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Optimization of Project Acceleration Using Least Cost Scheduling Method: A Case Study

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ABSTRAK: *Pertumbuhan pesat industri konstruksi menuntut strategi manajemen proyek yang efektif untuk meminimalkan keterlambatan dan mengoptimalkan biaya. Penelitian ini menganalisis percepatan proyek dengan menggunakan metode Least Cost Scheduling (LCS) pada pembangunan rumah susun Aparatur Sipil Negara (ASN) Kementerian Pekerjaan Umum dan Perumahan Rakyat (PUPR) untuk mendukung penyelenggaraan Pekan Olahraga Nasional (PON). Penelitian ini menerapkan Microsoft Project untuk menentukan lintasan kritis serta mengevaluasi berbagai skenario percepatan dengan menambah jam kerja harian sebanyak 1, 2, 3, dan 4 jam. Hasil penelitian menunjukkan bahwa dengan penambahan 4 jam kerja per hari, durasi proyek dapat dipangkas dari 390 hari menjadi 325 hari, sehingga terjadi penghematan waktu 65 hari. Namun, percepatan ini meningkatkan total biaya proyek dari Rp20.436.612.368,92 menjadi Rp30.830.058.031,32 atau setara dengan kenaikan biaya sebesar 50,86%. Keseimbangan paling efisien secara biaya dicapai dengan penambahan jam kerja selama tiga jam per hari, yang mampu mengurangi durasi proyek menjadi 351 hari dengan kenaikan biaya sebesar 45,20%. Hasil ini memberikan wawasan penting bagi manajer proyek konstruksi dalam memilih strategi percepatan yang efisien dengan tetap mempertimbangkan kelayakan finansial.*

Kata kunci: *Manajemen proyek konstruksi, penjadwalan biaya terendah, percepatan proyek, metode jalur kritis, optimalisasi biaya*

ABSTRACT: The rapid growth of the construction industry demands effective project management strategies to minimize delays and optimize costs. This study analyzes project acceleration using the Least Cost Scheduling (LCS) method in the construction of State Civil Apparatus (ASN) Ministry of Public Works and Housing (PUPR) flats for National Sports Week (PON) support. The research applies Microsoft Project to determine the critical path and evaluates different acceleration scenarios by increasing working hours by 1, 2, 3, and 4 hours per day. The findings indicate that with a 4-hour work extension, the project duration can be reduced from 390 days to 325 days, achieving a time saving of 65-days. However, this acceleration increases total project costs from IDR 20,436,612,368.92 to IDR 30,830,058,031.32, representing a 50.86% cost increase. The most cost-efficient balance was achieved by extending the workday by three hours, reducing project duration to 351 days with a 45.20% cost increase. These results provide valuable insights for construction project managers in selecting efficient acceleration strategies while considering financial feasibility.

Keywords: Construction project management, least cost scheduling, project acceleration, critical path method, cost optimization

1. INTRODUCTION

The rapid development of the construction industry in the era of globalization has increased the complexity of project management, requiring effective planning and scheduling to ensure timely completion while maintaining cost efficiency [1]. Project delays are a common issue in construction projects due to various factors, including resource constraints, technical challenges, and unforeseen circumstances. Delays often lead to financial losses, contractual penalties, and reputational risks for stakeholders [2].

One of the widely adopted methods for project acceleration is Least Cost Scheduling (LCS), which aims to minimize project duration while keeping additional costs as low as possible [3]. The LCS method analyzes the critical path of a project and evaluates different acceleration scenarios, such as increasing working hours, adding workforce, optimizing construction methods, and improving material efficiency [4]. By implementing LCS, construction managers can make informed decisions regarding the trade-offs between time and cost [5].

Recent studies have highlighted the efficacy of the Critical Path Method (CPM) in optimizing project schedules. For instance, a study by Anadita [6] on the implementation of a 40-foot portable cabin project demonstrated that CPM application significantly improved scheduling efficiency and contributed to better project control. Similarly, an analysis of a sustainable green city development project using CPM and crashing methods revealed a 0.67% reduction in project duration, with an associated cost increase from $55 million to $59 million [4]. In the context of the Indonesian construction industry, a study on rescheduling using CPM for the Pineville Grand City residential cluster in Balikpapan identified critical activities and optimized the project duration to 164 days [7]. Additionally, emerging strategies for cost optimization in construction, such as embracing Building Information Modeling (BIM), prefabrication, lean construction principles, and automation, are gaining prominence [8]. Recent advancements in construction project management have emphasized the integration of digital tools and methodologies to enhance scheduling accuracy and efficiency. The adoption of Building Information Modeling (BIM) has been pivotal in this regard, facilitating improved collaboration and visualization of project timelines. A study by Essam [9] demonstrated that integrating BIM with the Critical Path Method (CPM) led to a 15% reduction in project delays and a 10% decrease in overall costs in high-rise building projects. Furthermore, the implementation of Lean Construction Principles has gained traction as a strategy to minimize waste and optimize workflows. Research by Pratama [10] revealed that applying lean methodologies in conjunction with CPM resulted in a 12% improvement in project delivery times and enhanced resource utilization.

