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SIMULATION OF TAKT TIME PLANNING STUDY CASE: HOUSING IN THE NEW CAPITAL CITY OF INDONESIA

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ABSTRACT

The housing development project in Indonesia's Nusantara Capital City (IKN) deals with various challenges, including high complexity and uncertainty, limited resources, and logistical issues. Effective construction management strategies are therefore required for accomplishing the project on time. Takt Time Planning is a method in Lean Construction used to adjust the workflow and to create an efficient process for complex projects. This study aims to simulate Takt Time Planning on a finished project focusing on the alignment between planned takt time and actual performance. We employ a systematic quantitative approach by integrating takt time analysis with the Line of Balance method, utilizing project documents, and field documentation. Our findings suggest that subsequent adjustments lead to improved efficiency and earlier project completion while initial planning encounters balancing issues. We highlight that Takt Time Planning should be followed up with control mechanism to reach takt time consistency.

KEYWORDS

Housing Development, Lean Construction, Project Management, Takt Time Planning, Workforce Efficiency, Line of Balance

INTRODUCTION

Takt time, meaning rhythm or beat in German words, is the maximum allowable time to complete one unit of work to meet customer demand (Heinonen & Seppänen, 2016). In lean construction, takt time synchronizes workflow and creates a stable, efficient, and waste-free production process (Binninger et al., 2017). The rhythm of construction progress, often referred to as its "heartbeat," is dictated by what is known as "Takt time." This concept is particularly prevalent in work sequences that are nearly identical and frequently repeated (Haghsheno et al., 2016). This concept is particularly relevant in construction projects with high complexity and

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uncertainty, such as the Nusantara Capital City (IKN) development project, where efficiency and predictability are essential for punctual project completion.

IKN is an ambitious project by the Indonesian government to relocate the national capital from DKI Jakarta to East Kalimantan province, which intends to reduce the burden on Jakarta and promote equitable economic development throughout Indonesia (Bappenas, 2024). The project includes the construction of essential infrastructures, housing, and supporting facilities that are considered modern, sustainable, and environmentally friendly urban areas (PUPR, 2024). Housing construction is crucial for running the IKN activities since it is intended for government employees' residences. However, this project deals with critical challenges such as massive scale, limited human resources, and logistical complexities in a remote location. A practical construction management approach, such as Takt Time Planning (TTP), is necessary to address these challenges and ensure efficient work completion.

This research analyses TTP for housing development in IKN, Indonesia. We will address TTP simulation for a tower of a housing project for evaluation. TTP provides valuable insight into understanding the rhythm of repetitive and identical construction processes. This study is expected to become a better reference for other towers or further housing projects in IKN. Despite the limitation of takt time studies in developing countries (Vatne & Drevland, 2016; Adegbembo et al., 2016), we focus on evaluating the alignment between the simulated takt time and actual performance on the field. Our findings suggest practical recommendations to enhance the efficiency and effectiveness of construction projects in the IKN area and other similar projects.

LITERATURE REVIEW

TAKT TIME PLANNING THEORY & IMPLEMENTATION

TTP, a method rooted in lean construction management, is used to organize construction processes more efficiently by aligning production speed with customer demand. It is calculated by dividing the available production time by the required output, establishing a production rhythm synchronizing work with demand (Binninger et al., 2017). In construction, TTP serves as a work structuring method that paces production across sequential zones, aligning the progress of various trades. This ensures smooth handoffs and continuous workflow and provides a framework for ongoing process improvements. Moreover, takt time is a key design parameter for labor-paced operations, particularly in repetitive projects, where it enhances predictability, reduces project duration, and lowers costs (Frandson & Tommelein, 2016; Frandson & Tommelein, 2014). Vatne & Drevland (2016) further affirm that implementing TTP significantly improves project efficiency and shortens completion times. According to Susilo and Andi (2019), the method consists of six phases: gathering project information, identifying work zones, understanding task sequences, balancing workflow, analyzing task durations, and conducting detailed production planning.

