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The impact of overtime duration variations on labor productivity in apartment construction projects: A study on engineering and disaster management in the construction sector

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ABSTRACT

Background: Construction projects, especially apartment buildings, often face challenges such as resource limitations, unpredictable weather, and schedule delays, which lead to increased costs and reduced productivity. Overtime is a commonly adopted strategy to address these issues; however, its effect on labor productivity is complex. **Methods:** This study investigates the impact of varying overtime durations (1, 2, and 3 hours) on labor productivity and Labour Utilization Rate (LUR) for three critical tasks: rebar installation, concrete casting, and formwork installation in the Sky House Alam Sutera project. The Productivity Rating method and LUR analysis were used to evaluate normal productivity and productivity during overtime, with data collected through direct observation, interviews, and project documentation analysis. **Findings:** The results reveal that while overtime increases daily output, it also reduces productivity per hour as work hours extend. Rebar installation exhibited the most significant decline in productivity, from 493.529 kg/hour during regular hours to 345.470 kg/hour with 3 hours of overtime. Correspondingly, the LUR improved with overtime, with rebar installation increasing from 68% under normal conditions to 72% with 3 hours of overtime. Similarly, the cost of labor increased by 9%–23% due to overtime, depending on the task and duration. **Conclusion:** The findings suggest that the optimal overtime duration is 1 hour, balancing productivity gains, cost efficiency, and LUR improvements, while prolonged overtime may lead to diminishing returns due to worker fatigue. This study provides insights into managing overtime in construction projects, emphasizing the importance of controlling overtime durations to achieve project objectives efficiently. **Novelty/Originality of this article:** This study offers an original perspective by examining the impact of varying overtime durations on both labor productivity and Labor Utilization Rate (LUR) in the context of construction projects, using a detailed analysis of three critical tasks.

KEYWORDS: apartment building; construction projects; cost efficiency; labour utilization rate; labor productivity; overtime.

1. Introduction

Apartment construction is a complex and resource-intensive process that demands meticulous planning, coordination, and execution. Effective time and cost management play a pivotal role in ensuring project success. The challenges inherent in apartment construction projects encompass various dimensions, including resource constraints, environmental factors, and changes in design specifications. Limited resources often lead to scheduling conflicts and inadequate workforce allocation, which further exacerbate project

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timelines (Ngunadi & Anondho, 2018). In parallel, Purba (2022) elaborates on how unpredictable weather events can lead to delays and increased costs, which necessitate efficient contingency planning to maintain project viability.

Design changes present another significant challenge, as outlined by Hernandi & Tamtana (2020), who argue that alterations initiated by stakeholders or regulatory bodies can prompt significant shifts in project timelines and budgets. Such modifications often rely on swift communication and agile project management techniques to mitigate disruption. Shen & Sammani (2022) indicate that these factors culminate in pronounced cost overruns and can erode stakeholder trust, making effective communication and transparency essential throughout the project lifecycle.

To address schedule slippage, many construction managers resort to overtime work as a practical, short-term method for boosting output. However, the impact of overtime varies widely based on project type, labor capacity, task complexity, and management style. Yanti (2017) notes that overtime can temporarily increase productivity when implemented in a planned and limited manner. Yet, when applied excessively or without regard to workforce fatigue, it can lead to diminishing returns.

Research shows that overtime may benefit repetitive and task-based activities like rebar tying or basic formwork assembly in the short term, but prolonged schedules often result in physical exhaustion, reduced focus, and increased risk of errors (Ghodrati et al., 2022; Lenggogeni, 2016; Mahamid, 2022; Stimpfel et al., 2012; Zhang et al., 2015), further corroborate these concerns, illustrating how overtime-related fatigue can impair both physical and cognitive performance, leading to higher safety incidents and lower productivity.

The health and safety risks linked to excessive overtime have been widely documented in occupational health literature, particularly in labor-intensive sectors such as construction. Numerous studies demonstrate that extended working hours lead to cumulative fatigue, which significantly impairs both physical endurance and cognitive functioning, thereby increasing the risk of accidents and injuries on construction sites. (Evanoff et al., 2019) found that mandatory overtime correlates with heightened worker fatigue, reduced alertness, and lower productivity, all of which contribute to a greater incidence of workplace injuries. These risks are particularly pronounced in construction tasks that demand precision, such as rebar installation, formwork assembly, and concrete finishing.

