A Framework to optimize Construction Site Layout Planning

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Abstract: *The layout and positioning of temporary construction facilities is an important process in construction project planning that affect cost, productivity, and safety. Even though building site layout planning is a key procedure, systematic examination of the site layout is always challenging due to a large number of constraint and interconnected planning limitations. The construction area may consist of an unavailable area that includes existing facilities (sites) and available areas in which the objects can be located (Amit R Soygaonkar, 2014). The layout of objects is accomplished by optimizing a specific objective function and satisfying a variety of constraints (Elbeltagi, 2007). Thus, construction site layout is a complex problem whose solution requires the use of analytical methods (overview, 2019). Mathematical optimization procedures have been developed to produce optimal solutions, but they are only applicable for small-size problems (overview, 2019). In this research, an optimal framework for tackling the site layout design problem with linear and real distance between facilities is created. An ongoing building project is analysed to validate the performance of the proposed model. The results showed that appropriate solutions could be found and that this optimization framework might be utilized to improve building site planning. A score-based checklist to determine the requirement for CSLP optimization is also created and applied to 6 ongoing projects and result of the same are analysed.*

Keywords: Construction Site layout Planning, Optimization, site facilities.

1. Introduction

Construction site layout planning entails determining the size and location of temporary and permanent facilities within the construction site's perimeter, which has a substantial impact on the site's safety, efficiency, productivity costs, and duration. Although the contractor aims to minimise the travel cost of resources on-site by ensuring proper circulation, often they do not consider the constraints that are present at the site as the project progresses. Failure to plan the site layout for construction in advance is a leading source of operational inefficiency, and it can raise the project's overall cost and duration. This research aims to develop a site layout planning framework that will help in the optimization of site layout and the same shall be validated in terms of travel cost. An optimized site layout plan enables the most efficient use of available space, lowers project costs, decrease material relocation during construction, improves site accessibility and security and worker safety.

2. Aim

This study aims to identify issues at the construction job site due to construction site layout planning and to develop an optimization framework for Construction site layout planning**.**

3. Objectives

1. To research and analyse the construction site layout design of various projects to identify concerns and their impact on the project.

2. To list the issues that occur at the site due to CSLP during the construction timeline of the project.

3. Develop a checklist to determine the requirement for CSLP optimization and design a framework for optimising the layout in terms of cost.

4. Scope:

This study will focus on developing an optimization framework for the planning of construction site layout based on their location and distance between them.

5. Limitations:

Since every construction site is unique, this optimization framework only includes the constraints that are available in the planning of construction job-site layout. A case example has been used for developing the framework which is further validated through a case study.

6. Element-Issue-Effect Matrix

Elements	Issues	Effects
• Material Storage • Labour Hutment • Construction Equipment • Batching Plant • Bar-Bending Shop • Testing Lab • Accessibility • Site Office • Site Objects • Services • Parking • First Aid Station	• Increase in travel time. • Barriers/Diversions/narrow access roads. • Distance between the facility and the construction work area. • Material Storage: Damages, Limited space, non-segregation. • Labour Hutment: Lack of Ventilation, Hygiene and overcrowding.	• Accidents. • Fire Hazards • Vandalism and material loss. • Increased travel distance. • The increased cost of the project. • Increase the completion time of the project. • Reduction in the quality of work. • Double handling material. • Overcrowded Work Space. • Decrease in Quality

