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An Evaluation of Key Factors Influencing the Productivity of Plywood Shuttering in Construction Projects

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Abstract- This research paper examines the critical factors that influence the productivity of plywood shuttering in construction projects—a fundamental element in modern formwork systems. Although plywood shuttering is favored for its cost-effectiveness, reusability, and ease of handling, practical productivity often falls short of theoretical benchmarks due to issues related to material quality, labor proficiency, adverse site conditions, and management practices. By integrating a detailed literature review, rigorous field observations, in-depth case studies, and quantitative productivity measurements (including time–motion studies and benchmark comparisons with IS 7272 and CPWD DAR 2021), this study establishes realistic productivity standards and proposes actionable strategies to enhance on-site efficiency. The findings provide valuable insights for optimizing resource allocation, reducing material wastage, and ultimately improving construction performance.

Index Terms- Plywood Shuttering, Construction Productivity, Formwork Systems, Labor Utilization, Benchmarking

I. INTRODUCTION

Plywood shuttering, commonly used in formwork for concrete construction, plays a critical role in the efficiency and quality of construction projects. It involves the use of plywood panels to create molds for pouring concrete, which then hardens into structural components like walls, columns, and slabs. Effective shuttering is essential for achieving the desired structural integrity, maintaining project timelines, and controlling costs (Jha, 2021).

Historically, the productivity of plywood shuttering has been influenced by several factors, including the quality of materials (Khursheed S. , Sharma, Paul, Al-Farouni, & Yoldosheva, 2024), the design and installation of the shuttering system, and the skill level of the labor force (Singh, 2020). Material quality impacts the durability and strength of the shuttering, while design and installation affect the ease of use and the precision of concrete forms. Additionally, labor productivity can be influenced by training, experience, and working conditions (Kumar & Patel, 2022).

For determining the duration and resources required for each activity standard productivity values for various resources are considered as per DAR, IS Codes etc., (Vishwakarma, Paul, & Solanki, 2022) but in practice these standards are rarely met and are greatly influenced by environmental factors, site working conditions and nature of the resources and many other factors (G. & Seth, 2024)

According to scholars, formwork operations typically account for a substantial portion of construction costs and project duration (Arditi & Tokdemir, 1999).As a result, any improvements in the productivity of formwork systems, including plywood shuttering, can significantly impact the economic viability of construction projects. Previous studies have focused on the technical aspects of formwork, such as design and load-bearing capacity (Moura & Barbosa, 2016), but there is limited research on the operational and managerial factors that affect productivity. This research will fill that gap by evaluating the factors that hinder or promote the effective use of plywood shuttering.

In conclusion, the increasing adoption of plywood shuttering in construction projects highlights the importance of studying the factors that influence its productivity. This research aims to provide valuable insights into how construction managers can enhance the efficiency of plywood shuttering operations, leading to improved project outcomes in terms of cost, time, and quality.

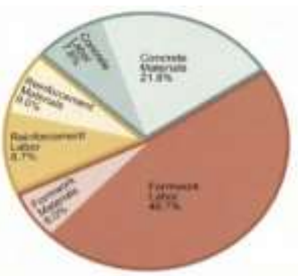

Figure 1: Composition of cost of concrete.

Source: PERI Formwork Systems, 2010, www.peri.com and structure magazine, Robert H, 2007

II. LITERATURE REVIEW

This chapter aims to review the existing literature on the productivity of plywood shuttering, focusing on the various factors that influence its effectiveness in construction projects. By synthesizing findings from relevant studies, this review will provide a detailed understanding of how different elements affect plywood shuttering performance, thereby offering valuable insights for improving construction productivity and efficiency.

There are several ways to describe productivity. According to Oglesby, a great deal of work has been done to comprehend the idea of productivity. Researchers have used a number of methodologies, leading to a broad range of definitions of productivity (Oglesby, Parker, & Howell, 1989). The connection between inputs and outputs is characterized by productivity. (Soe & Cho., 2017) assert that the inputs and outputs of various sectors vary.

