tool during different phase of construction projects.

III. GIS SYSTEM AND TECHONOLOGY

A. The Nature of GIS

For different professionals a meaning of GIS varies as explained below:

1) An urban planner might want to assess the extent of urban growth in their city, and estimation the population growth that some suburbs are witnessing. They might also like to understand why these particular suburban area are growing and others are not;
2) A biologist might be interested in the identify impact of environmental changes to species, forest, environment, degradation of natural resources and biodiversity;
3) A natural hazard analyst might like to identify pattern of cyclone, pattern of rainfall, prediction of flood and respective disaster management steps;
4) A geological engineer might want to identify the best localities for constructing buildings in an earthquake-prone area by looking at rock formation characteristics;
5) A mining engineer could be interested in determining different location for mining, expansion of mining area, determining depth of exploration and new sources of ore;
6) A geoinformatics engineer might want to determine the best sites for the telecommunication tower, networking for high-speed data and;
7) A forest manager might want to enhance timber production using data on soil, creatures living pattern and current tree pattern distribution;
8) A hydrological engineer might want to study a natural resource of water, future locations for various project of water conservations and water standard parameter determination;

   In the examples presented above, all the professionals work with positional data also called spatial data.

B. Defining GIS

This provides us with a functional definition:
A GIS is assemble following four types of georeferenced data:

1) Data capture and preparation
2) Data management, including storage and maintenance
3) Data manipulation and analysis
4) Data presentation

C. Spatial data

An indirect difference exists between the terms data and information. By data, we gives representations that can be activated upon by means of a computer. Sometimes spatial data is refer as a georeferenced data. Data can be understand by human and act upon information hidden in data. Spatial data combines of positional, attribute, temporal, lineage, completeness and logical accuracy. It 'knows' about spatial reference systems, and supports all kinds of analyses that are inherently geographic in nature, such as distance and area computations and spatial interpolation. The phenomena for which we want to store representations in a spatial database may have point, line, and area or image characteristics. Different storage techniques exist for each of these kinds of spatial data.

D. The real World and Representation of it

Major use of GIS tool is decision making during projects. Specifically, when we want to know about best location for a new facility, slum development, and solid waste disposal site. While using GIS we need to express some part of actual world as it is, as it was, or as we think it will be in future. Sometimes we face of restriction while some part of actual world because it cannot represented completely. Main thing about computer programme is all the data can generate for us will be based upon information which we provide to system. If we take right steps while collect, organize and frame data from actual world means if we have done our job properly then computer represent some part of real world and allow us to transmission of data. Fig. 4. Shown here explains the real world representation of data.

E. Models

Model gives representation of real world and help us answer ‘what if’ questions. In model we can test what happens under various conditions. We can enter updated

data or change the data of model, simultaneously we can investigate the effect of changes. Models as representations come in many different way. The most suitable model in GIS environment is digital map. Digital model are more advantageous compare to paper maps because it can store in softcopy, easily editable more flexible. This improve our understanding of world.

F. Representation of real world data

As discussed above, maps are the best models of actual world. The major disadvantage of traditional paper map is that it is available in two dimensional and with limitation of some fixed scale. Map scale is major aspect of mapping. The smaller the scale, the less information, data and detail on a map can show. Hence, the proper selection of scale map is one of the most important step in map design. Map is graphical representation of certain level of details. Today advancement is taken place and digital maps are taking place of paper map by special database. Modern tools and software helps in mapping at micro level. Fig. 4. Shown below explains the real world representation of data.

