

**Diagnosis of Schedule Delays in Cost-Efficiency Conditions
Integration of PLS-SEM, IPMA, and Earned Value Management in Road
Projects in Indonesia**

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Abstract

Project monitoring often separates objective control measures from implementers' assessments of the capabilities that shape project success. This separation limits the practical usefulness of both approaches. Earned Value Management (EVM) shows performance deviations, but does not directly determine the managerial aspects that require attention. In contrast, perception-based models identify relevant factors without pointing out actual schedule and cost issues. This study integrates EVM, Partial Least Squares Structural Equation Modeling (PLS-SEM), and Importance-Performance Map Analysis (IPMA) to diagnose the context of the selected road project improvement packages in Indonesia. The survey data came from 114 project personnel, while the schedule and cost data included the *Tambakreja-Bantarsari* and *Legundi-Planjan* packages. Both packages were late, with Schedule Performance Indices of 0.897 and 0.709, but remained cost-efficient, with Cost Performance Indices of 1.029 and 1.298. The PLS-SEM results are used to weight importance in IPMA, not to test determinants. Project procurement and labor behavior are highly important but underperform, so they should be prioritized for improvement. Management, planning, and organizational aspects perform better and should be maintained. Schedule recovery should focus on smooth procurement, supplier coordination, labor discipline, communication, and task execution without weakening cost control. This integrated framework links a project's objective status to actionable managerial priorities. Findings indicate intervention prioritization, not causality.

Keywords: earned value management; importance–performance map analysis; PLS-SEM; road construction; schedule delays; project procurement

1. Introduction

A project can incur lower costs than the value of completed work yet still fail to make progress on schedule. This imbalance between schedule performance and costs is important in road construction projects. Road project delays can impede community mobility, prolong on-the-ground risk exposure, and delay public benefits, even when project spending remains under control.

Various studies have identified the causes of construction project delays, including procurement disruptions, labor productivity, equipment availability, planning quality, and organizational coordination (Durdyev & Hosseini, 2020; Mohammed & Bello, 2022). However, a list of common delay factors may not indicate which organizational capabilities to address first under certain project conditions.

Earned Value Management answers questions about how far the project has progressed against the planned schedule and budget. The Schedule Performance Index (SPI) and the Cost Performance Index (CPI) indicate whether the project's progress and expenditure are on track.

EVM is useful as an early warning system and forecasting tool. However, EVM does not directly explain the cause of an organizational deviation or the intervention with the strongest managerial leverage (Netto et al., 2020). Therefore, an additional diagnostic layer is needed to translate project control signals into managerial action priorities.

Perception-based models can provide this diagnostic layer if interpreted carefully. PLS-SEM can estimate the relative relationship between managerial constructs and risk and perceptions of project success. Furthermore, IPMA combines each construct's importance level with the performance achieved.

Unlike much determinant research, this study does not again question whether project procurement, labor behavior, planning, organization, and operational risk relate to project success. This study examines how these relationships can guide managerial action after objective control data show a schedule problem.

This study uses the structural coefficients as diagnostic inputs and does not present them as the article's main contribution. The analysis's novelty lies in synthesizing three layers of evidence. First, the EVM identifies the patterns of schedule and cost performance that actually occur. Second, PLS-SEM shows the relative relevance of managerial capabilities and risks to project success. Third, IPMA distinguishes between capabilities that need improvement and those that need maintenance.

Based on these arguments, this study answers the following two questions.

1. What are the performance patterns of schedules and costs on the two road improvement packages studied?
2. What managerial capabilities and risk control need to be prioritized when the results of EVM and IPMA are interpreted in an integrated manner?

This research offers practical and methodological contributions. Practically, this study turns information about project performance irregularities into a more targeted intervention agenda. Methodologically, the study shows how objective project data and survey-based priority mapping can be integrated without concluding that cross-sectional perceptions cause delays in a project package. This distinction is important to maintain the credibility of using multiple sources of evidence in project performance evaluation.

2. Conceptual Foundations

2.1 Objective diagnosis through Earned Value Management

Earned Value Management integrates planned value, earned value, and actual cost in one basis for project control. The Schedule Performance Index is calculated by dividing the earned value by the planned value. An SPI value below 1 indicates that the work completed was less than the work planned for the same period.

