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DIGITAL MONITORING FOR LEAN CONSTRUCTION: EFFICIENCY IN MAJOR INDONESIAN TOLL ROAD PROJECT

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ABSTRACT

The Karangjoang-Kariangau Section 3A Toll Road Project in East Kalimantan, Indonesia, aims to connect Balikpapan City with Nusantara, the New Capital City. This 13.4 km project, primarily involving intensive earthwork, utilizes heavy equipment whose efficiency is crucial for enhancing productivity and reducing costs. Our study examines inefficiencies such as unnecessary equipment motion, transportation delays, and extended waiting times—common challenges in lean construction. We implemented a digital monitoring system to compare its effectiveness against traditional manual methods in improving resource utilization and minimizing waste. Findings indicate that digital monitoring, despite the higher initial costs, significantly helps to boost operational efficiency by providing detailed data, then the data can be used to analyze the core of the problem so that a solution is found that successfully reduces idle time by 37% and increasing equipment utilization by 39%. These results demonstrate the substantial benefits of integrating digital technologies into construction management, suggesting a crucial shift towards digital methods to meet the demands of modern infrastructure development effectively. This study underlines the alignment of digital monitoring with lean construction principles, advocating for its adoption to optimize productivity and cost-efficiency in large-scale projects.

KEYWORDS

Lean construction, waste, digital monitoring, continuous improvement

INTRODUCTION

The Karangjoang-Kariangau Section 3A Toll Road Project, referred to as the “New Capital City Nusantara” called Ibu (IKN), spans 13.4 kilometers and plays a crucial role in connecting Balikpapan City to the New Capital City, Nusantara, in East Kalimantan, Indonesia. Ensuring

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efficient and controlled use of heavy equipment is vital due to the project's extensive scope, where precision in monitoring and control are essential to adhere to the project schedule and prevent delays and cost overruns. Challenges such as equipment location monitoring and productivity rate assessments have been identified as key factors contributing to these delays and additional costs. These challenges are often exacerbated by traditional management methods, which typically involve low-frequency monitoring that does not provide real-time data, thus failing to allow timely corrective actions (Nasr E., 2013).

In response to these issues, this study aims to evaluate the impact of implementing a digital monitoring system on the operational efficiency of heavy equipment in the section 3A Toll Road Project. Our objectives include assessing how digital monitoring can enhance real-time tracking, reduce equipment idle times, and support lean construction principles by improving resource utilization and reducing waste. By transitioning from traditional to digital monitoring methods, this research seeks to provide empirical evidence on the improvements in project management that can lead to significant cost savings and efficiency gains. The adoption of a stricter and more sophisticated monitoring system is not just a requirement but a strategic enhancement in line with national strategic project goals.

LITELATURE REVIEW

This literature underscores the evolving landscape of construction technology and sets a foundation for this study's exploration of digital monitoring's impact on lean construction practices in the context of Indonesia's significant infrastructure projects.

LEAN CONSTRUCTION CYCLE PROCESS

Lean Construction is grounded in the philosophy of continuous improvement, influenced significantly by Kaizen, which promotes incremental enhancements to boost efficiency and foster collaborative innovation. The Plan-Do-Check-Act (PDCA) cycle and Lean Six Sigma's DMAIC framework are pivotal methodologies within this realm, enhancing workflow, reducing waste, and improving quality by utilizing structured, data-driven problem-solving techniques (Lean Construction Institute, 2023; IdeaScale, 2023). In line with the Toyota Way's principles, the adoption of new technologies in construction must be reliable and tested extensively to ensure they support continuous operations and enhance worker productivity.

IDENTIFICATION OF WASTE IN CONSTRUCTION

Waste in construction encompasses more than just material waste; it includes inefficiencies in time, labor, and processes that can lead to increased costs and project delays. Classic waste types identified in lean construction include defects, overproduction, waiting, non-utilized talent, unnecessary transportation, excess inventory, and excess motion (Ohno, 1988). Techniques such as Value Stream Mapping (VSM) and the Last Planner System (LPS) are employed to identify and mitigate these wastes by visualizing workflows and enhancing planning reliability (Koskela, 1992; Ballard, 2000). Emerging technologies like Building Information Modeling (BIM) and automated monitoring with drones and sensors have further advanced the capability to identify and reduce waste, particularly in large-scale projects (Smith & Doe, 2020).

DIGITAL MONITORING

Advancements in digital monitoring technologies, such as Global Positioning Systems (GPS) and On-Board Instrumentation Systems (OBIS), represent significant strides in construction management. GPS technology, known for its autonomous operation and real-time data provision, is crucial for monitoring equipment effectively on large-scale construction sites, facilitating better resource management and operational efficiency (Pradhananga & Teizer, 2013). OBIS complements GPS by monitoring mechanical conditions and operational parameters to optimize the productivity of heavy equipment, addressing issues such as equipment idle times and inefficient resource use, critical in projects like the IKN 3A Toll Road (Alshibani, 2015).

