

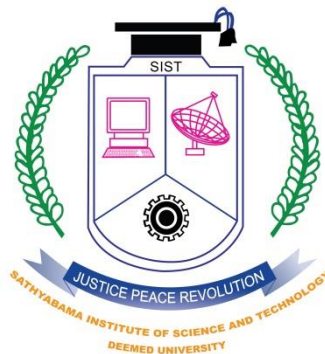
ANALYSIS STUDY OF PRODUCTIVITY DURING PLANNING AND CONSTRUCTION PHASE IN FORMWORK USING LEAN TOOLS

A Thesis

Submitted in partial fulfilment of the requirements for the award of
Master of Architecture degree in Building Management

By

SHINEY LOURDES I (40840014)



**DEPARTMENT OF ARCHITECTURE
SCHOOL OF BUILDING AND ENVIRONMENT**

SATHYABAMA

**INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)**

Accredited with Grade "A" by NAAC

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MAY 2022



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This is to certify that this Report is the bonafide work of **SHINEY LOURDES I(40840014)** who carried out the Thesis entitled "**ANALYSIS STUDY OF PRODUCTIVITY DURING PLANNING AND CONSTRUCTION PHASE IN FORMWORK USING LEAN TOOLS**" under our supervision from January 2022 to May 2022.

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DATE : 06.05.2022

PLACE: CHENNAI



SIGNATURE OF THE CANDIDATE

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ABSTRACT

Construction Labor Productivity (CLP) is important to the construction industry as it has a direct impact on the competitiveness of small and medium enterprises. This is to review out to date on identification of the factors related to CLP. The importance of CLP factors according to geographic regions is also to be identified. The methods used for CLP estimation from the factors should be briefly discussed and finally, the recommendations for the improvement of CLP should be summarized. Several studies related to labor productivity are performed for construction industry in past. Several of them were related to calculating the effect of productivity factors. Measurable calculations about the effects of those factors are required for several purposes, it includes estimation of the construction project, it's planning and scheduling. However, past study shows that it is tough to calculate such an impact, and at present there are no universally accepted standards to measure factors causing labor productivity loss in construction industry. Current practices in formwork assembly, machining, and transportation considerable waste. This thesis adapts lean manufacturing practices to establish a lean formwork construction model to reduce waste while increasing customer value. The *kanban* system is used to optimize mold inventory while creating a continuous formwork construction flow, allowing for improved progress control. In this case study have explained the proposed lean formwork construction model can reduce waste in the process of assembling, machining, and transporting molds, thus increasing customer value. Improving formwork quality depends on adopting a culture of continuous learning and improvement. The *andon* culture and *kanban* system can then be used to eliminate waste. However, in implementing such a system, the foreman and superintendent must take into account the potential for resistance to change. Implementing the lean formwork construction model would require extensive education and training. While the current study focuses on the mold assembly, machining, and transport processes. The factors identified reveal that the majority of the productivity problems faced by construction practitioners are a result of poor management of the construction projects, with the major factors entailing the need of implementing effective resource management practices on construction projects. Poor labor productivity is a chronic problem in most of the construction sites. However labor productivity is rarely measured on the construction sites and hence the losses are never identified.

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CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Several studies related to labor productivity are performed for construction industry in past. Several of them were related to calculating the effect of productivity factors. Measurable calculations about the effects of those factors are required for several purposes, it includes estimation of the construction project, it's planning and scheduling. However, past study shows that it is tough to calculate such an impact, and at present there are no universally accepted standards to measure factors causing labor productivity loss in construction industry.

1.2 AIM

The aim is to focus on views from the construction industry about various factors affecting labor productivity, analyzes factors affecting the labor productivity impact, and suggests appropriate measures that can be taken to improve labor productivity.

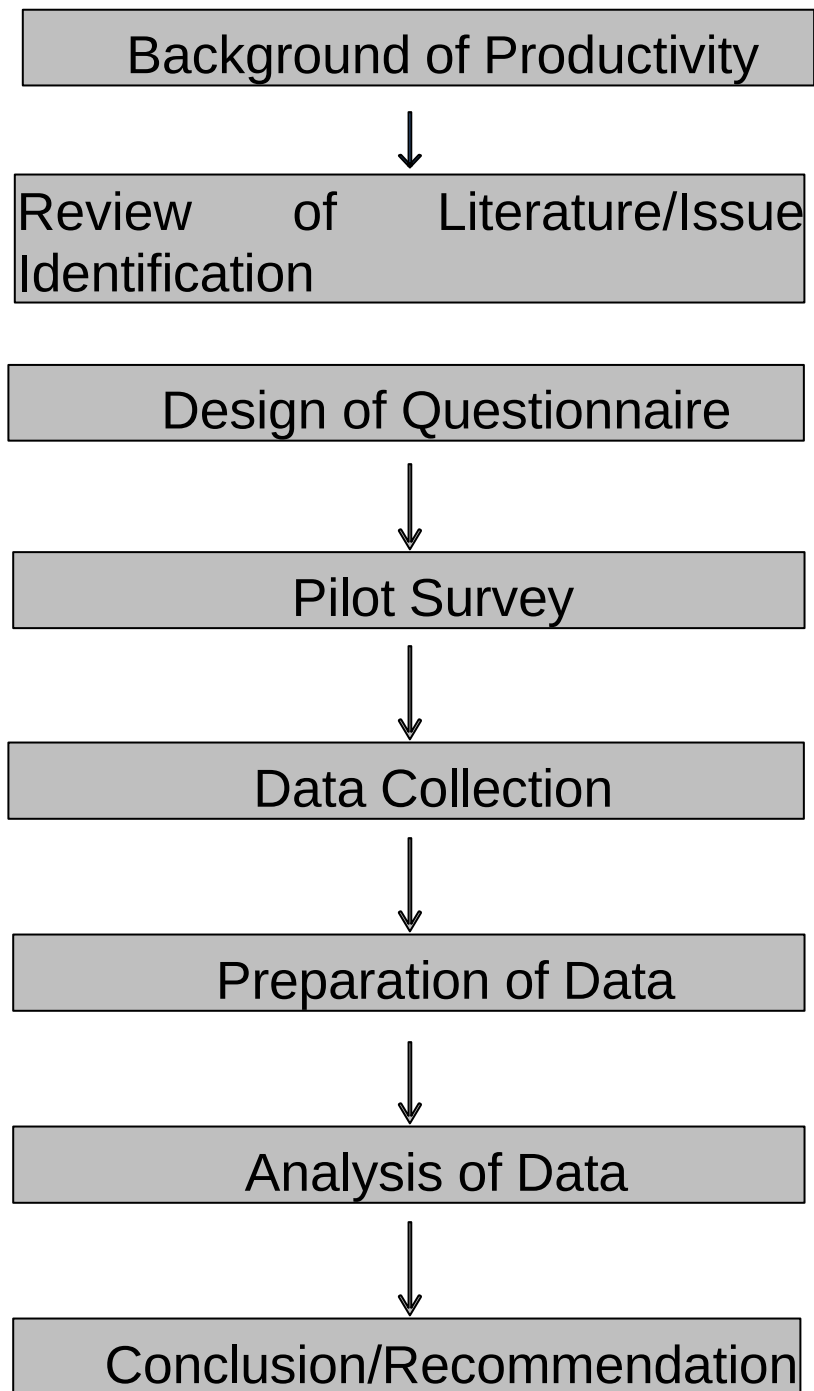
1.3 SCOPE AND OBJECTIVE

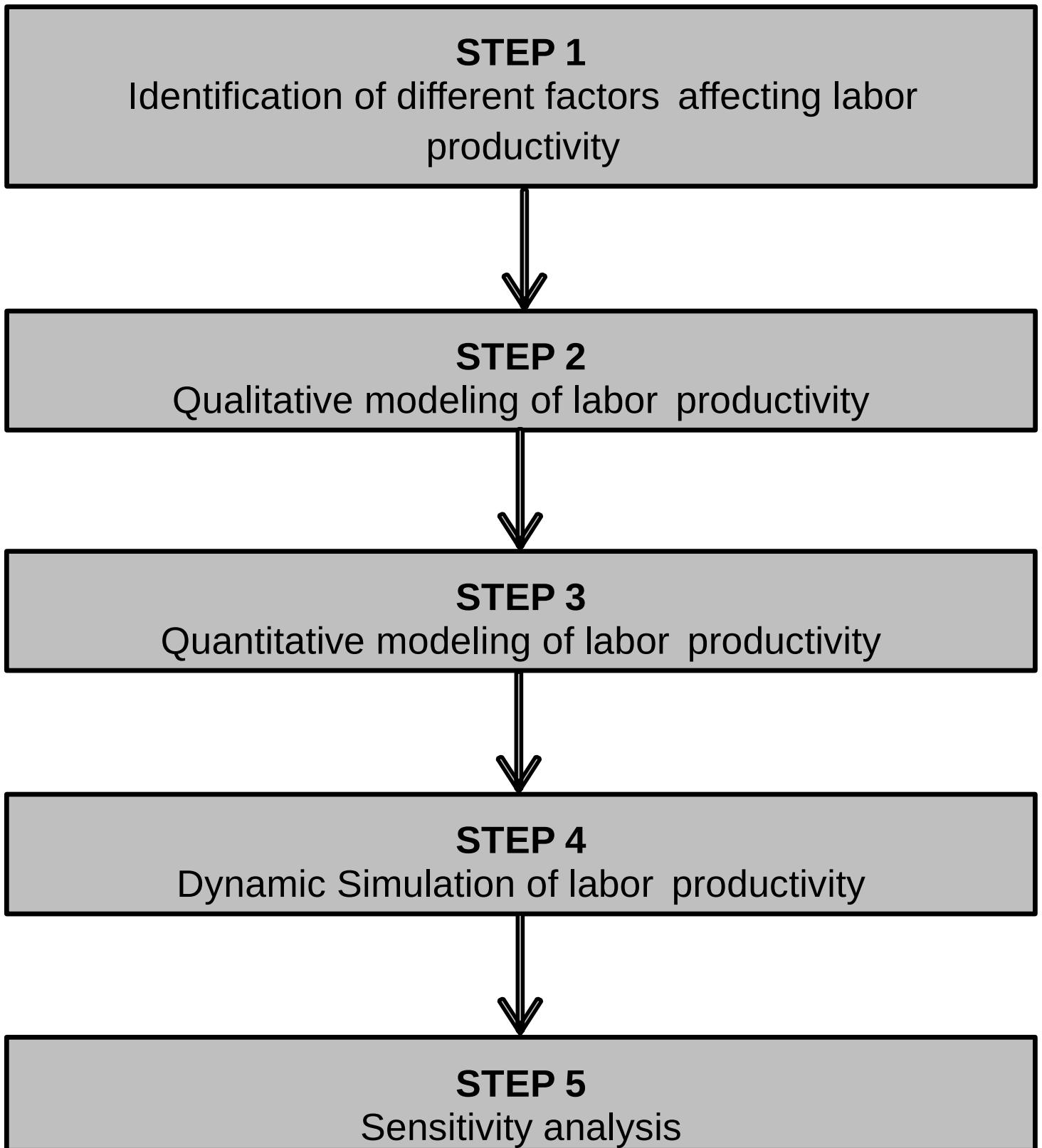
- To Study and discuss various factors affecting labor productivity in construction industry.
- To analyze and calculate the factors affecting labor productivity.
- To statistically analyze the factors affecting labor productivity.
- To make recommendations to improve labor productivity in construction.
- Analyze the relationships between skilled and unskilled labor and their impacts on project performance
- Identify whether there is a significant (positive) relationship between skilled labor and project performance
- Identify whether there is a significant (negative) relationship between unskilled labor and project performance.

1.4 RESEARCH QUESTIONS

- How does the type of labor influence the performance of building projects?
- How does the source of material influence labor productivity in performance of building projects?
- How does method of hiring labor influence the performance of project time in building projects ?
- How does the level of training of construction workers influence performance of building

1.5 METHODOLOGY

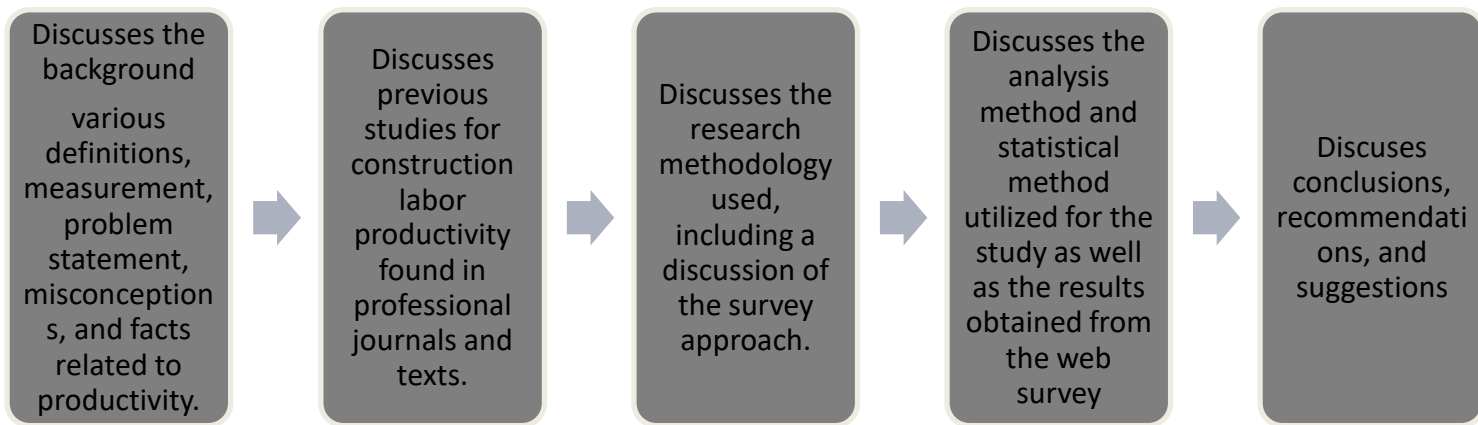
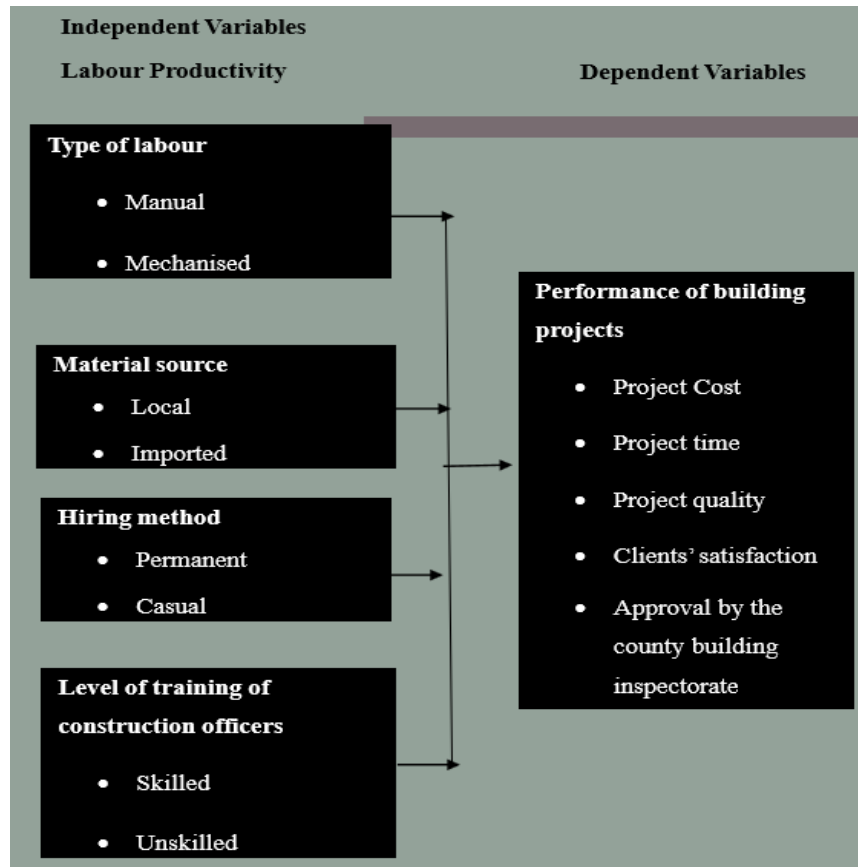


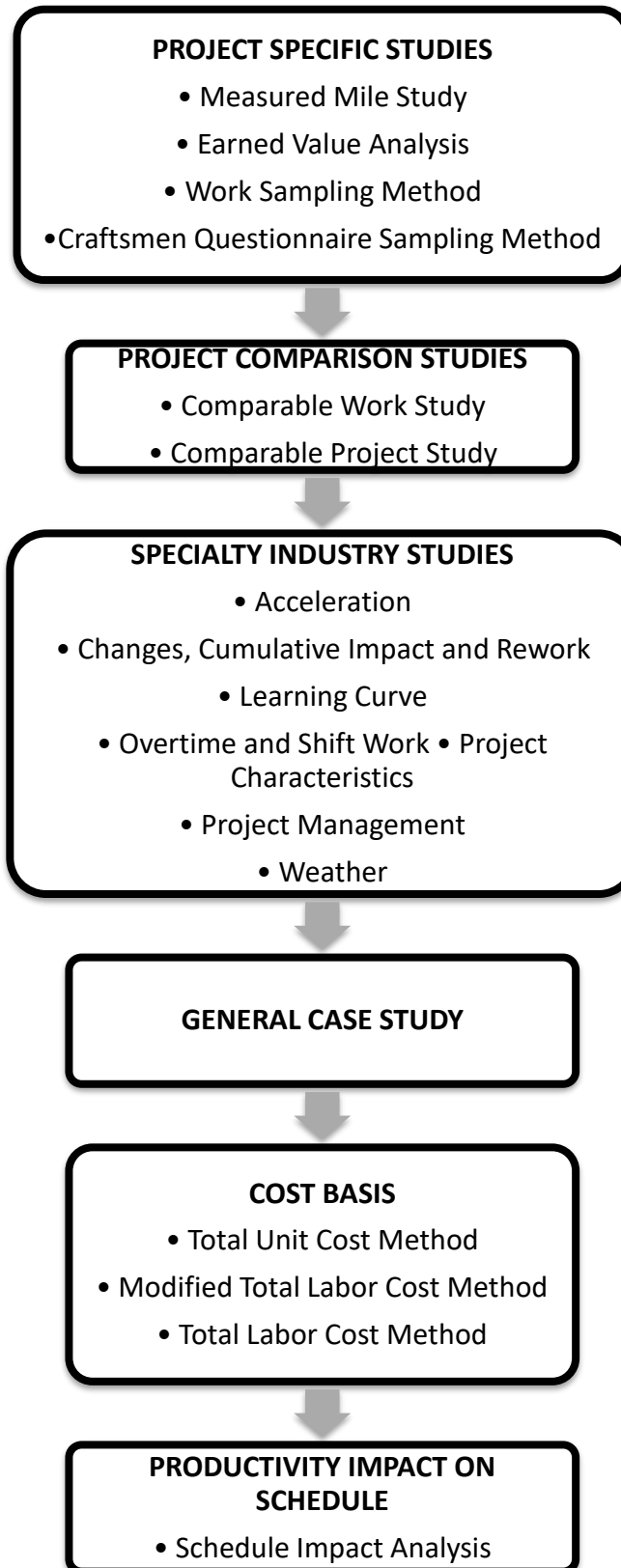


CHAPTER 02

LITERATURE REVIEW

2.1 INTRODUCTION



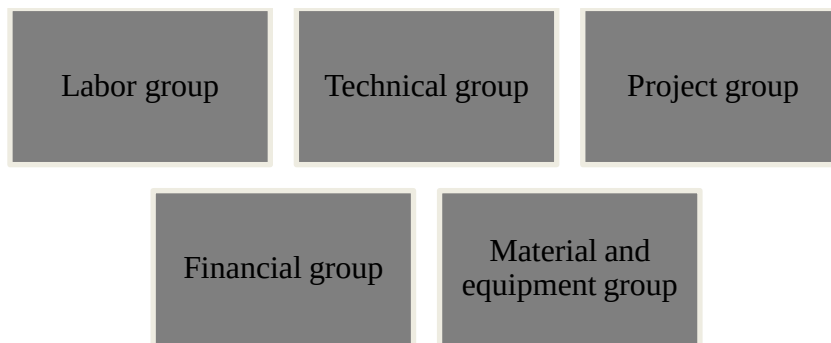


2.2 Study of Significant Factors Affecting Labor Productivity at Construction Sites in Jordan: Site Survey Dr. Ghanim A. Bekr Associate Professor, Civil Engineering Department, Faculty of engineering, Zarqa University, Jordan

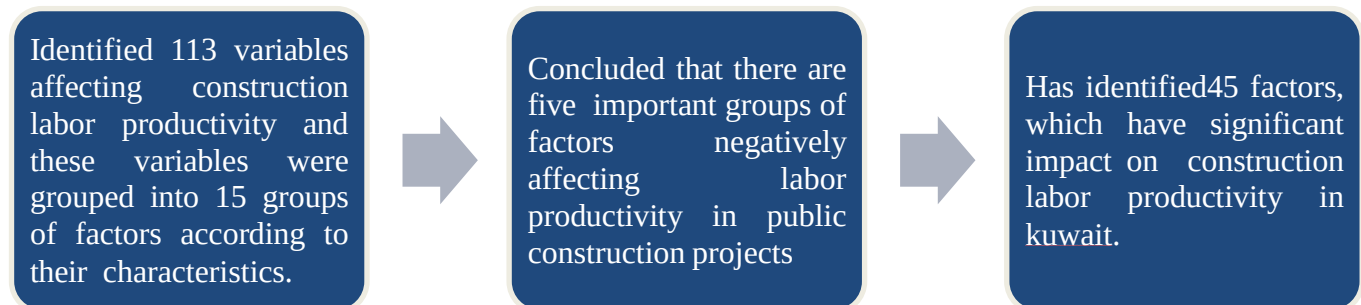
2.2.1 Objective

Identifying and ranks the factors that affect the productivity on Jordan in construction projects.

FACTORS IDENTIFIED THROUGH LITERATURE REVIEW



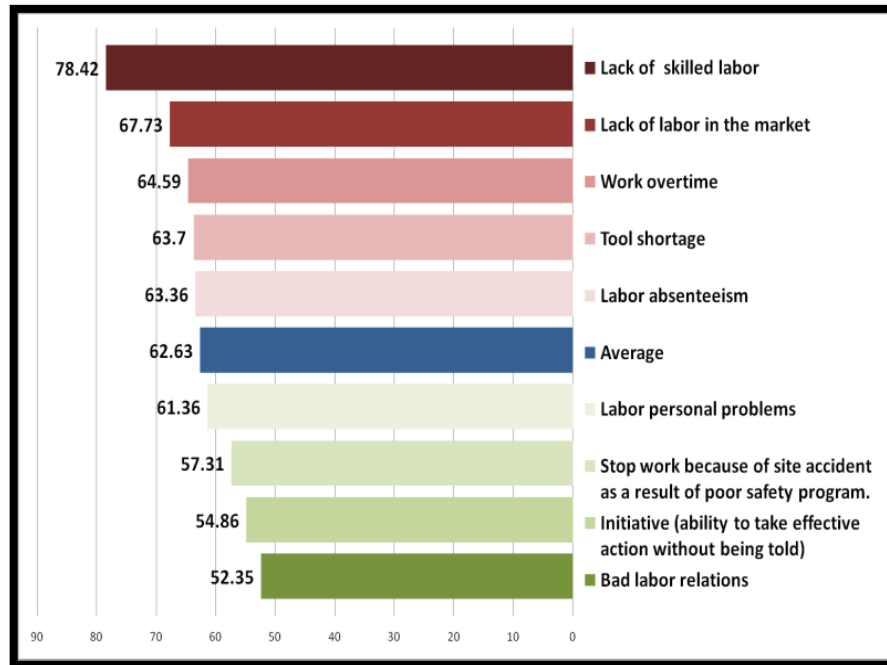
2.2.2 Literature Review



2.2.3 Questionnaire Results And Discussions

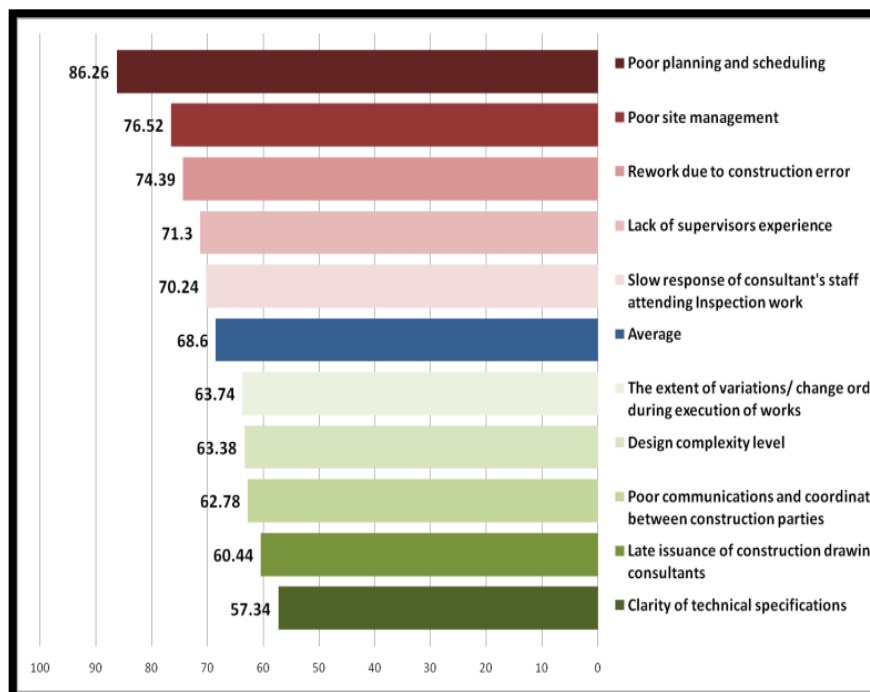
2.2.3.1 Group 1: Labor Group

- Lack of skilled labor
- Lack of labor in the market
- Work overtime
- Tool shortage
- Labor absenteeism



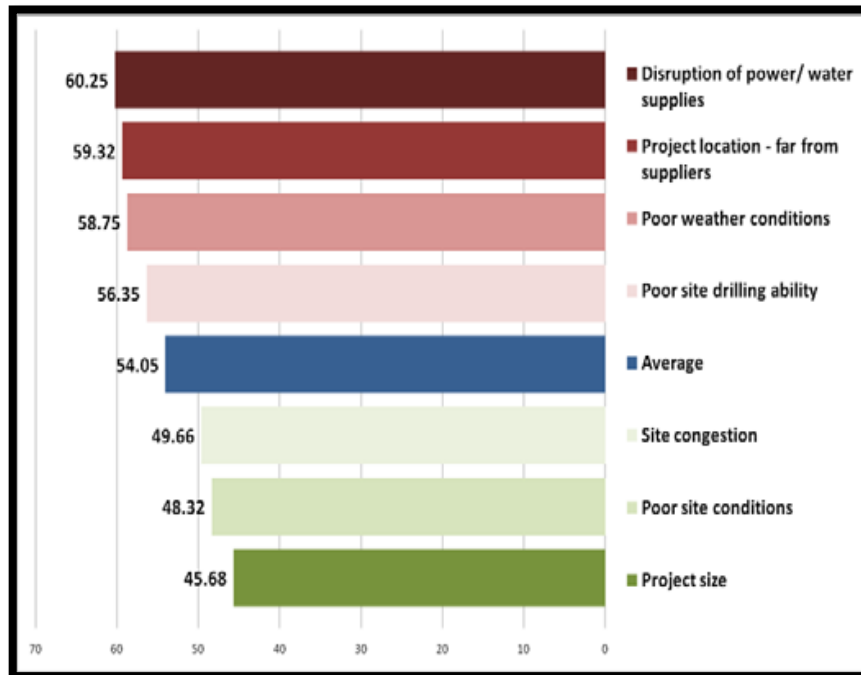
2.2.3.2 Group 2: Technical Factors

- Poor planning and scheduling
- Poor site management
- Rework due to construction error
- Lack of supervisor's experience
- Slow response of consultant's



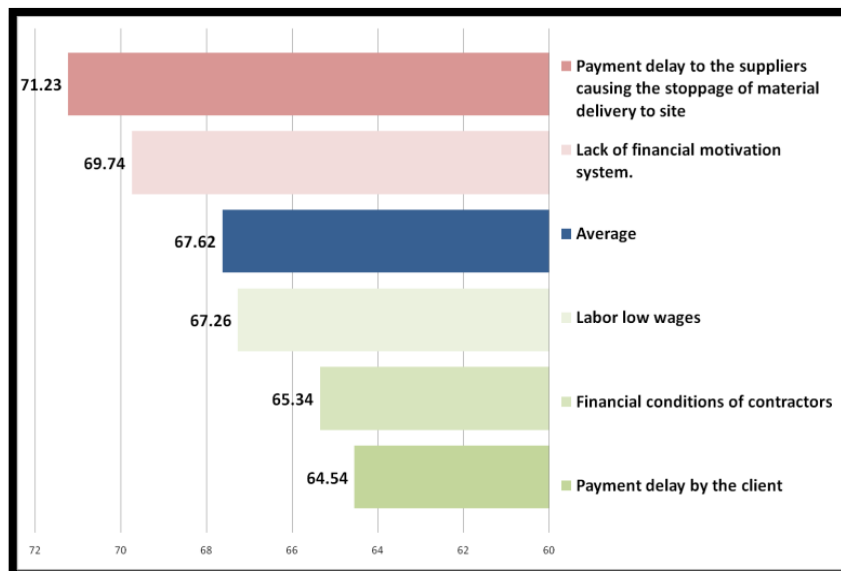
2.2.3.3 Group 3: Project Factors

- Disruption of power/ water supplies
- Project location – far from suppliers
- Poor weather conditions
- Poor site drilling ability



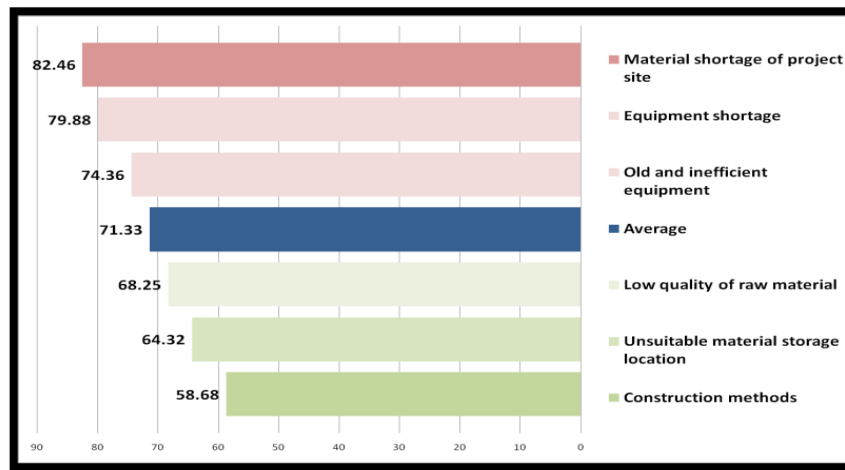
2.2.3.4 Group 4: Financial Factors

- Payment delay to the suppliers
- Lack of financial motivation
- Financial conditions of contractors



2.2.3.5 Group 5: Material And Equipment Factors

- Material shortage on project site
- Equipment shortage
- Old and inefficient equipment



2.2.4 Ranking Of Significant Productivity Factors

Factor affecting productivity	Import. Index	Overall Rank	Group
Poor planning and scheduling	86.26	1	Technical
Material shortage of project site	82.46	2	Mat. & Equip.
Equipment shortage	79.88	3	Mat. & Equip.
Lack of skilled labor	78.42	4	Labor
Poor site management	76.52	5	Technical
Rework due to construction error	74.39	6	Technical
Old and inefficient equipment	74.36	7	Mat. & Equip.
Lack of supervisors experience	71.30	8	Technical
Payment delay to the suppliers	71.23	9	Financial
Slow response of consultant's staff attending inspection of work	70.24	10	Technical
Lack of financial motivation system.	69.74	11	Financial
Financial conditions of the contractor	68.25	12	Financial
Work overtime	67.73	13	Labor
Design changes	67.26	14	Technical

2.2.5 Conclusions

- Provide adequate scheduling and programming taking into consideration time required to the supply of materials. Increase the level of technical and managerial skills of site managers and engineers by providing long term and short term training.
- Provide adequate assessment of risks and constraints such as alterations of design and payment delay before undertaking of construction projects.
- Selecting a suitable storage location for purchased materials in each project, which should be easily, accessible and adjacent to works locations.
- Paying more attention to the quality of construction materials and tools used in the project.
- Project management should employ the suitable people to do the work. Contracting companies to adopt motivational or personnel management measures to encourage the workforce.

2.3 Study on Labour Productivity by Learning Curve Effect Amrutha Raman¹, Aby Varghese²

2.3.1 Aim

This study aims at exploring the relationship between floor number and labor productivity in High-rise building activities, namely construction of partition walls and finishing works.

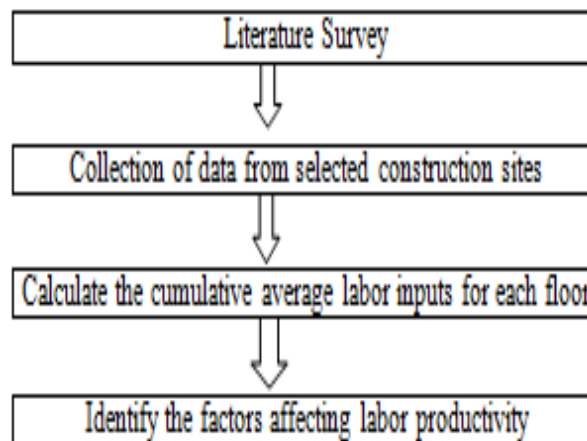
2.3.2 OBJECTIVE

This study is mainly aimed at finding out the factors that influence labor productivity. It also focuses on developing a straight line model.

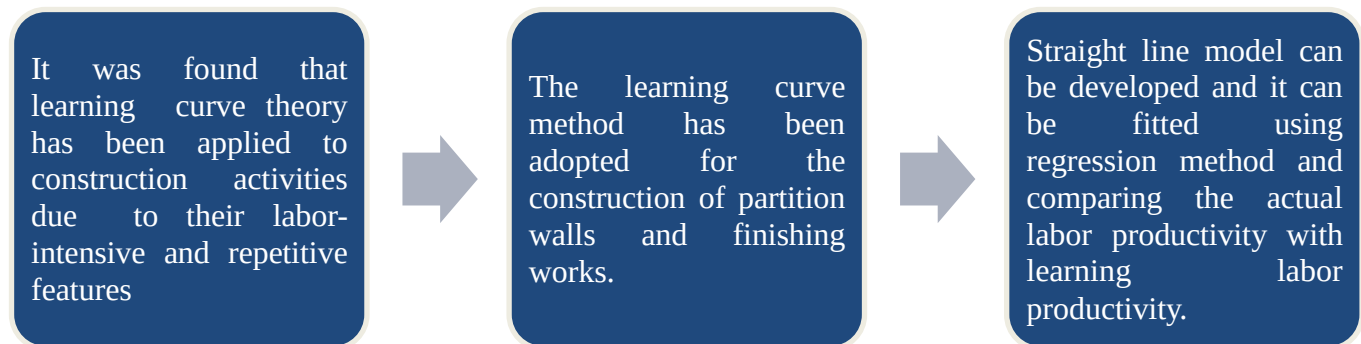
2.3.3 Factors Identified Through Literature Review



2.3.4 Methodology



2.3.5 Literature Review



2.3.6 Application Of Learning Curve Theory To Partition Wall And Plastering Works Labor Productivity Data Collection

Project no.	Project type	Floor area(m ²)	No. of identical floors
1	Residential	448	14
2	Residential	564	26
3	Residential	564	26

Company name	Silpa projects & infrastructure
Site	Army welfare housing organization, Tower A
Location	Silver sand Island, Vyttila
No. of identical floors	14

Labor productivity data such as man hours, quantity of work and number of workers of partition wall construction and plastering works were collected from building projects located in Ernakulum. The equivalent work hours for each floor were calculated by using the formula.

$$\text{Equivalent work hours} = \frac{\text{work hours}}{\text{quantity}}$$

2.3.7 Partition Wall Labor Productivity Data Of Project No.1

Cycle no:	Duration (days)	Work hours(h)	Work hours per day (h)	Additional work hours(h)	No. of workers	Quantity (m ³)	Equivalent work hours (h/m ³)	Cumulative work hours (h/m ³)	Cumulative average work hours (h/m ³)
1	10	80	8	0	7	76.34	1.047	1.047	1.047
2	9	72	8	0	7	76.34	0.943	1.99	0.995
3	9	72	8	0	7	76.34	0.943	2.933	0.977
4	9	72	8	0	7	76.34	0.943	3.876	0.969
5	8	64	8	0	7	76.34	0.943	4.819	0.963
6	9	72	8	1	7	76.34	1.047	5.866	0.977
7	9	72	8	0	8	76.34	0.943	6.809	0.972
8	9	72	8	0	7	76.34	0.943	7.752	0.969
9	9	72	8	0	7	76.34	0.943	8.695	0.966
10	9	72	8	0	7	76.34	0.943	9.638	0.963
11	9	72	8	0	7	76.34	0.943	10.58	0.961
12	9	72	8	0	7	76.34	0.943	11.52	0.96
13	9	72	8	0	7	76.34	0.943	12.46	0.958
14	9	72	8	0	7	76.34	0.943	13.41	0.957

2.3.8 Questionnaire Survey

Importance index= $5n_1+4n_2+3n_3+2n_4+n_5/5(n_1+n_2+n_3+n_4+n_5)$.

n_1 "extremely significant effect",

n_2 "very significant effect",

n_3 "significant effect",

n_4 "slight effect"

n "no effect".

