



Planning of Construction Site Layout: A Review

Al Kulabi Ahmed Kamil

ahmedk.kadhim@uokufa.edu.iq

Al Zahid Ali Adnan

alia.alzahid@uokufa.edu.iq

Department of Civil Engineering, University of Kufa,
Kufa-Najaf, 54001, Republic of Iraq

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Abstract:

In the recent years, researchers have been interested in planning of layout of projects' site since it is a basic factor for a successful project undertaking. Projects' sites comprise temporary facilities and heavy construction equipment that share the same space or may require the same area of construction site, therefore, construction site should be organized well, so that construction activity will be in its full swing. The site layout planning process includes identifying the needed temporary facilities for supporting operations of construction, specifying their shapes and sizes, and optimizing their positions within the boundaries of sites. In this review, a number of methods and techniques used for construction site layout planning are reviewed and discussed, the frequent problems at construction sites are included, the ways of improving the efficiency of planning of sites layout are listed and discussed. The advantages of good planning of sites layout and the effects of neglecting sites layout planning are reviewed.

Keywords: Construction site, Jobsite layout, Temporary facilities, Productivity, Safety.

1. Introduction

The process of placement of equipment, facilities, and materials within the space of construction projects is known as "site layout planning" (Pheng and Hui 1999). A well designed site layout is necessary to provide a safe working environment and effective operations at construction sites. Planning of site layout influences mainly all time, cost of construction, and productivity (Sjøbakk, 2015). The principle aim of sites layout planning is to know the wanted temporary facilities, specify their shapes and sizes, and to appoint their location within the construction site boundaries (Sanad, 2008). Temporary facilities and other variables change from a project to another relying on the type of project, therefore construction projects don't share the same site layout planning (Tam et al. 2002). Temporary facilities may comprise batch plants, heavy equipment, offices, warehouses, parking lots, tool trailers, fabrication yards, access roads, maintenance shops and storage shops, etc. (Marx and König, 2011).

Although of its great importance, planning of sites layout is usually neglected or counted as a less significance by practitioners (Tommelein, 1993). Hence, objects of site layout are marked at sites depending on the basis of first-come first-served (Andayesh et al., 2013). For that purpose, some of traditional rules



have been used because of their simplicity, such as code of practice and previous experience, expertise, and thumb rules (Tommelein et al., 1992; Chau et al., 2002). As a result, the planning of sites layout by using these rules will be highly influenced by the person who is involved in the sites layout design (Tommelein, 1992).

A number of static models have been utilized to use for designing sites layout. These models assume that the locations of temporary facilities are not changing along the progression time. While in fact, temporary facilities of any project are not part of the lasting construction, therefore they have relatively short span of life. These models are applicable for projects with big spaces, having short execution time, and with few changes in the design of sites layout. Moreover, these models do not permit for re-utilizing the space take up by temporary facilities that is not needed any more at construction sites (Andayesh et al., 2011; Soygaonkar et al., 2014).

The other developed models are dynamic models. These models take in consideration that the locations of temporary facilities will change along the progression time of execution. The required time for which temporary facilities are needed relies mainly on the activities that are linked (Mohsen Andayesh, 2013; Soygaonkar et al., 2014). Additionally, dynamic models suppose that there is no necessity for the existence of all temporary facilities at construction sites along the whole project duration. They are useful for projects with rare space, small sites, and with long execution time. Hence, by using these models, the occupied spaces by temporary facilities that are not needed any more at sites can be reused.

Needless to say that, developing a well-designed layout of a project's site is a critical task, which must be precisely completed and brought up to date during the project phases: planning and execution. It can result in lowering the needed cost of handling of construction materials, decreasing the travel time of all of equipment, material, and labour, increasing productivity, and improving both of quality and safety of construction (Dhanure et al., 2016).

