Use of GIS in Construction Site Layout Planning

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Abstract— The construction industry is adapting various new tools and techniques to yield high productivity, to attain safety and sustainability. Efficient layout planning of a construction site is fundamental part of a successful project. This task consists of identifying the temporary facilities needed to support construction operations, determining their size and shape, and positioning them in the unoccupied areas within the site boundaries. A procedure for optimum layout of temporary facilities is then developed in integration with a GIS tool (Gram++). Five aspects are considered during site-layout planning: (1) Selecting a site to design the site layout. (2) Scheduling of the construction activities. (3) Identifying the temporary facilities needed. (4) Applying various constraints for facility layout. (5) Preparing the GIS based site layout model. Thus The Quantity of materials required can be estimated and using proximity analysis proper stockpile area can be identified.

Key words: Geographic Information System (GIS), Temporary Facility, Site Zoning, Proximity Analysis, Construction Management, Project Management

I. Introduction

‘Space on construction sites is recognized as a resource that is as important as other resources of money, time, material, labor, and equipment’ (Tommelein et al. 1992b; Hegazy and Elbetagi 1999). Allocating site space to resources so that they can be accessible and functional during construction is a problem known as layout planning. A well planned and managed site can contribute to decreasing construction cost and time by minimizing travel time, reduce time required for material handling, increase the productivity and improving safety (Tommelein et al. 1992; Anumba and Bishop,1997). Construction site layout planning involves identifying, sizing, and positioning temporary and permanent facilities within the boundary of the construction site. Construction layout planning is a critical process as vast number of trades and interrelated planning constraints are involved.

Geographic Information Systems (GIS) is one of the fastest growing computer-based technologies since 1990s, but it is not used to its fullest extent. This technology allows analysis of large volumes of spatial and non-spatial data from a variety of sources. The GIS technology helps in the interaction of multiple participants such so that the problem can be approached in a more comprehensive and systematic way. GIS has ability to maintain spatial data (i.e. components corresponding to each activity) in separate themes, which can be superimposed spatially. The related non spatial information like schedule, material type and quantity, safety and quality control recommendations etc. are stored in the attribute tables of corresponding components, which can be extracted from the database maintained within the GIS itself. Spatial and non-spatial data are synchronized so that both can be quarried, analyzed, and displayed.

A. *Dynamic Planning of Site Layout*

A Dynamic site layout planning here can be defined as locating the needed temporary facility on site as per the changing schedule throughout the span of the project. As the schedule of a construction site is dynamically changing throughout the span of the project, temporary facilities are needed to be constructed. To determine the need of temporary facilities there are various steps which has to be followed: 1) Preparing a schedule of construction activities. 2) Identifying the temporary facilities needed. 3) Calculating the size and shape requirement of the temporary facility. 4)The temporary facility that serves the construction operation in any time interval can be considered as temporary facility on site in that particular time interval.

B. *Zoning the Site*

Construction site is categorized mainly into four different zones as Central zone, Inner zone, Outer zone and Neutral zone. Central zone is Right around and including the structure under construction. In the centre of central zone some main equipment’s like tower crane, lifting and boring equipment’s are usually located. Inner zone is close to central zone.in this zone the loading and unloading areas, active stores and deposits are located together with access of temporary roads. Outer zone is within reach of main tower, within reach of main crane, the auxiliary plants, workshop, yards etc. are located in this zone. Secondary deposits and stores are located in this zone. Neutral zone is inside boundary fences of construction site, typically out of reach of main crane tower. Surrounding the area, is accommodating auxiliary temporary facilities such as site offices, parking lots, on site production plants, workshops, laboratories, warehouses, casing yards, equipment stores, earth deposits, waste water tanks, hazardous material stores.

II. Positioning of Temporary Facility

Optimal positioning of the temporary facility needs to follow following steps: 1) Identifying the temporary facility needed at each interval of time. 2) Identifying the facility closeness relationship upon which the positioning of site layout will take place. 3) Allotting the positions of temporary facilities by considering the closeness relation.

A. *Facilities Closeness Relationships*

Optimized placement of temporary facility improves productivity and facilitates the movement among the facilities. Such interactions are referred to as the closeness relationships among the facilities and represent the desirability of having the facilities close or apart from each other (Hegazy and Elbeltagi, 1999). Six closeness relationships are usually set in previous literature; user can hence give the desired weight values as shown in table below.

