Aisyah, R. A., Farida, F., Gutomo, A., Putra, P., & Brata, P. S. (2026). Takt Planning and control in Indonesia: structure project twin tower Undip PTPP. In F. Hamzeh, M. Poshdar, N. P. Garcia-Lopez, & V. Gan (Eds.), *Proceedings of the 34th Annual Conference of the International Group for Lean Construction* (IGLC34) (pp. 1571–1582). https://doi.org/10.24928/2026/0158

TAKT PLANNING AND CONTROL IN INDONESIA: STRUCTURE PROJECT TWIN TOWER UNDIP PTPP

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ABSTRACT

Takt planning and takt control are increasingly applied in lean construction to stabilize workflow and improve project performance. However, empirical evidence explaining how performance improvements emerge over time remains limited. This study investigates how schedule performance improvements develop in a takt-based production system through an empirical case of a twin-tower project executed, focusing specifically on structural works. The research questions are how takt planning contributes to initial schedule performance improvements and how deviations between planned and realized production during execution contribute to further performance improvement over time. The project represents the first implementation of takt planning and takt control by PT PP (Persero) Tbk. Using a case-study approach, the study distinguishes performance gains through takt planning and additional improvements during execution through takt control. Our results show that takt planning significantly reduced planned project duration and stabilized workflow. Further schedule gains shown through deviations between planned and realization enabled learning and localized corrective actions. By comparing performance outcomes at the whole project level and zone level, this study demonstrates that early performance losses reflected a learning and adaptation process. Meanwhile, repeated workflows and continuous control supported improved coordination, predictability, and faster delivery over time. It enables the systematic incorporation of lessons learned from the first tower into the second tower in the near future.

KEYWORDS

Lean implementation, project production, Takt time, Takt planning, Takt control.

INTRODUCTION

Takt-based production has been increasingly adopted in lean construction to handle repetitive building projects. The principle improves coordination among trades, schedule performance, and workflow reliability (Aisyah et al, 2025; Fiallo et al; Frandson et al, 2013; Lehtovaara et al, 2019; Heinonnen and Seppänen, 2016). By organizing the work according to a fixed rhythm and spatial zones, takt planning aims to standardize production and reduce variability (Bonesi

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et al, 2025; Formoso et al, 2025; Lehtovaraa et al, 2022; Lehtovaraa et al, 2021; Riekki, 2025; Tommelein and Lerche, 2023). Previous studies have shown that takt planning can significantly shorten planned project durations and enhance transparency in execution (Fireman et al, 2025; Tommelein and Emdanat, 2025; Tommelein, 2024).

However, existing empirical research has predominantly focused on either the design of takt plans or final project outcomes. It provides limited information on how performance improvements emerge during execution. In particular, the interaction between takt planning and takt control, and how deviations between planned and realized activities contribute to learning and performance improvement over time, remains insufficiently explored.

This paper addresses the gaps through an empirical case study of a twin-tower in Indonesia, where takt planning and takt control were implemented for the first time by PT PP (Persero) Tbk., called PTPP. Our study is motivated by two research questions: (1) how does takt planning contribute to initial schedule performance improvement in repetitive high-rise construction and (2) how do deviations between planned and realized production during execution contribute to further performance improvement? The study focuses on structural works and the objective of the study is to examine how schedule performance improvements develop over time by distinguishing planning from execution, specifically for structural works. We define performance improvements through reduction in planned duration, work-in-progress (WiP) control, start-time deviation per zone per activity, and workflow stability and variability. By comparing planned and realized production at activity, floor, and zone levels, our study provides empirical insight into takt as a dynamic and learning-oriented production system.

LITERATURE REVIEW

PRODUCTION SYSTEM BASED ON TAKT TIME

Takt originates from Lean Production and refers to the “beat” or rhythm that synchronizes production pace with demand. In manufacturing, takt stabilizes work processes, minimizes waste, and enhances predictability through synchronized handoffs and continuous flow. When adapted to construction, takt time structures production into repetitive and rhythmically aligned work segments, where zones flow at a regulated pace to maintain stability. The historical evolution of takt into construction emphasized its role in preventing overproduction, reducing inventory accumulation, and shortening throughput time by enforcing cadence-based production discipline. These foundational concepts position takt as not only a scheduling technique but also a system for improving reliability, transparency, and coordination in complex and dynamic project environments. (Haghsheno et al. 2016).