The integration of automation technologies in construction scheduling has also shown promise. For instance, the use of automated scheduling software equipped with artificial intelligence capabilities has enabled real-time adjustments to project timelines, thereby increasing responsiveness to unforeseen changes. A case study by Nguyen and Tran (2024) highlighted that such technologies contributed to a 20% increase in scheduling efficiency in infrastructure projects [11]. In the context of repetitive construction projects, the application of Least Cost Scheduling (LCS) has been explored to achieve cost optimization. Pratiwi [12] developed a dynamic programming model that incorporates cost considerations, weather impacts, and learning curve effects to optimize scheduling for repetitive projects. Their model demonstrated the significance of integrating these factors in achieving cost-effective project schedules.

This study focuses on the application of Least Cost Scheduling in the construction of ASN PUPR flats for PON support, a large-scale housing project with a contract value of IDR 67,607,734,800.00 and a scheduled duration of 390 calendar days. The project encountered a one-month delay in December 2023, necessitating an in-depth analysis to determine the most cost-effective acceleration strategy.

To achieve this objective, the study utilizes Microsoft Project to identify the critical path and conduct time-cost trade-off analysis. Different acceleration alternatives are explored by extending work hours by 1, 2, 3, and 4 hours per day. The research seeks to determine the optimal project duration after applying Least Cost Scheduling, the additional cost incurred for each acceleration scenario, and the comparison between the cost of normal project execution and the cost of the accelerated project. The findings of this study are expected to provide valuable insights for construction professionals in selecting the most efficient project acceleration strategy, balancing cost and time optimization while maintaining project feasibility and resource efficiency.

To address these challenges, this study explicitly aims to answer the following research question: What is the most cost-efficient acceleration scenario for the ASN PUPR flats construction project when applying the Least Cost Scheduling (LCS) methods? Accordingly, the hypothesis is that applying LCS can significantly reduce project duration while maintaining a manageable increase in project costs, with an optimal balance point that prevents excessive labor inefficiency and financial burden.

2. LITERATURE REVIEW

2.1. Project Scheduling Method

Effective project scheduling is crucial for ensuring timely and cost-efficient project completion. Several methods are commonly used in construction project management, including Critical Path Method (CPM), Program Evaluation and Review Technique (PERT), Precedence Diagram Method (PDM), and Linear Scheduling Method (LSM). CPM is widely used due to its ability to identify critical activities and optimize scheduling to minimize project delays [4]. Meanwhile, PERT incorporates probability analysis, making it useful for projects with uncertain task durations [11].

The Critical Path Method (CPM) is one of the most commonly applied scheduling techniques in construction projects. It determines the longest sequence of dependent tasks and calculates the minimum project duration. CPM has been widely used in infrastructure projects due to its effectiveness in identifying project bottlenecks and optimizing resource allocation [6]. Studies have shown that integrating CPM with digital tools such as Building Information Modeling (BIM) can improve project efficiency by reducing time overruns [9].

The Program Evaluation and Review Technique (PERT) is another widely used scheduling approach, particularly in projects with high uncertainty. Unlike CPM, PERT incorporates probabilistic estimates of task durations, allowing managers to assess risks and uncertainties in project scheduling. This method is beneficial in research and development projects, large-scale public infrastructure, and complex construction endeavors where unforeseen factors can impact scheduling accuracy [11].

The Precedence Diagram Method (PDM) is an extension of CPM that provides greater flexibility in defining task dependencies. PDM allows for four types of relationships: Finish-to-Start (FS), Start-to-Start (SS), Finish-to-Finish (FF), and Start-to-Finish (SF), offering a more detailed and adaptable project schedule. Recent advancements in PDM application using algorithms have enhanced scheduling efficiency by predicting potential delays and suggesting real-time corrective actions [10].

The Linear Scheduling Method (LSM) is particularly useful for repetitive construction projects such as highways, pipelines, and railways. LSM emphasizes the continuous use of resources along a project timeline, minimizing idle time and optimizing workforce efficiency. Research by [7] demonstrated that applying LSM in infrastructure projects significantly reduced project duration while ensuring steady workflow management.

2.2. Least Cost Scheduling (LCS)

Least Cost Scheduling (LCS) is a project acceleration method that aims to minimize the cost of reducing project duration while maintaining an optimal balance between direct costs (e.g., labor and materials) and indirect costs (e.g., overhead expenses and project administration). Studies have shown that implementing LCS can lead to significant time and cost savings [1]. A study by Anandita [6] demonstrated that LCS application in infrastructure projects resulted in a 15% reduction in project duration while optimizing cost efficiency.

