Productivity Analysis of Column Formwork Erection

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Abstract

The construction industry contributes a huge number of employments in India, but despite its economic importance and job creation, it faces challenges such as low productivity, project delays, and a lack of professional practices in the industry. A construction project's time and cost performance are largely determined by Productivity. Although, there have been research which focuses on general productivity, but there is no research done specifically for any particular component. Therefore, the present research work focuses on productivity analysis of column erection activity. Key parameters that hinder the Column Formwork Erection are identified by preparing Work Breakdown Structure (WBS) and identifying factors which lead to preparation of a questionnaire that includes 37 questions. The questionnaire is used to collect data of 97 ongoing construction projects of Gujarat state. The data is used to calculate Relative importance index (Rii) value for severity and occurrence. As the ranking of reasons cannot be singly based either on severity or occurrence, a unique analysis is done by finding the Cumulative value which is a function of both severity and occurrence to rank the reasons. The result reveals the major reasons that affects formwork erection activity are improper planning and scheduling of formwork activities, lack of Finance, design fluctuation, pandemic and availability of labors as well as skilled labors and are discussed in this paper.

1. INTRODUCTION

Productivity is a term that can be defined in a variety of ways. In the construction industry, productivity refers to the number of units of work produced per man-hour. There is no specific formula to measure productivity in literature. Four different models of productivity are Economic Model, Project Specific Model, Baseline Productivity and Cumulative Productivity as defined by Mostafa et al., 2012 [1]. Activity Sampling technique was used for measuring the labors gang's productivity to know active or inactive time during the execution of work. Coefficient of variation in daily labor productivity and Project Management Index (PMI) was determined. It was observed that reduction in variation of labour productivity enhances project performance. Lean construction Principles, Material Supply and Handling Systems was used to reduce variability of the labor productivity. Work flow variation analysis was used to know the fault of either owner or contractor.

Kazaz et al., 2015 [2], a comparison of labor productivity was made from the perspective of craft workers and project managers. Craftworkers input should also be addressed when determining major factors, as they have greater impact on labor productivity. For this a questionnaire is prepared having 37 factors divided in four categories of physical, economic, organizational and socio-psychological and were marked using 5-point Likert scale. Cronbach's Alpha Reliability Test Method was applied to each category separately and it was observed that from Manager's perspective, Quality of Site Management and Material Management were the two major factors whereas from craft worker's perspective working in social insurance and on-time payment were the major factors.

Saurav Dixit et al., 2017 [4], used Relative important index (Rii) to examine the factors that influence construction productivity and ranks them based on responses to their impact on the productivity of construction projects in India.

Rex et al., 2017 [3], described the constraints influencing craft gang productivity and the impact of onsite learning on the

productivity of the blockwork craft gang. 3-D Bar charts were used to present the statistics on the top most significant constraints affecting the craft gang's productivity. Keeping man-hour as the dependent variable, correlation coefficient and regression model were calculated from the charts. Furthermore, the learning rate of the craft gang's blockwork repetitive work was computed using learning curve theory and unit straight-line model equations.

Saurav Dixit et al., 2019 [5], reviewed different studies on construction productivity and found out the major factors affecting were coordination, planning of drawings, tools and consumables, availability of material, skilled labours and redo of work. And thereby suggested on developing of a framework for improving on-site construction productivity in the Indian context. With that BIM has risen as one of the solutions for enhancing construction project.

2. METHODOLOGY

Techniques were used to carried out this research like, TIME STUDY AND MOTION ANALYSIS TECHNIQUES for the materials and workers like materials are available on site at the time of requirement or not, does anyone had done their work on time or not. Then from FOREMAN DELAY SURVEY we form our questionnaire and from ACTIVITY SAMPLING TECHNIQUES we assemble all the collected data in one page and do the analysis through which we find the productivity of different construction activities.

Key parameters that hinder the Column Formwork Erection Activity are identified and methodology for the same is described in the section.

First of all, Work Breakdown Structure for Column Formwork Erection is prepared. WBS is broadly divided in 3 parts which includes preparation, erection and removal process. Each part is further divided as shown in Table 1

Table 1: WBS of Formwork Erection for Column

PREPARATION	ERECTION	REMOVAL
Design and layout plan	**Installation of column formwork**	**Removal of formwork**
- Budgeting of plan - Dimensions of column - Ordering of formwork	- Grid marking - Ensemble formwork - Provide Supports	- Remove formwork as per IS code - Avoid damage while removing
Material Requirement	**Preparation of reinforcement**	**Cleaning of sheathing lates**
- Selection of formwork - Selection of material	- Instal rebars - Enclose reinforcement - Concrete pouring and use vibrators	- Clean planks and apply reagent to avoid corrosion - Provide curing