Recently, production planning and control methods *Takt Time Planning* (TTP) and *Takt Planning and Control* (TPTC) have received attention within the Lean Construction community. TTP and TPTC have shown great potential in radical decreasing production durations, and for example, Frandson et al. (2013) and Binninger et al. (2018) have documented 55% and 70% reductions, respectively, in durations by implementing takt production.

TAKT CONTROL: REALIZATION OF TAKT PLANNING

Recent research emphasizes that takt should not only be viewed as a planning tool but also as a comprehensive planning and control system. Takt control ensures takt plan consistency amidst uncertainty and variability. The implementation must incorporate adaptive learning mechanisms, responsive control actions, and robust performance metrics rather than being stiff in adherence to plans. Takt strongly emphasizes on synchronized capacity and rhythm within locations to improve predictability, reducing interference, and achieving continuous flow, suggesting takt as a viable evolution of existing location-based approaches rather than a

replacement (Frandson, et al, 2015). Studies on takt have moved beyond schedule pacing toward an integrated control philosophy essential for handling complexity (Formoso et al. 2025).

Empirical research on takt-controlled projects demonstrates substantial benefits, particularly in highly repetitive construction environments such as residential buildings. Studies reveal that takt planning significantly enhances flow efficiency, improves coordination among trades, and can drastically shorten production durations when supported by collaborative planning, visual tools, and disciplined control practices. However, findings also indicate that successful implementation requires organizational readiness, detailed planning, clear takt zoning, and strong leadership engagement. Barriers such as resistance to change, misalignment among stakeholders, and inadequate monitoring systems may limit performance if not addressed. Nonetheless, empirical pilots confirm takt's potential to transform project execution when properly institutionalized (Lehtovaara et al. 2019).

To better understand performance during execution, deviation-based metrics, such as start-time delays and duration gaps, are increasingly used to evaluate takt planning and control by comparing planned and realized production (Keskiniva, 2023; Tommelein & Emdanat, 2022). These deviations can be interpreted as indicators of production reliability, reflecting the degree to which work follows the planned takt rhythm. This aligns with the concept of takt attainment (Hopp & Spearman, 2011; Riekki et al., 2025), while also relating to the overall equipment effectiveness (OEE) framework (Nakajima, 1988; Muchiri & Pintelon, 2008. Start delays indicate availability losses, duration variability reflects performance losses, and disruptions correspond to quality losses (Formoso et al., 2025). Therefore, deviation-based metrics provide a practical and theory-informed proxy for assessing takt performance during execution.

METHOD

RESEARCH DESIGN AND DATA COLLECTION

This study adopted an empirical explanatory case-study approach to investigate the contribution of Takt Time implementation on repetitive-building project performance and the learning process during execution. The case study focused on the twin tower project of University of Diponegoro (Undip), Central Java, Indonesia. Our research combines takt time planning and control during execution to evaluate the actual project execution against planned schedules. Data were collected from the project site and project documents including planning of detailed work schedule, productivity rates, resource utilization and its realization that monitored from June until December 2025 within the focus of takt time is on structured works. This project is the first time for PTPP to implement takt time planning and control completely from the start. During the project execution, the project team also used the Last Planner System (LPS) since it is mandatory for PTPP. In this paper, however, we focused on takt time planning and control.

CASE STUDY

The project is a building within repetitive fourteen floors (Figure 1). The project is a typical integrated design–build construction for a lecture facility at Diponegoro University (Undip), located on the Pleburan Campus in Central Java, Indonesia. The Owner is the university itself and the main General Contractor is PT PP (Persero) Tbk. The completion duration was 510 days starting from October 14, 2024 until March 7, 2026, for stage-1 and 420 days for stage-2.

This project was divided into several packages containing planning/design works (2%) and construction physics, which contained preparation works (0.94%). Structural work (17,67%) was the most significant portion of all works. Architectural works (12,36%) included Drawing Engineering Design (DED) planning, construction method, and building calculation. It included Mechanical, Electrical and Plumbing (MEP) works (12,9%), external facility works (0,840%), licensing and connection works (0,52%) and safety management system (0,27%).

TAKT TIME PLANNING AND CONTROL

The takt time planning was done based on the Frandson et al. 2015 approach, further refined through more detailed developmental points. The Takt schedule was developed collaboratively by the project team through a six-stage process. We used the PTPP standard bar-chart schedule S-curve as the baseline for takt time planning. Then, we continued with determining the takt duration. At the same time, we also determined the zones, defined activities, and created the takt train along with individual duration and buffer. Ultimately, workflow balancing and finalization completed the takt plan schedule. The TTP procedure is summarized in Table 1.