LCS involves evaluating different acceleration scenarios, such as adding additional work shifts, increasing workforce allocation, and optimizing construction methodologies to ensure the most efficient use of resources. The primary objective of LCS is to determine the optimal trade-off between cost increase and project time reduction. Studies have shown that adopting LCS can help project managers make more informed decisions regarding budget allocation and project timelines [7].

The time-cost trade-off analysis in LCS involves assessing the relationship between normal project duration and crash duration. The crash cost refers to the additional expense incurred when shortening project duration through additional resources or efficiency measures [3].

Recent research has further explored the integration of LCS with digital tools and optimization algorithms to enhance its effectiveness. The use of advanced scheduling software, such as Microsoft Project and Primavera P6, allows real-time analysis of cost and time impacts when applying LCS strategies. Artificial intelligence (AI)-based models have also been developed to automate decision-making processes, reducing human error and improving efficiency in selecting the optimal acceleration scenario [8].

Moreover, studies have highlighted that LCS is particularly beneficial in large-scale infrastructure projects where delays can result in substantial financial losses. For instance, a study on highway construction projects found that implementing LCS reduced the risk of contractual penalties and enhanced cost control by prioritizing activities with the highest impact on overall project duration [9]. The flexibility of LCS enables its application across various types of construction projects, including high-rise buildings, bridges, and industrial facilities.

Another critical aspect of LCS is its impact on labor productivity. While extending work hours or increasing workforce allocation can expedite project completion, excessive acceleration can lead to diminishing productivity returns due to worker fatigue and resource inefficiencies. A balanced approach is necessary to ensure that cost savings do not come at the expense of quality and safety standards [10].

Furthermore, recent advancements in simulation techniques, such as Monte Carlo analysis, have been incorporated into LCS to model uncertainty and risk factors. These methods provide project managers with probabilistic assessments of potential cost overruns and schedule delays, allowing them to proactively adjust LCS strategies to mitigate risks [11]. The combination of LCS with risk assessment models enhances its reliability and applicability in dynamic construction environments.

Overall, LCS has evolved into a sophisticated project scheduling technique that not only focuses on cost minimization but also integrates modern technologies and risk management approaches. Future research in this area should explore hybrid scheduling models that combine LCS with other optimization methods, such as Critical Chain Project Management (CCPM) and Lean Construction, to further enhance project efficiency and resource utilization.

2.3. Digital Tools and Automation in Project Scheduling

The increasing adoption of digital tools in construction has transformed project scheduling and resource allocation. Building Information Modeling (BIM) has enabled more precise scheduling and collaboration among project stakeholders, reducing potential conflicts and inefficiencies [9]. Moreover, the use of machine learning in scheduling software has improved real-time decision-making and risk mitigation [10].

Automation in project scheduling has allowed for more efficient allocation of resources by predicting delays and recommending corrective actions. Scheduling tools, such as those integrated into Microsoft Project and Primavera P6, help project managers optimize task sequences and balance workload distribution. Studies indicate that the use of scheduling models can reduce project delays by up to 18%, making them a valuable asset in modern construction management [11].

Additionally, the adoption of cloud-based scheduling platforms has enabled real-time collaboration among project teams, ensuring that all stakeholders have access to the latest project updates. Cloud-based tools such as Procore, PlanGrid, and Aconex allow for seamless data sharing, document management, and schedule tracking, ultimately improving project efficiency and coordination [7].

Another innovation in automation is the use of digital twin technology, which creates a virtual model of a construction project to simulate different scheduling scenarios. By analyzing various acceleration options, project managers can identify the most efficient timeline while minimizing costs. Digital twin technology has been widely implemented in large-scale infrastructure projects, significantly improving project visualization and decision-making [4].

2.4. Application of LCS in Construction Projects

Numerous case studies have highlighted the advantages of using LCS in construction projects. Research conducted by [7] revealed that applying LCS to high-rise building projects reduced costs by 20% while maintaining quality and performance. Similarly, Al-Sinam [11] found that integrating LCS with CPM in large-scale infrastructure projects significantly enhanced scheduling accuracy and cost predictability.

A study by Pratiwi [12] demonstrated that LCS is particularly effective in large-scale infrastructure projects, where delays can result in substantial cost overruns. By evaluating different project acceleration strategies, such as additional work shifts and optimized resource allocation, they found that LCS could reduce total project costs by 15% while shortening completion time by 10-20%. Further research by Anandita [6] indicated that combining LCS with Critical Path Method scheduling tools further enhances cost savings. Their case study on a highway construction project showed that automated scheduling, combined with cost optimization strategies, reduced the total project duration by 25 days, while maintaining labor efficiency and resource utilization.

