ANALYSIS ON IMPROVING OPERATIONAL EFFICIENCY OF CONSTRUCTION PROJECT SITE

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ABSTRACT

Operational efficiency in any construction project is directly reflects the profitability of a project, It is for benefit of a construction project. The current research paper emphasized on high operational efficiency by reducing waste, better layout planning, sound administration, business practices and the review of existing facilities etc. Higher the operational efficiency will enhance the profit by adding the value to the project in the form of cost reduction in the areas of internal transportation, utilization of existing facilities effectively. The current research study adopted the computerized relative allocation of facilities techniques (CRAFT) and computerized relationship planning (CORELAP) algorithm to analyze the operational efficiency of construction project site.

Keywords: Operational efficiency, layout planning, CRAFT, CORELAP

1. INTRODUCTION

The construction projects are unique compared to other projects and requires attention at all the stages of the construction. Sound and effective communication is crucial for smooth functioning of project activities, Which in turn leads to enhance the operational efficiency and productivity.

Planning the layout of construction project is crucial task and it has significant impact on construction cost, productivity and safety. It involves positioning and dynamic relocation of temporary facilities that were needed to support various construction activities on site such as office, storage area, working area etc. Due to complexity of site layout planning problems, construction managers used to perform the task using previous experience, ad-hoc rules, first in first out(FIFO) approach which leads to ambiguity and even to inadequate facilities in the project site.

In order to fulfill this complexity several layout planning models are developed based on the suitable layout types adopted by which operational efficiency is enhanced to higher extent. A well designed layout may contribute to overall efficiency of operations in the project site and may cut down the operating cost drastically.

To improve the operational efficiency, the current study compares the transportation cost between the departments and materials movement cost with in a project site. Computerized relative allocation of facilities techniques (CRAFT) methodology is based on the heuristics approach and minimizes the material handling cost.

Computerized relationship and layout planning (CORELAP) attempts to find the near ness rating within the facility constraints. CRAFT was utilized to compare the real cost involved in existing layout and new layout.

2. LITERATURE REVIEW

A number of studies have been conducted in order to improve operational efficiency in construction projects by means of improving site layout planning thereby effectively reducing cost of construction and simultaneously reducing the wastage in the site due to inefficient layout management (CAI et al., 2012).

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These studies adopted a wide range of methodologies, development tools including neural networks, simulation, knowledge-based systems, and genetic algorithms (BORDOLOI, 2014; PATIL; JOSHI, 2014).

According to the organizational psychologists there are two ways to improve the productivity of employee's i.e performance: "financial" and "non-fina ncial" motivators. There must be uniform system for rewarding the employee performance and the review of performance appraisal of employees (HANDIER, 1985).

The design of measurement of performance of construction project employees should be different from the performance appraisal of the manufacturing employees (JARKAS, et al., 2015).

The concept of index of complexity, and work load indicator for designing the performance appraisal for construction employees is essential. The index complexity is a measurement of the congestion, around the tool and conditions for routing the connections. The work load indicator is the product of the index complexity and the number of connections of a certain type, such as piping, ductwork or electrical (WIEZELALI, 2003).

Sometimes relocation of the employees working in a critical operation in a simulated environment shows reduction in cycle time and higher productivity (GNANAVEL et al., 2004). Ergonomically designed U-formed line layout is quite useful in construction site for improving the productivity (ABDULAZIZ et al., 2009).

The small variation in operational efficiency helps to reduction of 20-40% in waste, may lead to reduce the cost upto 80% (BURNS; MERZ, 2012). Identifying the On-site segregation of recyclable and reusable materials may reduces the operating cost. It is underlined that location isolation of squanders is a successful route for augmenting site activities (DENNIS, 2001).

The previous studies on sitelayout problems emphasized the importance of waste reduction to increase the operational efficiency, irrespective of type of construction (ELGENDI et al., 2014; EI-RAYA ; SAID, 2009).

Zoning the various activities in the project site will assist for enhancing the operational efficiency (NESZMELYI; VATTAI, 2013), categorizing the facilities in

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temporary as well permanent manner is the basis to provide the facilities is the prime factor for selection and designing the layout (ELBBELTAGI, 1983; CHARY, 2003; GOEL, 2010).