Figure 1: Site project

Following the development of the takt plan, takt control was implemented through systematic comparison between planned and realized production. Control activities were conducted on a daily basis, where a dedicated team member monitored progress and recorded the status using a visual control worksheet across all active zones and floors. At the end of each day, the project team held a daily coordination meeting for ten to fifteen minutes to review performance, assess start-time readiness for subsequent trades, and decide whether to proceed as planned or implement adjustments. These meetings served as the primary forum for identifying deviations and defining corrective actions to maintain schedule adherence.

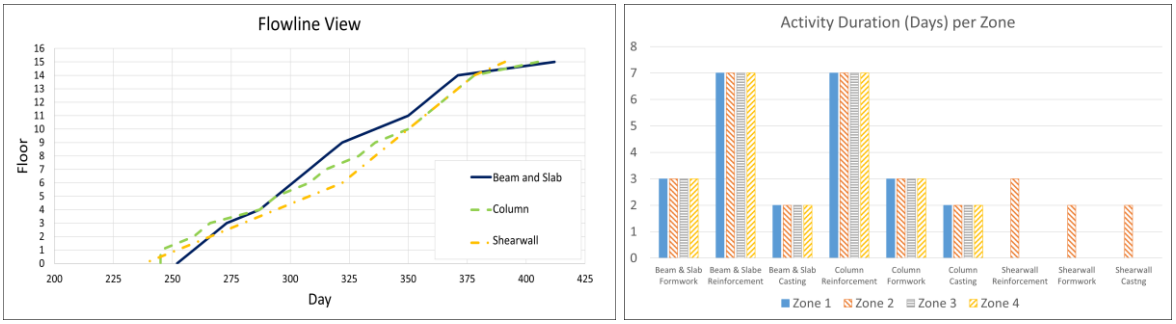
Table 1: Takt time planning six-stage procedure

Stage	Inputs	Tools	Outputs
1-Data Gathering	Drawings, BOQ, project schedule, historical data, calculated productivity rate	Document review, site visits, stakeholder group discussion	Dataset includes quantities, constraints, and productivity rates
2-Zone and Takt Time Definition	Building layout, repetition logic, stage-1 output	Zoning strategy, takt time benchmarking	Defined zones and selected takt time
3-Activity Sequence Identification	Dependencies, stage-1 output, technical constraints	Precedence diagram and Critical Path Method	Takt train
4-Activity Duration Determination	Quantities per zone, productivity rates, crew size	Historical benchmarking	Estimated duration per activity per zone
5-Workflow Balancing	Activity durations, takt time, resource availability	Line-of-Balance, resource levelling, crew adjustment, iteration	Balanced workflow where all trades align with takt time
6-Production Schedule Finalization	Balanced workflow, zone sequence, takt time	Takt schedule chart, visual planning boards	Final takt plan

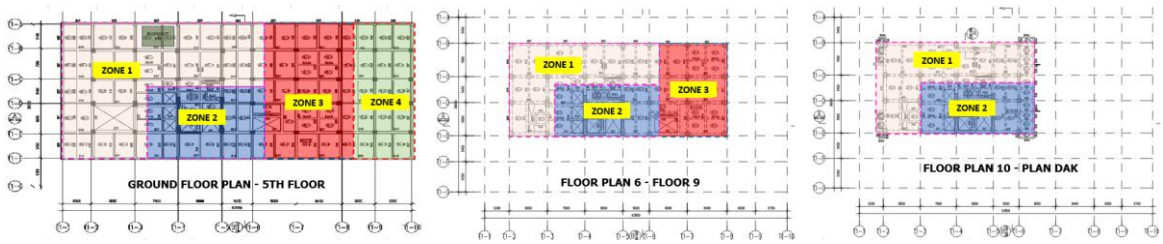
RESULTS

TAKT PLANNING IDENTIFICATION

The adoption of takt planning in the Twin Tower Undip project resulted in a reduction of 39 workdays relative to the PTPP standard bar chart schedule (190 days). The stages-1 and -2 are as follows. We transformed the initial bar-chart project schedule into a time-series representation of individual work items. We identified the waste shown in Figure 2a, where the irregularity and intersecting paths indicate a high potential for wasting time and bottlenecks. Figure 2b shows the average activity duration per zone derived from the initial project planning documentation. Only Zone 2 had shearwall reinforcement, formwork, and casting. The number of zones is determined based on a uniform productivity rate in order to maintain an optimal workflow. Figure 2c demonstrates the zoning plan for the Twin Tower Undip PTPP project. We divided the ground through the 5th floors into four zones, the 6th through 9th floors into three zones, and the 10th through 14th floors into two zones. The initial set of zones provided the reference framework for iterative planning and refinement.



