IMPORTANCE OF ENTERPRISE GIS IN CONSTRUCTION INDUSTRY

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Introduction

Construction is one of the major industries that deal directly with geography/nature for its productivity. Though the type of constructions are varying like Buildings, Factories, Roadways, Railways, Metros, Ports, Power transmission, Solar energy, Water supply, Effluent treatment, Hydro & Nuclear Power generation, etc. are being constructed on, above or below the earth. The unplanned and haphazard production of infrastructure/building construction causes imbalanced and unfriendly relation to environment and this creates a big threat to peace, prosperity, health and quality of human-environment interactive arena.

The subject Geography is concerned with the study of the earth’s surface features; their association with one another and derives meaningful spatial and regional patterns. It also studies the factors and processes, which change these features; their mutual relationships; and finally studies the implications of above changes for human beings and their activities. GIS is an acronym of Geographic Information System and it is one of the technologies that have been arrived from the discipline of geography. It is a multidisciplinary technology that integrates spatial and aspatial information from various other technologies like Global Navigation Satellite System (GNSS), Database, Survey, Satellite and Aerial Remote sensing etc.,

Role of the GIS i.e. systematic integration and retrieval of spatial and aspatial information, can be effectively extended when the users are using this technology in enterprises level as desktop GIS poses some inherent limitations in integrating other enterprise software, multiuser storing and retrieval of information etc. The key to maximizing the benefits of Geography / GIS technology is to deploy it in enterprise-wide.

In this perspective, Geospatial Technology section of L&T Construction, exploring the benefits of GIS at enterprises level through various construction industry related case studies. ESRI ArcGIS server, on .Net and JavaScript platforms using Personal GeoDatabase and shapfiles are used for these case studies and inferences of this application research are discussed in this paper. As work sequence of construction industry can be broadly grouped into three categories i.e. (i) Pre-construction, (ii) During construction and (iii) Post construction, applications of Enterprise level GIS are discussed in these three broad work sequences.

2.0 PRE CONSTRUCTION

In order to cope with an omnipotent and omnipresent nature, in the early stages of civilized life all the construction activities like dwellings are executed in geographically comfortable zones like along Coastal plains, River banks, etc. Most of the great cities of the world are developed in this type of geographically comfortable zones. High density of population at coastal plains and river banks, location of Metropolitan cities in India (Chennai, Mumbai & Kolkata) and around the world (New York, London, Singapore, etc.,) are stands as a typical evident for this. Thus Geography of a place played a vital role in determining the location for urban/construction development (Pari, 2006).

Augmenting lifestyle of the people, increased land cost and reduced availability of urban lands created necessity for infrastructure/construction developments at urban sprawl areas. Because of this, contractors, who did construction at geographically Gratified zones are now forced to do design and construction at geographically uncomfortable zones like marshy/swampy lands, low lying lands, rocky/stony wastelands etc. Construction activities at Wet lands (Chennai), Mud flats (Gulf of Kutch & Khambhat), Backwater areas (Mumbai), Coral Islands (Andaman & Lakshadweep), Dry deserts (Rajasthan), Cold deserts
(Himalayan ranges), Salt desert (Rann of Kutch), Shallow Sea (Ports & harbours), Deep Sea (Pipelines & data cables) are typical examples (Fig 1).

Fig 1. Construction activity at various challenging Geographical area

Traditional construction engineering design at this type of geographical areas is one of major cause where even the reputed civil contractors are losing their design credentials. Conventional engineering design without considering challenging geography creates adverse impact to human wellbeing. Casualties and huge economic loss due to flood, hurricane and other natural disasters are the major concern for most of the developed and developing countries. Design and development of construction activity by considering the existing natural environment/geography is the need of the hour and hence this is the right time to move from design to GeoDesign. GeoDesign integrates geographic science with engineering design, resulting in a systematic methodology for design engineering and decision making. This benefits both people and nature and provides more synergistic coexistence. Engineering design considering geography of the existing project site not only will reduce this adverse impact but also concede for a sustainable/Green certified infrastructure/construction development.