Table: Element, Issue & Effect Table

7. Need for Construction Site Layout Planning

Space on the job site is as valuable as money, time, materials, labour, and equipment. Because site space is restricted, all facilities must be provided within the property's perimeter. In most cases, site space is allocated based on the project manager's experience, and adequate site planning is overlooked. There are two general objectives that planners should seek to meet through the careful organization of the site for construction. (Dr. Emad Elbeltagi). First, the site must be designed to maximize the efficiency of operations to promote worker productivity, shorten project time and reduce cost. Second, the final plan must create a project with a good work environment to attract and retain the best personnel and thus contribute to better work quality and productivity (Dr Emad Elbeltagi). One of the most important tasks of site management is site layout planning. Huge projects with a large number of workers, subcontractors, and equipment may face severe schedule and cost overruns if site planning is not comprehensive and methodical. Precise design of the site layout and placing of temporary facilities can enable management to make considerable improvements by reducing travel time, increasing productivity, and exhibiting a better and safer work environment. Failure to prepare the site layout for construction ahead of time is a leading cause of operational inefficiency, and it can significantly raise the overall cost and duration of a project. A site layout plan should enable the most efficient use of available space, lower project costs, less material relocation during construction, greater site accessibility and security, and worker safety. Various aspects are considered when developing an optimal building site layout, many of which interact with site layout design. Through literature study following broad problem areas have been identified:

- Sequencing of activities and coordination.
- Site Circulation.
- Material storage, location and its sizing.
- Inadequate space availability.
- Temporary facilities location.
- Safety of workers.
- Security at the site.

8. Factors affecting Construction Site Layout Planning

Following are the various factors that affect Construction Site Layout Planning: Nature of the Project, Topography, size of Site, Construction Methods, Types and Availability of Resources, Phasing, Construction sequence, Pre-Existing site factors, Access to Site, Internal Roads, Availability of Accommodation, Services.

9. Optimization Framework of Construction Site Layout Planning

This chapter contains a framework for improving the construction site layout planning process. It includes the technique as well as the explanation of each step. Because it is a CSLP framework, it is best used on new construction sites where the site may be planned using the framework's standards and parameters to save money, improve safety, and increase productivity. The site constraint of irregular movement is taken into account by this framework. A marking system for the construction site plan will be developed at the end of the framework to determine whether the site is adequate or whether it needs optimization. This is accomplished by analysing the site and calculating the scores using a checklist. If the site's score falls below 50%, it's time to reassess the procedures and come up with a better solution.

01	Data Collection	Project and site details
02	Identification of Required Facilities	Appendix 1
03	Demarcation of Excavation Line	The first step before planning
04	Dividing Site into a Grid	Minimum of 1m X 1m
05	Group formation of identified Facility	Reference to Appendix 2
06	Sizing of Facilities Groups	As per Appendix 2
07	Distance identification between groups	
08	Generating Construction Site Layout Plan	CAD, BIM etc
09	Compliance with the Checklist	Table 5-1, 5-2
10	Generation of the optimum site layout.	
Re-iterate if required and then to be compared with the cost of travel.		

Table: Construction site layout planning methodology

Step 1: Data Collection

Data to be available to start planning construction site layout are:

Site details

Phasing of project

Available constraints at the site

Step 2: Identification of facilities required for CSLP

To identify all the facilities that are required or will be later required for the successful completion of a project. Through case example review and literature study, a data set of facilities has been developed in appendix 1.

Step 5: Group formation of identified Facility

For this study, based on literature and case example analysis, identified facilities are grouped to provide a more defined layout – in appendix 2. Out of the identified groups, Group 6 and 7 are not clubbed for their proximity but their type and for the optimization problem they will not be considered.

Step 6: Sizing of Facilities Groups

As developed through literature study, we can successfully calculate how much are would one group of the facility take. This step is required for layout planning.

Step 7: Distance identification between groups

The closeness relationship matrix has to be made and the required distances between them are identified on this basis of the literature study.

Proximity weight	Desired relationship	Representation
X	Undesirable	A
2x	Unimportant	B
3x	Ordinary	C
4x	Important	D
5x	Very important	E

Table: Closeness relationship and their proximity

It is represented in the proximity closeness relationship matrix as follows:

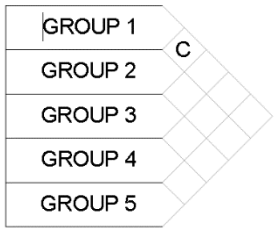

Figure 5.2.1 Proximity Matrix Source: (Amit R Soygaonkar, 2014)

Step 8: Generating Construction Site Layout Plan

The site and facilities are modelled in the present study using a two-dimensional grid. Each grid unit is called a cell, the area of which is user-defined. Hence, any irregular shape of the site can be modelled. A facility can be represented in the grid as several grid units, which can be calculated later.

