# Dynamic Site Layout Planning using Work Study

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**ABSTRACT -** *The construction projects are complex and dynamic in nature. The site layout planning has always been the challenging issue for the construction planners. Site layout planning implies identifying and locating construction facilities, equipment and storage areas on the site. Due to unplanned or ad hoc allocation of location to construction facilities, ineffective movement of men, materials and equipment may occur resulting in delay and increased project cost. The nature of construction project changes with construction activities and time. Since work study is a tool of operation management, it can be seen as a method for improving construction site layout bottleneck. The objectives of the research are to investigate method study techniques to plan appropriately for dynamic site layout planning. To achieve the objectives, case study of an ongoing construction project was taken for research study. All the facilities with their space requirements and actual duration for which they exit on site were estimated. Various method study charts were used to record and examine the movements of workers and materials and partial site layouts were drawn to show the changes occurring at sites. The use of dynamic concept using work study approach showed significant improvements.*

**Key Words: Site layout planning, Static layout, Dynamic layout, Work Study, Method Study**

## 1. INTRODUCTION

Site layout planning is a task of allocating construction facilities to optimum location to improve safety and productivity. Construction facilities e.g. site offices, batching plants, tower cranes, material storage areas, etc. are required on the site for specific period of time. These construction facilities are required to support the construction process and are temporary in nature. Generally, construction facilities are allotted space on first-come first served basis (Andayesh and Sadeghpour, 2014). As the project progresses many construction facilities will be required to complete the project.

Many researchers have tried to find the factors responsible for decrease in construction site productivity. Kaming et al. (1998) concluded that space constraints due to poor site management have been responsible for productivity loss at construction sites. Sanders et al. (1989) showed efficiency decreases up to 58% and 65% due to restricted access and congested workplace respectively.

The project site space is as important as other resources required at the construction site and requirement of site space changes with time. The activities required at various intervals of time, consequently the facilities involved are also required at various stages of construction. The site layout models are generally classified into two categories with respect to time factor: static models and dynamic models (Chau et al. 2004). In static models all the construction facilities are assumed to exist on the site for entire duration of the project (Andayesh and Sadeghpour, 2013). As the construction facilities are dynamic in nature i.e. they are required for certain period of time, the static model's assumption doesn't give the real picture. The dynamic models show the changes as the project progresses (Elbeltagi et al., 2001). In general practice the construction planners do not update the site layout as the project progress resulting in adoption of static models in their approach. Studies showed that site efficiency and productivity can be enhanced with dynamic site layout planning.

Efforts have been made by the researchers to optimize the site space using dynamic models. Li and Love (1998) took a case study of construction site and optimized the objective function for the temporary facilities using genetic algorithm (GA) method. Guo (2002) suggested using AutoCAD for space planning and MS Project for project scheduling to solve problems related to space utilization. Wang et al. (2004) used 4DSMM+ models and linked with the project activity schedule for using in resource management and layout development. Chau et al. (2004) gave the four-dimensional model by linking three dimensional geometrical models with construction schedule data. Andayesh and Sadeghpour (2014) showed the dynamic models allow reuse of space for the incoming temporary facilities on the construction site while static models don't utilize the construction space efficiently.

Researchers have taken the closeness weight factor among the facilities to optimize the respective objective functions (travel cost, total site layout cost etc.), but emphasis has not been given to determine the flow of materials or men. Work study is systematic study of methods of work in order to improve effective use of resources and set standard of performance. The method study, a component of work study can be defined as the procedure of systematic recording, analysing and critically examining the existing or proposed method of doing work for the purpose of developing more effective work. Method study can be used to simplify the various activities and determine the flow of men and materials.

Work Study concepts and techniques have been used for improvement in plant layout in manufacturing industries. The recording techniques along with the charts (ILO 1967) available help in finding the flow of men, material and equipment. Oglesby et al. (1989) has raised the fact that despite an important tool of operation management, work study approach has not been properly used in construction industries. Pandey and Maheswari (2015) highlighted that construction industries is complex and implementing work study in construction industries is a challenging job. A case study conducted on construction project (Pandey and Maheswari 2015) suggested use of work study.

In the present study the construction flow processes have been tracked using various method study charts to find the bottleneck. The entire study has been done to highlight the importance of construction site layout planning by adopting the dynamic approach and implementation of work study in construction projects.

## 2. METHODOLOGY

The entire project was divided into various phases of construction. The number of phases can be decided on the basis of construction schedule, changes in activities and temporary facilities required in the construction site. The size and type of temporary facilities depend on amount of work and type of activities involved. The estimation of duration of facility was done on the basis of activity schedule. For instance, concreting work is required for specific duration, the facilities associated with this activity would be required for that period of time. This approach included the time factor and helped in reuse of the space available at site in better way. After deciding the facilities required and their duration on site, the facilities were classified into fixed, stationary and moveable.