An effective GeoDesign requires enormous geographic information about on, below, above, and around the project site. GeoSpatial techniques like Aerial and Satellite Remote Sensing, Global Navigation
Satellite System, Photogrammetry, Digital Image Processing, Digital Cartography, Surveying etc., are playing a vital role in collecting spatial information of any geography. This spatial information along with project specific information can be used in various stages of the construction projects starting from tendering, conceptual design to monitoring and management of the completed projects.

2.1 GeoDatabank

Establishing connection between Geography and Engineering design require provision to super impose engineering design drawing on top of the geographic data. In this context, spatial information for most of the major cities in India are being collected and stored in a dedicated centralized data storage unit called “GeoDatabank”. This GeoDatabank consists Satellite Images, Topo sheets, Thematic Maps and database of National Remote Sensing Agency (NRSA), Survey of India (SOI), Geological Survey of India (GSI), National Bureau of Soil Survey and Land use Planning (NBSS & LUP), Indian Metrological Department (IMD), National Informatics Center (NIC), Census of India etc.,.

By understanding the significance of maps, most of the Government and private organizations are delivering their spatial data in hard/soft copy map formats. These maps are being prepared with multiplicity of standards like Scale, Projection, Data collection method, Content, Delivery formats and Quality etc., (Pari, 2004). Pros and cons of these spatial maps with respect their usage in construction industry was studied and brought into common co-ordinate system. Similarly spatial dimension with common co-ordinate system was assigned for some of data that are prepared in non-map formats (Excel, PDF, documents, etc.)

2.2 Web Based “Geographic Information for GeoDesign”

As a part of developing Enterprise Geographic Information System, a Web application entitled “Geographic Information for GeoDesign” is being developed to supply the required Geographic Information to the design engineers (Fig 2). This web application enables the design engineer to super impose their design data on top of the project specific Geographic information and GeoDatabank.
Conversion of design drawings from local coordinate system to Global co-ordinate system is the fundamental step for project specific GIS data preparation. By understanding the total area of the project site, scope of the project, this conversion methodology varies from using available Web Map Services based co-ordinate system to execution of single/dual/multi frequency GPS/GNSS based survey. Some geographical analyses (Project boundary validation, Average Mean Sea Level (AMSL), Flood flow direction, Catchment area delineation, Elevation, DEM, Slope, Aspect, Earth work quantity estimation, etc.) with respect to the proposed project site are being prepared and the results of the same are made available in the project specific GeoDatabase. Apart from this users can bring Web Map Services (WMS) like Google map, Bing map and ESRI online services as a back drop of their proposed project site.

With the help of web application i.e. “Geographic Information for GeoDesign” design engineers can superimpose their design data on top of the (i) Project Specific Geographical data (ii) Spatial data from GeoDatabank (iii) Spatial data from Web Map Services, and check their design compliance with the existing nature/geography (Fig 3). Menus and Tools available in this Web Application provides scopes to the users to Digitize new features, measure the Geometries of the features and to do some basic Geo-processing action on top of the features. Drawn features can be exported to CAD compatible formats/excel for their further usage during GeoDesign.
3.0 DURING CONSTRUCTION

Project progress monitoring and control is one of the most important tasks of construction project management. Progress monitoring seeks to assess how well the project adheres to the planned schedule over a period of time. Every team member of the project should know, how the project is progressing, where they are currently in comparison to the initially set plans, whether deadlines are met, budgets are safely measured and followed. Timely and precise communication of these information to owners, consultants, engineers, contractors, and higher management is a significant challenge for the project manager.

The current practice of project control is entirely dependent on cost, schedule, and quality reports and personnel performance reviews (Sanvido and Paulson, 1992). These factors are represented in construction monitoring schedule in variety of ways. The most common type of construction schedule includes Gantt chart, activity on the arrow, precedence network and line of balance. Among this Bar/Gantt charts are extremely useful, visual and graphical medium in construction scheduling.

