A Study of Static Site Layout using QAP & Its Visualization through BIM

Mr Shaikh Shafiq Ahmed[1] Mr R. D. Shinde[2] Dr. Shailesh Shriniwas Angalekar[3]
[1,2]RMD Sinhgad School of Engineering, Warje, Pune. 411058, India [3]STES's Sinhgad College of Engineering, Pune-411048, India

Abstract— Efficient layout planning and implementation of a construction site are essential for the successful completion of the project, as it improves productivity and safety on construction site. This task consists in identifying the temporary structures necessary to support the construction operations, determining their shape and size and then positioning them optimally in unoccupied areas or occupied areas within the boundaries of the site. The problem of site layout design is a complex problem of combinatorial optimization that involves various goals and develops fundamentally in measure as it builds the quantity of offices and limitations. The objective of this investigation comprises in the advancement of doable and effective site plan arrangements a realistic representation scheme that considers the total distance traveled and the frequency of travelling between them. An optimization model is developed with the aim of minimizing the travel distance the facilities of an actual commercial project. The reduced travel distance is achieved by optimizing the travel distances between the various temporary facilities. The factors taken into consideration are the travel distance between the facilities and the frequency of travel between them. An optimized model is suggested with the aim of reducing the total cost and energy of travelling to a minimum. Also, a BIM model is developed for better visualization of the improved site layout.

Key words: QAP, BIM

I. Introduction

The optimal planning of site space through the duration of a construction project is referred to as site layout planning. Due to its impact on safety, productivity and also security on construction sites, several site layout planning models were developed in the past decades. These models have the shared objective of creating best layouts considering the defined constraints and conditions. The formulation of the construction site layout problem (CSLP) refers to the location of a set of facilities in certain places inside the limits of the site, while optimizing layout goals and satisfying design restrictions. Optimum construction layout is essential for project management, as it reduces transport time and, therefore, the cost of a project and also improves productivity and safety of working conditions.

Several preoccupied facilities n, optimally being allotted to a few several predetermined vacant locations m, where m > n. The Site layout problem of construction can usually be demonstrated as assignment of location or can be modeled as facility to site arrangement. In the primary, a set of predefined temporary facilities are assigned to a set of predefined locations on the site. This technique is used in the following project. In the second technique, i.e. facility to site assignment, a set of predefined facilities are assigned to a vacant space or area available on the site and often becomes into a more complex formulation since several factors and spatial constraints must also be simultaneously satisfied.

Both problem forms can be modeled either as equal area or can be modeled as unequal-area depending on whether all facilities can fit to every possible location or not.

The Construction site layout problem can likewise be recognized as a static or a dynamic problem depending on whether changes on the site facilities and site spaces are considered in different project phases.

Improvements on the existing layouts can also be made after taking the actual data from the site and later optimizing it and suggesting and improvement on the existing layout. The suggested layout shall be feasible and offer less travel distance than the earlier layout. Large-scale construction projects can require setting up different types of construction site facilities, such as site offices, storage areas and, different types of workshops, inside the site area to conduct the various construction activities.

The layout of a construction site, comprising the available areas and locations, the size of the available locations and the various types of site facilities, can be varied across the construction stages to meet the site's geometry constraints. This layout problem can be complex if the sizes and sorts of the site offices required change over the development organizes and have diverse geometrical safety requirements.

An imperfect site layout design might be utilized by site layout organizers and undertaking supervisors if the site office design configuration is based purely on experience. A definitive goal of site design arranging is to distinguish the ideal area for objects on the development site.

A. Static Approach

In the static approach, it is assumed that all the objects are required for entire duration of the project, and hence, do not allow two objects to use the same location on the site. In this approach, the optimum location for each object is identified regardless of its duration of existence on the site.

The benefit of this assumption is that it simplifies the search process. The static approach can be considered suitable and sufficient for short term duration projects with a large available site space, where there are few changes that happen on the site and the available space is usually abundant.

However, for more troublesome projects with longer term, where various objects arrive and leave the site during the course of construction, the static approach will be limiting because the changes in site space requirements are not reflected in the static approach, the reuse of the space that was previously occupied by other objects is not considered.

Thus, the static approach does not give a reasonable portrayal space requirement, and consequently, does not lead to an optimum use of space. Inspired from industrial plant layout planning, early studies of construction site planning defined it as a static problem. While there are various similarities and dissimilarities between site and plant layout planning, static planning does not consider the alterations that happen on the development site over the span of time. At the end of the day, it is by and large expected that all items exist on the site for the whole length of the project.

This assumption is clearly a simplification of the dynamic nature of construction sites. Objects on the site are typically required for only a limited period during the project - a time referred to as the object's lifetime or service time. When an object is no longer required, its area becomes available for a new object arriving at the site.