Checklist for efficient site layout: Planning

Sr. No.	Questions	Y/N
1	Size of the temporary facility as per Appendix 1	
2	Design of material storage as / standards	
3	Compliance of facility groups as per closeness relation (Appendix 2)	
4	More than 1 access gate to the site.	
5	Adequate Parking for Construction Equipment	
6	Planned storage of material inside/near the building	
7	Segregated and properly barricaded storage for topsoil	
8	Absence of obstacles in material movement at the site	
9	Adequate Parking near the site office	
10	Availability of planned Material laydown area	

Points: A/10

Checklist for efficient site layout: Safety
Points: B/10

TOTAL: (A+B)/20

Sr. No.	Questions	Y/N
1	Availability of Fire Evacuation Route	
2	Entry/Exit sufficient for the movement Fire Fighting Vehicle	
3	Separation of Flammable Material Location	
4	Separate storage for Hazardous Material combination	
5	Segregation of Heavy Vehicle Movement and Pedestrian Movement	
6	Availability of First Aid Facility near Site Office	
7	Availability of Assembly area	
8	Segregation of waste material storage	
9	Closed storage for waste material	
10	Minimum 3m clear distance around the excavation line	

If the total point score is less than 50%, then it is essential to review the practices and come up with an optimised result. In appendix 2, Checklist compliance is done on 6 case examples (Appendix 3) out of which 4 sites received less than 10 marks. Site 3 is identified to receive the lowest marks.

10. Conclusion

By analysing various construction site layouts and through literature study, it is evident that all of them needs optimization in different criteria such as safety at the site, compliance with fire standards, excessive space utilization, distances between the facilities, etc. Since this study was based on only the planning aspect of CSLP, other constraint related to project schedule, stakeholder decision was not touched upon. There is a scope for further study in this area as well as scope for an increase in awareness of the proper planning of construction sites. By applying the framework to a case study, and modifying the Construction site layout, compliance with the checklist came to 18/20 instead of 7/20. Travel cost was reduced to 30%. This can be further be enhanced by using dynamic planning tools. Through literature and case example, it is also concluded that the current site layout practices that are being followed in our industry need thorough review as no one calculate the implication of cost and time it bears if it is not well planned.

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Appendix 1			
Sr. No.	Category	Quantity	Area
3	NO. OF ENTRY EXITS		
4	STAFF AND LIGHT VEHICLE ROAD		
5	HEAVY VEHICLE ACCESS ROAD		
6	ELECTRIC POLES		
7	FIRE EVACUATION ROUTE		
8	SITE OFFICE		
9	PARKING		
10	GUARD ROOM		
11	FABRICATION YARD		
12	REINFORCEMENT STORAGE		
13	FITTINGS STORAGE		
14	SCAFFHOLDING STORAGE		
15	BATCHING PLANT		
16	AGGREGATE STORAGE		
17	SAND STORAGE		
18	BRICK STORAGE		
19	CEMENT STORAGE		
20	QA/QC TEST LABORATORY		
21	WORKSHOP		
22	LABOUR HUTMENT		
23	TOILETS		
24	MESS		
25	MEDICAL FACILITY		
26	ASSEMBLY AREA		
27	TIME OFFICE		
28	WATER TANK		
29	CHEMICAL STORAGE		
30	DG SET		
31	TOP SOIL STORAGE		
32	FABRICATION WASTE		
33	DIESEL STORAGE		
34	TOWER CRANE		
35	EXISTING SITE ELEMENTS (TREES)		
36	WEIGH BRIDGE		
37	INDUSTRIAL WASTE		

