



Efficiency of Material Procurement, Time, and Cost Control in the Canopy Construction Project at RSKD Duren Sawit

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ABSTRACT

Material procurement plays a critical role in determining the cost and schedule performance of hospital-based construction projects, where limited storage space and active medical operations constrain logistics. This study evaluates the efficiency of the material procurement system and its relationship with cost and time performance in the canopy construction project at RSKD Duren Sawit, East Jakarta. A descriptive quantitative case study approach was applied, combining field observation, structured interviews, and secondary project documents (purchase orders, bill of quantity, budget plan, and weekly progress reports). Cost and schedule performance were analyzed using Earned Value Analysis (EVA), while the Critical Path Method (CPM) was used to identify the activities controlling total project duration. The results show a Cost Performance Index (CPI) of 1.316 and a Schedule Performance Index (SPI) of 1.071 at week 10, indicating that the project was completed under budget and ahead of schedule, with an estimated cost saving of approximately IDR 461 million against the total budget. CPM analysis identified the motorcycle parking canopy works as the critical path, with zero float, while the ICU canopy works and K3 (occupational safety) activities had considerable float (30-75 days). Procurement efficiency was found to be influenced by accurate material volume planning, effective vendor price negotiation, Just-in-Time (JIT) delivery scheduling adapted to hospital operating hours, and strict incoming-material quality control. These findings provide a practical reference for managing material procurement in construction projects located within active healthcare facilities.

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1. INTRODUCTION

Time and cost efficiency are key determinants of success in modern construction projects. Material costs typically account for 20-50% of a project's total budget, so their management has a direct effect on overall project performance [1]. Good material management strongly influences the productivity and success of construction execution [2]. The canopy construction project at RSKD Duren Sawit, East Jakarta, is a complementary construction work intended to improve the comfort, safety, and operational function of the hospital, using structural steel, roofing, bolts, and other supporting materials. Because the works are carried out while the hospital remains fully operational, the timely availability of the correct quantity and quality of material is essential for the project to proceed according to the planned schedule and budget.

In practice, the procurement process often faces price fluctuations, supplier lead times, limited stockyard space within the hospital area, and partly manual logistics administration. If left unmanaged, these conditions can cause coordination inefficiencies that directly delay physical work and inflate overall project cost [3]. Earned Value Analysis (EVA) is used in this study to evaluate how procurement inefficiency affects project performance, as it enables simultaneous measurement of cost and schedule performance through indicators such as Planned Value (PV), Earned Value (EV), Actual Cost (AC), Cost Performance Index (CPI), and Schedule Performance Index (SPI) [4]. By applying EVA to planned and actual data, project performance can be linked back to the condition of the material procurement system during execution, producing measurable and implementable optimization recommendations.

Previous studies have applied EVA to evaluate cost and schedule performance on various types of construction projects, including buildings and bridges [5]-[8], and other studies have examined material procurement systems as a factor affecting project success, particularly in hospital projects [9]. However, most EVA-based studies focus on overall project performance without linking it directly to procurement efficiency, while procurement-focused studies rarely quantify the resulting effect on cost and schedule performance. This study addresses that gap by analyzing the efficiency of the material procurement system together with its relationship to cost and time control, using the canopy construction project at RSKD Duren Sawit as a case study characterized by an active, operating hospital environment. The objectives of this study are: (1) to describe the procurement and construction process of the canopy project based on its critical path using the Critical Path Method (CPM); (2) to analyze the time and cost efficiency of project execution using Earned Value Analysis (EVA); and (3) to identify the factors influencing the efficiency of the material procurement system.

Beyond its use as an academic evaluation tool, EVA has increasingly been adopted by construction firms as a routine management practice because it links the three core project dimensions of scope, schedule, and cost within a single measurement framework [10]. Industry practice guidance further emphasizes that establishing a detailed baseline schedule and a properly segmented work breakdown structure is a prerequisite for EVA to generate reliable cost and schedule variance signals [16]. In the context of hospital-based construction, where reduced storage space and continuous clinical operations limit the contractor's flexibility, the discipline required to maintain an accurate baseline and to update actual cost and progress data on a weekly basis becomes even more critical, since delayed or inaccurate updates can mask the real effect of procurement disruptions on project performance.