The balancing phase is particularly critical, as it involves refining task durations for each trade within the predefined zones. Once the variations in task durations are understood, the production team can apply several strategies to equalize workflow, such as redesigning imbalanced zones, modifying work methods, or resequencing tasks. In certain instances, tasks may need to be prefabricated off-site to meet the lower takt time threshold and reduce on-site installation time. Additionally, breaking down larger work items into smaller subtasks can help reduce takt time and accelerate the project schedule (Frandson et al., 2015). These balancing efforts are essential to ensure that all trades work at a synchronized pace and that the project progresses smoothly from one zone to another without delays or congestion.

A reliable visual planning and control tool is required to monitor and support the implementation of this balanced and synchronized workflow. One widely adopted tool in repetitive construction projects is the Line of Balance (LOB). The method visualizes the construction process and is used for planning and control (Pereira et al., 2022). It uses linear scheduling methods and integrates time-location data into production planning (De et al., 2014). Biotto et al. (2017) noted that LOB is a production design technique that utilizes project location as the core unit of analysis, allowing planners to map progress and resource use across zones. Typically, the LOB chart plots quantity or spatial units on the vertical axis and time on the horizontal axis, with diagonal lines showing the intended work rate. This approach lets planners visualize continuity, identify overlaps, and avoid trade interference. According to Sterzi & Bonesi (2024), maintaining continuous flow through LOB ensures more efficient use of space, minimizes idle time, and supports overall production system stability in lean construction environments.

TAKT TIME PLANNING COMPARISON WITH OTHER METHODS

There are several significant differences between Location Based Management (LBMS) and takt time. Firstly, LBMS prioritizes time, space, and plan buffers, while TTP focuses more on capacity, space, and plan buffers. Capacity is the primary buffer from load reduction. Secondly, schedule control in LBMS is conducted using a top-down approach, where engineers track progress and collaboratively resolve issues, and TTP employs a visual approach to control all team members. Finally, in resource allocation, LBMS tends to load all resources on production tasks with a consistent crew size, while TTP opts to underload crews to ensure timely handoffs and allow workers to complete tasks ahead of the takt time. This strategy provides room for additional work or preparation for the next takt sequence (Frandson et al., 2015).

Takt time and Critical Path Method (CPM) have a different perspective. The first method aligns with lean production systems by enhancing production efficiency and reducing waste. It focuses on regulating the production speed rhythm so that the quantity of products fulfils market demand within a specific time period. CPM is more relevant in project management. It aims to identify the critical activities in a project, which consists of a series of activities that must be completed on time for the project to be finished according to schedule. Thus, both takt time and CPM contribute to operational efficiency. However, takt time is more oriented towards daily production management, while CPM emphasizes the planning and management of complex projects more (Seppänen, 2014).

METHOD

RESEARCH DESIGN & DATA COLLECTION

This study investigates the simulation of TTP for a housing development project (Rusun ASN) at IKN, Indonesia's New Capital City, by employing a systematic quantitative approach. Our research combines takt time analysis and the LOB method to evaluate the actual project execution against planned schedules. Data were collected from project documents, including detailed work schedules, productivity reports, progress tracking records, and resource allocation plans, which provided critical insights into workflows, productivity rates, and resource utilization. Field documentation, such as project progress pictures and videos, was used to understand on-site construction activities and identify inefficiencies that were not evident in the writing documentation.

The initial step involved determining the takt time for each task, calculated based on productivity rates from historical data. These takt times were plotted using the LOB method to ensure consistent workflows and identify imbalances. Adjustments in resource allocation, labour distribution, and task sequencing were made to address deviations. The study also analyzed external factors, such as resource availability and weather conditions, to understand performance gaps comprehensively.

Our findings revealed areas of success and improvement. We validated our findings through discussions and comparisons with stakeholders and industrial benchmarks. This integrated approach demonstrates how TTP combined with LOB can unveil workflow inefficiencies and offer practical lessons to enhance project outcomes for future infrastructure development in IKN and beyond.

