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GEOMATICS ALLIED WITH BUILDINGS

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Abstract— **We are all aware of the various Building Life Cycle stages. Before one can even start talking about the sustainability or smartness of a building, we should understand the different stages of a building, which are as follows:**

1. **Raw material extraction**
2. **Manufacturing**
3. **Construction**
4. **In use - Operation and Maintenance**
5. **Demolition**
6. **Disposal, Re-use, Recycle**

Each of the mentioned stages is intricately linked to the use of natural resources for energy consumption, forming the foundation for examining sustainable buildings. This paper will mainly focus briefly on how a 'GIS' can be linked to all or most of these steps. The scope of GIS is expanding every day and will also have a significant impact on architecture. When we think of "Smart Cities" or "Smart Buildings", the first thing that comes to mind is Automation or the Internet of Things, which is an integral part of the fourth phase i.e., Operation/In use. However, the reality is that a Smart Building is developed early in its Life Cycle of a Building. This paper will help people understand and grasp "how modern technologies (GIS and remote sensing) can be useful in the raw material extraction process" and "how GIS can be integrated into the process of Production, Construction, Operation and Maintenance". The study also aims to investigate the domain of demolition and the subsequent processes of disposal, reuse, and recycling, utilizing Geographic Information Systems (GIS). If you find this topic intriguing and captivating, I encourage you to continue reading. I genuinely hope that this paper proves to be both informative and engaging for you.

Keywords— **Building Life Cycle, GIS - Geographic Information System, Remote Sensing, Smart Cities, Smart Buildings, Automation, IoT - Internet of Things.**

I. INTRODUCTION: BUILDING LIFE CYCLE

As the term suggests, BLC is a cycle of different stages of a building, starting right from the extraction of raw material to the demolition and reuse of the building debris. In other words, overlooking the building's entire life including the initial stage of design as well as the final stage of waste management can be referred to as Building Life Cycle.

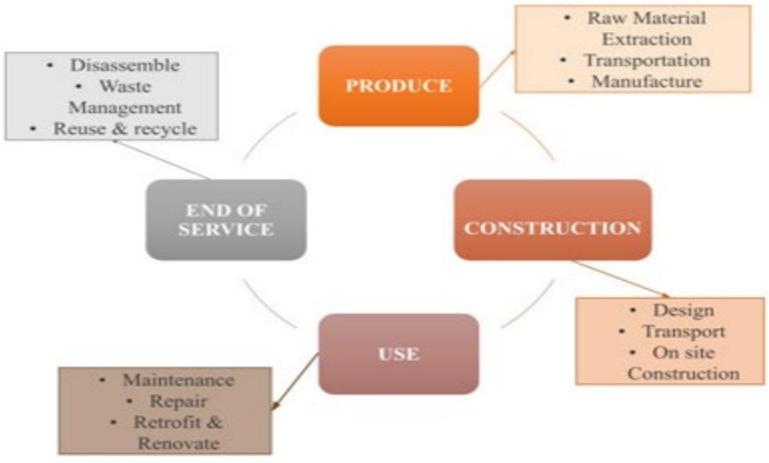

Fig 1: Building Life Cycle

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A. Produce

This is the very beginning stage of the construction of any structure. Various steps are involved in the process of Produce such as listed below.

a. Raw Material Extraction

Before any construction is planned, one of the first things that come to our mind is the material to be used. This is the stage where the required Raw Materials are extracted from their natural existence. It includes iron ore, limestone, bauxite, copper, timber, and petroleum, amongst others, which are naturally present on the earth. Large quantities of energy sources are consumed during this stage.

b. Transport

The extracted raw materials are then transported to the manufacturing sites of secondary forms of building materials.

c. Manufacture

Materials such as steel, cement, aluminium and plastic are manufactured at this stage using natural resources, that are to be used in a better way as forms of construction materials. These materials are further processed to customize the need of the design. A huge amount of Carbon emission occurs during this stage and it affects our environment and climate in the long and short run.

B. Construct

The stage where a structure is executed in reality. Simultaneously, the stage of production takes place as and when necessary.

a. Design

Although designing is done even before deciding on the materials to be used, it is considered under the construction stage that comes after materials are available. During this stage, designs can be prepared manually or using the software. Today's generation prefers using the latest technology to work and deliver the requirements. The designing stage consists of Site Selection, Site Analysis, Planning on a 2D level, 2D drawings, 3D views/models, Simulation, and BIM. Most of these steps consist of a huge dependency on software and technologies.

b. On-Site Construction

It is said that construction is directly proportional to the development of any region. Construction includes the building of any infrastructure large or small. It can be vast industries or small houses. It can be airports or underground metro stations. It can be flyovers, bridges or underwater resorts. This is one of the major steps in Building Life Cycle. Thankfully due to the latest technologies, the construction on-site is no more one of the longest stages.