2.3.9 Conclusions And Recommendations

The learning process stems from individuals or gangs repeating the same task and gaining skill or efficiency from their own experience or practice.

This acquired experience is attributable to:

- (1) increased knowledge about the task being performed;
- (2) greater familiarity with the task;
- (3) improved work organization;
- (4) better coordination; and
- (5) more effective use of tools and methods.

2.4 Dynamic modeling of labor productivity in construction projects Farnad Nasirzadeh ^{a,*}, Pouya Nojedehi ^B

2.4.1 Aim

- This research presents a system dynamics (SD)-based approach to model labor productivity. The complex inter-related structure of different factors affecting labor productivity is modeled using system dynamics approach.

2.4.2 Factors Identified Through Literature Review

- System dynamics (SD) introduced by Forrester (1961) is an objective-oriented simulation methodology enabling us to model complex systems considering all the influencing factors .
- System dynamics approach provides a rigorous method for description, exploration and analysis of complex systems.
- A dynamic system is a system in which the variables interact to simulate changes over time.
- SD modeling is useful for managing and simulation of processes with two major characteristics

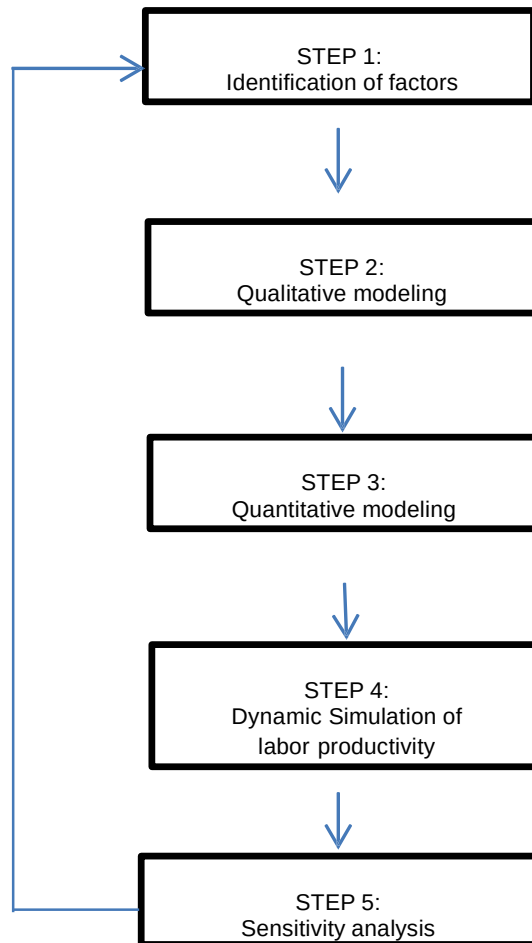
They involve changes overtime



They allow feedback — the transmission and receipt of information

2.4.3 Analyzed Method

Causal loop diagrams and stock and flows



- The qualitative model of labor productivity is constructed using cause and effect feedback loops.
- Then the inter-relationships that existed between different factors are defined by mathematical equations and the quantitative model of labor productivity is built.
- Dynamic simulation of labor productivity is performed using developed quantitative model and labor productivity is determined.
- Sensitivity analysis is conducted to assess the impact of different factors on labor productivity.
- Using the developed SD model, the impact of alternative solutions to improve labor productivity could be assessed.

2.4.5 Simulated Values Of Labor Productivity For Different Values Of Influencing Factors

Case no.	Weather temperature	Lack of working area	Skillfulness	Average workweek (hour)	Project management efficiency	Motivation	Lack of material	Unfamiliarity with new technique	Productivity
Base case	20	1	1	40	1	1	1	1	20
1	17.5	1.105	0.9	40	0.902	1	1	1	14.91
2	14	1.025	0.8	42.3	0.76	1	1	1	10.04
3	25	1	0.8	40.83	0.695	1	1	1	11.912
4	7.5	1.264	0.6	77.18	0.695	1	1	1	6.08

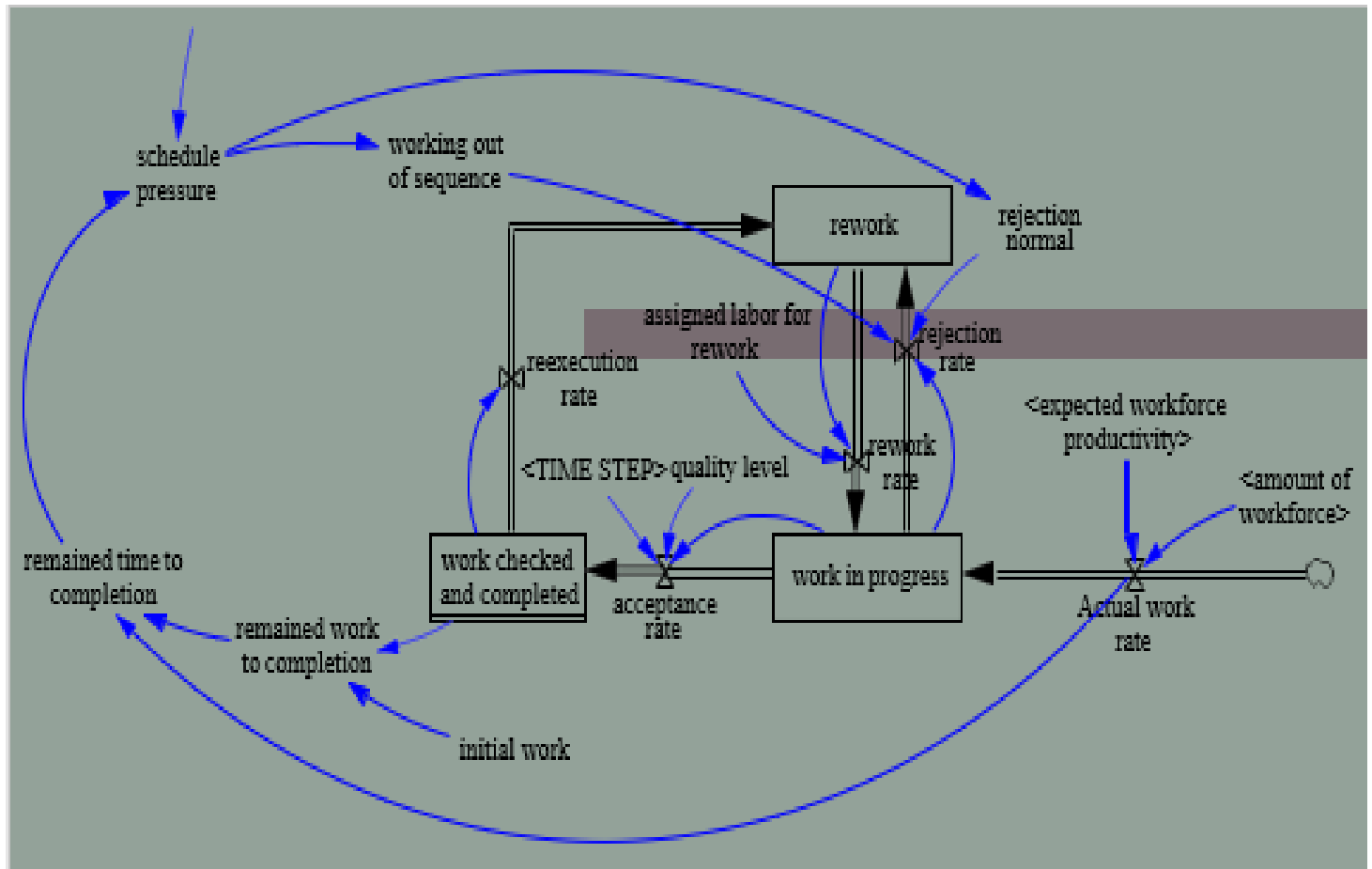


Fig 2.1 Project Workflow Sector

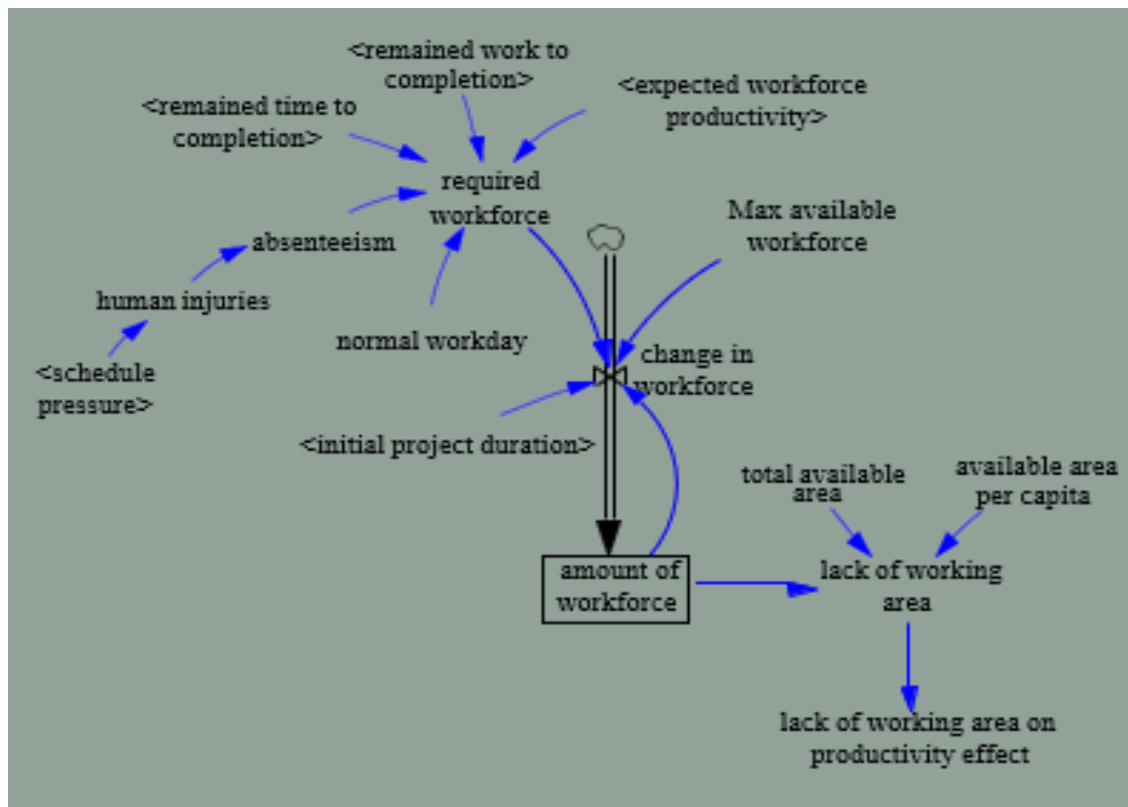


Fig 2.2 Modification In Labor

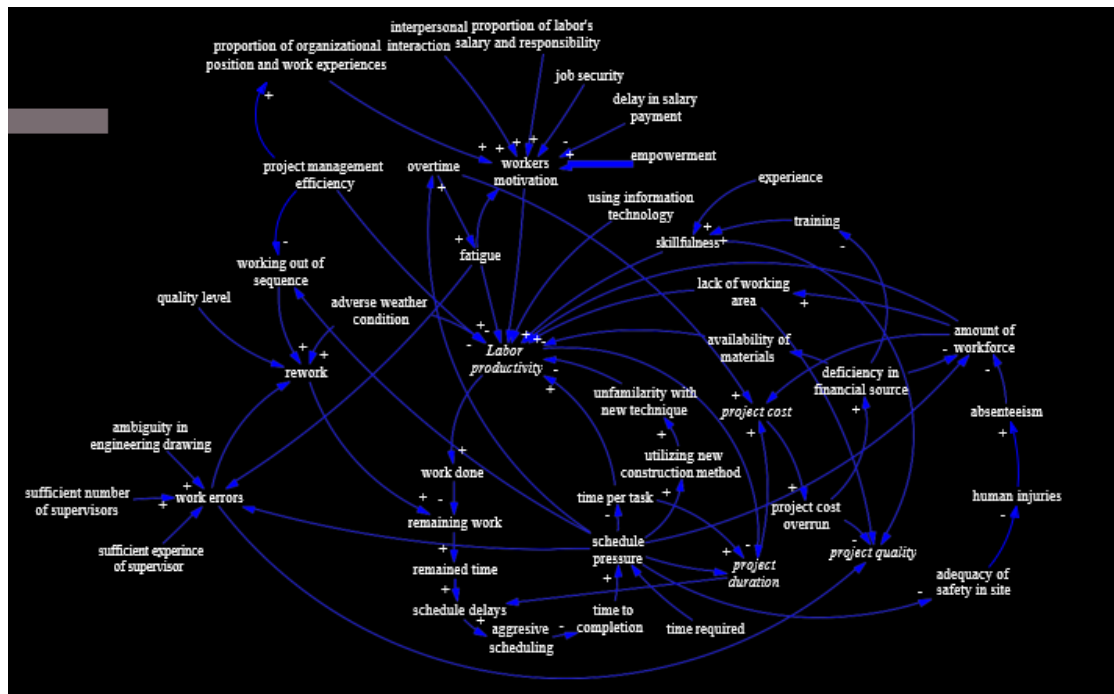


Fig 2.3 Conceptual Model Of Labor Productivity

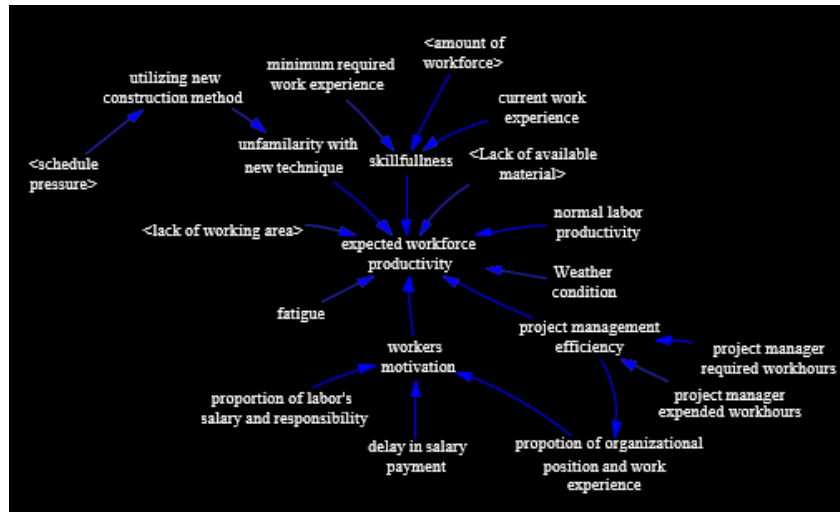


Fig 2.4 Labor Productivity Sector

As it can be seen in this figure, the labor productivity is affected by several factors directly and indirectly. The arrows indicate causal relationships and the positive or negative signs at the arrowheads indicate that there exists a positive or negative relation between two variables, respectively. To make the labor productivity model more comprehensible for practitioners, it has been divided into four sub-models including project workflow, workforce, project duration and cost, and labor productivity sectors. Moreover, each of these influencing factors has also been modeled considering the parameter affecting them. As an example, it has been shown that skillfulness is affected by three parameters including current work experience, minimum required work experience and amount of workforce.

2.4.6 Model Application

- Initial work: 600 m³ of concrete pouring.
- Initial project duration: 5 months.
- Number of workforce: 6.
- Normal labor productivity: 20 m³/month (per person).
- Labor salary: 1000 \$ per month (per person).
- Equipment cost: 4000 \$ per month.
- Indirect costs: 3000 \$ per month.

2.4.7 Conclusions

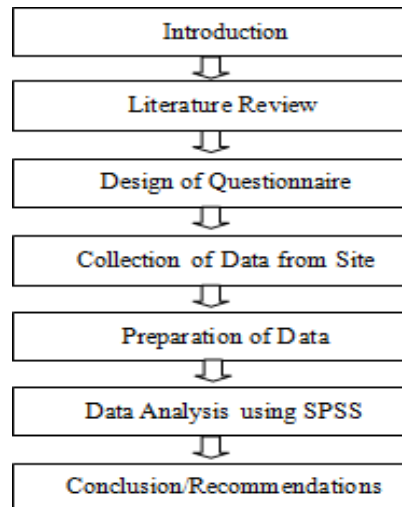
The complex inter-related structure of different factors affecting labor productivity was modeled using cause and effect feedback loops and the qualitative model of labor productivity was constructed. The relationships that existed between different factors were then determined and the quantitative model of the project was built.

2.5 Analyzing the Various Factors that Affect the Labour Productivity in Construction Industries and Recommending Remedial Measures Joseph M. G. Ravi Shankar S

2.5.1 Objective

- To identify the factors which affect the variation of labor productivity in the construction projects
- To evaluate the impact of influenced factors on the variation of labor productivity.
- To suggest recommendations to improve labor productivity in construction projects.

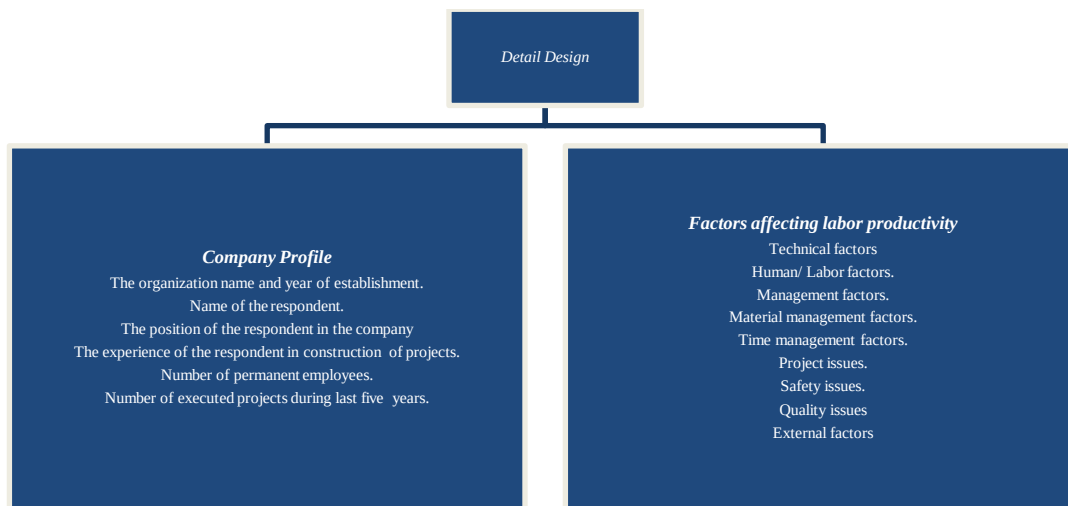
2.5.2 Methodology



2.5.3 Process

- The first step involves data collection which were collected from various sites in Kerala and Tamil Nadu.
- The second step involves the data analysis using Statistical Package for the Social Sciences (SPSS) software.
- The third step is conclusion of the project with recommendations.

2.5.4 Questionnaire



Tab 2.4 Factors Affecting Labor Productivity In Technical Group

No.	Factors affecting labour productivity	Mean	Rank
1	Clarity of technical specification	4.0714	1
2	The extent of variation/change order during execution	3.3571	6
3	Coordination level among design disciplines	4.0000	2
4	Design complexity level	3.6071	5
5	Rework	3.9643	3
6	Site Layout	3.1429	8
7	Drawings and specifications alteration during execution	3.3214	7
8	Site restricted access	2.4286	9
9	Accuracy of the Estimate	3.6786	4

Tab 2.5 Factors Affecting Labor Productivity In Material Management Group

No.	Factors affecting labour productivity	Mean	Rank
1	Shortage of materials	3.7143	2
2	Shortage of tools and equipments	3.6786	3
3	Unsuitability of materials storage location	3.0357	5
4	Construction methods	3.1071	4
5	payment delay	4.0000	1

Tab 2.6 factors affecting labour productivity in time management group

No.	Factors affecting labour productivity	Mean	Rank
1	Work overtime	3.1071	3
2	Working for 7 days of week without holiday	3.8214	1
3	Increasing No. of labours in order to accelerate work	3.0000	4
4	Misuse of time schedule	3.6071	2

Tab 2.7 Factors Affecting Labour Productivity In Project Issues Group

No.	Factors affecting labour productivity	Mean	Rank
1	Type of activities in the project	2.3214	3
2	Construction method	2.7143	1
3	Interference	2.5357	2
4	Working in confined space	2.2857	4

Tab 2.8 Factors Affecting Labour Productivity In Quality Issues Group

No.	Factors affecting labour productivity	Mean	Rank
1	Low quality of raw materials	3.2143	2
2	High quality of required work	2.7500	3
3	Inefficiency of equipments	3.6786	1

Tab 2.9 Factors Affecting Labour Productivity In Safety Issues Group

No.	Factors affecting labour productivity	Mean	Rank
1	Violation of safety precautions	3.7500	1
2	Working at high place	3.6786	2
3	Bad ventilation	2.8214	4
4	Insufficient Lighting	3.2500	3
5	Noise	2.5000	5

Tab 2.10 Factors Affecting Labour Productivity In Human/ Labour Group

No.	Factors affecting labour productivity	Mean	Rank
1	Motivation of labour	3.5000	13
2	Increase of labourer age	3.6786	9
3	Skill of labour	4.0000	2

4	Physical fatigue	3.8214	6
5	Shortage of experienced labour	4.1786	1
6	Labour personal problems	3.1786	15
7	Labour dissatisfaction	3.7857	8
8	Labour disloyalty	3.8214	7
9	Misunderstanding among labour	3.6786	10
10	Lack of competition	3.6429	11
11	Reassignment of staff/ crew	3.5357	12
12	Labour working for more than 10 years	4.0000	3
13	Government regulation	3.3929	14
14	Basic wages	3.8929	5
15	Inspection delay	3.9643	4

2.5.5 Conclusion With Recommendations

- Construction industry is rated as one of the key industries in the ever-growing world.
- Study and knowledge of productivity are very important because low productivity cause losses to the governing agencies and also influence the economy of the construction industry, which can finally affect the economy of the country.
- Investments made for construction projects are very high and because of the high complexity in construction, various factors can highly affect overall productivity which leads to the requirement of more time and money for a project to be completed.

2.6 COMPARITIVE STUDY

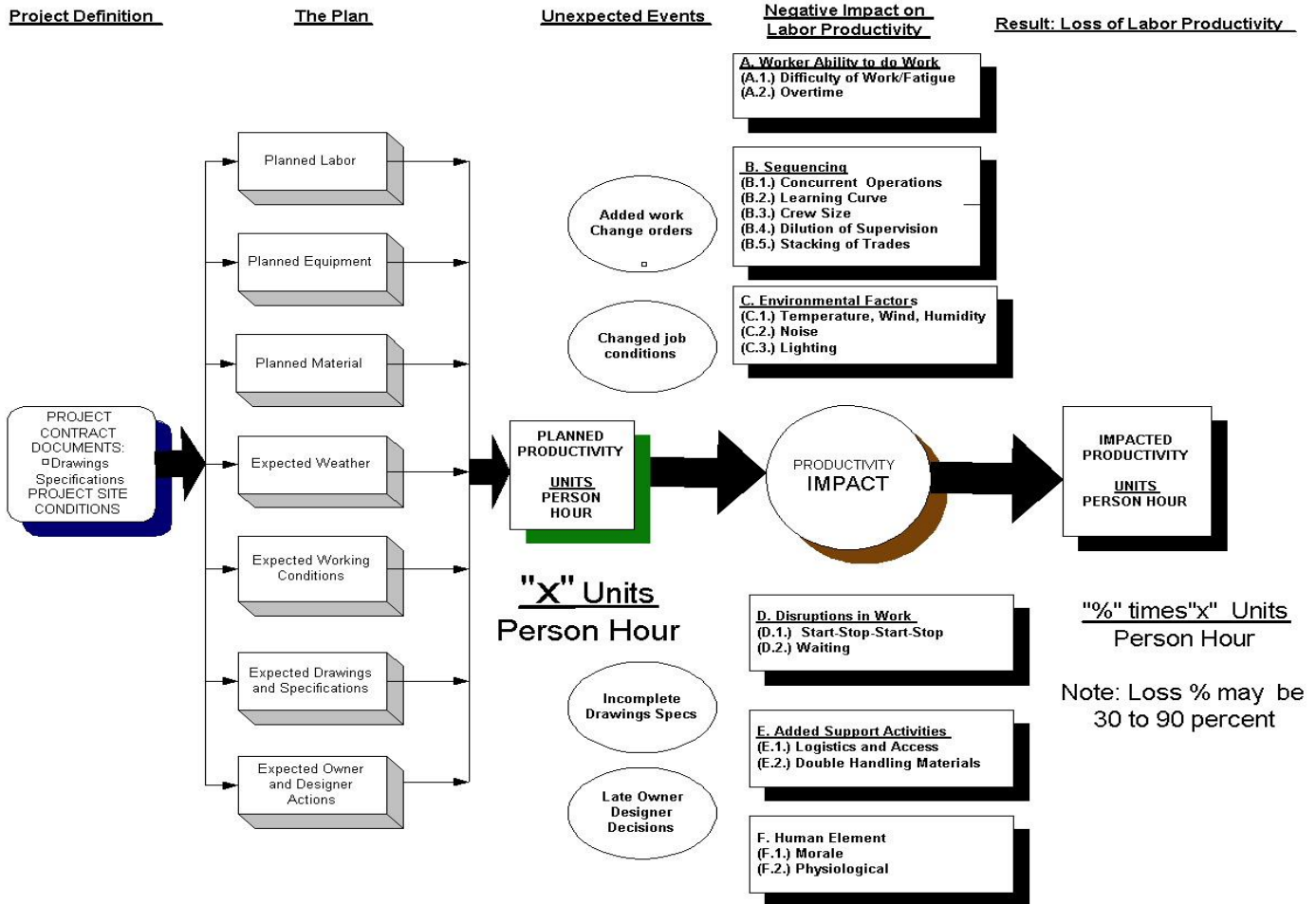
	RESEARCH PAPER 1	RESEARCH PAPER 2	RESEARCH PAPER 3	RESEARCH PAPER 4
OBJECTIVE	Identifying and ranks the factors that affect the productivity on Jordan in construction projects.	This study aims at exploring the relationship between floor number and labor productivity in High-rise	This research presents a system dynamics (SD)-based approach to model labor productivity.	To identify the factors which affect the variation of labor productivity in the construction projects

		building activities, namely construction of partition walls and finishing works.	The complex inter-related structure of different factors affecting labor productivity is modeled using system dynamics approach.	To evaluate the impact of influenced factors on the variation of labor productivity. To suggest recommendations to improve labor productivity in construction projects.
TOOLS AND TECHNIQUES	Data was analyzed using statistical package SPSS and Relative importance index method	Data was analyzed using learning curve theory and Straight line model	Causal loop diagrams and stock and flows	Statistical Package for the Social Sciences(SPSS) software.

2.7 LITERATURE STUDY

- Identify six different categories of factors that negatively impact labor productivity.
- Quantify lost productivity for working overtime.
- Quantify lost productivity due to worker learning.
- Quantify lost productivity due to unreasonable crew size.
- Quantify lost productivity due to the number of crews.
- Quantify lost labor productivity because of weather changes.
- Quantify lost labor productivity due to changes in project logistics.
- Quantify lost labor productivity due to change and change orders.

LOSS OF CONSTRUCTION PRODUCTIVITY OWING TO IMPACT



2.8 CONSTRUCTION LABOR PRODUCTIVITY MEASUREMENT

Labor Productivity

- Labor productivity is simply defined as the ratio of Total output to the Labor input
- Labor productivity depends upon how labors are utilized.
- Labor productivity can be higher or lower depending on factors like availability of work load, material, working tools, availability of power, work efficiency, level of motivation, level of training, level of working condition (comfortable or poor) etc.

$$\text{Labor Productivity} = \frac{\text{TOTAL OUTPUT}}{\text{LABOUR INPUT}}$$

$$\text{Total factor productivity (TFP)} = \frac{\text{Total output}}{\text{Labor} + \text{Materials} + \text{Equipment} + \text{Energy} + \text{Capital}}$$

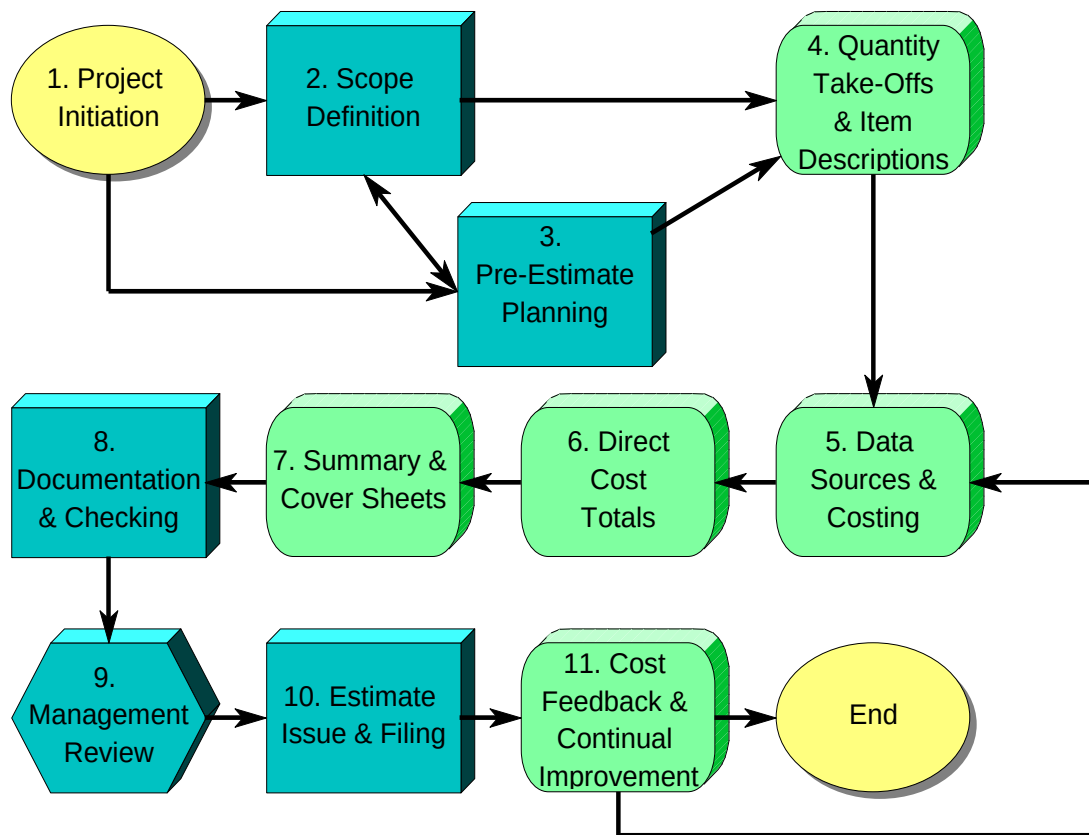
PRODUCTIVITY MEASUREMENT TECHNIQUES

- Activity sampling technique.
- Foreman delay surveys technique.
- Time study technique.
- Motion analysis technique.
- Group timing technique.

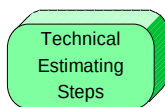
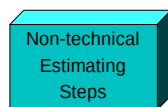
2.9 LABOR BASED TECHNIQUE

1. Financial incentives
2. Fringe benefits
3. Employ promotion
4. Job rotation
5. Education
6. Zero defects
7. Quality circle
8. Communication
9. Working environment
10. Punishment
11. Zero defect Method Of Productivity Improvement

2.10 THE ESTIMATING PROCESS



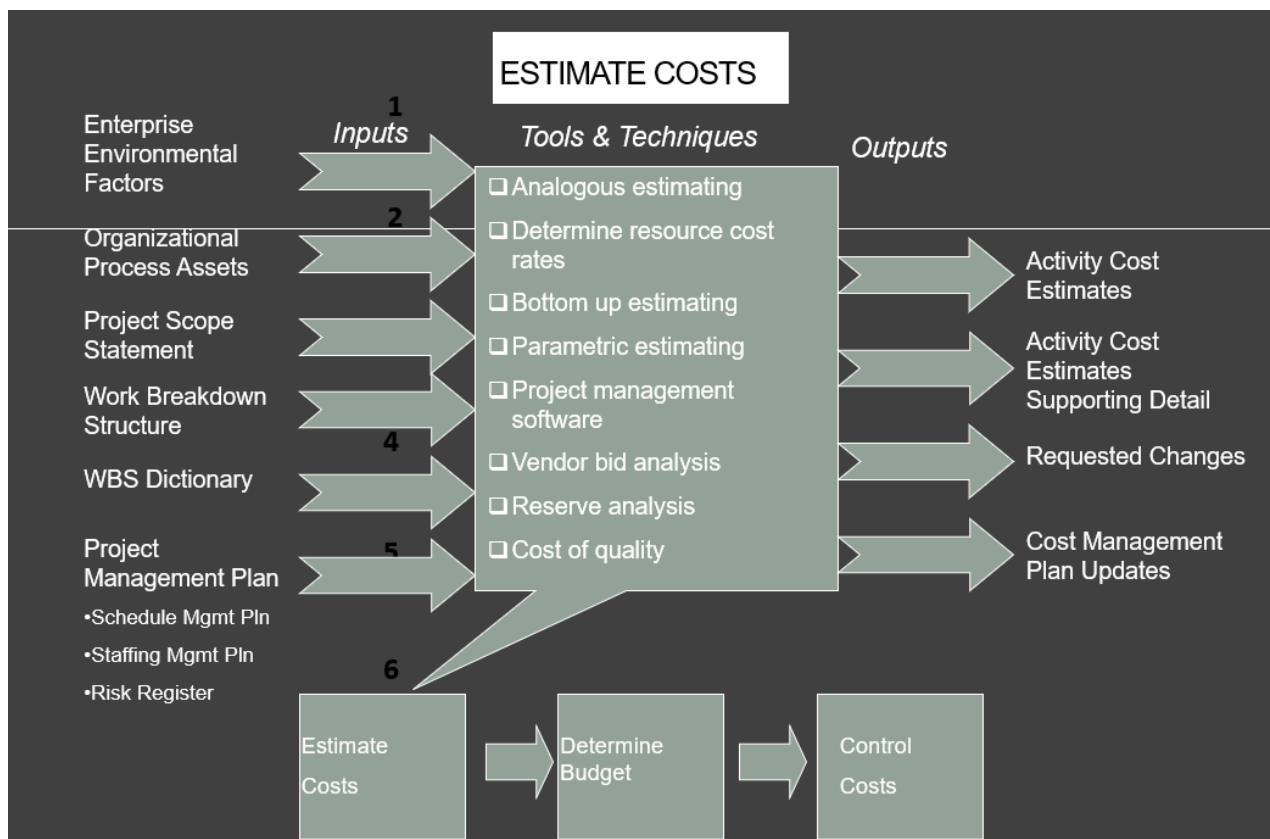
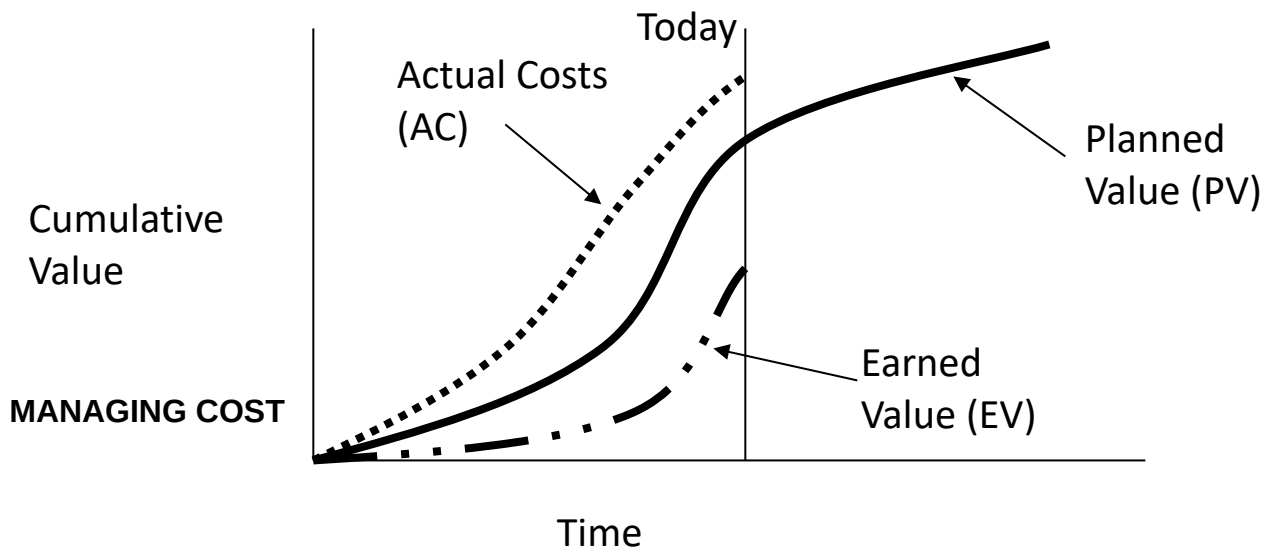
Legend:

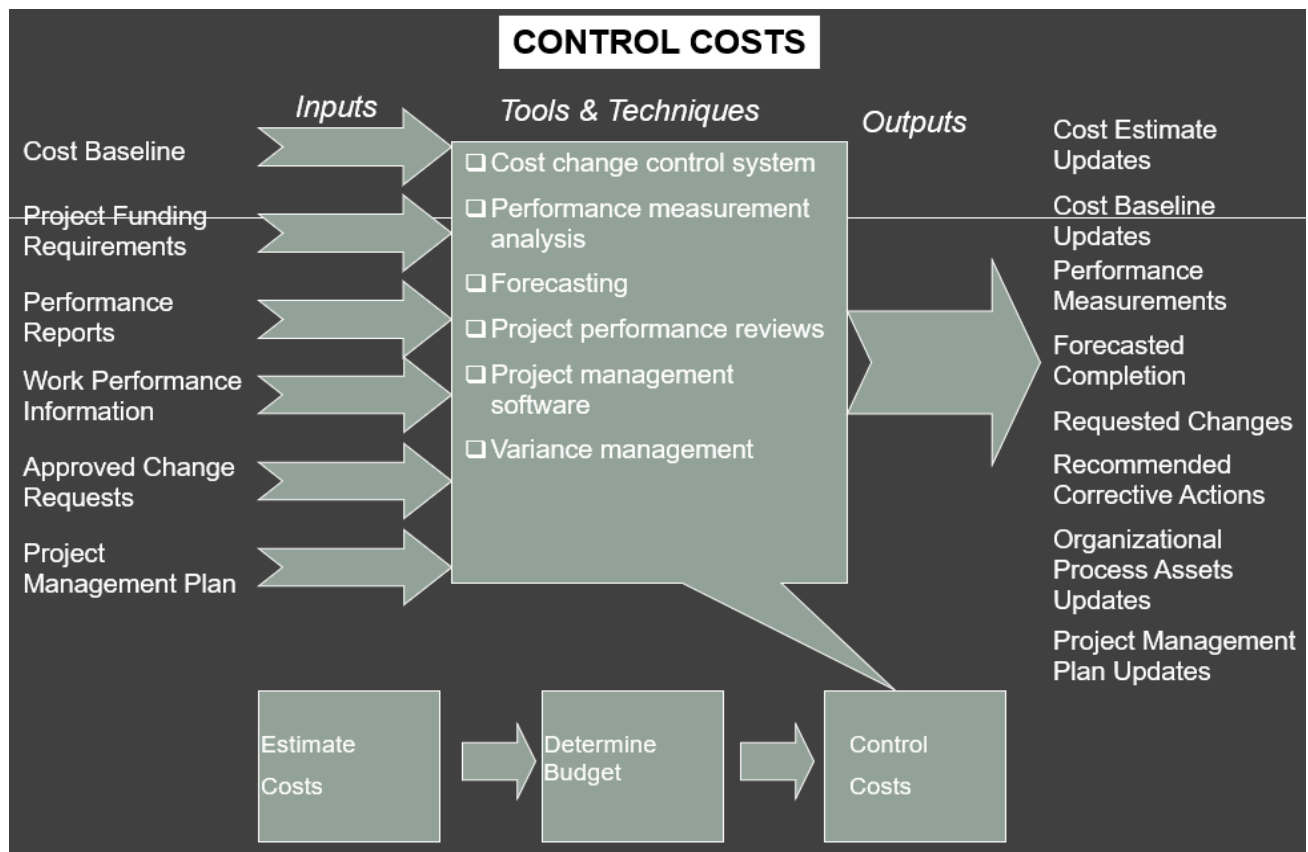
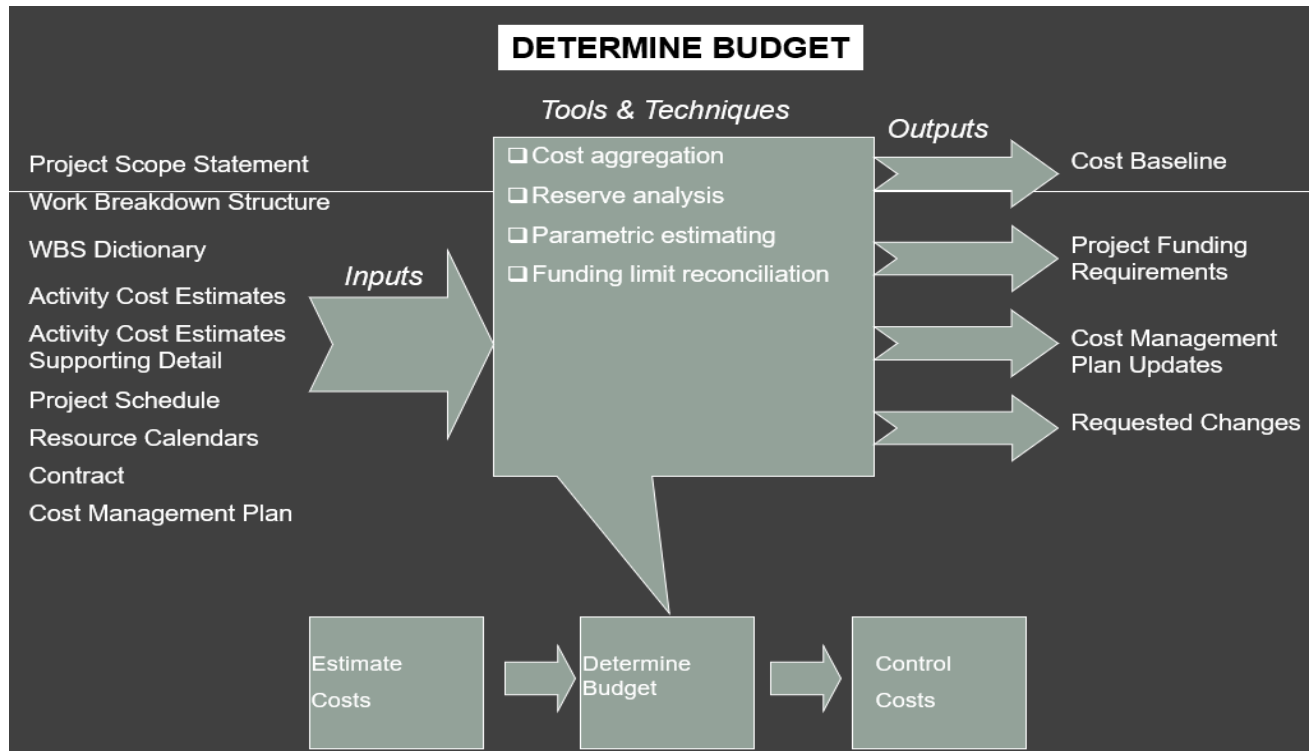


WHY DO WE MANAGE COST?

Part of triple constraint, can't manage one without the others (scope, time, and quality)

Plots of cost and scope against plan can help spot problems early



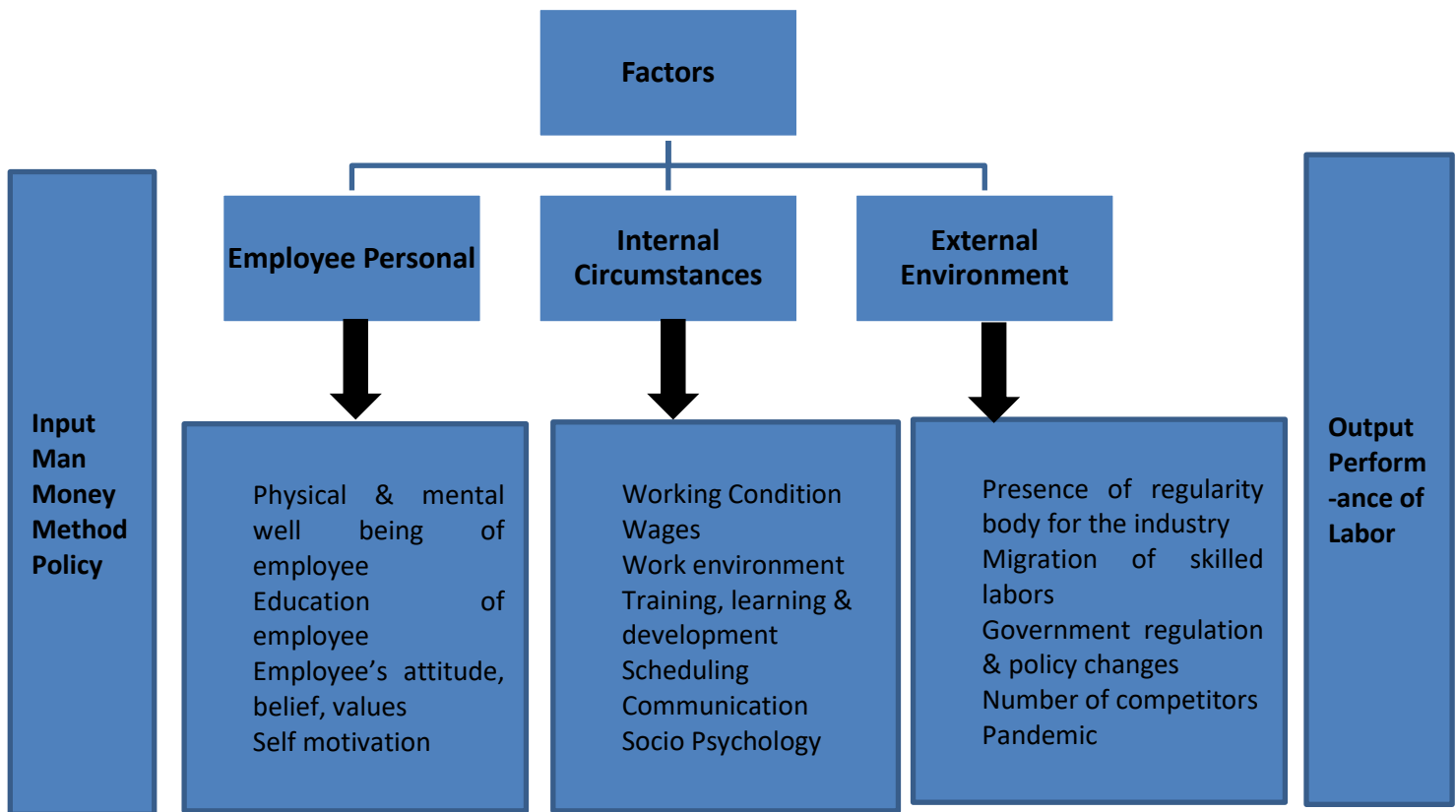


2.11 PRODUCTIVITY INDEX CALCULATION

In this normalized weightage of factor method is used to calculate the productivity index and formulating the datasets.

- Productivity Index = $\sum [(Weightage \text{ of factor } n) \times (Rating \text{ received by factor } n)]$ – – – – 1
- Factor weightage = $\sum [Rating \text{ of each expert } / \text{Maximum rating possible} \times \text{number of experts} \times \text{number of factors}]$ – – – – 2
- Normalized weightage of factor = $\sum [Weightage \text{ of factor} / \text{Total weightage of all factors}]$ – – – – 3
- Factor rating received from respondents = $\sum [Rating \text{ of each respondent} / \text{Maximum rating possible} \times \text{number of respondent}]$ – – – – 4
- Mean = $\sum [(Sum \text{ of all data points}) / \text{Number of data points}]$ – – – – 5
- Standard error of sample mean $SE \bar{x} = \text{Population of standard deviation } (\sigma) / \sqrt{\text{Total number of elements } (n)}$ – – – – 6

Standard deviation = $\sqrt{[\sum (x - \bar{x})^2 / (n - 1)]}$ – – – – 7 Two issues can enhance the practicality of this study: (1) **Develop the research method into a decision support system**, which can significantly increase users' willingness and reduce time and effort required in computation. (2) The research method used **triangular fuzzy numbers (TFNs)** to represent linguistic assessments. However, other types of fuzzy numbers (trapezoidal or bell-shaped fuzzy numbers) may be more appropriate.



2.12 ACTIVITY ANALYSIS LOG

- It can be noted that three rounds of observations were recorded for each project on hourly basis for more than 5 days.
- It should be randomly noted labors at different paths on site for each round by observing them, recording their activities into the standard mentioned categories and denoted it by a tally mark in the corresponding portion.
- Thus 3 rounds to be repeated for each hour and the number of ticks at the end of the hours recorded to display the number of labors corresponding to each category.
- The same exercise was repeated for all the hours of observations for more than 5 days and eventually summed up to reveal the total observations in accordance with the standard Activity Analysis procedure.

Activity Analysis Log					
Name of Observer					
Site Access Date					
# of Workers					
Weather					
Project Name					
Trades Observed					
Observation Records		Observation Round 1		Observation Round 2	
Time (From To)					
Direct Work					
Support	Preparatory Work and Instructions				
	Traveling				
	Tools and Equipment				
	Materials Handling				
Delays	Personal				
	Waiting				
Note:					

Fig 3.1 Activity Analysis Log

2.13 MEASURING AND INTERPRETING WORK AND CREW EFFECTIVENESS

1.FIELD RATING

Field rating = total observations of working/total number of observations+ 10%

2.WORK SAMPLING

1. Classify the worker's activity as one of three modes of activity: productive, semi-productive (involved in supporting the main activity), and non-productive.
2. Develop a data collection form that will facilitate tallying the observations on site
3. Take random observations of workers involved in a given operation in the field. The observation should indicate the workers' activity mode, i.e., productive, non-productive, or semi-productive. Random, for all practical purposes, means without any bias as to who is being observed and that each worker will have the same chance of being observed as any other worker.

3.FIVE-MINUTE RATING

- The five-minute rating technique, unlike work sampling, is not based on statistical sampling theory. The method relies on simply observing an operation for a short time.
- The observation does not result in a large enough sample to support work sampling.
- The method does, however, provide some insight as to the effectiveness of the crew and can identify areas where more observation is required.

Time	Spreader	Screeder	Grader	Bull-Floater
9:50	x	x	x	
9:55	x	x	x	
10:00				x
10:05	x	x	x	x
10:10	x		x	
10:15	x	x		x
10:20	x	x	x	x
10:25		x		x
Effective observations	6	6	5	5
Total observations = 32			Effectiveness = 22/32	
Observed effective = 22			5-Minute Rating = 68%	

Fig 3.2 Five-Minute Rating

Tab 2.11 Activity Classification

Classification (equivalent classification)	Productive (Direct Work)	Semi-Productive (Indirect Work) (Support Work)	Non-Productive (Delay) (Non-Working)
Description	Using trade tools	Supporting the main activity	Not contributing to The activity
Examples	Mason laying brick labourer mixing mortar, Electrician pulling wire, welder welding pipe	Tradesman getting material, travelling to work location taking instructions	Personal breaks, waiting for equipment to be fixed waiting for more instructions, late start or early Departure

Figure 2.2 Typical FDS form

Problem Causing Area	Person-Hours Lost		
	No. of Hours Lost	No. of Workers	Total Person- Hours
Redoing work (design error or change)			
Redoing work (prefabrication error)			
Redoing work (field error or damage)			
Waiting for materials (warehouse)			
Waiting for materials (vendor furnished)			
Waiting for tools			
Waiting for construction equipment			
Construction equipment breakdown			
Waiting for information			
Waiting for other crews			
Waiting for fellow crew members			
Unexplained or unnecessary move			
Other:			
Comments:			
Made by:			
Date:			

Fig 3.3 Typical FDS Form

2.15 FIELD SURVEYS

1. Foreman Delay Survey

- Foreman Delay Survey (FDS) relies on a questionnaire which is to be filled out by the job foreman at the end of a working day according to a particular survey schedule, e.g., one work week in each month.
- The questionnaire is primarily meant to identify the number of hours of a day lost due to delays. Most FDSs are divided into rework and delay categories.

2. Craftsman Questionnaire

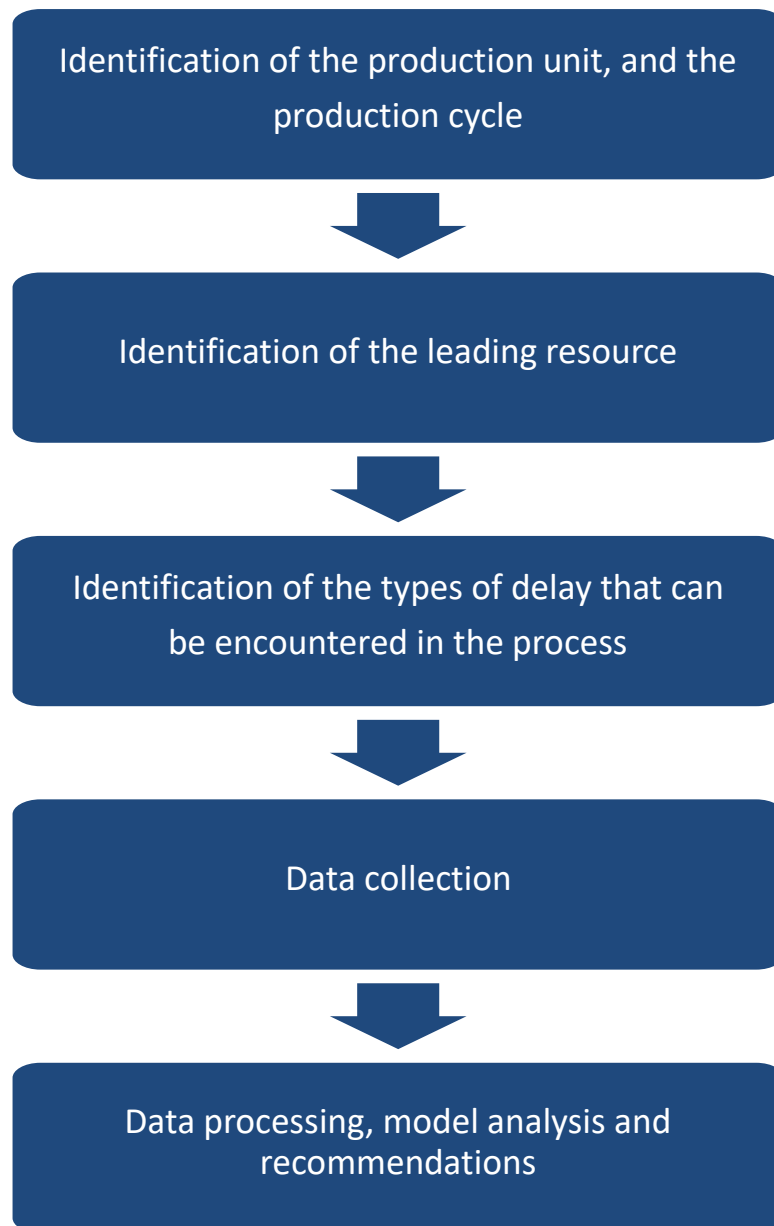
- Craftsman questionnaire (CQ) is a questionnaire-oriented technique attempting to address issues and concerns that relate to a craftsman's productivity and motivation.
- The basic idea is to distribute a simple questionnaire, to craftsmen on a job site to complete.
- The aim is to identify major factors that inhibit the productivity of craftsmen and estimate the lost per craftsman per week due to specific causes.

Personal data		Check ☒ the appropriate box for YES or NO, or fill the box with the required information.	
Craft			
Location			
Type of work			
Other			
	YES	NO	
Material			
Is material always available when you need it?			
How many hours do you estimate are lost per week due to material not being available?	_____ h		
Tools			
Are tools always available when needed?			
Are tools in acceptable shape?			
Are tools supplied always the right ones for the job?			
Are there any specific tools in short supply (please name)			
How many hours do you estimate are lost per week due to tools not being available or acceptable for the job?	_____ h		
Equipment			
Question 1 (Add more questions as under material and tools)			
Question 2 (Add more questions as under material and tools)			
How many hours do you estimate are lost per week due to ...	_____ h		
Rework			
Question 1 (Add more questions as under material and tools)			
Question 2 (Add more questions as under material and tools)			
How many hours do you estimate are lost per week due to ...	_____ h		
Safety Concerns			
Question 1 (Add more questions as under material and tools)			
Question 2 (Add more questions as under material and tools)			
How many hours do you estimate are lost per week due to ...	_____ h		
Others			
Question 1 (Add more questions as under material and tools)			
Question 2 (Add more questions as under material and tools)			

Fig 3.4 Craftsman Questionnaire

3. The Method Productivity Delay Model

- The method productivity delay model(MPDM) was proposed as a way to combine both time study and productivity measurement(Adrian and Boyer, 1976).
- MPDM relies on having an observer collect data, on a special form, pertaining to the cycle time of a leading resource on the operation. The observer also notes the nature of the delays during the period of observation.
- Once the data collection is complete, a set of computations is carried out that measures the productivity of the operation, indicates the major sources of delay, and gives other useful statistics.



2.16 Charting Techniques:

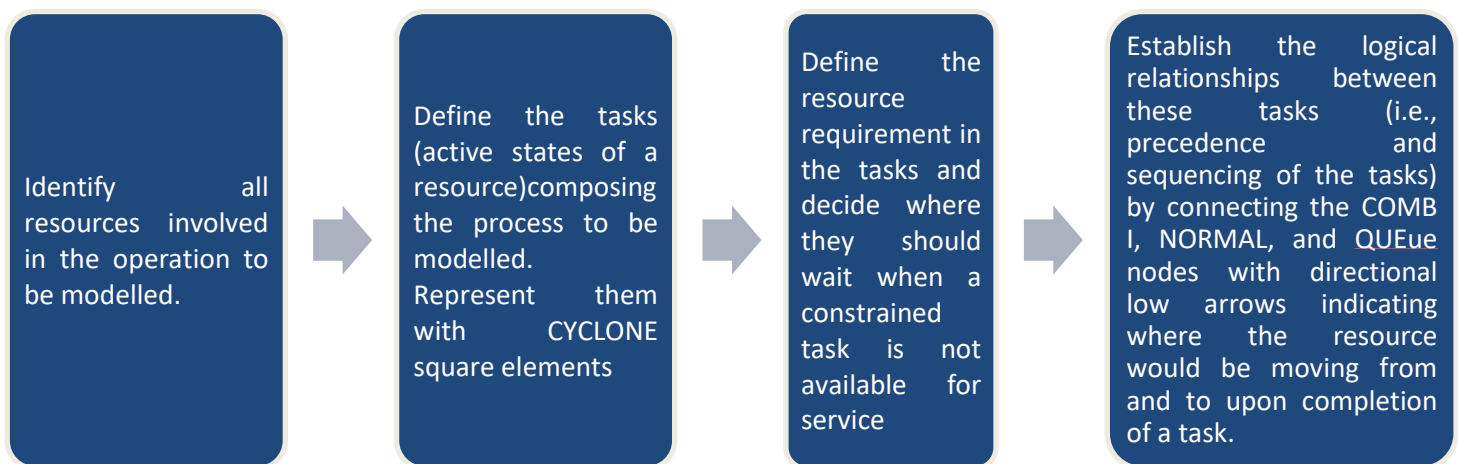
Crew-Balance Charts

- Crew balance charts are a method of comparing interrelationships among various crew members and equipment required to carry) out a task.
- This method is applicable to such cyclical tasks as placing concrete.

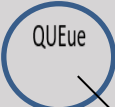
Simulation Modelling And Analysis

- Simulation in the context of this discussion is defined as "building a mathematical/ logical model of a system and experimenting with it on a computer" (Pritsker 1986).
- This publication addresses simulation only with regard to the CYCLONE methodology.
- Although other techniques exist, none has shown so much promise in construction as the CYCLONE methodology.
- The simulation process consists of two basic phases: modelling and experimentation.
- CYCLONE provides the modelling elements and methods that a modeller can use to represent a construction operation in much the same way as a scheduler would build a Critical Path Method (CPM) network for a construction project, i.e., by specifying activities, and their logicalrelationships, durations and resource requirements.
- To model an operation using CYCLONE, the modeller focusses on the resources involved and their interactions.

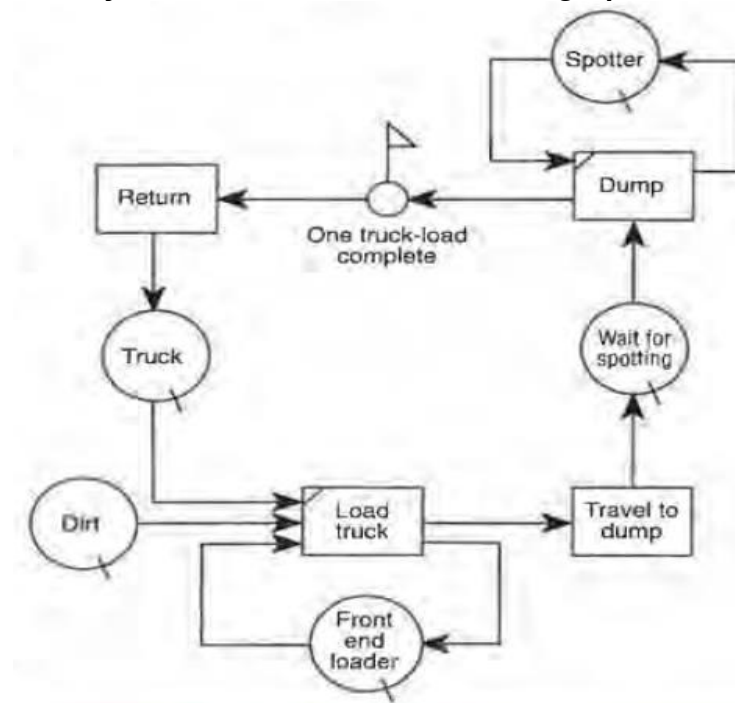
Building A Cyclone Model



Rules For Structuring Cyclone Models

CYCLONE ELEMENT	DESCRIPTION AND RULES FOR MODEL BUILDING
	The NORMAL is not a restrained task. Any resource that arrives at a NORMAL is given access and is immediately processed. It is like a serving station with an infinite number of servers. Can be preceded by all other CYCLONE elements except for a QUEUE node. Can be followed by all other elements except for a COMBI.
	A task that is restrained by the availability of more than one type of resource. A resource arriving at a COMBI will have to wait until all other required resources are available before it is given access to the task. Can be preceded by QUEUE nodes only. Can be followed by all other elements except COMBIs.
	A QUEUE node is a waiting area for a resource. Therefore it is used only when a task is restrained. A resource arriving at a QUEUE node will stay in the node until a COMBI is ready to process it. A QUEUE node has one other function in the Micro CYCLONE implementation, namely to multiply resources when specified. In other words, a modeller can specify that once a resource enters a specified QUEUE node, it will multiply into a finite number of duplicate resources. Can be preceded by any element except a QUEUE node. Can be followed by COMBI only.
	The FUNCTION element was devised to provide some flexibility. Different computer implementations of CYCLONE have somewhat different functions. In MicroCYCLONE, one type of function is allowed, namely the consolidate function. Its job is to take units and consolidate them into a specified number. Any unit arriving at this function will accumulate until a threshold value is reached, at which point only one unit is released from the function (all others are destroyed). Can be preceded by all elements except QUEUE nodes. Can be followed by all elements except COMBI.
 COUNTER	The counter keeps track of the number of times units pass it. It does not alter any of the resources or their properties. It just adds increments and keeps track of cycles and a few other statistics. Can be preceded by all elements except QUEUE nodes. Can be followed by all elements except COMBI.

Cyclone Model Of An Earth-Moving Operation



Assume that this simple operation will be accomplished by One front-end loader (FEL), three trucks, and one laborer to spot the dump location.



The equivalent CYCLONE elements are then matched with the proper task and arranged

2.17 EXPERIMENTING, ANALYZING, AND SIMULATING

Once a model has been built, it can be entered into a computer program such as Micro CYCLONE for processing and performing the simulation study. The results of the simulation study are:

- an estimate for completing the operation
- the hourly production rate
- other measures of equipment utilization
- The model can be used to balance resources, maximize productivity or achieve minimum unit cost, as well as to deal with uncertainty and risk.
- The operation considered in this model involves earth moving for a sports training facility in a university area.

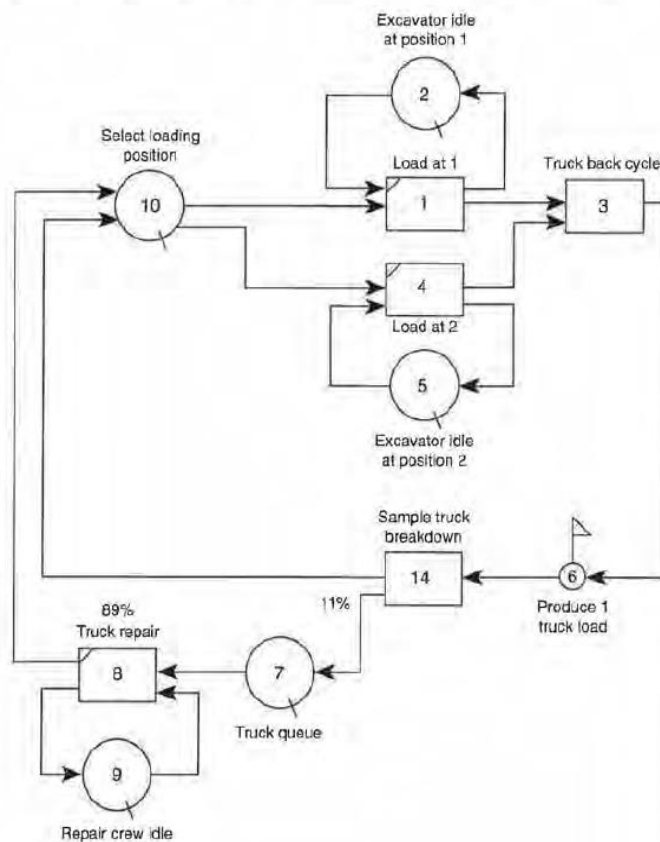


Fig 3.5 Sample Daily Work Report

Daily Work Report							
Project:				Prepared by:			
Date:				Comments:			
Temperature:							
Weather conditions:							
Work pkge. code	Description	Labour (h)	Supervision (h)	Craft-1 (h)	Craft-2 (h)	Craft-3 (h)	Total (h)
2-20	Concrete formwork	64	8	-	-	-	72

Fig 3.6 Time Card

TIME SHEET									
Employee Name: _____					Job No: _____				
Employee No: _____					Pay Period No: _____				
					Pay Period Date: _____				
	Date	Reg	O.T.	T.T.		Date	Reg	O.T.	T.T.
W									
T									
F									
S									
S									
M									
T									
Total					Total				

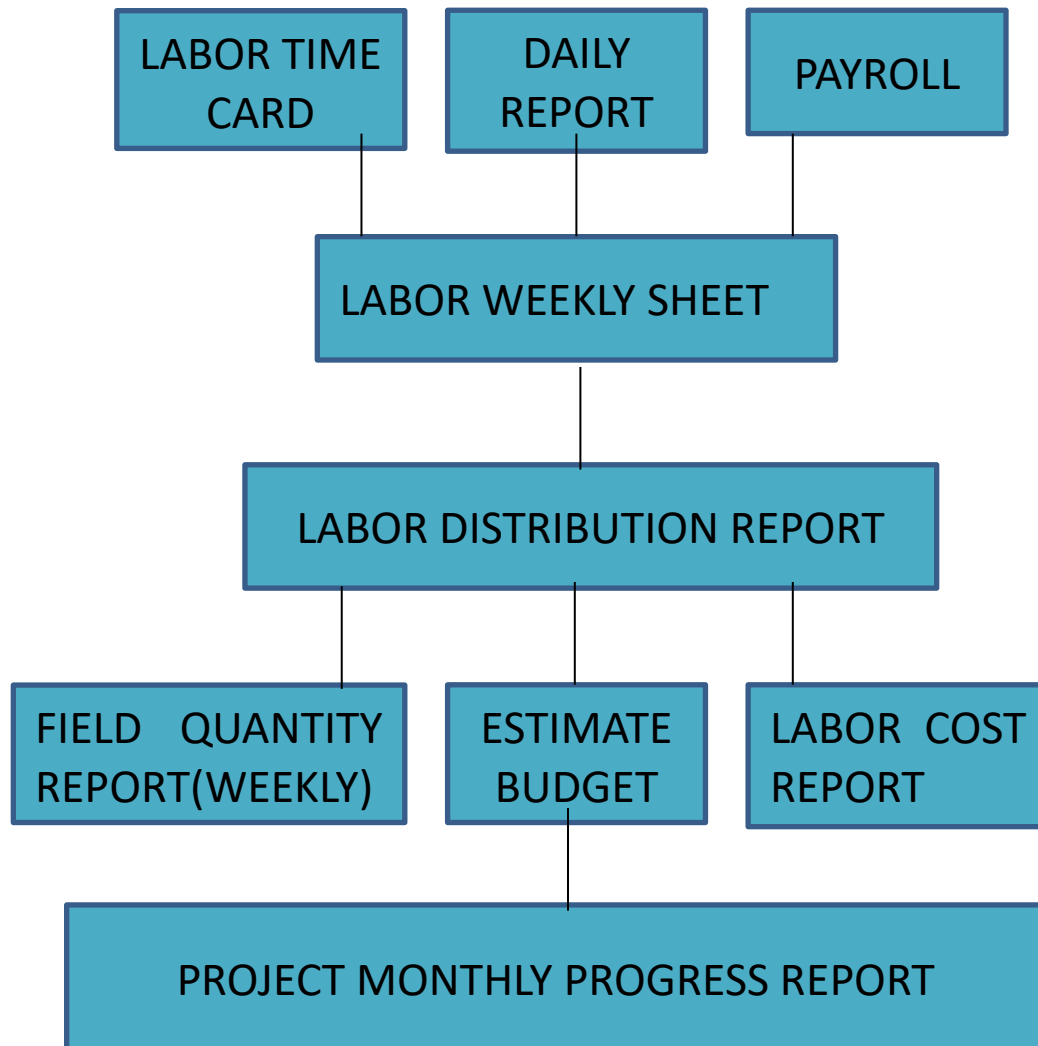
Certified Correct
 Employee: _____ Supervisor: _____
 Remarks: _____

Fig 3.7 Weekly Labour Report

Daily Labour Time Card				
Employee	Cost Rate	Cost Code	Total Hours	Amount
—	—	○	○	—

WEEKLY LABOUR REPORT					
Cost Code	Regular Hours	Overtime Hours	Regular Rate	Overtime Rate	Total
301	20	10	14	21	490
342	8	4	14	21	84

Total hours spent on package 301 is 30 person-hours for this period. This is transferred to job cost ledger to measure productivity on this package.



Tab 2.12 Labour on the basis of 8 hours working per day

S.No.	Item Description	Unit of Qty	Labour(on the basis of 8 hours working per day)	Quantity (Nos.)
1	Cement concrete in foundation		Head mason	
			Mason	
			Mazdoors	
2	R.C.C. (1:2:4)		Head Mason(Mate)	
			Mason	
			Mazdoor(ins. Bhisti)	
3	Supplying, fitting, fixing and removing shuttering and staging		Carpenter	
			Mazdoor	
4	Reinforcement for R.C.C. work including cutting, bending and placing in position		Bar binder	
			Mazdoor	
5	Damp proof course		Head Mason	
			Mason	
			Mazdoor	
6	First class brickwork in		Head Mason	
	1: 6 in superstructure		Mason	
			Mazdoor (2 nos as Bhisti)	
7	Brick on edge flooring with cement mortar 1:3		Head Mason	
			Mason	
			Mazdoor (1 no as Bhisti)	
8	flooring		Head Mason	
			Mason	
			Mazdoor	
			Mazdoor for rubbing	

9	C.G.I. sheet on roof			
			Fitter (Blacksmith)	
			Mazdoor	
10	H.C.I. rain water pipe fixing		Mason	
			Mazdoor	
11	12mm thk. cement plaster on brickwork in 1:6 or any proportion		Head Mason	
			Mason	
			Mazdoor (incl. 1 no. Bhisti)	
12	Ruled Pointing (1:3)		Head Mason	
			Mason	
			Mazdoor (incl. 1 no. Bhisti)	
13	White washing primer coat and 2 finished coats to new plaster		Painter	
			Mazdoor (Helper)	
14	Dry Distemper		Painter	
			Mazdoor (Helper)	
15	Plastic Emulsion paint on new work		Painter	
			Mazdoor (Helper)	
16	Primer coat on wood work/steel work		Painter	
			Mazdoor (Helper)	
17	Painting two coats over priming coat of new wood work/steel work		Painter	
			Mazdoor (Helper)	
18	Demolishing cement concrete (1:2:4/1:3:6) including lead upto 50m		Mazdoor	
19	Demolishing R.C.C. work including lead upto 50m		Mazdoor	

20	Demolishing Brickwork in cement mortar including stacking of serviceable material and disposal of unserviceable materials within a lead of 50m		Mazdoor	
21	Removing mortar from and cleaning bricks and stacking cleaned bricks		Mason	
			Mazdoor	
22	Dismantling doors, windows shutters including chowkhats and stacking of material		Mason	
			Mazdoor	
23	Supplying and fixing 12mm/15mm dia G.I. pipe with G.I. fittings and M.S. clamps including cutting holes in walls and making good the same		Fitter	
			Asstt. Fitter	
			Mazdoor (Beldar)	
24	Supplying fitting and laying 25mm G.I. pipes with G.I. fittings including trenching and refilling for external work		Fitter	
			Mazdoor	
			Mazdoor (for trenching & refilling)	
25	Laying, fitting and fixing 100mm dia G.I. pipes including testing of joint, trench cutting for pipe laying upto a depth of invert 90 cm and refilling, dressing etc.		Fitter	
			Asstt. Fitter	
			Mazdoor (for laying and jointing)	

			Mazdoor (for trenching & refilling)	
26	Supplying, laying, jointing 100 dia stoneware pipes with cement mortar 1:1		Mason	
	(excluding earthwork etc)		Mazdoor	
27	Wash basin with C.I. brackets, brass plug with brass chain, waste pipe including cutting walls and making good the same		Fitter (plumbing mistri)	
28	Sink		Fitter plumbing mistri)	
			Mason	
			Mazdoor	
29	9" thick brick flat soiling filled local sand		Mazdoor	
30	Earth work for road		Mazdoor	
31	Stone soiling for roads including packing with smaller stones		Mazdoor	
			With steam roller	
			(per day)	
32	Surface dressing / bituminous carpeting on roads		Mazdoor (for one layer	
			Mazdoor (for two layers)	
			(Roller attendant staff is extra)	

2.18 ACTIVITY BASED -FORMWORK

Labor productivity associated with formwork will be measured using 3 dimensional BIM modelling.