Several attempts have been made to solve site layout planning issues using techniques like Genetic algorithm, simulation modeling and ant colony optimization algorithm are used for site layout planning. These techniques resulted that the facilities identified are temporarily needed to support construction operations in the project but does not from a part of the finished structure (SHETTY; DESHMUKH, 2013).

Evolution Based models for site layout planning was also considered for improving operational efficiency by using software for the site layout problems (TOMMEELEIN; ZOUEIN, 1993). Properly Planned site layout facilities will improve the profitability, safety and productivity to achieve the higher speed while performing the site operations(SANAD et.al., 2013).

Better site layout can be achieved easily by minimization of travel time and removal of unnecessary movement of resources and proper material handling techniques (KUMAR; SINGH, 2007). Computer Aided Drafting (CAD) techniques are useful to improve the layout   and will overcome the limitations of other automated systems (ELBELTAGI et. al., 2004).

Many of the projects are not successful because of the lack of accountability, poor integration of isolated tasks, discrete functionality, lack of planning and controlling measures (KUMAR; BANSAL, 2016). Based on the gaps identified from the literature review has motivated to apply CORELAP and CRAFT techniques in the present study.

3. METHODOLOGY

The modular construction industry has made significant advances in implementing processes and materials to build and deliver more sophisticated and complex facility types. Many customers are turning towards modular sytem for multi-story, steel framed structures, health care facilities, educational structures, and also in large scale military projects.

Always this system is known for its time saving advantages, modular is now being recognized for being a more resource-efficient and it is inherently a greener

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process. The present research study has taken the   building project layout, and facilities are identified for the present site, relationship chart was developed for 15 departments available in the project site using A, E, I, O, U symbols. Proximity relation between facility locations are also identified based on the relationship diagram.

A = Absolutely Necessary that the two facility should be close (to be close)

B = Especially Important that the two facility must be close

C = Important that the two facility may be close

D = Unimportant or no need to be close the two facility

E = Undesirable or need to be far the two facility

3.1.   Craft analysis

CRAFT is an improvement algorithm, for the reallocation of available facilities. CRAFT algorithm, is developed by Armour and Buffa. It starts with an initial layout and improves the layout by interchanging the department pair wise so that the transportation cost is minimized. The algorithm continues until no further interchanges are possible to reduce the transportation cost. Centroid for each department is obtained with the real dimensions of the plot using AUTOCAD software.

3.1.1. Distance matrix

Matrix consisting of distances between each and every department is formed. It is obtained in kilometers using the formula: $(X1 - X2) + (Y1 - Y2)$ Where X1 represents x coordinate of centroid of department A, X2 represents x coordinate of centroid of department B, Y1 represents y coordinate of centroid of department A, Y2 represents y coordinate of centroid of department B.

3.1.2. Flow matrix

Matrix formed based on number of flow of trips that a vehicle has to cover to travel between any two departments. The content is subjective and based on subjective knowledge. Trip distance matrix is formed with values calculated based on the number of trips (Flow matrix) and distance between two departments (Distance matrix).

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3.1.3. Cost matrix

Final determinable matrix calculated using inputs from Trip distance matrix multiplied with assumed cost per km and cost of operating a vehicle. Handling cost: Handling cost associated with each and every department is calculated by summation of all the costs in the department from Cost matrix along with consideration of hiring charges.

3.2. CORELAP

Is a constructive algorithm and it deals the layouts by locating rectangular shaped departments. The relationship chart provides the basis for the order in which different departments are placed. The important step in CORELAP is learning about adjacency. It generates a layout on the basis of total closeness rating (TCR) for each department. Adjacency is a coefficient between two activities/spaces. The range of adjacency is between 0 and 1.

There are three types of adjacency as follows: Fully adjacent (side contact), partially adjacent (point contact), and Non adjacent (no contact at all). Fully adjacent has 1 value of coefficient; partially adjacent has 0.5 value of coefficient; and non-adjacent have 0 value of coefficient.

CORELAP adapts this theory. The input requirements of CORELAP consist of

1. Relationship chart with weights for the departments, 2. Number & area of departments.

The implementation requires the user to define weights in decreasing order A, E, I, O, U, and X. The 'X' relationship has to be assigned a negative weight. The same applies to cut-off. The cut-off values convert the flow scores into equivalent relationship values A, E, I, O, U, and X. Once the user has input the flows or the relationship values he or she can update the spreadsheet.