The Cost Performance Index is calculated by dividing the earned value by the actual cost. A CPI value above 1 indicates that the value of the completed work is greater than the actual cost incurred at that control point.

Other measures, such as Estimate at Completion (EAC) and Estimate to Complete (ETC), can estimate the final cost position if the observed cost-efficiency pattern continues.

These measures are useful as diagnostic indicators, but they cannot replace investigations into the operational and organizational conditions underlying project performance (Lipke, 2020; Netto et al., 2020). An SPI value below one indicates a schedule issue, but it does not automatically explain whether procurement, labor productivity, equipment availability, organizational coordination, or other factors caused the delay.

2.2 From the relevance of the explanation to the priority of improvement

PLS-SEM is suitable for use in prediction-oriented models involving multiple latent constructs. This method can estimate the relative contribution of project capabilities and risk conditions to the target construct, such as the perception of project success (Hair et al., 2021). Nonetheless, statistical significance alone does not indicate the most urgent areas for improvement. A factor can strongly relate to project success while also indicating a high performance level. Under these conditions, appropriate managerial actions do not always improve the factor; instead, they maintain the performance already achieved.

The IPMA complements the importance measure by adding the average performance level for each construct or indicator. Factors with relatively high importance but relatively low performance offer greater opportunities for improvement than factors that are equally important but have demonstrated good performance.

The direction of the relationship also matters if the IPMA includes an adverse construct. In this study, material risk, equipment risk, and occupational safety and health risk describe risk exposure after score reversal is performed. Higher scores indicate greater risk or weaker control. The negative influence of the risk construct means that a decrease in the risk score is expected. Therefore, negative interests cannot be interpreted in the same way as positive interests in project procurement, labor behavior, or planning capabilities.

2.3 Integrated diagnosis logic

The three methods answer questions in a complementary way, as shown in Table 1.

Table 1. The three methods

Analysis layer	Main questions	Evidence used	External results
EVM	What are the objective conditions of the project?	Schedule and cost data	Schedule–cost diagnosis and cost projections
PLS-SEM	What managerial domains are relevant to the success of the project?	Project personnel survey answers	The direction and magnitude of the relative relationship
IPMA	In which aspects are there opportunities for improvement?	Total impact and scaled performance	Prioritize fixing, maintaining, or strengthening controls
Integrated analytics	What needs to be addressed first?	Convergent interpretation of the three layers	A targeted and actionable intervention agenda

EVM establishes the form of deviations that occur. PLS-SEM shows that the managerial domain is relevant to the project success construct. The IPMA identifies relevant domains whose performance is still not optimal. Integrating the three results yields a portfolio of interventions while still distinguishing actual observed project performance from inferred managerial priorities.

3. Research Methods

3.1 Research design and unit analysis

The research used a sequential diagnosis design. The study first analyzed objective project data to assess the schedule and cost status of the two road improvement packages, *Tambakreja-*

Bantarsari and Legundi-Planjan. The study also used survey data to map managerial priorities and risks related to perceptions of project success.

The study integrated the two streams of evidence at the interpretation stage. The study design did not pair each respondent with an individual EVM observation time series. Therefore, integration served to triangulate findings and support decision-making, rather than establish causal relationships at the project package level.

3.2 Survey data and research constructs

The survey involved 114 personnel involved in road construction projects. The study used seven exogenous constructs, namely:

1. project procurement;
2. labor behavior;
3. management and planning;
4. organizational aspects;
5. material risk;
6. equipment risk; and
7. occupational safety and health risks.

The endogenous construct describes respondents' perceptions of the project's success.

Risk indicators are initially formulated as favorable operating conditions. The score of the indicator is then transformed using the equation:

Transformation result risk score = 8 – original answer

The research instrument used a seven-point scale. After transformation, a higher score indicates greater risk exposure or weaker controls. This coding decision must be explained because it affects the direction of structural relationships and the interpretation of IPMA.