METHODOLOGY

The methodology of this study systematically investigates the impact of digital monitoring on enhancing lean construction practices within the Section 3A Toll Road project in the middle of the project (August - October). Our approach combines qualitative and quantitative data to provide a comprehensive understanding of the role digital monitoring plays in waste reduction and process optimization. The research commences with identifying waste through both conventional and digital monitoring techniques to provide continuous improvement. Conventional monitoring serves as a baseline for comparison, while digital monitoring, enabled by a real-time dashboard, allows for a more detailed performance analysis and recognition of dominant waste streams. A comparative analysis between traditional and digital monitoring methods is conducted to evaluate their efficacy in waste identification and reduction. The digital monitoring system, featuring a dynamic dashboard, offers real-time insights and performance metrics that facilitate a continuous improvement cycle. Lean construction tools such as current state value stream mapping (VSM) and Fishbone Diagrams are employed to map out existing workflows and diagnose inefficiencies. This analysis is enhanced through root cause analysis, allowing us to develop targeted countermeasures. A future state VSM then helps to envision improved processes with higher cycle efficiency. The research aims to yield actionable outcomes, including a comprehensive guideline tested and refined through the research process to assist in the implementation of digital monitoring in lean construction & identification of digital monitoring features that contribute to lean construction waste reduction, substantiating the system's effectiveness in improving operational efficiency.

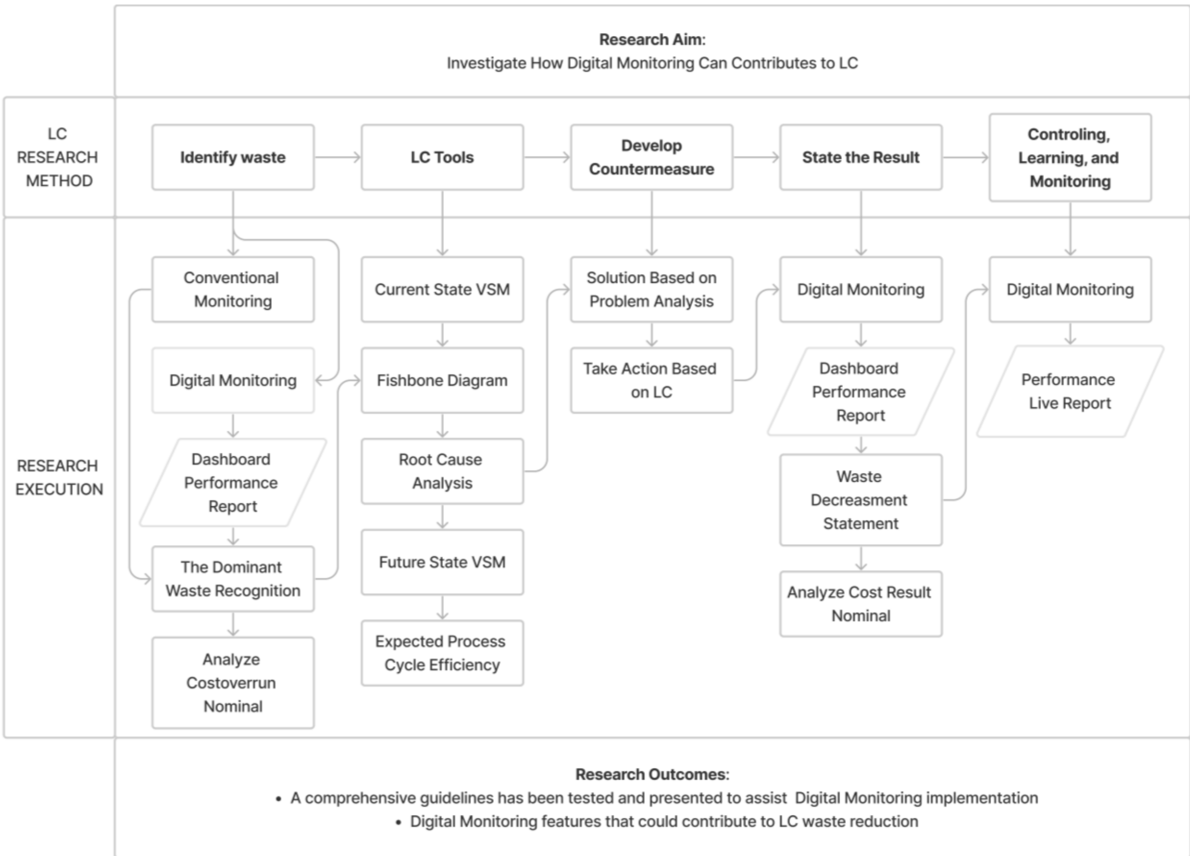

Figure 1: Research Methodology

INITIAL DATA REPORTS COMPARATION

Table 1: Report of Heavy Equipment Timesheet from Conventional Monitoring & Digital Monitoring