In countries such as Japan, the United States, and the United Arab Emirates, construction overtime policies are being reevaluated due to their implications on worker health and project safety. Japan has implemented labor law reforms following public outcry over karōshi (death by overwork), setting maximum limits on overtime hours (Tanemura et al., 2023). In the U.S., Occupational Safety and Health Administration (OSHA) regulations emphasize the importance of rest periods and task rotation to mitigate the effects of fatigue. These international developments highlight the need for a balanced approach in managing overtime—particularly in developing countries like Indonesia, where labor regulations are still evolving in response to economic demands and project timelines.

In the Sky House Alam Sutera Apartment Project, a shortage of skilled labor in rebar installation, concrete pouring, and formwork has led to project delays. These challenges are further compounded by material delivery disruptions and unpredictable weather conditions, which hinder concrete pouring and formwork execution, increasing reliance on overtime.

Labor productivity is a crucial factor in construction, as it significantly impacts the successful execution of a construction project (Mirnayani & Prakoso, 2024; Rana et al., 2023). Overtime productivity varies significantly across different construction projects (Mahamid, 2022; Vigneshwar & Shanmugapriya, 2022). While overtime can temporarily boost productivity, studies show that prolonged work hours may lead to diminishing efficiency due to worker fatigue (Lenggogeni, 2016). Research confirms that labor productivity differs between regular and overtime hours, with overtime not always yielding optimal output due to exhaustion and reduced focus (Jacobsen et al., 2024; Sujana & Hakim, 2021).

The effects of overtime vary across sectors. In residential projects, moderate overtime can enhance efficiency, especially for manual labor tasks. However, in large-scale infrastructure projects—such as bridges, roads, and dams—prolonged overtime can lead to declining productivity due to increased fatigue, cognitive decline, and heightened safety risks (Subakir & Sugiyanto, 2022). Precision-focused tasks, such as bridge construction and dam projects, require high levels of accuracy and safety compliance, making extended overtime a potential risk to work quality, (Darmawan, 2023; Mardikaningsih et al., 2022).

Moreover, work stress and environmental factors significantly influence productivity. High stress levels can lower efficiency, and an unsupportive work environment can amplify the negative effects of overtime (Wijaya & Waty, 2023). Additionally, worker motivation plays a crucial role in maintaining labor performance during extended work hours (Mirnayani & Kholida, 2022). Cost efficiency is another critical aspect—when productivity increases, the cost per unit of work decreases, while low productivity results in higher costs due to extended resource use (Nurhendi & Bastam, 2023).

At Sky House Alam Sutera Apartment Project, overtime schedules are flexible, starting after 6:00 PM on weekdays and 2:00 PM on Saturdays, depending on site conditions and project requirements. This flexibility aims to balance progress monitoring and deadline achievement. This study adopts a quantitative and qualitative approach to analyze the impact of overtime on labor productivity, cost efficiency, and Labour Utilization Rate (LUR) in apartment construction projects. The study focuses on three critical tasks: rebar installation, concrete casting, and formwork installation. The descriptive-analytical approach integrates data collection, productivity rating methods, and LUR calculations to assess labor efficiency under normal and overtime conditions.

The Productivity Rating method and LUR calculations are essential tools in construction project management, evaluating workforce efficiency and utilization (Nurhendi et al., 2022). LUR measures the proportion of productive labor time relative to total available hours, which includes effective, contributory, and ineffective work. It is a key metric in large-scale projects, particularly those requiring extensive labor coordination, such as apartment construction (Bista et al., 2024; Odesola et al., 2013).

By analyzing LUR under normal and overtime conditions, this research aims to determine the optimal overtime duration that balances productivity, workforce utilization, and cost efficiency. Additionally, the study assesses the financial implications of overtime and identifies best practices for project acceleration. The findings will provide practical recommendations for project managers to optimize labor performance and resource allocation, ensuring that project objectives are achieved efficiently and cost-effectively. This study's findings are also relevant to disaster management and risk assessment. Overtime labor plays a crucial role in post-disaster reconstruction, where rapid response is needed to restore essential infrastructure while maintaining safety standards. Proper risk management strategies must be applied to balance overtime workloads and ensure worker well-being in high-risk environments.

2. Methods

The study adopts a descriptive-analytical approach, integrating data collection and analysis to understand the effects of overtime on construction productivity. The Productivity Rating method and LUR calculations are employed to quantify labor efficiency and utilization.

