INTEGRATING RISK MANAGEMENT INTO PROJECT SCHEDULING: A CRITICAL PATH METHOD APPROACH IN COAL MINING DEVELOPMENT PROJECT

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Abstract

This study analyses the integration of risk management into project scheduling in a coal mining development project. A mixed-methods case study was applied, combining interviews, observations, document analysis, and structured questionnaires. Project scheduling was conducted using the Critical Path Method (CPM), while risk assessment followed the AS/NZS 4360:2004 framework. The initial CPM analysis identified five activities on the critical path (A–B–D–E–F) with a total duration of 90 weeks. A risk assessment revealed thirteen potential risks, including two high-priority items, six moderate-to-high risks, four moderate risks, and three low risks. Control strategies such as avoidance, reduction, transfer, and acceptance were proposed to mitigate these risks. After incorporating risk management into the CPM schedule, the project duration extended to 94 weeks, reflecting additional preventive measures and contingency buffers. While the schedule lengthened, the revised plan provided greater resilience against disruptions and improved reliability for project execution. These findings indicate that integrating risk management into project scheduling produces a more realistic and achievable timeline, especially for large-scale and high-risk projects such as mining operations. Theoretically, this research contributes a framework for risk-adjusted scheduling by combining deterministic scheduling with proactive risk analysis. Practically, it offers project managers valuable guidance to minimize disruptions, enhance decision-making, and increase the probability of successful and timely project completion.

Keywords: Risk Management, Critical Path Method, Project Scheduling, Coal Mining, AS/NZS 4360

INTRODUCTION

The coal mining industry, as regulated under Law No. 3 of 2020, encompasses a wide range of activities including general investigation, exploration, feasibility studies, construction, mining, processing and/or refining, transportation and sales, as well as post-mining activities. Broadly, these operations can be categorized into five main stages: exploration, evaluation, infrastructure preparation, exploitation, and reclamation.

A defining characteristic of coal mining projects is their high level of uncertainty. Even with well-structured strategies and substantial financial investment, the economic viability of mining outcomes is not always guaranteed (Mukiat & Asof, 2022). In this context, the application of systematic project management practices plays a crucial role in increasing the likelihood of project success.

Project management involves a series of structured processes designed to achieve predefined objectives within specific time, cost, and resource constraints. It requires the integration of knowledge, skills, tools, and techniques to coordinate project activities effectively. These processes are commonly divided into five phases: initiation, planning, execution, monitoring and controlling, and closure (PMBOK, 2017). Among these, time management is particularly significant, as it provides both direction for implementation and mechanisms for monitoring project progress.

Large-scale projects, such as those in the mining sector, are inherently exposed to various risks, including schedule delays, equipment failures, technical changes, and external disruptions. According to Larson & Gray (2018), risk management is the process of identifying potential threats, minimizing their impact, and developing appropriate responses. Effective risk management can prevent schedule overruns, cost escalation, and even project failure.

For this reason, more realistic and resilient scheduling approaches are required. The Critical Path Method (CPM) is one of the most widely applied techniques for identifying critical activities that determine overall project duration (Heizer et al., 2020). However, purely deterministic scheduling often fails to account for uncertainties that occur in practice. Integrating CPM with risk management analysis can therefore produce a more reliable project schedule, one that is better equipped to anticipate and withstand potential disruptions.

This study seeks to address the gap between optimistic scheduling and the uncertain realities of field implementation. By integrating risk management into project scheduling using the CPM framework, this research aims to produce schedules that are not only more accurate as predictive tools but also more resilient to risks. Theoretically, the study contributes by offering a framework that can be applied in mining operations to minimize unforeseen disruptions, while practically it provides valuable insights for decision-makers in managing large-scale, high-risk projects.

REVIEW OF LITERATURE

Project Management

According to PMBOK (2017), project management is the application of knowledge, skills, tools, and techniques to project activities in order to meet project requirements. It involves structured processes for planning, organizing, executing, and monitoring work to ensure that deliverables are achieved within the defined scope, schedule, and budget. Project management also requires effective coordination of technical and human resources to address

the complexity and uniqueness of each project, ensuring that goals are accomplished efficiently and effectively.