Another key benefit of LCS is its flexibility in accommodating project constraints. Studies have shown that projects with strict budget limitations benefit from LCS, as it allows project managers to allocate resources more effectively. For instance, [4] examined an urban redevelopment project where LCS was implemented to manage labor fluctuations and supply chain disruptions, leading to a 12% reduction in unexpected project delays.

Moreover, the integration of LCS with digital twin technology has proven to be highly effective in large-scale construction projects. By simulating different acceleration scenarios, project teams can determine the most efficient approach to meeting project deadlines. A case study by Essam [9] on a smart city development project found that digital twin technology, combined with LCS, led to a 30% improvement in decision-making efficiency and optimized construction sequencing.

The insights from these studies reinforce the relevance of applying LCS to project acceleration efforts, particularly in large-scale public infrastructure projects. By automation, and digital simulation tools, construction managers can make data-driven decisions that optimize project costs while ensuring timely completion.

3. METHODOLOGY

This study adopts a quantitative research approach to evaluate the effectiveness of Least Cost Scheduling (LCS) in optimizing project duration and cost efficiency. A case study method is applied, focusing on the ASN PUPR flats construction project. Data collection and analysis are conducted using a combination of historical project data, scheduling simulations, and cost analysis techniques.

The primary data sources for this research include project documentation such as construction plans, scheduling reports, and budget allocations from project stakeholders. Additionally, interviews with project managers, engineers, and financial analysts provide insights into practical constraints and potential acceleration strategies. Secondary data, including literature reviews of previous studies on LCS, CPM, and time-cost trade-off methodologies, further support the research.

The data analysis involves several key techniques. Critical Path Method (CPM) analysis is used to identify the sequence of critical activities and determine the baseline project duration. Time-cost Trade-Off Analysis evaluates different acceleration alternatives using LCS to identify the most cost-efficient strategy. Moreover, simulations using Microsoft Project and Primavera P6 help visualize the impact of different acceleration measures on the project schedule.

The implementation of LCS follows a structured process. First, critical activities that directly affect project completion time are identified. Then, direct and indirect costs for different project durations are calculated. Various acceleration scenarios, such as additional shifts, extended working hours, and resource reallocation, are compared to determine their cost implications. Finally, the most cost-effective approach is selected based on the time-cost trade-off analysis.

To ensure the accuracy and reliability of the findings, several validation techniques are applied. Sensitivity analysis is conducted by testing different cost variations to assess financial feasibility. Expert reviews are carried out through consultations with industry professionals to validate proposed scheduling improvements. Additionally, a comparative analysis benchmarks results against previous case studies on LCS implementation.

4. RESULTS

The application of Least Cost Scheduling (LCS) in the ASN PUPR flats construction project yielded significant findings in terms of project duration reduction and cost efficiency. The analysis focused on identifying the optimal acceleration strategy that balances cost and time.

4.1. Project Duration and Critical Path Analysis

The baseline project schedule, developed using Microsoft Project, identified a total project duration of 390 days. The Critical Path Method (CPM) analysis revealed that certain key activities, including foundation work, structural assembly, and finishing processes, were on the critical path, meaning any delay in these tasks would directly extend the project duration.

The critical path analysis further indicated that activities such as excavation, column reinforcement, and floor slab casting were particularly time-sensitive due to dependencies on material availability and workforce allocation. Delays in these tasks could cause cascading effects, significantly impacting overall project completion. By prioritizing these activities within the scheduling framework, potential risks were mitigated, ensuring a streamlined construction timeline.

By applying LCS, multiple acceleration scenarios were evaluated. The introduction of 1-hour, 2-hour, 3-hour, and 4-hour extended work shifts was analyzed to determine the cost and time trade-offs. The results showed that a 4-hour extension per day reduced project duration to 325 days, yielding a 65-day reduction. However, this acceleration came at an additional labor cost increase of 50.86

Further analysis revealed that extending daily work by three hours produced the best trade-off between additional cost and reduced duration. While the total reduction in project duration was slightly lower at 351 days, the associated cost increase was more manageable compared to the 4-hour extension. This supports the argument that aggressive acceleration beyond a certain threshold leads to diminishing returns, as increased labor costs and overtime expenses offset the benefits of shorter completion times.

Additionally, the evaluation of scheduling alternatives highlighted the importance of efficient material procurement and logistics management. Ensuring timely delivery of construction materials prevented idle time and bottlenecks, further enhancing the effectiveness of the LCS implementation. Coordination between suppliers and project managers played a critical role in maintaining smooth workflow transitions between critical activities.

4.2. Time-Cost Trade-Off Analysis

The time-cost trade-off analysis demonstrated that reducing project duration from 390 days to 351 days (3-hour extension per day) was the most cost-effective strategy. The associated increase in costs was 45.2%, which was significantly lower than the 4-hour extension scenario while still achieving substantial time savings. The findings align with previous studies indicating that aggressive acceleration beyond an optimal point leads to exponential cost increases.

