Identification and Resolution of Construction Space Conflicts Using Geographic Information Systems

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Abstract: - Construction activities need space on a jobsite for their execution. Workers, equipment, materials, temporary facilities (TFs), and a structure under construction share the available space on a jobsite during its execution. Planning for space helps in providing safe and productive site environment. Literature suggests the use of four-dimensional (4D) CAD modeling in the space planning. However, 4D CAD lacks in features like topography modeling and geospatial analysis, which affect space planning. In the present study, 4D geographic information systems (GIS) was utilized for space planning that facilitates the topography modeling and geospatial analyses. GIS facilitates the generation multiple types of spaces requirement corresponding to various activities defined in the master schedule. A GIS-based methodology was developed for construction space conflicts identification and resolution.

Key-Words: - GIS; workspace; space conflicts.

1 Introduction
Workspace requirement is one among various types of resource requirements on a jobsite to execute daily project activities. Contractor needs job specific workspace, equipment space, material storage space, travel paths, etc. Deficiencies in space planning results congested jobsite, productivity loss, space conflicts, and schedule interference or delay [1]. Hence, like any other resource activities also need execution space that has to be planned before finalizing a construction schedule [2].

Riley and Sanvido [3-4] identified space use patterns in multistory buildings. Thabet and Beliveau [5] studied workspace demand and loss of productivity due to the space constraints in the high-rise building. Akinci et al. [2] developed an approach to generate project specific work spaces from user-defined constraints assuming specific adjacency conditions and orientations of construction spaces. Akinci et al. [6] developed a methodology for automated generation of construction work spaces required by construction activities to reduce time-space conflicts based upon 4D production models. 4D model have a single level of detail that hinders the collaboration among general contractor and sub-contractors [7]. Despite of many researches in 4D CAD its use is not very common in the construction industry for identification of space conflicts.

Construction space planning is not only related to functionality developed in 4D CAD. For example, space planning for gravity dam or canal construction where topography plays a major role cannot be simulated without geospatial analysis capabilities (available in GIS) which are missing in existing 4D CAD-based systems. This generates the strong need of space planning within a GIS environment. Keeping the importance of topography and geospatial analysis capabilities in view, contractors or organizations create, store, and share 3D model, surrounding topography, 4D scheduling, and geospatial analyses capabilities together in a single platform may help in space planning much better way. Another reason is that layouts of different types of existing facilities/utilities like electricity, gas supply, water, sewage, etc. are GIS-based which plays a major role in construction site selection and space planning.

The present study was focused on the 4D sequence visualization along with topography, database management, and geospatial analysis capabilities into single GIS platform for space planning. GIS was also used to generate virtual spaces based upon a user-defined description. How space-planning methodology was developed for conflicts identification and resolution has been discussed in the paper.
The 4D execution sequence along with its surroundings, topography, and geospatial analysis capabilities into a single GIS platform helps in space planning. Hence, the main objective behind this study was to explore the use of GIS in space planning to identify and resolve the spatial conflicts in construction. The methodology for the identification and resolution of space conflicts was developed. The achievement of the objective was accomplished by:

1. Development of 4D execution sequence of construction,
2. Generation of work spaces in the GIS platform,
3. Linking work spaces and construction execution schedule to generate dynamic space requirement, and
4. Identify space conflicts and decide resolution strategies.

2 Identification of Space Conflicts

2.1 Development of Construction Sequence

Project was decomposed into various small tasks, interrelationships among them and durations were determined to develop the construction execution schedule. SketchUp facilitates 3D modeling with a set of simple tools [9]. 3D modeling of components corresponding to different activities in the schedule was done in SketchUp with full degree of internal detail. The modeled components were exported from SketchUp to ArcGIS in the multipatch format and maintained in data layer. The data layers form the basis of 4D visualization of the execution sequence in ArcGIS. It is not necessary to have 3D component/s corresponding to each activity in the schedule. For example, activities like clearing and leveling of construction site or curing of concrete does not have related 3D components. However, there should be an activity in the schedule corresponding to each 3D component. The number of data layers created corresponding to each activity will depend upon the degree of detail to be provided in the 4D model. Activities of the schedule, developed in ArcGIS, MS Project, or Primavera, were linked with the corresponding 3D components using the methodology developed by Bansal and Pal [8] to create a 4D execution sequence. Detail in a schedule and division of a 3D model into small components have serious implication on the time spend in developing a 4D execution sequence.

The present study assumes three categories of available spaces: on ground, temporary structures such as scaffolding or working platforms, and structure to be constructed with time. The categories of available spaces are described in terms of sizes, locations, and time of availability. An activity consists of several tasks which require spaces for labors, equipment, and materials storage; hence, various categories of space requirements for each activity were estimated. The spaces may be needed outside, inside, above, below, or around the reference component corresponding an activity. This study does not focus on capturing different types of space requirements, for more details about this, readers are directed to the earlier studies by Akinci et al. [2, 6].

2.2 Available Space and Spaces Demand

2.3 Space Loaded 4D Execution Sequence

The 3D Multipatch format available in ArcGIS was used to represent spaces in 3D as shown in Fig. 2. Location/position, size, shape, time period, and reference component of each space control the generation of space in 3D. The shape of space in this study could be cubical, spherical, or prism of square, rectangular, or pentagonal. The space requirements on a jobsite changes with schedule, therefore, the developed methodology links generated spaces requirement with execution schedule to generate space requirements in 4D. This integration extracts start and finish times of each project activity corresponding to each space from the execution schedule. Space loaded 4D animation shows work space requirements of activities along with 3D components to be constructed. The space overlaps among various spaces were identified visually through the animation. A space conflict is said to occur when a space during a same time period is demanded by more than one activity.

3 Resolution of Conflicts

a. To resolve conflicts, starting or finish times of the activities participating in conflicts are changed depending upon the availability of total float (TF).

b. The next strategy is to adjust the space demand by changing the locations of conflicting spaces or by dividing the originally assigned spaces into small parts. In this strategy, the space requirements for material storage, operation yards, etc. are altered to eliminate or minimize the conflicts.
c. The concurrent activities in a schedule sometime lead to site congestion, schedule delay, and unsafe working environment. Therefore, such situations must be avoided by correcting the execution schedule before its implementation. Alternate construction sequences have to be explored by re-sequencing project activities. This includes changes in interrelationships among activities, duration of space requirements, or splitting activities to resolve conflicts. Activities on the critical path should be given priority for their space demand. Attempts should be made to identify alternate sequences in such a way as to maximize the number of conflicts resolved.

4 Conclusion
Without considering the space requirements, the execution schedule should not be finalized. Therefore, the developed methodology displays spaces required along with the corresponding
components in 4D. This helps in the detection of time-space conflicts and accordingly in the modification of execution schedule in GIS environment itself to resolve the conflicts. GIS brings the capability of spatial analysis in a real-world spatial reference so that building construction can be understood with its participation in the surrounding landscape.

References: