CHAPTER 46

Crane Operation in Precast Construction

Prachi Sanjay Naidu[1], *Anagha Raghorte*[2*],
Abdulkadir Virdiwala[1] *and Tetali Lakshmi Narasimha Reddy*[1]

ABSTRACT

The study examines how weather conditions affect the productivity of tower cranes in precast construction projects. It analyses the crane's operational cycle in both dry and were weather, categorizing the tasks into Value-Added (VA), Non-Value-Added (NVA), Non-Value-Added – But-Necessary (NVAN) activities. By conducting site observations and reviewing video recordings, the research reveals notable differences in productivity, with delays mainly attributed to non-value-added tasks influenced by environmental factors, inefficiencies in material handling, and coordination challenges. The study highlights the need to reduce NVA activities to enhance workflow efficiency. Although the findings are based on specific weather conditions and site observations, they offer valuable insights for optimizing the crane operations and improving the resource utilization in lean construction practices, especially in adverse weather conditions.

Keywords: Tower crane; Operational cycle; Productivity; Workflow; Efficiency.

1.0 Introduction

Precast Construction is becoming more and more common Contemporary projects, particularly because it provides efficiency, quality and speed. The effective functioning of Tower cranes, which allow them to lift, move and position precast elements at the site, is the primary factor governing the successful installation of precast construction. Productivity, cost, and project timeline are directly impacted by the need for precise timing and resource management, which necessitates efficient crane operation in precast construction. However, variety of factors influence the crane's performance. Precast elements are lifted and placed by a tower crane during installation, but the efficiency is heavily influenced by the surrounding environment, particularly the weather (Feng *et al.*, 2017). Environmental Factors like extreme geator cold, strong winds and a lot of rain have a significant impact on their performance. Thus, the study presents and analyze the connection between Tower crane productivity and weather conditions recordings, the necessary information was gathered, and a comprehensive analysis of the crane's Operational cycle under various weather conditions was carried out.

[1]*School of Construction, NICMAR University, Pune, Maharashtra, India*
[2]*Corresponding author; School of Construction, NICMAR University, Pune, Maharashtra, India*
(E-mail: P2370644@student.nicmar.ac.in)

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This aids in examining the impact that both wet and dry conditions have on crane productivity during preconstruction. To identify inefficiencies and help predict workable strategies for minimizing disruptions, the study divided crane activity into value added, non-value added, and non-value added but necessary categories. The necessary data was gathered through site observations and video recordings, and a comprehensive analysis of the crane's operational cycle under various weather conditions was carried out. The study emphasizes that delays caused by rain or other wet weather conditions minimizes crane performance and are primarily caused by coordination issues inefficient material handling (Chan & Lu, 2008) and other environmental factors, performance and are primarily caused by coordination issues inefficient material handling (Chan & Lu, 2008) and other environmental factors.

2.0 Literature Review.

This paper mainly explains tracking of tower crane operations on construction sites with the help of computer vision in an automatic matter (Yang *et al.*, 2014) It utilizes surveillance cameras and some image processing algorithm to track the trajectory of the jib angle, from which crane activity states are inferred. A probabilistic graphical model was used to classify the crane activities into concrete pouring and non-concrete material movement by analysis of the movements and site layout information. The authors focused on the use of video-based systems, this achieved by use of computer vision and video processing methods, (Shapira *et al.,* 2008) which are intended to enhance the monitoring process for better assessment of productivity in crane operation. Although there exist some limitations of accuracy with respect to tracking the activities such as by lighting, weather, obstructions. This study could be helpful as it gives a data driven approach to monitoring performance, which would help optimizing the material handling, scheduling techniques etc. Also, the research by (Jeong *et al.,* 2023) depicts the application of computer vision techniques for monitoring and improving the productivity of the tower cranes during the curtain wall installation. To track the path completed by a crane and explain its effectiveness and performance, the researchers utilized deep learning object detection in conjunction with the video analytic techniques. Also, by adopting these techniques, it will improve productivity of the crane in precast element lifting and placement.

3.0 Methodology

The method adopted for research here is the observational method which allows for direct watch of crane operations at construction sites. This indicates a thorough understanding of the processes which include careful monitoring of crane operations, load handling process and observance of safety procedures. This allows to directly observe the crane activities noting any in efficiencies hazards or best practices that they have seen in real time, by emerging themselves in the operational environment. The first step of methodology is the collection of primary data-

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these are done through face-to-face interviews of the crane operators, construction staff, and project managers in order to get insight into their problems and things they are satisfied with the operation of the crane. One of the other methods of gathering quantifiable data of crane performance and technical methods is by asking the workers to fill out the surveys. Not only the workers but also the researchers became part of the crane inspections by recording the work hours, taking the photographs and doing documentation of the work done.

Video recording process and analysis: To analyse crane operations efficiently a video based observational study was conducted. These approaches help in categorising crane activities based on real time performance under different weather conditions. These recordings provide empirical data for measuring productivity and identifying inefficiency.

The entire crane operation was recorded on site to capture dry and wet weather concreting process separately. The recordings focused on the following key crane activities.

- Waiting for the transit mixer (TM)
- Filling concrete bucket
- Removing chute
- Signaling crane operator
- Lifting bucket for pouring concrete
- Leveling concrete
- Vibrating concrete
- Finishing surface
- Cleaning tools and area.

The recorded crane operations were analysed using a work sampling technique which categorizes tasks into value added (VA), non-value-added (NVA)and non-value-added-but-necessary (NVAN) which includes lifting, swinging, positioning, waiting, coordination, signaling, bucket feeling, safety checks, communication between crane operators and workers and post operation adjustment. These processes were documented in two different environmental conditions.

Recording process for dry weather conditions: In dry weather the crane operator works under stable and predictable conditions. The dry environment ensured consistent ground stability, reducing the risk of sleepage and uncontrolled crane movement. However high temperatures led to heat stress among workers, requiring frequent breaks and increasing the non-value added (idle time). The video was captured from multiple angles ensuring a Clear View of crane moments, worker interactions and task execution. A stationary camera was positioned at an elevated point to record the inter operational cycle from lifting to placement. A mobile camera was used for Close Up shots particularly during critical stages such as bucket felling, pouring and alignment. Audio recordings were also included to track communication patterns and signal efficiency.

Recording process for wet weather conditions: In wet weather conditions crane operations were impacted by increased humidity, slippery surfaces and reduced visibility. The

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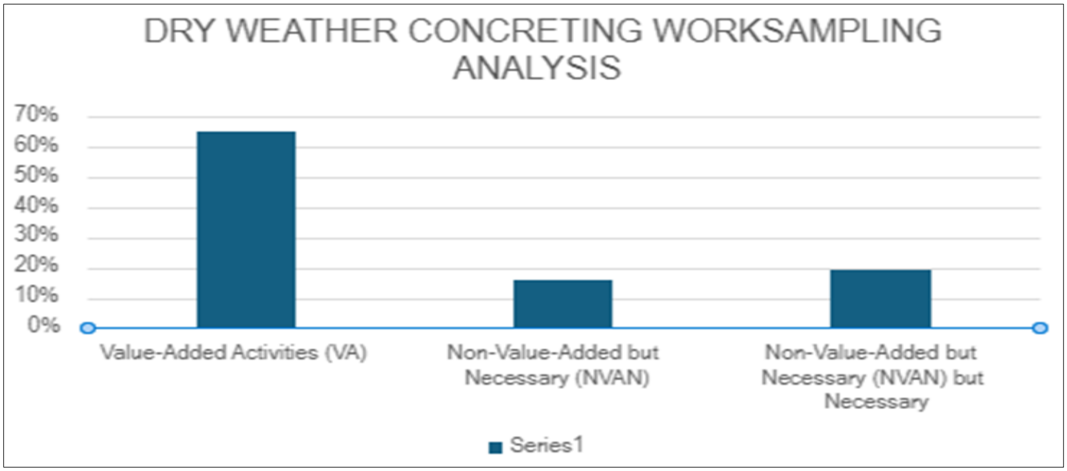
wet conditions created challenges in load stability, crane swing control and worker safety required in extra precautions and safety measures to stop the video recordings were conducted using a similar multi camera setup ensuring coverage from different angles. Additional focus was given to surface conditions how muddy and wet areas affected crane stability and movement. The time required for each activity was noted with particular attention to delays caused by weather conditions, increasing safety and rework efforts. Observations included how workers adjusted their workflow such as modifying bucket lifting speed, increasing communication frequency, and using protective measures of its environmental hazard.

Figure 1: Dry Weather Concreting Analysis



The analysis of the collected video data and work sampling observations evaluated crane performances, process efficiency, and areas for improvement. Hence, the research makes a wide view upon the analysis of time distribution among crane activities to identify all inefficiency and benchmark performance under different conditions.