Building Information Modelling or BIM, is a digital representation of the building process to facilitate the exchange and interoperability of information in a digital format.



The process is carried out as follows:

- 1) Preparing 3D model of a commercial building.
- 2) Extract quantities using 3D model.
- 3) Establish a standard productivity based on relevant IS Codes and labor data.
- 4) Measure and report daily input laborers and work volume.
- 5) Compare actual and planned productivity and progress.
- 6) Record the productivity and progress in the database.

The quantity of formwork is extracted based on attributes of structural components. The tasks for extracting the element information are as follows.

- Divide the BIM model into structural components in different levels.
- Insert the component information for the selected level.
- Extract the required information using the Schedule/Quantity function.
- Export the extracted information to Excel to sort, calculate and report.

Description of work	Unit	Labour	Recommended constant in Days	Remarks
		Mason	0.17	The constants include mixing, pouring, consolidating and curing. This doesn't include fair finish
Reinforced cement		Mazdoor	2.00	
concrete in situ in foundations, footings,	m ³	Bhisti	0.90	
bases for columns,		Mixer	0.07	

etc.		Operator		
excluding formwork and		Mixer	0.07	
reinforcement.		Vibrator	0.07	

Tab 2.13 IS-7272 (Part I) 1967; Section 2(f) Table-1

Code No	Description	Unit	Quantity	Rate	Amount
0155	Mason (Average)	day			
0114	Beldar	day			
0101	Bhisti	day			
0002	Hire charges of Concrete Mixer 0.25 to 0.40 cum with Hooper	day			
0012	Vibrator (Needle type 40 mm)	day			
9999	Sundries	L.S.			
	Total				

Tab 2.14 Delhi Analysis of Rates

Providing and laying in position specified reinforcement grade of reinforced cement concrete, excluding the cost of centering, shuttering, finishing and—all work up to plinth level:

Code No	Description	Unit	Rate
0123	1st Class Mason (brick layer)	Day	
0124	2nd Class Mason (brick layer)	Day	
0127	Driver (for Road Roller, Concrete Mixer, Truck, etc.)	Day	
0157	Operator (Pile/ Special machine)	Day	
0159	Skilled torch operator for laying tack	Day	
0002	Hire charges of Concrete Mixer 0.25 to 0.40 cum with hopper	Hour	
0012	Vibrator (Needle type 40 mm)	Hour	
	Water Charges @ 1%	kl	

Tab 2.15 Delhi Analysis of Rates; Labor basic rates

LABOUR		IS-7272 (1974)	DSR Building Data (state)	CPWD (central)
Skilled	Attributes	Mason	1st Class Mason + 2nd Class Mason	Mason (Average)
	Constants	0.17		0.17
Semi Skilled	Attributes	Mazdoor	Mazdoor	Beldar
	Constants	2		2
Machinery and Operators (M and O)	Attributes	Bhisti	Water including curing (kl)	Bhisti
	Constants	0.9		0.9
	Attributes	Mixer + Operator	Mixer (hours)	Mixer Hire
	Constants	0.07 + 0.07		0.07
	Attributes	Vibrator	Vibrator hire (hours)	Vibrator
	Constants	0.07		0.07
Miscellaneous	Attributes	-	-	Sundries (LS)
	Constants	-	-	14.3

Tab 2.16 Comparison Of Labour Parameters By State And Central Standard Schedule Of Rates

2.19 BENCHMARKING PROJECTS LABOR PRODUCTIVITY

- It is a common metric to describe labor productivity (the ratio of work hours to units of output); and productivity factor (the ratio of schedule to actual work hours).
- Benchmarking guides companies to improve their performance by establishing the best new performance practices.
- According to the construction Industry Institute CII for measuring the productivity a certain method has to be adopted by the project managers in determining the baseline for the best construction performance.
- Their model is widely applied to compare labor productivity of one construction project to that of another.
- This comparison could be based on the man-hours employed to the work produced.
- It is measured and compared to past records of the same firm or other firm's data in order to obtain a baseline measurement about how efficient a firm has been in executing its activities.

2.19.1 Advantages & Objectives Of Benchmarking Method

- It helps the management decisions to utilize resources across the project to obtain highest return and invest more in resources.
- Allows the contractor for better understanding their competitive positions and benchmark their efforts to improve their performance.
- To measure productivity in benchmarking is to control project cost and schedule also to obtain data for planning future projects.
- To identify shortages and gaps in the project's performance.

2.19.2 Baseline Productivity Definition

- This baseline productivity can be determined on the project level through the project's data of the daily productivity values for each task.
- The number of workdays of the daily productivity should involve those days which have the highest daily quantity of square meters and they should not be less than five days.
- It is the ratio of labor daily productivity in work hours(WHs)divided by the quantity of area produced in square meters(m2).
- The lowest this ratio is, the highest baseline productivity would be which indicates the best performance the contractor has achieved.

2.19.3 Measuring Steps Of Baseline

- Determine the number of days that include minimum 10 % of the total work days of reporting period.
- Select (5) scores (n) of those days which have the highest quantity produced.
- Calculate the sum of all those daily work hours which have highest quantity divided by the size of the score (5) for each day which is the average baseline productivity .
- This indicator or attribute can be measured through Equation no. **(1)** as below:
- ***Unite rate=Input /Output= WHs/Unit of work equation.....(1)***

2.19.4 Other Attributes

- To predict the productivity rate of a completed activity more accurately other attributes should be determined such as the cumulative productivity.
- This index is the ratio of the final work hours charged to the total quantities have been performed.
- It is a measure to overall effort needed to finish the work which can be measured in equation as below:
- ***Cumulative Productivity=Total work hours charged to a task/Total quantity installed equation.....(2)***
- Next index is Performance ratio (PR) which is the actual cumulative productivity divided by the average values of baselines for all activities or projects.
- It could be noticed that all projects have PRs of >1, however, the PR with a value >1.0 does not represent a poorly performing project.
- While it's a comparison against the best overall performance of the projects in the data set. The lower the PR is the better the project performance.
- The higher the PR is the poor performance.
- It can be measured as equation no. **(3):Performance Ratio=Cumulative Productivity/average of baseline productivity equation.....(3)**
- PMI project management index reflects the contribution of project management to the cumulative labor performance on the project. The lower PMI is, the better management leading role has on the overall project's performance.
- PMI is dimensionless but it provides basis to define the causes of poor material, equipment, information flows and improper planning in project management.
- The higher PMI value is the more indication of sub-standard labor performance and poor management found. It can be expressed as equation no. **(4)** in following:

$$PMI = \frac{\text{Cumulative productivity} - \text{baseline productivity}}{\text{baseline productivity}} \quad \text{equation(4)}$$

2.19.5 Productivity Benchmarking Model Of Thomas & Zvarski

- Different mathematical equations of this model were applied to measure projects baseline productivity attribute as the ratio of total WHs with respect to total quantity areas of reinforcement produced m2 as (wh/m2). Other equations were used to measure PMI and PR.
- The measured indexes for all projects baseline productivity were represented and indicated in the graphs by positioning the average of baseline productivity by drawing a line for each respective project.
- The tools which has been used to collect information, was a data calculation spreadsheet form three case study projects which contained entire materials, labor hours, all square meters of area produced for all the tasks involved in those projects.
- But only the labor hours spent, and the number of square meter reinforcement areas data have been accounted for in measuring the performance parameter of baseline productivity. Another method of activity analysis which is basically was WSM (Work Sampling Method).
- This analysis was conducted as a practical methodology to detect the management gaps during a practice implementation through site visits. Also, the same analysis was applied to establish an improvement strategy for the construction company as follows:

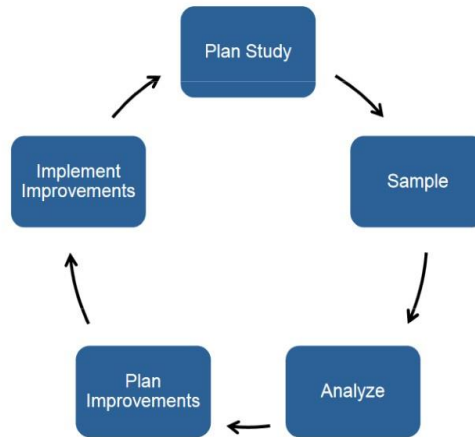
2.19.6 Carl Haas Activity Analysis Of Work Sampling Method

- Carl Haas model of Work Sampling technique method has been adopted to measure laborer's performance in reinforcement task. This technique was based on observing, collecting and recording the moments which contributes to loss of time.
- Random observations on 10 reinforcement laborers during 4 working days that was a total of 32 hours of work has been observed on site and 25 observations per hour have been registered which are distributed across the entire work day.
- The aim behind the application of activity analysis in Work Sampling method on project was to find the proportion of unutilized construction time efficiently. As well to identify the non-value activities which have contributed into reducing the site labors effectiveness.

The Plan Study

- The observation collection process lasted for four working days. It started at 07:30 am in the morning and ended at 04:00 pm by observing 10 reinforcement concrete laborers working on reinforcement activity for a slab.

Activity Analysis Continuous Performance Improvement Process



2.19.7 Sample Observing Work Behaviour

- Observations have to be classified into the activity modes level which involved productive, semi-productive and non-productive.
- Those observations are specifically focus on the working crew who are currently involved in operation.
- The method activities were defined as sampling work by classifying them into three categories modes as below:

Classification of observation into activity modes Source: (Haas, 2016) & (CII, 2017).

Classification	Productive	Semi-productive	Non-productive (No-working)
Description	Fully productive & direct work	Half productive as indirect work	Non contributing to any activity

Observation no	Productive (Direct work)	Semi-productive (support work)	Non-Productive (Delay)
1			
2			
3			
4			
5			
6			
7			
8			
9			
Total			
percentage			

Spreadsheet form to register data and observation based on activity modes Source: (Dozzi & AbdulRizk, 1993)

- All observations should be recorded on the form according to the appropriate mode of activity observed by check marking them.
- Breaks, lunch and clean up time is not included in the observation time.
- So, this time should be compensated if the data collected is inadequate for analysis.

2.19.8 VARIATION IN LABOR PRODUCTIVITY

- Variations in the WHs per week have been noticed in projects.
- Also, many reasons as weather, design errors, accidents and decision changes would vary the inputs on a regular basis.
- Input variations occur both in large and small projects, and in various geographical regions of a country.
- For example, if after the work start at 7:00 a heavy rain starts continuing to work would be impractical then the workers might be sent home early.
- This means if the work shift is 8 hours, the labor performance will suffer from shorter work shift. Similarly, if the work output (quantity) varies, the WHs should also vary.
- As variation in output is inevitable to encounter, so the input of work hours variability would be a direct reaction to output variability.
- Implying operating and assigning the crew size should be consistent with the work available to be done and the only way this can be maintained is by varying the WHs.
- A study of measuring labor productivity in masonry of stonework case projects to demonstrate how the daily variations in productivity is proceeding. Many project attributes have contributed to vary in project's output and functioned in this variation.

2.19.7 Sample Work Method Technique

- The metrics measured using work sampling with the limitation in mind were direct work.
- This technique involves periodical observations on workers, machines and equipment to analyze tasks.
- This method can be applied both on a single ongoing task only and also on many tasks which are ongoing concurrently at the same time.
- This method was developed in 1930s as a Statistical basis i.e. a sample of multiple random data points where the accuracy was dependent upon number of samples taken.
- Observations were taken randomly for workers involved in a delegated operation on site which should indicate the workers' activity mode if they were in a productive, non-productive or semi-productive mode.
- This method was carried out through employing site observers.

Classification (equivalent classification)	Productive (direct working)	Semi-productive (Indirect work support)	Non-productive (No-working)
Description	Using trade tools	Supporting the main activity	Non contributing to any activity

Examples	Mason laying bricks, laborer mixing mortar, electrician pulling wire, welder welding pipe	Material movement, getting material, traveling to work location, taking instructions	Personal breaks, waiting for equipment to be fixed, waiting for more instructions, late start and early departure
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determines how much time was utilized by the workforce and the cause of delay time area



draw more intensive management attention towards the most affected tasks that were subjected to delay and poor labor productivity.



establishing a plan for labor productivity improvement

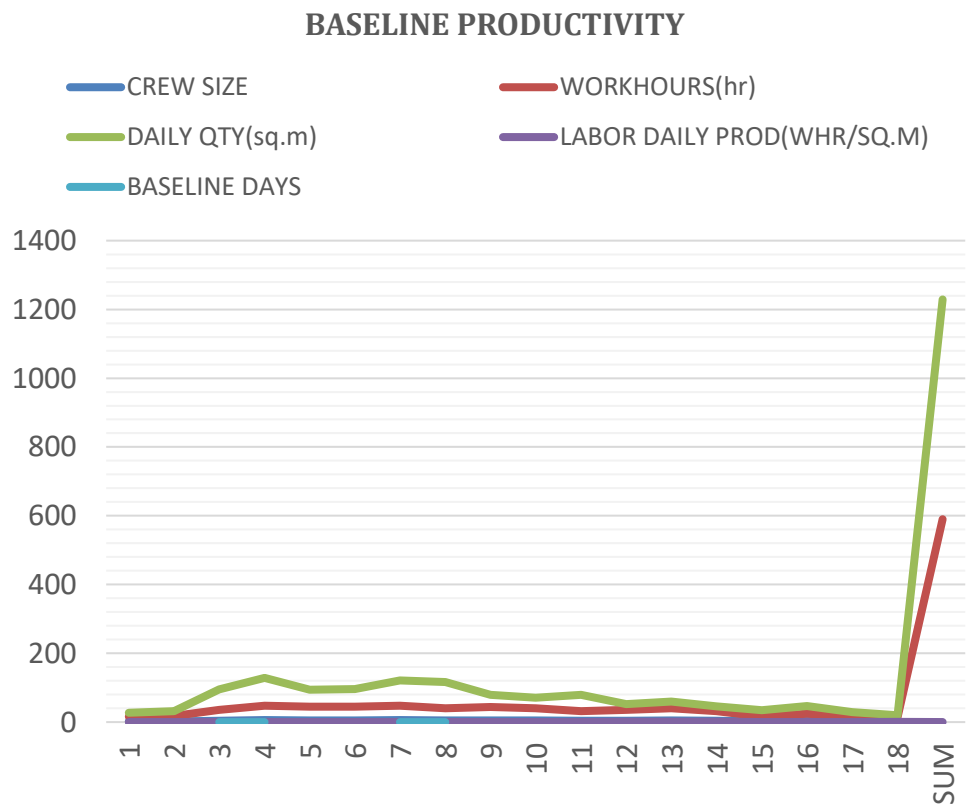
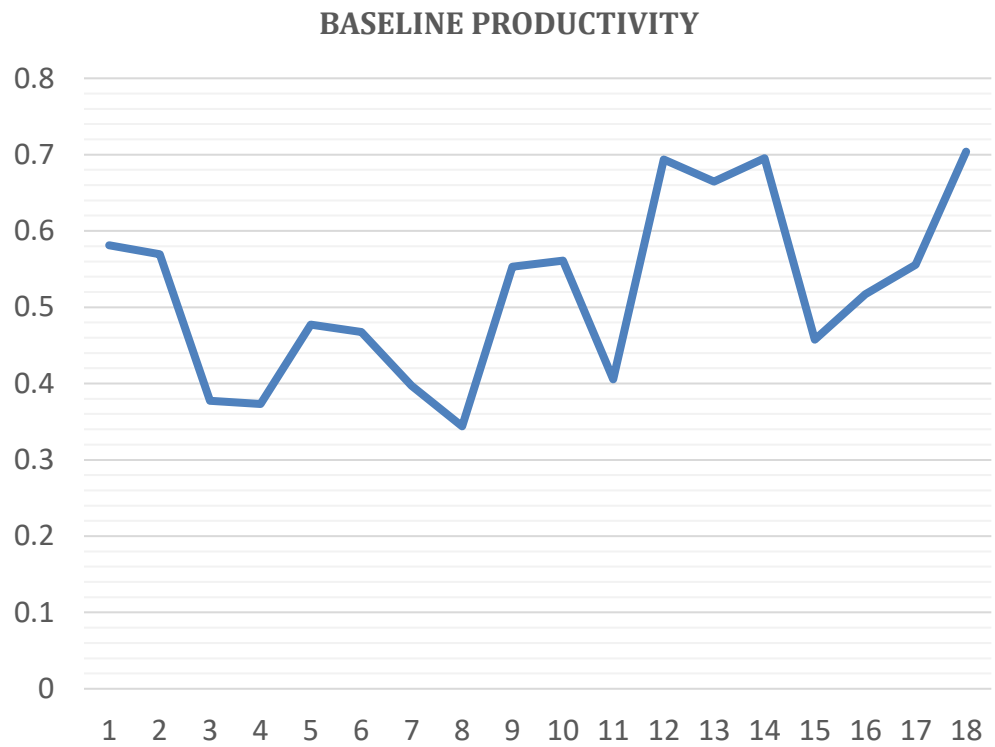
CHAPTER 03 METHODOLOGY

3.1 CASE STUDY 1

Data were collected for school building project to measure the labor productivity for masonry works where the data included the workforce size, daily working hours and the daily quantity output. The following table is data from only school as a single project just to define how measuring of baseline productivity attribute model functions as below:

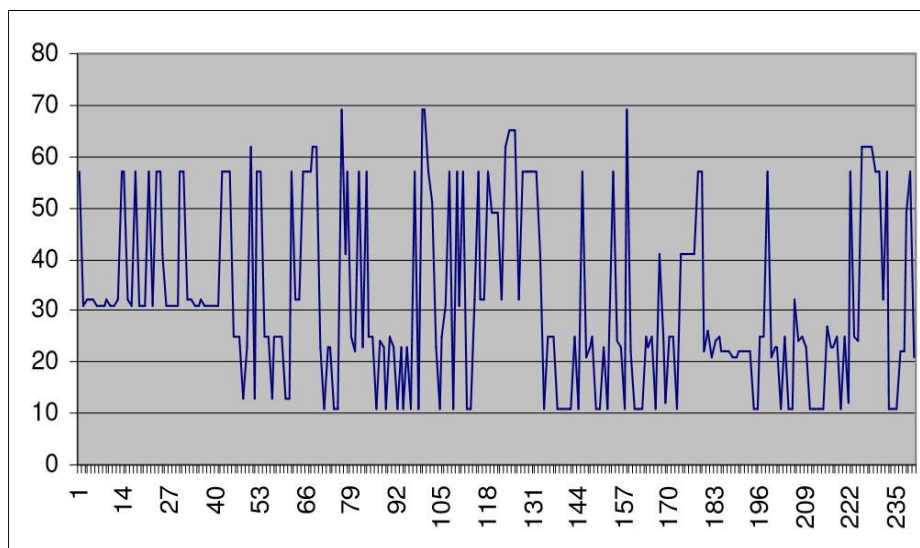
DAY	CREW SIZE	WORKHOURS(hr)	DAILY QTY(sq.m)	LABOR DAILY PROD(WHR/SQ.M)	BASELINE DAYS
1	2	16	27.53	0.5812	
2	2	18	31.62	0.5693	
3	4	36	95.44	0.3772	*
4	6	48	128.7	0.373	*
5	5	45	94.31	0.4771	
6	5	45	96.22	0.4677	
7	6	48	120.92	0.397	*
8	5	40	116.31	0.3439	*
9	5	44	79.56	0.553	
10	5	40	71.31	0.5609	
11	4	32	78.92	0.4055	*
12	4	36	51.91	0.6935	
13	5	40	60.2	0.6645	
14	4	32	46.02	0.6953	
15	2	16	34.96	0.4577	
16	3	24	46.4	0.5172	
17	2	16	28.79	0.5557	
18	2	14	19.89	0.7039	
SUM		590	1229.01	0.4801	

- To demonstrate the baseline productivity index, the best scores marked by (*) of the daily labors productivity which are the five lowest measured values are found as 0.3772, 0.3730, 0.3970, 0.3439 and 0.4055 whr/m² in the above table.
- Accordingly, the baseline productivity for school would be the summation of all daily labor productivity divided by five which is the average of those five values as equals 0.3793 whr/m²



3.2 CASE STUDY 2

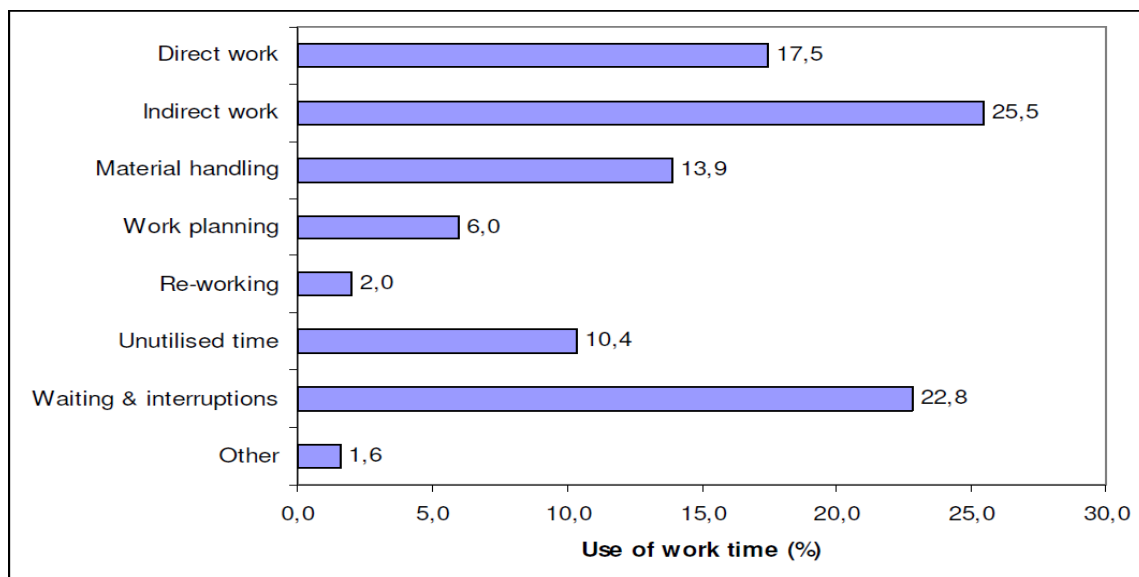
- The typical work day contains many interruptions for the project manager as disturbance and changes of work tasks.
- This could be breaking up of work which involves other workers as subcontractors.
- While this interruption does not include coffee break and lunch.
- In an eight-hour work day at a construction site, task changing within two minutes interval is a great issue to break up and interrupt their work.
- laborers changed their tasks and variated duties 156 times during the work day as shown in figure by observation taking every second minute.
- The changes involved certain activities of material handling and moving between different places for 28 times during the day.
- The work which adds value took only ten minutes on only 32 occasions.
- The horizontal axis shows the number of minutes during the day time and the vertical axis is the code number of involved activities.
- 11-19 codes were activities that added value(targeted level of labor productivity)
- 21-49 codes were preparation activities
- 51 –79 codes were non-value-added activities(lower rate of labor productivity)
- As such the work day consisted of only 9 codes from code no 11 to 19 for the value-added activities has made the individuals effectiveness become very low.
- While existing of many non-valued activities of 28 codes from code no 51 to 79 have resulted in too much waste in working hours during the work day.
- The project has experienced this waste because of frequent switching between different activities.
- Accordingly, the result was a high variation and fluctuation in the rate of labor productivity due to task swapping and substituting between different site activities.



3.3 CASE STUDY 3

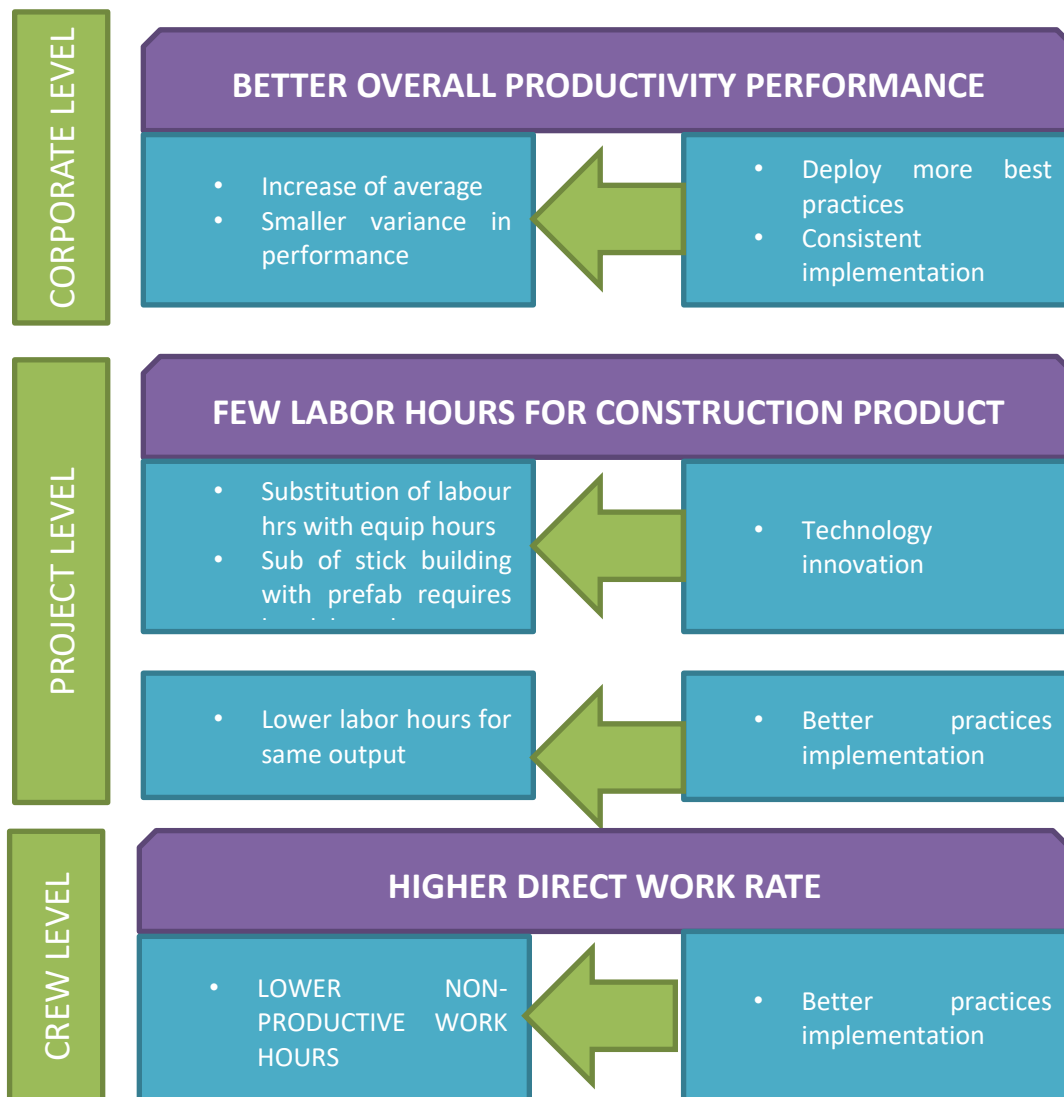
- The focus should be on the individual laborers to see what they do to understand how much work was devoted to adding value on construction.
 - An example was taken to observe a group of laborers for construction of new homes during 22 work days.
 - The observation was taken to all over tasks for the entire project.
 - Work time was divided into three parts.
1. 17.5 %(targeted project)
 2. 45.4%(preparation work as handling of equipment and material)
 - (25%)material and equipment preparation
 - (14%)material transport and movement
 - (6%)for the planning work
 3. 33.4 % (reworking, waiting for materials and work interruption)
 - (23%)waiting and moving between different workplaces
 - (10%) was for unutilized due to moving to and from the cabins
- This result showed a low proportion of work that increases value to the construction.
 - The work that was done by the construction laborers which directly added value estimated as 16.4 % if the sick laborers would have been included in this result.
 - It was seen that effectiveness of individuals was about 13.4 % of the total time on site .
 - This means seven laborers were needed to carry out the work for one person in order to add value on the project.
 - This approach can clearly draw a boundary between what is valuable and not valuable for the project.

THE DISTRIBUTED SHARES OF VALUE ADDED, AND NON-VALUE-ADDED WORKS IS PRESENTED AS BELOW:



The types of waste in those projects were classified into three processes as:

- **Operative work process** that directly add value to construction in the view of the client where the activities could be executed in another order to save and speed up the construction time.
- **Support process** includes monotonous activities as preparation for value adding work which are necessary for the operation.
- **Management process** includes activities that aim to determine the organization's strategies which do not add direct value to the productivity rate and absorbs resource. Examples of this one could be rework, waiting time, transport of materials, walking around without doing work and storing material that wait to be handled.
- The performance metric system consists of the direct work rate and cumulative labor productivity formula as below:
- *Direct work rate=Observation of direct work/Total number of observations*
- *Cumulative labor productivity=Work hours/ Unit of physical output*
- Certain performance metrics are used to measure the productivity level of the specific project on workforce level and identify the direct work, cost and schedule changes.
- The focus is more related to the site crew level where there is no workplace assessment method exists to identify productivity inhibitors affecting site labor.
- This activity analysis determines correlation between both the productivity and direct work rate.
- It analyses the impacting factors of indirect work rate with respect to environment and statistical analysis.
- It introduces multiple gap factors for each practice element, those factors respectively represent the improvement room to the best-in-class.



**Tab 3.1 GENERAL IMPACTING FACTORS ON LABOR PRODUCTIVITY
MANAGEMENT FACTORS**

FACTORS	RELATIVE IMPORTANCE INDEX (%)	RANK
Lack of labour supervision	81.67	1
Proportion of work subcontracted	80.64	2
Lack of incentive	78.60	3
Construction manager's lack of leadership	77.71	4
Unsuitability of storage area position	67.64	5
Composition and size of the crew	55.41	7
Inappropriate scheduling	55.13	8
Labour site congestion	54.65	9
Shortage of material (supply chain mismanagement)	52.87	10
Construction method	52.44	11
Payment delay	52.36	12
Communication issue between management and labour	52.10	13
Accident due to poor site safety program	51.59	14
Late arrival, early quit, unscheduled breaks	50.57	15
Unavailability of tools	50.45	16
lack of training	49.81	17
Inspection delay by site manager	49.04	18
Sequencing problems	43.85	19
Lack of recognition program	43.74	20
Lack of periodical meeting with the foreman	43.44	21
Clients intervention with management	37.96	22
Lack of suitable area offered to labours	36.18	23

Tab 3.2 Technology & Innovation Factors

FACTOR	RELATIVE IMPORTANCE INDEX	RANK
Clarity of technical specification in design drawings	84.33	1
Change orders during execution	83.69	2
Coordination between design disciplines	82.55	3
Design complexity level	79.62	4
Intensive inspection by engineers	77.07	5
Delay in responding to request for information	76.69	6
Consistency among contract documents	71.08	7
Rework	66.88	8
Site restricted access	63.95	9
Working space	60.64	10
Site layout	51.46	11
Inspection delay from engineer	50.32	12

Group	Average Relative Importance Index (%)	Rank
Technological	70.69	1
Human/labour	60.54	2
Management	54.91	3
External	54.05	4

3.4 CASE STUDY 4

PROJECT LOCATION :SIPCOT,SRIPERUMBUDUR

SIBUILD UP AREA :1,00,000 sq.ft

NO OF FLOORS :16 FLOORS

Tab 3.3 Schedule Vs Actual

Schedule Vs Actual									Status up to:	18-10-2021		
Description of task	Unit	Total Qty	As on date completed	Balance to be completed	As per Schedule start date	Actual start date	Target date	As per Schedule (to be achieved/ day)	Actual achieved up to date	Status	Labour Category	Productivity
LEVEL 6 TO LEVEL 7												
EFGH SHAFT REINFORCEMENT 1ST LIFT	MT	7.90	7.90	0.00	08-10-21	08-10-21	11-10-21	0.00	0.00	Completed	Barbender	15.38
EFGH SHAFT BEAM REINFORCEMENT	MT	2.00	2.00	0.00	12-10-21	11-10-21	13-10-21	0.00	0.00	Completed	Barbender	15.38
EFGH CASTING CHANNEL FIXING 1ST LIFT	RMT	157.00	154.20	2.80	14-10-21	08-10-21	18-10-21	2.80	15.42	Ahead the schedule	Welder	0.6
EFGH WALL SHUTTERING 1ST LIFT	SQM	292.00	225.00	67.00	19-10-21	14-10-21	22-10-21	0.00	56.25	Ahead the schedule	Carpenter	0.33
EFGH WALL CONCRETING 1ST LIFT	CUM	44.00	0.00	44.00	23-10-21		23-10-21	0.00	0.00	As per the schedule	Unskilled	0.4
CORE WALL ABCD												
ABCD SHAFT WALL REINFORCEMENT 1ST LIFT	MT	7.90	1.50	6.40	14-10-21	17-10-21	17-10-21	6.40	1.50	Behind the schedule	Barbender	15.38

ABCD SHAFT BEAM REINFORCE MENT	MT	2.00	0.00	2.00	18-10- 21		19- 10- 21	0.00	FALSE	Ahead the schedul e	Barben der	15.38
ABCD WALL CASTING CHANNEL FIXING 1ST LIFT	RM T	157. 00	0.00	157.00	20-10- 21		24- 10- 21	0.00	0.00	As per the schedul e	Welder	0.6
ABCD WALL SHUTTERING 1ST LIFT	SQ M	292. 00	0.00	292.00	23-10- 21		26- 10- 21	0.00	0.00	As per the schedul e	Carpen ter	0.33
ABCD WALL CONCRETIN G 1ST LIFT	CU M	44.0 0	0.00	44.00	27-10- 21		27- 10- 21	0.00	0.00	As per the schedul e	Unskille d	0.4
STAIRCASE 1 WALL												
STAIR 1 WALL REINFORCE MENT 1ST LIFT	MT	4.00	4.00	0.00	11-10- 21	08- 10- 21	14- 10- 21	0.00	0.00	Comple ted	Barben der	15.38
STAIR 1 WALL SHUTTERING 1ST LIFT	SQ M	150. 97	150.97	0.00	14-10- 21	12- 10- 21	16- 10- 21	0.00	0.00	Comple ted	Carpen ter	0.33
STAIR 1 WALL CONCRETIN G 1ST LIFT	CU M	18.0 0	18.00	0.00	17-10- 21	16- 10- 21	17- 10- 21	0.00	0.00	Comple ted	Unskille d	0.4

Description	Unit	Total Qty	As on date completed	Balance to be completed	Productivity
STAIRCASE 2					
STAIR 2 WALL REINFORCEMENT 1ST LIFT	MT	4.00	0.00	4.00	15.38

STAIR 2 WALL SHUTTERING 1ST LIFT	SQM	146.48	0.00	146.48	0.33
STAIR 2 WALL CONCRETING 1ST LIFT	CUM	20.91	0.00	20.91	0.4
STAIRCASE 2					
FLIGHT-1 & 2					
STAIR 2 LEVEL 4 TO LEVEL 5 SHUTTERING	SQM	46.67	46.67	0.00	0.33
STAIR 2 LEVEL 4 TO LEVEL 5 REINFORCEMENT	MT	0.80	0.80	0.00	15.38
STAIR 2 LEVEL 4 TO LEVEL 5 CONCRETING	CUM	6.67	6.67	0.00	0.4
STAIRCASE 2					
FLIGHT-3 & 4					
STAIR 2 LEVEL 5 TO LEVEL 6 SHUTTERING	SQM	46.67	0.00	46.67	0.33
STAIR 2 LEVEL 5 TO LEVEL 6 REINFORCEMENT	MT	0.80	0.00	1.10	15.38
STAIR 2 LEVEL 5 TO LEVEL 6 CONCRETING	CUM	6.67	0.00	6.67	0.4
Description	Unit	Total Qty	As on date completed	Balance to be completed	Productivity
STAIR 1 LEVEL 5 TO LEVEL 6 SHUTTERING	SQM	40.00	0.00	40.00	0.33
STAIR 1 LEVEL 5 TO LEVEL 6 REINFORCEMENT	MT	0.80	0.00	0.80	15.38
STAIR 1 LEVEL 5 TO LEVEL 6 CONCRETING	CUM	6.67	0.00	6.67	0.4
STAIRCASE 1					
FLIGHT-5 & 6					
STAIR 1 LEVEL 5 TO LEVEL 6 SHUTTERING	SQM	40.00	0.00	40.00	0.33
STAIR 1 LEVEL 5 TO LEVEL 6 REINFORCEMENT	MT	0.80	0.00	0.80	15.38
STAIR 1 LEVEL 5 TO LEVEL 6 CONCRETING	CUM	6.67	0.00	6.67	0.4
COLUMN					
COLUMN REINFORCEMENT	MT	13.40	0.00	13.40	15.38

COLUMN SHUTTERING	SQM	106.00	0.00	106.00	0.33
COLUMN CONCRETING	CUM	17.00	0.00	17.00	0.4
SLAB AND BEAM					
LEVEL 7 SLAB SHUTTERING	SQM	627.00	0.00	627.00	0.33
LEVEL 7 SLAB REINFORCEMENT	MT	20.26	0.00	20.26	15.38
LEVEL 7 SLAB CONCRETE	CUM	102.00	0.00	102.00	0.4

3.5 CASE STUDY 5

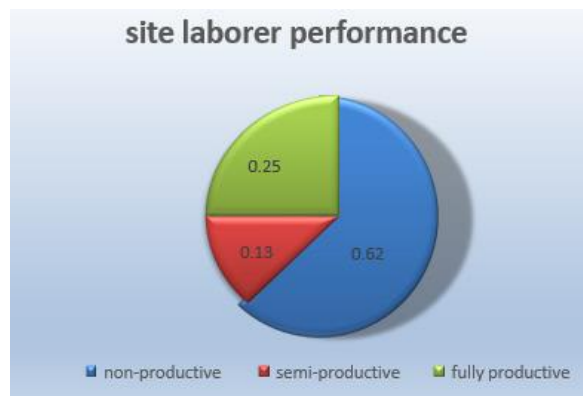
WORK SAMPLING METHOD TECHNIQUE

- Work Sampling technique is applied in the project of residential building to analyze the laborers performance rate.
- Many managerial reasons of rework, wasting in construction time and work interruption were directly linked to the decline in labor productivity during two stages of pre-construction and construction.
- This method can function as a detecting approach to find out the failure in pursuing the required level of work and diagnose the major factors resulting in poor labor performance.
- The analysis outcome of this method determines how much laboring time spent is being non-productive in relation to the total time the person is involved in the operation.
- It establishes the foundation for an improvement plan for managing those shortcomings.
- Applying this technique in taking observation data was conducted on slab reinforcement task through classifying this task into three main parameters as direct, support(indirect) and no-working.