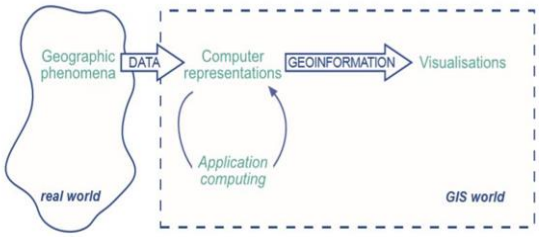

Fig. 4. Representation of real-world data

G. Raster data and vector data

There are main two common data format used to store geospatial data are Raster and Vector. Raster data use a matrix pattern of square areas to define where particular features are located. These squares also called pixels, cells, and grinds. Typically these matrix are of uniform size and their size determines the detail sustained in dataset. Raster data represent square areas, they describe interior rather than boundaries. Vector data use horizontal coordinates X and Vertical coordinates as Y to define the locations of points, lines and areas. Vector data defines center and edges of features. Vector data are good at capturing and storing details such as fire hydrants, trail, etc. while raster data perfect for capturing storing, and analyzing data such as elevation, temperature, soil type, Water level, etc.

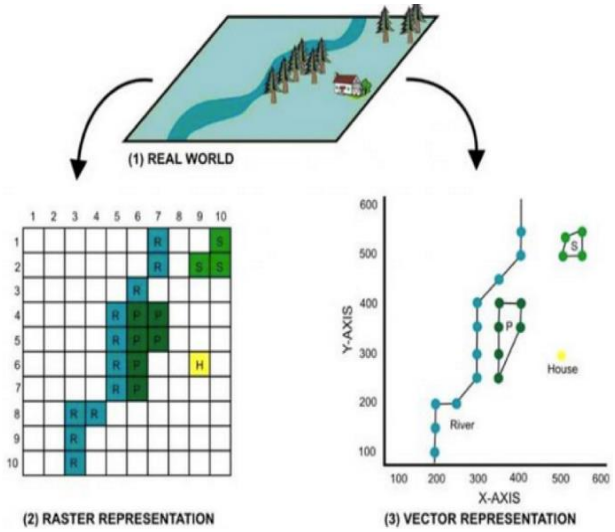

Fig. 5. Representation of real world and data type

IV. GIS IN CIVIL ENGINEERING

Civil engineering is very vast field of engineering about developing and sustaining infrastructure. Civil engineers, project managers, team of labour and supervisors are deals with tremendous amount of data from different sources. GIS allows civil engineers for creating, managing, analyzing and visualizing the data corresponding to developing facility. Data gives broader picture of whole project to construction team including stakeholders which creates better team work by means of communication at foundation level. It also helps private vehicle company and governments work together to develop strategies for sustainable development. GIS supports many data formats which allows civil engineers to provide data to various consultancies in the required format. GIS is very helpful tool for managing project with real time data and resources during life cycle. It can implemented at various stage of project life cycle as explained below.

A. GIS in construction management and infrastructure life cycle

1) *Planning:* - It contains high-level planning functions for site location including environmental impact mitigation, economic analysis, regulatory permitting, alternative siting analysis, routing utilities, what-if scenarios, visualization of concept options, data overlay, modeling, and benefit/cost alternatives analysis.
2) *Data Collection:* - GIS helps to collect precise site data which can be used for pre analysis, design, and determining field survey, topography, types of soil, subsurface geology, traffic volume, and sensitive zone of environment, hydrology and other essential design data.
3) *Environmental Analysis:* - It provide the momentum and management for building new infrastructure facility such as machine control, earth movement, volume and quantity, estimation and payment, material tracking, logistic, scheduling and traffic management.
4) *Design:* - It allows user to creation of construction data

for new civil works such as grading, contouring, cross section, design calculations, load distribution pattern and equipment staging. This allows engineers to understand new design possibilities

5) *Construction:* - GIS tools establish the momentum and management for building new infrastructure facility such as machine control, earth movement, volume and quantity, estimation and payment, material tracking, logistic, scheduling and traffic management.
6) *Data Collection:* - Precise site data is very essential for minimizing error and obstructions. Surveying GIS tools very beneficial for collect and store precise site data which eliminating costly of data conversion and delay.
7) *Operations/Maintenance:* - It models infrastructure networks and build connections with other type of data such as vector images and raster images and CAD drawings. Spatial tools allows users to visualize planned work, actual work, remaining work, ongoing activities, analyzing maintenance problems and historic information. Fig. 6. Shown below is showing implementation of GIS at different level lifecycle of project in civil engineering project.