(a) (b)



(c)

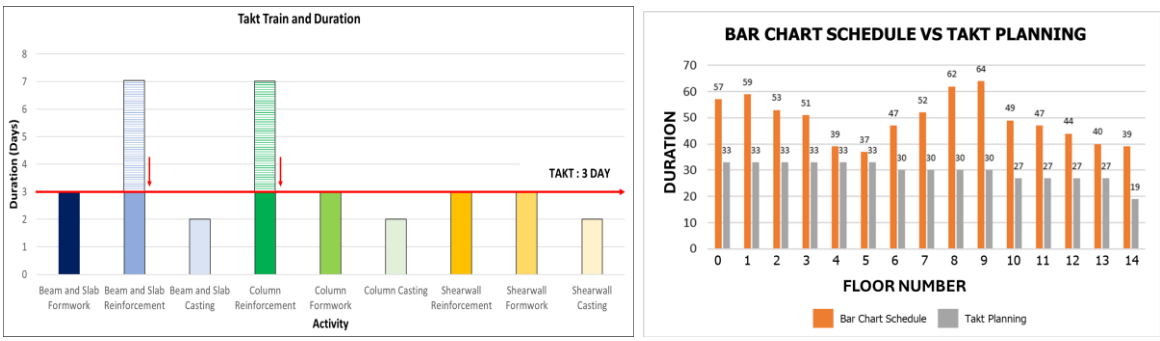
Figure 2: Flowline visualization, activity duration, and floor zone map

The next stage of determining takt time, takt train, and individual activity duration, including balancing and levelling, is as follows. We selected takt time to be 3 days, as indicated in Frandson et al (2015) and Lehtovaara et al (2019). When determining the takt train, we specified each activity's requirements to enable reliable zone handovers according to the Parade of Trades principle in Tommelein et al (1999). We involved workflow balancing and determining the duration of each activity. Levelling was implemented for activities with long cycle durations. The objective was to achieve relatively uniform activity durations across the entire scope of work. Figure 3a shows the resulting balanced and levelled durations with activity order from left to right indicate the takt train. Following workflow balancing and levelling, the takt duration for each zone was defined. We included 1-day buffer in the takt plan resulting in a 39-day reduction in project duration or 20.53% faster relative to the initial plan of 190 days. Figure 3b shows duration comparison between the initial and resulting takt plans.

COMPARISON ANALYSIS ON PLANNING AND CONTROL

Effective implementation of Takt Planning relies on consistent and reliable handoffs among activities. To support this, schedule control must be conducted at intervals shorter than the takt time to assess whether planned handoffs are likely to be achieved. Such short-cycle control fosters a sense of urgency within the project team (Frandson et al, 2013).

Figure 4a presents a metric that served as a visual control for monitoring WiP and task completion. Through this visualization, two progress curves were generated: the first indicated the overall project progress, while the second tracked completed activities. Figure 4b shows a complementary metric to evaluate standardization performance and WiP control. Figure 4c demonstrates the distribution of the duration gap between takt planning and realisation for each floor across work activities. We presented results separately for floors with negative, mixed, and positive gaps. Negative gaps mean delayed production delivery.



(a) (b)

Figure 3: Workflow balancing and resulting plans

Despite showing delayed activity deliveries, the work was completed within 148 days, showing a reduction of 3 days compared to the takt plan duration of 151 days. The implementation of Takt Control focused on localized recovery actions. This outcome has resulted in faster completion times, corresponding to an approximately 2% acceleration.