CASE STUDY

We chose the IKN project for our study case. The project is a typical integrated construction to design and build housing in Sepaku, Penajam Paser Utara, East Kalimantan Province. There were Precinct Core Tower (4 towers) and West Residence Tower (5 towers). Figure 1 illustrates the project map. We focus on a specific project in West Residence Tower, the construction project of Tower B Rusun ASN. This building has 10 floors and a roof.

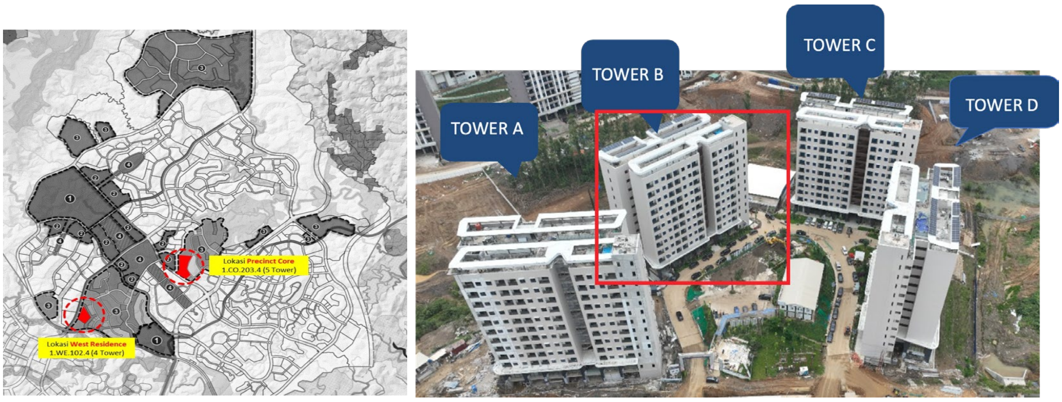

Figure 1 Project Location

The Owner is the Ministry of Public Works and Housing, and the main General Contractor (GC) is the consortium of PT PP (Persero) Tbk, PP Urban, and Jaya Konstruksi. The completion duration was 464 days starting from August 25, 2023, until November 30, 2024, and the maintenance duration is 180 days. This project was funded by the East Kalimantan Provincial Housing Provision Work Unit DIPA State Revenue and Expenditure Budget with a lump sum contract value of $105.495 million.

Based on contract value, this project was divided into several packages containing planning works (1.2559%), including Drawing Engineering Design (DED) planning, construction method, and building calculation. Other packages were sub-structure works (0.8598%), structural works (30.0361%), architecture works (29.9401%), and MEP works (27.5576%). Moreover, this project also had a working area, including pavement works (inside the site), MEP works, drainage works, landscape works, gate and guard post works, and road construction (outside the site).

RESULT

BALANCED TAKT TIME WITHOUT BUFFER TIME

The project initially had 16 tasks, and each project stage had to finish within the established schedule. Figure 2 illustrates the schedule inferred from the project data. The project team incorporated TTP into designing the project schedule. The project TTP showed that the project was set to be completed on June 29. However, we identified that some tasks in the planning were completed too quickly or slowly. This condition caused an unbalanced distribution of working time. In this subsection, we evaluate the project's planned schedule through a time reassessment and balancing process.