Closeness relationship weights:

Desired closeness relationship	Weight
Absolutely necessary	10^5

Especially important	10^4
Important	10^3
Ordinary closeness	10^2
Unimportant	10^1
Undesirable	10^0

Table 1: Closeness Relationship Weights
(Emad Elbeltagi, et. all, 2004)

The method used to evaluate a specific layout is a weighted sum of all travel distances is as follows:

$$\sum_{i=1}^{n-1} . \sum_{j=i+1}^{n} di\ jRi\ j$$

Where, di j = distance between facilities i and j.

Ri j = closeness weight value between facilities i and j.

N =number of facilities.

III. Database Management in GIS

A Geographic data base consists of both spatial and non-spatial data entities which may change in time. The spatial data represent the location and topology of points, lines, polygons and surface features while the non-spatial data describe the characteristics of these features.

A. *Spatial Data Base*

The spatial data attributes can be metrical or topological. Metrical attribute include position, shape and size while the topological attribute are those which describe the characteristics such as connectivity and adjacency. Spatial entities are conventionally divided into points, lines, polygons and surfaces. Polygons are perhaps the most frequently encoded features in GIS (Burrough, 1986). The computer representation of point, line, polygon and surface entities is in the form of grid (raster) or in the form of vector data (peuquet, 1984, Aronoff, 1991).

In the vector data model, the basic logical unit is the line that is used to encode the locational description of an object and represented as a string of coordinates of points along the line, while In raster data model, the data is represented in a matrix of cell of uniform size, each cell referenced by a unique row and column number. The cell contains a number or code representing the type of value of the attribute being mapped.

B. *Non Spatial Data Base*

In addition to the spatial database each of the entity has a number of other important attributes associated with it. These attributes may be land use pattern, population of region, type of soil, etc. If spatial data represents boundary of village, then each entity will have a number of corresponding non spatial attributes such as population, occupational pattern, infrastructure, land use etc. This database can be organized using a database management software and proper linkage should be established between the spatial and non spatial database.

IV. Spatial Analysis for Quantity Takeoffs

As mentioned above, spatial operations involve a series of database queries and topological overlays. The data layers constituting an architectural design are the basis for GIS-based quantity take off calculation. Different working activities require different spatial attributes for quantity take offs. The attributes needed for GIS-based quantity take offs in the study include area, perimeter, length, and width. The default spatial attributes, area and perimeter, are automatically generated when the polygon coverage is created.

A. *Method Statement*

1) Firstly, the softcopy of the site layout was made available in the RAW format.
2) Then in the Map Edit module of GRAM++ application the map was Digitized.
3) Each facility was digitized in a separate polygon layer. Cleaning b) Form polygon. c) Label polygon.
4) These operations were carried out on each of the polygon layer.
5) Then Database was created for each of the polygon layer in create table menu of Map Edit module.
6) Rasterization operation was carried out on each of the polygon.

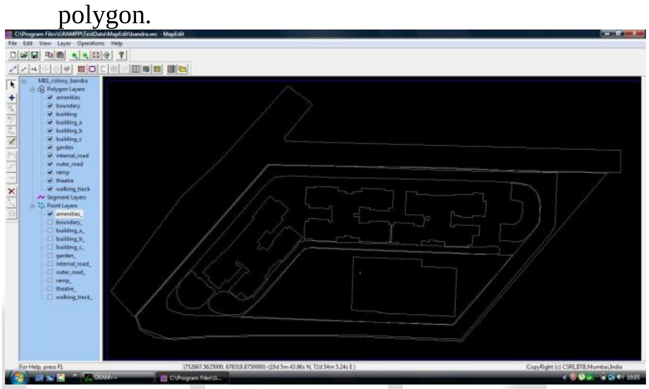

Fig. 1: Digitized image of map in GRAM++ module

As the database created in GRAM++ in Map Edit module is not complete as the module represents the data in sq.m. So to find out the exact quantity of material required a run time application of visual basic is needed to be installed and the database in GRAM++ has to be interlinked with the visual basic application. Hence we get the exact quantities in M3 of the material to be stockpile.

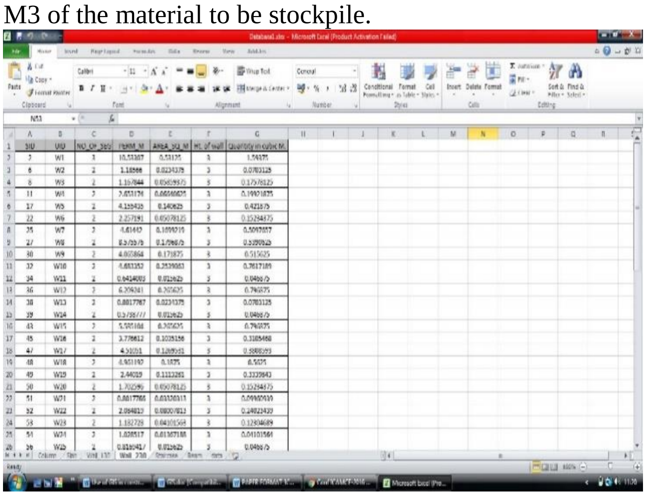

Fig. 2: Database in Microsoft access.