The factors that hinder the productivity are broadly classified into two factors i.e., Internal and External factors. Table 2 shows various factors identified

Table 2: Factors affecting Column Formwork Erection

INTERNAL FACTORS	EXTERNAL FACTORS
- Operation And Maintenance - Element elevation - Management - Execution - Quality - Design - Time - Cost	- Socio-economic - Environment - Resources - Labor

Based on internal and external factors total 37 questions were quoted to prepare the questionnaire for collecting the data and are shown in Table 4. A google form is prepared using the questionnaire, which allows to rate each questions severity and occurrence on a Likert's scale of 1-5. The google form is shared with site engineer, site manager, supervisor, contractor, owner, project head, project manager of various ongoing construction project of Gujarat State. Total data was collected from 97 sites out of which 69 sites was visited physically and the data of other 28 sites was collected by contacting the site engineer/manager virtually due to Covid Situation.

3. ANALYSIS OF DATA

From the collected data, most common reasons for poor column formwork productivity are identified and shown in Table 3

Table 3: Major Factors affecting Column Formwork Productivity

Sr. No.	Reasons for delay	Occurred at
1	Delay due to Pandemic	62
2	Delay due to festival	54
3	Delay due to availability of skilled labors	41
4	Delay due to change in plan (fluctuation of Layout plan)	32
5	Delay due to Lack of finance	36
6	Delay due to Improper planning and scheduling of activities	30
7	Delay due to unavailability of Material (Cement, aggregates, etc.)	30

The graphical representation only helps to identify the reasons which are occurring on the common basis. However, it doesn't represent the severity of the reasons. Therefore, the respondents were asked to rate the factors affecting construction productivity on a Likert scale of 1 to 5 as per their degree of impact and influence with respect to they observed to impacting construction productivity in the Indian context.

It is noticed that the numbers allow to the reactions (1-5) did not show that the interims between the scales are equivalent, nor do they demonstrate outright amounts. Therefore, a relative importance index (Rii) was applied to prioritize the severity of the factors. Relative importance index (Rii) for severity and occurrence for all 37 reasons is calculated using Equation (1) and presented in Table 4.

$$Rii = \frac{\sum_{r=1}^{5}(r \times nr)}{5N} \qquad (1)$$

where, r = Rating on a Likert scale (1-5) as for the impact on construction efficiency for a specific element influencing construction profitability.
nr = Quantity of respondents giving a specific Likert scale rating r.
N = aggregate number of respondents to a specific inquiry

Table 4: Rii Value of Severity and Occurrence

Sr No.	Reason	Total Responses	Severity		Occurrence		Cumulative Rii Value	Rank
			Total Score	Rii	Total Score	Rii		
1	Was there any delay due to improper Planning and Scheduling of Formwork Activities?	30	131	0.87	48	0.32	6.96	8
2	Was there any delay due to lack of Finance for the Project?	36	159	0.83	62	0.34	11	1

3	Was there any delay due to mismanagement between Owner and Contractor?	23	69	0.60	34	0.29	4.5	23
4	Was there any delay due to Change in Plan (Design / Fluctuation of Layout Plan)?	32	131	0.82	51	0.31	6.48	10
5	Was there any delay in ordering the formwork components?	6	16	0.53	11	0.37	4.90	17
6	Was there any delay due to increase in cost of formwork component?	10	26	0.52	34	0.68	5.2	15
7	Was there any delay due to increase in labor charges/wages?	27	96	0.71	79	0.59	6.56	9
8	Is there any delay due to lack of availability of labors?	26	87	0.67	71	0.55	9.075	3
9	Is there any delay due to lack of availability of skilled labors?	41	127	0.62	116	0.57	8.69	5
10	Was there any delay due to miscommunication between Site Management and Labor Force?	8	22	0.55	22	0.55	4.53	22
11	Was there any delay due to lack of Supervision of Labors?	2	7	0.7	5	0.5	8.75	4
12	Is there any delay due to lack of understanding among labors regarding work?	4	11	0.55	12	0.6	4.81	19
13	Is there any delay due to internal friction (fight) among the labors?	4	10	0.5	11	0.55	3.12	31
14	Was there any delay due to improper storage for Formwork Components (which makes it difficult for inventory management)?	4	11	0.55	9	0.45	3.97	27
15	Was there any delay due to transportation of Formwork Component on Site?	3	8	0.53	6	0.4	5.8	12
16	Was there any delay due to unavailability of Material (Cement, Aggregates, etc.) on Site?	30	87	0.58	68	0.45	4.16	25
17	Was the formwork a Proprietary (Patent) Formwork or Conventional Formwork? If Conventional then did it take longer time in its erection?	7	13	0.37	10	0.29	4.71	21
18	Was the dimension of every column being same or different? If different then does it made any delay in erection?	4	13	0.65	9	0.45	3.37	29