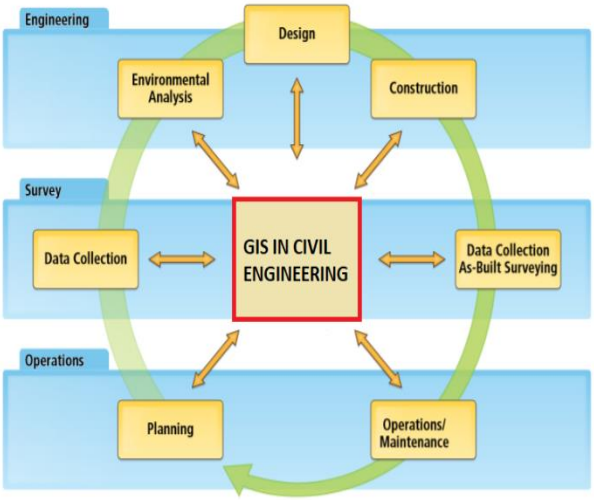

Fig. 6. GIS in Civil Engineering

B. *Workflow of GIS*

In civil engineering work as transfer of information beginning with the collection of project management data with a server based single database and multiple access. It enables user to collect field data, store data, analysis data, reporting and mapping from analysis, design from available reliable data and display to whole project team with help of internet and portals. Fig. 7. Shown below is showing workflow in civil engineering project.

Fig. 7. Workflow of GIS

GIS enhances workflows in

1) Project management
2) Analysis and design
3) Logistics
4) GIS provides
5) Data accuracy
6) Data sharing
7) Analysis capability
8) Modeling

C. *GIS in Site Analysis*

GIS quickly analysis many types of information and images for site analysis. It gives systematic representation that customers can relate easily to a map. In GIS various base map gives idea about zoning, land use pattern, topography, developed zone, under developed area and soil map. It shows meaningful representation of population growth, commercial activity and traffic flow pattern. Which is very beneficial for decision of site selection opportunity and constraint. Urban planners use GIS for tracking growth of city. It gives wider picture of very suitable site is available for particular type of work. A GIS solution save lots of time of planner and engineers and it save indirect cost of various survey.

D. *Critical Infrastructure Protection*

For protection of critical infrastructure such as historical buildings, landmarks, bridges, railways, highways and other critical infrastructure is responsibility of authority. GIS technology provides information regarding highest flood level, hydrological data, contour, traffic at real time and allow new changes. Fig. 8. Shown below is showing workflow in civil engineering project.

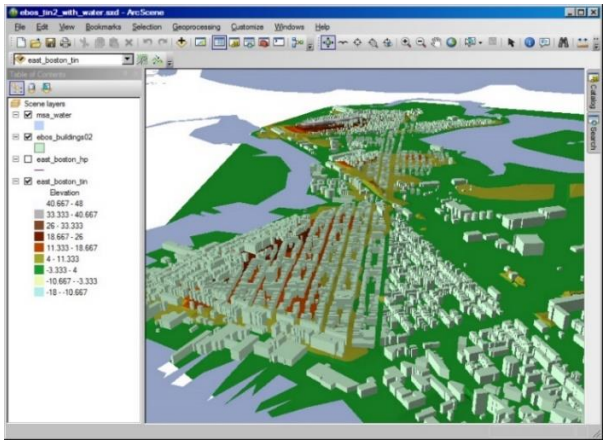

Fig. 8. GIS in Infrastructure Planning

E. GIS in Construction Management

Proper construction management is very important factor for success of any project. From initial stage to closer stage there are lots of revision made for better execution, operation and maintenance of project. GIS can helpful in manage all project data and information in form of various models, maps and spreadsheets. It is very beneficial while preparing estimates, determination of land value, survey data, soil and geological data and environmental impact analysis. GIS is help full in tracking progress of work, material planning, job layout preparation, logical sequencing of activity, financial planning, inflow outflow of cash, tracking challenges and constraints, equipment planning, mine chart preparation and risk management.