B. *Flow Chart of Work Performed*

Thus the quantities of all elements of building can be calculated in GRAM++ module od GIS software itself. Only the database has to be converted into cubic quantity using an additional software, hence here Microsoft access is used to convert the quantities from Sq. meter to cubic meter.

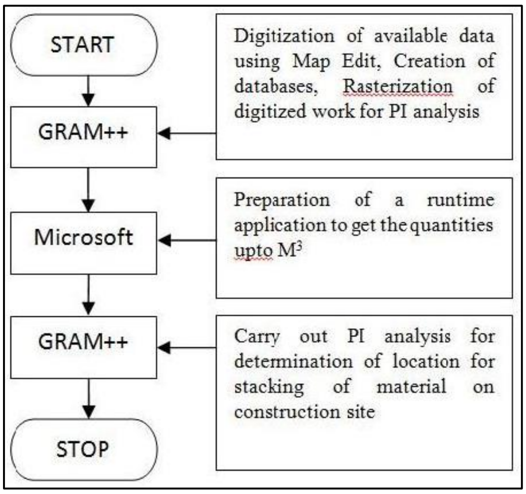

Fig. 2.1: Flow Chart of Work Performed

V. Proximity Analysis

Proximity Analysis is an analytical technique used to determine the relationship between a selected point and its neighbours. It is an objective function used to rank the potential site and determining which is best. It is mostly done for the purpose of Zoning and convenience. In site layout planning proximity analysis plays an very important role as it shows the empty space available for the stockpile of raw material needed which is calculated previously.

Buffer is applied on and around the building keeping the record of facility closeness relationship. A certain condition is applied to get the buffer image. A buffer zone gets created around the building which is empty and has a potential to stockpile the material on site. Thus it facilitates a proper layout of site.

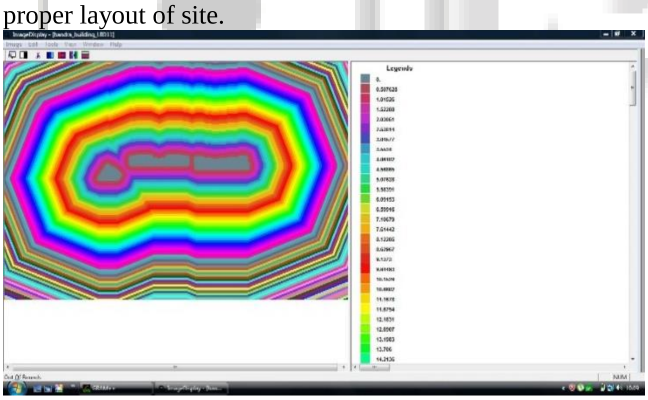

Fig. 3: Buffer image before applying condition.

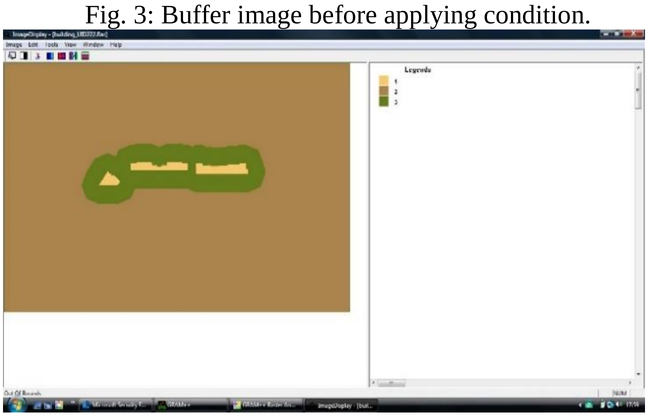

Fig. 4: Buffer image after applying condition.

Above image represents the buffer condition around the building layout. Here the buffer layers are applied around the building without any criteria. But to do proximity analysis around the building certain condition has to be applied so that the conditions are satisfied and area for stockpile of material can be identified. The image below shows the buffer layer with condition applied.

Here we can see the yellow representation is building and the green representation is the area around building available to stockpile the material.