C. Use

Talking about all the stages, this can be considered one of the longest stages, as a majority of the life of a building is spent under this category. Several events as discussed below, take place during this stage.

a. Maintenance

While the building is in use, after a certain period it starts deteriorating functionally as well as physically. To keep the building liveable, maintenance of all the services along with the structure becomes a necessity. A large quantity of waste is generated during maintenance that has to be managed.

b. Repair

Repair and maintenance go hand in hand. They are performed to increase the life of the structures. As per my understanding, the only hairline difference between maintenance and repair is that the first is prevention and the latter is the cure.

c. Retrofit and Renovate

Retrofitting is when we add any additional features or elements that were not present during the construction. It may be structural or aesthetical. Whereas, Renovation is nothing but repairing itself on a larger scale. Both these procedures are applied majorly when the building has lived more than half of its lifespan. It not only increases life but also gives a new look to the building.

D. End of Service –

This particular stage states the dying of a structure and thus involves steps that tend towards the ending of an entire lifecycle of the building. The following measures are taken during this stage.

a. Disassemble or Demolish

When the building is no longer strong enough to offer its use, the entire structure is either demolished or disassembled so that a new structure can be constructed at its location, having the same or different functions. During this stage, a humongous amount of waste and disassembled parts are generated. Massive production of dust and gasses fill the neighbouring, which leads to the next step of the stage.

b. Waste Management

All wastes generated during the above step have to be taken care of whether they are hazardous or non-hazardous. A few common wastes generated are bricks, steel, concrete, wood, plastic etc. There are various methods by which wastes can be disposed of, for example, landfill, incineration, landscaping works, transfer to recycling centre etc.

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c. Reuse and Recycle
Once a building is disassembled, many components can be used after a little servicing. Such components are set for their Reuse. Another category of things is the ones that can be recycled before being used and thus sent to the Recycling unit.

II. INTRODUCTION: GEOMATICS

Geomatics is defined as "a discipline concerned with the collection, distribution, storage, analysis, processing, and presentation of geographic data or geographic information". (International Organization for Standardization)
Geomatics or Geo-Informatics can be said to have 3 sub-topics under it, that are interconnected while working with GIS.