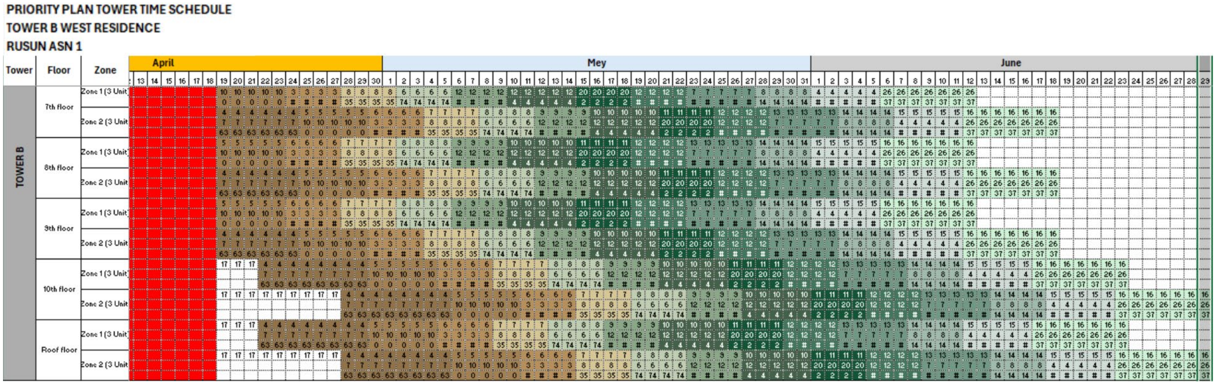

Figure 2 Bar Chart Schedule Project

Our first step is to establish takt time for the construction of Tower B Rusun ASN IKN and to redefine tasks. The takt time is set at 4 days. We divided the total available working time by the number of units that need to be completed to determine takt time. We combined formwork, ironing and casting as one task to finish within 4 days. Some tasks that need attention include the installation of brick walls and plumbing, electrical and data installation, precast facade installation, and finishing works such as painting and interior completion. By making improvements to these tasks, we expected better efficiency and productivity for each task to be completed in a shorter amount of time.

Figure 3 shows the balancing workflow process. Based on the data above, each task was balanced, resulting in a takt time of 4 days. This allows us to identify and address potential obstacles that may arise during project execution, ensuring that the workflow runs smoothly, and that each element of the project can operate synergistically.

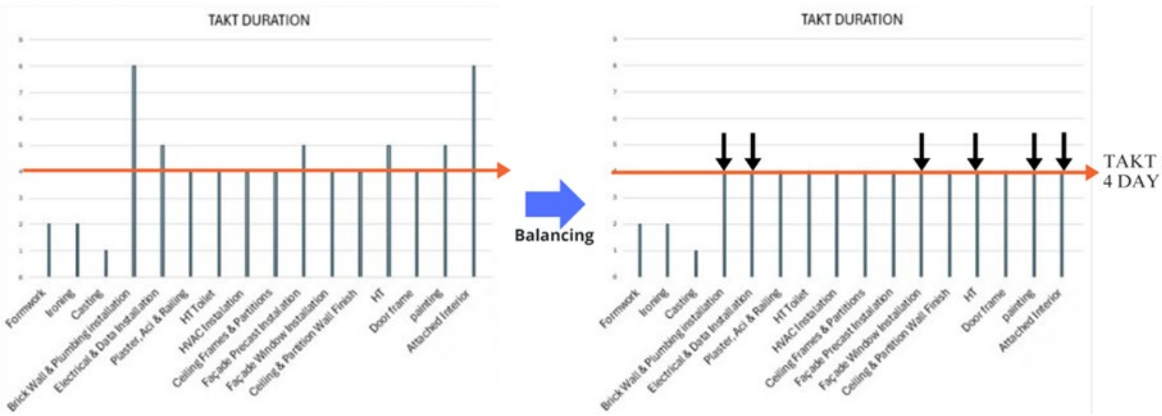

Figure 3 Balancing Workflow Takt Duration to 4 Days for Each Job

After we redefined the 16 tasks into 14 tasks, we now have the takt train (shown in Figure 4), where each wagon indicates a task to be performed and has a specific assigned colour. For example, light green represents structural works, light blue represents brick wall and plumbing installation, yellow represents electrical and data installation, and purple represents HVAC installation. Some task wagons are marked with different colour combinations to distinguish every task and make it easier to understand.