3.3 PLS-SEM and IPMA Procedures

The PLS-SEM model was estimated using SmartPLS 4. We evaluated the quality of the measurement model before interpreting the structural model. The model explained 87.4% of the variation in the perception of project success, with the following values:

$$R^2 = 0.874$$

The model also produces:

$$Q^2_{\text{predict}} = 0.870$$

In this article, structural path results are not presented as the main findings; instead, they are used to determine the level of importance in the IPMA. The performance of each construct is transformed to a scale of 0–100.

Prioritize positive capability constructs with relatively high importance but relatively low performance. Meanwhile, the risk construct is evaluated by considering the direction of the relationship. Negative influences indicate that risk reduction, not improved performance scores, is an expected managerial goal.

3.4 Earned Value

The EVM analysis uses *the planned value*, *earned value*, and *actual cost* recorded at the control point of each project package. SPI and CPI are calculated using the following equation:

$$SPI = \frac{EV}{PV}$$

$$CPI = \frac{EV}{AC}$$

Description:

- EV is *earned value*;
- PV is the *planned value*; and
- AC is *the actual cost*.

EAC and ETC describe the projected cost position if the observed cost efficiency continues. The *Tambakreja–Bantarsari* package was evaluated in the 21st month, namely February 2021. The *Legundi–Planjan* package was evaluated in the 18th month, namely December 2020. Because each package provides only one control portrait, the analysis cannot be used to assess performance progress after the observation point or the final project result.

3.5 Results integration rules

A managerial domain is classified as an intervention priority if it meets the following three conditions:

1. The EVM profile shows the presence of important project control issues;
2. The construct has a relevant relationship with the perception of project success; and
3. IPMA's performance shows that there is room for improvement.

Domains with relatively high importance and better performance are classified as capabilities to maintain and use to support corrective action. Risk domains are prioritized for strengthening controls when risk exposure remains relatively high and the structural relationship is adverse.

4. Research Results

4.1 Objective diagnosis of schedules and costs performance

Both project packages resulted in SPI values below 1. The results showed that the project's physical progress was lower than the planned schedule at the observation point.

The *Legundi-Planjan* package experienced a greater delay, with an SPI of 0.709. The *Tambakreja-Bantarsari* package had an SPI of 0.897.

At the same time, the CPI on both packages is above 1. This means that both packages generate a greater work value for each unit of actual cost incurred compared to the standard cost in the plan. Nonetheless, a favorable cost position does not mean the project was completed on time.

Table 2. Earned value profile of both road project packages

Project packages	Observation point	SPI	CPI	BAC	EAC	ETC	Diagnosis
<i>Tambakreja-Bantarsari</i>	21st month, February 2021	0.897	1.029	IDR 95,454,528,960	IDR 92,764,362,448	IDR 9,487,922,293	Late, but cost-efficient
<i>Legundi-Planjan</i>	18th month, December 2020	0.709	1.298	IDR 69,884,318,211	IDR 53,839,998,621	IDR 15,666,388,642	Experiencing greater delays, but cost-efficient

The EAC value for both packages is below their respective budgets, consistent with the CPI value above 1. However, the cost advantage does not eliminate the risk of delays.

Slow mobilization, delayed procurement, limited work ready to be done, or activities not yet implemented can reduce actual expenses while slowing progress. The relevant managerial question is not whether to relax cost controls, but how to recover schedules without eliminating still-profitable cost positions.

4.2 Importance and performance at the construct level

Project procurement has the largest positive interest value (0.379), but its performance value is only 53.125. Labor behavior has the second-largest positive interest value among managerial constructs (0.249), with a performance value of 51.099. Figure 1 shows the construct-level IPMA results.