On contrast, poorly designed site layout can lead to tacky results as ensured by a number of published studies and surveys. For instance, Mamat et al. (2008) performed questionnaires to specify the frequent problems happening at sites because of poor planning of sites and the impacts of poor design of sites layout. They revealed that eight problems occur frequently at sites as a result to the poor planning of sites layout, which are: materials are piled wrongly, equipment and machinery are located in an incorrect way, construction sites are with an insufficient space, temporary facilities are placed in an suitable way, access roads are narrow, access roads are in poor conditions, fence does cover the whole site, and the distance is far between area of construction work and temporary facilities. While the influences of poor design site layout included: accident happen at sites, project's cost increases, travel distance increases, materials require double handling, project's completion time increases, works quality decreases, materials lost, and damages properly occur.

2. Techniques and tools of site layout

A significant research has been carried out, and numerous methods have been considered to perform the process of optimization. The site lay out planning problem has been solved by adopting two main



approaches, which are heuristic methods and mathematical optimization. Heuristic methods depend on knowledge-based systems and on the concepts of artificial intelligence. Heuristic methods are adopted to give good but not optimum results. Mathematical optimization has been developed to result in optimal results. Anyhow, mathematical optimization is not applicable for projects with large-scales because of its complexity in computations and the need for great efforts, therefore, heuristic methods are the adopted ones for these projects (Sanad et al., 2008).

The process of optimization has been conducted on different parts of the process of site layout planning like optimizing the size and shape of project temporary facilities, and optimizing their locations at site. The decision of selection any of these methods or systems relies primarily on a number of factors like complexity, time of computation, quality of solution, mutual action among parameters, and the algorithm behaviour (Papadaki, 2016). In the following paragraphs, a quick summary of the developed systems and models for site layout planning is comprised.

Tommelein et al. (1992) developed site plan, which is one of heuristic methods, that is based on knowledge-based systems by implementing the techniques of artificial intelligence programming. It is used to layout facilities by representing them as rectangular on the sites of construction, symbolized as a space with two dimensions.

Cheng et al. (1996) developed an automated site layout system for the temporary facilities of construction sites. The system comprises a geographic information system that is conjoined with database management system. The developed system suggests a method to get and explain the experience and knowledge of experts in planning of sites. By usage of searching concept by elimination, it can develop a heuristic process to model the human decision-making process and produce a possible site for each temporary facility.

Li and Love (1998) developed a model based on a genetic algorithm to optimize the location of temporary facilities. The model's objective is minimizing the travel distance between temporary facilities of a project. In this developed model, the problem of temporary facilities layout is described as allocation of set of temporary facilities that are determined in advance into a set of location specified and defined in advance. In this model, the size of each location is assumed to be equal to the area of the largest temporary facility. Also, locations are represented as rectangular in this study.

Zouein et al. (1999) developed a mathematical model for planning of site layout dynamically. In the developed model, resources of construction are represented as rectangular and subjected to constraints with two-dimensional geometry on sites. The objective of the developed model is to let site space available for all construction resources and to prevent conflicts from happening with minimizing costs of relocation and distance-based adjacency.



Hegazy et al. (1999) developed Evosite, which is a comprehensive system used for planning of site layout planning. It is developed by developing a model based on a genetic-algorithm. The developed model can handle the irregular shapes of site by utilizing a grid with two dimensions. Every temporary facility is modelled as number of units of grid. Every unit's area is already calculated for each construction site. The main benefits of this model is its ability in dealing with any site shape, so it is not specified to only squares or rectangular shapes. Additionally, this model takes in consideration center-to-center distance, Eucliden distance as a distance measurement method.

Tommelein (1999) applied "travel-time simulation" to specify the locations of temporary facilities and capacity sizing. In this study, the real circumstances of construction sites like temporary facilities locations according to the locations of workers needs for workers, service time, and travel time are considered.

Akinci et al. (2000) presented a 4D work planner to identify the needed space for activities of construction and then treat time-space conflicts. 4D work planner firstly specifies conflicts within areas of working and after that collects the specified time-space conflicts. Next, it groups conflicts into different categories like safety conflicts and design. After that, class them depending on their risk. This system is helpful for projects managers in expecting the possible conflicts at sites of construction and using solutions to them before the beginning of construction projects.