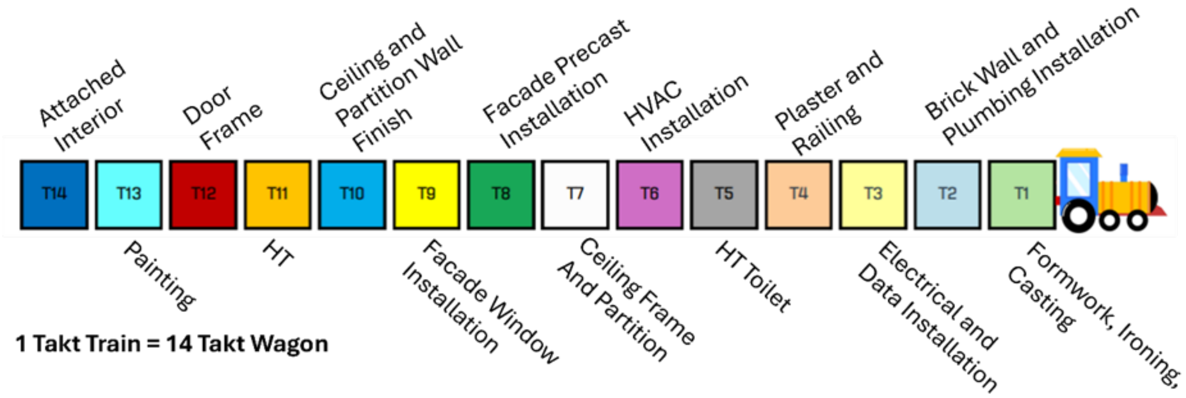

Figure 4 Takt Train that Explains 14 Jobs that Become Takt Wagon

Figure 5 shows the balanced takt time. With a takt time set at 4 days for each takt wagon, from formwork, ironing, casting (task 1; T1 in takt train) to attached interior (task 14; T14 in takt train), the entire series of tasks is expected to be completed efficiently. Therefore, considering this duration, the target completion date for all work could be completed by June 17, which is earlier than the planned schedule of the project data. However, the actual completion time was still far behind the planned schedule.

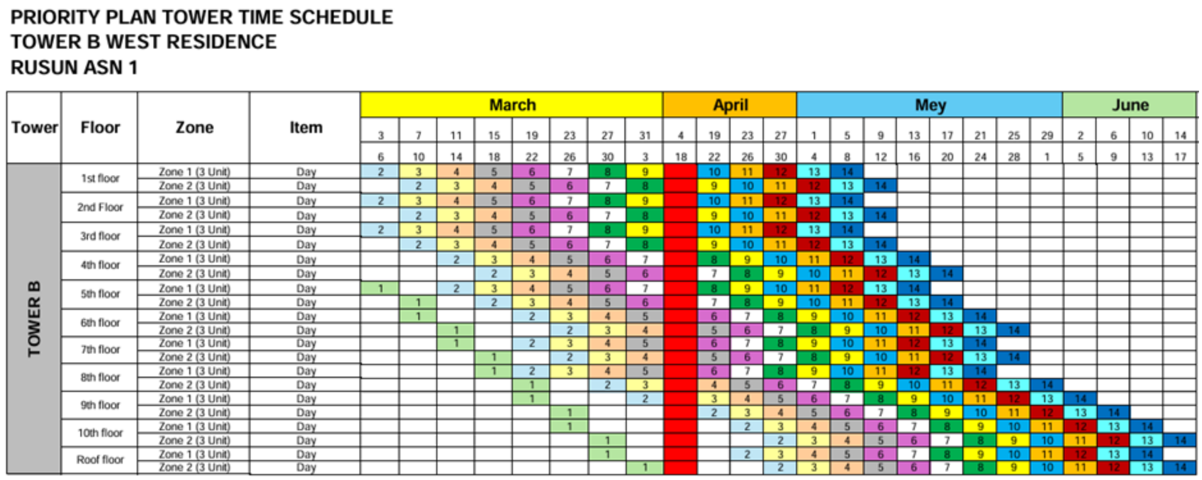

Figure 5 Bar Chart of Balanced Takt Time Planning (Bright Red Blocks are Holiday Time)