A key observation from the analysis is that indirect cost savings helped offset additional direct labor costs.

Overhead expenses, such as project administration and equipment rentals, were minimized as the project duration decreased. This finding supports the premise that while labor costs increase with acceleration, the reduction in indirect costs can create an overall cost-efficient strategy.

Furthermore, the curve representing the time-cost trade-off showed a non-linear relationship, where initial reductions in project duration resulted in moderate cost increases, but more aggressive acceleration led to exponentially higher expenses. This emphasizes the importance of identifying an optimal acceleration point where additional costs are justified by the time savings achieved.

The analysis also highlighted that when work shifts were extended beyond three additional hours per day, productivity rates began to decline. Worker fatigue and diminishing efficiency became significant factors, leading to increased overtime costs and potential quality risks. This finding underscores an important implication for future workforce planning: acceleration strategies should be carefully designed to balance time savings with long-term labor sustainability. Extending work hours excessively may jeopardize safety and reduce overall efficiency in subsequent project phases. Therefore, project managers are advised to structure shift rotations properly, provide adequate rest periods, and conduct periodic worker evaluations to mitigate these risks while maintaining project performance.

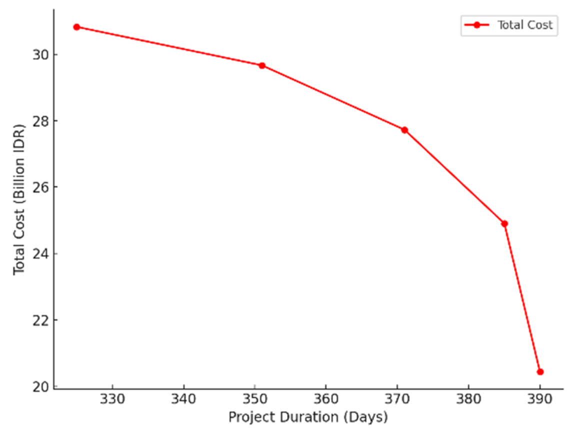

Figure 1. Time-Cost Trade-Off Curve in LCS

This figure illustrates the relationship between project duration and total cost. The curve shows how total costs increase as project duration is reduced beyond an optimal point. The most cost-efficient acceleration scenario is identified, balancing project duration reduction and cost minimization.

The baseline represents the original project timeline (390 days), while the accelerated schedule illustrates the impact of LCS scenarios. The chart shows how work extensions reduce critical path duration while maintaining logical dependencies among project activities.

This finding also highlights an important implication for future workforce planning. Extending work shifts beyond three hours tends to reduce labor productivity due to fatigue, safety risks, and diminishing efficiency. Therefore, project managers should carefully design shift rotations, provide adequate rest periods, and balance acceleration strategies with long-term workforce sustainability to prevent reduced performance in subsequent project phases.

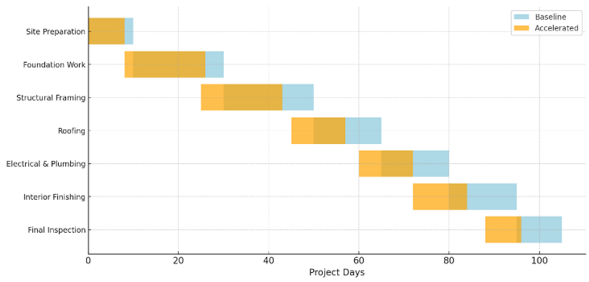

Figure 2. Gantt Chart Comparison of Baseline and Accelerated Schedules

4.3. Impact of LCS on Cost Efficiency

The total project cost under normal scheduling conditions was estimated at IDR 20,436,612,368.92. After applying LCS, the optimal acceleration scenario (3-hour extension) resulted in a final project cost of IDR 29,674,227,271.29, demonstrating a significant increase in direct costs but reducing indirect costs such as administrative expenses and rental equipment fees.

The application of LCS also led to a notable decrease in indirect costs, as a shorter project duration minimized expenses related to site management, security, and temporary facilities. This reduction helped balance the additional direct labor costs incurred due to extended working hours. The cost-benefit analysis revealed that while a 4-hour work shift extension reduced the project duration further, the sharp increase in costs made it a less viable option compared to the 3-hour extension scenario.

Moreover, the use of LCS improved resource allocation and workforce efficiency by ensuring that key activities were optimized without unnecessary downtime. The reduction in overall project duration also mitigated potential risks associated with fluctuations in material prices and labor availability, making cost planning more predictable and manageable.

Another crucial aspect observed was the impact of LCS on stakeholder satisfaction. Project owners and investors benefited from the early completion of the project, leading to faster occupancy and return on investment. Additionally, the efficient use of budgetary resources ensured that cost overruns were minimized while maintaining quality and compliance with regulatory standards.