2.1 Data collection

The data collection in this study focuses on three critical tasks in apartment construction: rebar installation, which involves the placement and binding of reinforcing steel bars to ensure structural stability; concrete casting, which includes the mixing, transportation, and placement of concrete to form building elements; and formwork installation, which refers to the assembly of temporary structures that shape and support poured concrete until it hardens. These tasks were selected due to their high labor intensity and significant reliance on skilled workers, making them highly susceptible to productivity variations caused by overtime work.

Primary data for this study was obtained through direct observations, time studies, structured interviews, and worker surveys, all of which were conducted at the Sky House Alam Sutera Apartment Project across five floors (30 to 34). As part of the time and motion study, labor activities were categorized into three main types: Effective Work, referring to time spent on actual productive tasks. Contributory Work, which includes necessary but non-productive activities such as material handling. And Ineffective Work, representing time lost due to waiting, delays, or rework. Data collection was carried out during both regular working hours and overtime periods, covering 1, 2, and 3 additional hours of extended work. Secondary data sources were analyzed, including project documentation, such as labor rosters, work schedules, wage reports, and productivity records.

2.2 Population data of workers

The workforce involved in this study consists of construction personnel assigned to three main tasks: rebar installation, concrete pouring, and formwork installation. The distribution of workers is categorized by job roles, which include general workers (*pekerja*), skilled workers (*tukang*), assistant foremen (*wakil mandor*), and foremen (*mandor*). For rebar installation (*pembesian*), the total number of workers is 40, consisting of 10 general workers, 25 skilled workers, 4 assistant foremen, and 1 foreman. For concrete pouring (pengecoran), the total workforce amounts to 12, including 6 general workers, 4 skilled workers, 1 assistant foreman, and 1 foreman. And formwork installation (bekisting Aluko), there are 27 workers, composed of 10 general workers, 15 skilled workers, 1 assistant foreman, and 1 foreman.

According to the Decree of the Minister of Manpower and Transmigration of the Republic of Indonesia Number KEP. 102/MEN/VI/2004, specific regulations govern overtime work to ensure fair treatment of workers. Overtime is limited to a maximum of 3 hours per day to prevent excessive fatigue among employees. Additionally, if overtime exceeds 3 hours, employers are required to provide food and beverages containing at least 1,400 calories to support workers' energy needs. Furthermore, the first hour of overtime work must be compensated at 1.5 times the regular hourly wage, ensuring workers receive fair remuneration for their additional effort. These standards highlight the importance of balancing productivity demands with workers' welfare and rights.

The Productivity Rating method was employed to assess labor productivity. This involved comparing output per hour during regular work hours with that during various overtime durations (1, 2, and 3 hours).

3. Results and Discussion

3.1 Normal work productivity

The productivity calculation aims to determine the difference between normal productivity and overtime productivity across three key tasks: rebar installation, concrete casting, and formwork installation (Bekisting Aluko). Normal productivity is calculated using the formula (Citra et al., 2025).

$$Normal\ Productivity = \frac{work\ volume}{Normal\ Duration} \tag{Eq. 1}$$

The calculation of normal work productivity aims to measure the capability of the workforce to complete a specific work volume under standard working hours (without overtime). Table 1 is the results of the normal productivity calculations.

Table 1. Results of normal work productivity calculation

No	Type of Work	Volume	Normal Duration (days)	Normal Productivity
1	Rebar Installation	51,327 kg	13	3,948.231 kg/day
2	Concrete Casting	260 m^3	8	32.5 m^3/day
3	Formwork Installation	1,800 m^3	8	225 m^3/day

3.2 Labor productivity with 3 alternative overtime durations

The addition of working hours aims to increase daily output, enabling faster completion of specific activities. The overtime planning in this study is based on an 8-hour regular work schedule with a 1-hour break (08:00 – 17:00), followed by overtime performed after regular working hours (17:00 – 18:00). This research focuses on three types of overtime durations: 1-hour overtime, 2-hour overtime, and 3-hour overtime extensions. These scenarios are analyzed to assess their impact on labor productivity, project completion time, and cost efficiency, providing insights into the optimal management of extended working hours in construction projects. Here's the formula breakdown and its interpretation for calculating productivity during overtime work.