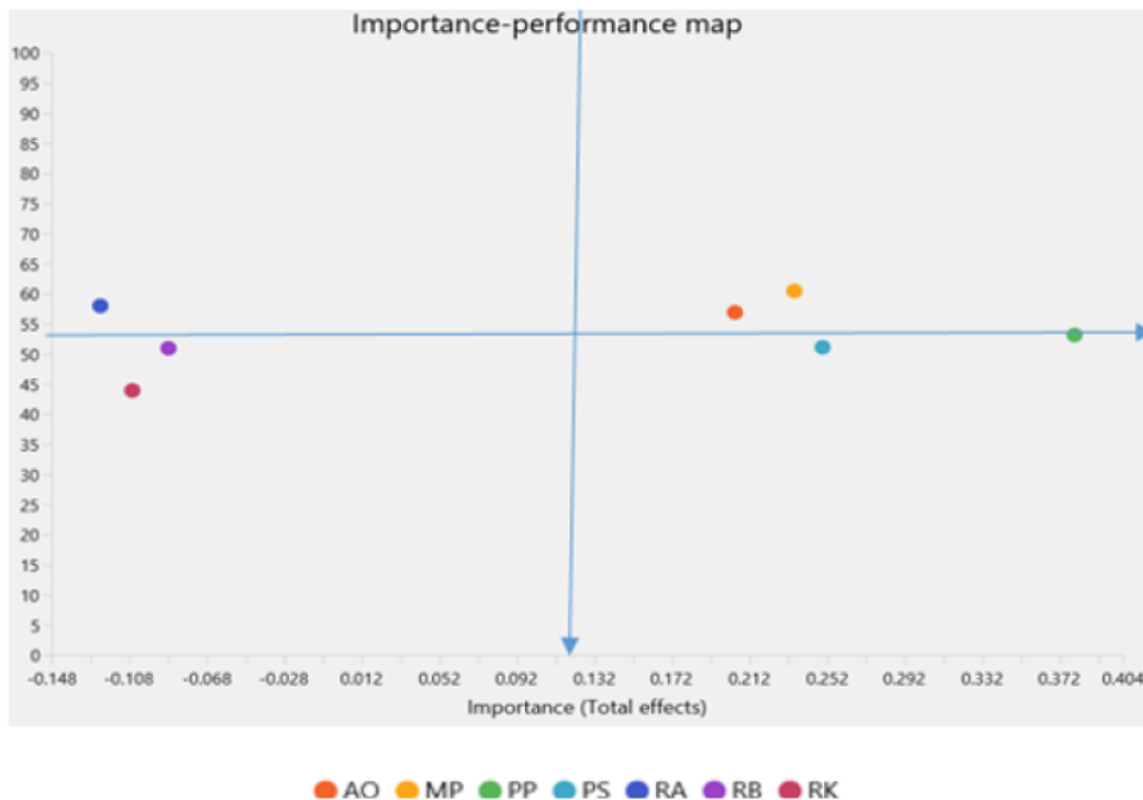


Figure 1. Output of the construction IPMA

These two constructs form a portfolio of major improvements. Management, planning, and organizational aspects also have positive importance, but performance is higher. Maintain and use both capabilities to support corrective actions.

Table 3. Importance–performance results at the construct level

Construct	Influence or importance	Performance	Interpretation
Project procurement	0.379	53.125	Top priority for improvement
Labor behavior	0.249	51.099	Top priority for improvement
Management and planning	0.235	60.432	Maintained and utilized
Organizational aspects	0.204	56.89	Maintained and utilized
Equipment risk	−0.123	57.964	Handling is maintained, and exposure is reduced

Occupational safety and health risks	-0.107	43.911	Mitigation and compliance strengthened
Material risk	-0.088	50.926	Material control and supply chain strengthened

The negative coefficients in all three risk constructs correspond to their encoding as adverse conditions. Increased risk exposure is associated with lower perceptions of project success. Occupational safety and health risks had the lowest performance values (43.911), followed by material risks (50.926). These values do not mean the risks need to increase to achieve a higher IPMA score. The relevant managerial goal is to reduce risk exposure by strengthening control systems.

4.3 Improvement agenda at the indicator level

All indicators of project procurement and labor behavior are priority areas for improvement in the IPMA mapping. The indicator-level results support the need for coordinated improvement actions rather than stand-alone actions. Figure 2 shows the IPMA output results for the indicator.