Labour Productivity

According to (Bitar & Jarkas, 2014), some researchers have determined methods of measuring and analyzing productivity on-site for setting baselines and improving productivity in construction, including average labor productivity (ALP), single factor input, total productivity (multifactor), work measurement, cycle time, and so on. According to (Saini, Khursheed, Paul, & Kuma, 2021), indicators of productivity may be established in terms of all components, including capital. Labor, equipment, intermediary commodities and services (including natural resources), or a single element like labor. Single Factor Productivity analyzes the influence of a single input (labor), while Multi-Factor or Total Factor Productivity examines the impact of all inputs on output. (Judson & Paul, 2019)

Types Of Labour Productivity

Single Factor Productivity

(Lema, 2010) defined it as the ratio of the output to one class of input. For example labour productivity is the ratio of output per man-hour comes under single factor productivity concept (Vishwakarma, Paul, & Solanki, 2022). So output per ton of material and interest revenue generated per rupees of capital etc. (Chitra & Kumari, 2018).

Labour Productivity

Labour productivity most widely used to calculate operational efficiency and output (Devika , Basu, Seth, & Paul, 2020).

Average Labour Productivity = $\frac{Q}{L}$

Where Q = Output and L = Labour-Hour

Capital Productivity

Capital productivity defined in terms of a percentage return on capital invested. Average rate of return can be calculated (Judson & Paul, 2022)

Average Capital Productivity = $\frac{Profit}{Capital\ Invested}$

Total Factor Productivity

It defines as the ratio of net output to the sum of associated labour and capital input. The net output here is also known as value – added output. In this, ratio, we explicitly consider only the labour and capital input factors in the denominator (Lema, 2010).

Total Factor Productivity (t) = $\frac{Output}{(Ht+Ct)}$

Where Ht = Labour Input over period ‘t’ and Ct = Capital Invested over period ‘t’

Total Productivity

It is defined as the ratio of total outputs to the sum of all input factors. This is a holistic measure that takes into consideration the joint and simultaneous impact of all the input such as labour, materials, machine, Capital, energy, etc. This measure has received much attention over the past ten years, as evidence by many paper and case studies (Lema, 2010).

Total Productivity = $\frac{Total\ Output}{Total\ Input}$

Thus, Total Productivity over period ‘t’ (TPt) = $\frac{Qt}{(Ht+Ct+Mt+Et+Ot)}$

Where Qt = Output value over period ‘t’ Ht = = Labour Input over period ‘t’

Ct = Capital Invested over period ‘t’ Mt = Material input over period t

Et = Energy input over period ‘t’ Ot = Other expenses over period ‘t’

Total productivity has the advantage of considering all inputs yet quantification of these remain a major disadvantage of this measure which makes it impractical. These measure may vary depending upon the situation, purpose of the analysis, type of process and ease with which the data can be obtained (Sidana, AVSM, VSM (Retd.) & Paul, 2022).

Factors Influencing Productivity

This section explores the key factors affecting productivity in plywood shuttering, including material quality, labor efficiency, management practices, design considerations, tools and equipment, and other relevant factors. Material characteristics, such as plywood quality and handling, directly impact performance (Kumar & Suresh, 2006). Labour productivity is influenced by skill levels and organization (Rawat, Solanki, Paul, & Khursheed, 2022) (Naidu & Rao, 2019). Effective management and project planning are critical for resource allocation and schedule adherence (Varghese & Thampi, 2017) (Saif, Rastogi, Paul, & Anwesha , 2020). Additionally, the design of the formwork system, the quality and maintenance of tools, and environmental conditions all play significant roles (Halligan, Heste, & Thomas, 1987).