$$Productivity\ Per\ Hour = \frac{Total\ Productivity\ (units)}{Total\ working\ Hours} \quad \text{(Eq. 2)}$$

$$Accelerated\ Productivity\ (1\ Hour) = (8 \times Productivity\ Per\ Hour) + (Overtime\ Duration \times Productivity\ Per\ Hour) \quad \text{(Eq. 3)}$$

The concept of productivity per hour is used to determine the average output of workers during standard working conditions. This serves as a baseline for evaluating changes in productivity when overtime is introduced. To calculate accelerated productivity for one hour, the formula combines the total output from normal working hours (8 hours) with the added productivity from one hour of overtime. The research analyzed the impact of varying overtime durations on labor productivity for three key tasks: rebar installation, concrete casting, and formwork installation in the Sky House Alam Sutera Apartment construction project. The main findings are summarized at Table 2 and Table 3.

Table 2. Productivity during normal and overtime conditions

Task	Normal Productivity	Overtime Productivity (1 hour)	Overtime Productivity (2 hours)	Overtime Productivity (3 hours)
Rebar Installation	493.528 kg/hour	444.176 kg/ hour	394.823 kg/hour	345.470 kg/hour
Concrete Casting	4,062 m^3/hour	3,657 m^3/ hour	3,250 m^3/hour	2.844 m^3/hour
Formwork Installation	28.125 m^3/hour	25.313 m^3/hour	22.500 m^3/hour	20.625 m^3/hour

From the analysis Table 2 reveal that productivity progressively decreases as overtime hours increase, highlighting the impact of extended working hours on worker efficiency. Among the tasks studied, rebar installation exhibits the most significant decline in productivity, likely due to the physical intensity and laborious nature of the task. In contrast, shorter overtime durations, such as 1 hour, maintain relatively higher productivity levels compared to extended durations, emphasizing the importance of limiting overtime to achieve a balance between project acceleration and worker performance.

Table 3. Accelerated productivity during normal and overtime conditions

Task	Normal Productivity	Accelerated Productivity (1 hour)	Accelerated Productivity (2 hours)	Accelerated Productivity (3 hours)
Rebar Installation	3,948.231 kg/day	4,329.408 kg/day	4,737.878 kg/day	4,984.643 kg/day
Concrete Casting	32.5 m^3/day	36.161 m^3/day	39.005 m^3/day	41.036 m^3/day
Formwork Installation	225 m^3/day	250.313 m^3/day	270.000 m^3/day	284.063 m^3/day

Table 3 reveal that productivity increases progressively across all tasks with the addition of overtime hours, with rebar installation showing the highest increment due to its intensive nature. However, the benefits of extended overtime diminish over time, as the rate of productivity improvement reduces progressively due to worker fatigue. For instance, in rebar installation, the jump in productivity from normal conditions to 1-hour overtime is substantial, but the additional gains become less significant with 2- and 3-hour overtime durations. Achieving an optimal balance is crucial, as 1-hour overtime provides a significant productivity boost while maintaining high efficiency. In contrast, extended overtime (2-3 hours) further increases productivity but can strain workers and lead to disproportionate cost increases, highlighting the need for careful management of overtime durations.

Each task exhibits different productivity levels under normal working conditions and overtime durations of 1, 2, and 3 hours. The graph highlights how productivity initially increases with overtime but eventually declines due to fatigue. Under normal conditions, daily productivity values were recorded as follows: 3,948.23 kg/day for rebar installation, 32.50 m^3/day for concrete casting, and 225.00 m^3/day for formwork installation. These figures serve as a benchmark for evaluating the impact of overtime on labor performance. With the introduction of 1 hour of overtime, productivity increased across all tasks: rebar installation reached 4,329.41 kg/day, concrete casting improved to 36.16 m^3/day, and formwork installation rose to 250.31 m^3/day. However, the per-hour productivity declined slightly in each category, indicating the early onset of fatigue.