APPENDIX 2- CONSTRUCTION SITE PLANNING FACILITIES					
PROJECT NAME					
BUILDING TYPE					
SITE AREA					
SITE FORM					
Sr. No.	Group	Category	Value	Area	Existing Area
1	GROUP 1	GUARD ROOM		0	
2		SITE OFFICE		0	
2.1		Cabins		0	
2.2		Meeting room		0	
2.3		Pantry		0	
2.4		Storage		0	
2.5		Toilets		0	
2.6		First-aid room		0	
3		PARKING		0	
4	GROUP 2	FABRICATION YARD		0	
4.1		Reinforcement storage		0	
4.2		Cutting		0	
4.3		Bending		0	
4.4		Waste Storage		0	
5		Formwork storage		0	
6	GROUP 3	BATCHING PLANT		0	
7		AGGREGATE STORAGE		0	
8		SAND STORAGE		0	
9		CEMENT STORAGE		0	
10		WASTE STORAGE		0	
		TOTAL		0	
11	GROUP 4	QA/QC TEST LABORATORY		0	
12		BRICK STORAGE		0	
13		MATERIAL STORAGE		0	
14		EQUIPMENT STORAGE		0	
15		WORKSHOP		0	
		TOTAL		0	
16	GROUP 5	LABOUR HUTMENT		0	
17		LABOUR TOILETS		0	
18		MESS		0	
19		FIRST AID		0	
20		WATER TANK		0	
21		ASSEMBLY AREA		0	
		TOTAL		0	
21	GROUP 6	DG SET		0	
22		TOP SOIL STORAGE		0	
23		DIESEL STORAGE		0	
24		TOWER CRANE			
25		EXISTING SITE ELEMENTS (TREES)			
26		MACHINARY PARKING		0	
1		NO. OF ENTRY EXITS			
2		STAFF AND LIGHT VEHICLE ROAD			
3		HEAVY VEHICLE ACCESS ROAD			
4		ELECTRIC POLES			
5		FIRE EVACUATION ROUTE			

Appendix 3: Construction site facility study if 6 Construction Sites								
Sr. No.	Category	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7
	Building Type	Institutional	Administration	Institutional	Residential	Mixed use	Hospital	Hospital
	Site Area	75878 sqm.	49,331.18 Sqm.	44,686 sqm.	10,010 sqm.	7205 sqm.	60,000 sqm.	20,90,00 sqm.
1	Size of temporary facility as per Appendix 1	N	Y	N	Y	N	N	Y
2	Design of material storage as / standards	Y	N	N	N	N	N	N
3	Compliance of facility groups as per closeness relation (Appendix 2)	N	N	N	N	N	Y	N
4	More than 1 access gate to site.	Y	Y	Y	Y	Y	Y	Y
5	Adequate Parking for Construction Equipment	N	N	N	N	Y	N	Y
6	Planned storage of material inside/near the building	Y	N	N	N	Y	Y	N
7	Segregated and properly barricaded storage for top soil	Y	Y	N	Y	Y	Y	Y
8	Absence of obstacles in material movement at sit	N	N	Y	N	N	N	N
9	Adequate Parking near site office	Y	N	Y	Y	Y	N	Y
10	Availability of planned Material laydown area	Y	Y	N	N	N	N	N
11	Availability of Fire Evacuation Route	N	N	N	N	N	N	N
12	Entry/Exit sufficient for the movement Fire Fighting Vehicle	Y	N	N	N	N	N	Y
13	Separation of Flammable Material Location	Y	N	N	N	N	N	N
14	Separate storage for Hazardous Material combination	N	N	N	N	N	N	N
15	Segregation of Heavy Vehicle Movement and Pedestrian Movement	Y	N	Y	N	Y	N	Y
16	Availability of First Aid Facility near Site Office	Y	Y	Y	Y	Y	Y	Y
17	Availability of Assembly area	Y	Y	N	Y	Y	Y	Y
18	Segregation of waste material storage	Y	Y	N	Y	Y	Y	N
19	Closed storage for waste material	Y	Y	N	N	Y	Y	Y
20	Minimum 3m clear distance around the excavation line	Y	Y	Y	Y	Y	Y	Y
	TOTAL POINTS (A+B) OUT OF 20	14	8	6	8	11	9	10