Table 1 : Factors Affecting Shuttering Productivity (Source – Author)

Sr No.	Group	Factors	Sources
1	Material Factors	Size and weight , Chemical adhesive , Poor quality , Unavailability , Poor handling	➢ (Paul & Advai, 2013) ➢ (Alinaitwe , 2007) ➢ (Gupta & Mehta, 2020) ➢ (Arora, 2024) ➢ (Chitra & Kumari, 2018) ➢ (Ghate, More, & Minde, 2016) ➢ (Khursheed & Paul, 2022) ➢ (Judson & Paul, 2022)
2	Tools and Equipment Factors	Non-availability of vertical & horizontal shifting equipment , Unavailable tools , Scaffolding	
3	Labour Factors	Inefficient crew , Unskilled workers , Lack of training , Language barriers , Labour changes , Overtime , Fatigue , De-motivation , Shortage of labor.	
4	Site Factors	Congestion , Poor site access , Distance between production and placement	
5	Design Factors	Frequent design changes , Reinforcement congestion , Height of placement , RCC volume , Project complexity	
6	Management Factors	Poor management of space , Improper sequencing , Lack of supervision , No daily targets , Unrealistic scheduling , Delayed inspections	
7	Other Factors	Non-availability of work front , Idle waiting time , Unproductive movement , Extreme weather	
8	Safety Factors	Lack of safety measures , Safety compliance delays , Accidents and injuries.	
9	Economic Factors	Delayed payments , Labor shortages	
10	Communication Factors	Poor communication between teams , Unclear instructions	

Work Flow in Shuttering Activity

Plywood shuttering is essentially a temporary mold used to shape and support concrete while it sets and cures. Think of it like the form or "mold" for a cake, but for concrete. It's a critical part of the construction process for creating structural elements like walls, slabs, and columns. (Khursheed S. , Sharma, Paul, Alzubaidi, & Israilova, 2024)

The activities involved in plywood shuttering are:

- **Material Preparation –** Gather plywood, supports, and tools.
- **Measurement and Cutting –** Measure and cut plywood to fit.
- **Support Installation –** Set up scaffolding and vertical props.
- **Plywood Fixing –** Secure plywood sheets in place.
- **Release Agent Application –** Apply oil to prevent sticking.
- **Alignment Check –** Ensure everything is level and aligned.
- **Reinforcement Installation –** Place reinforcement bars inside.
- **Inspection –** Check for gaps and secure fastening.
- **Concrete Pouring –** Pour and vibrate concrete to avoid voids.
- **Curing –** Let the concrete set and cure.
- **De-shuttering –** Remove plywood after curing.
- **Cleaning –** Clean and store materials for reuse.

Before plywood shuttering can begin, several preparatory activities must be completed to ensure the formwork is set up correctly and the construction process proceeds efficiently. These initial steps are essential for establishing a solid foundation and providing the necessary support for the concrete structure (Judson & Paul, 2022). Proper planning, material preparation, and safety measures help prevent delays, ensure quality, and minimize risks during the shuttering process (Khursheed & Paul, 2022). The following key activities must be addressed before plywood shuttering installation.

Before plywood shuttering, the following activities need to be completed:

- **Site Clearance –** Clean and level the area.
- **Setting Out –** Mark dimensions and alignment.
- **Reinforcement Placement –** Install and secure rebar.
- **Material Inspection –** Check plywood and materials for quality.
- **Tool Preparation** – Gather necessary tools and equipment.
- **Scaffolding Setup** – Install supports and scaffolding.
- **Formwork Planning** – Finalize formwork design and materials.
- **Level Check** – Ensure levels and alignment.
- **Waterproofing –** Apply waterproofing if needed.
- **Safety Measures** – Implement safety precautions.

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These steps ensure proper formwork installation and smooth construction progress.

III. RESEARCH METHODOLOGY

Research methodology has adopted to involve the following:
Literature survey: A comprehensive literature review identified significant factors affecting labor productivity. These factors were ranked using a Severity Index, based on model, and further validated with a survey employing a Rennis Likert scale. This study utilizes primary data, collected directly from construction professionals (engineers, foremen, workmen).