Dry weather concreting analysis: The crane motions were quite continuous with very few interactions full stop the whole process duration was 9 minutes and 20 second which is 560 seconds. Breakdown of time categories depicted as value added (VA) 5minutes 15seconds 56%, non-value added (NVA) 1minute 21seconds 14%, non-value added but necessary (NVAN) 2minutes 44 seconds 30 %. The value-added task mainly included lifting, swinging, positioning, pouring and vibrating. The non-value-added task includes idle waiting time and unnecessary movements. The non-value added but necessary task includes signaling, bucket filling and lowering the bucket back.

Wet weather concreting analysis: The climate conditions impacted crane performance, thus prolonging the process duration. Total time taken was 17 minutes of 7 seconds (1027

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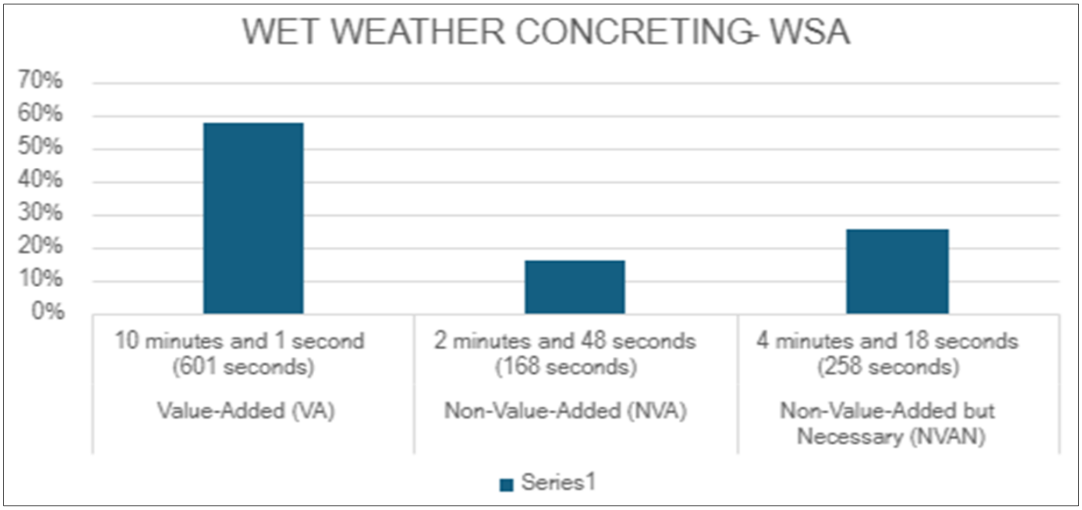
seconds). Time Categories of Value-Added: 10minutes 1second 601seconds w.r.t. 58% Non-Value-Added: 2 minutes 48 seconds 168seconds w.r.t. 16%. Non-Value-Added (NVAN): 4 minutes 18 seconds (258s) w.r.t. 26%. When that happens, these increased delays took longer time due to slippery surfaces, slower movements, and safety precautions. More NVAN tasks were done as extra signaling and cautioning was donfor stability.

Figure 2: Wet Weather Concreting Analysis



Activity	Dry Weather	Wet Weather
Waiting for TM to pour	0:00	0:39
Filling bucket from Transit Mixer	1:13	0:49
Removing the chute	0:07	0:30
Signal to crane operator	0:13	0:05
Lifting the bucket	0:24	0:04
Swinging the crane	0:40	1:11
Lowering the bucket	0:31	0:56
Positioning the bucket	1:19	2:38
Pouring concrete	1:03	6:27
Vibrating concrete	1:58	0:00
Waiting period for lifting	0:00	0:42
Lifting and Swing Time	0:52	1:03
Lowering bucket to Transit Mixer	0:38	1:42

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To know in which weather efficiency and productivity can be achieved, can be known by comparing these dry weather and wet weather analysis.

4.0 Applying Process Mapping

Value Stream Mapping (VSM) was used to increase crane operations' efficiency. This lean tool aids in detecting non-value-added operations, visualizing the present workflow, and suggesting changes to increase productivity VSM's main objectives were:

1. To see the entire crane operating cycle, from installation to lifting.
2. To quantify value-added (VA), non-value-added (NVA), and non-value-added but necessary (NVAN) activities.
3. To identify waste and suggest process improvements.
4. To estimate potential time reductions and efficiency improvements.

5.0 Result and Findings

Wet weather analysis findings: During rainy conditions, the VA work contributed to 58%, one percentage higher compared to the dry weather conditions.