Since static layouts do not consider the actual lifetime of the objects, they do not allow reuse of space on the site. While the static approach simplifies the complex nature of the site layout problem significantly, in and restricted accessibility of space, disregarding the likelihood of reusing space can prompt designs with space clashes or wasteful designs.

B. Temporary Facilities

Temporary facilities are structures that support construction teams or activities, such as site workplaces, storage areas or guardhouses. Temporary facilities are a standout amongst the most generally objects in the site layout literature. In fact, the scope of a large number of the past site layout studies is limited to only temporary facilities.

Temporary facilities are easier to model as their time of arrival is often at the beginning of the project, their shape and size are normally known, and their location often remains unchanged throughout the term of the project.

C. Building Information Modeling

(BIM) Building Information Modeling (BIM) has become a very effective tool in the architecture, engineering, and construction industry. BIM tools have given a typical interface in which numerous users can create, store, and retrieve data relating to a construction project to a development venture. A standout amongst the most noted advantages of utilizing BIM is that a precise virtual model of the structure is carefully developed in three-dimensions, in this way permitting all the project participants an opportunity to see what is to be constructed.

This altogether diminishes any misconception that may be related with the more conventional two-dimensional illustrations. Ongoing years have seen a surge in the appropriation of Building Information Models (BIMs) by construction contractors to successfully and effectively oversee complex construction projects which should be conveyed under progressively compacted plan and budgetary necessities.

Construction contractors are progressively using BIMs for constructability analyses, enhancing correspondence with different stakeholders, and creating time-lapsed (4D) simulations of the construction processes over the project life cycle. A 4D model represents the various activities of a construction project obliged to a project schedule.

Information obtained from a 4D simulation can likewise incorporate conflicts between objects. This data can possibly diminish modify and spare a lot of time and money due to the simple fact that errors can be rectified prior to the start of field installation. In most cases, however, these simulations involve the objects within the building systems that have been defined by the various design professionals.

Most of the Building Information Modeling tools have been traditionally developed keeping the requirements of the designers in mind and construction contractors as considered downstream users, that is consumers of the design information (BIMs) produced by the A/E professionals. While programming software, for example, SYNCHRO, VICO Office®, and ® Navisworks® have been developed with the requirements of the construction contractors in mind, these tools often only integrate models created by designers and add schedule and cost information to them for various analyses.

These tools lack native capability of modeling construction objects; as well as, equipment and temporary facilities that are vital for effective planning of construction operations. As construction projects turn out to be more detailed and complex, the construction community confronting challenges related with overseeing projects within tight budgetary limitations, packed schedules and stringent safety necessities.

As talked about before, the dominating utilization of BIM in supporting the administration of construction projects has been constrained to recreating the arrangement components defined by the architectural, structural, MEP and HVAC designers; as well as, detecting conflicts and clashes and also calculating clearances between components. The process of construction, specifically the means and methods of construction, are generally not visualized or simulated.
Thus, the simulation of the construction process, at best, is partial.

II. PROPOSED MODEL

The issue presented in the study can be demonstrated as a quadratic assignment problem (QAP) in which equal numbers of locations and facilities exist. In the event that the quantity of locations exceeds that of facilities, dummy (fictitious) facilities can be added to the model (with zero distances or frequencies to existing real facilities so that they do not influence the layout planning). The optimization model incorporates the following decision parameters which contribute to the total cost to be minimized:

- Frequencies of trips made between pairs of facilities (per day).
- Distances between the predetermined locations (in meters).

Besides pure economic parameters, the decision for facility placement in practice may depend on other criteria as well. One of them is safety which imposes certain facilities to be close to each other and others to be as far away from others as possible (e.g., storeroom of hazardous materials). The safety enhancement goal is facilitated by means of preference in proximity or remoteness between two facilities. For instance, the project manager may decide to place the site office or the labour residence facility close to a side gate to avoid large interference of the personnel with the main gate, which primarily serves machinery entrance and exit, and to provide prompt evacuation in case of emergency.

Such preferences can be modeled by increasing artificially the frequency or the cost of movements between the selected facilities. Construction site facilities usually have varying shape and space requirements. Consequently, some locations may not be appropriate to accommodate certain facilities because of their size or other physical constraints (this is known as the unequal-area CSLP problem).

Also, the location of specific facilities, such as the gates to the site, is often crucial for the operability of the construction mechanism in term of access and transport. These facilities are commonly set to predefined locations and are not subject to change but rather still influence the overall layout planning through their connection with the rest of the facilities. In different cases, certain facilities may be allocated within a subset of the available locations but not everywhere. The CSLP problem falls within the NP-problems meaning that as the problem size (number of facilities, locations, and constraints) increases, the set of possible solutions grows exponentially. For this reason, Quadratic assignment problem has been employed for the optimization process. Quadratic assignment problems are generally used to assign locations to various facilities using the data collected from the site and, they efficiently address hard NP problems because of their ability to escape from local optima during the optimization search.