Project management success can be defined as a series of project objectives achieved within the established time, budget and resource constraints by meeting the expected performance standards in order to obtain results that are acceptable to customers or stakeholders (Kerzner, 2017). In large-scale industrial projects such as coal mining, controlling time and cost is critical to achieving operational and financial objectives. Delays in the project timeline can lead to increased operational expenses, contractual penalties, and reduced profitability, while uncontrolled costs can undermine the feasibility of the entire project. Effective time and cost management not only supports the successful delivery of project outcomes but also enhances resource utilization, minimizes waste, and strengthens stakeholder confidence.

Project Risk Management

Larson & Gray (2018), define project risk management as a proactive process for identifying potential events that may affect project objectives, assessing their probability and impact, and implementing responses to minimize threats and exploit opportunities. This approach emphasizes the importance of anticipating uncertainties rather than reacting to them, ensuring that project execution remains aligned with planned objectives despite potential disruptions.

The primary purposes of risk management in projects are to mitigate the likelihood of delays, prevent budget overruns, and ensure operational continuity. By systematically identifying and addressing potential risks, project managers can safeguard project performance, enhance decision-making, and create a more resilient execution plan. Additionally, proactive risk management helps maintain alignment between project outcomes and stakeholder expectations.

According to Acebes et al. (2024) the identified risks will be selected to obtain the highest priority risks with the aim of minimizing failure and increasing project success. This study applies the AS/NZS 4360 standard, which assesses risks based on the combination of likelihood and consequence. This framework allows for the prioritization of high-impact risks, ensuring that mitigation efforts are focused where they are most needed. The standard also promotes consistent and transparent risk evaluation, facilitating better communication among project stakeholders and improving the effectiveness of response strategies.

Project Scheduling

Project scheduling refers to the process of defining, sequencing, and allocating time for activities to ensure that a project is completed within its planned duration. According to Rao et al. (2013), the main focus of the project scheduling technique used is the critical path method (CPM), which can help project managers complete projects on time. A well-structured schedule provides a roadmap for project execution, clarifies task dependencies, and enables monitoring of progress against planned milestones. In industries like mining, precise scheduling is essential to coordinate multiple interdependent activities and optimize the use of resources.

The Critical Path Method (CPM) is a widely used scheduling technique that identifies the sequence of dependent activities determining the minimum project duration (Heizer et al., 2020). CPM calculates earliest start, earliest finish, latest start, and latest finish times for each task, enabling the identification of critical activities with zero slack. According to (Syifa

Nur Afiya et al. (2023) a project's work to be able to run efficiently and effectively requires structured project scheduling and proper control, time management has become part of supporting the success of a project in order to achieve the goals and deadlines that have been set. In mining projects, CPM helps minimize idle time, improve resource allocation, and ensure that production and delivery targets are met within contractual obligations.

Integration of Risk Management and Scheduling

Integration of risk management and time scheduling on activities on the critical path contributes greatly to the preparation of the most reliable schedule on a project (Razaque et al., 2012). Integrating risk management into CPM involves identifying critical path activities that are vulnerable to high-impact risks and adjusting their planned durations accordingly. This integration ensures that potential disruptions are anticipated and addressed before they occur, thereby improving the reliability of the schedule. By embedding risk assessment within the scheduling process, project managers can make informed decisions about resource allocation and contingency planning.

Risks can directly influence the duration of project activities, resulting in the need for contingency time, additional time allowances built into the schedule to accommodate uncertainties. Properly estimating and incorporating contingency time creates a more realistic and achievable project timeline. In high-risk environments such as mining, this approach increases the likelihood of on-time project delivery while reducing the chances of cost overruns and contractual disputes.

RESEARCH METHOD

This study adopts a mixed-methods approach with a case study design (Migiro & Magangi, 2011) to examine the integration of risk management and project scheduling in the development of a new coal mining site at PT Satria Bahana Sarana. The mixed-methods design combines qualitative techniques, direct observation during the internship period and in-depth interviews, with quantitative analysis through method AS/NZS 4360 standard. Mixed methods can provide a deeper understanding of qualitative methods and gain measurement objectivity from quantitative methods, resulting in a far superior analysis. The purposive sampling method Amelia et al. (2023) ensures the inclusion of informants with direct involvement, expertise, and managerial responsibility in project planning, including managers from Business Development, Human Resources Operations, Legal, Finance & Budget, Civil Infrastructure, and the Risk Department.

Data collection was conducted through four primary techniques: (1) Interviews, to obtain detailed insights from managerial-level respondents (Sugiyono, 2013); (2) Observation, involving active participation in relevant operational activities; (3) Document analysis, reviewing company records such as organizational structures, job descriptions, business process documents, and meeting notes (Abdussamad, 2021); and (4) Literature review, drawing from relevant books, journal articles, and industry references.