We observed several obstacles from the data that hindered project realization and caused delays or postponements. The obstacles include tasks from floor 1 to the roof, such as brick wall and plumbing installation, electrical and data installation, plastering, finishing and railing, HT toilet, HVAC, ceiling frames and partitions, facade window installation, ceiling and partition wall finishing, HT, door frame, painting, and attached interior. However, there are some tasks whose takt wagons still align with our balanced takt time. We found 4 days ineffective in the project because there was no buffer time in the balancing process.

REBALANCED TAKT TIME WITH BUFFER TIME

The previous subsection suggested that the project suffered from delayed completion because no buffer time was included in the planning. In this subsection, we simulated a rebalancing process to the previous result by including buffer time. However, during the execution phase, several activities—particularly brick wall installation (task 2; T2 in takt train)—experienced delays due to decreased productivity following public holidays. This caused a ripple effect that pushed subsequent tasks backward and effectively extended takt time. As a result, although rebalancing efforts were made, the takt time had to be adjusted, with some work packages requiring longer durations than initially planned. Therefore, the entire sequence of activities is now projected to be completed by September 17, as reflected in the Contractor's addendum.

Subsequently, a rebalancing was conducted based on the data obtained from the project data for each task, where the initial takt time of 4 days was adjusted to 12 days. This adjustment is expected to anticipate the completion of all work, which may otherwise be at risk of delays or postponements.

Figure 6 depicts the result of the rebalancing process of 4 days to 12 days. Based on the rebalanced takt time planning, the construction of Tower B Rusun ASN could be completed by September 17. The overall work is assumed to take 12 days (3 takt wagons), except for the structural work. However, there is a difference in completion time between floors 1-5 and floors six and above. Floors 1-5 could be completed on August 12, while floors six and above could be completed on September 17. This result indicates that the work duration for floors 1-5 was shorter compared to floors six and above.

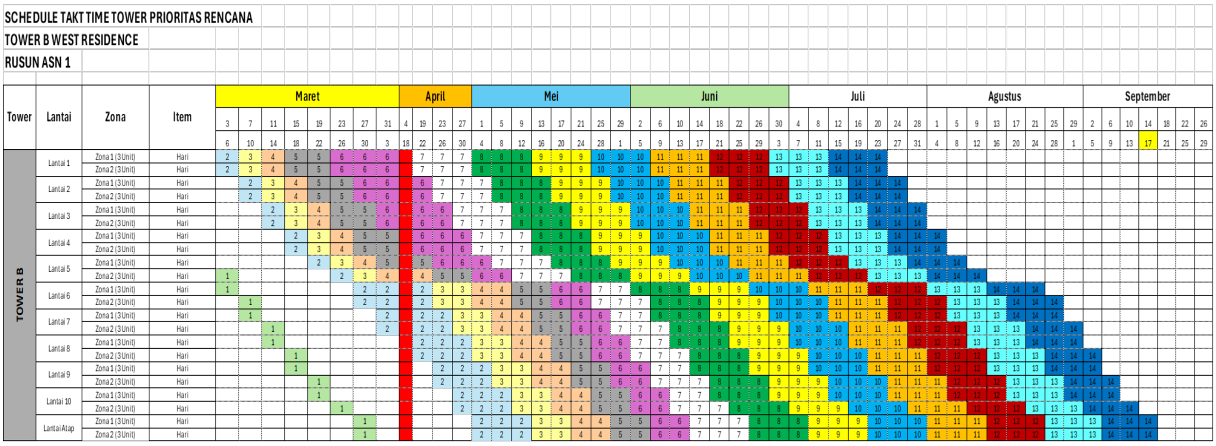

Figure 6 Rebalanced Planning with Buffer Time (Bright Red Blocks are Holiday Time)

From the rebalanced planning, it is suggested that structural work, brick wall work, and plumbing installation on floors 1-5 in zone 1, as well as plastering, finishing, and railing work on floors 1-5 in zone 1, could be accelerated. Additionally, tasks related to facade precast installation, door frame installation, and painting could be accelerated. In total, there are about six tasks that could be accelerated. The new completion time on September 17 indicates the importance of buffer time involvement in planning to complement TTP. The rebalanced schedule suggested plausible planning and the actual completion time could be considered ahead of the planned schedule.