Review of CPWD DAR (2021)

- **Source:** CPWD DAR (Delhi Analysis of Rates) will be the primary reference for standardized productivity rates related to plywood shuttering.
- **Focus:** Extract relevant productivity data (e.g., labour hours per square meter) to form a benchmark for current plywood shuttering practices.
- **Method:** Analyse sections in CPWD DAR specific to formwork and compare them with site data to ensure relevance to plywood shuttering.

Review of IS Codes for Productivity

- **Source:** Key IS Codes like IS 7272 for Productivity.
- **Focus:** Identify the benchmark for shuttering Productivity.
- **Method:** Analyse the IS Codes to extract technical standards that guide the use of plywood in shuttering.

Data collection: The factors outlined in Table 4 will be preserved to facilitate the collection of field data. Site visits will be conducted during the data collection phase to gather primary data directly from the sites while activities are being performed. This approach will follow an engineering-based approach that utilizes the "time and method study" technique, which will enable accurate and reliable data collection by observing and analyzing the activities being performed at the site. The time and method study as elaborated in Literature review is divided into 2 parts:

Method study
Work measurement
Under the "method study", the activities under consideration are broken down into smaller operations under the heads of Direct, In-direct and Non-contributory operations, which are then observed to determine the number of times a particular operation is performed by the gang in a given period of time (Handa & Abdalla, 1989).

The time period (1Hour in this case) is also broken into smaller intervals of 30 seconds each depicted by "1-10" equaling to a total of "5 minutes" ((30 seconds X 10)/(60 seconds)) , and in the prepared worksheet, a code is entered to indicate the operation performed in that particular interval. The format used for this purpose is as below.

The number of times direct, indirect and non-contributory operations are performed is calculated from the observation sheet and recorded and used for calculations of Labour utilization Rate as well as the time taken in minutes by each direct and indirect operations using the formula:

Table 2: Observation Table Format for Work Study

Morning to Afternoon Shift (09:00 AM to 01:00PM)												
09:00AM												
10:00AM												
11:00AM												
12:00AM												
Afternoon to Evening Shift (02:00 AM to 06:00PM)												
02:00PM												
03:00PM												
04:00PM												
05:00PM												

$$\text{LUR (\%)} = \frac{Direct + \frac{1}{4} Indirect\ contributory}{Total\ no.\ of\ observation} \text{ x } 100$$

(By & Seth, 2024; Grover & Solanki, n.d.) , (Kaming, Olomolaiye, Holt, & Harris, 1998)

For the purpose of work measurement, the total quantity of work which is done during the observation period is calculated using drawings/schedules/visual inspection, and interactions at site.

$$LP = \frac{ESQ_d}{ALS_d \text{ X } Nd_d} \quad \text{Sqm./person/day}$$

Where:

LP	= Labour productivity
ESQ_d	= Executed shuttering Quantity in a day
ALS_d	= Average labour strength in a day
Nd_d	= No of working hours in a day / 8

Data synthesis: Case study data will be organized and checked for outliers to prepare for statistical analysis (IBM SPSS Software) . (Moza & Paul, 2024)

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IV. RESULTS AND DISCUSSIONS

Current Benchmark/ Standards for Plywood Shuttering

Table 3 IS Code 7272-1974

Productivity of Plywood Shuttering - IS CODE 7272-1974				
S. No.	Shuttering Type	UNIT	Carpenter	Mazdoor
1	Rectangular Column and Walls	sq.m/day/person	4	5
2	Suspended Floors/Roofs	sq.m/day/person	4.35	5
3	Sides and Soffits of Beam	sq.m/day/person	3.33	5

From the DAR 2021, the carpenter productivity for plywood formwork can be estimated using the provided labor requirements and unit output data. For assembling, erection, dismantling, and cleaning of formwork, the following labor norms are noted:

Second-Class Carpenter:

- **Quantity:** 1.00 Day for 4 sqm.
- **Equivalent Productivity:** 4sqm/day per carpenter(AOR Vol_ -1 (2021)).