Osman et al. (2003) developed evolutionary dynamic site layout planner, (EDSLP). It is an automated computer system, which can be adopted for specifying the optimal locations of temporary facilities of a project on sites with taking the dynamic nature of projects in consideration. Its main objective is lowering the costs of relocation and transportation. It comprises all of facilities input data, AutoCAD, and an evolutionary engine for performing optimization by using the genetic algorithms principles. The system uses a new approach known as "the Mini-Mini". The outputs that can be obtained from this system includes a sequence of layouts covering the whole duration of a project.

Elbeltagi et al. (2004) presented a model that takes in consideration issues of productivity and safety. Additionally, some of the constructed space is used as temporary facilities to decrease the happening squeeze on restricted sites. When a safety percentage increases between any temporary facilities, then a large negative value will be given to the weight of closeness. Otherwise, the further the space between temporary facilities, the less the layout score, enhancing by that the site layout. Moreover, the method of Eucliden distance is applied for distances measuring between temporary facilities on construction sites.

Ma et al. (2005) suggested a 4D integrated site planning system that integrates all of 3D models, schedules, site spaces, and resources with the technology of 4D CAD to get a capability of of 4D graphical visualization for planning of construction sites. The only problem with this system is the functionality deficiency in the exchange of data standards that don't permit data share by users with the other 4D systems.



Chau et al. (2005) noticed that most of the developed 4D techniques suffer of missing a number of constraints like management of resources and data exchange. Therefore, they tried to supply an additional comprehensive system for planning of construction by integrating all of 3D model, work breakdown structure, resources, scheduling, and tools of decision support.

Yeh (2006) suggested using of annealed neural networks model that is a combination of hopfield neural network and simulated annealing to lay out the temporary facilities that are determined in advance on predetermined locations of sites with the satisfaction of constraints.

Sadeghpour et al. (2006) proposed a model for layout of sites basing on computer-aided design. In this study, site layout problem is symbolized by developing a model based on a flexible objective. The suggested model allows for the formulation of the physical objects to match the exceptional demands of any project.

Essa et al. (2008) proposed a mathematical model to optimize the layout of sites. In their study, they divided the area of construction into unavailable area for the existent sites, and facilities, and available area for the objects that could be placed. The objective function of the model is subjected to a number of functional and physical constraints. The objective function of the model is formulated in a way leads to reducing the weighted distance between the sites and objects. Additionally, a number of constraints were developed to prevent objects of overlapping.

Zhou et al. (2009) chose the specialty area, tunnel construction, to develop a site plan application that is partially automated. In their approach, they integrated the common purpose simulation for logistics, resources dynamics, and space modelling with genetic algorithms, so that the layout would be optimized based on different rules and constraints.

Taneja et al. (2010) developed a WLAN-based model as a localization technology. For developing this model, authors have selected fingerprinting algorithms.

Chavada et al. (2012) developed a 4D/5D model by integration building information modelling and critical path method data, a traditional process of planning, achieving by that a real-time management.

Abdelrazig (2015) presented a general formula for planning layout of a project's site dynamically by adopting the algorithm of colony optimization. The developed model's objective is to reduce the cost of movements of equipment fleet among facilities. The movements' cost in this model is represented as product of distances of traveling among the facilities and the traveling frequency.

Papadaki et al. (2016) developed an optimization model of multiple objectives. The main goal of the developed model is lowering the construction cost of a facility posited at substitutional places, lowering cost of transportation among locations, and taking in consideration safety concerns by specifying the amount of remoteness or proximity of a specific facility to another or to area of work.



Oral et al. (2018) proposed a user-friendly model for planning of construction site layout that comprises an approach of risk assessment for the constraints of safety by utilizing the algorithm of “multi-objective particle swarm optimization”. The proposed model is developed based on the approach of Pareto dominance to reduce the risks of construction projects that operate cranes and to minimize the whole distance of traveling of resources among temporary facilities.

3. Software for site layout

Many software has been utilized to use by researchers for planning of construction site layout, but in this section only five of them are included. These software are chosen because they are accepted in a high percentage by the practitioners of construction industry, easily implemented, and used in an extensive way in various industries. A quick summary of each software is included in this section.