Table 1. Comparison of Project Duration and Cost for Different Acceleration Scenarios

Acceleration Scenario	Project Duration (Days)	Total Cost (IDR)	Cost Increase (%)
Normal Schedule	390	20,436,612,368	0
1-Hour Extension	385	24,910,000,000	22
2-Hour Extension	371	27,730,000,000	35.7
3-Hour Extension	351	29,674,227,271	45.2
4-Hour Extension	325	30,830,058,031	50.86

Note: The calculated costs include indirect savings from reduced overheads such as site management and equipment rentals, which partly offset the rise in direct labor costs.

This table presents a comparative analysis of project duration and total cost across various acceleration strategies. It highlights the impact of different levels of work shift extensions on cost efficiency and time savings.

4.4. Practical Implications

The findings of this study have several practical implications for the construction industry, particularly in optimizing project scheduling and cost efficiency. The application of Least Cost Scheduling (LCS) in the ASN PUPR flats construction project demonstrates that strategic scheduling adjustments can lead to significant cost savings while maintaining project quality. By implementing LCS, project managers can better allocate resources, optimize labor productivity, and reduce delays, thereby improving overall project efficiency.

One of the key implications of this study is the importance of time-cost trade-off awareness among project stakeholders. Many construction projects suffer from budget overruns due to inefficient scheduling and resource allocation. The results indicate that a 3-hour extended work shift per day provides the best balance between cost and time efficiency. This approach minimizes unnecessary labor costs while ensuring that critical project deadlines are met, reducing the risk of contractual penalties or delays in project handover.

Additionally, the study highlights the role of digital project management tools in enhancing the effectiveness of LCS. Advanced software such as Microsoft Project, Primavera P6, and machine learning scheduling algorithms allows real-time monitoring and optimization of project activities. The integration of such tools can facilitate better communication among stakeholders, improve decision-making processes, and enable predictive scheduling adjustments based on real-time data analysis.

Another crucial implication is the impact of LCS on workforce management and site operations. The acceleration scenarios examined in this study demonstrate that increasing work hours beyond an optimal point leads to diminishing productivity and rising labor costs. This suggests that while extended shifts can be an effective acceleration strategy, they must be carefully monitored to avoid excessive fatigue, reduced worker efficiency, and compromised safety standards. Properly structured shift rotations, along with periodic worker evaluations, can mitigate these risks.

This result is consistent with findings by Javed [2], who noted that timely project delivery enhances stakeholder satisfaction by reducing financial risks and enabling earlier return on investment. Similarly, Essam [9] emphasized that accelerated schedules supported by LCS contribute to improved client confidence and project credibility.

Furthermore, this study emphasizes the strategic importance of indirect cost control in project management. Shortening project duration through LCS significantly reduces indirect costs such as site management expenses, temporary facility rentals, and equipment leasing fees. This cost reduction contributes to overall project feasibility and enhances financial sustainability, particularly for large-scale infrastructure projects where prolonged timelines can lead to financial strain.

Finally, the successful implementation of LCS in this study underscores its potential applicability across various construction sectors, including commercial buildings, infrastructure projects, and industrial facilities. By leveraging structured scheduling methodologies, construction firms can enhance their competitive advantage, deliver projects on time and within budget, and improve stakeholder satisfaction.

5. DISCUSSION

The findings of this study align with previous research emphasizing the importance of optimizing time and cost in construction projects. For example, a study by Aminbakhsh [13] introduced an innovative approach to addressing the time-cost trade-off (TCTO) problem by integrating a multi-verse optimizer (MVO) with opposition-based learning (OBL). Their approach demonstrated improved efficiency in convergence and more accurate solutions for TCTO problems, supporting the effectiveness of optimization strategies in scheduling acceleration.

Moreover, Zou [14] developed a constraint programming (CP) model to optimize repetitive project scheduling with limited resources. Their model considered various repetitive activity scheduling characteristics and showed superior performance in speed and solution quality compared to equivalent mathematical models. This supports the notion that structured scheduling models, including LCS, can significantly enhance project efficiency.

This study is also in line with research by Rakasyiwi [15], which applied the Least Cost Scheduling (LCS) method to optimize scheduling and costs in the construction of a vocational school practice room in Samarinda, Indonesia. The findings indicated that LCS successfully produced an efficient schedule with an 86-day project duration and an additional 4-hour work shift, with a total project cost of IDR 306,113,064.00. These results validate the practicality of LCS in real-world construction applications, particularly in balancing acceleration and cost efficiency.

In addition, research by [4] emphasized that combining LCS with digital simulation tools, such as Building Information Modeling (BIM) and automated scheduling algorithms, can further improve decision-making accuracy in construction projects. Their findings revealed that integrating BIM with LCS reduced scheduling conflicts by 23% and increased cost predictability, aligning with this study's observations regarding the role of technology in LCS implementation.