If the work on site is carried out in three stages:

A. *Stage 1*

Stage 1 on construction site is only the construction of Building A. So buffer is applied on and around building A. It shows the area around building A where free space is available to stockpile the material around building A as shown in fig 5.

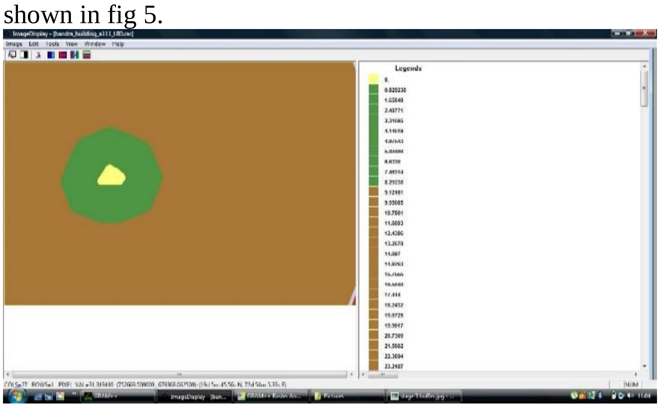

Fig. 5: Buffer image at stage 1.

B. *Stage 2*

Stage 2 on construction site is only the construction of Building A and B. So buffer is applied on and around building A and B. It shows the area around building A and B where free space is available to stockpile the material around buildings. The buffer layer of various pixels are merged together from building A and B to get a single buffer image for building A and B as shown in fig 6.

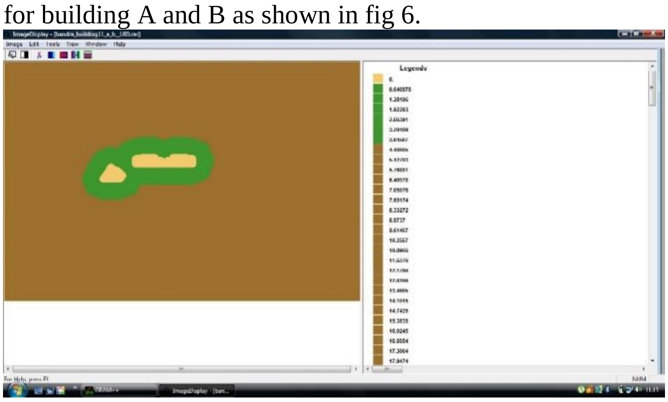

Fig. 6: Buffer image at stage 6

C. *Stage 3*

Stage 3 on construction site is the construction of Building A, B and C. So buffer is applied on and around buildings A, B and C. It shows the area around buildings A, B and C. where free space is available to stockpile the material around buildings. The buffer layer of various pixels are merged together from building A, B and C to get a single buffer image for the buildings. Hence a complete buffer image is obtained as shown in fig 7.

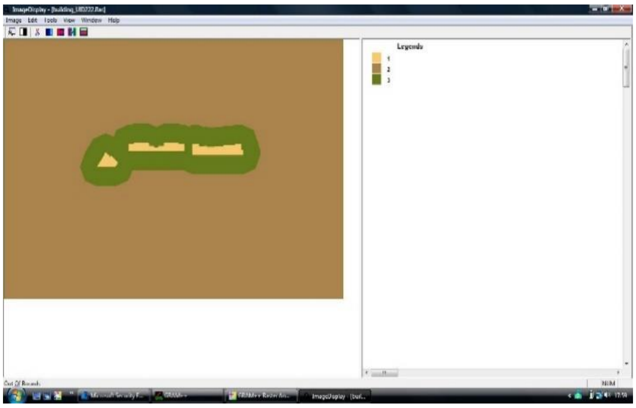

Fig. 7: Buffer image at stage 7

VI. CONCLUSION

This paper demonstrates that GIS is an effective tool for quantity take offs, presenting a new process for the development of computer-aided quantity estimate. GIS-based quantity estimates with construction scheduling to develop a dynamic materials requirements plan, continuously passing the retained information into construction phases for materials planning. The information required for the development of this system was thus represented and integrated within a computer environment. In addition, an automated site layout system was also developed and included in the program to identify options and solutions for problems regarding materials layout. It was developed to replace manual methods, and it assists planners in quantity take offs and assessing materials layout design. It proves that GIS is a promising tool for solving quantity take offs and materials layout problems and thus opens up a new way of thinking in the management of spatial information for construction planning and design. GIS improves construction planning and design efficiency by integrating locational and thematic information in a single environment. This not only speeds by the modelling process by avoiding data extraction from various resources but also, more importantly, ensures data integrity and accuracy. GIS forms an effective foundation for planning construction activities.

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