ZONE PERFORMANCE AND CONTROL

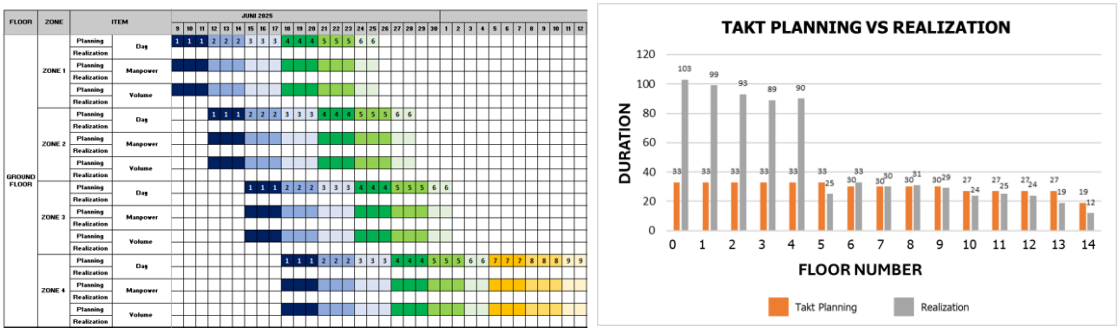
This section presents the effects of takt control on zone level. We examined the project performance through planned-realization start-time deviations between activities across all floors and zones. Figure 5 demonstrates the start-time deviation and illustrates execution deviation over time. To maintain consistency, negative values indicate a delayed start.

Zones 1 and 3 exhibited highly similar deviation patterns for Floors 0 to 4. It was characterized by start delays across multiple activities. The pattern suggests that the delay propagated between these zones during the early stages of execution. The disruptions were not fully absorbed locally and influenced downstream zones. However, the subsequent recovery starting from floor 4 suggests a transition from initial instability to more stable execution over time. This shift indicates that corrective actions and learning during execution enabled the project team to recover and stabilize towards higher floor works.

We observed that Zone 2 suggests a distinguished performance. Across most floors, start deviations remained relatively small and mostly positive indicating accelerated or on-time starts. The absence of Zones 1 and 3 similar pattern suggests that Zone 2 operated independently.

In contrast, Zone 4 experienced consistently large negative start deviations. These delays were due to extensive preparatory works associated with the groundwater tank and sewage treatment plant. However, the deviation magnitude decreases progressively and the performance recovered gradually over higher floors, where Floor 5 emerged as a turning point.

Figure 6 demonstrates the average start deviation between planning and realization for each activity and aggregated across floors. Positive values indicate earlier starts. The figure shows a monotonic increasing trend in start deviation as activities progress across zones along the takt train. Early activities exhibit relatively small deviations, while later activities show progressively larger deviations. This pattern indicates that deviations accumulated along the takt train. It is suggested that systematic adjustment effects occurred as production advanced. The similarity of the curves for Zones 1 and 3 further indicates that these zones exhibited comparable execution dynamics, which is consistent with the previous observation.



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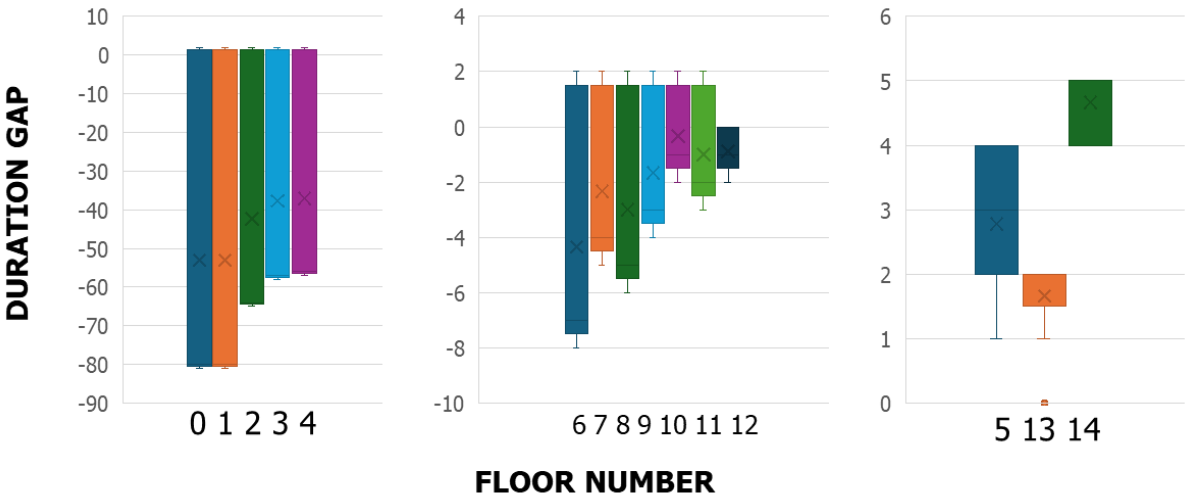

(c)

Figure 4: Production Takt Planning, TP vs realization, duration gap distribution

Zone 2 exhibited lower initial deviations and a smoother increase across activities indicating stable execution and stronger decoupling with other zones. In contrast, Zone 4 showed large negative deviations, although the deviation gradually decreased as activities progressed.