Work study techniques were used to understand the flow of materials and workers at the selected project sites. Various charts of method study were used to record and analyze the flow of materials among temporary facilities. The string diagram was avoided and split into travel and frequency chart. Travel and frequency charts were needed to estimate the distances and number of trips among various facilities. A relationship diagram (Wiyaratn, W. and Watanapa, A. 2010) was drawn to show the closeness among the temporary and fixed facilities. The ratings used in relationship charts were based on literature review. The idea was to rate the closeness between two facilities based on the flow, frequency of trips, easy exchange of information and hindrance. The site layout was developed using AutoCAD. All the facilities were represented using rectangles for developing site layouts in AutoCAD.

## 3. CASE STUDY AND FINDINGS

A case study was conducted at an ongoing construction site of luxurious residential project. The project was of 39 months duration. Table 1 shows the facilities identified at the construction project.

### 3.1 Facilities identification and classification

It was noticed that site layouts were not regularly updated at the site and used only during client and contractor meetings. Since the construction site has enough space for temporary facilities, space allocation for incoming facility would never be a problem. This could be one of the factors for not considering the dynamism of the site planning during initial stage.

The construction project was divided into two phases. The phases of construction were decided based on the activities and the incoming facilities. Most of the facilities were present in the first phase. The finishing activities started after the underground works and some extent of superstructure work were completed. This marked the second phase of the project. The construction project has been divided into phases so as to highlight the importance of dynamism of the site. The facilities were then classified into fixed, stationary and moveable as shown in table 2 to look for any possibilities of reuse of space.

Table 1: Facilities identification and area requirement

| S.No. | Facility | Number | Area ($m^2$) | Total Area ($m^2$) | Duration (months) |
|---|---|---|---|---|---|
| 1 | First Aid Centre | 1 | 15 | 15 | 36 |
| 2 | EHS Department | 1 | 15 | 15 | 36 |
| 3 | Worker's Induction Room | 1 | 15 | 15 | 34 |
| 4 | Time Office | 1 | 15 | 15 | 34 |
| 5 | Visitor induction Room | 1 | 15 | 15 | 34 |
| 6 | Workers Rest Room | 1 | 180 | 180 | 34 |
| 7 | Workers Canteen | 1 | 180 | 180 | 34 |

| | | | | | |
|---|---|---|---|---|---|
| 8 | Stack Bins for Aggregates, Sand | 4 | 120 | 480 | 33 |
| 9 | Batching Plant 1 | 1 | 200 | 200 | 33 |
| 10 | Batching Plant 2 | 1 | 200 | 200 | 33 |
| 11 | Cement Storage | 2 | 445 | 890 | 33 |
| 12 | Concrete Testing | 1 | 30 | 30 | 31 |
| 13 | Quality Lab | 1 | 280 | 280 | 33 |
| 14 | Reinforcemen t Yard | 1 | 700 | 700 | 35 |
| 15 | Formwork yard | 1 | 153 6 | 1536 | 35 |
| 16 | P&M Yard | 1 | 338 | 338 | 35 |
| 17 | Store | 1 | 430 | 430 | 34 |
| 18 | Office | 1 | 430 | 430 | 36 |
| 19 | Vendors Room | 1 | 360 | 360 | 34 |
| 20 | Marble Cutting Yard | 5 | 150 | 750 | 19 |

The definitions of various types of facilities are given below:

1. Fixed facilities: These facilities have predetermined fixed location at the construction site and don't change over project duration.
2. Stationary facilities: These are temporary facilities which are allotted space only once during the entire project duration such as tower cranes and batching plants.
3. Moveable facilities: These are those temporary construction facilities which can be relocated at any stages of project. For example reinforcement yard, godown etc.

Table 2: Classification of facilities

| FACILITIES | PHASE 1 | PHASE 2 |
|---|---|---|
| Tower A | Fixed | Fixed |
| Tower B | Fixed | Fixed |
| Tower C | Fixed | Fixed |
| Tower D | Fixed | Fixed |
| Tower E | Fixed | Fixed |
| Tower F | Fixed | Fixed |
| Batching Plant 1 | Stationary | Stationary |
| Batching Plant 2 | Stationary | Stationary |
| Tower Crane 1 | Stationary | Stationary |
| Tower Crane 2 | Stationary | Stationary |
| Tower Crane 3 | Stationary | Stationary |
| Quality Lab | Moveable | Moveable |
| Reinforcement Yard | Moveable | Moveable |
| Formwork Yard | Moveable | Moveable |
| Cement Godown 1 | Moveable | Moveable |
| Cement Godown 2 | Moveable | Moveable |
| Site Office | Moveable | Moveable |
| First Aid Centre | Moveable | Moveable |
| EHS Department | Moveable | Moveable |
| Worker's Induction Room | Moveable | Moveable |
| Time Office | Moveable | Moveable |
| Visitor's Induction Room | Moveable | Moveable |
| P&M Yard | Moveable | Moveable |
| Store | Moveable | Moveable |
| Marble Cutting Yard | - | Moveable |
| Worker Canteen | Moveable | Moveable |
| Worker Rest Room | Moveable | Moveable |
| Stack Bins | Moveable | Moveable |