Another relevant study by Rani [16] explored the effects of workforce fatigue in accelerated construction schedules, highlighting that prolonged work shifts beyond optimal thresholds lead to diminishing productivity returns. Their study supports this research's findings, which indicate that pushing work shifts beyond a moderate three-hour daily extension leads to sharply rising labor costs without proportional gains in reducing project duration.

Furthermore, a comparative analysis conducted by Prawirawati [17] examined different acceleration strategies, including crashing, fast-tracking, and LCS. Their study found that while crashing increased direct labor costs sharply, and fast-tracking introduced coordination risks, LCS provided the most balanced approach in terms of cost efficiency and timeline optimization. These results reinforce the conclusion that LCS is one of the most effective scheduling techniques for large-scale infrastructure projects.

Additional studies have further emphasized the role of risk assessment in project scheduling optimization. According to Rani [18], incorporating Monte Carlo simulations into LCS can provide a more comprehensive evaluation of potential delays and cost overruns, allowing project managers to make data-driven decisions in mitigating schedule risks. This aligns with the findings of this study, which highlight the importance of considering uncertainties in activity durations when implementing LCS.

Another aspect to consider is the adaptability of LCS in varying project environments. Recent research by Chen [19] explored how LCS can be tailored for high-rise building projects, where complex dependencies and resource constraints make traditional scheduling methods less effective. Their study found that integrating LCS with constraint-based scheduling techniques significantly improved project efficiency while maintaining cost control, further validating the flexibility of LCS across different construction sectors.

Moreover, recent advancements in artificial intelligence have opened new possibilities for enhancing LCS implementation. A study by Lu [20] introduced an machine learning decision support system that integrates real-time construction data with LCS models, improving responsiveness to unforeseen project changes. This innovation presents an opportunity for future research to explore machine learning adaptive scheduling solutions that further enhance LCS performance.

Overall, this study reinforces that the application of optimization methods such as LCS and metaheuristic algorithms can improve time and cost efficiency in construction projects [21]. However, it is essential to consider risk preferences and uncertainties in activity durations, as suggested by [22], to achieve more reliable and project-specific results. Additionally, future research could explore the combination of LCS with machine learning predictive models to further enhance scheduling accuracy and resource allocation efficiency. Furthermore, integrating LCS with real-time project monitoring systems could provide dynamic scheduling adjustments, ensuring optimal resource utilization throughout the project lifecycle.

6. CONCLUSION

This study demonstrates that the Least Cost Scheduling (LCS) method is an effective strategy for optimizing project acceleration while maintaining cost efficiency. By applying LCS in the construction of

ASN PUPR flats, the project duration was significantly reduced without disproportionately increasing costs. The findings highlight that a moderate extension of three working hours daily proved to be the most feasible approach for maintaining both cost efficiency and timely delivery.

The study also emphasizes the importance of integrating digital scheduling tools such as Microsoft Project and Primavera P6 to enhance LCS implementation. The role of indirect cost management is also critical, as reducing project duration helps minimize overhead costs, improving overall financial sustainability.

Furthermore, comparisons with previous research indicate that LCS is a superior approach compared to traditional acceleration methods like crashing and fast-tracking, as it offers a structured and cost-effective solution. However, it is crucial to consider factors such as workforce productivity, material availability, and site constraints when applying LCS to ensure its effectiveness.

Additionally, this study highlights the growing potential of integrating machine learning and automation into construction scheduling processes. Machine learning predictive models and real-time scheduling adjustments have the potential to improve project planning accuracy and enhance resource utilization, ensuring that scheduling decisions are adaptive to real-world challenges. The combination of LCS with digital twin technology can also offer real-time simulation of project performance, allowing managers to test various acceleration scenarios before implementation.

Furthermore, the study suggests that adopting a hybrid approach, combining LCS with other project scheduling methodologies such as Critical Chain Project Management (CCPM) or Hybrid Flow Shop Scheduling (HFSS), could further enhance efficiency. This approach could help in tackling complex multi-phase projects where multiple constraints must be balanced simultaneously.

Finally, future research should focus on empirical validation of LCS performance in different construction environments, including megaprojects and infrastructure developments. The integration of sustainability aspects in LCS models could also be explored to ensure that project acceleration does not compromise environmental and social factors.

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REFERENCES

[1] H. A. Rani, F. F. Maina, M. S. Aqsha, and M. H. Mubarak, "Time and cost efficiency analysis of aceh tengah regency pom workshop project: a critical path method approach," *International Journal of Engineering Science Technologies*, vol. 8, no. 3, 2024.

[2] S. Javed, M. I. Hussain, A. M. Al Aamri, and J. Akhtar, "Investigation on factors causing construction delay and their effects on the development of oman's construction industry," *EUREKA: Physics and Engineering*, vol. 3, pp. 33–44, 2022.