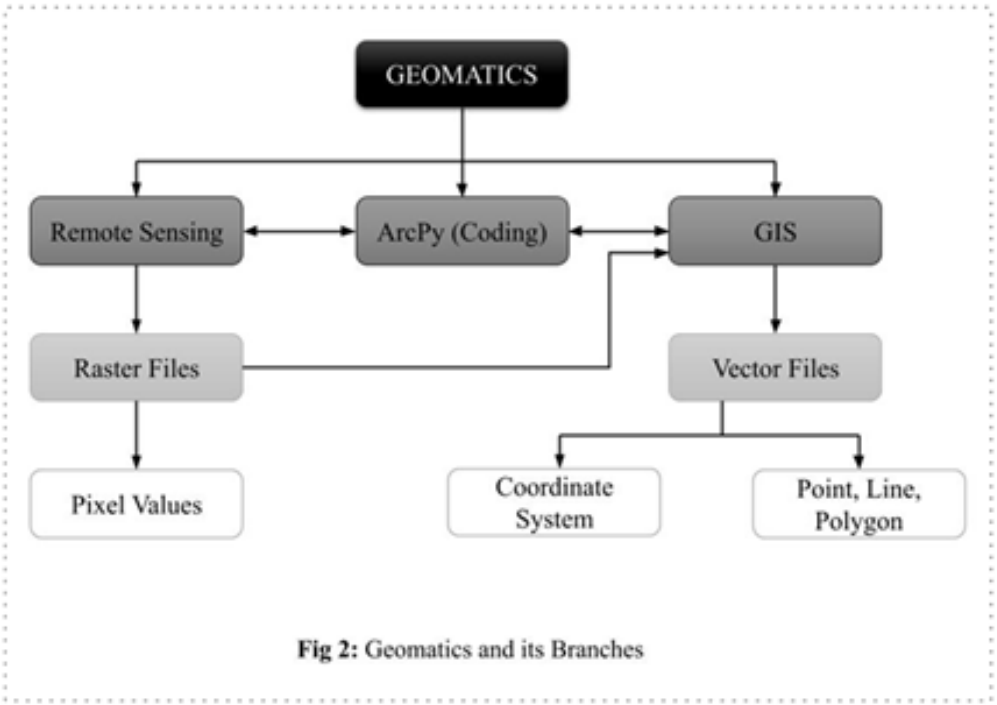

Fig 2: Geomatics and its Branches

A. Remote Sensing
"Remote sensing is the process of detecting and monitoring the physical characteristics of an area by measuring its reflected and emitted radiation at a distance (typically from satellite or aircraft). Special cameras collect remotely sensed images, which help researchers sense things about the Earth". (USGS)
It uses satellite images that contain pixel values based on the reflectance, radiations and temperature, to do the analysis.

B. Geographic Information System
"A geographic information system (GIS) is a system that creates, manages, analyzes, and maps all types of data. GIS connects data to a map, integrating location data (where things are) with all types of descriptive information (what things are like there). This provides a foundation for mapping and analysis that is used in science and almost every industry. GIS helps users understand patterns, relationships, and geographic context. The benefits include improved communication and efficiency as well as better management and decision making". (ESRI)

C. Coding
Among the various platforms for coding, GIS has Python (majorly termed as ArcPy) as a coding medium. "ArcPy is a site package that builds on (and is a successor to) the successful ArcGIS scripting module and its goal is to create the cornerstone for a useful and productive way to perform geographic data analysis, data conversion, data management, and map automation with Python". (Elkins)

The following are the functions of ArcPy:
- Charts module
- Data Access module
- Geocoding module
- Image Analysis module
- Mapping module
- Metadata module
- Network Analyst modules
- Sharing module

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- Spatial Analyst module
- Workflow Manager module

III. RELATION BETWEEN GEOMATICS AND EACH STAGE OF BUILDING LIFE CYCLE

There are various applications of Geomatics (GIS or Remote Sensing) in today's world when it comes to technology and advancement in science. This paper is trying to focus on the Architectural applications of it. GIS is already in demanding use when it comes to Urban Planning, but the architectural projects are of a much smaller scale and have to be studied in detail to implement its use. To understand the possible application of Geomatics, an attempt has been made by considering various stages of an architectural project for a basic insight.

Functions of Remote Sensing:
Data acquisition –> Processing –> Analysis –> Accuracy Assessment –> Information distribution to Users.

Functions of ArcGIS:
Data Capture –> Storage –> Management –> Analyse/Manipulate/Process –> Presentation of Geographical or Spatial Data.

R.S. + ArcGIS:
Monitor/Edit/Gather –> Process – > Store/Organise –> Query/Analyse –> Visualise

a. Geomatics in Produce

For the procedure of production, firstly we need to know the location and quantity of the availability of Raw Materials. Using satellite images and Remote Sensing analysis, we can easily detect the physical features present at a remote location through their pixel values, without physically visiting the site. This can be useful for Resource Exploration on land as well as the ocean floor. These features can also be monitored for estimating their Supplies in terms of quantity and quality. Remote Sensing can also be used for Environmental Studies for example predicting Climate Change and identifying Disaster Prone areas. That can further help in Decision Making regarding the time when to excavate and extract. It can also prepare Land use Maps and perform a temporal analysis showing the Growth of a City, Changes in Farmland or Forest area over several years. That can be used to decide the location of an industry or a Factory for Manufacturing purposes.

ArcGIS can be extremely helpful in Database Management. It can support and monitor multi-user access to any database and can edit, update, organise and retrieve the database. Satellite images are used in ArcGIS for Data Processing, few tools for the same are listed below:

- Classification: We can classify the type of physical features present in an area and use the result for deciding what to extract.
- Query: Query can be run including various parameters based on our necessity.
- Locations: The location of various resources can be mapped that may be used even for deciding the location of factories/industries.
- Conditions: The quality of the present resources can be analysed.
- Spatial Representation/Visualisation concerning Information: Any information collected and stored can be represented in connection with its spatial characteristics and thus helping in analysis using visualisation.