Calculation Details:
For a single carpenter, 1 day of work corresponds to completing 4 sqm of plywood formwork, as specified for typical tasks related to assembling and dismantling.
Thus, the average productivity of a second-class carpenter for plywood formwork is 4 sqm/day.

Productivity Range
This is the Productivity Range as per by Planning Engineer Website. It told about the productivity of different Plywood Shuttering works based on their past experiences.
Shuttering Carpenter productivity:

- Form work-Footings, foundations, ground 8 m2 / day.
- Form work-Columns, pedestals 6 m2/day.
- Form work-Beams and slabs 8 m2/day.
- Form work-Tie beams, arches, and lintels 5 m2/day.
- Form work-Walls 8 m2 / day.
- Form work-Circular, special shapes 4 m2/day.
- Formwork- Making timber shutters 8 m2/day. (Ismail, 2013)

Productivity and LUR data for case studies:

S.	Project Name	Project Location	Type	Crew	Nos of Observation					PFS Area	Average
					Direct	In-direct	Non-Contributory	Total			
1	Whiteland Bliss Ville	Sector 76 Gurgaon	Retaining Wall	1 Carpenter + 2 Labour	65	18	13	96	72.40%	26	10.031
2	GLS Courtyard	Sec -95 , Gurugram	Footing	1 Carpenter + 2 Labour	75	12	9	96	81.25%	34	7.505
3	Whiteland Bliss Ville	Sector 76 Gurgaon	Slab	1 Carpenter + 2 Labour	71	16	9	96	78.13%	42	9.272
4	DLF Garden City Floors	Sec -92, Gurgaon	Retaining Wall	1 Carpenter + 2 Labour	73	12	11	96	79.17%	51	14.401
5	Type 5 Staff Quarters	Jamia Millia Islamia , Delhi	Slab	1 Carpenter + 2 Labour	66	18	12	96	73.44%	29	6.629
6	Our Homes	Sector – 6, Sohna	Slab	1 Carpenter + 2 Labour	59	21	14	94	68.35%	28	11.2

Data Analysis:
From the Q-Q graph, it is evident that the data is normally distributed. Consequently, I analysed the data using IBM SPSS software.
Various graphs and statistics obtained through IBM SPSS show the mean productivity, and Labour Utilization Rate (LUR).

Table 4: Case Study Data

Case Study No.	Project Name	Project Location	Avg. LUR (%)	AFS Area Completed in one day (in SQM.)	Average Productivity (in SQM./Person/Day)
1	Whiteland Bliss Ville	Sector 76 Gurgaon	0.724	26	10.031
2	GLS Courtyard	Sec -95 , Gurugram	0.813	34	7.505
3	Whiteland Bliss Ville	Sector 76 Gurgaon	0.781	42	9.272
4	DLF Garden City Floors	Sec -92 , Gurgaon	0.792	51	14.401
5	Type 5 Staff Quarters	Jamia Millia Islamia , Delhi	0.734	29	6.63
6	Our Homes	Sector – 6, Sohna	0.684	28	11.2

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Table 5: Case Studies Data Analysis (Source: IBM SPSS Statistics 27)

Statistics				
Avg. LUR (%)			PFS Area Completed in one day (in SQM.)	Average Productivity (in SQM./Person/Day)
N	Valid	6	6	6
	Missing	0	0	0
Mean		.75467	35.00	9.840
Median		.75750	31.50	9.652
Std. Deviation		.048685	9.716	2.7845
Range		.129	25	7.8
Minimum		.684	26	6.6
Maximum		.813	51	14.4

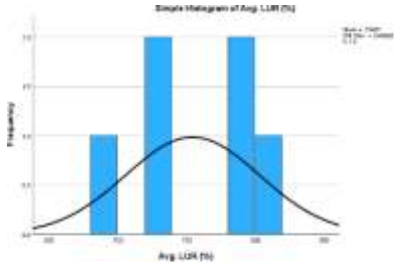

Figure 2: Case Studies LUR Data Analysis Graph (Source: IBM SPSS Statistics 27)

The above graph shows that, the mean Labour Utilization Rate (LUR) is 75.467% and the Labour Utilization Rate (LUR)
range is 68% - 82%.