As overtime increased to 2 hours, daily output continued to grow (4,737.88 kg/day for rebar, 39.01 m^3/day for concrete, and 270.00 m^3/day for formwork), but hourly productivity further declined. At 3 hours of overtime, the trend became more pronounced: although daily output peaked (e.g., 4,984.64 kg/day in rebar installation), per-hour productivity fell significantly, with formwork dropping to 20.625 m^3/hour and concrete casting to 2.844 m^3/hour. This analysis confirms that while daily output may increase with longer work hours, hourly productivity shows a consistent downward trend, particularly beyond the second hour of overtime

3.3 Crash duration calculation

Crash duration is calculated to determine the reduced time required to complete a task by utilizing additional resources, such as overtime. The formula for crash duration incorporates both normal productivity and productivity during overtime, reflecting the accelerated pace of work (Fardila & Adawyah, 2021).

$$Crash\ Duration = \frac{Work\ Volume}{Accelerated\ Productivity} \quad \text{(Eq. 4)}$$

Table 4. Crash duration

Task	Normal Duration	Duration with 1 Hour Overtime	Duration with 2 Hours Overtime	Duration with 3 Hours Overtime
Rebar Installation	13 days	12 days	11 days	10 days
Concrete Casting	8 days	7 days	7 days	6 days
Formwork Installation	8 days	7 days	7 days	6 days

Based Table 4, that task durations gradually decrease with the addition of overtime hours. Adding 1 hour of overtime significantly accelerates task completion while maintaining relatively high productivity levels, making it an efficient choice for balancing time and performance. However, utilizing 3 hours of overtime achieves the greatest reduction in task duration but comes with a notable decline in hourly productivity due to worker fatigue.

3.4 Cost calculation

Cost calculation is an essential part of analyzing the impact of overtime on project expenses. The total labor cost during normal and overtime conditions is calculated by incorporating the regular hourly wage and additional overtime rates (Table 5).

Table 5. Normal wage and workforce

Worker Type	Wage for Rebar Installation (IDR)	Wage for Concrete Casting (IDR)	Wage for Formwork Installation (IDR)	Workforce for Rebar Installation	Workforce for Concrete Casting	Workforce for Formwork Installation
Worker/labourer	95,000	90,000	115,000	25	4	15
Craftsman	125,000	120,000	150,000	4	1	1
Assistant foreman	150,000	150,000	175,000	1	1	1

The Accelerated Wage accounts for the additional costs incurred due to overtime. It includes both the normal daily wage and the overtime costs for a given task and duration. The formula is:

$$Accelerated\ Wage = (Normal\ Daily\ Wage + Total\ Overtime\ Wage) \times Number\ of\ Workers \times Crash\ Duration \qquad \text{(Eq. 5)}$$

The accelerated wage cost analysis Tabel 6, highlights the financial trade-offs of implementing overtime to reduce project duration. Rebar installation exhibits the highest increase in wage costs during overtime. This reflects the labor-intensive nature of the task, making it costlier to accelerate. Concrete casting, relatively more cost-efficient to accelerate compared to other tasks.

Table 6. Accelerated wage cost calculation

Task	Total normal wage cost (IDR)	Overtime wage cost (1 Hour, IDR)	Overtime wage cost (2 Hour, IDR)	Overtime wage cost (3 Hour, IDR)
Rebar installation	51,025,000	55,931,424	62,064,222	66,234,520
Concrete casting	9,120,000	9,476,250	11,471,271	11,542,518
Formwork installation	24,800,000	25,768,841	31,193,841	31,387,578

Formwork installation experiences a significant cost increase during overtime. While it is less costly than rebar installation, the additional costs are still considerable. Cost Slope is used to determine the additional cost per unit time saved during project acceleration. It helps in evaluating the efficiency of time-cost trade-offs in project management (Fardila & Adawyah, 2021). Formula for Cost Slope:

$$Cost\ Slope = \frac{Crash\ Cost - Normal\ Cost}{Normal\ Duration - \ Crash\ Duration} \quad \text{(Eq. 6)}$$

The analysis presented in Table 7 provides critical insights into the cost implications of overtime and project acceleration for various construction tasks. Rebar installation exhibits the steepest cost slope across all overtime scenarios. This reflects the high financial impact of accelerating labor-intensive tasks, suggesting that overtime for rebar installation should be used sparingly or optimized for efficiency. Conversely, concrete casting demonstrates a more gradual increase in cost slope, this indicates that concrete casting is a more cost-effective task to accelerate, offering significant time savings with moderate financial trade-offs. Similarly, formwork installation displays a manageable cost slope of IDR 968,841 for 1 hour of overtime, but it escalates to IDR 6,393,841 for 2 hours, making longer overtime durations less financially viable. The findings underscore the importance of balancing cost and time savings. Tasks with lower cost slopes, such as concrete casting, should be prioritized for acceleration, while tasks with higher cost slopes, like rebar installation, require strategic planning to minimize cost overruns.