Criteria	Month	Idle Time (Monthly)		Driving Times (Monthly)		Total Timesheet (Hour)	Total Cost
		Hour	%	Hour	%		
Conventional Monitoring	Aug	Undetectable		Undetectable		5,880.00	3,80 Bio
Digital Monitoring	Sept	3,134.77	*55.28%*	2,267.12	44.72%	5,401.88	3,48 Bio

The comparative analysis depicted in Table 1 substantiates the advantages of digital over conventional monitoring in evaluating operational activities. In August, conventional methods failed to capture idle and driving times, which stands in sharp contrast to the following month, September, where the digital monitoring system was able to precisely quantify idle time at 3,134.77 hours. This accounted for 55.28% of the total timesheet, surpassing the driving times, which were 44.72% or 2,267.12 hours. The significant proportion of idle time, outstripping active operation, signals a pressing concern for resource wastage, potentially caused by extensive queuing during excavation tasks. Corroborating field observations confirmed these inefficiencies, particularly the protracted waiting periods of machinery, which not only diminish productivity but also elevate operational costs, as indicated by the total cost of IDR 3,487,472,454.74. Of this amount, approximately IDR 1,927,874,772 is attributed to waste. The implementation of digital monitoring thus emerges as a pivotal tool for operational management and cost reduction, providing a clear path to mitigate inefficiencies and optimize resource allocation.

LEAN CONSTRUCTION TOOLS IMPLEMENTATION

CURRENT STATE MAPPING

Advancing from the initial data capture through digital monitoring, applying the Lean Construction methodology to dissect and understand inefficiencies. The deployment of Value Stream Mapping (VSM) is pivotal in this phase, as it provides a visual representation of the current state of operations, laying bare the flow and accumulation of waste. By charting each step in the excavation and construction process, VSM helps us pinpoint where delays occur, where resources lie idle, and where processes diverge from the ideal lean workflow. The Value Stream Mapping (VSM) applied to the Section 3A Toll Road project's earthwork stages has offered us a granular view of the project's current workflow and efficiency. Based on Figure 2, That illustrates the sequence of earthwork activities for every 100 meters of the construction project, encapsulating the flow of operations from excavation to compaction. The process commences with mobilization of heavy equipment, taking half a day, leading to the excavation phase, which has a value-adding duration of 4 days and a cycle time of 7 days. Subsequent dumping activities contribute 3 days of value-adding and a cycle time of 4 days, followed by grading with 3 days of value-adding and a 5-day cycle time. The final compaction step culminates the sequence with a value-adding time of 5 days and the longest cycle time of 8 days. This VSM, part of a broader project spanning 13.4 km and scheduled for 365 days, is overseen by a project manager conducting daily follow-ups and weekly progress updates. The visualization indicates a total lead time of 28 days for the earthwork process, distinguishing between 15.5 days of value-adding work and 12.5 days potentially available for lean improvement, underscoring the significant opportunity for enhancing operational efficiency and reducing waste.