In summary, the increase in average start deviation across sequential activities indicates an adaptation phase. The project team adjusted work sequencing, coordination, and execution practices resulting in performance acceleration rather than a static outcome.

DISCUSSION

Takt Time Planning (TTP) and its supporting strategies have been shown to generate significant improvements in productivity and execution efficiency (Pradoto et al., 2022). We frame the discussion into during execution learning, after project insight, and spatial behaviour.

During execution learning−We highlighted that takt control operated primarily at a local level. It allowed the project team to recover from early disturbances and ultimately accelerate the overall project. The real-time control mechanisms, such as daily huddles, visual management, and micro-adjustments, enabled localized recovery without altering the initial takt plan. Local adaptability is a key strength of takt-based control systems.
We observed delays in the initial stage with recovery after activity 3 and performance improvement from Floor 4 onwards. Temporary productivity losses occurred because of understanding development, coordination routines, and control practices. This reflects learning and adaptation commonly reported in takt planning and control implementation as suggested in Riekki et al (2025), Lehtovaara et al (2022), and Binninger et al2017). The team, ultimately, demonstrated better adjustments, faster delivery rates and localized acceleration.

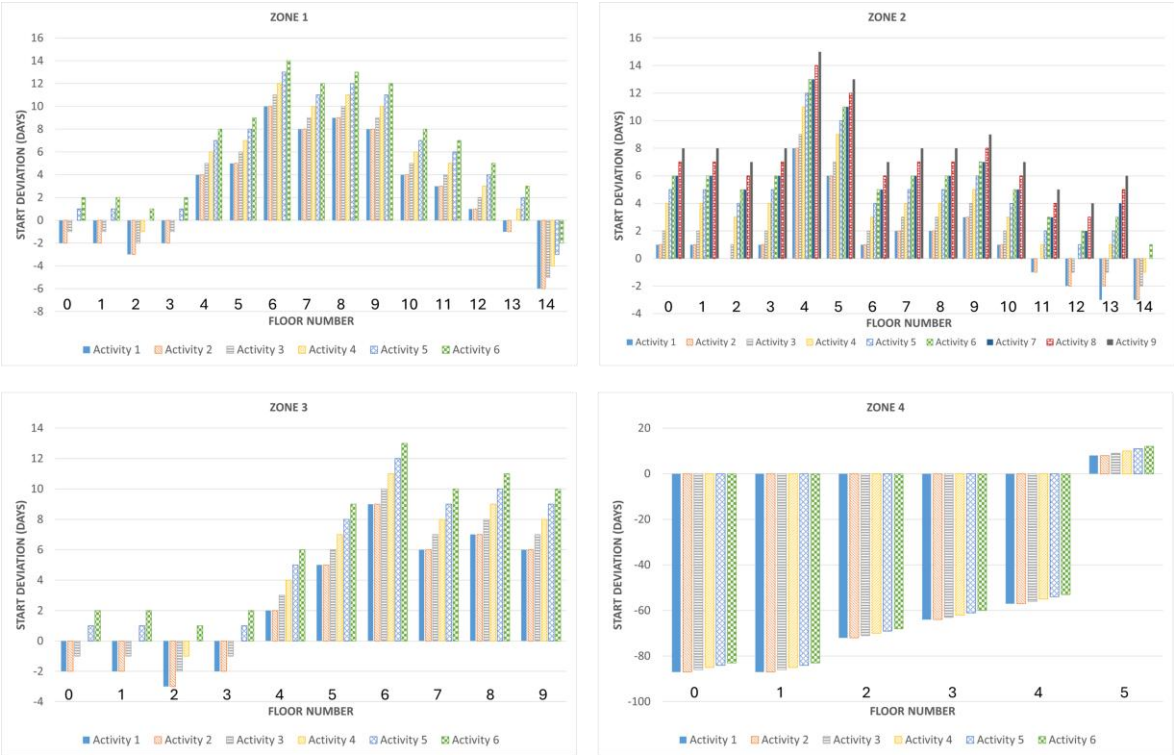

Figure 5: Zone start-time deviation performance

Enhanced execution resulted from the transition to aluminium formwork, readiness of materials and manpower for subsequent tasks, column head formwork usage, and two-shift overtime work. The control mechanism became noticeable after Activity 3 as in Figure 5.