SR NO.	TASK ACTIVITY	CATEGORY	ACTUAL DURATOIN (SEC)	ESTIMATED DURATION (SEC)
1	waiting for TM	NVA	39	#
2	filling concrete bucket	VA	49	49
3	removing chute	NVAN	30	
4	signal crane operator	NVAN	10	25
5	lifting the concrete bucket	VA	12	12
6	swinging crane the pouring area	VA	71	71
7	lowering bucket to pouring area	VA	12	12
8	positioning bucket above pouring area	NVAN	158	60
9	pouring concrete	VA	65	
10	pouring paused	NVA	45	
11	pouring resumed	VA	405	450
12	vibrating of concrete	VA	120	120
12	waiting for next lift	NVA	42	#
13	lifting the emptyn bucket	VA	11	
14	swing back to TM	NVA	63	50
	TOTAL DURATION		1132	849

This improvement primarily resulted from taking additional precaution measures to undertake despite unfavorable circumstances. Non-value-added (NVA) time did increase to 16% as a result of unforeseen postponements, standby waiting, and external setbacks such as rainfall

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to hinder tasks. Moreover, required non-value-added (NVAN) work accounted for 26%, largely because of mandatory safety precautions and operational limitations that could not be avoided in rainy weather.

5.1 Calculation and conclusion for wet weather

% of time saved initial duration = 1132 seconds

Optimized duration (After lean tool) = 849 seconds

Time saved =1132-849=283seconds

% of time saved = 283/1132*100 = 25%

So, 25% of the total time was saved after eliminating non-value-added activities.

Productivity and efficiency improvement: Since each cycle is 25% faster, more cycles can be completed per shift leading to a direct increase in overall productivity. Also, elimination of non-value-added tasks increases the proportion of non-value-added time, leading to an efficiency improvement of approximately 25%. Value Stream Mapping and Work Sampling have been used to lower the cycle time for rainy weather activities by around 283 seconds, or 25%. Because there were so many more inefficiencies in the wet circumstances that we were able to effectively address, the benefits were far larger in the wet than in the dry.

SR NO.	TASK ACTIVITY	CATEGORY	ACTUAL DURATOIN (SEC)	ESTIMATED DURATION (SEC)
1	waiting for the TM	NVA	60	X
2	filling concrete bucket	NVAN	66	66
3	removing chute	NVAN	10	15
4	signal crane operator	NVAN	13	
5	lifting the concrete bucket	VA	24	24
6	swinging to pouring area	VA	40	40
7	lowering to the pouring area	VA	31	31
8	positioning above the pouring area	NVAN	79	45
9	pouring the concrete	VA	63	63
10	vibrating the concrete	VA	118	118
11	waiting for next lift	NVA	0	0
12	lifting the empty bucket	VA	29	50
13	swing back to TM	VA	52	
14	lowering to the TM	VA	38	38
TOTAL DURATION			623	490

Dry weather analysis findings: In the condition of dry weather, 56% of activities were value-added, and hence most crane movements were productive. The NVA percentage was less

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at 14%, so fewer inefficiencies prevailed, though unnecessary movements and idle time did prevail. Yet NVAN activities were more at 30%, indicating that improvements in coordination and pre-planned signaling mechanisms can diminish these needed but non-productive activities. Whereas dry conditions enabled more efficient operations, further efficiency in NVAN operations could be enhanced by optimizing operations.

5.2 Calculation and conclusion for dry weather

% of time saved initial duration = 623seconds

Optimized duration (after lean tools) = 490seconds

Time saved =623 – 490 =133seconds

%of time saved =133/623*100 =21.35%

So, 21.35% of the total time was saved after applying lean tools

The same work that was initially scheduled to take 623 seconds will now be completed in 490 seconds. As a result, beginning immediately, more cycles may often be finished during working hours, which inevitably increases productivity. Overall, crane operations in dry weather had a 21.35% (133-second) shorter cycle time. With careful planning, communication aids, and crane movements, there is a great deal of potential to achieve new heights in crane operation. This could help reduce cycle time from 490 seconds further, potentially leading to greater cost savings and improved construction workflow efficiency.