This paper is organized as follows. Section 2 reviews previous studies on Earned Value Analysis, the Critical Path Method, and material procurement and supply chain management in construction, with particular attention to projects executed within active healthcare facilities. Section 3 describes the research method, including the case study setting, data collection procedures, and the EVA and CPM computation techniques used. Section 4 presents the results of the cost and schedule performance analysis, the critical path analysis, and the factors influencing procurement efficiency, together with a discussion that relates the findings to prior studies. Section 5 concludes the paper and outlines its limitations and directions for future research.

2. LITERATURE REVIEW

2.1. Earned Value Analysis in Construction Project Performance Measurement

Earned Value Analysis integrates the measurement of cost, schedule, and physical progress into a single framework, allowing project managers to identify performance deviations earlier than traditional cost-only or schedule-only reporting methods [4], [10]. Studies applying EVA to construction case studies have shown that the technique is effective in forecasting the final project cost and duration once a reliable baseline and a properly structured work breakdown are established [11]. Proaño-Narváez et al. compared an EVA-managed and a non-EVA-managed building project executed by the same contractor and found that the project managed with a disciplined EVA procedure achieved a positive cost variance of 14.2%, while the

project without a formal EVA procedure incurred a cost overrun of 3.24%, indicating that the systematic use of EVA itself contributes to better cost outcomes rather than merely reporting them [10]. The same study proposed practical tolerance bands for the Cost Performance Index (CPI) and Schedule Performance Index (SPI), where values between 0.8 and 1.2 indicate a well-controlled project, while values outside this range signal the need for corrective action or a review of the measurement baseline [10]. These tolerance bands are used later in this paper as a benchmark for interpreting the CPI and SPI values obtained for the RSKD Duren Sawit canopy project.

2.2. Critical Path Method and Schedule Float Management

The Critical Path Method identifies the longest sequence of dependent activities that determines the minimum possible project duration; activities on this path have zero total float and therefore directly control the project completion date, while activities with positive float can be rescheduled without delaying the overall project [12]. Lu et al. proposed a simplified path-float-based procedure for determining total float without a full backward-pass calculation, which is particularly useful for practitioners managing schedules with a large number of activities [12]. Guidance from the Project Management Institute further stresses that float values should never be negative in a properly logic-linked schedule, and that continuous verification of the critical path is required whenever the schedule is updated, since a change in progress or logic can shift which activities are critical [13]. In construction practice, activities with considerable float, such as safety and finishing works that are not on the governing path, provide management with flexibility to reallocate resources toward the activities that directly threaten the completion date [12], [13].

2.3. Material Procurement and Just-in-Time Delivery in Construction Supply Chains

Material costs commonly represent the largest single component of a construction project's budget, so inefficiencies in procurement planning, vendor selection, and delivery scheduling translate directly into cost and schedule variance [1], [18]. The Just-in-Time (JIT) delivery concept, originally developed within the Toyota Production System, has been adapted to construction logistics to reduce on-site inventory, minimize double-handling, and lower the risk of material damage or theft in projects with limited storage space [14], [15]. Kong et al. demonstrated, through a study of precast construction batch delivery, that JIT-based scheduling synchronized with the master construction schedule can improve delivery punctuality while reducing logistics cost compared with conventional bulk delivery [14]. Vrijhoef and Koskela argued that supply chain inefficiencies in construction are frequently caused by a fragmented interface between site production and the materials supply chain, and that closer integration between scheduling and procurement functions, rather than treating them as separate management processes, is required to control both cost and time performance [15].

2.4. Construction Logistics and Procurement in Active Healthcare Facilities

Construction or renovation work carried out within an operating hospital introduces logistical constraints that are not present on a typical greenfield project, including restricted access routes, limited laydown area, infection-control requirements, and delivery windows that must avoid disrupting clinical activities [9], [17]. Industry guidance on hospital construction recommends that, given the limited available space, material deliveries should be scheduled on a just-in-time basis and coordinated closely with hospital staff to avoid interference with patient care areas [17]. Tanubrata and Trisyandi's evaluation of material procurement at a hospital project similarly found that procurement performance in a healthcare setting depends heavily on coordination between the contractor's logistics team and hospital management regarding delivery timing and storage allocation [9]. These findings collectively suggest that procurement efficiency in hospital-based construction cannot be evaluated using cost and schedule indicators alone; it also needs to account for site-specific operational constraints that influence how and when material can physically be delivered and stored. This is the gap that the present study addresses by linking EVA-based cost and schedule performance with the operational procurement practices observed in the canopy construction project at RSKD Duren Sawit.