Project Planning Acceleration

In this subsection, we simulated an accelerated project planning scenario to acknowledge the actual completion date of August 12, which was ahead of the rebalanced takt time schedule. Figure 7 illustrates this project's acceleration. The construction schedule for Tower B of the Rusun ASN project, initially planned to conclude in March, is now projected to finish earlier in August. The work had task durations ranging from 5 to 10 days. Tasks with durations of 10 days were further split into two takt wagons to accommodate better sequencing and manageability.

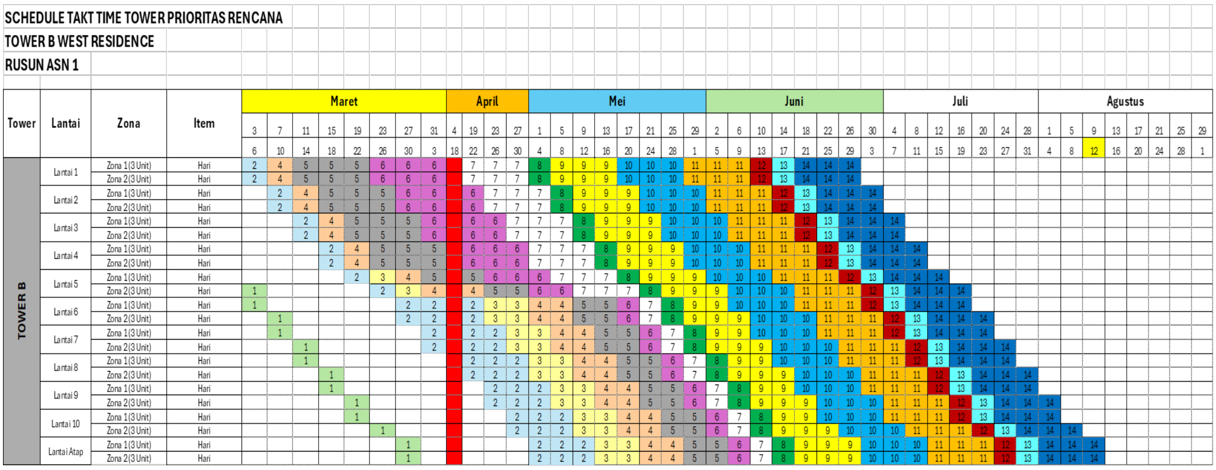

Figure 7 Bar Chart of Project Planning Acceleration (Bright Red Blocks are Holiday Time)

Some tasks, such as tasks 8, 12, and 13 (specifically facade works, door frame installation, and painting; T8, T12, T13 in takt train) were identified as having acceleration potential. These tasks were levelled across floors, allowing concurrent execution from the first floor up to the roof. However, the attached interior, which includes interior works, could not be accelerated. This was primarily due to the fact that these works were managed by a nominated subcontractor (NSC) appointed by the project owner, thereby limiting the contractor's control over scheduling.

In contrast, plastering, railing, HT toilet, and HVAC installation (tasks 4, 5, and 6; T4, T5, T6 in takt train) faced significant constraints in terms of acceleration. These activities were directly affected by delays stemming from the revised takt time, which had been changed from 4 days to 12 days due to resource reallocation and workflow adjustments. As a result, these tasks became critical path items with limited flexibility for rescheduling, making further acceleration impractical. Despite these constraints, the overall project was successfully expedited and completed by August 12.