CLASSIFICATION	PRODUCTIVE	SEMI-PRODUCTIVE	NON-PRODUCTIVE (NO-WORKING)
Description	Fully productive & direct work	Semi-productive as indirect work	Non-contributing to any activity
reinforcement activity	• Exerting physical efforts directed towards the activity. • laying reinforcement bars & fixation • Fixing the balcony slab • reinforcement bars bending	• Preparation work to assignment and determine requirement • Material movement. • Scaffolding as preparation for slab fixing.	• Waiting period of idleness (personal break). • Hanging about empty handed. • waiting for more instructions. • waiting for

	work	• Taking instructions. • Equipment & tool movement. • Equipment adjustment & (set up)	equipment to be fixed. • waiting for materials • equipment movement. • Personal breaks
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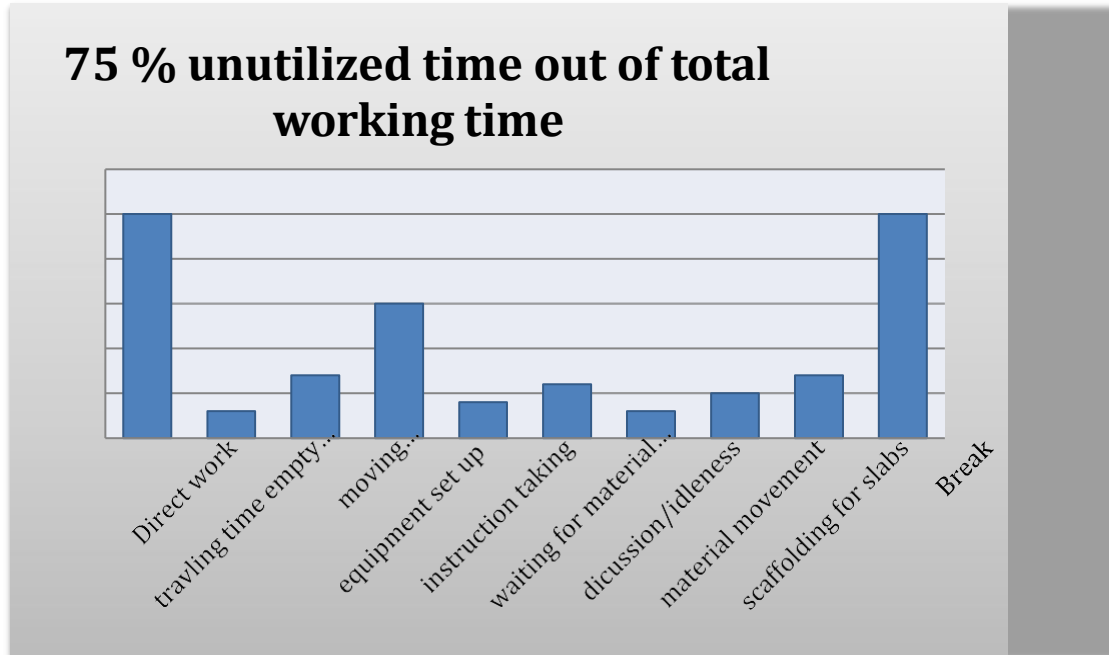
- Each of the above site observations has been taken and measured on the bases of time expenditure.
- How much time lasted for each activity has taken was measured together with how much wasted time each activity involved in compared to the total time of p- hours spent on site.
- The above parameters of non-productive work as non-value added and fully productive as value added were criteria's to estimate the percentage rate of utilized and unutilized time.
- The indexes below were the final result after conducting a field study of data collection through site observation.
- The following graphical chart depicts laborer's performance proportion for all the labor-hours which were utilized and not utilized according to the descriptions classified in allocation percentage included following:



Work utilization	site labourer performance
non-productive	0.62
semi-productive	0.13
fully productive	0.25

- This following graphical chart represents the percentage of man hours effectively utilized as value added work and ineffectively utilized as non-value-added work out of the total working hours.

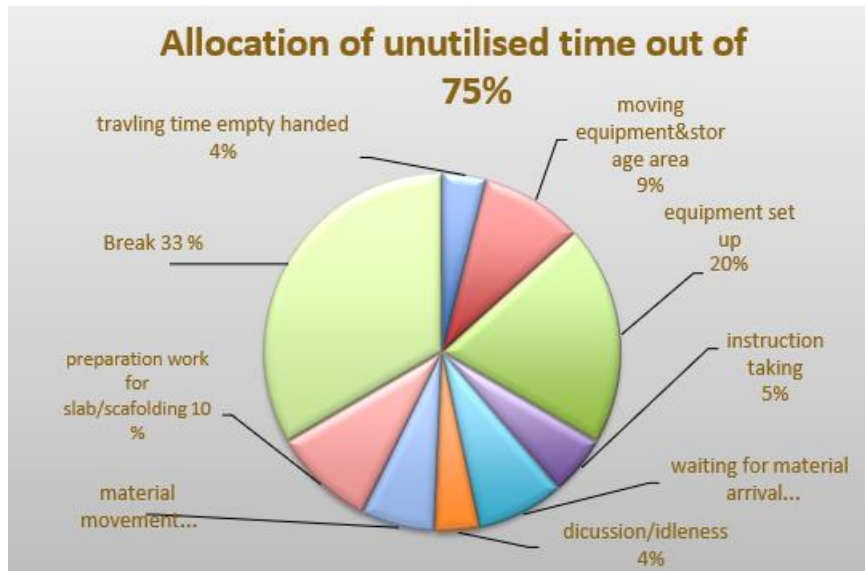
- Each activity has been allocated its own specific percentage shares.
- 75 % of the total reinforcement working hours was estimated as non-productive and 25 % as a productive and a direct work hour during the whole days of observation taking.
- The figure shows a distribution shares between all the value-added and non-value-added activities for project during conducting the Work Sampling Method.



Traveling Time Empty Handed	03 %	139 Min
Direct Work	25 %	1188 Min
Equipment /Storage Area Movement	07%	354 Min
Equipment Set Up	15%	720 Min
Instruction Taking	04%	173 Min
Waiting For Material Arrival	06%	308 Min
Discussion/Idleness	03%	148 Min
Material Movement	05%	220 Min
Preparation Work For Slab/Scaffolding	07%	350 Min
Break	25%	1200 Min

percentage shares of non-value activities impacting the workforce decline out of 100 % of working hours.

- The table contains percentage shares for all activities with respect to their ranks of relative importance index which have impacted on 75 % wasting time.
- It shows which activity had the highest influence on the workforce's productivity decline in the task.
- The most effective activity has impacted was graded with a highest relative importance index and the lowest rate had the minimum impact on productivity decline.



Relative importance percentage shares distribution of non-value adding activities & wasting time

Activities of non-productive and support work	Relative importance index	Rank
Break	33 %	1
Equipment set up	20 %	2
Preparation work for slab/scaffolding	10 %	3
Moving equipment storage area	09 %	4
Waiting for material	08 %	5
Material movement	07 %	5
Instruction taking	05 %	5
Traveling time empty handed	04 %	6
Discussion & idleness	04 %	7

As a result of applying WSMT method many causes for decline in labor productivity and time delay has shown up together with pinpointing those reinforcement elements which need improvements. Adopting this method of activity analysis helped to find the responsible factors for productivity decline

and reduction in their value-added activities.

CONSTRUCTION PRODUCTIVITY DISRUPTIONS

- Productivity is a very old but still-relevant concept that corresponds to the ability to improve value and quality of services or products.
- In other words, productivity is measured as the relation between output and input, where “input” consists of resources used in the product creation process, such as materials, equipment, and labor, and “output” inheres in a given product or service.

The term productivity can be applicable in measuring total labor productivity, crew productivity, project productivity, or even the productivity of particular resources, e.g., cash or construction equipment

$$\text{Construction productivity} = \frac{\text{Dollars of Output}}{\text{Dollars of Input}}$$

The diagram illustrates the components of the productivity formula. Two boxes are shown with arrows pointing to the numerator and denominator of the fraction.

Output Components (Numerator):

- Money (revenue, value added)
- Product (quantity or value)
- Services (quantity or value)

Input Components (Denominator):

- Manpower (man - hour)
- Machinery (machine - hour)
- Materials (materials - quantity)
- Money (value of input)

USING LEAN PHILOSOPHY TO IMPROVE CONSTRUCTION PRODUCTIVITY

- Once an area is identified for construction productivity improvements, management should then work towards and maintain the improvements over time.
- In this regard, “Lean construction”, an alternative management system with well-defined tools, is introduced in the current study to assist in improving the construction process and increasing productivity.
- One of the top priorities in lean construction theory is eliminating waste in a process, which is a consequence of disruptions that affect construction productivity.
- Furthermore, a wide range of lean theory benefits have been listed including the following:
 - ✓ A reduction in waste, production cost, production cycle time, labor and inventory;
 - ✓ an increase in quality, profit, and system flexibility; and an improvement in cash flow and the capacity of existing facilities.
 - ✓ The application of six lean tools in a construction project, as follows: Last Planner, increased visualization, huddle meetings, first-run studies, 5S (sort, set in order, shine, standardise, and sustain), and fail-safe for quality.
 - ✓ The implementation of these lean tools helped in improving the relationship between subcontractors and general contractors, completing the project under budget within the set schedule, and reducing the incident rate.

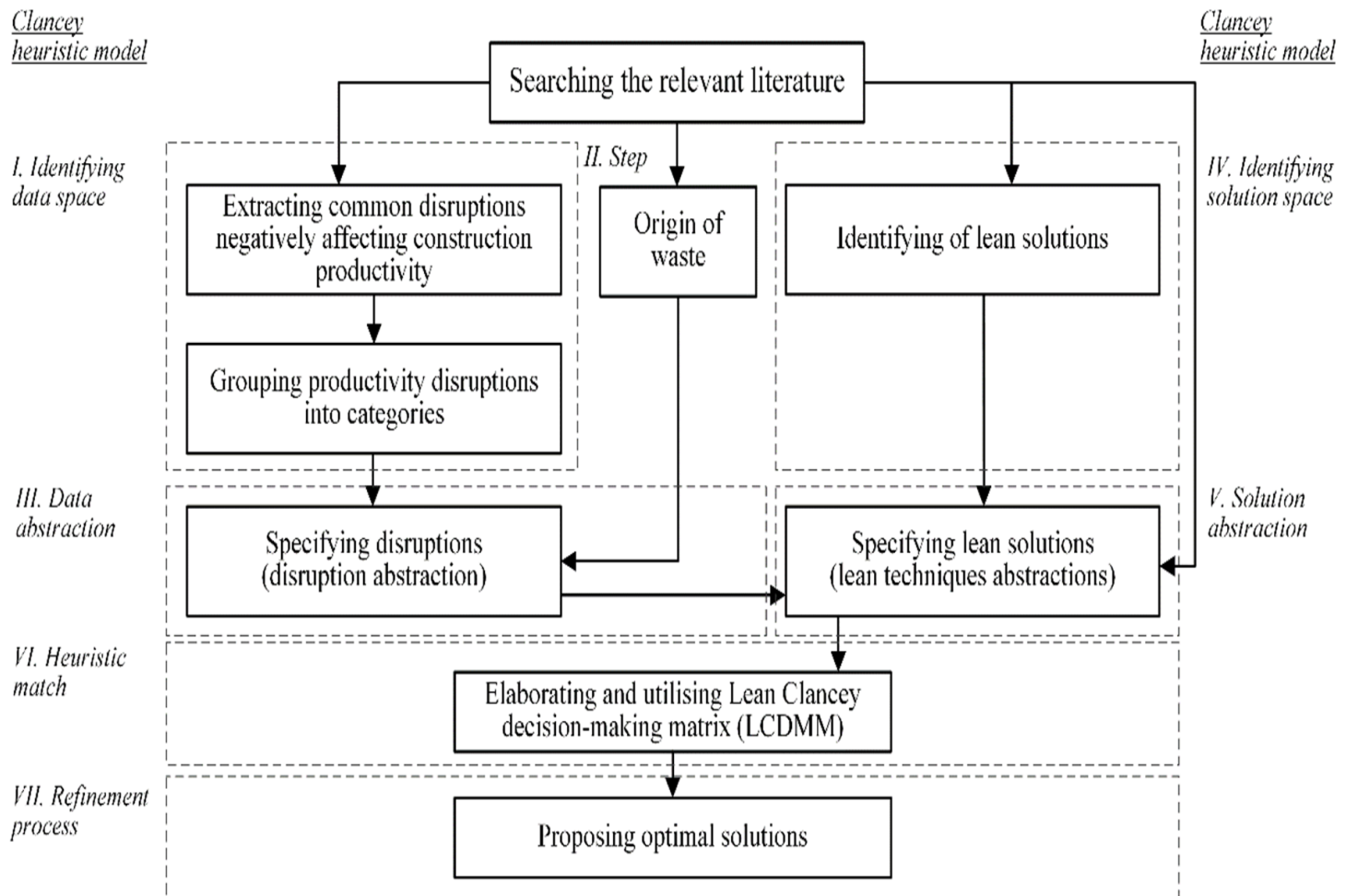
CLANCEY HEURISTIC MODEL

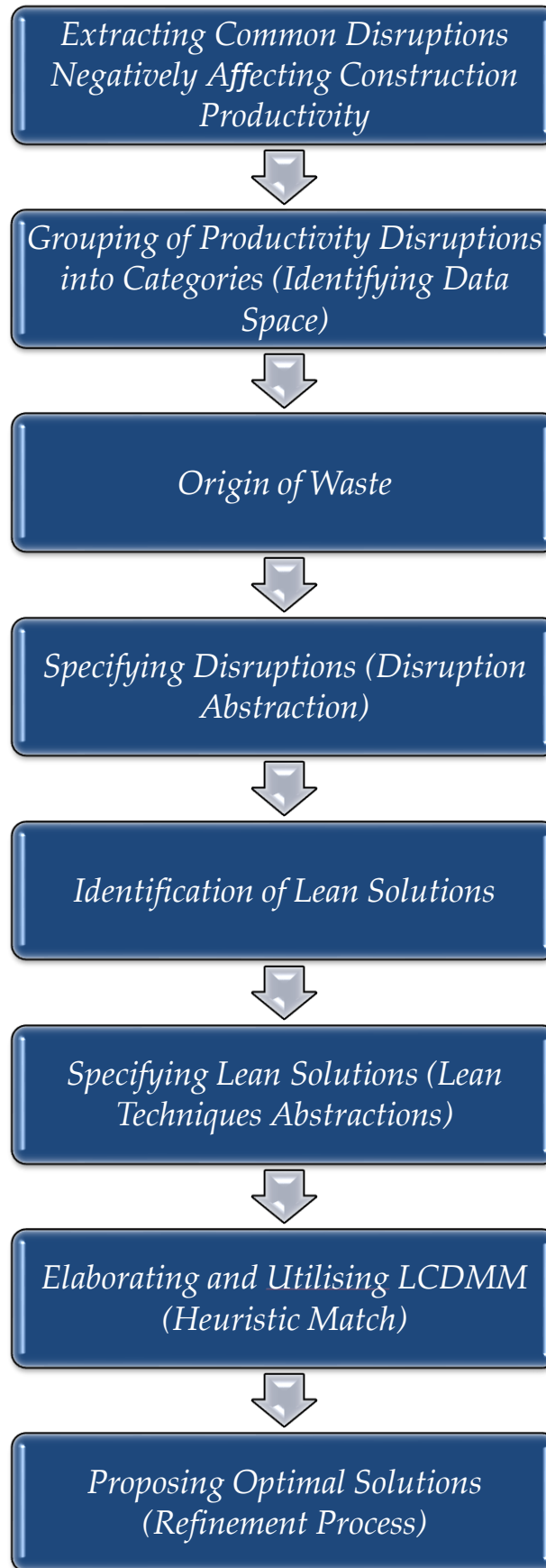
- Although lean construction consists of various methods, it does not provide a framework that

assists managers in choosing optimal lean tools to overcome productivity disruptions.

- A literature review extended to various scientific fields revealed the “Clancey heuristic model”, which is aimed at classifying and determining a satisfactory solution by employing a structured framework.
- The Clancey method is the process that consists of sequential parts—“data abstraction”, “heuristic match”, and “refinement”.
- “Data abstraction” is the process of hiding data details while maintaining the essential features of the data.
- A “heuristic match” refers to the process of finding an appropriate general solution.
- “Refinement”, which is the inverse process of “abstraction”, consists of using a general solution such as input to generate more specialized ones; in other words, to go from abstract solutions to more concrete ones, the process of which applies domain knowledge on the solution.

METHODOLOGICAL APPROACH

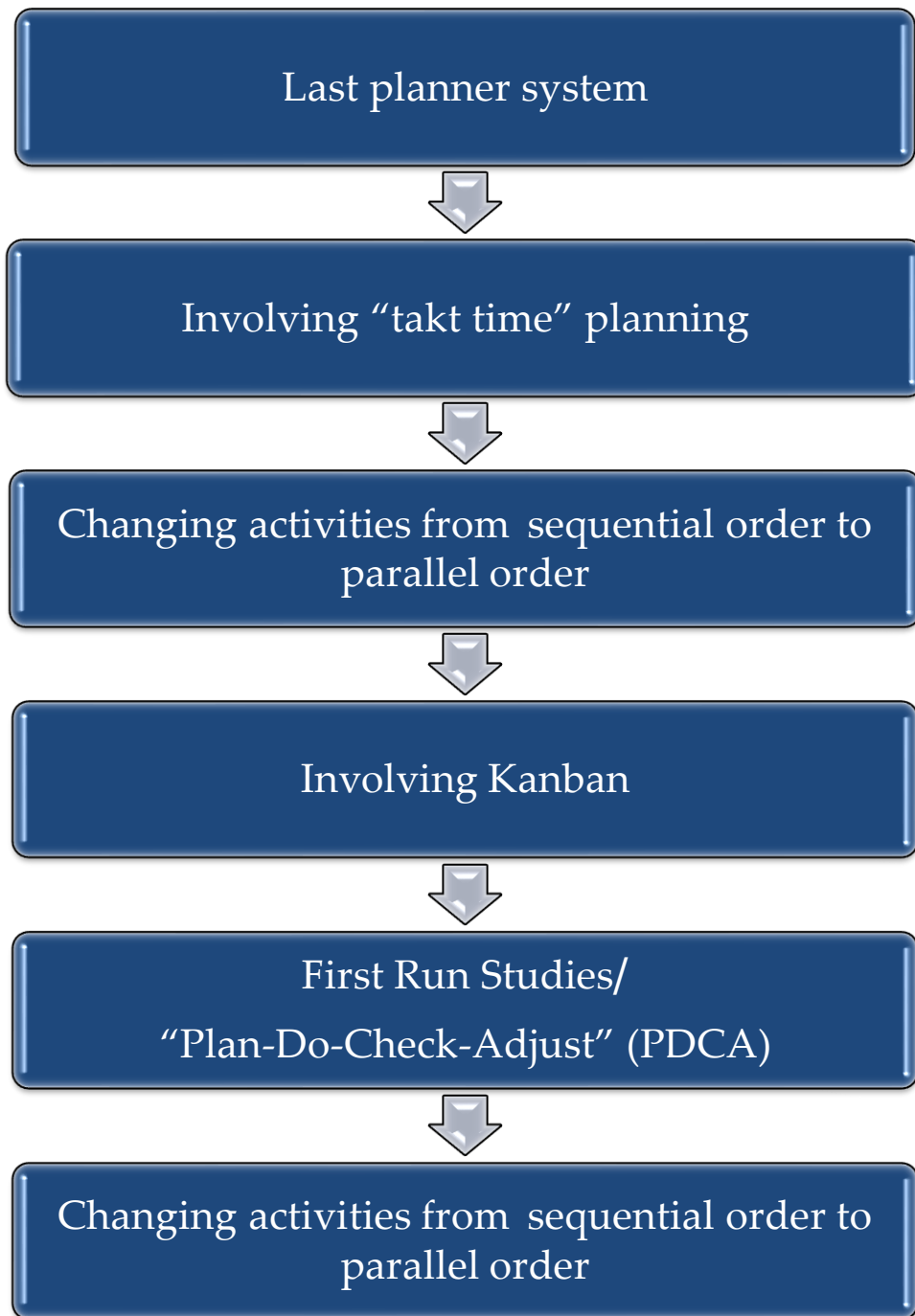


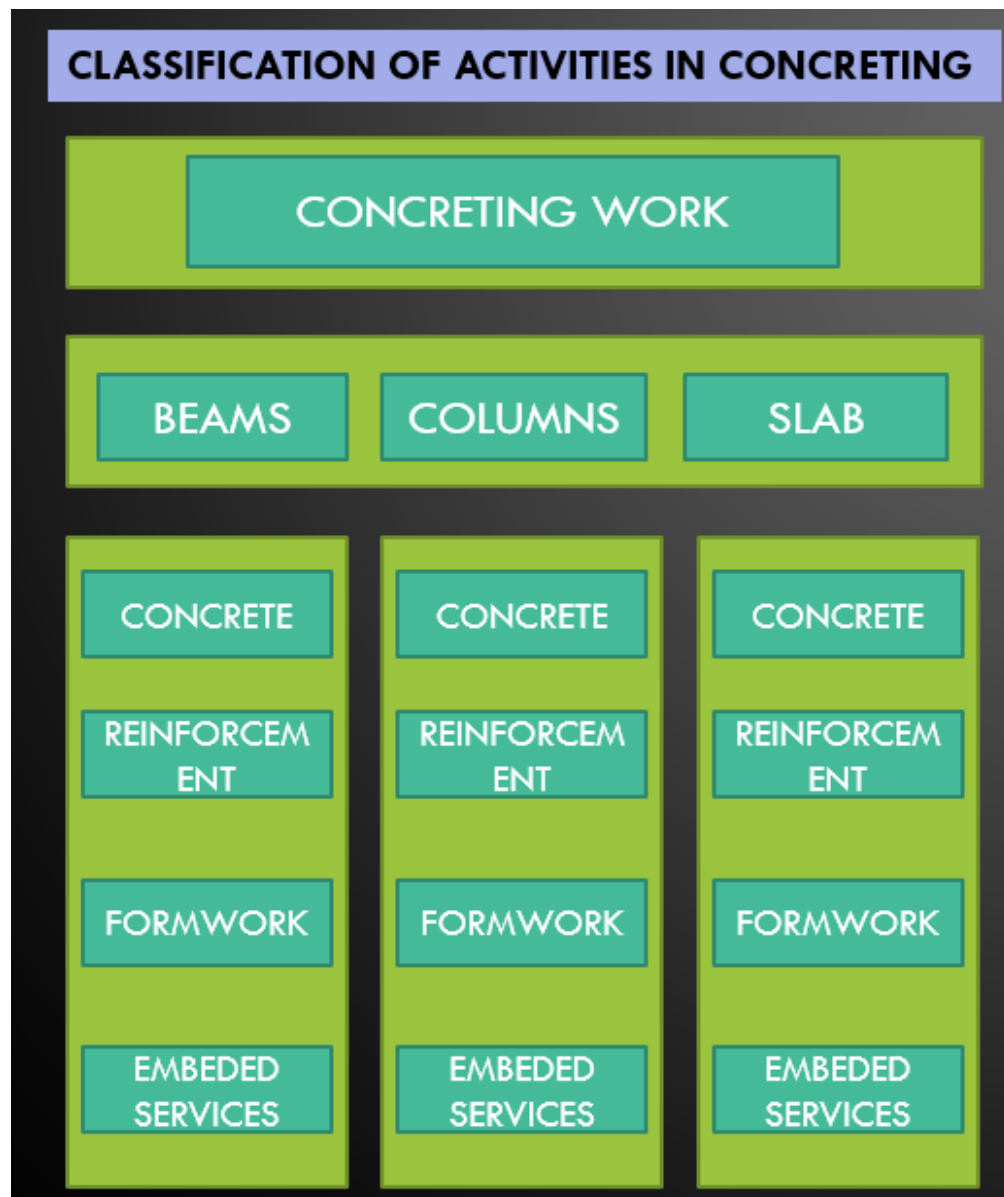


	Poor qualification/experience of management at different levels
	Inadequacy of planning and risk management process
	Inappropriate construction method
	Schedule changes and acceleration
Management (method and control) disruptions	Relationship management/degree of harmony, trust, and cooperation
	Slow management decision process
	Instruction time and supervision delay
	Inspection delays
	Poor supervision, performance monitoring, and control
	Improper crew size/composition
	Design changes, errors and omissions
	Improper coordination between different construction trades
	Low worker motivation
	Fatigue, mental and physical worker stress
Manpower disruptions	Physical worker limitations
	Worker absenteeism
	Worker turnover frequency
	Skilled/experienced worker shortage
	Indifference to worker opinion
	Tools and equipment unavailability
	Equipment breakdown
	Poor quality of power tools
Equipment and tools disruptions	Improper tool/equipment allocation
	Unnecessary equipment movement
	Improper equipment capacity
	Transportation and/or equipment installation delay
	Extensive multiple-handling of materials
	Materials improperly sorted/marked
	Debris impeding material access/movement
	Late material delivery
Material disruptions	Material shortage at construction site

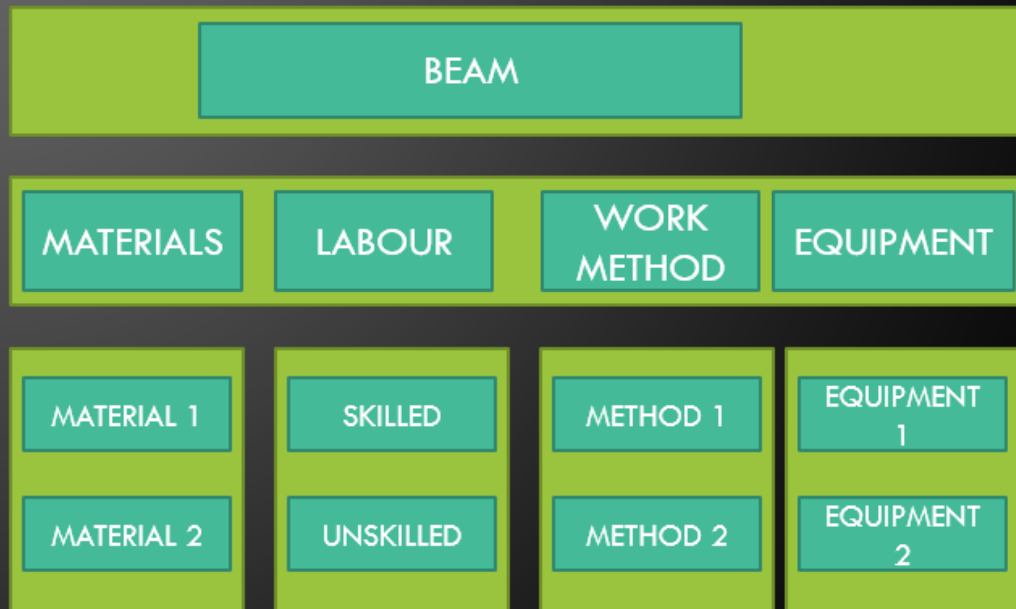
	Low fabrication shop production rates
	Poor material quality
	Delivery material out-of-specification
	Material damage from deficient stockpiling and handling

OBTAINED LEAN TECHNIQUES TO PREVENT DISRUPTIONS IN PRODUCTIVITY





CLASSIFICATION OF INPUT OF ACTIVITIES



FOR LABOR

LABOR TIME	LABOR COST
Man Hrs Per Day	Per Day Labour Cost
No Of Working Days In A Week	Incentive/Other Concessions
Productivity per day(sq.m or cu.m per day)	
Estimating The Activity Duration Based On Productivity Per Day Data	Estimating The Cost Based On The Duration And Calculated
Delay(if Any)/Life Time	Cost Incurred Due To Delay(overrun)
Measures To Improve Labor Productivity To Save Cost And Time Of The Activity	

FOR EQUIPMENT	
EQUIPMENT TIME	EQUIPMENT COST
Equipment Hrs Per Day	Per Day Owning Or Renting Cost
Productivity Per Day Of The Equipment	
Estimating The Duration To Complete The Activity For The Calculated	Estimating The Cost To Complete The activity With The Estimated Duration For The Calculated Productivity Per Day
Cost Overrun Calculation And Reason	Time Overrun Calculation And Reason
Measures To Improve Equipment Productivity To Save Cost And Time Of The Activity	

FOR MATERIAL	
MATERIAL TIME	MATERIAL COST
Material Delivery Time(planned Vs Actual)	Material Quantity And Corresponding Cost
	Material Procurement , transportation And Storage Expenses
	Cost Incurred Due To Excess Material(material Storage)
Material Productivity Per Day(planned Vs Actual)	
Measure To Improve Material Productivity To Save Cost And Time Of The Activity	

FIRST LEVEL	SECOND LEVEL	INFERENCE
REBAR WORKS	• Cage Assembling U Shape Bars • Footrest Cage Transfer • Main Bars Alignment • Hoops & Ties Side Bars	More details from observation ,work , quality , rework , destruction,....
FORM WORKS	• Concrete Joint Scaffolding • Formwork Lubrication Frame Fabrication • Beam Bed Alignment Sealing • Formwork Disassembling Anchoring • Fixing Side Frames	More details from observation ,work , quality , rework , destruction,....
CONCRETE PLACING		Details & method/equipment for concreting , finishing , vibrators, scope,.....
DISTRUPTION OF WORKS	• Waiting for right materials Normal process • Construction rework Unavailability of labour • Weather Crew interference • Waiting for tools /machinery Waiting for drawing • Unbalanced crew Waiting for inspection • Concrete curing	More details about root of disruption
INTERRUPTION OF WORKS	• Break time Crew interference • Lunch , dinner Waiting for inspection • Waiting for materials	More details about root of interruption

S.NO	DESCRIPTION OF WORK	UNIT	LABOR	RECOMMENDED CONSTANT IN DAYS.
1)	Excavation over areas (hard/dense soil),depth up to 1.5m and removal (up to one meter from edge)	M3	Mate	0.06
			Labor	0.62
2)	Excavation in trenches (soft/ loose soil),for foundations not exceeding 1.5m in width and for shafts, wells, cesspits and the like, not exceeding 10m3 and on plan, depth up to 1.5m and removal(up to one meter away from edge)	M3	Mate	0.05
			Labor	0.5
3)	Returning, filling and ramming of excavated earth in layers not exceeding 20 cm in depth, watering, well ramming and leveling, lead up to 50m	M3	Mate	0.02
			Labor	0.25
			Bhisti	0.02
4)	CONCRETE :Mixing by machine (mixer) at banker, cement concrete (with 20mm graded coarse aggregate)	M3	Labor	0.5
			Bhisti	0.1
			Mixer operator	0.07
			Mixer	0.07

5)	Mixer mixed cement concrete	M3	mason	0.1
			Labor	1.63
			bhisti	0.7
			mixer operator	0.07
			mixer	0.07
			vibrator	0.07

6)	Reinforced cement concrete in situ in foundations, footings, bases for columns, etc excluding form work and reinforcement. (The constants for items include mixing, pouring, consolidating and curing. This does not include fair finish.)	M3	mason	0.17
			Labor	2
			bhisti	0.9
			mixer operator	0.07
			mixer	0.07
			vibrator	0.07
7)	Reinforced cement concrete in situ in suspended floors/roofs excluding form work, and reinforcement.	M3	mason	0.24
			Labor	2.5
			bhisti	0.9
			mixer operator	0.07
			mixer	0.07
			vibrator	0.07

8)	MORTARS:	M3	Labor	0.75
	Mixing by hand, cement mortar of any mix/proportions (Labor required will be approximately same for different mix proportions.)		Bhisti	0.07
9)	BRICK WORK (STRAIGHT WALLS):	M3	mason	0.94
	Brick work in walls exceeding one brick thick, in cement / lime mortar (The constants include labor involved in scaffolding.)		Labor	1.8
			bhisti	0.2
10)	Brick work in walls, one brick thick, in cement/lime mortar. (The constants could be adopted for brick work with any mix or mortar.)	M2	mason	0.25
			Labor	0.4
			bhisti	0.1

11)	FORMWORK / SHUTTERING:	M ³	Carpenter	0.25
	a) fabrication and erection with all supports, struts, braces, etc, and dressing with oil as cleaning of formwork:	M2	Labor	0.2
	1) rectangular column and walls		Carpenter	0.23
	2) suspended floors/roofs		Labor	0.2
	3) sides and soffits of beam		Carpenter	0.3
			Labor	0.2

12)	REINFORCEMENT:	Quintal	Bar bender	1
	Bar reinforcement including cutting to length, hooked ends, cranking or bending, hoisting and placing in any position, binding wire and holding firmly so as not to be disturbed while placing and ramming of concrete		Labor	1
13)	PLASTERING AND POINTING:	M ²	mason	0.08
	a) 15mm thick cement plaster to ceiling including mixing of mortar.			
	b) 15mm thick cement plaster on brick walls (exterior) including mixing of mortar	M2	Labor	0.1
	c) Tuck pointing to random rubble masonry in cement mortar including mixing mortar.	M2	bhisti	0.1
			mason	0.06
			Labor	0.1
			bhisti	0.1
			mason	0.1
			Labor	0.15
			bhisti	0.1
14)	DAMPING PROOF COURSE:	M3	Mason	0.1

	a) Laying damp proof course 40mm thick cement concrete including form work and fair finishing to edges and mixing.	Labor	0.1
		bhisti	0

4 PROPOSAL PROJECT

Proposal Project Details

Project Location :Thada

Site Extent :1 Acre

Build Up Area :1,00,000 Sq.Ft

No Of Floors :Basement+Ground + 3

Basement:Car Parking

Ground :Restaurant

First :Commercial Space

Second :Banquet(2 Halls)

Third :Rooms

4.1.1 The Key Components Of The Project :

The proposed commercial building is a G+3 structure with cellar. The adaptive use and facilities provided in the building is mentioned below :

- Fine dining restaurant space with 700 seating capacity in Ground and First floor.
- Two numbers of Premium Banquet halls each providing seats for 600 pax.
- Luxurious double occupancy rooms of 36 numbers.
- Car parking slots provided for 75 numbers.
- Sewage treatment plant also provided along with other basic amenities such as 100% power back up, RO plant and 7 numbers of high speed of elevators.The expected footfall for the proposed hotel is 2500 people per day.The expected target customers are Marriage events, medical tourism and native residents.