## 3.2 Facility representation and site layout

The site layouts were drawn to scale using the AutoCAD software which is mostly used in Indian construction industries. The facilities were represented in Fig. 1 using the rectangles as suggested in literature (Rayes and Said 2009). Initially most of the temporary facilities were planned to locate little far from towers as excavation was going on for underground works. The stationary facility like batching plant was given preference while giving space. The other facilities like reinforcement yard, P&M yard, formwork yard etc were given preference after batching plant. Site office, stores and vendor office locations were planned such as to avoid movement of heavy vehicles with those of staffs. According to the planners at work site, initially most of the materials used during construction process were of rugged in nature. Therefore, the temporary facilities such as batching plant, reinforcement yard etc. those which handles rugged materials were planned to locate separately away from movement of workers to ensure safety. The facilities such as workers induction room, EHS and first aid room were planned close to towers.

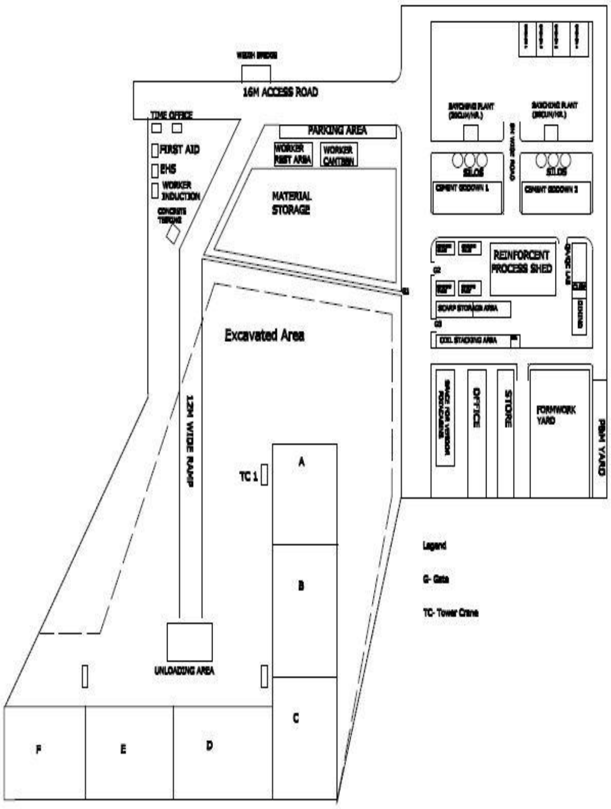


Fig. 1: Site layout for phase 1

## 3.3 Construction Schedule

The construction schedule shown in table 3 was estimated from the schedule of activities required on the site and their duration. Every facility was given 2 months for installation and mobilization on site i.e. November 2013 to December 2013. Facilities like batching plant, reinforcement yard, formwork yard, P&M yard etc. were needed at the start of project as reflected from the activities schedule. The finishing activities started after completion of underground work and some extent of superstructure work. For this, the marble cutting yard was established.

## 3.4 Implementation of work study

Work study was used to collect information regarding the flow processes of materials and workers. Various method study charts were applied to understand the flow of materials. The idea was to understand how the activities are related to various facilities. The material flow chart drawn gives the current practices or path adopted for movement of materials among the various facilities at the work site. The construction activities were divided into various sub activities to track the work flow among the facilities. Table 4 shows the flow process chart of concrete using various elements of method study i.e. operation, transportation, inspection, storage and delay. The total distances covered by transit mixer during one-way flow was 372 meters. A total number of 8 transit mixers were operating at site with each of maximum capacity of 7 cubic meters.