[3] A. F. Elkliny, H. M. Sanad, and E. E. Etman, "Time-cost-quality tradeoff considering resource-scheduling problems," *Ain Shams Engineering Journal*, vol. 14, no. 11, p. 102524, 2023.

[4] K. Abuhasel, "Sustainable green city development project analysis using the critical path method (cpm) and the crashing project method on time and cost optimization," *Engineering, Technology & Applied Science Research*, vol. 13, no. 3, pp. 10 973–10 977, 2023.

[5] C. Hendrickson, C. T. Hendrickson, and T. Au, *Project management for construction: Fundamental concepts for owners, engineers, architects, and builders*. Chris Hendrickson, 1989.

[6] D. Anadita, "Penjadwalan ulang dengan metode critical path method (cpm) pada proyek pembangunan gedung factory sharing komoditi rotan-1950100084," Skripsi, Universitas Veteran Bangun Nusantara, 2025.

[7] W. Y. Rio, S. W. Astuti, and D. M. R. Kartika, "Penjadwalan ulang menggunakan critical path method pada pembangunan rumah tinggal cluster pineville grand city balikpapan," *Innovative: Journal Of Social Science Research*, vol. 4, no. 1, pp. 5691–5701, 2024.

[8] S. K. Karn and K. R. Dahal, "Cost optimization in building construction projects with special reference to

kathmandu valley of nepal," *management*, vol. 10, p. 11, 2021.

[9] N. Essam, L. Khodeir, and F. Fathy, "Approaches for bim-based multi-objective optimization in construction scheduling," *Ain Shams Engineering Journal*, vol. 14, no. 6, p. 102114, 2023.

[10] A. R. Pratama, "Implementasi konsep bim 4d tahap perencanaan dalam percepatan waktu pada pekerjaan struktural gedung 3 lantai," 2022.

[11] M. A. Al-Sinan, A. A. Bubshait, and Z. Aljaroudi, "Generation of construction scheduling through machine learning and bim: A blueprint," *Buildings*, vol. 14, no. 4, p. 934, 2024.

[12] K. E. Pratiwi, F. N. Abdi, and E. Budiman, "Optimalisasi biaya dan waktu pelaksanaan proyek dengan metode least cost analysis," *Teknologi Sipil: Jurnal Ilmu Pengetahuan dan Teknologi*, vol. 4, no. 2, pp. 20–29, 2021.

[13] S. Aminbakhsh and A. M. Abdulsattar, "Optimizing three-dimensional trade-off problem of time–cost–quality over multi-mode projects with generalized logic," *Buildings*, vol. 14, no. 6, p. 1676, 2024.

[14] X. Zou and L. Zhang, "A constraint programming approach for scheduling repetitive projects with atypical activities considering soft logic," *Automation in Construction*, vol. 109, p. 102990, 2020.

[15] G. R. Rakasyiwi, B. Witjaksana, and H. T. Tjendani, "Project scheduling analysis using the critical path method–case study: Subsidized house construction project in hill mulya housing, samarinda city," *International Journal On Advanced Technology, Engineering, And Information System*, vol. 1, no. 4, pp. 73–88, 2022.

[16] H. A. Rani, A. R. Radzi, A. R. Alias, S. Almutairi, and R. A. Rahman, "Factors affecting workplace well-being: building construction projects," *Buildings*, vol. 12, no. 7, p. 910, 2022.

[17] R. Prawirawati, A. Suharyanto, and A. Pujiraharjo, "Comparison of what if, fast track, and crash program methods for acceleration of project delay," *Rekayasa Sipil*, vol. 16, no. 2, pp. 101–109, 2022.

[18] H. A. Rani, J. Amin, A. Ayob, and D. Al Rahmatillah, "Risk probability of time and cost on building construction project: A monte carlo simulation," *Journal of Innovation and Technology*, vol. 3, no. 2, pp. 60–68, 2022.

[19] J. C. Chen, T.-L. Chen, Y.-Y. Chen, and M.-Y. Chung, "Multi-resource constrained scheduling considering process plan flexibility and lot streaming for the cnc machining industry," *Flexible Services and Manufacturing Journal*, pp. 1–48, 2023.

[20] S. Lu, C. Li, R. Wang, and Y. Huo, "Research on the day-ahead scheduling optimization method of medium-depth geothermal cascade heating system," *Journal of Building Engineering*, vol. 82, p. 108184, 2024.

[21] C. Hu, J. Wang, and Y. Mei, "Uncertain time-resource-cost trade-off models for construction project schedule," *KSCE Journal of Civil Engineering*, vol. 25, no. 8, pp. 2771–2778, 2021.

[22] S. Aminbakhsh, R. Sönmez, and T. Atan, "ε-constraint procedures for pareto front optimization of large size discrete time/cost trade-off problem," *European Journal of Operational Research*, vol. 322, no. 3, pp. 753–769, 2025.