However, these tools are not communicating the spatial aspect of the project progress. They have provision to convey what is to be built when. Even the commercially available project scheduling tools such as Primavera and Microsoft Project are not providing spatial dimension for construction progress monitoring (Bansal and Pal, 2011). Non-spatial schedules only convey what is built ‘when’, whereas schedule through GIS conveys what is being built ‘when and where’ (Bansal and Pal, 2008).
Researchers reported in GIS based construction planning are limited, as efforts in the direction to use GIS in construction industry have not embraced the issue associated with its implementation in industry practice (Bansal, 2007). The recent liberalized policies opened up the wide market for projects like Special Economic zones (SEZ), integrated townships, satellite towns, expansion / establishment of Airports, Roadways, Railways, Ports and harbours. As these projects are covering larger geographical area, consideration of spatial dimension in progress monitoring is becoming mandate.

In large scale construction projects project managers use to receive more spatial and non-spatial data and they have to take major decisions based on the careful investigation and analysis of this large amount of data. This makes monitoring system to have a structured spatial database based approach and reduces the task of maintaining paper maps/CAD drawings.

In pre-cast building construction projects, structural elements are pre-fabricated in the manufacturing plant and transported to the job site for installation. The punctual project completion relies on connectivity among the manufacturing unit, transportation and execution site. In these cases though extend of project area is insignificant, their spatial connectivity like manufacturing, storage and execution units locations are spatially distributed. Hence geographic intelligence places a vital role in project schedule monitoring.

Construction projects like, Roads, Railways, Power transmission and various Pipe lines are covering several kilometers of linear lengths. In these type of projects progress monitoring without considering geographical/spatial dimension may not reflect the real hindrance that are caused due to the changing Landuse/Landcover features like River crossings, Wetlands, Forest covers etc., In these type of projects Project manager may not have chance to make frequent/complete site visit at a time. Especially in Railways construction projects, execution of site inspection at problematic areas by project manager is a challenging
task because of the inaccessibility issues. Even communicating site problems to higher level managers are also very difficult if the project progress is represented without spatial dimension.

In these types of projects GIS based Project progress monitoring is the only solution as it requires careful monitoring, effective progress communication, coordination, and management for their efficient project delivery. GIS based project monitoring system (Fig 4) enables the project manager to develop progress reports in a more consistent and accurate manner through integrating digital satellite images with Engineering design drawings. Visualizing project progress with assets and the surrounding environment helps project manager to prioritize his work and make good decisions.

![Diagram of Enterprise Integration Platform](source: www.esri.com)

**Fig 5. Architecture of Enterprise GIS**

Apart from handling construction progress monitoring, architecture (Fig 5) of the enterprise level GIS supports

- Linking GIS with other enterprise systems like ERP, CRM, and SCADA etc.
- Control on sharing information among various levels of users through multiple access rights
- Purchasing process, store inventory, maintaining documents related to Work order permits and inspections, Vehicle and Equipment tracking.
- Field engineers, surveyors and managers to conveniently use the mapping interface to browse critical locations and to discuss work before, during and after execution.
- Communicating sensible information to high level management, design & execution teams through multimedia like movies, photos, etc.,
- Online access of multiple users without any need of taking print outs
- Taking multiple hardcopy copy printouts (if necessary), as all the progress information are being handled in digital formats.

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4.0 POST CONSTRUCTION

Utility organizations like water, sewer, electrical, etc., are spending large amount of money and time on monitoring and maintaining of their infrastructures. Economic and efficient management of utility systems require precise information on as built data. As-built drawings are the final set of drawings produced at the completion of a construction project. They include all the changes that have been made to the original design drawings. These as built drawings provide information about the locations of hidden components like wiring, plumbing and other services for their easier repairs and maintenance. Traditionally as built drawings are being prepared with Computer Aided Design (CAD) software along with handwritten notes and sketches if required.

But CAD system lacks ability to provide the information in database. The location based database technology of GIS has great extent of ability to effectively manage the utility assets. It also provides the utility organizations with endless amounts of information about their assets, whether it is spatial or non-spatial. Utility organizations not only use GIS for the spatially referenced data, but also for any information that could be used to carry out further analysis, if needed. A GIS allows utility operators and managers to not only determine where their assets are located but also analyze attributes about those assets (Hughes, 2006).