Table 3: Construction schedule of facilities

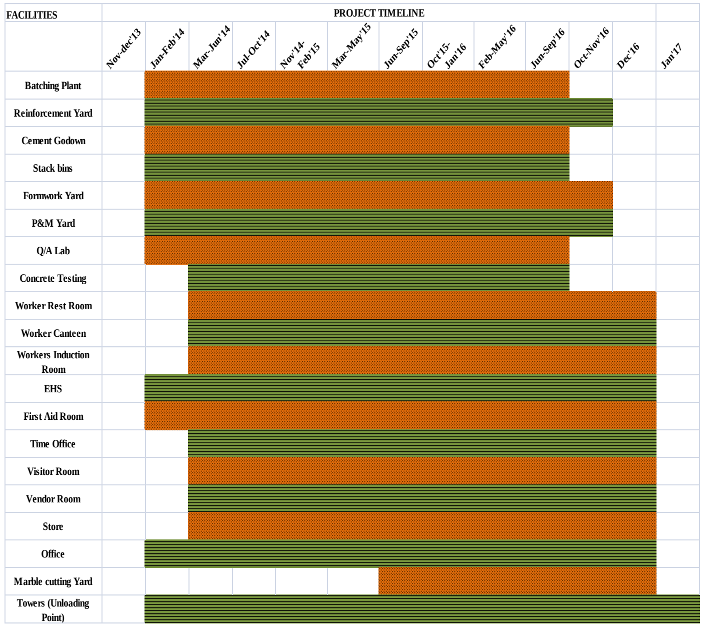


Table 4: Material flow process chart of concrete

| | Chart: Material Flow Chart<br>Material: Concrete | | | | | | |
|---|---|---|---|---|---|---|---|
| Step No. | Activities | Operation | Transportation | Inspection | Delay | Storage | Distance Covered (m) |
| 1 | Requisition for concrete from site | | | | x | | |
| 2 | Aggregates from stack bins to batching plant | | x | | | | |
| 3 | Preparation of concrete | x | | | | | |
| 4 | Discharge of concrete from batching plant to transit mixer | | | | | x | |
| 5 | Waiting of transit mixer driver for batch sheet | | | | x | | |
| 6 | Transportation of concrete from batching plant to concrete testing through transit mixer | | x | | | | 222 |
| 7 | Collection of concrete sample and batch sheet | | | | x | | |
| 8 | Truck mixer from concrete sampling facility to site | | x | | | | 150 |
| 9 | Pumping of concrete to towers | x | | | | | |
| | TOTAL | | | | | | 372 |

Table 5 shows the existing method of material flow chart for rebar at construction site. The average requirement of the reinforcement at the site including the slab, column and shear walls was 25 metric tons per day and average carrying capacity of truck was 4 metric tons.

Table 5: Material flow chart for rebar

| | **Type: Material Flow Chart** | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Material: Rebar** | | | | | | |
| **Step No.** | **Activities** | **Operation** | **Transportation** | **Inspection** | **Delay** | **Storage** | **Distance Covered (m)** |
| 1 | Arrival of truck with rebar at site | | x | | | | |
| 2 | Weight measurement at weigh bridge | | | x | | | |
| 3 | Moved from weigh bridge to stacking yard | | x | | | | 190 |
| 4 | Stacking of rebar | | | | | x | |
| 5 | Cutting of rebar | x | | | | | |
| 6 | Bending of rebar | x | | | | | |
| 7 | Loading of rebar to truck through mobile cranes | x | | | | | |
| 8 | Moved rebar to site (unloading point) | | x | | | | 445 |
| 9 | Moved rebar to towers through tower cranes | x | | | | | |
| | TOTAL | | | | | | **635** |

Material flow chart for marble is shown in table 6. Phase 2 of the construction noticed establishment of marble cutting yard. The marble cutting yard was placed near to the passenger hoists. During the initial planning, marble cutting yard was not considered for allocating space as only one site layout was drawn. The marble blocks were transported to the yard through tractor carrying around 70 marble tiles at a time of dimension 2800mm by 1600mm. The unloading of the marble blocks took around an hour with the help of 1 skilled and 1 unskilled labours.

Most of the movements of workers were among the following facilities i.e worker induction, EHS, near towers to be constructed, worker rest room and worker canteen. Another point to be mentioned is that from activity 1 to activity 5 in worker flow diagram shown in table 7 were almost common every day at the work site. The only difference was that some of the worker instead of going to unloading point (towers), they moved to facilities like batching plant and reinforcement yard. The charts prepared are part of method study and data collected are based on observations and investigations at site.

Table 6: Material flow chart for marble

| | **Type: Material Flow Chart** | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Material: Marble** | | | | | | |
| **Step No.** | **Activities** | **Operation** | **Transportation** | **Inspection** | **Delay** | **Storage** | **Distance Covered (m)** |
| 1 | Transportation of marbles through tractors to marble cutting yard | | x | | | | 337 |
| 2 | Unloading of marble blocks | | | | x | | |
| 3 | Stacking of marble blocks | | | | | x | |
| 4 | Laying of marble block on bed | x | | | | | |
| 5 | Checking of alignment and marking | | | x | | | |
| 6 | Cutting of marble block into required pieces | x | | | | | |
| 7 | Stacking of marble pieces on trolley | | | | | x | |
| 8 | Transportation of marble pieces to passenger hoist | | x | | | | 30 |
| 9 | Distribution of marble pieces to respective floors | x | | | | | |
| | TOTAL | | | | | | **367** |

Table 7: Worker flow chart

| | **Type: Worker flow chart** | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Staff/worker: Worker** | | | | | | |
| **Step No.** | **Activities** | **Operation** | **Transportation** | **Inspection** | **Delay** | **Storage** | **Distance Covered (m)** |
| 1 | Entry of worker at the site (Entry point) | | x | | | | |
| 2 | Movement of worker from entry | | x | | | | 40 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | point to worker induction room | | | | | | |
| 3 | Waiting for safety officer to organize safety meeting | | | | x | | |
| 4 | Arrival of safety officer from EHS to worker induction room | | x | | | | |
| 5 | Inspection of worker's PPE | | | x | | | |
| 6 | Movement of worker from worker induction room to unloading point | | x | | | | 168 |
| 7 | Jobs performed by worker | x | | | | | |
| 8 | Movement of worker from unloading point to worker rest area | | x | | | | 210 |
| 9 | Movement from worker rest room to worker canteen | | x | | | | 23 |
| | TOTAL | | | | | | **441** |