b. Geomatics in Construct

The two sub-stages of building construction under Construct are Designing and on-site construction. As we know Remote Sensing is extremely useful for analysing Disaster-Prone areas, we can use the result to decide the Architectural Type of the building, the Materials and Construction Techniques to be used and any specific Design strategies or elements to mitigate the effect of the particular disaster. Similarly, the prediction of Climate Change is useful during the planning of a city for the location of building typologies, land use, infrastructure provisions etc. It is also used for mapping any type of topography either land or ocean floor, identifying the depth of the ocean floor, which can further be used during the designing process. It gets easier to collect any form of data from inaccessible or dangerous areas in order to propose a solution for the same area to make it liveable.
The land-use map created by the ArcGIS and its Environmental study is used for Urban and Regional Planning, and the provision of services like electrical, plumbing, drainage, gas pipeline, telephone and internet connection. Additional planning can be done for the location of providing Solar panel fields, water reservoirs, dams, and transportation networks. The rivers and other natural water resources can be mapped and used for the water supply network. Land cover, Soil types, Land degradation, Elevation profile and contour lines can be mapped and the result can be used for decision-making in Landscape designing, provision of Public Parks and provision of level difference using the contours while designing. Microwave Remote Sensing uses the microwave energy emitted by all the objects and tells us the details like Soil moisture, atmospheric water (humidity), water pollution etc. Such information can be used to decide on the construction technique, and the materials to be used for a project. Geomatics can also analyse Human impact change from past to present again providing a base for the decision of development of any city. A very commonly created map using ArcGIS is Watershed analysis, which shows the general water drainage of a land parcel through a concentrated common

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outlet. This map can be used during the design of drains of any project, to provide any form of rainwater harvesting or groundwater recharge, or to give the provision of any underground service connection like optic fibre. ArcGIS can be used to analyse and display the population growth, and economic development of a city based on the number of industries or other infrastructures, that can help in Urban and Regional Planning. Buffer tools can also be used for deciding on the proposal of the location of any project. Database Management is done while Coping with any system failure and also it can provide for Communication Linkage with other systems while multiple people are working on the same project but different jobs related to the design or services or structures etc. Spatial Data Analysis is done to find the relation between the project and its surroundings that is done for the Site Analysis. The following are the listed tools for Data Processing during the Construction stage:

- Validation and Editing: Data related to Site location, boundary, and area can be validated and edited using ArcGIS as per the spatial information.
- Structure Conversion: It is a Geoprocessing tool to convert the data from one format to another for achieving compatibility to be used in ArcGIS, for example from .xls to .csv or raster to Feature Class.
- Geometric Conversion: Converting the data from one geometry to another for better attribute data, for example from polygons to lines or lines to points or polygons to points or vice versa.
- Integration: It is a data processing method to assign the exact coordinates to any two or more points of one or more feature classes that lie within a specified distance from each other.
- Map Enhancement: It is a feature-specific effect applied to get a clearer and more focused map of a chosen layer and data.
- Buffer: It creates a buffer polygon around any selected feature up to a specified distance.
- Network: It is an analysis tool used to solve a few common network problems like the nearest places, and best route, depending on the parameters given by the user.
- Spatial Operations: Map Union, Intersection, Subtraction, and Selection are commonly used for surrounding studies.
- Connectivity: Nodes, Links, Distance, Cost, and Time are a few parameters covered underconnectivity.
- Proximity and Contiguity: Measure the distance between locations or any location's degree of adjacency to its neighbours.
- Intervisibility: To check if a direct Line of Sight is possible or not.
- Digital Terrain/Elevation Modelling: the 3D surface is created using digitalised height data.

c. Geomatics in Use

Once the project is being used by the users, it still keeps undergoing several dynamic changes or updations of the data, which results in the useability of Geomatics. Once any disaster is predicted using Remote Sensing, the region can be evacuated and the people can be relocated to another location for the time being thus saving thousands of lives. Remote Sensing also has military, intelligence, commercial, economic and humanitarian applications, information gathered and analytical results can be extremely helpful for Urban and Regional Planning. It can also detect and monitor Green House Gas emissions which again can be used to plan its reduction measures. Mapping the presence, quantity and quality of water resources above and underground can help in planning and providing water to households and other buildings. Regional Economic Activities at night of various kinds can be mapped using ArcGIS can guide the Electric Power Distribution and the entire analysis may help in calculating their effects on the GDP of the Nation. Another prediction can be done regarding the abundance of pests and insects and thus channelise the pest control methods. Water pollution, chemicals in the atmosphere and diseases can be detected using Microwave Remote Sensing and suggesting to take steps to mitigate it. ArcPy can be used for coding and making applications based on street networks, for example, a mobile application with a live database to show available blood donations happening in the city. Several databases of similar platforms can be linked using ArcGIS to make Dynamic Displays. The application may also provide Location-based as well as Attribute information, for example, information under FIR lodged in Police Stations is already available on the internet for a few cities and can be available on mobile applications. Such information may be used to create a buffer for the safety of the public. Spatial Relationships between crimes or other parameters and their Geographic location can be analysed and any related issue may be resolved. The application may also include Model-Based Queries for optimum paths, suitable land parcels etc. The majority of the above integration of Geomatics and Architecture is about the Planning level, talking about the Architectural aspect, a single building base application can be made for the location, path, service request for Repairs and other queries. Database Management during the use of any building can be kept as "Data Independent" while at the same time maintaining the database's security and integrity.