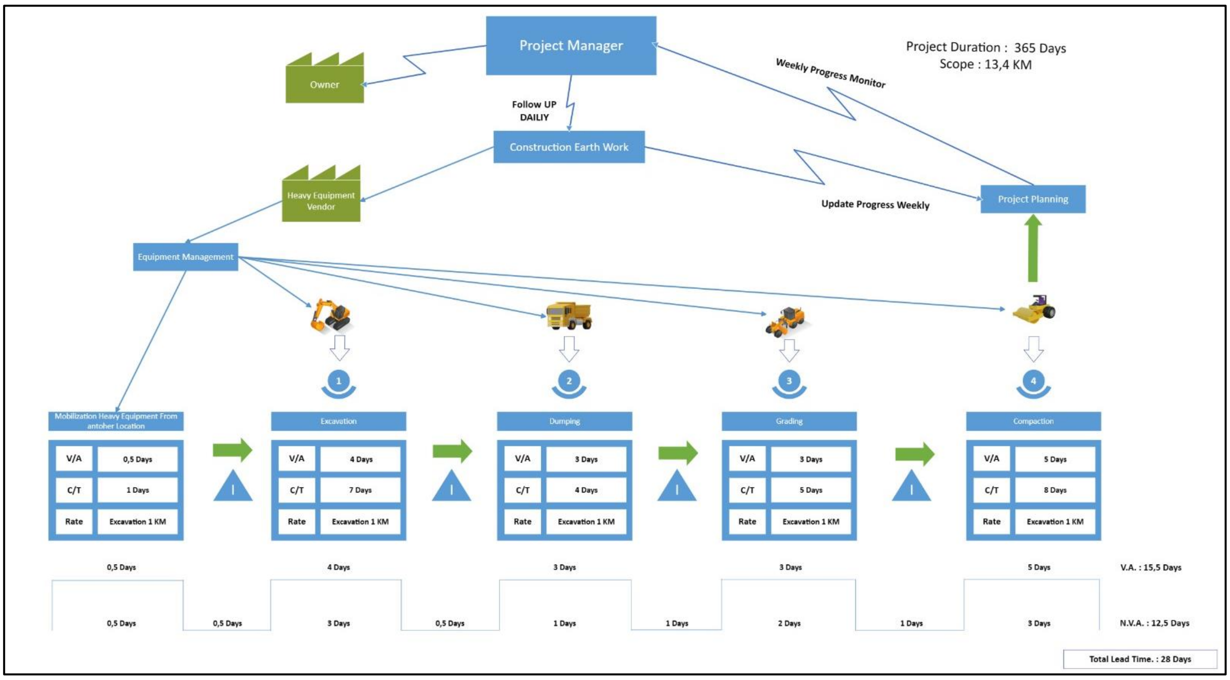

Figure 2: Current State VSM Diagram

With the current state now analyzed through VSM, we shift our attention to the causes of the identified waste. This sets the stage for the Fishbone diagram analysis, which will explore the systemic reasons behind the inefficiencies and pave the way for developing actionable strategies for waste reduction

Fishbone Diagram and Root Cause Analysis

The Fishbone analysis is expected to provide a structured investigation into the complexities of project delays and inefficiency, offering the next critical layer of understanding necessary for implementing Lean Construction principles effectively. In the comprehensive Fishbone analysis conducted for the Section 3A Toll Road project based on Figure 3, systematic exploration of root causes across categories methods, materials, machine, manpower, measurement, and environment has revealed key inefficiencies impacting the project.

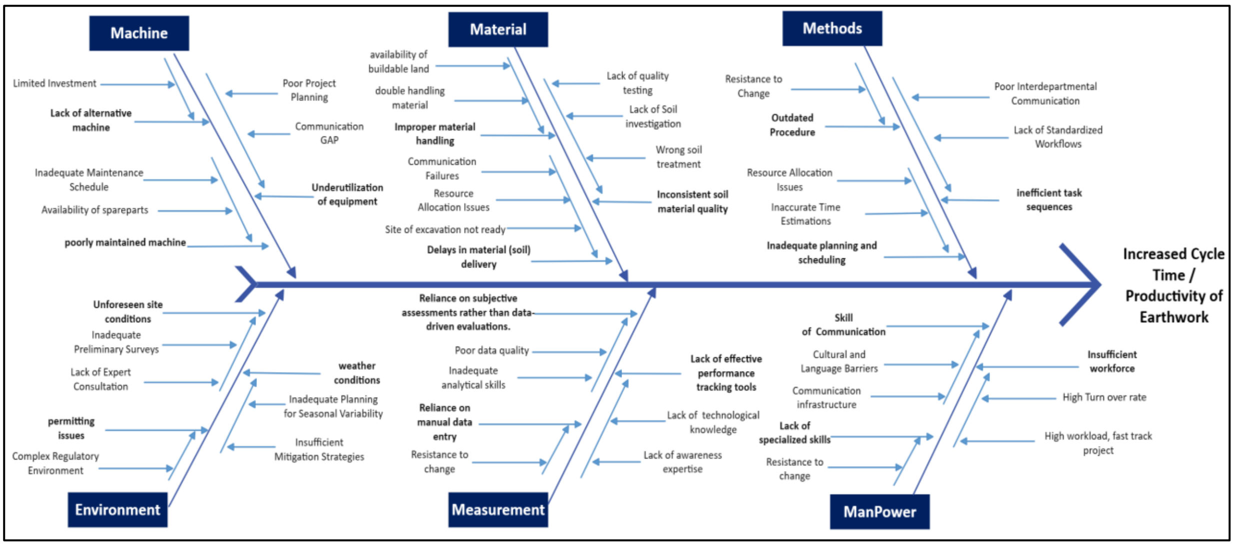

Figure 3: Fishbone Diagram

Based on the Fishbone analysis derived from field reports, several significant issues frequently arise across different categories. Within Methods, the main problems identified include planning and scheduling processes that are inadequate, lacking in detail, and not applicable as field references. For Materials, the soil often used cannot be utilized for earth filling because it does not meet the required criteria. In terms of Machinery, there is a lack of maintenance planning and coordination, leading to significant downtime with many machines remaining idle. Regarding Manpower, there is a substantial communication gap between field staff and management office personnel. Measurement issues persist due to reliance on manual measurement and monitoring systems, resulting in inaccurate data. In the Environment category, the complexity of obtaining excavation permits at the project's commencement poses challenges. Based on the results presented in Table 2, root causes have been categorized and ranked according to the frequency of occurrences over the past two months and the extent of their impact, as discussed in weekly meetings. This was done during periods of both conventional monitoring and digital monitoring. Subsequently, these root causes have been prioritized to determine which issues are most urgent and need to be addressed immediately.