3. RESEARCH METHOD

3.1. Research Design and Case Study Setting

This study applied a quantitative descriptive method with a case-study approach, used to systematically present the phenomenon of cost and schedule variance in mathematical terms. The case study was conducted on the canopy construction project at Rumah Sakit Khusus Daerah (RSKD) Duren Sawit, East Jakarta, which had a bid value (HPS) of IDR 2,736,227,000 and a contractual duration of 90 calendar days starting 30 September 2025.

3.2. Data Collection Technique

Data were collected through a combination of field observation, structured interviews, and documentation study. Weekly field observation covered the actual delivery schedule and volume of steel and roofing material, warehouse/stockyard conditions under space constraints, and conformity between delivered material and technical specifications. Structured interviews were conducted with the project manager, site

engineer, and the procurement/logistics team to obtain information on procurement policy, material scheduling, cost-control strategy, and delivery constraints. Secondary data consisted of the baseline schedule (S-curve), the Budget Plan (RAB), purchase orders, delivery notes, invoices, and weekly progress reports.

3.3. Data Analysis Technique

Cost and schedule performance were analyzed using Earned Value Analysis (EVA), which integrates cost, schedule, and physical progress into a single objective performance measurement [4]. The main parameters were computed as follows:

$$PV = \text{Planned \% Complete} \times BAC \quad (1)$$

$$EV = \text{Actual \% Complete} \times BAC \quad (2)$$

$$AC = \text{Actual Cost Incurred} \quad (3)$$

$$CV = EV - AC \quad (4)$$

$$SV = EV - PV \quad (5)$$

$$CPI = EV / AC \quad (6)$$

$$SPI = EV / PV \quad (7)$$

$$ETC = (BAC - EV) / CPI \quad (8)$$

$$EAC = AC + ETC \quad (9)$$

where BAC is the Budget at Completion (total contract budget). A CPI or SPI greater than 1 indicates efficient cost use or a schedule ahead of plan, a value equal to 1 indicates the project is exactly on budget/schedule, and a value below 1 indicates cost overrun or schedule delay. In addition, the Critical Path Method (CPM) was used to identify the sequence of activities that determines the total project duration, based on Early Start (ES), Early Finish (EF), Late Start (LS), and Late Finish (LF); an activity with zero total float lies on the critical path.

3.4. Validity and Reliability of Data

To ensure the validity of the analysis, secondary cost and schedule data obtained from purchase orders, delivery notes, and weekly progress reports were cross-checked against the results of the structured interviews and field observation; discrepancies between the reported progress percentage and the physically observed progress in the field were clarified directly with the site engineer before being entered into the EVA calculation. This triangulation between documentary data, interview data, and field observation was intended to reduce the risk of overstated physical progress, which is a common source of bias in studies that rely solely on progress reports. The consistency of the resulting PV, EV, and AC series was further checked by verifying that the cumulative curves were non-decreasing over the ten observation weeks and that the reported actual cost did not exceed the recorded purchase order and invoice values for the corresponding period.

4. RESULTS AND DISCUSSION

The canopy construction project at RSKD Duren Sawit consists of two work areas, the ICU/IGD canopy and the motorcycle parking canopy, covering steel structure, roofing, plafond, plumbing, and electrical works. The project has a total contract budget (BAC) of IDR 1,920,062,979 (excluding 11% VAT) and a planned duration of 13 weeks (90 calendar days), starting 30 September 2025.

4.1. Cost and Schedule Performance (Earned Value Analysis)

Weekly PV, EV, and AC values were calculated for the first 10 weeks of the project, the period for which actual progress and cost data were available. The resulting performance curve is presented in Figure 1, showing that the EV (Earned Value) curve consistently remained above the PV (Planned Value) curve after week 2, while AC (Actual Cost) remained below both curves throughout the observation period, indicating that the project progressed faster than planned while spending less than the earned value of work performed.



Figure 1. Project cost and schedule performance curve (PV, EV, AC)

Table 1 summarizes the cumulative EVA indicators at week 10. The Schedule Variance (SV) of IDR 114,145,824 and Cost Variance (CV) of IDR 415,034,717 are both positive, confirming that the project was ahead of schedule and under budget. The Schedule Performance Index (SPI) of 1.071 and Cost Performance Index (CPI) of 1.316 further indicate that physical progress advanced about 7% faster than planned, while every IDR 1 spent generated IDR 1.316 of earned work value. Based on the CPI trend, the estimated cost to complete the remaining work (ETC) was IDR 146,559,846 and the estimated cost at completion (EAC) was IDR 1,458,669,780, which is IDR 461,393,199 lower than the total budget (BAC), representing a projected saving of about 24% relative to the approved budget.