Particular to Zone 4, all activities were suspended due to the delayed material availability. Work resumed only after material readiness was ensured resulting in a delayed, but more stable restart as in Figure 5. The delayed work, notably, did not propagate to the other zones and floors. This performance improvement aligns with the learning curve effect where repetitive workflows under TPTC enhance predictability, crew familiarity, and problem-solving capability (Riekki et al, 2025; Lehtovaara et al, 2022; Lehtovaara et al, 2019).

After project insight−We extend our discussion to the reflection of empirical observations from TPTC implementation. The following lessons in Table 2 highlight both the strengths and limitations of the implemented takt system and identify directions for improvement in future project phases. The control focus reflects key takt control propositions by Formoso et al. (2025). Specifically, the control focus observed during implementation aligns with the propositions of batching and takt definition (P2), deviation-based control (P3), slack and recovery strategies

(P4–P5), pull-based sequencing (P10), and learning (P11). We divide levels into strong, moderate, and weak to suggest full, partial, or minimal implementation consistency.

Spatial behaviour−The spatial analysis reveals that spatial configuration and inter-zone relationships played a decisive role in shaping production dynamics. The strong coupling between Zone 1 and Zone 3 led to delayed propagation and formed a train of delays once an initial disturbance occurred in Zone 1. This behaviour is consistent with prior findings that takt systems are highly sensitive to inter-zone dependencies, particularly when zones share crews, resources, or tight sequence constraints, causing local disruptions to cascade downstream.

Meanwhile, Zone 2 exhibited a train of acceleration, where stable work conditions and reduced interferences were observed. It enabled a maintained productivity gain across activities.

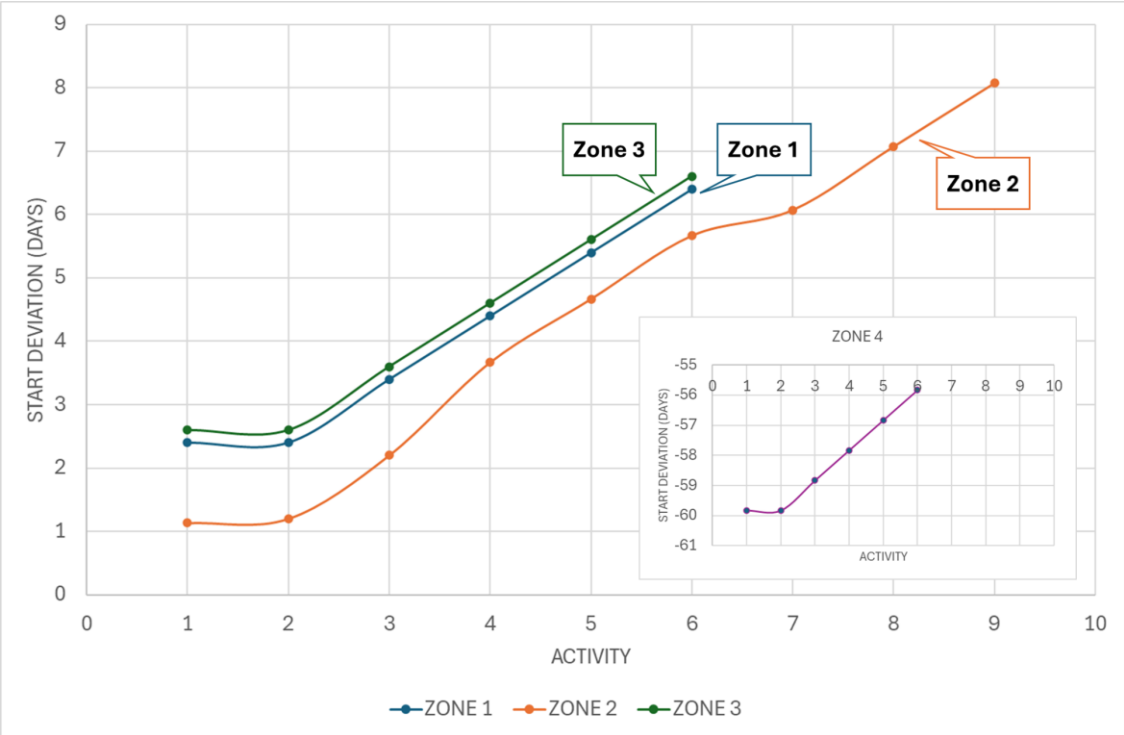

Figure 6: Activity performance through the average of start-time deviation for every zone

In contrast, we argue that Zone 4 functioned as a *de facto spatial buffer*. It was not explicitly designed as such during takt planning. Zone 4 experienced a start-time delay of 87 days due to groundwater tank and sewage treatment works, acting as true external constraints. Nonetheless, it completed 17 days before the planned project completion and provided a decoupling window without propagating them to other zones and interrupting overall completion. The interruption temporarily separated Zone 4 from the takt train indicating a disconnected work stream. Once constraints were resolved, improved readiness enabled accelerated execution. This indicates that spatial separation can inadvertently absorb variability and prevent disturbance propagation.