PROJECT DESCRIPTION :

S.NO	FLOOR	CARPET AREA (IN SQ.FT)	LEASABLE AREA (IN SQ.FT)	DESCRIPTION
1	Basement floor	16765	N/A	Car parking
2	Ground floor	12838	15361	Restaurant
3	First floor	12830	15361	Proposed rooms
4	Second floor	12830	15361	Banquet halls
5	Third floor	12655	15260	Rooms
6	Fourth floor	12655	15260	Rooms

Room details :

S.NO	FLOOR	ROOM TYPE	NOS	AREA OF ONE ROOM
1	First floor	Executive rooms	35	290 Sq.ft
2	Third floor	Executive rooms	35	290 Sq.ft
3	Fourth floor	Executive rooms	19	290 Sq.ft
4	Fourth floor	Suite rooms	8	579 Sq.ft
Total			97	

Car parking details :

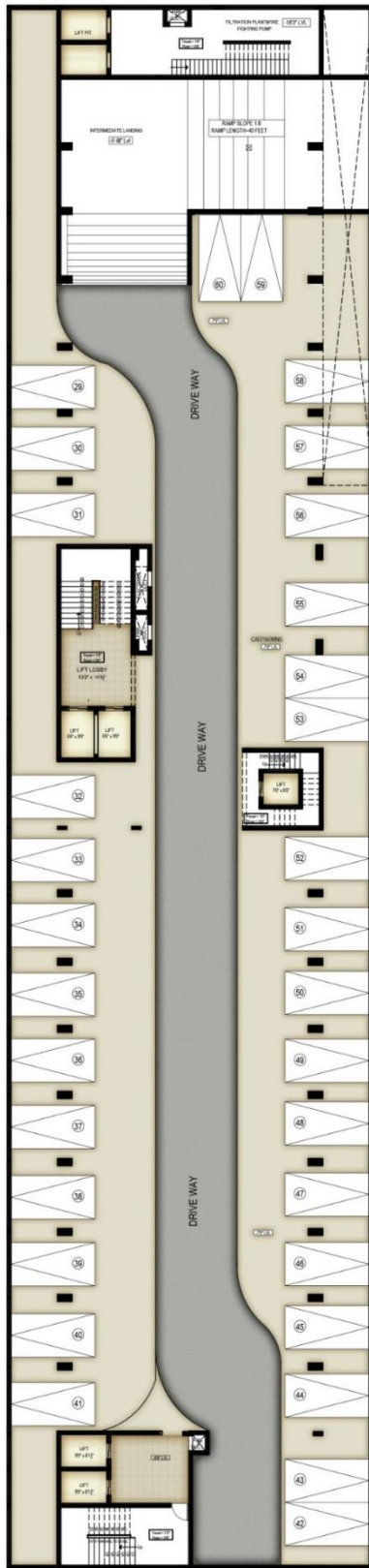
S.NO	FLOOR	CAR PARK NOS
1	Basement floor	32
2	Ground floor	28
3	Valet Parking	15+
Total		75

Banquet hall details

S.NO	FLOOR	HALL	CAPACITY
1	Second floor	Banquet hall 1	600 ppl
2	Second floor	Banquet hall 2	400 ppl



SITE CUM GROUND FLOOR PLAN



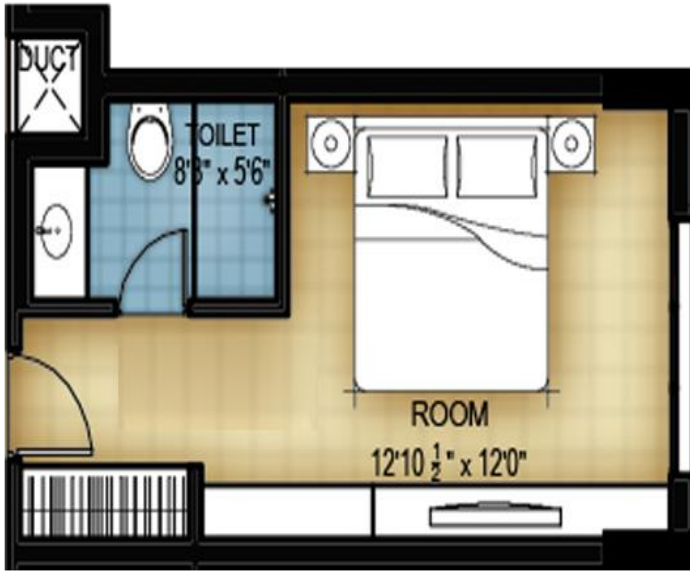
CELLAR FLOOR PLAN



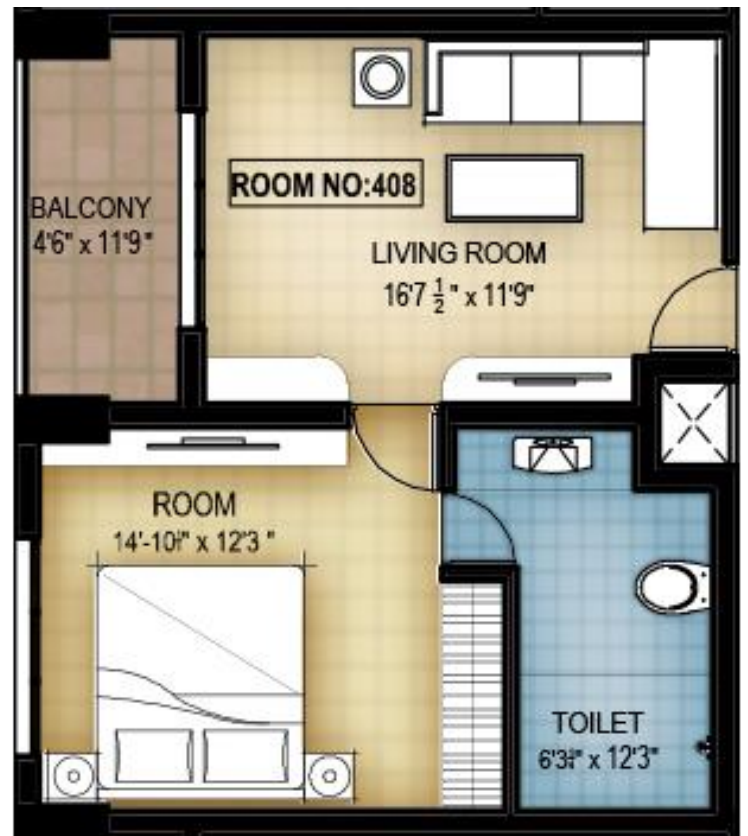
GROUND FLOOR PLAN



ROOM TYPES :



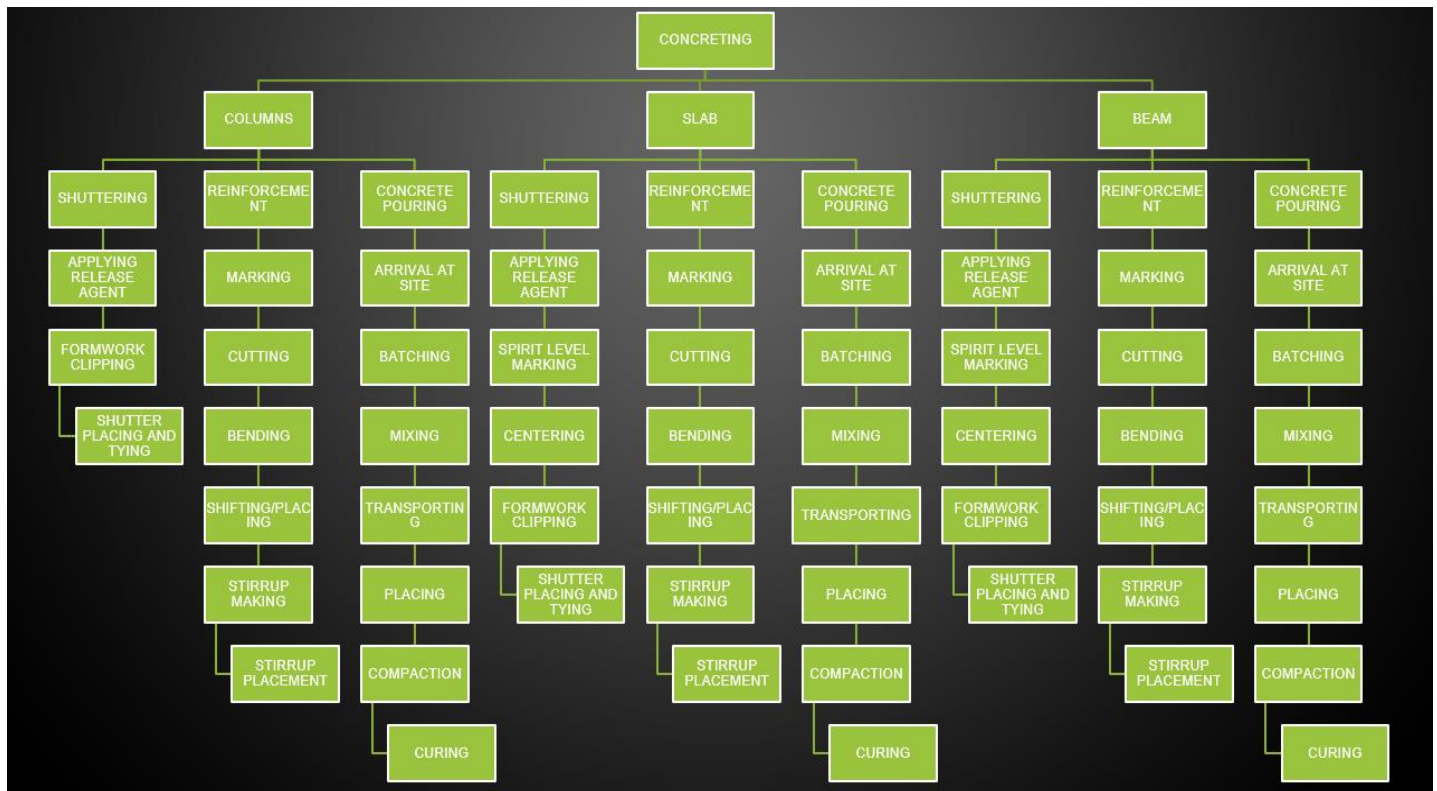
Executive room - plan



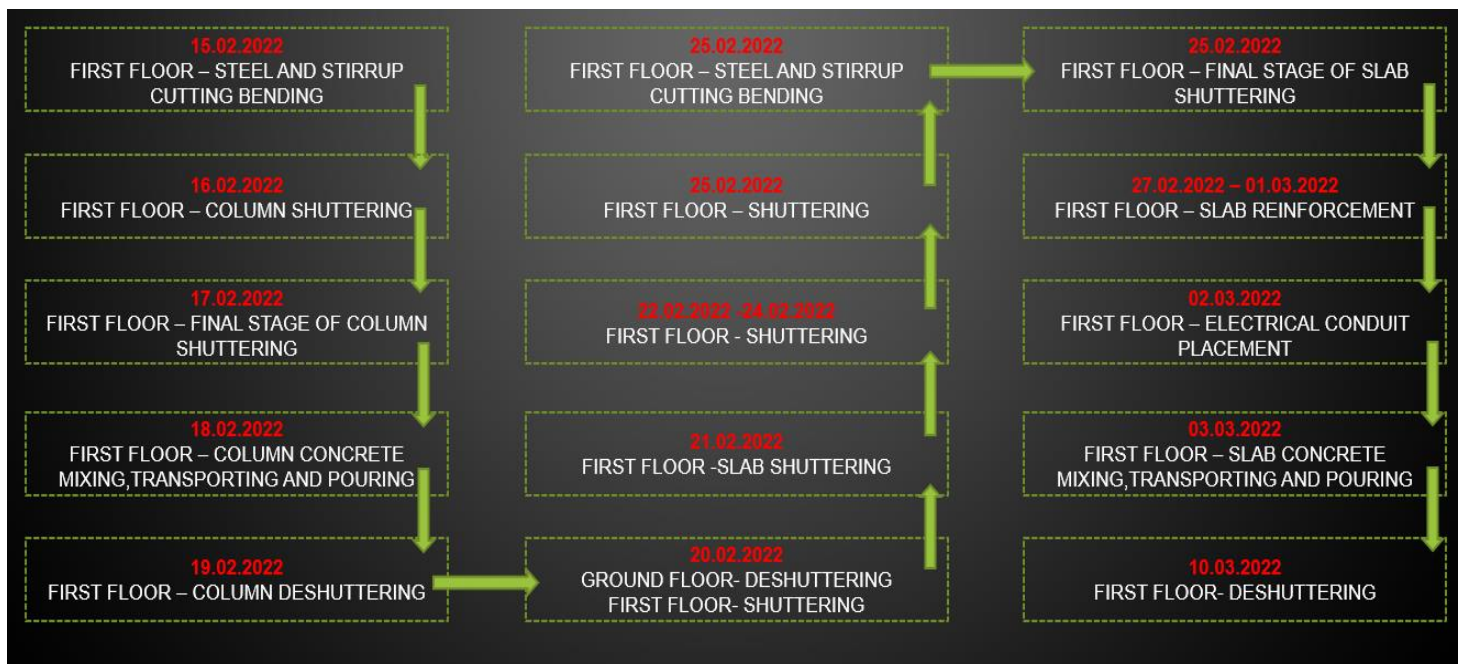
Suite room - plan



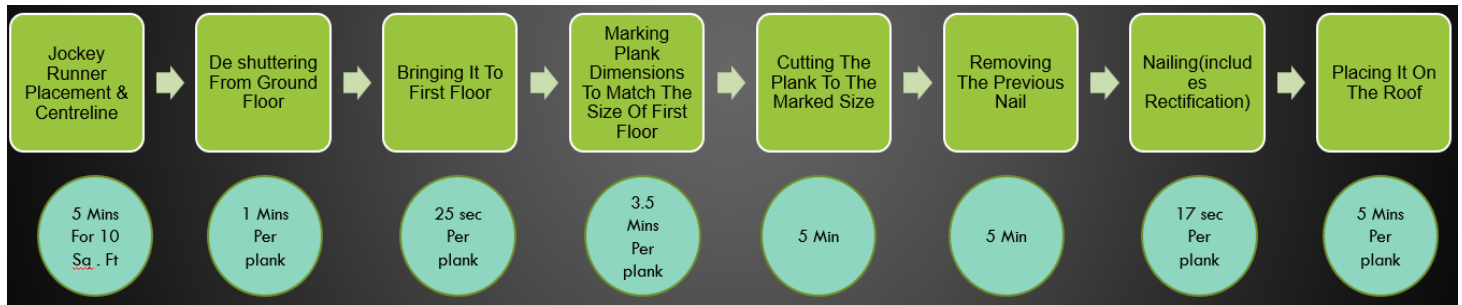
4.1.2 Scheduling Of Activities



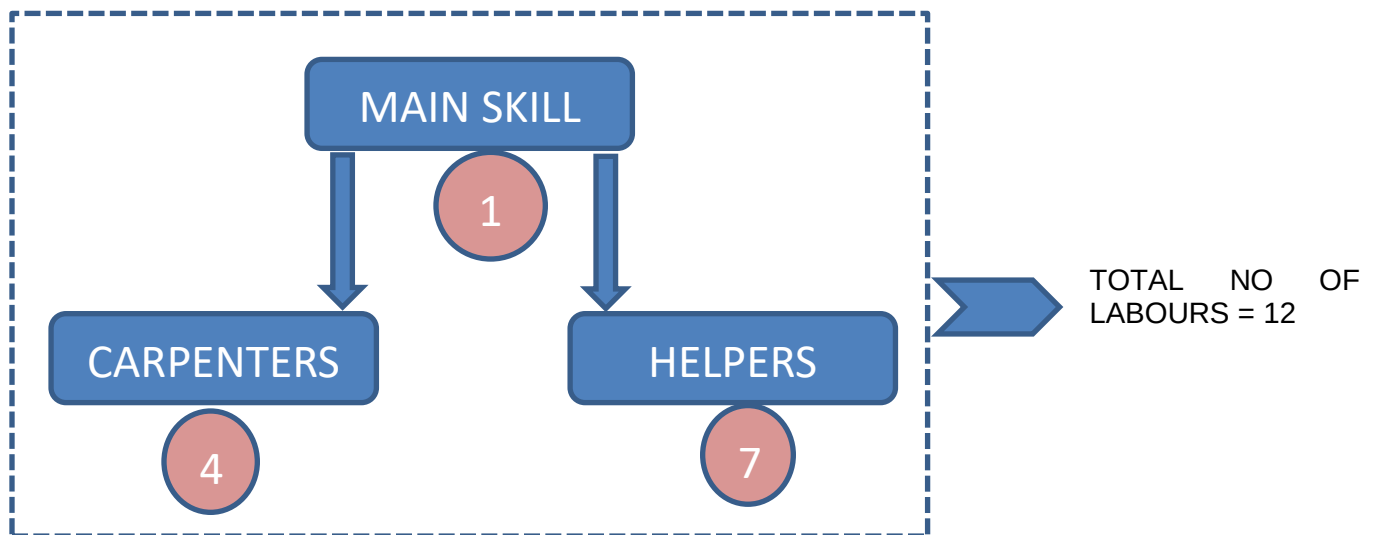
4.1.3 Activity Sequence



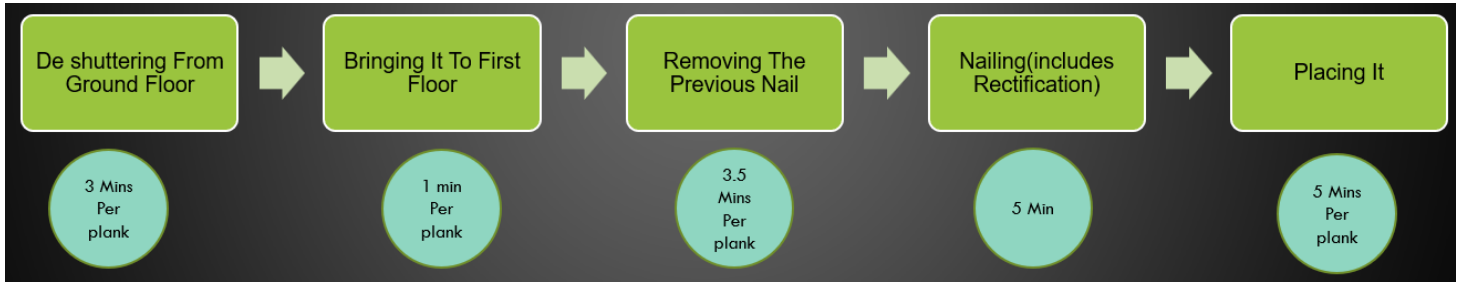
4.1.3 Cycle Time For Slab Shuttering



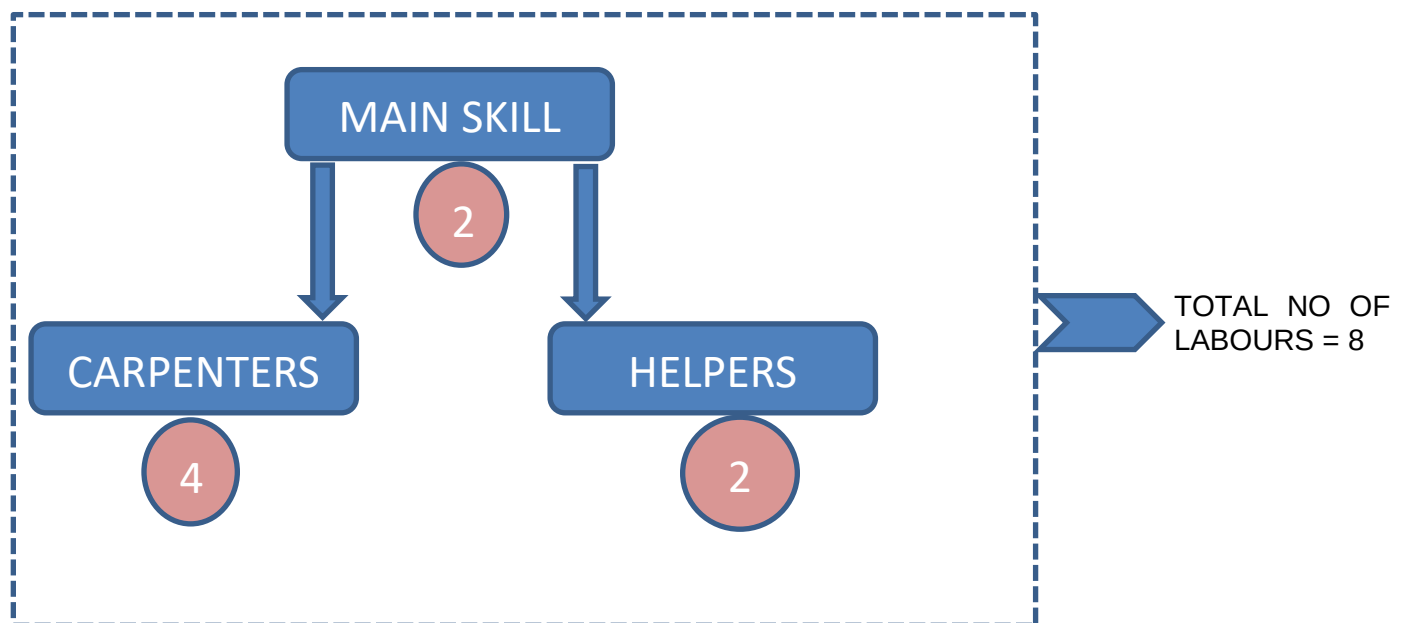
ACTIVITIES	TIME	NO .OF .LABOURS
Jockey Runner Placement & Centreline	5 mins for 3 sq.m	4
De shuttering From Ground Floor	1 mins	1
Bringing It To First Floor	25 sec	1
Marking Plank Dimensions To Match The Size Of First Floor	3.5 sec	1
Cutting The Plank To The Marked Size	5 mins	2
Removing The Previous Nail	17 mins	1
Nailing(includes Rectification)	5 mins	2
Placing It On The Roof	5 mins	2
FOR SLAB SHUTTERING	CYCLE TIME = 36.53 mins	12



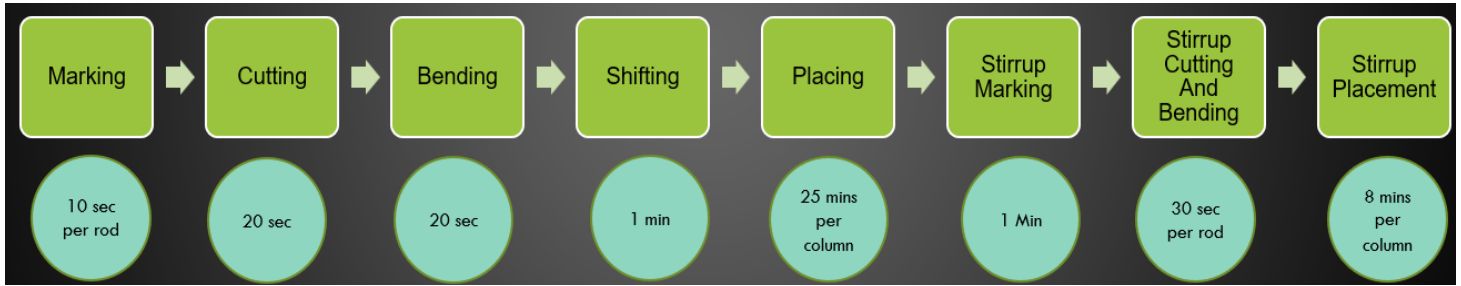
4.1.4 Cycle Time For Column Shuttering



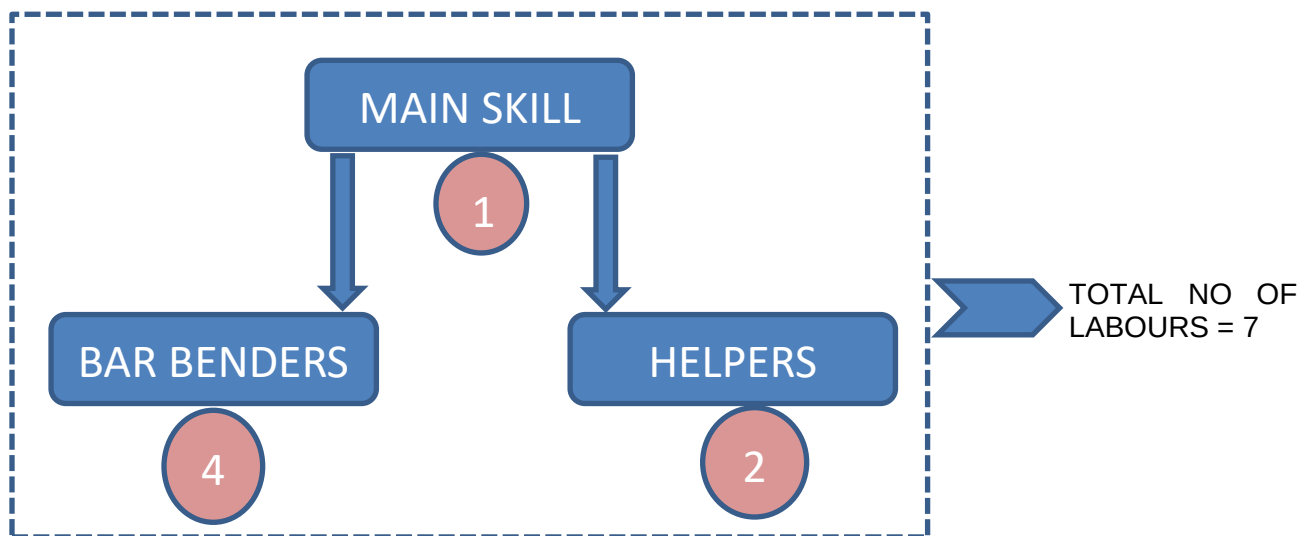
ACTIVITIES	TIME	NO .OF .LABOURS
De shuttering From Ground Floor	3 mins	2
Bringing It To First Floor	1 sec	1
Removing The Previous Nail	3.5 mins	2
Nailing(includes Rectification)	5 mins	
Placing It	5 mins	3
FOR BEAM & SLAB SHUTTERING	CYCLE TIME = 17.5 mins	8



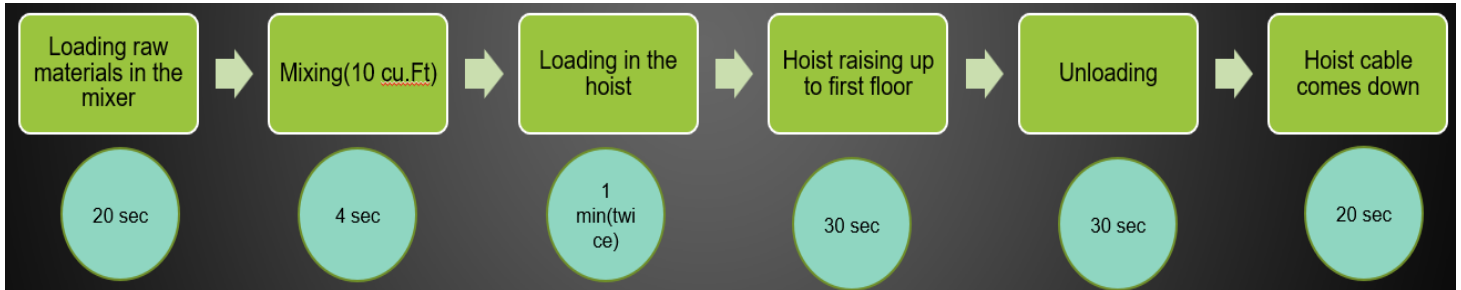
4.1.5 Sequence Of Activities For Reinforcement



ACTIVITIES	TIME	NO .OF .LABOURS
Marking	10 sec per rod	2
Cutting	20 sec	1
Bending	20 sec	2
Shifting	1 mins	5
Placing	25 mins per column	4
Stirrup Marking	1 Min	1
Stirrup Cutting And Bending	30 sec per rod	2
Stirrup Placement	8 mins per column	2
Placing (beam or slab)	0.0075 sq.m per hour	15
For column reinforcement	Cycle time = 32 mins	7
For slab reinforcement	Cycle time = 8 hrs 30 mins	30

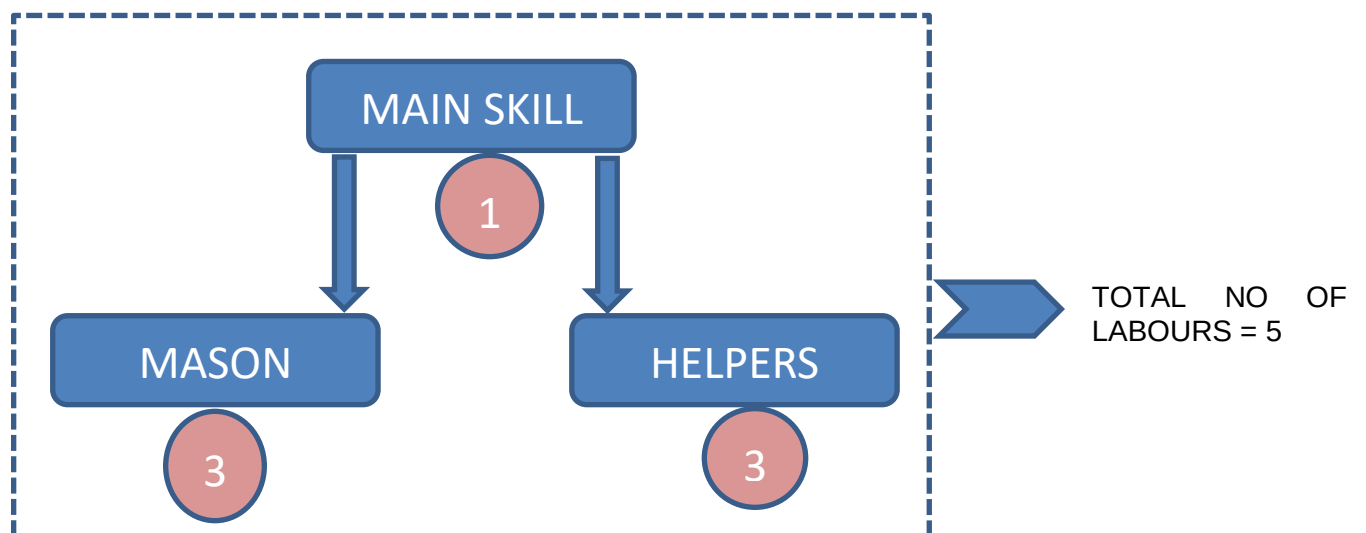


4.1.6 Sequence Of Activities For Concreting



ACTIVITIES	TIME	NO .OF .LABOURS
Loading raw materials in the mixer	20 sec	2
Mixing(10 cu.Ft)	4 sec	1
Loading in the hoist	1 min(twice)	1
Hoist raising up to first floor	30 sec	1
Unloading	30 sec	1
Hoist cable comes down	20 sec	1
For concreting	Cycle time = 6 mins 51 sec	7

FOR COLUMN

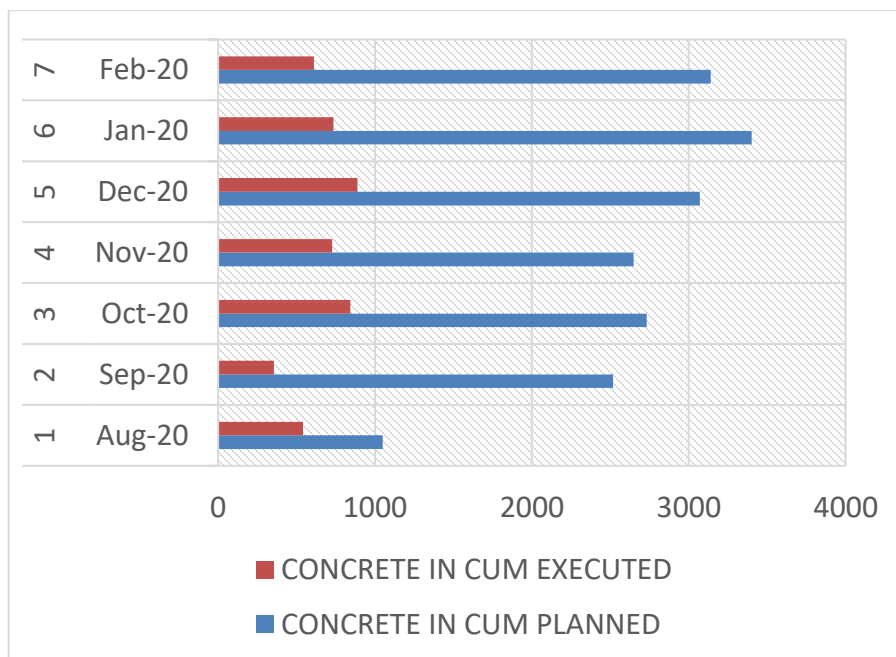


4.1.7 Sequence Of Activities For column Concreting

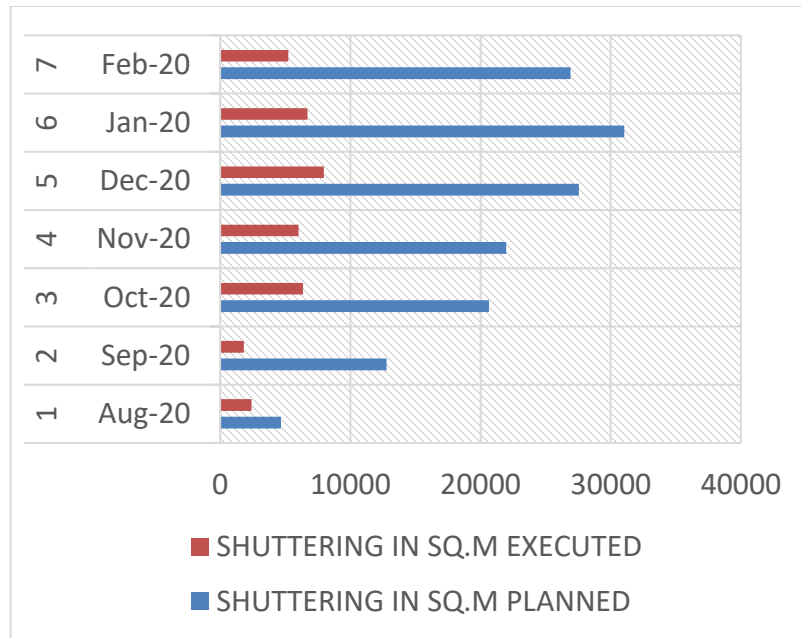
4.1.7 Material Productivity

Planned And Executed Quantities Of Major Activities

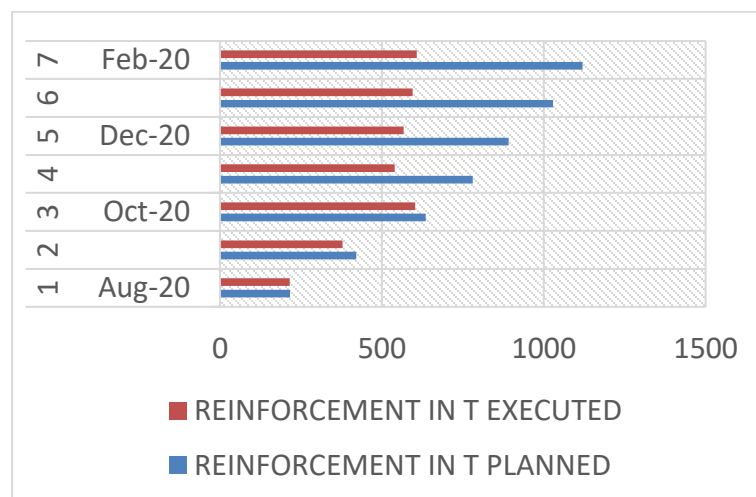
S.NO	MONTH & YEAR	CONCRETE IN CUM	
		PLANNED	EXECUTED
1	Aug-20	1050	541
2	Sep-20	2518	356.1
3	Oct-20	2731	843.17
4	Nov-20	2649	726.26
5	Dec-20	3070	887.1
6	Jan-20	3400	734.4
7	Feb-20	3139	611



S.NO	MONTH & YEAR	SHUTTERING IN SQ.M	
		PLANNED	EXECUTED
1	Aug-20	4663	2402.56
2	Sep-20	12790	1808.78
3	Oct-20	20643	6373.33
4	Nov-20	21980	6026.12
5	Dec-20	27558	7963.1
6	Jan-20	31054	6707.66
7	Feb-20	26915	5238.95

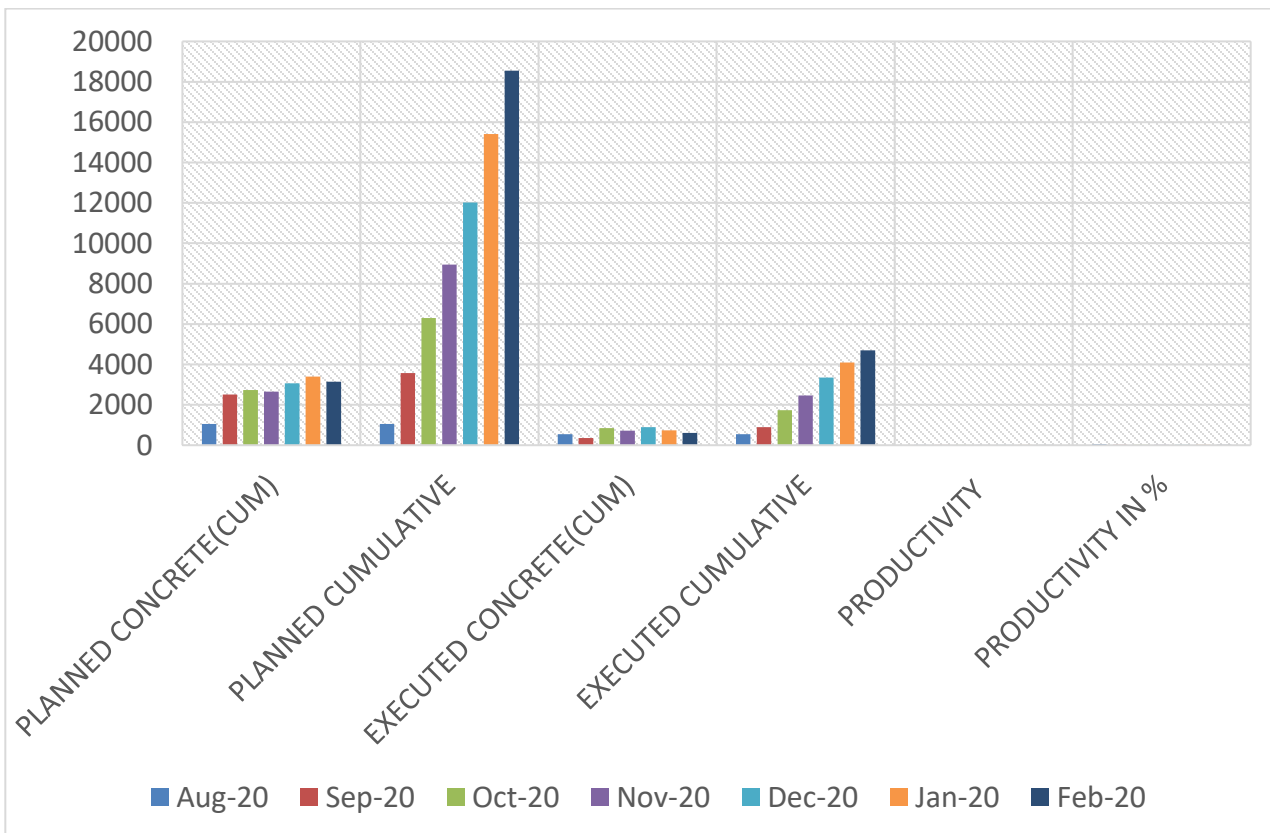


S.NO	MONTH & YEAR	REINFORCEMENT IN T	
		PLANNED	EXECUTED
1	Aug-20	216.62	215.28
2	Sep-20	421.3	378.71
3	Oct-20	635.18	602.84
4	Nov-20	780.68	539.81
5	Dec-20	891.92	567.32
6	Jan-20	1029.2	595.24
7	Feb-20	1120	607.53