Quantitative data were gathered via a structured questionnaire using a five-point scale, assessing the likelihood and impact of identified risk indicators, with scoring based on the Australia/New Zealand Standard (AS/NZS 4360:2004) framework. Risk values were computed using the formula Risk Value = Probability × Impact (AS/NZS 4360:2004), enabling prioritization of risk factors through a risk heatmap categorization. The method

(AS/NZS 4360:2004) can be a systematic tool for processing qualitative data (interview and observation results) into a measurable risk priority sequence, thus making it easier for the management team to control risks (Kartika., 2021) .

Project scheduling analysis employed the Critical Path Method (CPM) (Heizer et al., 2020; PMBOK, 2017) to identify critical activities and determine minimum completion time. The CPM process included defining the work breakdown structure, estimating activity durations, mapping dependencies in a network diagram, performing forward and backward pass calculations, and identifying total float and critical path activities. Kim (2020) concluded that the critical path method (CPM) still has fundamental limitations because this technique requires the availability of unlimited resources. This study focuses on the impact on project completion time and therefore does not include a cost analysis. Scheduling calculations utilized MS Excel 2019 and Production and Operations Management–Quality Control software.

Unit of Analysis

The unit of analysis is the Business Development Department of PT Satria Bahana Sarana, focusing on the planning phase of the new mining project, from contract acceptance to operational handover. The methodological integration of CPM and AS/NZS 4360:2004 aims to generate a more realistic and risk-adjusted project timeline, improving planning reliability and execution success.

Research Questions

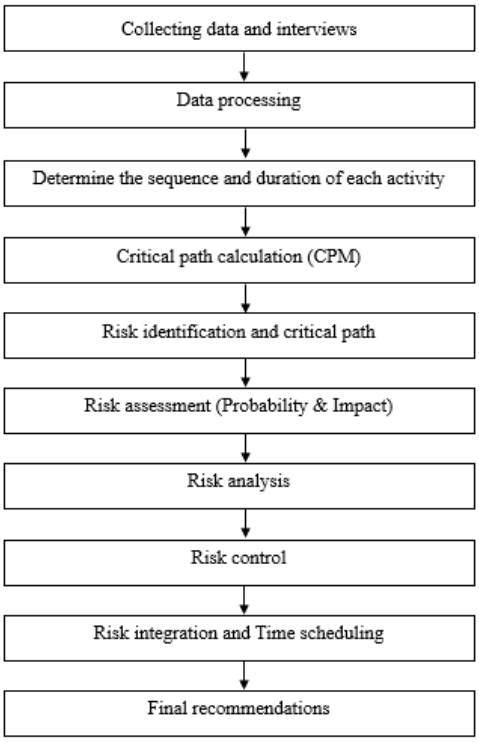
The issues to be examined in this research concern the planning of a new mining project to be implemented by PT Sastria Bahana Sarana. The details of the issues to be discussed are as follows:

1. How is the time scheduling of new mining development projects performed?
2. What are the potential risks that could hinder the critical path in new mining development projects?
3. How does the integration of risk management and time scheduling affect time efficiency and project success?

Research Model

This research model describes the sequential relationship between each stage of research in integrating risk management with project scheduling for new mining development projects. This model can be illustrated in figure 1 as follows:

Figure 1.
Framework of Analysis



The image of this study's model shows that the research process begins with data collection and continues through data processing, determining activity sequences and durations, calculating the critical path (CPM), identifying risks on the critical path, assessing risks based on probability and impact, conducting risk analysis, implementing risk control, and integrating risk management with project scheduling, before arriving at the final recommendations. This study uses a mixed methods approach, combining qualitative techniques (interviews, observations, document analysis) and quantitative techniques (Critical Path Method and AS/NZS 4360 risk assessment). The results are expected to provide valuable insights for mining companies in developing more realistic and effective project schedules by integrating accurate scheduling with proactive risk management.