4. APPLICATION OF CRAFT AND CORELAP- A CASE STUDY

The study was conducted at a residential project spread over 29 acres and totally 15 departments are working for the project. The entire site plan is made using AutoCAD with the exact inputs from the site. The site is a residential project in Chennai, Tamilnadu.

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The project is planned to build 1224 residential units. The supporting functional departments are setup to help complete the execution and operation subjecting to the six residential blocks. Cost matrix [cij] cell is formed. Figureure 1 depicts the pictorial representation of layout plan of existing site. Block 1 to block 6 represents residential blocks.

Other departments are the supporting functional blocks placed around the major blocks. The existing site layout is shown in Figure 1 and centroid between the departments is shown in table 1. For the existing layout as shown in Figure 1 centroid for each and every department is obtained using AutoCAD software and centroid is calculated for every department portrayed in the Table 1.

Then the distance matrix, flow matrix, is calculated in the Table 2 and Table 3 respectively. By using the Table2 and Table 3 handling cost is calculated for the existing site layout. As per the existing site layout average kilo meters covered per week is 1.95 kilometers.
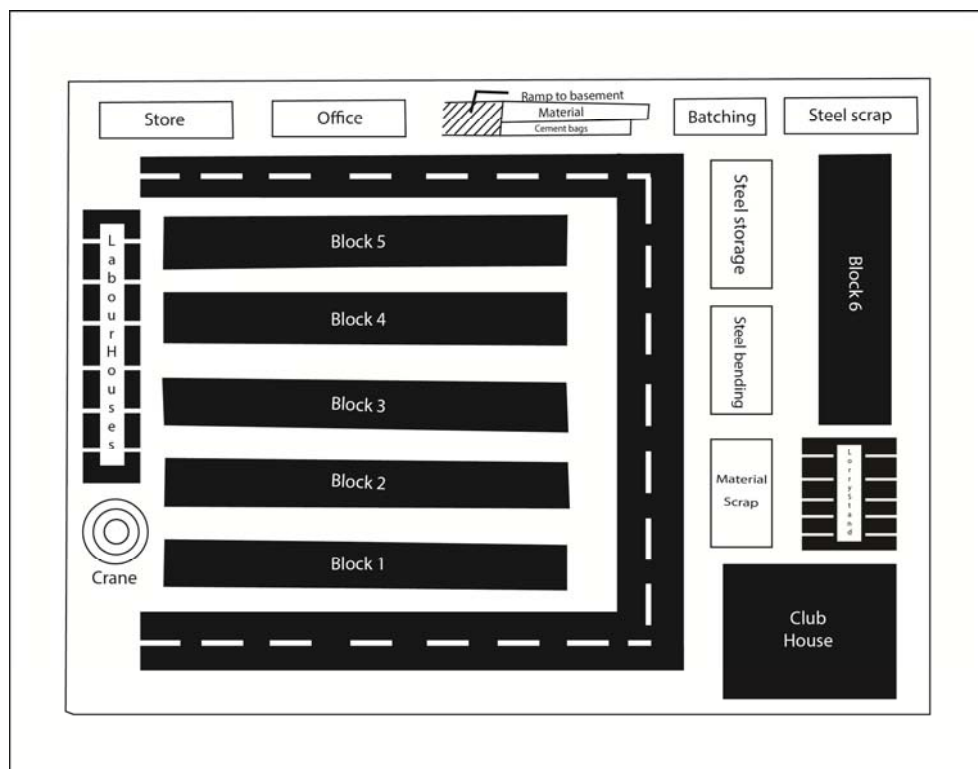

Figure 1: Site layout of exiting site

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Table 1: Centroid of departments using CRAFT

Department number	Nomination	Centroid	Department number	Nomination	Centroid
1	Block 1	(113,82)	9	Steel scrap	(265,368)
2	Block 2	(113,115)	10	Steel storage	(202,230)
3	Block 3	(113,145)	11	Steel bending	(202,160)
4	Block 4	(113,190)	12	Block 6	(265,192)
5	Block 5	(113,220)	13	Lorry stand	(258,112)
6	Store	(102,310)	14	Club house	(225,18)
7	Cement bag storage	(152.5,342)	15	Material scrap	(202,113)
8	Batching plant	(213,335)			