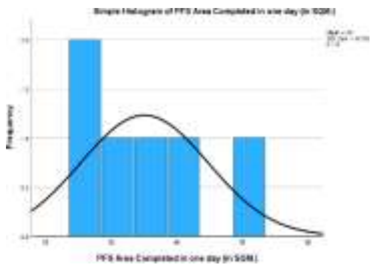

Figure 3: Case Studies PFS Area Completed Data Analysis Graph (Source: IBM SPSS Statistics 27) The above graph shows that, the avg.

Plywood Formwork area completed is 35sq.m and the range is 24-53 Sqm.

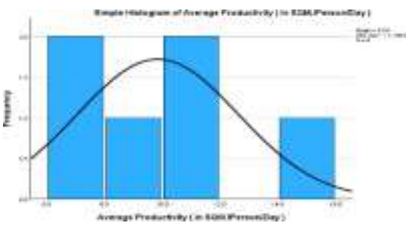

Figure 4 : Case Studies Productivity Data Analysis Graph (Source: IBM SPSS Statistics 27)

The above graph shows that, the mean productivity is 9.84 Sqm/Person/Day days and the productivity range is 6-16 Sqm/Person/Day.

Case Study Inferences:

Productivity Data Collection Inferences:

In this chapter, the focus is on gathering on-site labor and productivity data related to Plywood formwork activity along with the issues that are faced during each operation during execution with the help of interactions with the experts.

The collected data is then synthesized and subjected to statistical analysis.The results of the statistical analysis indicate that the time of day when Plywood formwork activity is carried out does not affect productivity.

Table 6: Case Studies Data Analysis (Source: IBM SPSS Statistics 27)

Statistics				
Avg. LUR (%)			PFS Area Completed in one day (in SQM.)	Average Productivity (in SQM./Person/Da y)
N	Valid	6	6	6
	Missin g	0	0	0
Mean		.75467	35.00	9.840
Median		.75750	31.50	9.652
Std. Deviation		.048685	9.716	2.7845
Range		.129	25	7.8
Minimum		.684	26	6.6
Maximum		.813	51	14.4

From Case Study data, the mean productivity is 9.84 Sqm/Person/Day and the productivity range is 6-16 Sqm/Person/Day, and the mean Labour Utilization Rate (LUR) is 75.47% and the Labour Utilization Rate (LUR) range is 68% - 82% and the avg. Plywood Formwork area completed is 35 Sq.m and the range is 24-53 Sqm.

V. CONCLUSIONS

This Research investigates the productivity range for plywood formwork activities and compares actual site performance with established standards. Variations between planned and achieved productivity often lead to project delays and cost overruns.

The study first identifies key plywood shuttering activities, including material preparation, measurement, fixing, reinforcement, concrete pouring, and de-shuttering. Next, it examines 56 productivity-affecting factors, later refined to 11 key factors across six categories, including material handling, labor efficiency, design complexity, and site management.

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Benchmark productivity values from IS Code 7272, DAR, and industry reports indicate rates between 4–8 m²/day per worker, varying by task complexity. However, time and motion studies from six case studies reveal a significantly higher actual productivity range of 6–16 m²/day, with a mean of 9.84 m²/day.The findings emphasize the gap between standardized benchmarks and real-world performance, highlighting the need for revised productivity norms to enhance accuracy in project planning and execution

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