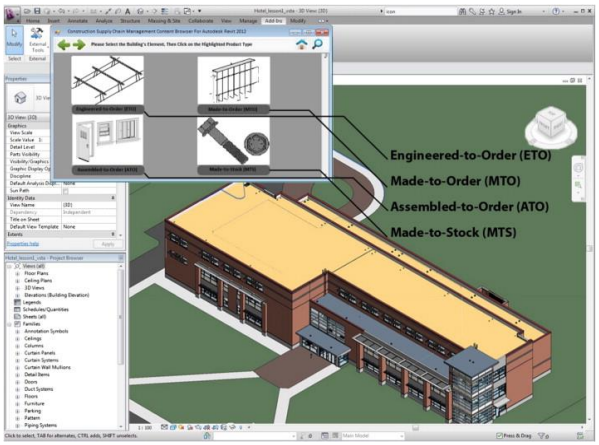

Fig. 9. GIS with BIM for project management

V. CASE STUDY

A. Case study-1: 4D applications of GIS in construction management

4D GIS modelling means combination of 2D, 3D and time amendment data. 4D tool represent graphical form of overall construction process, constraints related to project progress, work breakdown structure, comparison of actual completed work and planned work. It is helpful in reducing conflict, analyzing of constrains and generate schedule helps the construction manager. Simulation of construction progress in 3D view with CPM schedule help the construction team for better decision making. Fig. 10 explains about the linking of project schedule with 3D model in GIS tool.

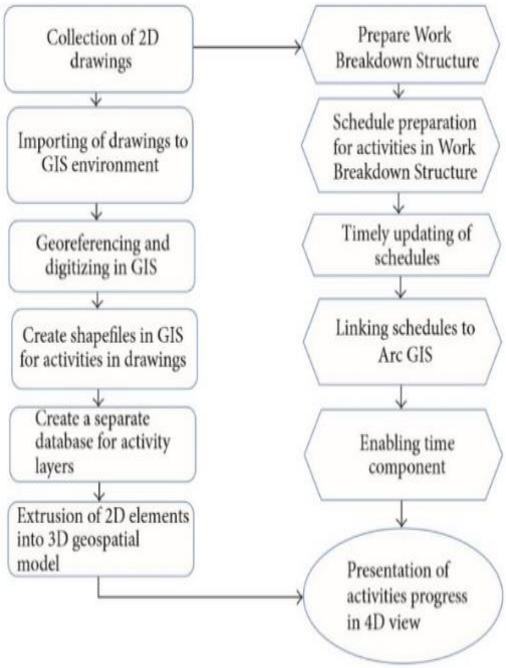

Fig. 10. GIS Implementation Methodology

B. Methodology of work:-

1) Collection of 2D Drawings.
2) Create Work Breakdown Structure.
3) Importing of Drawings to GIS
4) Geo-referencing and Digitizing in GIS Software
5) Schedule Preparation for Activities in Work Breakdown Structure.
6) Timely Updating of Schedules.
7) Creation Database for Activity Layers.
8) Linking of Schedules.
9) Creation of 3D Geospatial Model.
10) Preparation of Final 4D Output.

Fig. 11 shown below is defining concept of 3D model plus CPM schedule for project progress in real time.