Table 7. Accelerated wage cost calculation

Task	Overtime (Hours)	Crash cost (IDR)	Normal cost (IDR)	Crash duration	Normal duration	Cost slope (IDR)
Rebar Installation	1	55,931,424	51,025,000	12	13	4,906,424
	2	62,064,222		11		5,519,611
	3	66,234,520		10		5,069,840
Concrete Casting	1	9,476,250	9,120,000	7	8	356,250
	2	11,471,271		7		2,351,271
	3	11,542,518		6		1,211,259
Formwork Installation	1	25,768,841	24,800,000	7	8	968,841
	2	31,193,841		7		6,393,841
	3	31,387,578		6		3,293,789

3.5 Labour utilization rate (LUR) calculation

Labour Utilization Rate (LUR) is a metric used to evaluate the efficiency of labor utilization on a construction project. It represents the percentage of time workers spend on productive activities compared to the total time available (Alaloul et al., 2021). These categories help evaluate how effectively labor is utilized in different tasks across the project.

$$LUR = \frac{Effective\ Work\ Time + 0{,}25\ x\ Contributory\ Work\ Time}{Total\ Observed\ Work\ Time} \quad \text{(Eq. 7)}$$

Based on the observed activities, the Labor Utilization Rate (LUR) is calculated by categorizing worker activities into three types: effective work, essential contributory work, and ineffective work. Effective work includes activities that directly contribute to the construction process, such as tying rebar or pouring concrete. Essential contributory work refers to supporting tasks that are necessary for the operation but do not directly add to the final result, such as material preparation or equipment setup. Ineffective work encompasses time spent idle or engaging in activities unrelated to the construction task, for instance, waiting for materials or making unnecessary movements.

Table 8. Work time classification in rebar installation, concrete casting, and formwork installation

Task	Effective Work Time	Contributory Work Time	Ineffective Work
Rebar Installation	Cutting, bending, tying, and placing rebar as part of structural reinforcement.	Preparing materials, transporting rebar, setting up equipment, and coordinating with other teams.	Unplanned Breaks and Rest Periods, Waiting for Materials or Equipment
Concrete Casting	Mixing and preparing concrete (if done on-site). Transporting concrete using buckets, wheelbarrows, or pumps. Pouring concrete into formwork. Vibrating and compacting concrete to remove air voids. Finishing concrete surfaces to ensure proper leveling.	Cleaning and setting up casting areas. Checking reinforcement and formwork before pouring. Waiting for concrete delivery from batch plants. Installing temporary protection for fresh concrete. Tool and equipment preparation.	Waiting for concrete trucks to arrive due to site congestion. Rework due to segregation or honeycombing in concrete. Delays in vibrating or compacting, leading to cold joints. Excessive worker breaks due to physical fatigue. Interruptions due to equipment failure (e.g., broken concrete pump, vibrator malfunction).
Formwork Installation	Measuring and cutting formwork materials (plywood, timber, steel, etc.). Assembling formwork components and securing them into place. Aligning and bracing formwork to maintain structural integrity. Applying release agents to prevent concrete adhesion. Dismantling formwork after concrete curing.	Transporting formwork materials to the designated work area. Checking alignment, verticality, and reinforcement placement before installation. Waiting for crane or hoisting equipment to lift large formwork panels. Organizing and stacking dismantled formwork for reuse. Cleaning formwork panels after removal.	Waiting for materials or equipment (e.g., formwork panels, nails, or braces). Rework due to misaligned or incorrectly installed formwork. Delays in dismantling due to premature removal risks. Worker fatigue leading to frequent and extended rest breaks. Communication issues between site workers and supervisors, causing downtime

The data presented in Fig 2 shows a clear upward trend in LUR as overtime hours increase, demonstrating the potential benefits of overtime in improving productivity. The analysis of Labour Utilization Rate (LUR) across the three tasks reveals that rebar installation benefits the most from overtime, with a steady increase from 68% to 72%, making it an ideal task for project acceleration. Concrete casting also sees improvements, rising from 68% to 71%, though with smaller incremental gains, indicating limited benefits beyond a certain overtime duration. Formwork installation, which starts at the highest LUR (69%), shows only marginal improvements, reaching 71% after 3 hours, suggesting that overtime has minimal impact on this task's efficiency and may not be necessary for optimization. These findings highlight that rebar installation is the most suitable for overtime scheduling, while formwork installation may not require extended hours for optimal productivity.