Table 2: Top Root Causes by Frequency and Impact to Productivity

Category	Root Cause	Waste Category	frequence (2 month)	Impact
Methods	Resources Allocation Issue	Waiting, Motion	35 cases	Major
	Schedule not suitable with real condition on site	Waiting, Motion	40 cases	Major
Material	Wrong soil treatment	Defect	12 cases	Major
	lack of soil investigation	Defect, Motion	15 cases	Major
	Double handling material	Transportation, Motion	18 cases	Major
Machine	Availability of spareparts	Waiting	9 cases	Major
	inadequate maintenance schedule	Defect	28 cases	Major
Man Power	Miss coordination between field coordinator	Waiting, Motion	48 cases	*Severe*
Measurement	lack of tecnological knowledge	Non – Utilized Talent	8 cases	Major
	lack of awareness expertise	Non – Utilized Talent	8 cases	Major
Environment	Insufficent mitigation strategies for weather condition	Waiting, Defect	10 cases	Major
	Inadequate planning for seasonal variability	Waiting, Defect	10 cases	Major

COUNTERMEASURE DEVELOPMENT

To effectively address the major root causes identified in our analysis, we have developed and evaluated targeted solutions aimed at preventing ongoing issues and mitigating cost escalations. Table 3 outlines how these challenges were addressed using Lean Construction concepts. By implementing strategic actions grounded in Lean Construction methodologies, we aim to enhance operational efficiency and control project costs more effectively.

Table 3: Solution Based on Lean Approach

Root Cause	Solution
Resources Allocation Issue	Collaborate with the scheduling, procurement, and equipment departments to ensure that resources are prepared in accordance with the planned requirements. This preparation should be informed by the outcomes of previous productivity evaluations. Additionally, involving field coordinators in discussions about heavy equipment needs is essential. Together, develop a more comprehensive pull planning schedule that incorporates insights from all levels of the project team.
Schedule not suitable with real condition on site	Engage with key stakeholders including schedulers, procurement staff, equipment managers, field coordinators, foremen, and vendors. By facilitating a comprehensive discussion among these parties, we aim to develop a new, more dependable Last Planner System. This revised planning approach will serve as a fresh benchmark for ongoing schedule monitoring and evaluation, ensuring that all project activities are aligned and optimized for maximum efficiency.
Wrong soil treatment	Initiate further discussions with planning and design consultants to resolve the issues arising from differences between actual soil conditions and initial design specifications. It's imperative to quickly determine suitable soil treatment solutions to prevent heavy equipment from remaining idle while waiting for decisions.
Lack of soil investigation	Undertake a comprehensive reassessment of the soil conditions and quickly communicate the results to the planning consultants. This will ascertain whether the excavated soil meets the requirements for reuse as fill material or if there is a need to import soil from an external source.
Double handling material	Develop a detailed work plan for excavation and backfill activities, ensuring that every excavation task has a predefined disposal area to prevent inefficient practices such as double handling. Utilize weekly Last Planner System (LPS) planning to strategically sequence the excavation activities, coordinating which sections are to be excavated first and confirming the availability of designated backfill locations.
Availability of spareparts	Develop a procurement strategy for frequently replaced spare parts informed by the Last Planner System (LPS) and pull planning analyses. Should spare parts be unavailable, formulate a contingency plan to borrow heavy machinery from other sites temporarily. This plan requires a reassessment of the project timeline to accommodate machinery availability and prioritizes critical areas to prevent project delays.
Inadequate maintenance schedule	Begin scheduling routine inspections for heavy machinery, particularly during holidays, to ensure that the equipment operates at its maximum efficiency during working periods. This strategy minimizes technical issues with each piece of heavy machinery during operations and mitigates the cost of repairs by addressing potential problems early. Regular maintenance checks can prevent significant downtime and expensive fixes.
Miss coordination between field coordinator	Implement daily coordination meetings between on-site workers and field managers to effectively manage and optimize the utilization of available resources. Use these sessions to track the status of equipment and identify any operational constraints, ensuring that any deficiencies or challenges are immediately reported to the engineering and procurement teams.
Lack of tecnological knowledge	Deploy programs to rapidly and effectively upskill workers on new technologies, enhancing their proficiency and adoption.
Lack of awareness expertise	Develop a skills matrix to identify expertise gaps and implement cross-training programs to broaden the skill sets of the workforce

Table 3 (continued): Solution Based on Lean Approach

Root Cause	Solution
Insufficent mitigation strategies for weather condition	Develop comprehensive risk management plans that include specific mitigation strategies for adverse weather, integrating contingency plans into the project schedule.
Inadequate planning for seasonal variability	Create a construction schedule by integrating historical weather data provided by the local meteorological agency. This data should be carefully analyzed to anticipate potential weather disruptions over the upcoming month. By aligning this information with the project timelines, you can adjust the work schedule proactively to factor in likely weather conditions.