### 3.5 Travel chart and relationship diagram

To track the movements of materials and workers string diagrams are useful and in this study string diagrams were split into travel charts and frequency charts to record the distances and frequencies of movement respectively. The matrix used in the travel chart shown in table 8 is symmetric in nature to avoid complexities and for uniform measurements. The distances were measured among the facilities using AutoCAD software as site layout was drawn to scale. The frequency chart was prepared shown in table 9 based on the number of trips among the facilities. The data collected was based on the observations taken at the work site for particular duration of time. The duration of observation varied for every activity but the idea was to observe which of the facilities were heavily loaded with activities.

The travel chart and frequency chart shown in table 8 and table 9 respectively are for phase 1 and phase 2 facilities. The units in frequency chart are different for every facility. For example, frequency from batching plant to towers is 16; it means 16 times the transit mixers move from batching plant to towers for particular duration of observation. The relationship chart shown in table 10 was drawn on the basis of flow of materials or workers among the facilities. Ratings A, E, I, O, U and X (Wiyaratn and Watanapa 2010) were used to show closeness among the facilities.

Table 8: Travel chart for phase 1 and phase 2 facilities (all distances are in meters)

| From/To | Batching Plant | Reinforcement Yard | Cement Godown | Stack Bins | Formwork Yard | P&M Yard | Q/A Lab | Concrete Testing | Worker Rest Room | Worker Canteen | Workers Induction Room | EHS | First Aid Room | Time Office | Visitor Room | Vendor Room | Store | Office | Marble Cutting Yard | Towers (Unloading Point) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Batching Plant | 0 | 112 | 20 | 57 | 176 | 157 | 101 | 222 | 122 | 99 | 202 | 194 | 186 | 177 | 166 | 236 | 206 | 221 | 414 | 336 |
| Reinforcement Yard | | 0 | 49 | 169 | 154 | 135 | 30 | 301 | 193 | 170 | 331 | 323 | 315 | 306 | 295 | 214 | 184 | 199 | 493 | 445 |
| Cement Godown | | | 0 | 77 | 132 | 113 | 35 | 242 | 142 | 119 | 222 | 214 | 206 | 197 | 186 | 255 | 225 | 240 | 434 | 363 |
| Stack bins | | | | 0 | 211 | 192 | 121 | 279 | 179 | 202 | 259 | 251 | 243 | 234 | 223 | 292 | 262 | 277 | 471 | 380 |
| Formwork Yard | | | | | 0 | 19 | 122 | 284 | 186 | 163 | 264 | 256 | 264 | 255 | 244 | 60 | 30 | 45 | 476 | 480 |
| P&M Yard | | | | | | 0 | 103 | 265 | 167 | 144 | 245 | 237 | 245 | 236 | 225 | 79 | 49 | 64 | 457 | 500 |
| Q/A Lab | | | | | | | 0 | 287 | 187 | 164 | 267 | 259 | 251 | 242 | 220 | 182 | 152 | 167 | 479 | 433 |
| Concrete Testing | | | | | | | | 0 | 58 | 81 | 20 | 28 | 36 | 45 | 54 | 268 | 298 | 313 | 192 | 150 |
| Worker Rest Room | | | | | | | | | 0 | 23 | 89 | 81 | 73 | 75 | 62 | 176 | 206 | 221 | 107 | 210 |
| Worker Canteen | | | | | | | | | | 0 | 112 | 104 | 96 | 98 | 85 | 153 | 183 | 198 | 130 | 233 |
| Workers Induction Room | | | | | | | | | | | 0 | 8 | 16 | 25 | 36 | 290 | 320 | 335 | 212 | 168 |
| EHS | | | | | | | | | | | | 0 | 8 | 17 | 28 | 282 | 312 | 327 | 220 | 176 |
| First Aid Room | | | | | | | | | | | | | 0 | 9 | 20 | 274 | 304 | 319 | 228 | 184 |
| Time Office | | | | | | | | | | | | | | 0 | 11 | 265 | 295 | 310 | 337 | 193 |
| Visitor Room | | | | | | | | | | | | | | | 0 | 254 | 284 | 299 | 348 | 204 |
| Vendor Room | | | | | | | | | | | | | | | | 0 | 30 | 15 | 460 | 412 |
| Store | | | | | | | | | | | | | | | | | 0 | 15 | 475 | 448 |
| Office | | | | | | | | | | | | | | | | | | 0 | 490 | 432 |
| Marble cutting Yard | | | | | | | | | | | | | | | | | | | 0 | 222 |
| Towers (Unloading Point) | | | | | | | | | | | | | | | | | | | | 0 |

