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Balance Scorecard Strategy for the West Wanagon Slope Stability (Wwss) Grasberg Earthworks Industri Mining Project (Case Study: Pt. Xzy, Papua)

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ABSTRACT: This study aims to analyze the implementation of the Balanced Scorecard (BSC) as a performance management tool in the West Wanagon Slope Stability (WWSS) project carried out by PT XZY at the Grasberg mine, Papua. The WWSS project plays a critical role in post-mining slope stabilization to minimize landslide risks and environmental impacts. Performance issues recorded between 2021 and 2024 include damaged or uncalibrated instruments (-8% from the > 95% target), limited predictive landslide analysis (+4 from the target of zero incidents), suboptimal geotechnical design and modeling (-0.15 from the ≥1.3% target), and unstable telemetry networks (-13% from the ≥ 98% target). The research applied a mixed-method approach, combining quantitative financial ratio analysis (NPM, ROI, ROE) and statistical correlations with qualitative methods through questionnaires and in-depth interviews involving 100 respondents across various levels. The findings demonstrate that BSC provides a more holistic and measurable framework for managing project performance, with the highest score in the Environmental & Social perspective, followed by Financial, Stakeholder, Learning & Growth, and Internal Business Process perspectives. Recommended strategies derived from SWOT analysis and action plans include achieving zero fatality through early detection with real-time radar and deformation sensors, modernizing monitoring with integrated dashboards, strengthening human resources through training and certification in slope stability engineering, and ensuring cost control through risk-based budgeting and cost-benefit ratio audits.

KEYWORDS: Balanced Scorecard, Performance Management, Slope Stability, Mining Project, Freeport Indonesia, WWSS (West Wanagon Slope Stability).

I. INTRODUCTION

PT XZY is one of the largest mining companies in the world, operating in Grasberg, Papua, with slope stability in open-pit areas being one of its major technical challenges. Slope stability is crucial to ensure worker safety, environmental protection, and the continuity of mining operations. To address this, Freeport initiated the West Wanagon Slope Stability (WWSS) project, which focuses on mitigating landslide risks through geotechnical approaches. The success of this project depends heavily on effective performance management and systematic monitoring to achieve the targeted outcomes.

The Balanced Scorecard (BSC), developed by Kaplan and Norton (1992), has been adopted as a performance management framework for the WWSS project. The BSC evaluates organizational performance not only from the financial perspective but also from stakeholder, internal business process, and learning and growth perspectives. By applying this method, the project can be assessed holistically, covering budget efficiency, compliance with safety and environmental standards, adoption of slope stabilization technologies, and the development of human resource competencies. The key advantage of the BSC lies in its ability to align strategic objectives with project operations, making it particularly relevant for complex mining environments such as Grasberg.

The WWSS project faced several performance issues between 2021 and 2024, as reflected in its Key Performance Indicators (KPIs). These include damaged or uncalibrated monitoring instruments (-8%), low compliance with audit recommendations (-22%), limited predictive landslide analysis (+4 incidents), delayed slope movement response time (+2.2 hours), suboptimal geotechnical design and modeling (-0.15 in Factor of Safety), shortage of geotechnical human resources (-34% in design evaluation), and unstable telemetry networks (-13%). These gaps highlight the urgent need for systematic improvements through a comprehensive performance management system.

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Although the Balanced Scorecard has been widely applied in various industries, its adaptation in mining projects poses challenges such as limited real-time data and workforce resistance to new evaluation systems. Nevertheless, compared to other approaches such as PMBOK, Six Sigma, or EFQM, the BSC offers greater advantages due to its holistic, strategic, and adaptive nature. Examining the implementation of BSC in the WWSS project is expected to enhance project management effectiveness, strengthen geotechnical stability, and contribute to the development of performance management practices within the Indonesian mining industry.

Table 1-1. Issues of the WWSS Project at PT XZY Based on KPI Data (2021–2024)

No	KPI Indicator	Annual Target	Actual (%)	Gap (%)	Worst Year	Main Issues
1	Monitoring Instrument Availability (%)	≥ 95%	87%	-8%	2021	Instruments damaged or not calibrated
2	Compliance with Audit Recommendations	100%	78%	-22%	2021	Slow implementation of internal audit recommendations
3	Number of Landslide Near Miss Incidents	0 incidents	4 incidents	+4	2022	Limited predictive landslide analysis
4	Slope Movement Detection Response Time	≤ 4 hours	6.2 hours	+2.2 h	2022	Delayed response to early warning
5	Slope Stability Factor of Safety (FoS)	≥ 1.3	1.15	-0.15	2023	Suboptimal geotechnical design and modeling
6	Percentage of Design Evaluation per Year	100%	66%	-34%	2023	Limited geotechnical human resources
7	Data Integrity & Transfer Rate (%)	≥ 98%	85%	-13%	2024	Unstable telemetry network (weather, interference)