DISCUSSION

TTP and supporting strategies demonstrate significant improvements in productivity and execution efficiency (Pradoto et al., 2022). Balancing the TTP suggested that the project could be completed early by leveraging the project's initial TTP by emphasizing structured workflows and synchronized activities. The improvement from the completion time of June 29 to June 14 suggested that there was room for refining the original plan based on the project data. However, a comparison between the actual completion time on August 12 and both theoretical completion times indicates a touch of over-optimism bias and negligence of project complexity and uncertainty from the project planner (De Cossio et al., 2024).

One of the solutions to define a plausible project schedule is introducing buffer time in the balancing process of TTP. The inclusion of buffer time accommodates delays due to the IKN project's high complexity and uncertainty. The combination of balanced takt time with and without buffer time provides a time interval for project completion, which could give the project team the possibility to adapt to the real project situation. For a project with similar complexity and uncertainty, we suggest project planners employ TTP with and without buffer time to estimate the optimistic and plausible project schedule; pure TTP could be unsuitable for such projects (Tommelein et al., 2024).

In the project planning acceleration, where the project was completed significantly ahead of rebalanced schedule by August 12, we noted that this success was primarily attributed to the optimization of supporting strategies, including facade precast modularization, supplier segmentation, and a structured workflow sequence for gondola operations during the project. As we probed into the project data, some factors that played a pivotal role were the operation of the gondola, supplier segmentation, and modularization and prefabrication, leading to time reductions in tasks 8, 12, and 13. The structured sequence of gondola operations ensured a well-organized workflow and minimized idle time. Supplier segmentation reduced risks associated with material delivery. Modularization and prefabrication enabled parallel production and installation.

In the context of TTP, this method aligns the pace of production with demand and optimizes workflows to reduce inefficiencies (Aisyah & Putra, 2024; Aisyah et al., 2023). Our findings underscore the adaptability of TTP in handling dynamic project environments and integrating innovative strategies to accelerate completion time. Overall, the results in project acceleration exemplify how the combination of TTP, effective resource management, and advanced construction techniques can deliver projects ahead of schedule while maintaining high-quality standards.

The simulation of TTP in the Rusun ASN housing project at IKN provided valuable insights into its effectiveness and areas for improvement. One of the key lessons learned was the lack of proper balancing during the initial planning phase. This oversight resulted in an uneven distribution of workloads, causing inefficiencies and disruptions across the project timeline. Furthermore, it was observed that when takt time was disturbed, the entire workflow sequence was affected. For instance, delays in a single phase escalated from a 4-day delay to a 12-day disruption, demonstrating the cascading impact of takt time disturbances on project schedules.

Efforts were made to mitigate these issues through lean construction practices aimed at accelerating workflows and realigning the takt time to match the original TTP schedule. These efforts included rebalancing tasks and optimizing workflows. However, despite this integration, maintaining control over takt time remained challenging. The lack of continuous monitoring and control of takt time further highlighted the need for integration between TTP and LPS, ensuring a smoother and more predictable workflow throughout the project lifecycle.

Another critical insight was that TTP, at the beginning of the project, was overoptimistic and overlooked the project's complexity and uncertainty. As rebalanced TTP with buffer time was introduced, plausible planning could be performed. Additionally, the evaluation of TTP performance was conducted toward the end of the project, limiting its ability to provide timely feedback and improvements during the critical phases of construction. This delay in evaluation underlined the importance of conducting regular assessments and adjustments during the project rather than waiting until the final stages.

This study serves as a reminder that successful TTP requires thorough preparation, continuous monitoring, and proper integration with other project management methodologies. For future improvement, TTP implementation must be supported by a properly executed LPS to ensure that takt time is balanced, controlled, and aligned with the overall project objectives (Tommelein and Emdanat, 2022). By addressing these lessons learned, future projects in IKN and beyond can achieve higher levels of efficiency, predictability, and overall success.

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