RESULTS AND DISCUSSION

The initial project schedule was developed using the Critical Path Method (CPM) to determine the minimum completion time of the coal mining development project. The analysis involved defining the sequence of activities, estimating their durations, and mapping dependencies to identify which tasks were critical to timely project completion. As presented in Table 1, five activities namely A (Licensing and Investment Approval), B (Funding Negotiation), D (Equipment Preparation), E (Workforce Recruitment), and F (Infrastructure Construction) were identified as lying on the critical path with a total duration of 90 weeks. These activities have zero slack, meaning that any delay in their execution would directly result in a delay in the overall project completion. In contrast, Activity C (Working Capital

Preparation) is categorized as non-critical, with a slack of 14 weeks, thus providing flexibility without affecting the final project timeline. This initial scheduling result highlights the vulnerability of the project to delays in critical activities and underlines the importance of incorporating risk management strategies to enhance schedule reliability.

Following the identification of critical activities, a risk assessment was conducted to examine potential factors that could hinder project execution along the critical path. The assessment was based on data collected through interviews, direct observations, and the review of project documentation

Table 1.
CPM Calculation Results for the Coal Mining Development Project

Code	Activity	Duration (Week)					
		ES	EF	LS	LF	Slack	Remark
A	Completion of Licensing Study Documents and Investment Approval Requirements	0	26	0	26	0	Critical
B	Search and Negotiation for Funding Sources	26	38	26	38	0	Critical
C	Preparation of Working Capital	38	42	52	56	14	Non-Critical
D	Preparation of Self-Managed and Subcontractor Equipment	38	56	38	56	0	Critical
E	Recruitment and Arrangement of Workforce	56	66	56	66	0	Critical
F	Construction of Infrastructure and Facilities	66	90	66	90	0	Critical

Source: Data processed (2025)

A total of thirteen potential risks were identified, each linked to one of the five critical activities determined in the initial CPM analysis. As summarized in Table 2, these risks vary in both probability and impact, producing risk values ranging from as low as 2 to as high as 20. The highest risk value (20) is associated with the doubtful competence of consultants and the reliability of external study results under Activity B, highlighting the potential for flawed planning and costly delays if this issue is not addressed. This finding emphasizes the necessity of prioritizing risk management interventions to safeguard the overall project timeline.

Table 2.
Risk Identification

No	Activity	Risk	Probability	Impact	Risk Value
1.	A	License/permit not issued in time	4	4	16
2.		Incorrect document submission	3	1	3

3.		Bureaucratic delays in licensing process	2	4	8
4.	B	Doubtful competence of consultant and external study results	4	5	20
5.		Inability to fulfill complete documentation	3	4	12
6.	D	Uncertainty in availability of heavy equipment	2	5	10
7.		Increase in currency exchange rate	4	3	12
8.		Delay in delivery of heavy equipment	1	5	5
9.	E	Errors in labor allocation	1	2	2
10.		Lack of worker skills/competence	3	4	12
11.		Demonstrations by local labor forum	2	3	6
12.	F	Delay in material delivery	2	4	8
13.		Vendor qualifications not meeting requirements	4	3	12

Source: Data processed (2025)

To provide clearer prioritization, the identified risks were further analysed and ranked based on their calculated values. This ranking allowed the classification of risks into high, moderate-to-high, moderate, and low categories, enabling project managers to allocate resources more effectively toward the most critical threats. As shown in Table 3, two risks emerged as high priority: (1) the doubtful competence of consultants and external study results (Risk Value =20) and (2) delays in permit issuance (Risk Value =16). Several other risks, such as incomplete documentation, fluctuations in currency exchange rates, insufficient workforce skills, vendor qualification issues, and heavy equipment availability, were categorized as moderate-to-high, reflecting their potential to disrupt the schedule if not properly managed. Meanwhile, risks such as bureaucratic delays, material delivery issues, and local labour demonstrations were classified as moderate, while errors in documentation and labour allocation were considered low. This ranking highlights the areas where proactive mitigation is most urgently required to minimize potential delays on the critical path.

In response to the identified and ranked risks, a series of control strategies were formulated to mitigate their potential impact on project scheduling. These strategies include avoidance, reduction, transfer, and acceptance, depending on the severity and nature of each

risk. As outlined in Table 4, high-priority risks such as consultant competence issues were addressed through avoidance strategies, including stricter quality-based consultant selection and the development of comprehensive Terms of Reference (TOR).