Preparation of as built information, while doing construction is easier and cost effective, than preparation of the same in later stage by a different contractor. The method, extent, accuracy and correctness of the as built data are critical considerations for the development of the final integrated enterprise GeoDatabase. With this understanding nowadays, most of the clients of utility organizations demands as built information in GeoDatabase formats. Moreover they include this demand as part of their contract itself.

![Water utility Information System – L&T Construction](image)

Fig 6. Enterprise GIS for water utility system
Enterprise GIS based water utility information system (Fig 6) is being prepared for one of our water utility client. As a case study a small portion of water utility information was converted in to ESRI ArcGIS GeoDatabase and an information system is being developed. This information system has basic tools like zooming tools, identifying tools, measuring tools and attributes querying tools with which client at the user end can browse the required data in quick and user friendly manner. They can also access WMS services like Google map, Bing map etc., as a back drop of their utility network data. This allows the users to understand spatial relationship of their utility data with the existing geographic features. They can also export the required Area of Interest as jpg/tiff file format it required for multiple distribution/printouts. Further works on enriching this GIS based Web information system with lots of tools like address locator, spatial and non-spatial query builder, etc., are ongoing.

Collection of published literatures reveals that many of the water utility organizations are preparing similar kind of GIS based web applications and incorporating their work order and billing systems into that, which saves even more time and resources. These organizations are able to use one GIS based dashboard system to effectively manage all their utilities. Apart from this, Enterprise GIS offers utility organization, the convenience of viewing and analyzing their utility network over the web and generating condensed yet comprehensive statistical reports pertaining to the utility data (Pravin, 2011).

5.0 DISCUSSION AND CONCLUSION

As discussed, in construction industry types of construction are varying from one to another. However, requirement of Geographical information for all the types of construction are same and hence geographic information collected for one project site can be referred for other project types also. Requirement of same spatial information during various stages of one or multiple construction projects creates necessity for GIS at enterprises level, which offers storing and accessing of all the Geographic information from a centralized and structured GeoDatabase.

Activities of the construction business can be broadly grouped into three categories i.e. (i) Contracts that includes Marketing, Estimation, Bidding & Contracting, etc., (ii) Design that encompasses Schematic, Conceptual and Detailed designing etc.), (iii) Execution that covers Planning and Management Cost, Time, Quality, Safety, Materials & Logistics etc. Though the types of activities are varying in contracts, design and execution all are interlinked with one another (Fig 7). Since all the type of constructions as happening on, below/above the earth all these types of construction activities requires spatial/geographic information in various stages of their work schedule.
Fig 7. Work Sequence of Construction Business

Location, administrative boundary, existing landuse, soil characteristics, geology & geomorphology, climatic & terrain conditions of in and around the site, required built-up area, bill of quantity, manpower, rate and availability of construction materials at nearby locations are some of the spatial & aspatial information that require at the tendering/bidding stage of a construction projects. Once the project is awarded, apart from the detailed/precise information of above components topography, geotechnical characteristics, average mean sea level, rainfall of various return periods, ground water and high flood levels, surface water flow directions, catchment area, availability of nearby river/canal, power and service stations, are some of the additional information that are essential for effective designs. During the execution stage in addition to the above information, location information of nearby hospitals, banks, market places, labour colonies, travels and transport agencies are required.

These are various geographic information about in and around the proposed project site. Though the required amount and accuracies of these information are varying with respect to the stage of construction business process, the need of these information are unavoidable. When the same information is repeatedly referred by different people at different locations during different stages of construction business, augments the need of GIS in enterprise level. Documents and information that are compiled after the completion of project can be reused as a reference for bidding new projects, if location of the same falls near to the completed projects.

An effective Enterprise GIS acts as a blend of Geographic understanding, Management practices, engineering and technology and it reduces unwanted duplication of spatial information among various stages of design, execution and contract. Results of the case studies revealed that GIS in enterprise level is playing a vital role in construction business for its effective GeoDesign, work progress monitoring and maintenance/management of constructed features. However, implementation difficulties of this technology in Indian conditions of existing spatial policies and accuracy standards are being explored with real time projects.
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