The solutions derived from the Lean approach analysis have been integrated into the current state map to develop a comprehensive future state map. This map projects substantial enhancements in the productivity of earthwork operations and aims to significantly reduce waste. A key focus is on minimizing idle time for equipment, thereby streamlining operations, and improving overall project efficiency. This strategic integration highlights the potential for tangible improvements in project execution and cost-effectiveness.

FUTURE STATE MAP

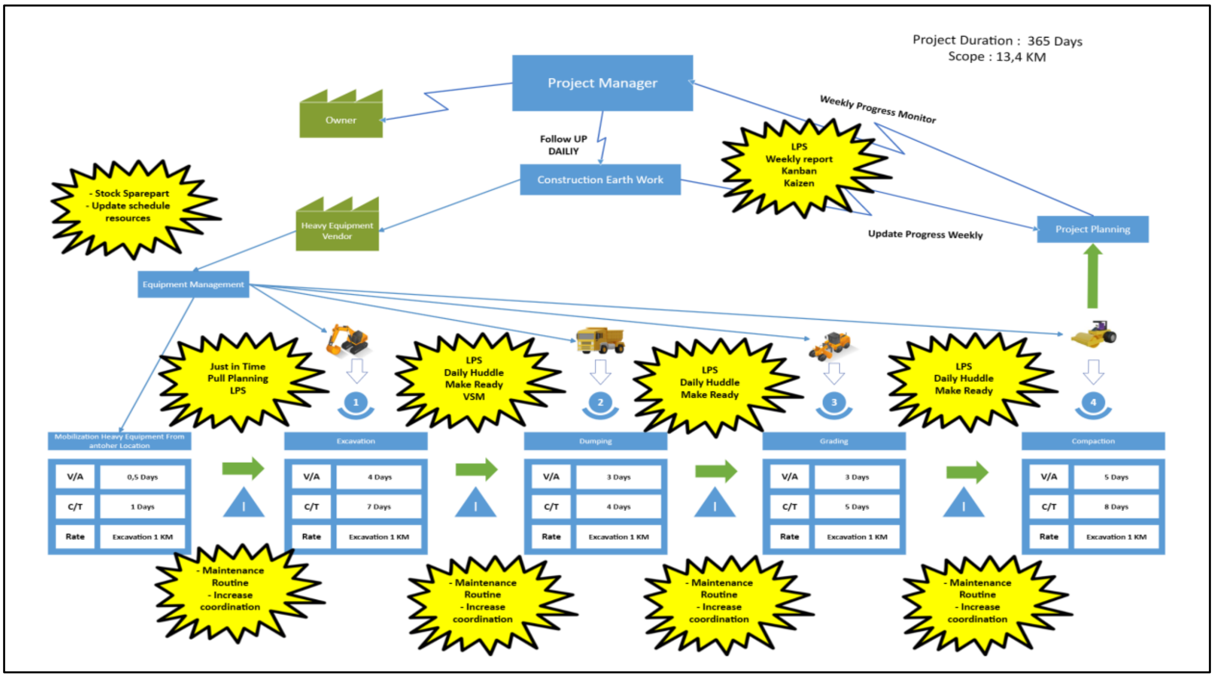

Figure 4: Future State Map

The Future State Map for the Section 3A Toll Road project based on Figure 4 reflects an adoption of Lean practices, integrating lean tools to align resource allocation and task execution with real-time needs. Maintenance is scheduled more effectively with improved coordination to minimize equipment downtime. Weekly reviews incorporate continuous improvement through Kaizen, allowing the project to adapt quickly to changes. A focus on increasing coordination between key person, also maintaining an updated inventory for spare parts and adjusting resource schedules is essential to prevent equipment idleness and boost productivity. This map sets a new standard for operational efficiency by embedding Lean methodologies into the project's processes. This streamlined approach is anticipated to increase non-value-added activities and diminish waste time, setting a new benchmark for operational efficiency and project performance.