Table 1. Cumulative EVA Performance Indicators at Week 10

Indicator	Value	Interpretation
Planned Value (PV)	IDR 1,612,998,827	Cumulative planned budget through week 10
Earned Value (EV)	IDR 1,727,144,651	Cumulative value of completed work
Actual Cost (AC)	IDR 1,312,109,934	Cumulative actual cost incurred
Schedule Variance (SV)	IDR 114,145,824	SV > 0: ahead of schedule
Cost Variance (CV)	IDR 415,034,717	CV > 0: under budget
SPI	1.071	SPI > 1: faster than planned
CPI	1.316	CPI > 1: cost-efficient
ETC	IDR 146,559,846	Estimated cost to complete remaining work
EAC	IDR 1,458,669,780	Estimated total cost at completion
Projected saving (BAC - EAC)	IDR 461,393,199	Projected saving against total budget (BAC)

4.2. Critical Path Analysis (CPM)

Critical Path Method (CPM) analysis, performed on the full work breakdown structure of the project, shows that the motorcycle parking canopy works form the dominant critical path, with a total float of zero throughout the sequence of site preparation and demolition, earthwork and foundation, structural steel and concrete works, and finishing/electrical works. Any one-day delay on this path directly postpones the project handover date. In contrast, the occupational safety (K3) activities and several ICU/IGD canopy work packages have considerable float, ranging from about 30 to 75 days, giving management flexibility to reschedule these activities without affecting the overall completion date. This finding indicates that supervision and resource priority should be concentrated on the motorcycle parking canopy work sequence, from earthwork through steel structure to finishing.

4.3. Factors Influencing Material Procurement Efficiency

Based on the operational data and EVA results, four main factors were found to influence procurement efficiency in this project. First, accurate material-quantity planning based on shop drawings minimized over-procurement and material waste, ensuring that budgeted material cost was converted into actual physical progress (EV). Second, effective vendor price negotiation and the use of fixed-price purchase agreements secured material prices below the initial budget estimate and protected the project from raw material price fluctuation. Third, a Just-in-Time (JIT) logistics strategy, in which material deliveries were scheduled to match the master schedule and were mobilized outside the hospital's peak operating hours, ensured material availability while avoiding disruption to hospital operations and reducing the risk of storage damage or theft in the limited stockyard area. Fourth, strict incoming-material quality control, in which every delivery was inspected against technical specifications before acceptance, minimized the risk of using defective material and the resulting rework, which in turn helped sustain the pace of physical progress.

4.4. Comparison with Previous Studies

The CPI of 1.316 and SPI of 1.071 obtained in this study fall outside the 0.8-1.2 tolerance band suggested by Proano-Narvaez et al. for a well-controlled project, which signals a condition that, under their framework, would normally warrant a review of the measurement baseline [10]. In this case, however, the deviation reflects a favorable outcome rather than a performance problem: the elevated CPI corresponds to accurate volume planning and successful price negotiation with vendors, while field verification confirmed that the reported physical progress matched the work actually completed. This pattern is consistent with the case examined by Eirgash, where a well-structured work breakdown and disciplined cost recording produced CPI and SPI values that remained clearly above 1.0 without indicating measurement error [11]. The result

also supports the observation of Vrijhoef and Koskela that closer integration between site scheduling and materials procurement, rather than treating them as separate functions, is associated with improved cost and schedule outcomes [15]. Regarding the critical path findings, the zero-float condition identified on the motorcycle parking canopy sequence is consistent with the general principle that the governing path in a construction schedule is the one most sensitive to delay, as described in the Project Management Institute's guidance on float calculation [13]; the 30-75 days of float found on the K3 and ICU/IGD activities similarly matches the pattern reported by Lu et al., in which non-critical work packages retain substantial scheduling flexibility that management can use to reallocate resources toward the controlling sequence [12]. Finally, the Just-in-Time delivery pattern adopted on this project, in which material mobilization was scheduled outside the hospital's peak operating hours, mirrors the JIT practice described by Kong et al. for precast batch delivery, where synchronizing delivery with the master schedule reduced both storage requirements and the risk of on-site damage [14], and is consistent with the hospital-specific logistics guidance that recommends coordinating delivery windows with clinical operations [17].