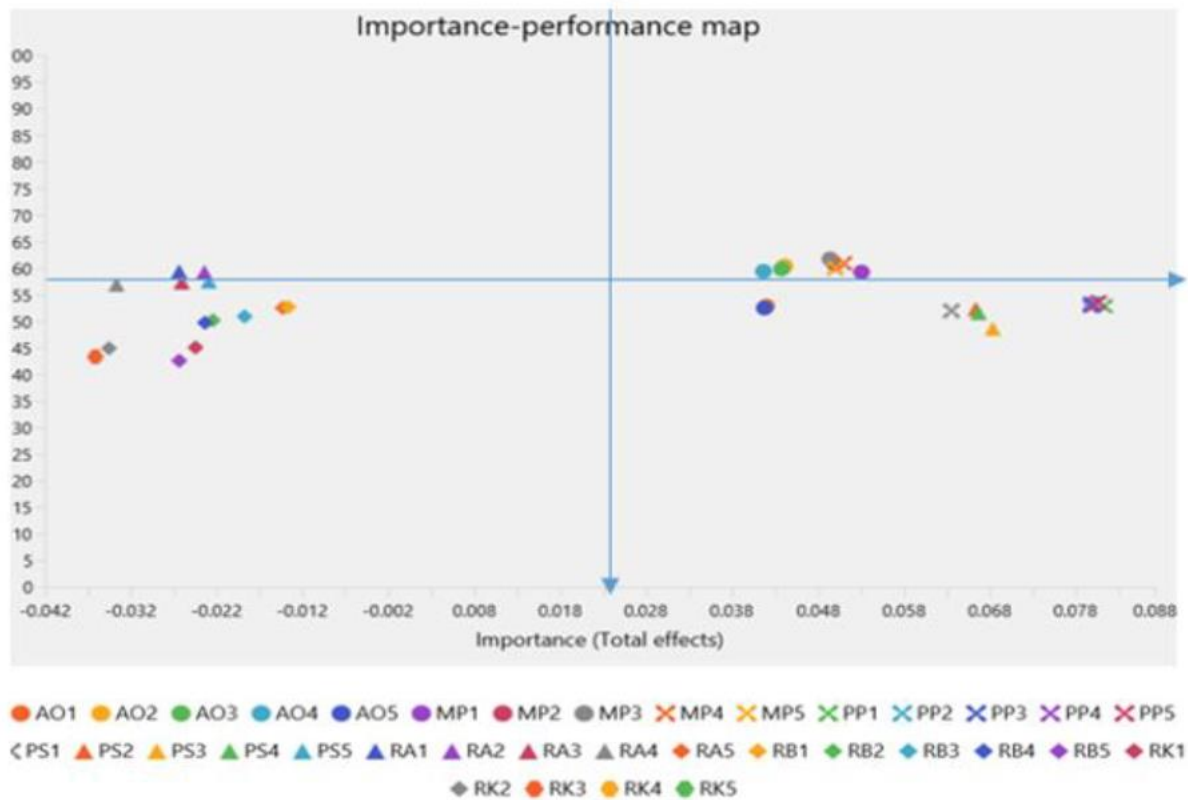


Figure 2. Output IPMA indicator

Procurement improvements must cover the entire process, from needs planning and sourcing to supplier coordination and on-site input availability. Improving workforce behavior requires discipline, clear task execution, communication, coordination, and consistent work completion.

Table 4. Indicators of procurement priorities and labor behavior

Code	Domain	Importance	Performance	Operational interpretation
PP1	Project procurement	0.082	52.807	Strengthening procurement readiness and accuracy of meeting needs
PP2	Project procurement	0.08	53.333	Improve supplier and shipping coordination
PP3	Project procurement	0.081	53.158	Guarantee the availability of inputs for the planned part of the work
PP4	Project procurement	0.08	52.807	Strengthen the monitoring of procurement implementation
PP5	Project procurement	0.081	53.509	Resolve procurement constraints before impacting progress
PS1	Labor behavior	0.064	51.93	Strengthen the reliability of task execution
PS2	Labor behavior	0.038	47.193	Addressing the biggest behavioral gaps
PS3	Labor behavior	0.067	52.281	Improve coordination and response speed
PS4	Labor behavior	0.069	48.596	Strengthen discipline and adherence to work plans
PS5	Labor behavior	0.067	51.579	Improve communication and cooperative behavior

4.4 Integrated intervention matrix

Integrating EVM, PLS-SEM, and IPMA yields four distinct managerial responses.