DATA REPORT AND RESULTS

After thorough evaluations, the following month saw the deployment of the designed solutions and the Future State Map that had been previously analyzed. Discussions on root cause analyses and corresponding solutions took place in weekly meetings, with updates being made to the Last Planner System. These meetings, attended by representatives across all levels, especially the last planners on-site, were crucial for unifying the understanding and ensuring a coordinated approach to field operations for the next month. Table 4 in the subsequent section will detail the outcomes of applying the Lean tools to the digital monitoring system, showcasing the tangible improvements, notably in increased driving time, indicating a stride toward enhanced operational efficiency.

Table 4: Data Report Recap

Criteria	Month	Idle Time (Monthly)		Driving Times (Monthly)		Total Timesheet (Hour)	Total Cost
		Hour	%	Hour	%		
Manual	Aug	Undetectable		Undetectable		5,880.00	3,800,428,500.00
Digital Monitoring Without Lean Improvements	Sept	3,134,77	55.28	2,267.12	44.72	5,401.88	3,487,472,454.74
Digital Monitoring After Lean Improvements	Oct	1,237.78	18.26	5,589.81	81.74	6,827.59	4,450,175,157.25

Efforts to optimize the capability of heavy equipment by allocating it led to a total timesheet (hours) increase of about one thousand hours, resulting in a total cost increase to Rp. 4,450,175,157.25. Table 5 shows that the driving times before the implementation of lean construction were only at a percentage of 44.72%, unlike after the implementation of lean construction, which reached a percentage of 81.74% driving times. Additionally, from the recap table above, a comparison of idle time percentage between Digital Monitoring After Lean Improvements and Digital Monitoring Without Lean Improvements reveals a percentage decrease from 55.28% to only 18.26%.

Table 5: Waste Improvements

Criteria	Without Lean Improvements	After Lean Improvements	Deviation (Waste Improvements)	Info
Idle Time (Hour)	3,134.77	1,237.78	*-1,896.98*	Idle Time Decrease, Driving Time and Productivity Increase
Waste (%)	58.03%	18.13%	*-39.90%*	Waste % Decrease, Efficiency Increase 39%
Waste Cost / Idle Cost (Rp)	$ 124,787.00	$ 49,745.00	*-$ 75,041.00*	Waste Cost Decrease, Turn into Cost Productivity

The implementation of lean construction based in Table 5 on reducing waste and increasing value, is proven by the impact of corrective actions that have been conducted. There is a decrease in idle time, coupled with an increase in driving time. In other words, there has been a 39% increase in efficiency due to the decrease in waste. This change transforms costs that were previously used for waste into costs that are now used for productivity.

CONTROL AND MONITORING

Following the successful implementation of Lean tools and digital monitoring in October, it is imperative to ensure the continued application of these strategies to sustain the improvements achieved. A critical component of this ongoing effort is the deployment of a real-time monitoring dashboard for heavy equipment, utilizing integrated OBS (On-Board Systems) according to Figure 5. This system allows for the continuous measurement of each piece of heavy machinery's performance. The dashboard not only monitors productivity levels of individual equipment but also quickly identifies issues such as equipment breakdowns or idle times. Immediate identification enables a rapid response to apply Lean principles to diagnose and address the root causes of any discrepancies. This proactive approach fosters a culture of continuous improvement, or Kaizen, ensuring that the project continually adapts and evolves to improve efficiency and effectiveness.