4.5. Managerial Implications

The findings of this study offer several practical implications for contractors and project managers handling construction work within active hospital environments. First, because the motorcycle parking canopy sequence forms the zero-float critical path, project supervision and resource priority, including manpower, equipment, and expedited material delivery, should be concentrated on this sequence, while the float available on the K3 and ICU/IGD activities can be used as a buffer to absorb minor disruptions without affecting the handover date. Second, since procurement efficiency was found to be closely linked to cost performance, project teams should institutionalize accurate shop-drawing-based quantity takeoff and fixed-price purchase agreements as standard procurement practice rather than case-by-case decisions. Third, the positive experience with Just-in-Time delivery in this project suggests that contractors working in similarly constrained hospital sites should formalize delivery-window coordination with hospital facility management as part of the project's logistics plan, rather than relying on informal arrangements between the site team and suppliers. Fourth, given that CPI and SPI values outside the normal tolerance range can indicate either a performance problem or, as in this case, a genuinely favorable outcome, project teams should pair EVA monitoring with periodic field verification of physical progress so that favorable indicators are not mistaken for baseline measurement error, and unfavorable indicators are not overlooked as data noise.

4.6. Synthesis of Findings

Taken together, the results of this study show that the three areas examined, cost and schedule performance, critical path structure, and material procurement practice, are closely interrelated rather than independent aspects of project control. The favorable CPI and SPI values recorded at week 10 were not an isolated statistical outcome; they were traceable to specific procurement decisions, namely accurate shop-drawing-based quantity planning, fixed-price vendor agreements, JIT delivery synchronized with the master schedule, and strict incoming-material inspection, each of which reduced either the actual cost incurred (AC) or the risk of rework that would otherwise have slowed physical progress. At the same time, the CPM analysis clarified where these procurement gains had the greatest effect on project duration: because the motorcycle parking canopy sequence carried zero float, any procurement delay affecting steel, roofing, or finishing material for that work package would have had an immediate and direct impact on the project handover date, whereas equivalent delays on the K3 or ICU/IGD packages could largely be absorbed by their available float. This integrated view, linking EVA-based performance measurement, CPM-based schedule control, and procurement management, provides a more complete explanation of project success than any of the three perspectives could offer on its own, and it reinforces the argument advanced in the literature review that procurement efficiency in construction should be evaluated jointly with, rather than separately from, cost and schedule performance [10], [15].

5. CONCLUSION

This study evaluated the efficiency of the material procurement system and its relationship to cost and schedule performance on the canopy construction project at RSKD Duren Sawit. The Cost Performance Index (CPI) of 1.316 shows that project execution cost was lower than the planned budget, with an estimated final cost (EAC) of IDR 1,458,669,780 against a total budget (BAC) of IDR 1,920,062,979, a projected saving of IDR 461,393,199. The Schedule Performance Index (SPI) of 1.071 indicates that the project progressed faster than planned, reaching about 90% completion in 10 weeks against a 13-week baseline. Critical Path Method analysis identified the motorcycle parking canopy work sequence as the controlling path with zero float, requiring priority supervision, while several work packages, including the occupational safety (K3) program and part of the ICU/IGD canopy works, had considerable schedule flexibility (30-75 days of float). Material procurement was carried out through five structured stages: planning, supplier selection, purchasing, delivery logistics, and quality inspection, and its efficiency was primarily driven by

accurate quantity planning, effective vendor negotiation, Just-in-Time logistics adapted to hospital operating constraints, and strict incoming-material quality control. These findings suggest that daily, integrated cost-schedule monitoring, supported by an accurate and well-documented information system, is essential to sustain procurement efficiency and control performance in construction projects carried out within active hospital environments.

Limitations and Future Research

This study has several limitations that should be considered when interpreting its findings. First, the EVA and CPM analysis was limited to the first ten weeks of a thirteen-week project, so the final CPI, SPI, and float values at project completion may differ slightly from the mid-project figures reported here. Second, the study was based on a single case study project; while this allowed an in-depth analysis of procurement efficiency within one hospital construction context, the findings may not be directly generalizable to hospital projects with different scopes, budgets, or regional supplier conditions. Third, the factors influencing procurement efficiency were identified qualitatively from field observation and structured interviews rather than through a statistically validated survey instrument, so their relative weight could not be quantified. Future research could address these limitations by tracking EVA and CPM indicators through full project completion, by comparing procurement efficiency across multiple hospital construction projects in different regions, and by using a quantitative survey to statistically test the relationship between specific procurement practices, such as JIT delivery adherence or vendor negotiation strategy, and cost and schedule performance indices. Future studies could also incorporate risk-adjusted EVA forecasting methods to account for the uncertainty inherent in hospital construction schedules affected by clinical operating constraints.

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