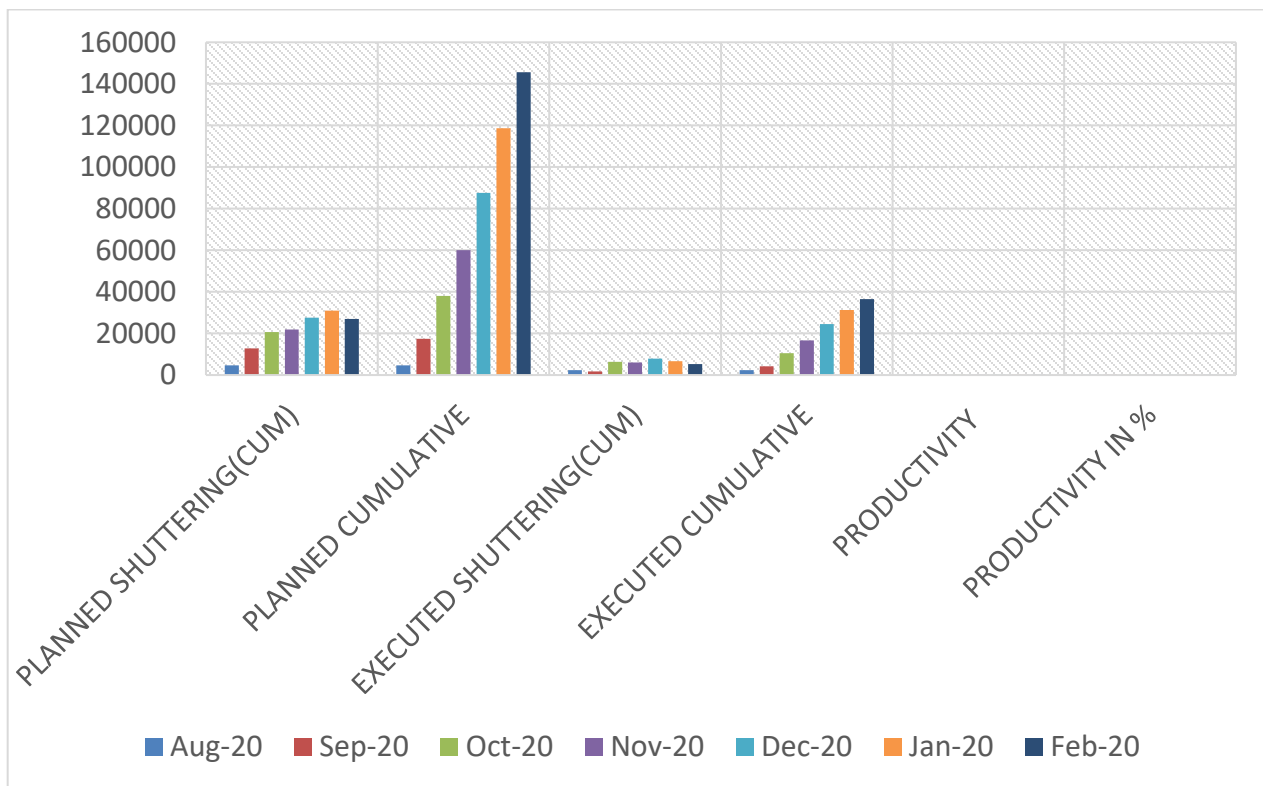
Tab 3.5 PLANNED AND EXECUTED QUANTITIES(CUMULATIVE) FOR CONCRETE

MONT H & YEAR	PLANNED CONCRETE(CU M)	PLANNED CUMULATIV E	EXECUTED CONCRETE(CU M)	EXECUTED CUMULATIV E	PRODUCTIVIT Y	PRODUCTIVIT Y IN %
	A	B	C	D	D/B	D/B
Aug-20	1050	1050	541	541	0.515238095	51%
Sep-20	2518	3568	356.1	897.1	0.251429372	25%
Oct-20	2731	6299	843.17	1740.27	0.276277187	25%
Nov-20	2649	8948	726.26	2466.53	0.275651542	27%
Dec-20	3070	12018	887.1	3353.63	0.279050591	27%
Jan-20	3400	15418	734.4	4088.03	0.265146582	26%
Feb-20	3139	18557	611	4699.03	0.253221426	25%



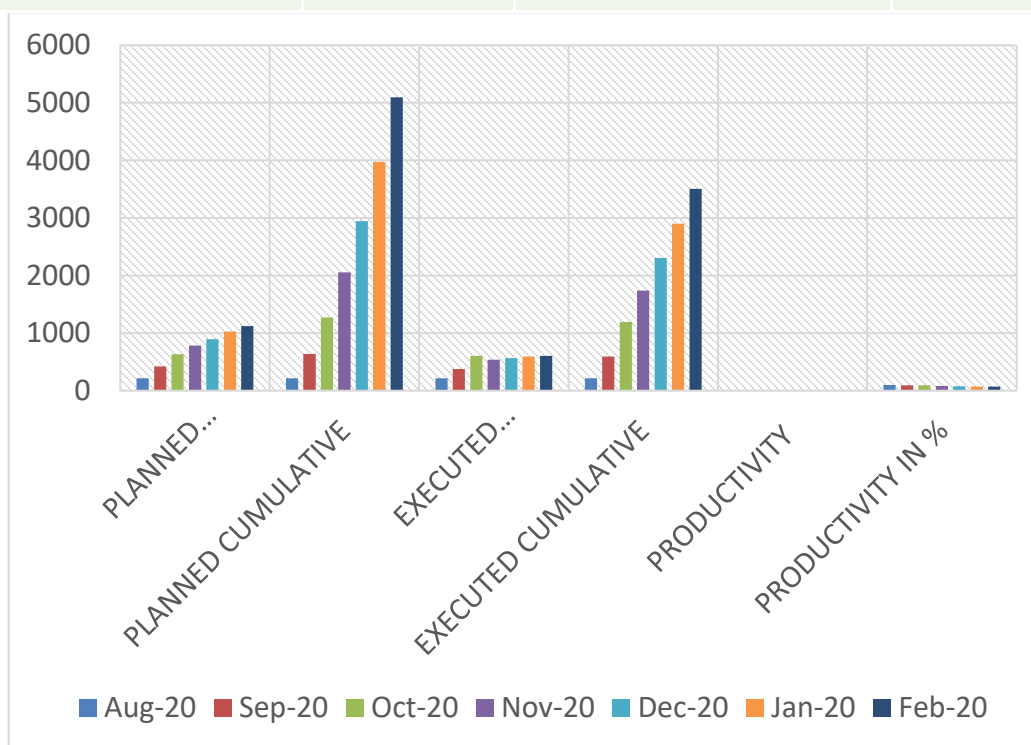
Tab 3.6 PLANNED AND EXECUTED QUANTITIES(CUMULATIVE) FOR SHUTTERING

MONT H & YEAR	PLANNED SHUTTERING(CU M)	PLANNED CUMULATI VE	EXECUTED SHUTTERING(CU M)	EXECUTED CUMULATI VE	PRODUCTIVI TY	PRODUCTIVI TY IN %
	A	B	C	D	D/B	D/B
Aug-20	4663	4663	2402.56	2402.56	0.515239116	51%
Sep-20	12790	17453	1808.78	4211.34	0.241296052	24%
Oct-20	20643	38096	6373.33	10584.67	0.277842031	27%
Nov-20	21980	60076	6026.12	16610.79	0.276496271	27%
Dec-20	27558	87634	7963.1	24573.89	0.280415022	28%
Jan-20	31054	118688	6707.66	31281.55	0.263561186	26%
Feb-20	26915	145603	5238.95	36520.5	0.250822442	25%



Tab 3.7 PLANNED AND EXECUTED QUANTITIES(CUMULATIVE) FOR REINFORCEMENT

MONTH & YEAR	PLANNED REINFORCEMENT(CUM)	PLANNED CUMULATIVE	EXECUTED REINFORCEMENT(CUM)	EXECUTED CUMULATIVE	PRODUCTIVITY
	A	B	C	D	D/B
Aug-20	216.62	216.62	215.28	215.28	0.993814052
Sep-20	421.3	637.92	378.71	593.99	0.931135566
Oct-20	635.18	1273.1	602.84	1196.83	0.940091116
Nov-20	780.68	2053.78	539.81	1736.64	0.845582292
Dec-20	891.92	2945.7	567.32	2303.96	0.782143463
Jan-20	1029.2	3974.9	595.24	2899.2	0.72937684
Feb-20	1120	5094.9	607.53	3506.73	0.6882824

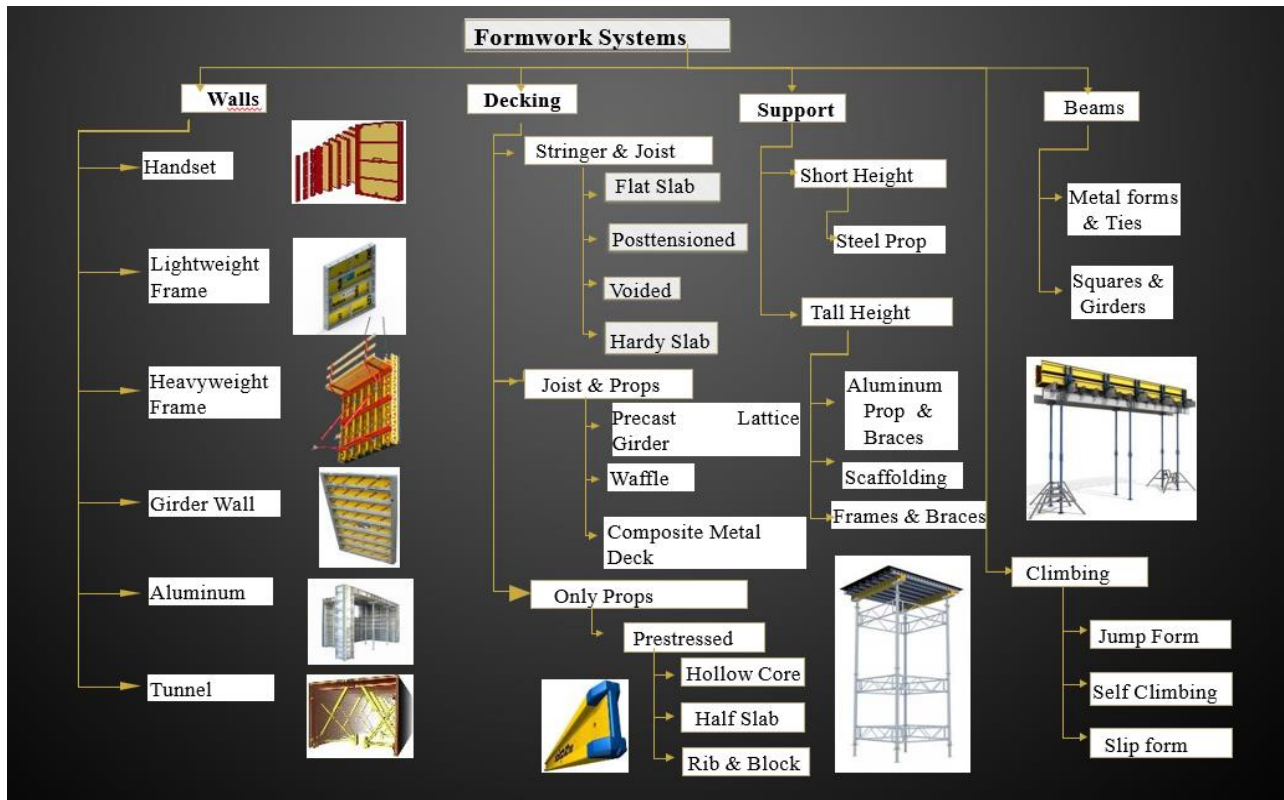


4.1.8 Formwork Management Map

FORMWORK MANAGEMENT MAP

PROBLEM	PRODUCTIVITY	REUSE	ECONOMY	STANDARDIZATION
	Formwork is labor intensive.	Manual and time-consuming planning process.	Find best load capacity with less formwork components.	DBB does not involve contractor experience.
SOLUTION	Consider formwork systems with fewer pieces.	Use of Lean principles (maximize value & reduce waste) and BIM methodology	Renting modular prefabricated formwork with latest technology available.	Collaborative delivery systems like IPD ensure better standardization and constructability.
STATUS	Industry oriented to develop industrialized systems.	Lack of methodologies available in literature for formwork management	Formwork companies oriented to develop best engineering solutions and systems.	Practitioners understands better the importance of standardization in construction.
				

DEFINE LAYOUT PLANNING AND WORK ZONES PLANNING					
INPUT	SCHEDULE	WORK ZONES SIZE	MAIN FLOOR PLANS	LAYOUT FLOOR PLANS	WORK ZONES LEVELING
	Duration objective 	№ of work zones 	Building floor plans 	Tower main plan Basement main plan Building main plan 	Work zone layouts 
PROCESS	Determine project schedule $\text{Duration} = \text{total lag time} + \text{cycle time}$ 	Check work zones size & № of production sets 	Define main floor plans 	Define construction joints & work zones 	Work load leveling 
OUTPUT	№ of work zones 	№ of production sets 	Tower main plan Basement main plan Building main plan 	Work zone layouts 	Optimal work zone layout & minimum variability 

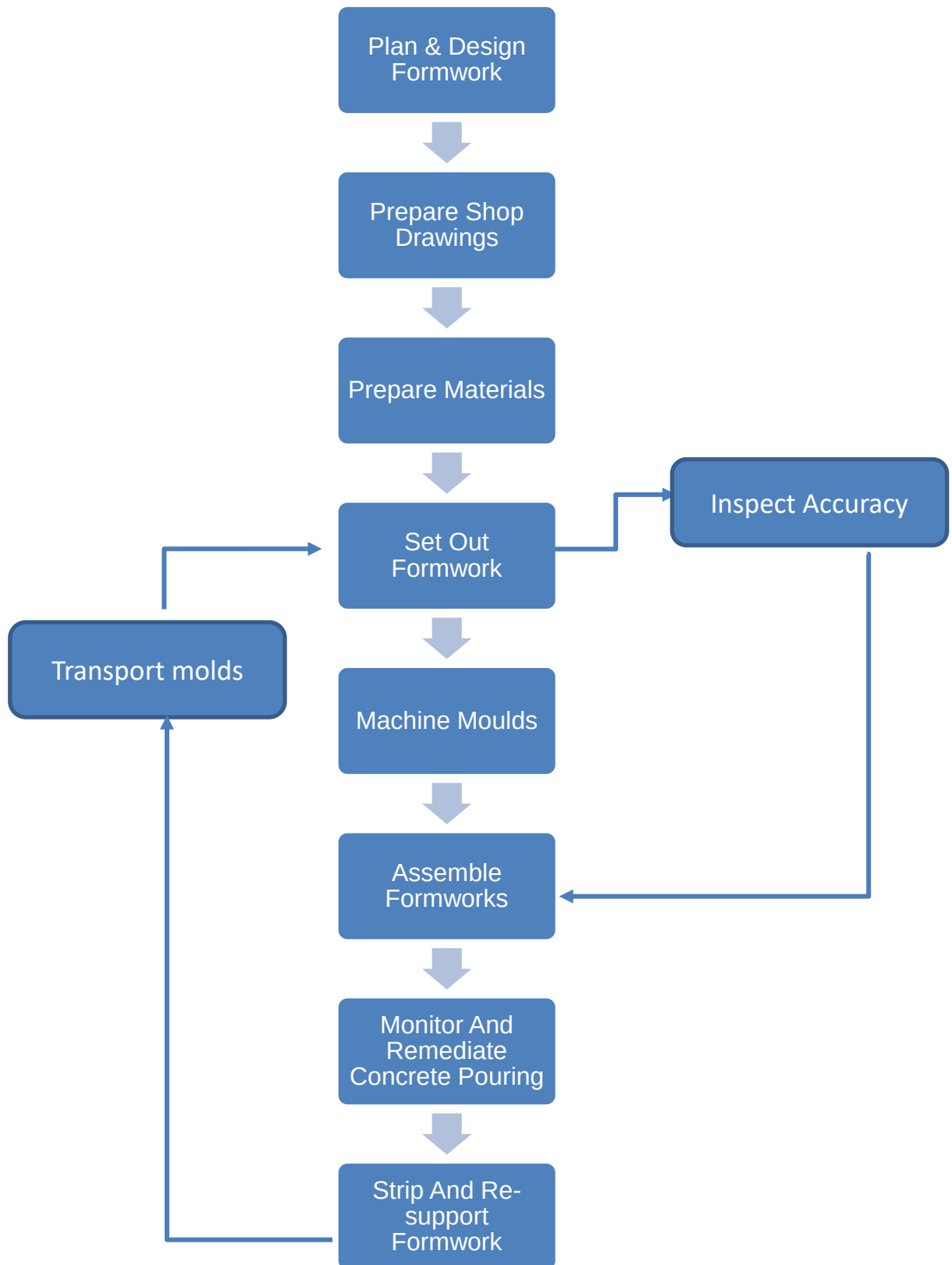


CHAPTER 04

ANALYSIS AND RESULTS

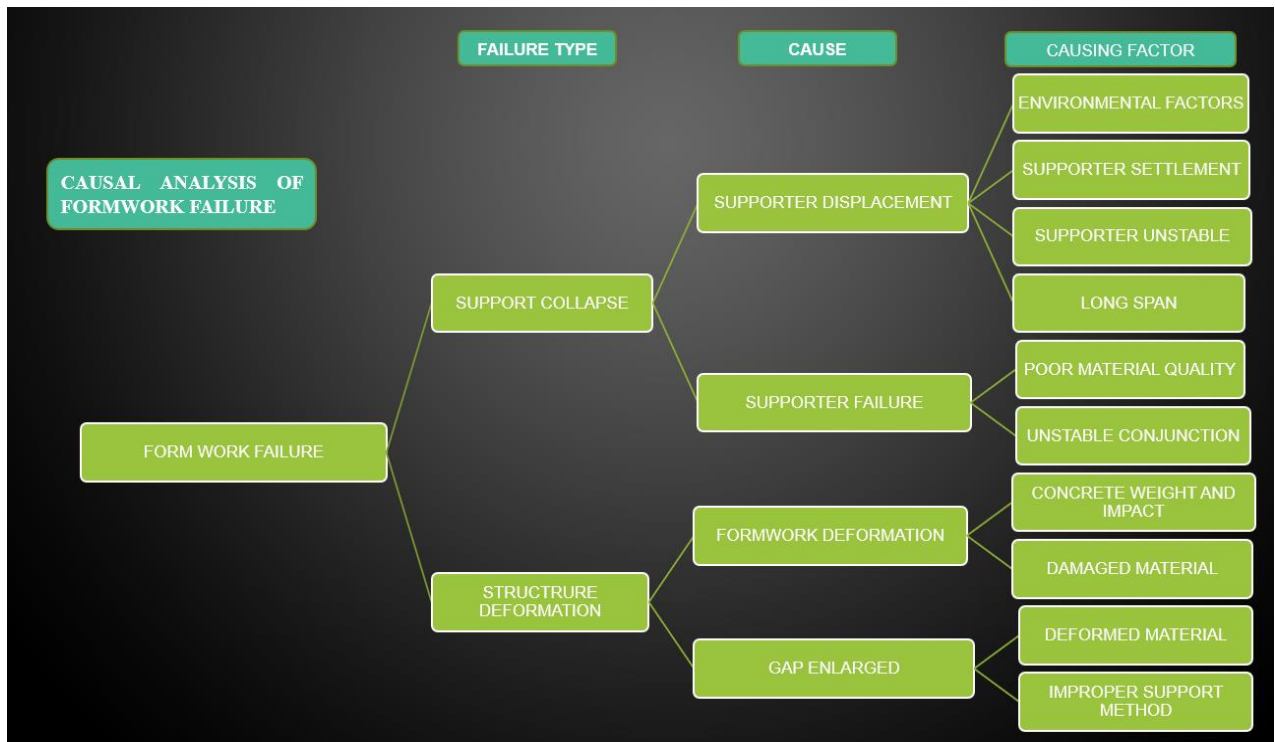
Operation	Motion	Description	Time, %
Assemble & machine formworks	Measure	Measure the size of the required formwork	6.8
	Walk	Walk to the mold storage area	13.5
	Search	Search for required materials among molds	22.1
	Pull	Pull nails out of the molds	3.8
	Machine	Cut mould materials	2.3
	Pass	Pass moulds to workers	9
	Wait	Wait while an assistant looks for materials	7.9
	Nail	Nail moulds in position	31.3
Transport molds	Mend	Mend gaps between moulds	3.6
	Move	Move the stripped molds to the next area	52.9
	Wait	Wait for transporting	47.1

5.1.1 FORMWORK OPERATION ANALYSIS

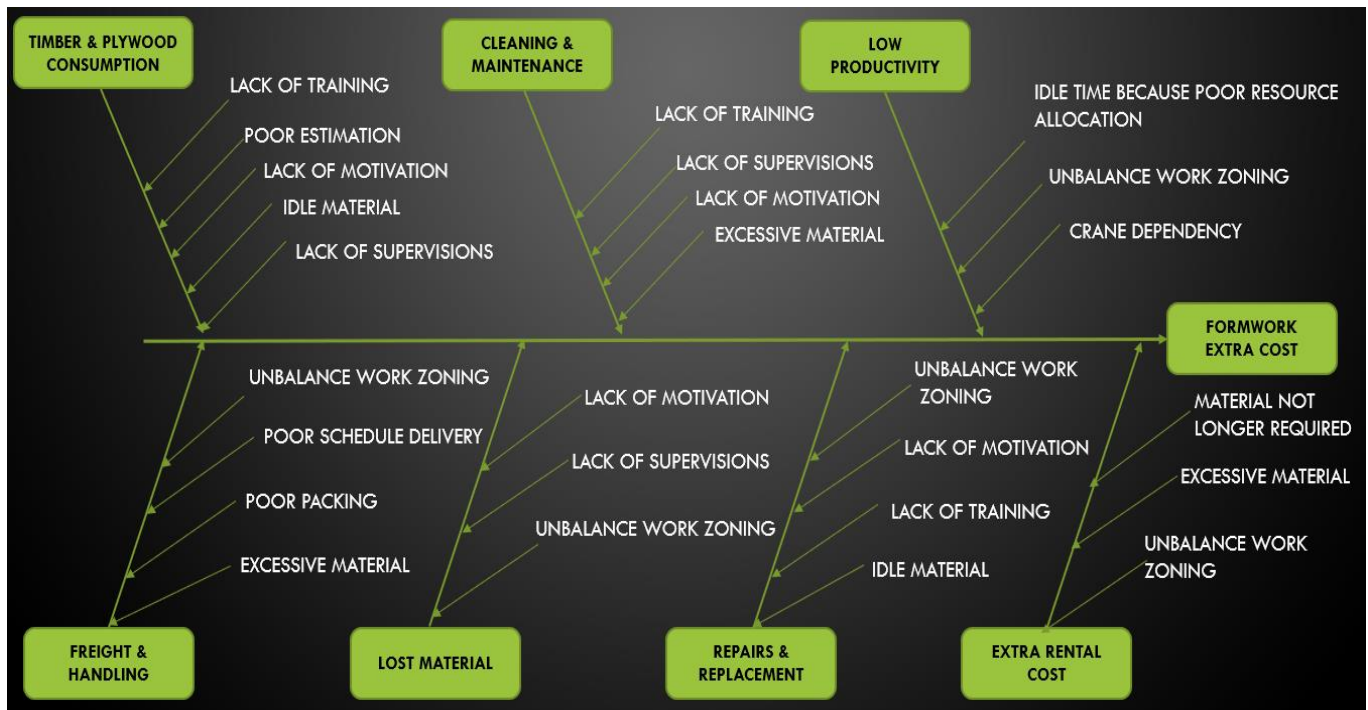


5.1.2 FORMWORK OPERATIONAL FLOW

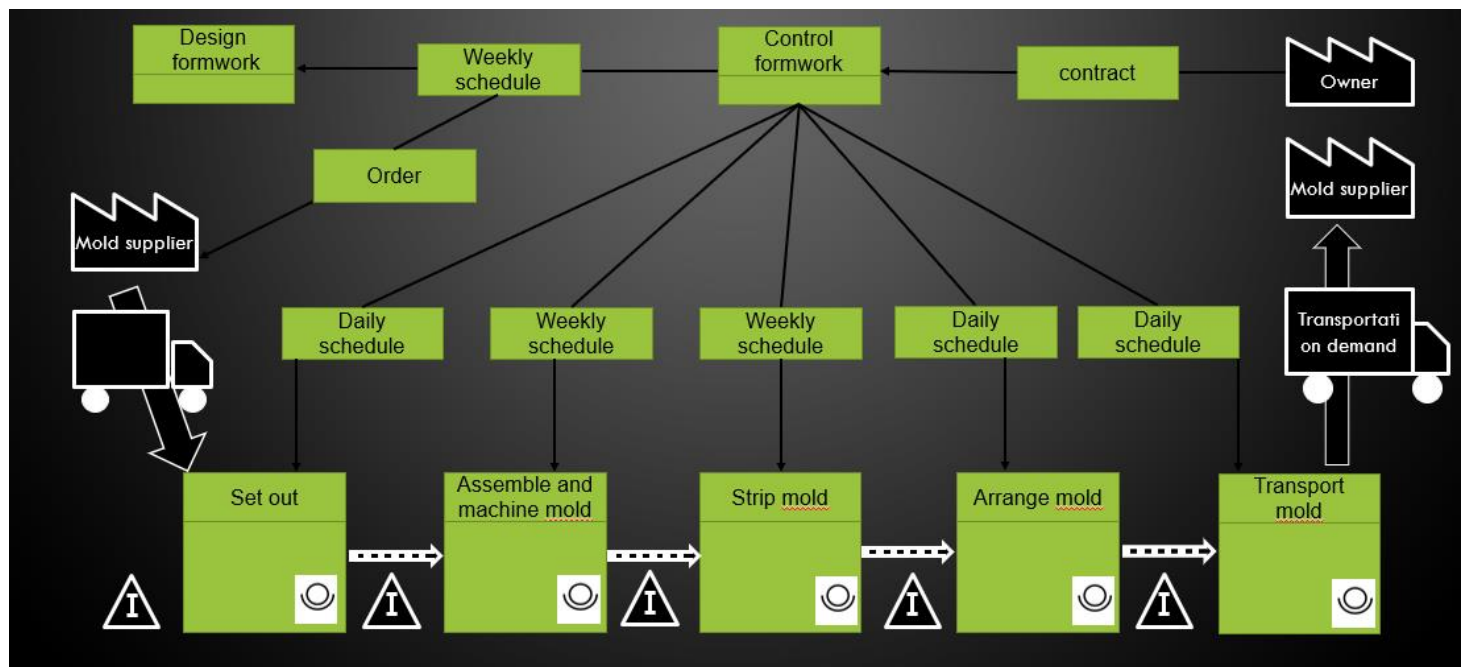
5.1.3 CASUAL ANALYSIS OF FORMWORK FAILURE



5.1.3 CAUSE EFFECT OF FORMWORK EXTRA COST



5.1.4 VALUE STREAM MAP FOR CURRENT FORMWORK CONSTRUCTION PRACTICES



5.1.5 LEAN FORMWORK CONSTRUCTION MODEL

1. Excess inventory is spread among all stations from material delivery to mold transport.
2. The general contractor and other managers may be unaware of onsite problems or product defects.
3. The formwork subcontractor outsources work to third parties (e.g. scaffolding, rebar, electro mechanical equipment, and concrete work). Waste may occur while one subcontractor waits for another to complete a particular task.
4. As far as formwork engineering is concerned, the skill and experience of crew members should be considered in addition to the foreman's leadership and capability. Inexperienced workers could produce substandard or defective formwork which requires repair, thus increasing project duration and cost.

ANDON

1. The *andon* system establishes a culture of on-site quality control to reduce defects resulting from inadequate worker skills.
2. Reducing the incidence of defects also reduces waste from actions associated with repairing those defects, i.e. transporting, assembly, and machining replacement formworks.

Construction *kanban*

This *kanban* is mainly used by the formwork foreman to deliver clear construction orders to the group leader before construction.

Material withdrawal *kanban*

This *kanban* is mainly used by workers removing materials from the storage yard to the construction

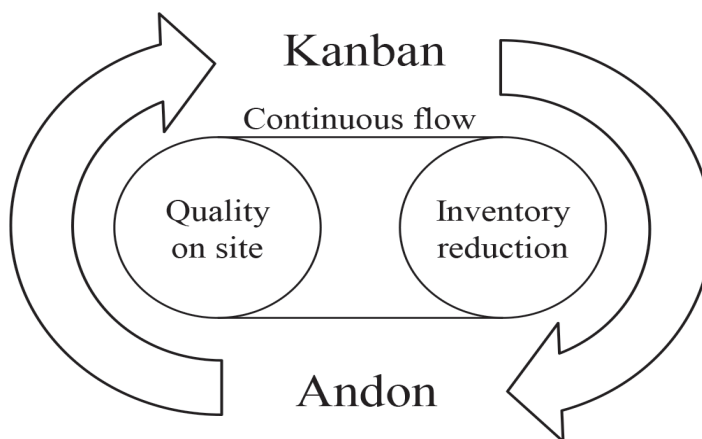
location. The foreman prepares the *kanban* for the group leader when the construction *kanban* is delivered.

Storage yard display *kanban*

This *kanban* is mainly used for displaying the information related to the working area, moulds, hardware fittings, supporter locations, and reor- der point.

Signal *kanban*

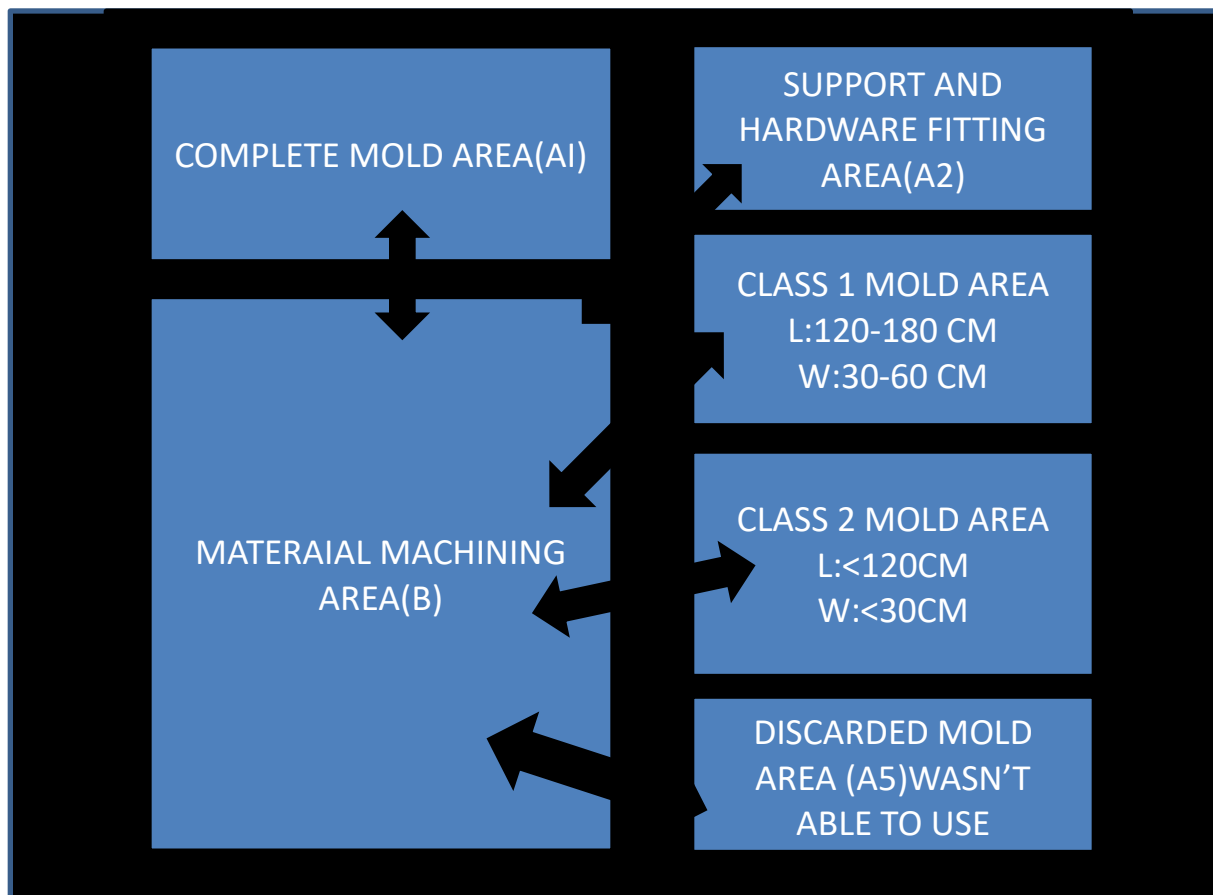
The signal *kanban* is mainly to alert workers to changes in construction activity. In formwork operations, assembling and machining formworks is a continuous operation.