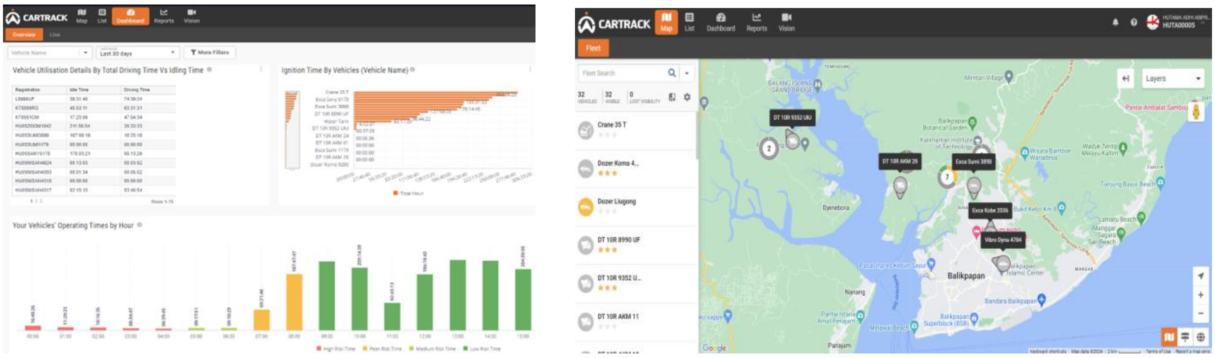

Figure 5: Dashboard in the Digital Monitoring by Cartrack

DISCUSSION

Following the significant improvements detailed in Tables 4 and 5—where driving times increased from 44.72% to 81.74% and idle times decreased from 55.28% to 18.26%—it is evident that Lean construction tools can illuminate hidden operational issues that regular meetings might miss. These tools, integrating with digital technologies, provide the project team with enhanced capabilities to identify and address inefficiencies promptly. future research could focus on several impactful areas. Quantitative assessments could explore the environmental impacts, particularly in terms of reduced fuel consumption and carbon emissions due to enhanced equipment efficiency. A cost-benefit analysis would be valuable, especially considering the reported increase in total project costs to USD 274,393.00 alongside a 1000-hour increase in total timesheet hours. Further studies might include longitudinal tracking to evaluate the long-term sustainability of these improvements, the integration of predictive analytics to optimize efficiency further, and an investigation into workforce adaptation to these changes.

CONCLUSIONS

The primary objective of this paper was to investigate the impact of digital monitoring on waste identification and management in Lean Construction (LC). The findings indicate that digital monitoring is instrumental in detecting and reducing waste, providing teams with the instant data necessary to implement rapid changes for waste minimization. Furthermore, it facilitates effective control measures to sustain improvement efforts and promotes continuous enhancement of processes. The application of digital monitoring in LC delivers a significant advantage by allowing for the prompt identification of inefficiencies that manual methods may overlook. By integrating Lean principles, the approach systematically highlights waste and its root causes, and pinpoints specific equipment that adds to inefficiencies. The analysis demonstrates that digital monitoring enables a structured and precise evaluation process, enhancing the capability to identify underperformance that is not readily apparent through conventional Lean practices. The research has successfully shown that with the aid of digital monitoring, underutilized heavy equipment can be quickly identified, leading to the reallocation of value-added time previously lost to idle periods. It quantifies waste accurately and in real-time, substantially improving the effectiveness and productivity of construction work, as well as facilitating a more informed performance evaluation of individual machinery. The results of this study confirm that the integration of digital monitoring into LC practices fulfills the research aim by substantiating its role in improving the efficiency and reducing the waste of construction projects.

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REFERENCES

Al-Jibouri, S. H. (2003). Monitoring systems and their effectiveness for project cost control in construction. International Journal of Project Management, 21(2), 145–154.

Alshibani, A. (2015). Forecasting project cost and time using fuzzy set theory and contractors' Judgment. Proceedings Of The 6th International Conference on Construction Engineering and Project Management (ICCEPM 2015)

Danku, J. C., Agyekum, K., & Asare, F. T. (2020). Critical Barriers to Traditional Project Progress Measurement: Perspectives of Ghanaian Construction Professionals. Journal of Building Construction and Planning Research, 8(2), 119–137.

Eldin, N. N., & Mayfield, J. (2005). Determination of most economical scrapers fleet. Journal of Construction Engineering and Management, 131(10), 1109–1114.

Ergen, E., Akinci, B., & Sacks, R. (2007). Tracking and locating components in a precast storage yard utilizing radio frequency identification technology and GPS. Automation in Construction, 16(3), 354–367.

Holness, G. V. R. (2008). BIMGaining.

Isaac, S., & Navon, R. (2014). Can project monitoring and control be fully automated? Construction Management and Economics, 32(6), 495–505.

Kiziltas, S., & Akinci, B. (2005). The need for prompt schedule update by utilizing reality capture technologies: A case study. Construction Research Congress 2005: Broadening Perspectives, 1–10.

Koo, B. and Fischer, M. (2000) Feasibility Study of 4D CAD in Commercial Construction. Journal of Construction Engineering and Management, 126, 251-260. https://doi.org/10.1061/(ASCE)0733-9364(2000)126:4(251)

Nasr, E., Shehab, T., & Vlad, A. (2013). Tracking systems in construction: Applications and comparisons. 49th ASC Annual International Conference Proceedings, 9–13.

Pradhananga, N., & Teizer, J. (2013). Automatic spatio-temporal analysis of construction site equipment operations using GPS data. Automation in Construction, 29, 107–122. https://doi.org/10.1016/j.autcon.2012.09.004

Tengan, C., Aigbavboa, C., & Thwala, W. D. (2021). *Construction Project Monitoring and Evaluation.* CRC Press.

The Lean Way. (2022). What is Continuous Improvement (Kaizen)? Retrieved from TheLeanWay.net.

Lean Construction Institute. (2023). Kaizen & Continuous Improvement. Retrieved from LeanConstruction.org.
IdeaScale. (2023). What is Continuous Improvement? Definition, Model, Methodology, Process and Examples. Retrieved from IdeaScale.com.
Boom and Bucket. (2022). Lean Construction Principles: Improve Efficiency and Reduce Waste. Retrieved from BoomandBucket.com.
Lean Construction Institute. (2023). PDCA in Lean. Retrieved from LeanConstruction.org.