Table 9: Frequency chart for phase 1 and phase 2 facilities

| From/To | Batching Plant | Reinforcement Yard | Cement Godown | Stack Bins | Formwork Yard | P&M Yard | Q/A Lab | Concrete Testing | Worker Rest Room | Worker Canteen | Workers Induction Room | EHS | First Aid Room | Time Office | Visitor Room | Vendor Room | Store | Office | Marble Cutting Yard | Towers (Unloading Point) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Batching Plant | | | | | | | | 16 | | | | | | | | | | | | 16 |
| Reinforcement Yard | | | | | | | | | | | | | | | | | | | | 6 |
| Cement Godown | 10 | | | | | | 2 | | | | | | | | | | | | | |
| Stack bins | 16 | | | | | | | | | | | | | | | | | | | |
| Formwork Yard | | | | | | | | | | | | | | | | | | | | 2 |
| P&M Yard | 8 | | | | | | | | | | | | | | | | | | | |
| Q/A Lab | | | | | | | | | | | | | | | | | | 3 | | |
| Concrete Testing | | | | | | | 1 | | | | | | | | | | | | | 16 |
| Worker Rest Room | | | | | | | | | | 20 | | | | | | | | | | |
| Worker Canteen | | | | | | | | | 20 | | | | | | | | | | | |
| Workers Induction Room | | | | | | | | | | | | | | | | | | | | 20 |
| EHS | | | | | | | | | | | 20 | | | | | | | | | |
| First Aid Room | | | | | | | | | | | | 20 | | | | | | | | |
| Time Office | | | | | | | | | | | | | | | 5 | | | | | |
| Visitor Room | | | | | | | | | | | | | | | | | | 5 | | |
| Vendor Room | | | | | | | | | | | | | | | | | | 10 | | |
| Store | | | | | | | | | | | | | | | | | | 10 | | |
| Office | | | | | | | | | | | | | | | | 10 | | | | |
| Marble cutting Yard | | | | | | | | | | | | | | | | | | | | 6 |
| Towers (Unloading Point) | | | | | | | | | | 20 | | | | | | | | | | |

Table 10: Relationship chart

| | Batching Plant | Reinforcement Yard | Cement Godown | Stack Bins | Formwork Yard | P&M Yard | Q/A Lab | Concrete Testing | Worker Rest Room | Worker Canteen | Workers Induction Room | EHS | First Aid Room | Time Office | Visitor Room | Vendor Room | Store | Office | Marble Cutting Yard | Towers (Unloading Point) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Batching Plant | | X | A | A | X | I | O | I | X | X | X | X | X | X | X | X | X | X | X | A |
| Reinforcement Yard | | | X | X | U | I | U | X | O | O | O | O | O | X | X | X | X | X | X | A |
| Cement Godown | | | | I | X | I | O | O | U | U | U | U | U | X | X | X | X | X | X | O |
| Stack bins | | | | | X | O | U | U | X | X | X | X | X | X | X | X | X | X | X | U |
| Formwork Yard | | | | | | O | U | X | X | X | X | X | X | X | X | X | X | X | X | I |
| P&M Yard | | | | | | | U | U | X | X | X | X | X | X | X | O | O | O | X | U |
| Q/A Lab | | | | | | | | E | U | U | U | U | U | U | U | O | O | O | X | U |
| Concrete Testing | | | | | | | | | U | U | U | U | U | U | U | U | U | U | X | U |
| Worker Rest Room | | | | | | | | | | A | E | E | E | E | E | O | O | O | I | A |
| Worker Canteen | | | | | | | | | | | E | E | E | E | E | O | O | O | O | I |
| Workers Induction Room | | | | | | | | | | | | A | A | E | E | O | O | O | I | E |
| EHS | | | | | | | | | | | | | A | E | E | O | O | O | O | E |
| First Aid Room | | | | | | | | | | | | | | E | E | O | O | O | U | I |
| Time Office | | | | | | | | | | | | | | | E | O | O | O | U | O |
| Visitor Room | | | | | | | | | | | | | | | | O | O | O | U | O |
| Vendor Room | | | | | | | | | | | | | | | | | E | E | U | U |
| Store | | | | | | | | | | | | | | | | | | E | U | U |
| Office | | | | | | | | | | | | | | | | | | | U | U |
| Marble cutting Yard | | | | | | | | | | | | | | | | | | | | A |
| Towers (Unloading Point) | | | | | | | | | | | | | | | | | | | | |

Table 11: Relationship chart with ratings, values and their reasons

| Values/Ratings | Closeness | Reasons |
|---|---|---|
| A | Absolutely essential | Flow and frequency |
| E | Especially important | Flow |
| I | Important | Frequency |
| O | Ordinary closeness | Contact necessary |
| U | Unimportant | No effect or No flow |
| X | Not desirable | Hindrance or obstacle |

## 3.6 Site layout for phase 2

As the the construction project has been divided into two phases based on the activities involved. Phase 1 of construction site layout planning includes excavation, underground works and some extent of superstructure work. The excavated portion of the site was shown in fig. 2 with doted lines. Once the underground work was completed, the superstructure work started. The excavated portion of land was backfilled up to the ground level, which created a lot more space. This demarcates the beginning of phase 2 of site layout planning shown in fig. 2. Due to the space created after relocation, it was suggested to have relocation of reinforcement yard close to the towers because of the flow and frequency.