Table 2: Distance matrix using CRAFT

DISTANCE MATRIX (in Kms)

From/To	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0	0.033	0.062	0.108	0.138	0.239	0.299	0.353	0.438	0.237	0.167	0.262	0.175	0.176	0.12
2	0.033	0	0.03	0.075	0.105	0.206	0.267	0.32	0.405	0.204	0.134	0.229	0.148	0.209	0.091
3	0.062	0.03	0	0.045	0.075	0.176	0.237	0.29	0.375	0.174	0.104	0.199	0.112	0.239	0.121
4	0.108	0.075	0.045	0	0.03	0.131	0.395	0.245	0.33	0.129	0.119	0.154	0.223	0.284	0.166
5	0.138	0.105	0.075	0.03	0	0.101	0.162	0.215	0.3	0.099	0.149	0.18	0.252	0.314	0.196
6	0.239	0.206	0.176	0.131	0.101	0	0.083	0.136	0.221	0.18	0.25	0.281	0.354	0.415	0.297
7	0.299	0.267	0.237	0.395	0.162	0.083	0	0.068	0.139	0.162	0.232	0.263	0.336	0.397	0.279
8	0.353	0.32	0.29	0.245	0.215	0.136	0.068	0	0.085	0.116	0.186	0.195	0.268	0.329	0.233
9	0.438	0.405	0.375	0.33	0.3	0.221	0.139	0.085	0	0.201	0.271	0.176	0.263	0.39	0.318
10	0.175	0.204	0.174	0.129	0.099	0.18	0.162	0.116	0.201	0	0.07	0.101	0.174	0.235	0.117
11	0.167	0.134	0.104	0.119	0.149	0.25	0.232	0.186	0.271	0.07	0	0.095	0.104	0.165	0.047
12	0.262	0.229	0.199	0.154	0.18	0.281	0.263	0.195	0.176	0.101	0.095	0	0.087	0.214	0.142
13	0.175	0.148	0.112	0.223	0.252	0.354	0.336	0.268	0.263	0.174	0.104	0.087	0	0.127	0.057
14	0.176	0.209	0.239	0.284	0.314	0.415	0.397	0.329	0.39	0.235	0.165	0.214	0.127	0	0.118
15	0.12	0.091	0.121	0.166	0.196	0.297	0.279	0.233	0.318	0.117	0.047	0.142	0.057	0.118	0

Table 3: Flow matrix using CRAFT

FLOW MATRIX (No. of trips between facilties)

From/To	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0	0	0	0	0	1	3	10	1	6	8	0	5	0	10
2	0	0	0	0	0	1	2	9	1	5	8	0	5	0	10
3	0	0	0	0	0	1	4	11	1	7	7	0	5	0	10
4	0	0	0	0	0	1	2	8	1	3	9	0	5	0	10
5	0	0	0	0	0	1	3	6	1	5	6	0	5	0	10
6	1	1	1	1	1	0	1	5	0	1	3	1	2	1	3
7	3	2	4	2	3	1	0	14	1	0	0	4	5	4	5
8	10	9	11	8	6	5	4	0	0	0	0	7	5	6	10
9	1	1	1	1	1	0	1	0	0	2	1	1	5	1	10
10	6	5	7	3	5	1	0	0	2	0	12	8	5	6	2
11	8	8	7	9	6	3	0	0	1	12	0	10	5	5	4
12	0	0	0	0	0	1	4	7	1	8	10	0	5	0	10
13	5	5	5	5	5	2	5	5	5	5	5	5	0	5	5
14	0	0	0	0	0	1	4	6	1	6	5	0	5	0	5
15	0	0	0	0	0	1	0	0	0	0	0	0	10	0	0

After the calculation of handling cost for the existing site layout, the new site layout has been formed as per Figure 2.Centroid of the departments are calculated again using CRAFT for the newly formed site layout and represented in the Table 9. The trip distance and flow matrix are formulated for the new site layout as shown in the Figure 2. The distance covered per week is 1.67 kilometers for the newly formed layout using the CRAFT.