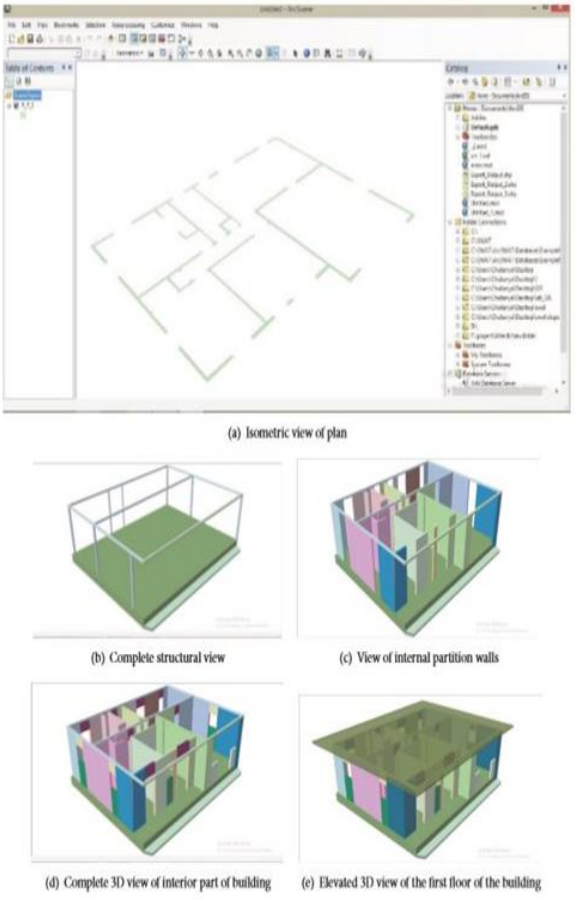

Fig. 11. Linking of GIS with WBS & Schedule

C. Case study-2: Applications of GIS in construction management

As earlier discussed in above case study, 4D model helps project manager, engineers and an architect for brief understanding of constructed structure. It helps manager for planning of extra resources if project is running behind the schedule. Here in Fig. 12 shown below is showing delay during the execution work with help of different colour use. GIS tool help project manager for purchasing right material at right time and in right quantity. For proper arrangement of finance of project is essential to fulfill demand. 3D model give idea to stakeholder or owner for financial planning at different level and breakdown of project. Main thing keep in mind is that GIS tool is as much as deep data given to system more clear picture of project will come out.

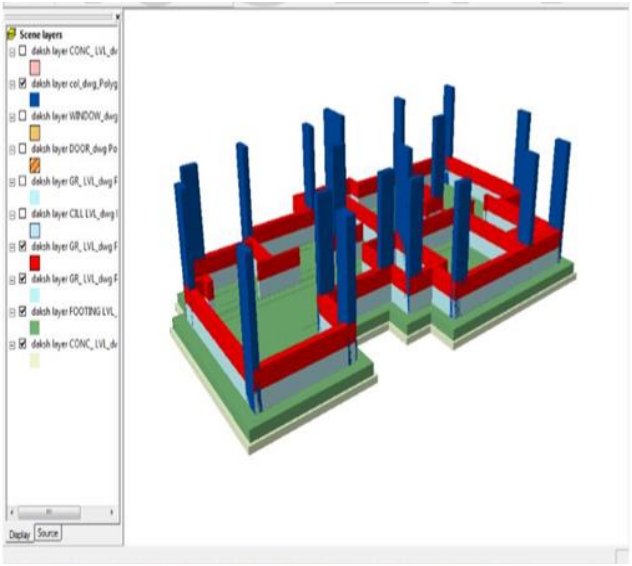

Fig. 12. Comparison of Actual work and Progress Work

D. CASE STUDY-3: Singapore is moving to 3D maps for urban planning and infrastructure planning

Singapore has limited land, but its skyline is constantly changing. The city's urban planning agency has found that 2D maps and physical models are not able to keep up with such a complex environment so they decide to plan city with 3D maps which gives more meaningful picture for planning and real time data of city for understanding better growth of city. Fig 13. Shown below gives visualisation of 3D view of city. It is recent development in GIS filed.

Fig. 13. Urban Planning in 3D (SINGAPUR)

VI. CONCLUSION

The following conclusion based on literature review and case studies.

1) GIS is one of best tool for future of construction and infrastructure planning because it creates virtual world in 3D and as well as in 4D.
2) It help professionals to relate project with schedule, progress and Planning.

3) GIS made users more comfortable for their project because of its multi feature such as spatial analysis, map model, 3D Visualization and focus on decision making.
4) GIS gives idea about existing facilities of city or area and we can develop for future.
5) GIS can be helpful to create job layout, Mine chart, Materials and resource plan.
6) Highly expertise persons and professionals are requires for proper way of work with GIS.

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