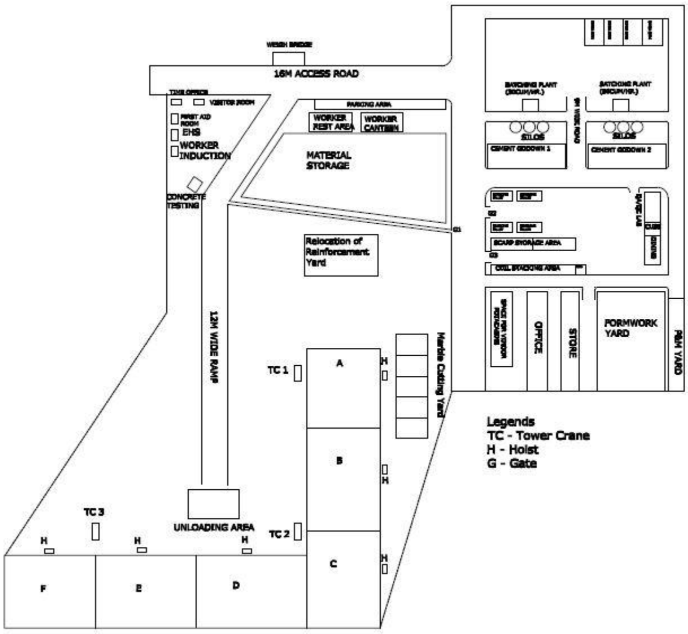


Figure 2: Site layout for phase 2

## 4. ANALYSIS

The travel chart in table 8 showed that facilities like P&M yard, formwork yard, office, reinforcement yard and batching plant were far from the towers to be constructed. The frequency chart in table 9 and the flow charts indicated that movements of materials and workers from facilities like batching plant, concrete testing, marble cutting yard, and reinforcement yard and workers induction room towards the towers for most number of times. Relationship chart in table 10 showed extreme closeness among towers and reinforcement yard; towers and batching plant for material movements.

The site layout for phase 2 showed the excavated area of phase 1 was backfilled and incoming facility i.e. marble cutting yard was placed in close proximity of tower. The site layout planning done by site planners are static in approach. The backfilling of the excavated land created space for the incoming facilities and that space was not properly utilized by the site management. Interactions with the site management revealed increased duration of slab cycle in most of the towers and processing and transportation of rebar was one of the many reasons behind increased slab cycle. Based on the factors like flow of materials, space available, distance between the facilities and duration for which facility exist, the relocation of reinforcement yard has been suggested in the site layout of second phase. The improved material flow chart for rebar is shown in table 12.

Table 12: Improved material flow chart for rebar

| | **Type: Improved Material Flow Chart** | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Material: Rebar** | | | | | | |
| **Step No.** | **Activities** | **Operation** | **Transportation** | **Inspection** | **Delay** | **Storage** | **Distance Covered (m)** |
| 1 | Arrival truck with rebar at site | | x | | | | |
| 2 | Weight measurement at weigh bridge | | | x | | | |
| 3 | Truck moved from weigh bridge to relocated reinforcement yard | | x | | | | 140 |
| 4 | Unloading and stacking of rebar | | | | | x | |
| 5 | Cutting of rebar | x | | | | | |
| 6 | Bending of rebar | x | | | | | |
| 7 | Moved rebar to site using mobile crane | | x | | | | 178 |
| 8 | Moved to towers through tower cranes | | x | | | | |
| | TOTAL | | | | | | **318** |

Revised travel chart is shown in table 13 after relocation of reinforcement yard. The revised travel chart has been shown in table 4.14 after relocation of reinforcement yard. The revised travel chart showed the distance between relocated reinforcement yard and towers to be 178 meters which was initially 445 meters in phase 1. Initially the rebar handling distance was 635 meters which was reduced to 318 meters in phase 2.