19	Was there any delay as the column was at higher Storey?	4	9	0.45	9	0.45	2	35
20	Was there any delay due to casting of Concrete Kicker?	2	6	0.60	8	0.8	2.85	32
21	Did the Labor took longer time in erecting formwork than usual?	9	26	0.58	23	0.51	5.1	16
22	Was there any delay due to longer time taken while preparing reinforcement?	4	13	0.65	13	0.65	4.5	23
23	Was there any delay due to any causality in taking Safety Measures?	7	21	0.6	13	0.37	5.55	14
24	Was there any delay due to improper erection of formwork (Gaps which lead to leakage)?	5	11	0.44	11	0.44	4.84	18
25	Was there any delay due to complex reinforcement? (As Complex Reinforcements requires proper compaction)	7	19	0.54	15	0.42	5.80	11
26	Was there any delay due to malfunction of Concrete Pump?	22	47	0.42	26	0.23	2.52	34
27	Was there any delay due to improper casting of Concrete? (E.g., Honeycombing)	13	39	0.6	25	0.39	5.7	13
28	Was there any delay due to difference in stratification? (Casting in Parts for proper Compaction)	7	13	0.37	15	0.43	3.97	26
29	Was there any delay due to deterioration of Sheathing Plate (while removing it)?	6	13	0.43	10	0.33	3.54	28
30	Did it take any extra time for Cleaning of Sheathing Plates after using it?	11	18	0.33	22	0.4	3.2	30
31	Was there any delay due to Festival?	54	196	0.76	147	0.55	7.92	6
32	Was there any delay due to Labor strike?	5	7	0.28	10	0.4	2.8	33
33	Was there any delay due to any kind of pandemic?	62	235	0.76	154	0.50	9.18	2
34	Was there any delay due windy weather?	5	12	0.48	13	0.52	4.8	20
35	Was there any delay due rainy weather?	20	57	0.57	49	0.49	6.98	7
36	Was there any delay in work due high temperature?	2	8	0.80	6	0.6	1	37
37	Was there any delay due natural calamity?	3	6	0.40	2	0.13	1.3	36

After calculating Rii values a comparison table is been made to know the top 5 Reasons that for Rii value for severity as well as for Rii value for occurrence. Table 5 shows the list of top 10 reasons for Severity and for Occurrence.

Table 5: Top 5 Reasons for Severity and Occurrence

Rank	Order	Rii Value
Order for Severity		
1	Was there any delay due to lack of Finance for the Project?	0.87
2	Was there any delay due to improper Planning and Scheduling of Formwork Activities?	0.83
3	Was there any delay due to Change in Plan (Design / Fluctuation of Layout Plan)?	0.82
4	Was there any delay due to any kind of pandemic?	0.76
4	Was there any delay due to Festival?	0.76
5	Was there any delay in work due high temperature?	0.8
Order for Occurrence		
1	Is there any delay due to lack of availability of skilled labors?	0.57
2	Is there any delay due to lack of availability of labors?	0.55
3	Did the Labor took longer time in erecting formwork than usual?	0.51
4	Was there any delay due to lack of Supervision of Labors?	0.5
4	Was there any delay due to lack of Finance for the Project?	0.5
5	Was there any delay due to any kind of pandemic?	0.49
5	Was there any delay due rainy weather?	0.49

It can be seen that the top 5 reasons that we got from Rii of Severity and Rii for Occurrence are different and no conclusion can be drawn for the reasons of delay. Therefore, a cumulative value is calculated using Equation (2) and presented in Table 4.

$$Cumulative\ Rii\ Value = 5(Rii\ for\ Severity) \times 5(Rii\ for\ Occurence) \quad (2)$$

The Cumulative Rii Value also helps to know the Intensity of Risk by looking into the Risk Matrix Chart. The reasons are highlighted with the color code showing the risk intensity. A 5×5 version of Risk chart matrix is plotted for Occurrence v/s Severity as shown in Table 6 which helps in categorizing the reasons into extreme, high, moderate and low risk based on the Cumulative Rii Value of respective reasons.

It is observed that the Cumulative Rii Value varies between values 1 to 11, hence the risk of reasons varies between "High" to "Low" that implies that none of the reasons have extreme risk. Out of 37 reasons, 10 reasons fall in high, 18 reasons fall in moderate and 9 reasons fall in low-risk category.