Table 4: Centroid of the newly formed layout using CRAFT

| Departme nt number	Nomination	Centroid	Department number	Nomination	Centroid
1	Block 1	(163.07,88.39)	9	Steel scrap	(232.4,382.45)
2	Block 2	(163.07,240.72)	10	Steel storage	(60.9,204.9)
3	Block 3	(163.07,319.96)	11	Steel bending	(222.5,204.9)
4	Block 4	(121.9,48.77)	12	Block 6	(121.9,280.34)
5	Block 5	(121.9,128.02)	13	Lorry stand	(129.5,382.45)
6	Store	(60.9,28.2)	14	Club house	(53.3,382.45)
7	Cement bag storage	(163.07,28.2)	15	Material scrap	(186.7,382.45)
8	Batching plant	(143,204.9)			
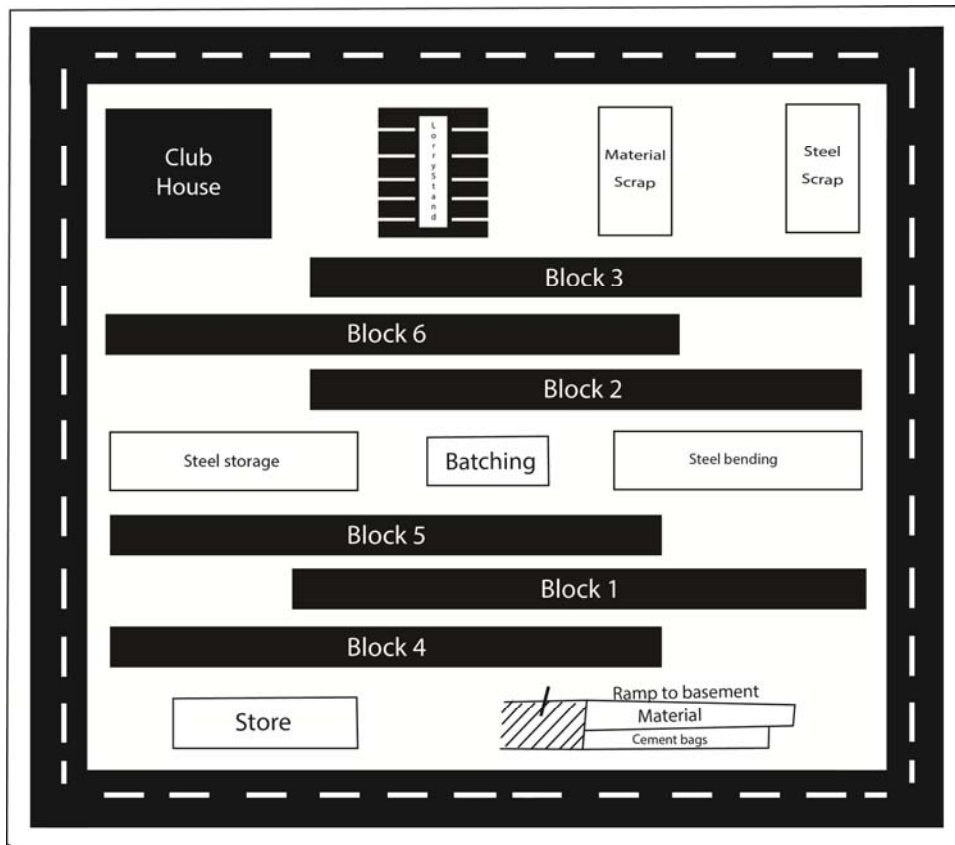
Figure 2: New site layout design using CRAFT

Now   the distance is calculated for revised site layout using Corelap method and represented in the Table 6, Table 7, Table 8 respectively.

Table 5: Relationship table using CORELAP

Relationship	Relationship values	Corresponding values
Absolutely necessary	A	6
Especially important	E	5
Important	I	4
Ordinary	O	3

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Unimportant	U	2
Undesirable	X	1