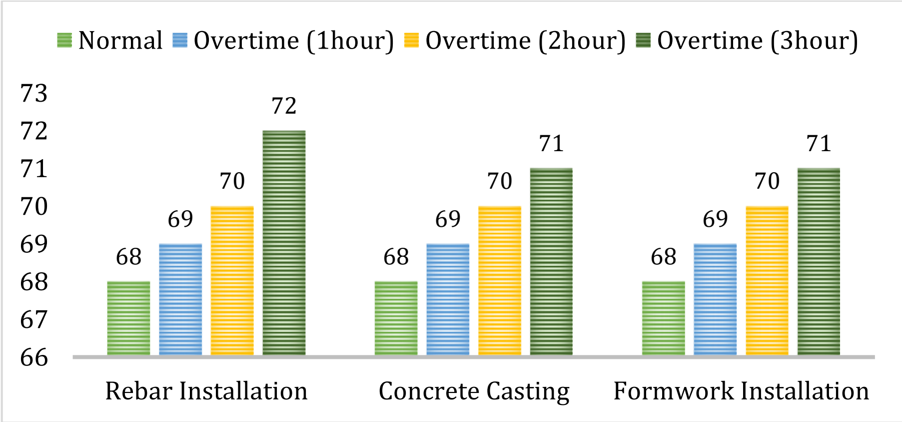

Fig. 2. The Labour Utilization Rate (LUR) recapitulation for overtime (1–3 hours)

Figure 3 presents a comparative analysis of three labor-intensive construction activities—rebar installation, concrete casting, and formwork installation—under varying overtime durations (1–3 hours). The data visualized includes three key metrics: hourly productivity, Labour Utilization Rate (LUR), and total wage cost (IDR).

Fig. 3. Comparison of productivity, labour utilization rate (LUR), and cost across construction tasks under different overtime durations

For rebar installation, overtime initially enhances daily output, but at the cost of declining productivity per hour. Productivity drops from 493.53 kg/hour (no overtime) to 345.47 kg/hour (with 3 hours of overtime). However, LUR improves from 68% to 72%, indicating that more time is being utilized for productive activities. The cost increases significantly from IDR 51,025,000 to IDR 66,234,520. These results suggest that although LUR improves, the efficiency per hour diminishes due to worker fatigue—making overtime beyond 2 hours increasingly inefficient and costly.

Concrete casting follows a similar pattern. Productivity falls from 4.06 m^3/hour to 2.84 m^3/hour over the overtime duration range, while LUR increases marginally from 68% to 71%. Labor costs rise steadily from IDR 9,120,000 to IDR 11,542,518. This indicates a diminishing return on both productivity and cost beyond 2 hours of overtime, confirming that benefits taper off despite LUR improvements.

Formwork installation shows the steepest productivity decline—from 28.13 m^3/hour to 20.63 m^3/hour—suggesting that this task is particularly vulnerable to the negative effects of fatigue. While LUR increases from 68% to 71%, the efficiency loss outweighs its benefit. Cost escalates from IDR 24,800,000 to IDR 31,387,578. This task demonstrates the lowest cost-efficiency when subjected to extended overtime, reinforcing the need for time limits.

Overall, the figure supports the hypothesis that while overtime may enhance LUR and daily output, it results in diminishing hourly productivity and rising costs. Worker fatigue becomes a critical limiting factor beyond 2 hours of overtime. These findings align with studies by (Ghodrati et al., 2022; Tanemura et al., 2023; Zhang et al., 2015), which emphasize that excessive working hours impair both physical performance and cognitive function.

3.6 Health and safety risks associated with overtime work

Extended overtime significantly elevates the risk of fatigue-induced incidents, posing a serious challenge to occupational health and safety in construction environments. As demonstrated in the preceding analyses, while daily outputs and Labour Utilization Rate (LUR) show a marginal increase with additional overtime, hourly productivity declines steadily—an indication of physical exhaustion and decreased mental focus. This divergence reveals a critical paradox: more hours do not necessarily yield better performance, particularly when human endurance limits are surpassed.