Ultimately, our findings highlighted the nonlinear nature of takt-based production. It emphasized that zoning decisions can simultaneously generate buffering capacity, delay propagation, or acceleration effects. Lessons from spatial behaviour indicate that *optimal takt planning* remains an open research challenge. Further research is needed to optimize takt plans and would benefit the subsequent construction packages of the Undip PTPP Twin Tower project.

CONCLUDING REMARK

This study examines how schedule performance improvements emerged over time in a takt-based production system using an empirical case study of a high-rise construction project. The

results show that takt planning improved performance by stabilizing workflow through zoning, sequencing, and workflow balancing, leading to notable reductions in planned duration. However, final project performance was not fully determined at the planning stage. Additional gains emerged during execution through takt control, where deviations between work-as-planned and work-as-done enabled learning and localized corrective actions. Overall, the findings indicate that performance improvement in takt-based production systems results from the interaction between planning stability and control-driven learning during execution.

The study also highlights that performance outcomes in takt-based production systems evolve dynamically rather than being fixed through upfront planning alone. While takt planning established a stable production baseline, takt control supported adaptive responses during execution. This research is limited by its focus on a single project and the retrospective interpretation of control practices. Future research should therefore compare takt planning and takt control across similar projects, such as the second building of the twin tower, to examine how lessons learned from an initial implementation influence performance emergence in subsequent projects. The emergence of a *de facto spatial buffer* and the interaction between takt time and groundwater tank and sewage treatment plant zone must be investigated further.

Table 2: Summary mapping table of reference vs Takt Time actual implementation

Stage	Focus	Level	Justification Evidence	Key Lesson Learned
1. Data gathering	P11 (Learning) , P3 (WiP control)	Weak	Initial planning relied primarily on contract schedules and limited historical productivity data; systematic recording of zone-level progress began only after execution started.	Insufficient early production data delayed understanding of WiP behaviour and constrained learning to post-execution analysis.
2. Zone & takt time	P2 (Batching) , P3 (WiP control)	Moderate	The project was divided into several takt zones depend on its floor; differences in work capacity across zones became visible only during execution, requiring informal adjustments.	Zoning supported flow structuring but must be treated as a design hypothesis subject to iteration.
3. Trade sequence	P10 (Pull by system status)	Moderate	Trade sequences were defined during planning; however, handoffs followed calendar dates rather than verified zone readiness.	Reliable handoffs require pull-based release of work grounded in actual system status.
4. Workflow balancing	P5 (Slack), P4 (Recovery strategies)	Weak-Moderate	Buffers embedded in the takt plan were gradually consumed due to productivity variation and minor disruptions, with limited mechanisms for replenishment.	Slack must be explicitly designed and actively managed to support resilience.
5. Final Schedule	P4 (Early deviation detection)	Weak	The takt schedule was finalized early to meet milestone commitments; subsequent deviations were handled locally rather than through plan revision.	Freezing takt plans too early limits adaptability and shifts control toward reaction.
6. Short-cycle takt control	P3 (WiP visibility), P10 (Pull control)	Moderate	Progress tracking relied on periodic planned-versus-actual comparison rather than per-takt or daily status monitoring.	Short-cycle monitoring is essential for anticipating missed handoffs before they occur.
Post-Project Learning	P11 (Work-as-imagined vs work-as-done)	Strong	Time differences between planned and realized production were analyzed after project completion.	Learning occurred mainly retrospectively; continuous learning cycles during execution are needed.

ACKNOWLEDGEMENTS

This study was made possible through the good cooperation between the project team of PTPP Building Division (Twin Tower Undip project), PTPP Division of Strategic, Planning, Technology and Engineering (Stratec), and the Indonesian Professional Society in Lean Construction Management (IAMKRI), whose commitment to advancing lean construction practices in Indonesia motivated this research. The authors extend their gratitude to them for its valuable role in fostering innovation and lean construction spirit to gain the effectiveness and efficiency as the real output and recognized as an output of lean practice in the company and Indonesia construction industry. The authors also made use of AI for improving and paraphrasing the manuscript written in English for clarity and readability purposes.

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