6.0 Conclusion

The study on crane operations for concreting activities in both dry and wet weather has shown that huge inefficiencies lay within the initial processes. Value Stream Mapping and Work Sampling were used to identify these non-value-added activities and eliminate them, allowing for significant time savings and an increase in efficiency. The cycle time for dry weather concreting was initially 623 seconds and was shortened to 490 seconds after the changes were made, realizing a total dedicated time saving of 133 seconds, which is a reduction of 21.35%. In wet weather, it was set at 1132 seconds and changed to 849 seconds, achieving savings of 283 seconds or 25 % of the time. The large savings in wet conditions imply that there were larger inefficiencies, perhaps due to environmental factors and unoptimized workflows. Most notable was the improvement in efficiently planning crane movements and labor positioning so that workers were in place prior to the commencement of each cycle.

Also, the change from hand signals to walkie-talkies assisted in curtailing the lags in communication, thereby aiding synchronization. Another important adjustment is the optimization of the crane's movement path, which saves more time versus following a vertically horizontal lifting path; diagonal movements can be used if the bucket is empty. Efficiency improved through a higher ratio of value-added to non-value-added cycles. All of these improvements were coordinated: better planning, real-time communication improvements, and

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optimized lifting paths leading to reduced time registrations. Furthermore, additional refinement of weather-specific strategies, training of workers, and introduction of technology integration can provide gains in efficiency in the long run. A systematic elimination of delays and a concomitant enhancement of task execution will allow construction projects to become more operationally efficient (lower costs) and reduce timelines.

References

Abdul Kadir, M. R., Lee, W. P., Jaafar, M. S., Sapuan, S. M., & Ali, A. A. A. (2005). Factors affecting construction labour productivity for Malaysian residential projects. *Structural Survey*, 23(1), 42–54.

Bekdik, B., Hall, D., & Aslesen, S. (2016). Offsite prefabrication: What does it require from the trade contractor? *24th Annual Conference of the International Group of Lean Construction*.

Etges, B. M. (2018). Value-added activities in Brazilian infrastructure construction company – 9 case study. *26th Annual Conference of the International Group of Lean Construction*, Chennai, India.

Indian Lean Construction Conference. (2019). *Proceedings of ILCC 2019*.

Insoo, J., Jeongbin, H., Junghoon, K., & Seokho, C. (2023). Vision-based productivity monitoring of tower crane operations during curtain wall installation using a database-free approach. *Journal of Construction Engineering and Management*. https://doi.org/10.1061/JCCEE5.CPENG-5105

Jun, Y., Patricia, V., Jochen, T., & Zhongshan, S. (2022). Vision-based productivity monitoring of tower crane operations during curtain wall installation using a database-free approach. *Journal of Civil Engineering*, 28(1). https://doi.org/10.1061/(ASCE)CP.1943-5487.0000242

Kumar, B. B., & Sheikh, A. (2021). Study on improvement of labour productivity using crew balance chart. *International Journal of All Research Education and Scientific Methods (IJARESM)*, 9(6). https://www.ijaresm.com

Larson, J., & Simonsson, P. (2012). Decreasing complexity of the onsite construction process using prefabrication: A case study. *20th Annual Conference of the International Group of Lean Construction*.

DOI: 10.17492/JPI/NICMAR/2507046 *ISBN: 978-93-49790-54-4*

Leung, A. W. T., & Tam, C. M. (1999). Prediction of hoisting time for tower cranes for public housing construction in Hong Kong. *Construction Management and Economics*, 17(3), 305–314. https://doi.org/10.1080/014461999371510

Sanjana, M., Jyoti, T., Ganesh, T., & Hrishikesh, J. (2019). Value stream mapping – Changing the perspective in traditional practice. *Indian Lean Construction Conference (ILCC 2019)*.

Sarkar, D. (2021). Advanced material management for Indian construction industry by application of statistical process control tools. *Materials Today: Proceedings*. https://doi.org/10.1016/j.matpr.2021.12.082

Shapira, A., & Elbaz, A. (2012). Tower crane cycle times: Case study of remote-control versus cab-control operation. *Journal of Construction Engineering and Management*, 138(10). https://doi.org/10.1061/(ASCE)CO.1943-7862.0000904

Shapira, A., & Elbaz, A. (n.d.). Measurement and risk scales of crane-related safety factors on construction.

Sudhakar, N., & Vishnuvardhan, K. (2017). Improving productivity in construction by using value stream mapping. *International Journal of Engineering Technology Science and Research*, 4(11).

Thomas, A. V., & Sudhakumar, J. (2013). Critical analysis of the key factors affecting construction labor productivity – An Indian perspective. *The International Journal of Construction Management*, 13(4), 103–125.

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