First, project procurement and labor behavior require immediate improvement because both are relatively important, but their performance is not yet optimal.

Second, management and planning, along with organizational aspects, need to support schedule recovery.

Third, risks related to materials, equipment, and occupational safety require targeted management to reduce exposure.

Fourth, maintain cost discipline because both packages' CPI profiles remain favorable.

Table 5. Integrated diagnosis and recommendations for action

Observed signals	Survey-based evidence	Priority actions	Monitoring indicators
SPI below one on both plans	Procurement has the highest importance, but its performance is not yet optimal	Eliminate procurement bottlenecks and synchronize deliveries with short-term schedules	SPI trends: delays in ordering and delivery
SPI below one on both plans	Workforce behavior has high importance and lowest managerial performance	Clarify daily targets and strengthen supervision, communication, coordination, and discipline	Percentage of completed plans; labor productivity; rework
CPI above one on both plans	Planning organization and have relatively good performance	Use existing planning and governance routines to support acceleration	CPI trends; approved recovery measures; decision-making time
The influence of risk is negative	Occupational safety and material risk indicate relatively poor handling	Reduces exposure during acceleration and does not trade safety or reliability of supply for speed	Safety findings; material shortages; equipment downtime

5. Discussion

5.1 Why can delays coincide with cost efficiency?

The study's main empirical pattern is not project failure as a whole, but an imbalance between time and cost performance. The CPI above one indicates that expenditure is relatively efficient compared with the value of the work obtained. In contrast, an SPI below one indicates that work progress has not reached the planned level.

In a construction project, this combination can occur when expenditures and work progress are delayed. Similar conditions can also occur when resources are used economically, but not mobilized with sufficient capacity to meet the schedule. Procurement and coordination barriers can also limit how much work is ready to be executed.

The research data cannot distinguish the mechanisms at work in each package. However, the analysis results show that a favorable CPI cannot be taken as proof that the project's overall condition is healthy.

Cost efficiency can come from productive resource use, but it can also reflect expenses that have not occurred because the work is still pending. Therefore, project performance evaluation needs to consider CPI and SPI together.

These findings add a decision-making perspective to research on construction delays. Previous studies have consistently identified procurement, labor, equipment, coordination, and planning as delay-causing categories (Durdyev & Hosseini, 2020; Mohammed & Bello, 2022)

This research framework narrows the category by identifying domains that combine importance levels with performance gaps. Project procurement and workforce behavior emerge as higher priorities than management and planning or organizational aspects.

These results do not mean planning and organization are unimportant. Both perform relatively well, so they can support efforts to improve weaker areas.

5.2 Project procurement and workforce behavior as interconnected priorities

Project procurement and labor behavior should not be managed as two separate areas. Uncertainty or delays in material availability can disrupt the work sequence, increase labor idleness, and weaken commitment to daily production targets.

Conversely, poor field communication and work discipline can reduce the benefits of timely procurement. Available materials and equipment will not automatically drive progress if the workforce cannot convert those inputs into completed work.

Thus, the most relevant intervention unit is the work front. Materials, equipment, information, and labor need to be prepared simultaneously on a short-term schedule.

A schedule recovery routine can be initiated through a rolling look-ahead plan that identifies constraints before scheduling a work package. Procurement milestones need to be linked to the number of needs and work ready for implementation, not just to the completion of procurement administration.

Daily coordination needs to compare the promised work with the work successfully completed. Any deviations need to be accompanied by an explanation of the cause, the responsible party, and the completion deadline.

This action translates IPMA results into project control behavior while using stronger management, planning, and organizational capabilities.

5.3 Maintaining cost control during schedule recovery

Scheduling acceleration can incur additional costs from overtime, premium delivery, inefficient reordering of work, and rework. The CPI advantage both packages have must be treated as an asset to maintain, not an excuse to delay intervention.

Evaluate each recovery action based on its impact on SPI and its cost consequences. Planning capabilities and organizations that have demonstrated relatively good performance can be used to select actions that truly eliminate constraints or increase productive output.