Table 3.
Ranking of Key Risks

Activity Code	Risk	Risk Value	Rank	Category
A	License/permit not issued in time	16	2	High Risk
	Incorrect document submission	3	12	Low
	Bureaucratic delays in licensing process	8	8	Moderate
B	Doubtful competence of consultant and external study results	20	1	High Risk
	Inability to fulfill complete documentation	12	3	Moderate to High
D	Uncertainty in availability of heavy equipment	10	7	Moderate to High
	Increase in currency exchange rate	12	4	Moderate to High
	Delay in delivery of heavy equipment	5	11	Moderate
E	Errors in labor allocation	2	13	Low
	Lack of worker skills/competence	12	5	Moderate to High
	Demonstrations by local labor forum	6	10	Moderate
F	Delay in material delivery	8	9	Moderate
	Vendor qualifications not meeting requirements	12	6	Moderate to High

Source: Data processed (2025)

Similarly, risks related to permit issuance were mitigated by regulatory mapping and the appointment of liaison officers to streamline communication with authorities. For equipment-related risks, long-term rental agreements and vendor qualification processes were recommended to ensure availability and reliability. Workforce-related risks, such as insufficient skills, were addressed through targeted training programs and subcontracting specialist labour where necessary. These control measures not only provide preventive actions but also enhance flexibility in handling uncertainties, thereby contributing to the development of a more resilient and realistic project schedule.

Tabel 4.
Risk Control Recommendations

No	Risk	Treatment Options	Risk Control

1.	The permit letter has not been issued yet	Risk Reduction, Risk Transfer	Conducting regulatory mapping and compiling a permit registry matrix containing a list of required documents, issuing institutions, field data requirements, estimated processing time, etc.
2.	Document fulfillment errors	Risk Acceptance	Conduct regular review and monitoring scheduling with stakeholders to ensure that no errors or changes to requirements are missed.
3.	Obstructed by the bureaucratic process of obtaining permits	Risk Reduction, Risk Transfer	Appointing specialized personnel with experience and communication skills to coordinate with relevant parties (Liaison Officers). Negotiating contract clauses with MIND ID to ensure PT. SBS's employment contract is protected from the impact of external bureaucratic delays.
4.	Questionable consultant competence and external review results	Risk Avoidance	Conducting a quality-based selection of credible consultants and compiling a comprehensive review based on more detailed Terms of Reference (TOR). The additional time required to implement this strategy is 7 weeks.
5.	Document completeness cannot be met	Risk Reduction, Risk Transfer	Develop comprehensive project investment proposal documents, providing full transparency regarding risks and risk management to gain shareholder confidence. Build partnerships with funding institutions to develop financing schemes to reassure shareholders.
6.	Heavy equipment availability cannot be guaranteed	Risk Avoidance	Changing strategy to long-term heavy equipment rentals by qualifying major vendors for mining equipment production units and prioritizing service (Full Maintenance Contracts – FMCs). The time efficiency gained by using this strategy accelerated the previous schedule to three weeks.
7.	Exchange rate increase	Risk Reduction	Forming contractual agreements with suppliers using Currency Hedging so that transactions can be protected from exchange rate fluctuations by involving financial institutions or banks.
8.	Delay in delivery of heavy equipment	Risk Avoidance	Changing strategy by procuring from available authorized dealers, this guarantees the units ordered and a guaranteed arrival time. Time adjustments are unnecessary due to the strategic shift in self-managed equipment preparation and subcontracting.

9.	Errors in fulfilling labor requirements	Risk Acceptance	Conduct an evaluation of the recording of workforce needs and the number of workers to ensure it is in accordance with organizational structure planning.
10.	Insufficient workforce abilities/skills	Risk Reduction, Risk Transfer	Providing training programs based on job position and competency. Through training programs, employees can obtain certifications in competency, leadership, and supervisory skills. Contracting out expert labor (manpower supply) to fill specific specialist positions.
11.	Local workers forum demonstration	Risk Acceptance, Risk Reduction	Establish a rapid response team to negotiate and resolve issues with local workers. Conduct a social risk assessment to analyze potential issues with local workers.
12.	Delay in material delivery	Risk Reduction, Risk Transfer	Manage inventory at mining sites using warehouse storage (laydown areas). Develop scheduling by integrating material requirements with construction schedules. Negotiate with suppliers for Delivered at Place (DAP) or Delivered Duty Paid (DDP) contracts.
13.	Vendor qualifications do not meet the requirements	Risk Reduction	Distributing tender invitations and registering tenders on Multi-Channel Tender Publications, such as electronic tendering services (LPSE). Developing a prequalification (PQ) system using the Vendor Qualification Standard, which covers legal aspects, etc.