Empirical studies support this finding. Evanoff et al. (2019) and Matre et al. (2021) identified a direct relationship between prolonged work hours and an increase in musculoskeletal injuries, mental fatigue, and reduced worker responsiveness. The repetitive and physically demanding nature of construction tasks—such as rebar tying, concrete vibration, and formwork assembly—amplifies these risks. As fatigue sets in, the margin for error widens, potentially compromising structural integrity and workplace safety.

Research by Luther et al. (2017) and Niu & Yang (2022) expands on these risks by highlighting the physiological strain associated with extended shifts. These include chronic back pain, joint stress, visual strain, and cardiovascular stressors—conditions exacerbated by inadequate rest and hydration, high heat exposure, and manual handling of heavy loads. Moreover, prolonged overtime is associated with increased absenteeism and a higher incidence of near-miss events and workplace accidents, including falls from height, tool misuse, and equipment mishandling (Bista et al., 2024; Stimpfel et al., 2012).

Recognizing the dangers of overwork, several countries have instituted strict legal frameworks to protect workers. In Japan, high-profile cases of karōshi (death from overwork) prompted the government to enforce tighter regulations, capping overtime to no more than 45 hours per month, with exceptions only under emergency conditions (Tanemura et al., 2023). In the United States, the Occupational Safety and Health Administration (OSHA) recommends proactive fatigue management strategies, including scheduled rest breaks, ergonomic task design, and task rotation to reduce the risk of overexertion.

These international precedents offer valuable insights for domestic implementation. The Sky House Alam Sutera Apartment Project, for instance, could adopt a preventive approach by establishing an overtime rotation system, wherein no worker is assigned overtime shifts for more than three consecutive days. This policy would allow adequate recovery time, thus minimizing cumulative fatigue. Additionally, mandatory hydration breaks, micro-naps in shaded rest zones, and wearable fatigue monitoring devices could be incorporated into the Health, Safety, and Environment (HSE) plan.

Furthermore, safety briefings before and after overtime shifts can help raise awareness among workers and supervisors about the signs of physical and mental exhaustion. Site supervisors should be trained to recognize early symptoms of fatigue and have the authority to reassign or relieve workers at risk. Combined with real-time productivity tracking, this can create a safer and more responsive work environment.

In summary, while limited overtime may be a practical strategy to accelerate project timelines, its use must be weighed carefully against the rising risk of injuries and performance decline. Sustainable construction practices must prioritize not only output metrics but also worker resilience, safety culture, and long-term health outcomes. Integrating safety-centered overtime protocols into project planning is therefore not just a regulatory obligation—it is a strategic investment in labor sustainability.

4. Conclusions

This study underscores the multifaceted impact of overtime on labor productivity, cost efficiency, and worker well-being in the context of apartment construction projects. While overtime can accelerate project completion and serve as a short-term corrective strategy for delays, the findings reveal a complex trade-off: hourly productivity declines steadily with prolonged overtime, largely due to worker fatigue and reduced task precision. This trend is particularly evident in labor-intensive and accuracy-dependent activities such as rebar installation, concrete casting, and formwork installation.

The analysis also indicates that while Labour Utilization Rate (LUR) may improve modestly with increased overtime, the practical benefits begin to diminish after the first hour of extension. Beyond this threshold, productivity gains are offset by growing inefficiencies and operational strain. In terms of economic performance, labor costs escalate significantly—rising between 9% and 23% depending on the task type and overtime duration. Among the scenarios analyzed, one hour of overtime emerged as the most cost-effective option, balancing output gains with manageable cost and fatigue levels. Conversely, extending overtime to two or more hours results in diminishing returns and unsustainable workforce pressures.

Furthermore, the health and safety implications of extended working hours are substantial. Prolonged overtime heightens the risk of musculoskeletal disorders, cognitive fatigue, and attention lapses, which can lead to site accidents, rework, and even structural errors. These outcomes not only jeopardize worker safety but also compromise project integrity and stakeholder trust.

To mitigate these risks while preserving productivity, construction managers are encouraged to adopt a strategic and data-informed approach to overtime planning. Key recommendations include: Prioritizing high-impact tasks during overtime, Implementing rotating shift systems, Utilizing ergonomic and assistive tools to reduce physical strain, And enforcing stricter health and safety protocols during extended work hours. By integrating these sustainable labor practices, construction projects can maintain high operational standards while safeguarding the long-term health, morale, and productivity of their workforce.

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