Cost efficiency that occurs only because the work has not been carried out is not sustainable. The expected condition is cost efficiency accompanied by SPI improvements.

5.4 Targeted interpretation of risk priorities

The reversal of risk indicator scores for materials, equipment, and occupational safety raises interpretation problems that IPMA often overlooks in its presentation. Higher scores indicate greater risk. Therefore, the negative importance coefficient has a consistent substantive meaning: as risk exposure increases, perceptions of project success decrease.

The right managerial target is to reduce risk exposure. Occupational safety and health risks require special attention because they have the lowest performance scores.

5.5 Theoretical and methodological contributions

This study shifts the analysis of project success from merely confirming factors to diagnostic complementarity. Objective measures and perception-based measures need not be treated as conflicting definitions of performance.

The EVM describes actual deviations from the basis of project planning. The survey model describes the practitioner's assessment of managerial conditions related to broader project success. The IPMA links these by translating relative influence into a map of improvement priorities.

This layered approach matters when project problems are multidimensional, and managers must choose interventions before final project results are available.

The research also contributes by limiting claims to what the research design can support. Integrated evidence supports the hypothesis of prioritized interventions, but does not prove that procurement or labor behavior directly causes the delays recorded in each project package.

Proving causality requires longitudinal data, measurements linked to each package, and repeated observation of EVMs. Such boundary affirmations yield more accountable managerial

recommendations than a list of significant pathways not tied to project conditions or the use of SPI and CPI without organizational diagnosis.

6. Managerial Implications

Management of both project packages should form a schedule recovery team that integrates planning, procurement, field supervision, labor coordination, and occupational safety. The team's first task is to translate the master schedule into a rolling list of obstacles for each work package. Procurement commitments should include the required date and quantity. The field team needs to report work readiness, daily output, unresolved constraints, and who is responsible for corrective actions.

Strong planning and organizational capabilities can form the basis for governance in implementing these mechanisms.

A balanced recovery dashboard should include:

- the development of SPI and CPI;
- reliability of procurement milestones;
- availability of materials;
- labor productivity;
- the percentage of work plans that have been successfully completed;
- rework;
- the time of inoperability of the equipment;
- unresolved obstacles; and
- Results of occupational safety and health observations.

An intervention can be sustained if it improves work progress without transferring unacceptable risks to cost, quality, or safety.

The EVM shows whether the schedule has recovered. Meanwhile, the indicators derived from the IPMA show whether the prioritized managerial conditions have improved.

7. Conclusion

The two road improvement packages studied were delayed but still showed cost efficiency at the time of observation. Integrated interpretations of EVM, PLS-SEM, and IPMA results identified project procurement and workforce behavior as the most urgent managerial improvement priorities.

Management, planning, and organizational aspects need to be maintained and utilized to support schedule recovery. At the same time, exposure to hazards to materials, equipment, and occupational safety and health needs to be reduced through targeted control.

The main implication of this study is that a structured diagnostic process should follow a performance index, rather than being handled separately. EVMs identify project performance conditions, PLS-SEM indicates relevant managerial domains, while IPMs show performance gaps that still need to be fixed.

Integrating all three methods yields a more targeted, auditable intervention agenda without making causal claims unsupported by the research design.

8. Limitations and Further Research

This research has four main limitations.

First, the survey was cross-sectional, so it may have been subject to *general method bias*. Second, we observed EVMs at one control point per package and included only two project packages. The development of schedules and costs after the observation point is unknown.

Third, the survey responses were not longitudinally correlated with changes in SPI and CPI at the project package level. Therefore, this study cannot prove that improvements in procurement or labor behavior preceded improvements in project objective performance.

Fourth, using score reversals on risk constructs requires a directed interpretation, which may be overlooked if the IPMA is presented conventionally.

Further research can collect EVM data and survey data on a recurring basis. Respondents, managerial interventions, and control outcomes need to be associated with a specific project package. The longitudinal design allows testing whether improvements in procurement indicators and labor behavior occurred before the increase in SPI, while maintaining acceptable levels of CPI, quality, and occupational safety.

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