- CRAFT: it stands for “computerised relative allocation of facilities techniques”. It was firstly proposed by Armour and Buffa (1963). It is a computer based technique used for temporary facilities layout, resulting in minimizing the construction materials handling cost. The main benefit of this software is its ability in treating as many as forty departments, and it can perform computations by fixation the locations of departments through specifying them in the instructions that the departments will not be exchanged. That is why is considered as an improvement way because it needs an initial layout to begin its job. The main inputs of this software include: chart of cross relationship giving number of units moved between departments over a given time period and cost of moving one unit distance between departments, areas of departments, and initial layout. Thereafter, the main outputs comprise a heuristically optimal layout diagram, whole distance moved, and cost (Bhattacharya, 2014).
- CORELAP: it stands for computerized relationship layout planning, and it was proposed by Lee and Moore (1967). It is classified as a construction method since it does not require an initial layout to start. This technique needs the relationships of closeness between departments and their sizes. The departments’ sizes are allowed to change as inputs. Next, adjacency is the most important factor in CORELAP where adjacency is defined as a coefficient between two places. Adjacency coefficient ranges between 0 and 1. Adjacency types include: fully adjacent that has value of 1, partially adjacent with value of 0.5, and non-adjacent with value of 0. The main input comprise chart of relationship with the departments weights and areas and numbers of the departments. The outputs include one final optimal layout that will specify the wanted shapes of facilities.
- ALDEP: this abbreviation stands for automated layout design program. Seehof and Evans developed it in (1967). This technique utilizes the relationships of closeness between sizes of departments with shapes and sizes of facilities as inputs. Outputs of this technique comprises producing a number of options of the last layout design. It starts its job by randomly choosing the first department then selecting the adjacent ones depending on the closeness ranking with placed department in advance.



After that, all the produced designs are scored depending on the adjacent department that is existed in the produced layout to specify the optimal one. This technique is workable only with facilities having regular shapes.

- QAP: it stands for “quadratic assignment problem”. This technique is difficult in implementation because it has a number of limitations. The limitations include flow between departments is assumed to be constant over the facilities’ life, and the size of all departments is equal, the shapes of all departments is uniform (Hosseini-Nasab et al., 2017).
- MULTIPLE: This abbreviation stands for “multi-floor plant layout evaluation”. This technique was firstly developed in (1994) by Bozer et al. It is useful for planning of site layout with facilities having regular shapes, multiple floors, and fixed departments. In this technique, it is allowed to change any of non-adjacent departments to produce a new layout.

4. Discussion

A number of the published studies are mentioned in the previous sections. As indicated previously, the process of construction site layouts are influenced primarily by a number of factors, such as the applied construction method, project’s activities schedule, workers and equipment distribution, materials mobilization, etc.; the thing that limits the effectiveness of the optimization methods where interactions would happen among those factors and let the process of planning of site layout very complicated practically. Next, Zhou et al. (2009) stated that when the site layout of a project is planned by using of optimization methods, then an optimal layout can’t be guarantee developed. Optimization methods don’t take in consideration a number working factors, such as relationships between projects activities, resources allocation, rate of production, and idleness of construction equipment. On contrast, the developed simulation tools are capable of considering those factors, although very few applications of simulation have been utilized in planning of site layout as a number of them are aforementioned. Moreover, the published studies didn’t consider the environmental impacts caused by projects in the developed sites layout planning; usually, time and cost of travelling are the decision variables. Why environmental impact is a necessity because global warming is the whole world’s problem, and statistics declared that carbon dioxide emitted from construction industry contributes for about 30% of the annual global greenhouse gas emissions (IPCC, 2007).

5. Conclusion

Planning of layout of projects’ sites is one of the most essential processes in construction media. A well-planned site layout results in a safer environment for working and more effective operations at sites of construction. It affects principally time, cost, and production of construction. Two main adopted methods for performing the process of planning of site layout: heuristic methods and mathematical optimization. Heuristic methods are utilized for planning of site layout of large-scale projects to give good but not optimal



results. Mathematical optimization methods are usually adopted for developing site layout designs of smaller projects because they require performing complex computations to result in optimum designs.

6. References:-

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