Table 6: Relationship matrix using CORELAP

From/To	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	-	O	O	O	O	U	I	A	O	E	I	O	X	O	I
2	O	-	O	O	O	U	I	A	O	E	I	O	X	O	I
3	O	O	-	O	O	U	I	A	O	E	I	O	X	O	I
4	O	O	O	-	O	U	I	A	O	E	I	O	X	O	I
5	O	O	O	O	-	U	I	A	O	E	I	O	X	O	I
6	U	U	U	U	U	-	A	A	U	O	I	O	X	O	O
7	I	I	I	I	I	A	-	O	U	O	A	O	X	O	U
8	A	A	A	A	A	A	O	-	U	I	E	O	O	O	I
9	O	O	O	O	O	U	U	U	-	A	I	O	U	O	I
10	E	E	E	E	E	O	O	I	A	-	A	O	X	O	U
11	I	I	I	I	I	I	A	E	I	A	-	O	X	O	O
12	O	O	O	O	O	O	O	O	O	O	O	-	U	O	O
13	X	X	X	X	X	X	X	O	U	X	X	U	-	O	I
14	O	O	O	O	O	O	O	O	O	O	O	O	O	-	U
15	I	I	I	I	I	U	U	I	I	U	O	O	I	U	-

Table 7: Total closeness rating (TCR) using CORELAP

Dept.	Closeness Relationship	TCR
1	O+O+O+O+U+I+A+O+E+I+O+X+O+I	47
2	O+O+O+O+U+I+A+O+E+I+O+X+O+I	47
3	O+O+O+O+U+I+A+O+E+I+O+X+O+I	47
4	O+O+O+O+U+I+A+O+E+I+O+X+O+I	47
5	O+O+O+O+U+I+A+O+E+I+O+X+O+I	47
6	U+U+U+U+U+A+A+U+O+I+O+X+O+O	41
7	I+I+I+I+I+A+A+U+O+A+I+O+X+O+O	49
8	A+A+A+A+A+A+O+U+I+E+O+O+O+I	63
9	O+O+O+O+O+U+U+U+A+I+O+U+O+I	43
10	E+E+E+E+E+O+O+I+A+A+O+X+O+U	56
11	I+I+I+I+I+I+A+E+I+A+O+X+O+O	55
12	O+O+O+O+O+O+O+O+O+O+O+U+O+O	41
13	X+X+X+X+X+X+X+O+U+X+X+U+O+I	23
14	O+O+O+O+O+O+O+O+O+O+O+O+O+U	41
15	I+I+I+I+I+U+U+I+I+U+O+O+I+U	46

It is found that the distance covered per week is 1.67 kilometers for the newly formed layout using the CORELAP. As the distance is proportional to the cost and same was proven in the table 9.

Table 8: Assumptions for handling

Assumptions		
	Fuel Cost	INR 50/ litere
	Mileage	6 km/liters
	Wages	INR 250/ Km
Hiring Charges	Cranes	INR 100/day
	Trucks	800/day
	Transit mixers	600/day

5. ANALYSIS OF RESULTS

Analysis has been done between the existing and the new layout. As the distance is directly proportional to the cost and the same was reflected in the cost

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estimation per week. The savings are substantial with new layout compared to the existing layout in the project. The results are tabulated in the Table 9.

Table 9: Cost associated with old layout and new layout

Parameters	Considerations	Actual estimate using CRAFT(old layout)	Actual estimate using CRAFT and CORELAP (New layout)
Average kms covered/week	From CRAFT	1.95kms	1.67kms
Transportation Cost/km	Assumed value: wages – Rs. 250/km from table 8	INR. 258.3	NR. 258.3
Hiring cost/week	Assumed: 5 operating days a week.	INR. 12000	INR. 12000
Total handling cost/week		INR. 2,52,455	INR. 2,42,100
Estimated duration of project	Actual project estimate	200 weeks	200 weeks
Overall handling cost associated with this site layout	Calculation: Rs. 2,52,455 * 200 weeks for old layout Calculation: Rs. 2,42,100 * 200 weeks For new layout	INR. 5,04,91,000	INR. 4,84,20,000
Savings per week – INR. 10,355			
Estimated saving – INR. 20,71,000			
% of saving from overall handling cost – 23.38%			

6. CONCLUSIONS:

From the above analysis, it is observed that an amount of INR 10,355 can be saved per week if the same project has been done with newly formed layout using CRAFT and CORELAP. This tends to prove that the site layout which has been adopted currently in the site applying the expertise regarding the operational importance is not optimal and the site layout which has been analyzed by using the application of CRAFT and CORELAP software yield positive results.

Taking into consideration the modified layout in the present scenario would save an amount of INR20, 71,000 for the estimated project duration the opportunity cost for the project duration is estimated to be INR 6,42,010. The operational efficiency of a construction site was analyzed by CRAFT and CORELAP techniques by considering above case study of building project.

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