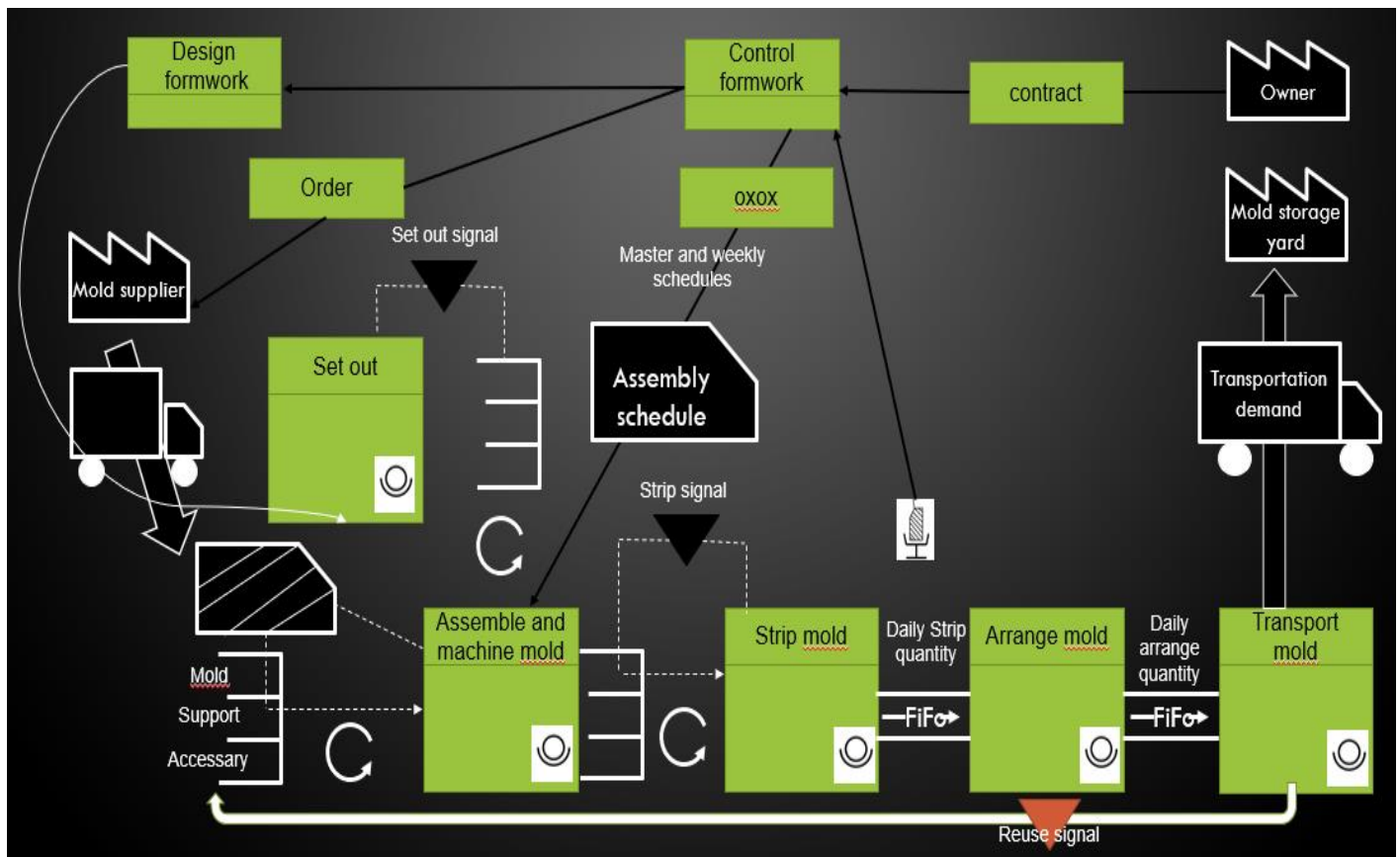
Formwork Construction Kanban		
Construction Time	Mm Dd Yyyy	
Construction Location		
Construction Quantity		
Previous Construction Activity		
Next Construction Activity		
Storage Yard Location		Photos(completion Image Or Bim Model)
No Of Workers		Tel:
Remarks		

Formwork Storage Yard Display Kanban			
Material Name			
Number Of Reuse			
Material Specification		Responsible Person	
Inventory		Telephone	
Remarks	Recorder Point		

5.1.6 FORMWORK CONSTRUCTION SITE LAYOUT



FUTURE FORMWORK VALUE STREAM MAPPING



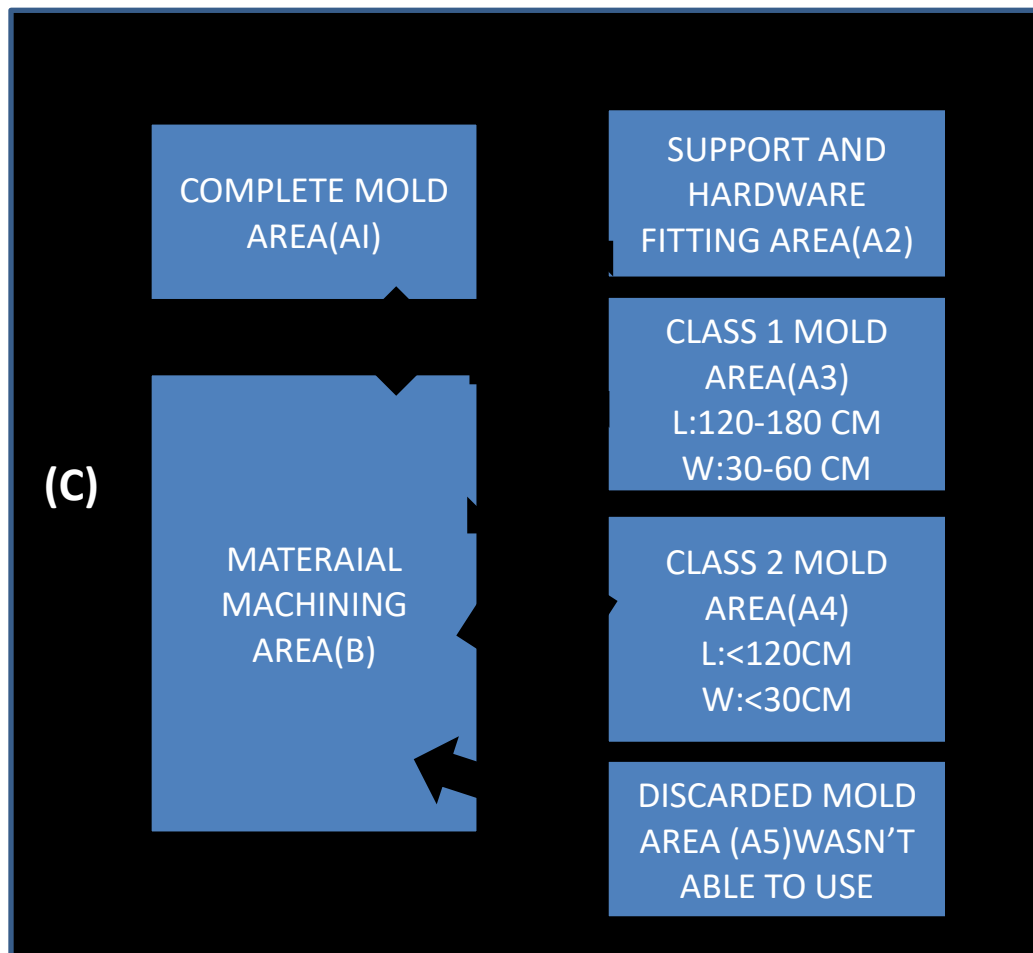
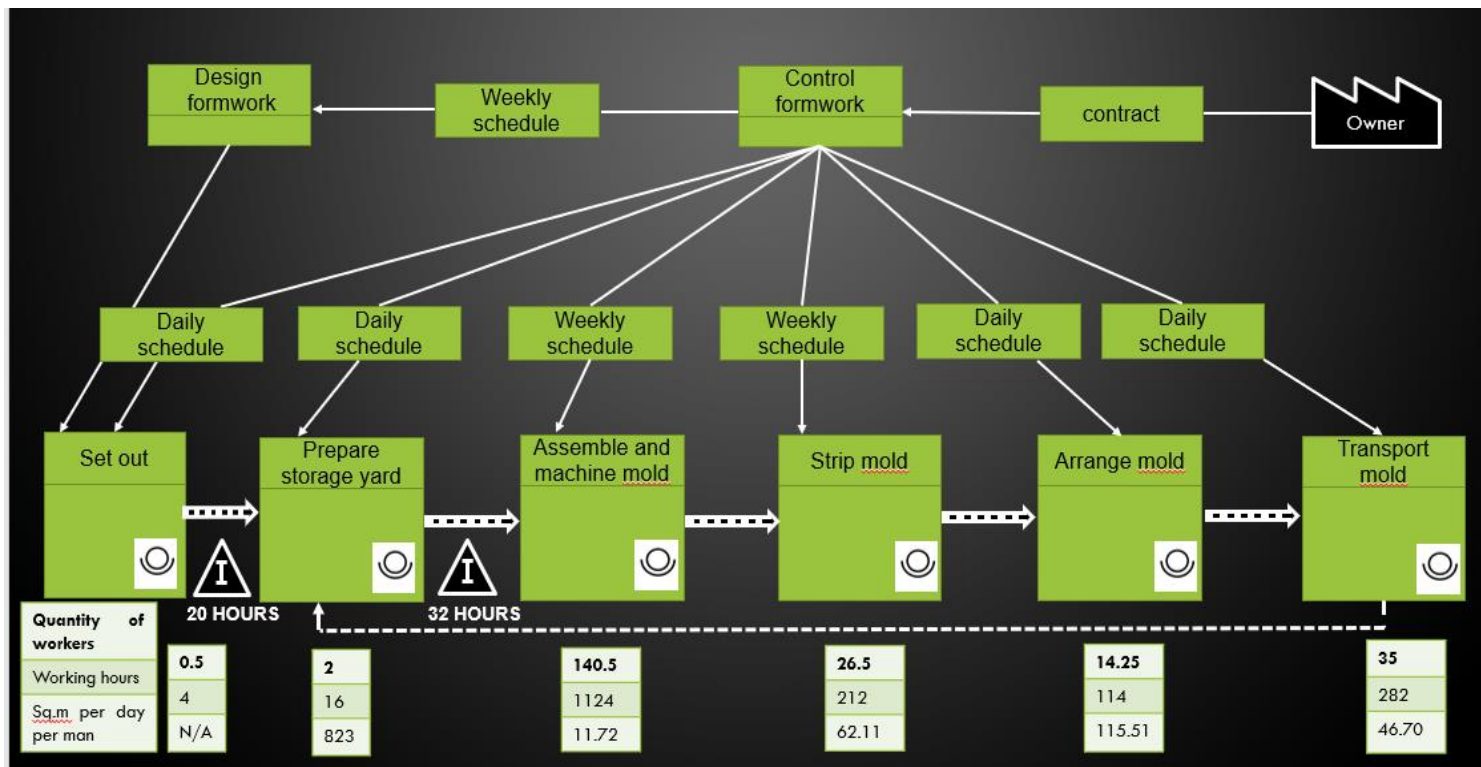
5.1.7 CASE STUDY

In this an actual construction case from Thada to illustrate the feasibility of the proposed lean formwork construction model. The main structure has four stories and one basement level, with a total floor of 9300 square meters. This study focuses on the formwork construction in the first floor. The formwork area in the first floor totals 1400 square meters, and is accomplished using wooden molds, wooden supports, steel tube supports, and shaped steel. Aside from formwork subcontractors, the project involves scaffolding, rebar, electromechanical, and concrete engineering work. Data were collected on site, with worker-hours averaged over a one month period of observation.

5.1.8 CURRENT-STATE VALUE STREAM MAPPING

To understand the site's formwork operational flow, the current-state value stream map is done. In between setting out the formworks and storage yard preparation, the formwork subcontractor had to wait for the rebar construction team, wasting 20 hours. Another 32 hours of waiting occurred between storage yard preparation and the formwork assembly and machining stage while the formwork subcontractor waited for the scaffolding crew. A total of 1124 worker-hours were spent on the assembly and machining of 1400 square meters of formwork. Formwork productivity = formwork quantity / number of workers. In this case, the average productivity is 9.96 square meters (i.e. 1400/140.5) per day per worker. A total of 280 worker-hours were spent on mold transport for an average of 46.7 square meters per day per worker.

5.1.9 VALUE STREAM MAP FOR CURRENT FORMWORK CONSTRUCTION PRACTICES

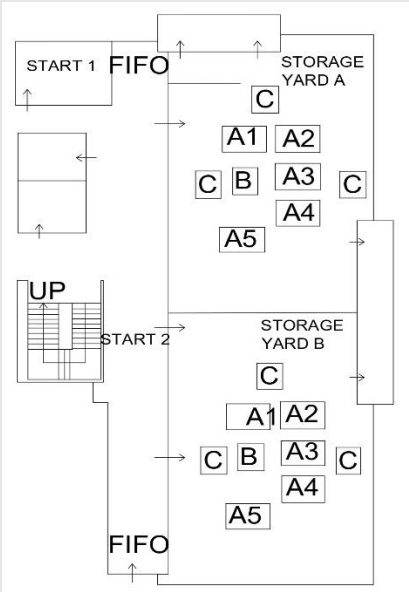


kanban are positioned in highly visible locations in the storage yard to help workers find and replace formwork materials.

From the display *Kanban*, the formwork foreman can ascertain material reuse times, allowing him to visually assess material usage conditions. Overused and damaged materials can be discarded to avoid defects.

Formwork construction is driven by the information contained in the construction instruction, material withdrawal, and signal *kanban*.

Formwork Storage Yard Display Kanban			
Material Name	Wooden mould		
Number Of Reuse	2		
Material Specification	180 * 60	Responsible Person	
Inventory	100 sheets	Telephone	
Remarks			

Date	March 23		
Work Item	Setting Out		
Location	Second Floor		
Construction Quantity	600 Sq.M		
Previous Work Item	Concrete Pouring		
Next Work Item	Shipping Formworks,supports And Hardware Fittings To Site		
Storage Yard	B	Responsible Person	
Number Of Workers	2	Telephone	
Remarks			

- Example of a signal *kanban* used to signal a change in construction activity, e.g. scaffold, rebar or concrete engineering.
- The first job in formwork engineering is to set out the formwork positions.
- The foreman prepares the construction *kanban* to specify shop drawing, location, quantity, worker, previous construction item and next construction item.
- The workers then follow this information to implement formwork operations.
- The instruction *kanban* improves operational continuity by specifying the previous and next construction items.
- The next work item (e.g. shipping materials to site) cannot proceed until the previous work item (e.g. concrete pouring) has been confirmed completed.
- Moreover, when confronted by problems that may affect construction progress (e.g. illegible drawings, undetermined construction locations, or broken equipment) the *andon* culture encourages workers to stop the process and seek help from their group leader.
- This involvement in the problem-solving process helps workers develop their own skills, creating a culture of continuous improvement which further enhances formwork quality.

Activity	Worker-hours
Set out formworks	4
Prepare storage yard	16
Assemble and machine mould	1124
Strip mould	212
Arrange mould	114
Transport mould	282
worker-hours = Workers * 8 hours	

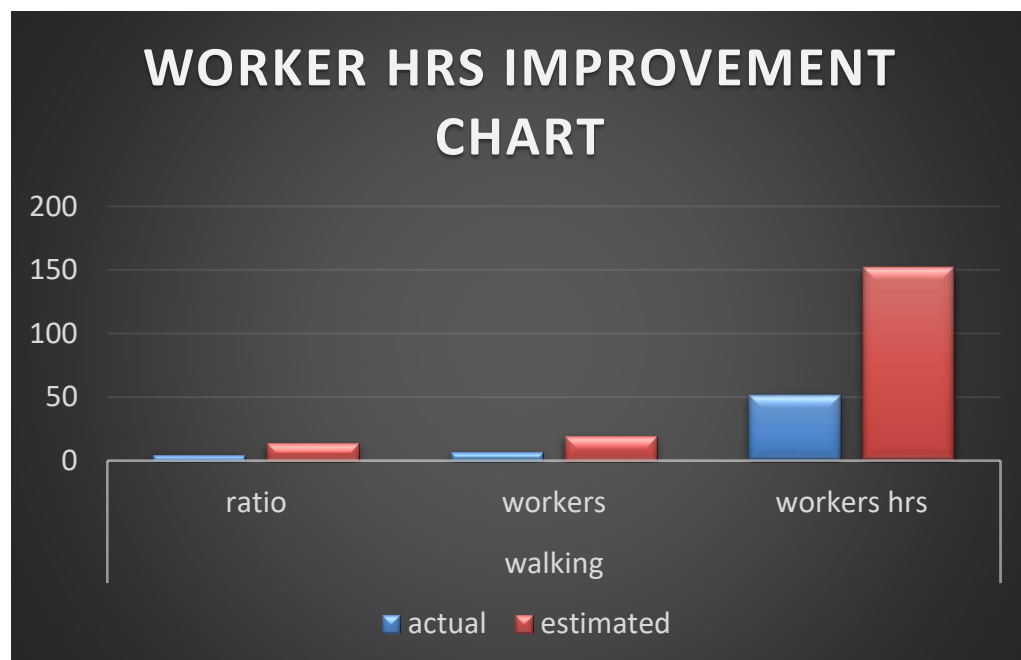
- In formwork assembly and machining, actions including measuring, pulling, cutting, passing, nailing, and mending are value-adding activities, whereas walking, searching and waiting are waste.
- The movement involved in transporting molds produces value, but waiting for transport is waste.
- The use of the proposed site layout can reduce the non-value-adding actions, such as walking and waiting during formwork assembly and machining, and waiting during mold transport. As a result, work efficiency can be enhanced.

Work Item	Worker Hrs	Productivity (Sq.m/Worker/Day)	Motion		
			Name	Ratio %	Worker-hours
			Walk	13.5	151.74
			Search	22.1	248.4
			Pull	3.8	42.71

Assemble & Machine Formwork	1124	11.72	Cut	2.3	25.85
			Pass	9	101.16
			Wait	7.9	88.8
			Nail	31.3	351.81
			Mend	3.6	40.46
Transport Moulds	282	46.7	Move	52.9	149.04
			Wait	47.1	132.96

- Using the proposed layout significantly reduces the amount of time workers spend in searching and waiting during formwork assembly and machining.
- Furthermore, trolleys are used in conjunction with the construction *kanban* to further improve on traditional material transport methods.
- Traditionally, workers carry the molds from the storage area. Given the average worker can only carry about 2 square meters of mold each time, he has to make multiple trips per day to retrieve the amount he needs to produce.
- When moving materials using trolley, workers only need to withdraw material once each morning and afternoon.

Activity	Estimated Ratio	Actual Ratio	Estimated Workers	Actual Workers	Estimated Worker Hrs	Actual Worker Hrs
Walking	13.5%	4.6%	18.97	6.46	151.74	51.7



walking, searching, and waiting from formwork assembly and machining, and waiting in mold transport

eliminates

570.24

Formwork assembly and machining

eliminates

437.28

PRODUCTIVITY

11.72 sq.m per day

increases

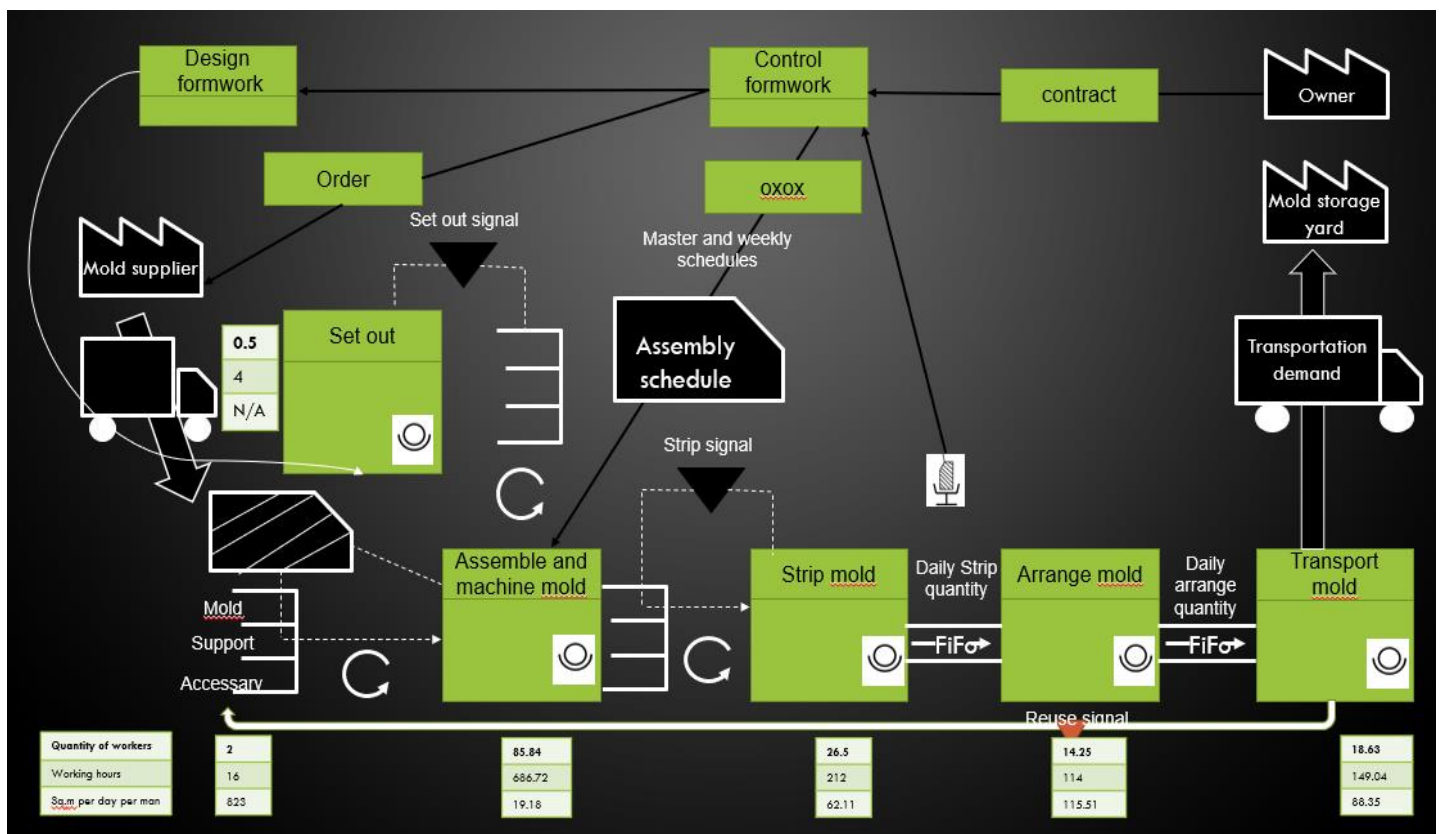
19.18 sq.m per day

46.7 sq.m per day

increases

88.35 sq.m per day

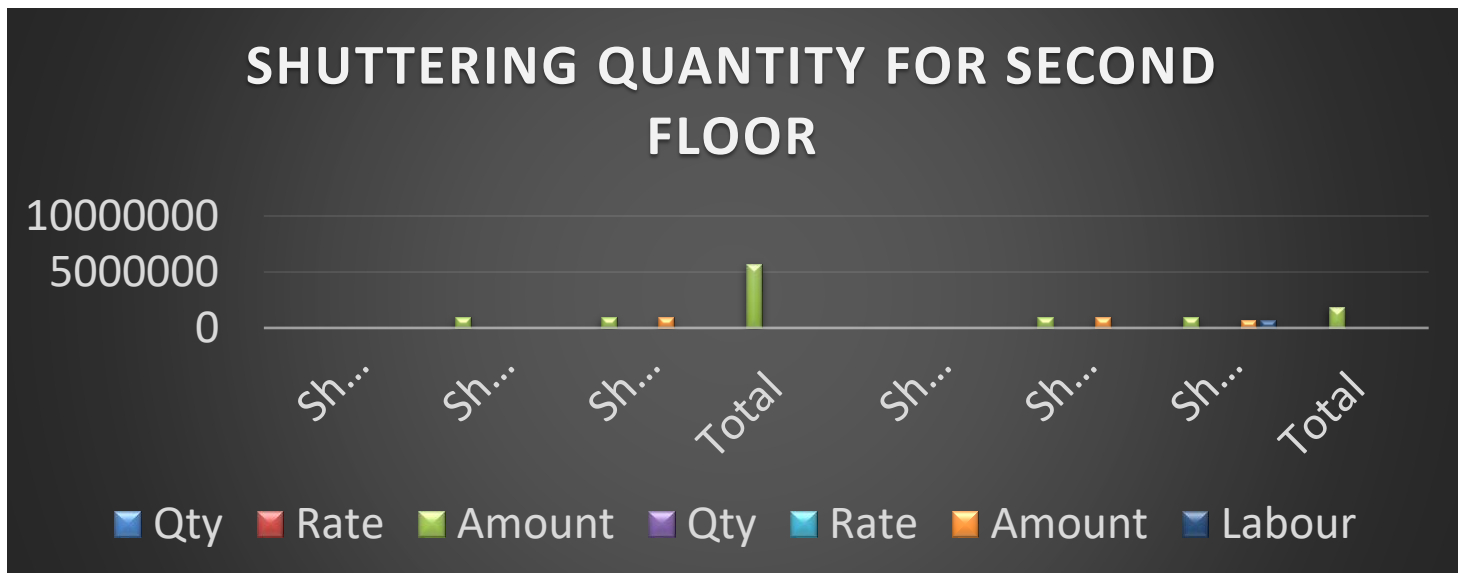
FUTURE FORMWORK VALUE STREAM MAPPING



	VALUE STREAM FORMWORK FOR CURRENT			VALUE STREAM FORMWORK FOR FUTURE		
	Quantity of workers	Working hours	Sq.m per day per man	Quantity of workers	Working hours	Sq.m per day per man
Set out	0.5	4	N/A	0.5	4	N/A
Prepare storage yard	2	16	823	2	16	823
Assemble and machine mold	140.5	1124	11.72	85.84	686.72	19.18
Strip mold	26.5	212	62.11	26.5	212	62.11
Arrange mold	14.25	114	115.51	14.25	114	115.51
Transport mold	35	282	46.7	18.63	149.04	88.35

SHUTTERING QUANTITY FOR SECOND FLOOR							
	Estimation Qty				Actual Qty		
Description	Shuttering Work	Shuttering Materials	Shuttering Labours	Total	Shuttering Work	Shuttering Materials	Shuttering Labours
Unit	Qty	Sq.ft	Sq.ft		Qty	Sq.ft	Sq.ft
Qty	35147.2	35147.2	35147.20		35147.2	35147.2	35147.20
Rate		26	26			26	26

Amount		913827.2	913827.2	2811828		913827.2	913827.2
Qty	35147.2	35147.2	35147.20		35147.2	35147.2	35147.20
Rate		26	26			26	19
Amount			913827.2			913827.20	667796.8
Labour							667796.8



CHAPTER 06

SUMMARY AND RECOMMENDATIONS

Tab 6.1 Factors Affecting The Productivity

Attributes	Rank	Attributes	Rank	Attributes	Rank
Unavailability of material on time at the workplace	1	Strikes called by political parties or hartals	1	Unavailability of material on time at the workplace	1
Delayed material delivery by the supplier	2	Unavailability of material on time at the workplace	2	Delayed material delivery by the supplier	2
Unavailability of drawings on time at the worksite	3	Harsh weather conditions	3	Strikes called by political parties or hartals	3

Equipment necessary to do the job not available on time	4	Frequent revisions of drawing/design resulting in additional work/ rework	4	Frequent revisions of drawing/design resulting in additional work/ rework	4
Poor pay	5	Craftsmen turnover	5	Unavailability of drawings on time at the worksite	5
Labour strikes	6	Craftsmen absenteeism	6	Craftsmen absenteeism	6
Poor project planning and scheduling	7	Delayed material delivery by the supplier	7	Improper project coordination	7
Unavailability of tools on time at the worksite	8	Lack of recognition of good and efficient workers	8	Harsh weather conditions	8
Poor quality of materials	9	Improper project coordination	9	Craftsmen turnover	9
Improper project coordination	10	Errors in the drawings	10	Poor project planning and scheduling	10

Unsafe working conditions	11	Interference from other trades or other crew members	11	Errors in the drawings	11
Accidents causing stoppage	12	Lack of periodic meeting among	11	Equipment necessary to do the	12
of work at the site		the management, site personnel and the contractors		job not available on time	
Lack of experience of craftsmen	13	Unavailability of drawings on time at the worksite	11	Lack of experience of craftsmen	13
Errors in the drawings	14	Lack of adequate space for storage of materials	14	Poor pay	14

Frequent revisions of drawing/design resulting in additional work/ rework	15	Excessive overtime	15	Slow equipment repair in case of breakdown	15
Inadequate instructions provided by supervisor	16	Lack of weekly project evaluation meetings	15	Lack of experience of supervisor	16
Slow equipment repair in case of breakdown	17	Rework due to field errors committed by craftsmen	17	Craftsmen unaware of safety precautions	17
iCraftsmen absenteeism	18	Lack of monetary incentives	17	Poor quality of materials	18
Poor quality of tools provided /used	19	Poor project planning and scheduling	19	Lack of maintenance of tools and plants	19
Lack of maintenance of tools and plants	20	Lack of experience of supervisor	19	Rework due to field errors committed by craftsmen	20

Craftsmen unaware of safety precautions	21	Slow equipment repair in case of breakdown	21	Unsafe working conditions	21
Lack of experience of supervisor	22	Lack of experience of craftsmen	22	Unavailability of tools on time at the worksite	22
Strikes called by political parties or hartals	22	Unrealistic project goals and deadlines	23	Lack of team spirit among craftsmen	23
Communication problem among craftsmen and supervisors	24	Craftsmen unaware of safety precautions	23	Lack of adequate space for storage of materials	24
Lack of team spirit among craftsmen	25	Lack of team spirit among craftsmen	25	Inadequate instructions provided by supervisor	25

Rework due to field errors committed by craftsmen	26	Equipment necessary to do the job not available on time	26	Lack of recognition of good and efficient workers	26
Slow response on doubts arising from the drawings	27	Lack of maintenance of tools and plants	26	Communication problem among craftsmen and supervisors	27
Harsh weather conditions	28	Lack of interaction among the site community	28	Labour strikes	28
Craftsmen turnover	29	Site congestion	29	Slow response on doubts arising from the drawings	29
Disputes with consultants/ owner causing stoppage of work	30	Slow response on doubts arising from the drawings	30	Poor quality of tools provided /used	30

Lack of adequate space for storage of materials	31	Design difficult to construct	30	Accidents causing stoppage of work at the site	31
Lack of interaction among the site community	32	Disregard of craft worker suggestions/ideas	30	Disputes with consultants/ owner causing stoppage of work	32
Poor temporary facilities at the site	33	Poor temporary facilities at the site	33	Lack of interaction among the site community	33
Site congestion	34	Disputes with consultants/ owner causing stoppage of work	34	Interference from other trades or other crew members	34
Lack of monetary incentives	35	Communication problem among craftsmen and supervisors	34	Lack of periodic meeting among the management, site personnel and the contractors	35
Interference from other trades or other crew members	36	Poor pay	34	Lack of weekly project evaluation meetings	36
Lack of periodic meeting	36	Inadequate instructions provided by supervisor	37	Lack of monetary incentives	37

among the management, site personnel and the contractors					
Design difficult to construct	38	Poor quality of materials	38	Unrealistic project goals and deadlines	38
Lack of recognition of good and efficient workers	39	Unsafe working conditions	38	Poor temporary facilities at the site	39
Supervisor absenteeism	40	Supervisor absenteeism	40	Site congestion	40

RESPONDENTS	NO OF RESPONDENT
PROJECT MANAGERS	5
SITE ENGINEERS	10
LABORS	35

Attributes	I.I.	Rank	Attributes	F.I.	Rank	Attributes	S.I.	Rank
Unavailability of material on time at the workplace	0.879	1	Strikes called by political parties or hartals	0.550	1	Unavailability of material on time at the workplace	0.442	1
Delayed material delivery by the supplier	0.839	2	Unavailability of material on time at the workplace	0.503	2	Delayed material delivery by the supplier	0.395	2
Unavailability of drawings on time at the worksite	0.816	3	Harsh weather conditions	0.497	3	Strikes called by political parties or hartals	0.394	3
Equipment necessary to do the job not available on time	0.778	4	Frequent revisions of drawing/design resulting in additional work/ rework	0.492	4	Frequent revisions of drawing/design resulting in additional work/ rework	0.362	4
Poor pay	0.775	5	Craftsmen turnover	0.483	5	Unavailability of drawings on time at	0.357	5

						the worksite		
Labour strikes	0.771	6	Craftsmen absenteeism	0.477	6	Craftsmen absenteeism	0.346	6
Poor project planning and scheduling	0.770	7	Delayed material delivery by the supplier	0.470	7	Improper project coordination	0.341	7
Unavailability of tools on time at the worksite	0.769	8	Lack of recognition of good and efficient workers	0.463	8	Harsh weather conditions	0.340	8
Poor quality of materials	0.761	9	Improper project coordination	0.449	9	Craftsmen turnover	0.329	9
Improper project coordination	0.760	10	Errors in the drawings	0.441	10	Poor project planning and scheduling	0.329	10
Unsafe working conditions	0.752	11	Interference from other trades or other crew members	0.438	11	Errors in the drawings	0.325	11
Accidents causing stoppage of work at the site	0.746	12	Lack of periodic meeting among the management, site personnel and the contractors	0.438	11	Equipment necessary to do the job not available on time	0.324	12
Lack of experience of craftsmen	0.744	13	Unavailability of drawings on time at the worksite	0.438	11	Lack of experience of craftsmen	0.315	13
Errors in the drawings	0.737	14	Lack of adequate space for storage of materials	0.436	14	Poor pay	0.310	14

Frequent revisions of drawing/design resulting in additional work/ rework	0.736	15	Excessive overtime	0.434	15	Slow equipment repair in case of breakdown	0.309	15
Inadequate instructions provided by supervisor	0.731	16	Lack of weekly project evaluation meetings	0.434	15	Lack of experience of supervisor	0.306	16
Slow equipment repair in case of	0.726	17	Rework due to field errors committed by	0.429	17	Craftsmen unaware of safety	0.303	17

breakdown			craftsmen			precautions		
iCraftsmen absenteeism	0.724	18	Lack of monetary incentives	0.429	17	Poor quality of materials	0.300	18
Poor quality of tools provided /used	0.720	19	Poor project planning and scheduling	0.427	19	Lack of maintenance of tools and plants	0.299	19
Lack of maintenance of tools and plants	0.719	20	Lack of experience of supervisor	0.427	19	Rework due to field errors committed by craftsmen	0.298	20
Craftsmen unaware of safety precautions	0.718	21	Slow equipment repair in case of breakdown	0.425	21	Unsafe working conditions	0.297	21
Lack of experience of supervisor	0.717	22	Lack of experience of craftsmen	0.423	22	Unavailability of tools on time at the worksite	0.296	22
Strikes called by political parties or hartals	0.717	22	Unrealistic project goals and deadlines	0.422	23	Lack of team spirit among craftsmen	0.295	23
Communication problem among craftsmen and supervisors	0.716	24	Craftsmen unaware of safety precautions	0.422	23	Lack of adequate space for storage of materials	0.292	24
Lack of team spirit among craftsmen	0.704	25	Lack of team spirit among craftsmen	0.420	25	Inadequate instructions provided by supervisor	0.291	25
Rework due to field errors committed by craftsmen	0.694	26	Equipment necessary to do the job not available on time	0.416	26	Lack of recognition of good and efficient workers	0.286	26
Slow response on doubts arising from the drawings	0.690	27	Lack of maintenance of tools and plants	0.416	26	Communication problem among craftsmen and supervisors	0.286	27
Harsh weather conditions	0.684	28	Lack of interaction among the site community	0.407	28	Labour strikes	0.285	28
Craftsmen turnover	0.682	29	Site congestion	0.405	29	Slow response on doubts arising from the drawings	0.278	29

Disputes with consultants/ owner causing stoppage of work	0.681	30	Slow response on doubts arising from the drawings	0.404	30	Poor quality of tools provided /used	0.278	30
Lack of adequate space for storage of materials	0.670	31	Design difficult to construct	0.404	30	Accidents causing stoppage of work at the site	0.276	31
Lack of interaction among the site community	0.668	32	Disregard of craft worker suggestions/ideas	0.404	30	Disputes with consultants/ owner causing stoppage of work	0.272	32
Poor temporary facilities at the site	0.642	33	Poor temporary facilities at the site	0.402	33	Lack of interaction among the site community	0.272	33
Site congestion	0.622	34	Disputes with consultants/ owner causing stoppage of work	0.400	34	Interference from other trades or other crew members	0.271	34
Lack of monetary incentives	0.621	35	Communication problem among craftsmen and supervisors	0.400	34	Lack of periodic meeting among the management, site personnel and the contractors	0.271	35
Interference from other trades or other crew members	0.619	36	Poor pay	0.400	34	Lack of weekly project evaluation meetings	0.267	36
Lack of periodic meeting among the management, site personnel and the contractors	0.619	36	Inadequate instructions provided by supervisor	0.398	37	Lack of monetary incentives	0.266	37
Design difficult to construct	0.618	38	Poor quality of materials	0.395	38	Unrealistic project goals and deadlines	0.259	38
Lack of recognition of good and efficient workers	0.618	39	Unsafe working conditions	0.395	38	Poor temporary facilities at the site	0.258	39
Supervisor	0.617	40	Supervisor	0.391	40	Site congestion	0.252	40

absenteeism			absenteeism					
-------------	--	--	-------------	--	--	--	--	--

Respondents	RANK CORRELATION		
	Importance index	Frequency index	Severity index
Project Managers – Site Engineers	0.846	0.632	0.751
Site Engineers – Craftsmen	0.666	0.465	0.541
Project Managers – Craftsmen	0.606	0.595	0.381

Online Eigenvalue Calculator

Compute eigenvalues with Wolfram|Alpha

$$\begin{pmatrix} 1 & 2 & 3 \\ 3 & 2 & 1 \\ 2 & 1 & 3 \end{pmatrix}$$

Tab 6.2 Factor Analysis On Importance Of The Factors

Grouped Factors	Factors/Attributes	Factor loading	Eigen value	Percentage of variance explained	Cumulative percentage of variance explained
1. Tool and equipment	1.1. Lack of maintenance of tools and plants	.730	4.053	9.426%	9.426%

issues	1.2. Poor quality of tools provided /used	.708			
	1.3. Equipment necessary to do the job not available on time	.681			
	1.4. Slow equipment repair in case of breakdown	.642			
	1.5. Unavailability of tools on time at the worksite	.576			
2. Poor labour motivation	2.1. Lack of monetary incentives	.727	3.351	7.794%	17.220%
	2.2. Lack of recognition of good and efficient workers	.691			
	2.3. Disregard of craft worker suggestions/ideas	.607			
	2.4. Poor pay	.576			
	2.5. Poor temporary facilities at the site	.554			
3. Improper supervision	3.1. Supervisor absenteeism	.681	3.295	7.663%	24.883%
	3.2. Lack of experience of supervisor	.645			
	3.3. Inadequate instructions provided by supervisor	.637			
	3.4. Lack of experience of craftsmen	.525			
4. Poor material planning	4.1. Unavailability of material on time at the workplace	.718	3.136	7.294%	32.177%
	4.2. Delayed material delivery by the supplier	.708			
	4.3. Craftsmen absenteeism	.546			

5. Poor site management	5.1. Site congestion	.679	2.713	6.310%	38.487%
	5.2. Interference from other trades or other crew members	.631			
	5.3. Disputes with consultants/ owner causing stoppage of work	.578			
6. Improper drawing management	6.1. Frequent revisions of drawing/design resulting in additional work/ rework	.683	2.473	5.750%	44.237%
	6.2. Slow response on doubts arising from the drawings	.593			
	6.3. Errors in the drawings	.586			
7. Project	7.1. Improper project coordination	.771	2.467	5.737%	49.974%

management incompetency	7.2. Poor project planning and scheduling	.651			
	7.3. Unrealistic project goals and deadlines	.582			
8. Craftsmen issues	8.1. Craftsmen turnover	.724	2.357	5.482%	55.456%
	8.2. Lack of team spirit among craftsmen	.648			
	8.3. Rework due to field errors committed by craftsmen	.545			
9. Lack of meetings	9.1. Lack of periodic meeting among the management, site personnel and the contractors	.818	2.331	5.421%	60.877%
	9.2. Lack of weekly project evaluation meetings	.744			
10.Lack of communication	10.1. Communication problem among craftsmen and supervisors	.628	2.035	4.731%	65.608%
	10.2. Lack of interaction among the site community	.600			

CHAPTER 07

CONCLUSION

- Current practices in formwork assembly, machining, and transportation considerable waste.
- This thesis adapts lean manufacturing practices to establish a lean formwork construction model to reduce waste while increasing customer value.
- The *kanban* system is used to optimize mold inventory while creating a continuous formwork construction flow, allowing for improved progress control.
- In this case study have explained the proposed lean formwork construction model can reduce waste in the process of assembling, machining, and transporting molds, thus increasing customer value.
- Improving formwork quality depends on adopting a culture of continuous learning and improvement.
- The *andon* culture and *kanban* system can then be used to eliminate waste.
- However, in implementing such a system, the foreman and superintendent must take into account the potential for resistance to change.
- Implementing the lean formwork construction model would require extensive education and training.
- While the current study focuses on the mold assembly, machining, and transport processes.
- The factors identified reveal that the majority of the productivity problems faced by construction practitioners are a result of poor management of the construction projects, with the major factors entailing the need of implementing effective resource management practices on construction projects.
- Poor labor productivity is a chronic problem in most of the construction sites.
- However labor productivity is rarely measured on the construction sites and hence the losses are never identified.

FUTURE STUDY

- Future study can apply the model to improve other formwork operations.
- In addition, the proposed model has potential for application to enhance other construction activities such as steel erection, rebar installation, and concrete pouring.
- The research has highlighted factors impacting productivity in the Indian context and the research findings can guide construction practitioners in their efforts to achieve productivity improvement.
- Future research efforts can be directed in replicating the study in other parts of the country to validate the findings of this research.

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