Reduction in distance from tower to reinforcement yard = (445-178) meters = 267 meters

Total reduction of material handling distance = (635-318) meters = 317 meters

Percentage reduction in material handling effort= (317/635) *100 = 49.9%

Table 13: Revised travel chart

| From/To | Batching Plant | Reinforcement Yard | Cement Godown | Stack Bins | Formwork Yard | P&M Yard | Q/A Lab | Concrete Testing | Worker Rest Room | Worker Canteen | Workers Induction Room | EHS | First Aid Room | Time Office | Visitor Room | Vendor Room | Store | Office | Marble Cutting Yard | Towers (Unloading Point) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Batching Plant | 0 | 315 | 20 | 57 | 176 | 157 | 101 | 222 | 122 | 99 | 202 | 194 | 186 | 177 | 166 | 236 | 206 | 221 | 414 | 336 |
| Reinforcement Yard | | **0** | **335** | **372** | **351** | **370** | **380** | **93** | **193** | **170** | **113** | **121** | **129** | **138** | **149** | **361** | **331** | **316** | **96** | **178** |
| Cement Godown | | | 0 | 77 | 132 | 113 | 35 | 242 | 142 | 119 | 222 | 214 | 206 | 197 | 186 | 255 | 225 | 240 | 434 | 363 |
| Stack bins | | | | 0 | 211 | 192 | 121 | 279 | 179 | 202 | 259 | 251 | 243 | 234 | 223 | 292 | 262 | 277 | 471 | 380 |
| Formwork Yard | | | | | 0 | 19 | 122 | 284 | 186 | 163 | 264 | 256 | 264 | 255 | 244 | 60 | 30 | 45 | 476 | 480 |
| P&M Yard | | | | | | 0 | 103 | 265 | 167 | 144 | 245 | 237 | 245 | 236 | 225 | 79 | 49 | 64 | 457 | 500 |
| Q/A Lab | | | | | | | 0 | 287 | 187 | 164 | 267 | 259 | 251 | 242 | 220 | 182 | 152 | 167 | 479 | 433 |
| Concrete Testing | | | | | | | | 0 | 58 | 81 | 20 | 28 | 36 | 45 | 54 | 268 | 298 | 313 | 192 | 150 |
| Worker Rest Room | | | | | | | | | 0 | 23 | 89 | 81 | 73 | 75 | 62 | 176 | 206 | 221 | 107 | 210 |
| Worker Canteen | | | | | | | | | | 0 | 112 | 104 | 96 | 98 | 85 | 153 | 183 | 198 | 130 | 233 |
| Workers Induction Room | | | | | | | | | | | 0 | 8 | 16 | 25 | 36 | 290 | 320 | 335 | 212 | 168 |
| EHS | | | | | | | | | | | | 0 | 8 | 17 | 28 | 282 | 312 | 327 | 220 | 176 |
| First Aid Room | | | | | | | | | | | | | 0 | 9 | 20 | 274 | 304 | 319 | 228 | 184 |
| Time Office | | | | | | | | | | | | | | 0 | 11 | 265 | 295 | 310 | 337 | 193 |
| Visitor Room | | | | | | | | | | | | | | | 0 | 254 | 284 | 299 | 348 | 204 |
| Vendor Room | | | | | | | | | | | | | | | | 0 | 30 | 15 | 460 | 412 |
| Store | | | | | | | | | | | | | | | | | 0 | 15 | 475 | 448 |
| Office | | | | | | | | | | | | | | | | | | 0 | 490 | 432 |
| Marble cutting Yard | | | | | | | | | | | | | | | | | | | 0 | 222 |
| Towers (Unloading Point) | | | | | | | | | | | | | | | | | | | | 0 |

Therefore, the total material handling distance was reduced by 317 meters and percentage reduction in material handling effort was reduced by 49.9%. In addition to reduction in material handling distance, the relocated reinforcement yard would be in proximity of tower cranes. The construction schedule also showed reinforcement yard would be required for most of the period in phase 2.

The relocation of reinforcement yard was suggested to show the dynamism of the construction site. With proper planning, the space can be utilized in more efficient way. The partial layouts generated in this study can be drawn at the initial stage for better understanding of the construction site and their changes. If these changes were conceived by the contractor during the initial stage of planning, they could have planned for mobile reinforcement yard. So, when the changes would occur, they could easily relocate the facility without much cost.

## 5. CONCLUSION

This study showed that the dynamic approach of site layout planning in construction project can be used in effective utilization of space. Often the site management uses static approach, leading to ineffective movement of men and materials. In addition to this, the lack of literature on how to record the flow and movement in construction project during dynamic or static approach, offers huge possibility of work study implementation. Work study implementation in construction project is challenging due to complex nature of construction projects. Present study showed that various method study charts can be effectively used to record the movement of men and materials in construction projects. Accordingly, relationship among the facilities was derived by understanding the flow and frequency recorded by method study charts. This approach was used to derive the partial layouts of the site during two phases and relocation of reinforcement yard was suggested leading to reduction of material handing effort by 49.9%. The partial site layouts helped in showing the dynamism of project in better way. The proposed methodology can be instrumental in developing partial layouts by implementing work study in complex construction project and thereby helping the site management to monitor the site space at different stages of the project. In addition, the proposed methodology along with cost analysis of relocation of facilities can offer more possibilities of improvement at initial and subsequent phases of the complex construction project.

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