The proposed model was implemented through an add-in of the Microsoft Excel software. Additionally, a BIM model was created for the case study to help better visualization of the project. The modeling was done in Autodesk Revit software which is ideal for Building information modeling.

III. Case Study

The goals of this analysis are (a) To assess the data of the site and offer an improvement over the existing layout and (b) To reduce the travel distance for the various personnel and the movement of equipment. The data for the study was collected from FORT VIEW resorts, Aurangabad. There were three buildings in the development site and the information was gathered from around these three buildings.

This study analyses the CSLP problem utilizing differing QAP to obtain the optimal solution. However, every one of these examinations confine their investigation consider only input regarding frequencies of movement and distances with the fitness function to express the total distance travelled between location pairs. The case study project refers to the construction of the buildings.

The construction site comprises 6 facilities which are to be assigned out 6 accessible locations inside the development territory (Figure 1). The frequencies of day by day trips between offices are recorded in Table 1 while the distances between the accessible areas are appeared in Table 2. The facilities of this case study are: which are to be assigned to 6 available locations within the construction area (Figure 1).

The frequencies of day by day trips between offices are recorded in Table 1 while the separations between the accessible areas are appeared in Table 2. The facilities of this case study are:

1) Site Office
2) Labour Residence
3) Store Room 1
4) Store Room 2
5) Carpentry Workshop
6) Reinforcement Steel Workshop

0	1	2	3	4	5	6
1	0	1	2	1	1	4
2	1	0	7	4	4	9
3	2	7	0	6	7	8
4	1	4	6	0	3	4
5	1	4	7	3	0	5
6	4	9	8	4	5	0

Table 1: Frequency Matrix

0	1	2	3	4	5	6
1	0	17.4	25.8	25.2	15.6	16.8
2	17.4	0	18	16.8	24	16.9
3	25.8	18	0	10.8	30.8	22.2
4	25.2	16.8	10.8	0	27	16.4
5	15.6	24	30.8	27	0	18
6	16.8	16.9	22.2	16.4	18	0

Table 2: Distance Matrix

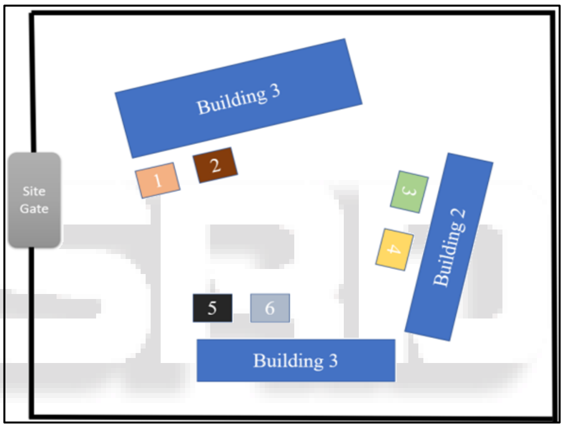

Fig. 1: Original Layout

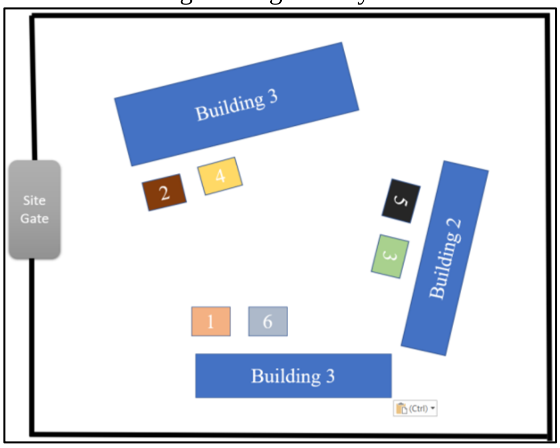

Fig. 2: Suggested Layout

IV. Conclusions

The construction site layout planning (CSLP) sequencing problem means to create optimal layouts in regards the positioning of the temporary project facilities within the construction site limits. The problem can realistically be modelled in a multi-objective optimization formulation aiming at optimizing the total travelled distance among facilities and the corresponding transportation cost and the existing safety concerns which result from the distance or remoteness of certain facilities to others.

The CSLP problems are among the toughest ones in project planning process especially as the quantity of facilities and constraints increases. In this study, an improvement model is proposed for the construction site layout problem incorporating transportation combined with safety concerns. The data was collected from the proximity of the three buildings in the premises of FORT VIEW resorts, Aurangabad.

QAP has been utilized for the optimization because of its capability to effectively search within a large set of conceivable solutions. The assessment indicates that the optimized proposed model provides successful planning effective and rational layout planning solutions. The BIM working model is expected to help in better visualization and planning of the project before the construction is commenced.

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