d. Geomatics in End of Service

Maps of any kind of land cover, ocean floor and changes in their pattern may be useful for the location of dump yards or incineration. Certain tools like Buffer can also be used to identify the regions where this procedure cannot be executed. Waste Management data of possibilities can be mapped according to the quality and re-usage of the materials.

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IV. CONCLUSION

As we can see, multiple tools can be used repeatedly in all stages for different purposes. Based on the study mentioned above on Geomatics allied with Architecture, the following pie chart can be concluded, yet keeping in mind that a detailed and practical study might infer some alterations to the result.

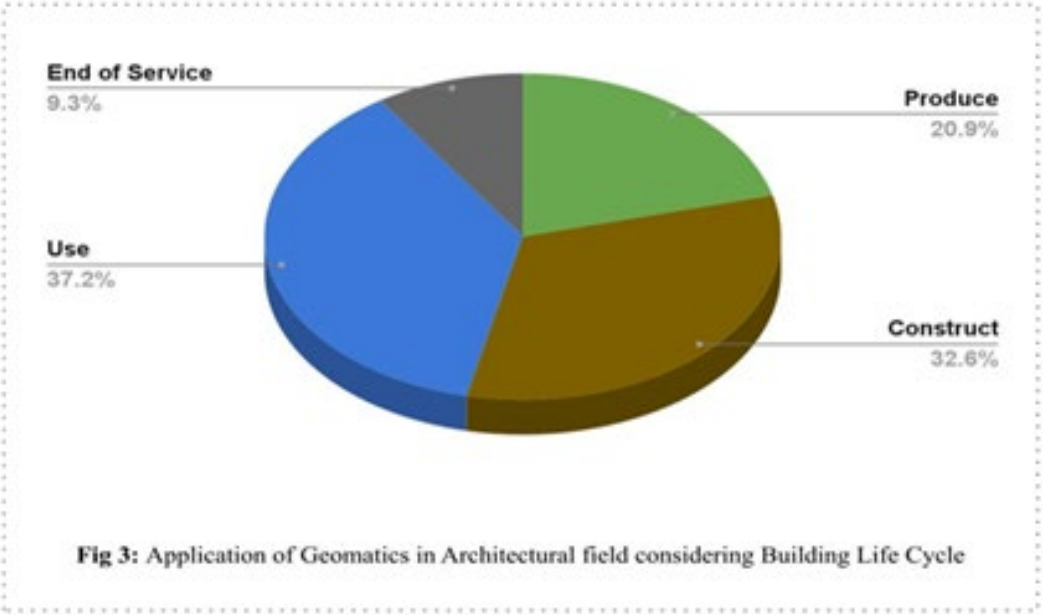

Fig 3: Application of Geomatics in Architectural field considering Building Life Cycle

Once the mobile application is in process, all the energy resources used during the entire procedure are eliminated. Any energy being used for the transportation for the site analysis will be reduced to a minimum. Specific and calculated use of energy using Geomatics analysis will reduce any additional consumption of energy and hence resulting in the least wastage of energy, water and materials. The entire process of saving energy using Geomatics will lead to a Sustainable Designing of a building.

V. SCOPE FOR FURTHER RESEARCH

The first and foremost way ahead is the practical use of the above-mentioned theoretical study. Still, a number of theories for Geomatics and Architecture are yet to be studied. A few among them are as follows:

- Geodetic Remote Sensing that includes Gravimetric Study.
- Photogrammetry Analysis.
- Access Changes of a location over time.
- Simulation models on data (like runoff modelling) to create useful information for planning.
- Spatial Statistical Analysis.
- Model-Based Management System (MBMS).
- Trend Surface Analysis.

This paper aims to create major interest in Architects for applied Remote Sensing and ArcGIS. I hope it gives way to further research in the same field.

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