Table 6: Risk Matrix Chart

		SEVERITY				
		Negligible 1	Minor 2	Moderate 3	Major 4	Catastrophic 5
OCCURRENCE	5 Almost Certain	**Moderate 5**	**High 10**	**Extreme 15**	**Extreme 20**	**Extreme 25**

	4 Likely	**Moderate 4**	**High 8**	**High 12**	**Extreme 16**	**Extreme 20**
	3 Possible	**Low 3**	**Moderate 6**	**High 9**	**High 12**	**Extreme 15**
	2 Unlikely	**Low 2**	**Moderate 4**	**Moderate 6**	**High 8**	**High 10**
	1 Rare	**Low 1**	**Low 2**	**Low 3**	**Moderate 4**	**Moderate 5**

4. RESULT

For developing country lack of finance is one of the major reasons for poor productivity. The same is also observed in the present research with the highest Cumulative Rii Value of 11 for the lack of finance. Requirement of finance is very high for construction projects. Promoters fails to raise the fund for the project time to time sometimes find it difficult to manage the capital for the required resources. Poor economic conditions, such as currency and inflation rates, would have a substantial impact on the project's cash flow, and thus affect the project's timely completion. The main causes to financial market instability that leads to cash flow problems in construction project includes increment of interest rate in repayment of loan, inflation of material prices, labour wages and transportation costs and increment of exchange rate for imported equipment, formwork components, etc.

Delay due to pandemic is at the 2nd position with Cumulative Rii Value of 9.18. As we all had a bad time during this pandemic, the construction industry was greatly impacted. As the work was shut down, the industries were also shut down, so the ongoing industries that work 365 days a year were also shut down for a short period of time and lost money, causing a rise in all material prices. As a result, everything from labor to materials risen in price. The required number of workers were not available, materials may not be delivered on time, and everyone is concerned about their health. These are some of the many reasons why the project will be delayed during the pandemic.

Lack of availability of labours at site is seen in the current research with the 3rd highest Cumulative Rii value of 9.075. Shortage of laborers hits during pandemic as all the workers went to their hometown during lockdown and when relaxation is given by the government, to start work then at that time workers were afraid to come at work, as they were not so aware about the whole pandemic situation. And even after more relaxation and people started to live normal lives at that moment due to inflation all the prices were on peak and no. of workers are not available as many they required for a particular site.

With or without pandemic there was always a lack of skilled workers in the market seen as in the current research Cumulative Rii value for delay due to availability of skilled labour is 8.69. As their rates(wages) are more and as they do particular work only, so for any construction site there are less skilled laborer's and more normal(general) masons or laborer's. The work of skilled labor is not only to do work but to handle the other workers also, so in that case skilled laborers are important for any construction sites. So, by less availability of skilled workers, it majorly affects the construction project from the delays to the productivity of the work.

In the construction industry, the work majorly depends on the laborers and workers, as India is a diversified country, we have many festivals coming over the whole year. The main delay is seen during two major festivals i.e., Holi and Diwali. During these festivals the workers took almost 1 months (30 days) leave for each festival. The same is witnessed in the research as Cumulative Rii value for delay due to festival is 7.92. And apart from that on Amavasya also the workers took the day off, but this particular thing was followed by some of the workers only.

Improper Planning and Scheduling of Formwork has the Cumulative Rii value of 6.96. In developing country like India, many of the construction projects lacks in Planning and Scheduling of Formwork activity. Still old construction practices are followed at site, this often leads the project managers to make

mistake in identifying the adequate time for certain activities. Improper time estimation, resource allocation and clashing of activities are the main reasons for of project. Thus, for the developing country like India, proper project management techniques should be implemented for planning and execution of the project.

It is also observed that in developing country like India that design fluctuation happens which leads to change in plan. As per data collected this has the Cumulative Rii value of 6.48. The changes may occur in architectural layout which leads in change of structural drawing as well. Also, when the plan or designs doesn't get an approval from government institutions, changes are made in plan and designs.

CONCLUSION

A construction project's time and cost performance are largely determined by labour productivity. Only real-like productivity values can be used to design a dependable timetable. As a result, project managers will find it easier to control time and costs if they can identify the reasons that affect productivity.

The research is about determining productivity of column formwork erection activity. Which includes how the activities fall under the column formwork, what are the reasons due to which there will be seen delay in column formwork.

Some of the Measuring Techniques for Improving Productivity such as Group Time Technique, Time Study & Motion Analysis, Activity Sampling, Foreman Delay Survey are discussed. For the current research work, a Work Breakdown Structure (WBS) is prepared for the Colum Formwork Erection Activity. With the help of WBS and factors the questionnaire is also prepared which were used to collect the data from the different construction sites.

The data of **97 construction sites** was collected from which Rii value for severity and Rii value for Occurrence was calculated. Further a Cumulative Value was calculated and rank is given to all the reasons. The major reasons identified are delay due to lack of Finance for the Project, Pandemic, lack of availability of labour as well as skilled labour, improper Planning and Scheduling of Formwork Activities and design fluctuation.

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