After the integration of risk control strategies, the project schedule was recalculated using the Critical Path Method (CPM). The revised schedule, presented in Table 5, shows that the critical path remains unchanged comprising Activities A, B, D, E, and F but certain durations were adjusted to incorporate preventive measures and contingency buffers. In particular, the durations for funding negotiations (Activity B) and equipment preparation (Activity D) were extended to allow for consultant verification, procurement contingency, and vendor diversification. As a result, the overall project duration increased from 90 weeks in the initial plan to 94 weeks after risk control integration. This adjustment, while lengthening the timeline, strengthens the schedule's resilience by reducing vulnerability to unexpected disruptions. The updated network diagram in Figure 2 further illustrates the revised sequencing of activities, highlighting that the critical path activities have zero slack while non-critical Activity C retains significant flexibility. This visualization confirms that incorporating risk management into project scheduling produces a more realistic and achievable project plan, ultimately increasing the probability of on-time project completion.

The network diagram above illustrates the revised project schedule after integrating risk control measures. The red arrows indicate the critical path, consisting of Activities A → B → D → E → F. These activities have zero slack, meaning any delay in them will directly

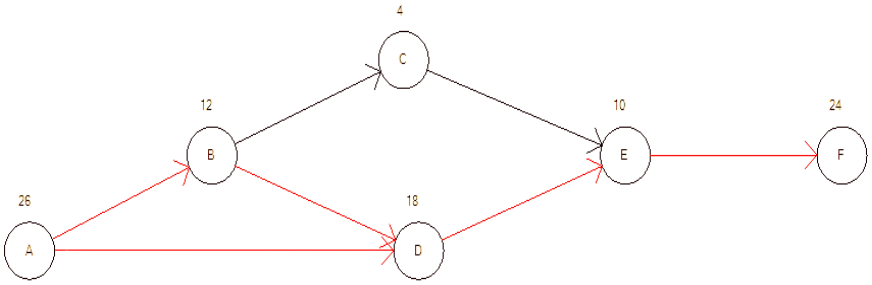
result in an overall project delay. The non-critical activity, C, is shown branching from B and feeding into E, with a slack of 24 weeks

Table 5.
CPM Results After Duration Adjustments (Revised Schedule)

Code	Activity	Duration (Week)					
		ES	EF	LS	LF	Slack	Remark
A	Completion of Licensing Study Documents and Investment Approval Requirements	0	26	0	26	0	Critical
B	Search and Negotiation for Funding Sources	26	45	26	45	0	Critical
C	Preparation of Working Capital	45	49	56	60	11	Non-Critical
D	Preparation of Self-Managed and Subcontractor Equipment	45	60	45	60	0	Critical
E	Recruitment and Arrangement of Workforce	60	70	60	70	0	Critical
F	Construction of Infrastructure and Facilities	70	94	70	94	0	Critical

Source: Data processed (2025)

Figure 2.
Network Diagram After Risk Control Integration



This flexibility allows the project team to adjust resources without affecting the final completion date, provided that delays in this activity do not exceed its available slack. The total project duration in the revised plan is 94 weeks, compared to 90 weeks in the initial schedule. While the completion time has increased, the added duration accounts for preventive actions and buffers, making the project more resilient to high-priority risks identified in the earlier risk analysis.

CONCLUSION

This study examined the integration of risk management into project scheduling using the Critical Path Method (CPM) in the context of a coal mining development project. The initial scheduling results identified five critical activities (A–B–D–E–F) with a total duration of 90 weeks, indicating that any delay in these tasks would directly impact the overall project

timeline. Risk assessment revealed thirteen potential risks, with two classified as high priority and several others falling into moderate-to-high categories. These findings underscored the vulnerability of the project to both internal and external uncertainties.

The application of tailored risk control strategies, as mapped in this study, led to the adjustment of activity durations and the inclusion of contingency buffers in the project schedule. Although the revised schedule extended the total duration to 94 weeks, this adjustment provided greater resilience and reduced the likelihood of unforeseen disruptions. The revised CPM analysis, supported by the updated network diagram, demonstrated that embedding risk management into scheduling produces a more realistic and reliable project timeline.

Theoretically, this research contributes by offering a framework that combines deterministic scheduling methods with proactive risk analysis, thereby enhancing both accuracy and robustness in project planning. Practically, the study provides valuable insights for managers of large-scale and high-risk projects, particularly in industries such as mining, where uncertainty is inherent and the consequences of delays can be significant. Integrating risk management with project scheduling not only improves the probability of on-time completion but also strengthens decision-making processes, ensuring that projects are executed more efficiently and effectively.

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