II. METHODS

The research was conducted at the West Wanagon Slope Stability (WWSS) Project, Grasberg Earthworks, PT XZY Papua, from June 2024 to August 2025, encompassing data collection, analysis, and implementation of the Balanced Scorecard (BSC) in project evaluation. Data were obtained from both primary and secondary sources. Primary data included interviews with project management and stakeholders, direct observations, and questionnaires distributed to employees. Secondary data consisted of project performance reports, financial and operational records, internal company documents, and relevant literature on BSC in mining. The population comprised 300 individuals involved in the WWSS Project, including managers, engineers, supervisors, operators, and related staff. Using Slovin's formula with a 10% margin of error and 90% confidence level, a sample of 75 respondents was determined, which was increased by 30% to anticipate nonresponse, resulting in a final sample size of 100 respondents. All respondents participated in QR Code-based surveys. The dependent variables were the five BSC perspectives (financial, stakeholder, internal process, learning and growth, environmental & social), while the independent variables were the survey attributes. The research framework followed three stages: (1) identification of project issues through field studies, KPI data (2021–2024), financial data, literature review, and Focus Group Discussions (FGDs) to refine the project vision and mission; (2) strategic objective formulation through survey analysis, validity and reliability testing, and Multi-Attribute Attitude Model (MAAM) weighting to determine priority issues for Strategy Map development; and (3) SWOT analysis to derive sustainable strategic actions for WWSS.

III. RESULT AND DISCUSSION

3.1 Strategic Objectives of the West Wanagon Slope Stability (WWSS) Project

The WWSS project at the Grasberg mine aims to maintain slope stability to minimize landslide risks. Ensuring stable slopes is essential for operational continuity, environmental protection, and worker safety. By applying proper geotechnical methods, the project seeks to maintain slope angles within recommended limits while reducing failure risks.

Additional objectives include optimizing overburden removal to meet annual production targets, implementing real-time slope monitoring, improving drainage, and applying safe work practices. These measures ensure mining operations remain stable while complying with safety and environmental standards.

To support these objectives, WWSS employs a QR Code–based questionnaire for collecting rapid feedback from field workers, supervisors, and support teams. The survey evaluates understanding of safe work procedures, compliance with stabilization programs, and identification of field issues. Results will serve as a basis for continuous improvement and ensure strategies remain effective.

The questionnaire covers **five perspectives** with 100 respondents:

1. **Financial** – project competitiveness, financial risk, cost–benefit, ROI, cost efficiency, and funding support.
2. **Stakeholder** – relations with NGOs, corporate image, compliance with social standards, community acceptance, and regulatory support.
3. **Internal Process** – slope design reliability, SOP compliance, early warning response, monitoring tools, and technology innovation.

4. **Learning & Growth** – employee satisfaction, learning culture, innovation support, technology use, retention, and competence.
5. **Environmental & Social** – emergency procedures, hazard detection, zero fatality commitment, and regular emergency drills.

The survey uses a **five-point Likert Scale** (1 = Strongly Disagree to 5 = Strongly Agree) to measure respondents' attitudes.

3.2 Strategic Map of the West Wanagon Slope Stability (WWSS) Project

The West Wanagon Slope Stability (WWSS) Project at Grasberg, PT Freeport Indonesia, illustrates the application of geotechnical risk management in open-pit mining with complex challenges, including slope stability and multi-stakeholder engagement. To align strategic objectives with operational outcomes, the **Balanced Scorecard (BSC)** framework is adopted, integrating four perspectives—Learning & Growth, Internal Process, Stakeholder, and Financial.

From the **Learning & Growth perspective**, human resource competence is central. Continuous training in geotechnical expertise, adoption of technologies such as Slope Stability Radar (SSR), IoT-based sensors, and real-time deformation monitoring strengthen risk response and operational safety. The **Internal Process perspective** emphasizes slope stabilization, adaptive construction methods, and rapid, data-driven decision-making. Integrated monitoring platforms, as highlighted by Zhang et al. (2018; 2022), demonstrate the effectiveness of real-time geotechnical evaluation in preventing slope failure.

In the **Stakeholder perspective**, compliance with environmental regulations, protection of community safety, and transparent engagement are critical to securing a **social license to operate (SLO)**. Literature (Omotehinse et al., 2023; Suanti et al., 2024) confirms that participatory communication and digital engagement reduce community resistance and strengthen legitimacy. The **Financial perspective** focuses on cost efficiency in slope stabilization and monitoring without compromising safety or sustainability. Evidence from Wang & Song (2021) shows that BSC improves ROI while integrating financial and non-financial performance outcomes.

The strategic cause–effect chain links investments in training and technology (**Learning & Growth**) to optimized slope management (**Internal Process**), which enhances trust and legitimacy (**Stakeholder**), ultimately ensuring cost efficiency and profitability (**Financial**). This integrated strategic map confirms that financial outcomes are not isolated, but rather the culmination of sustainable long-term strategies.

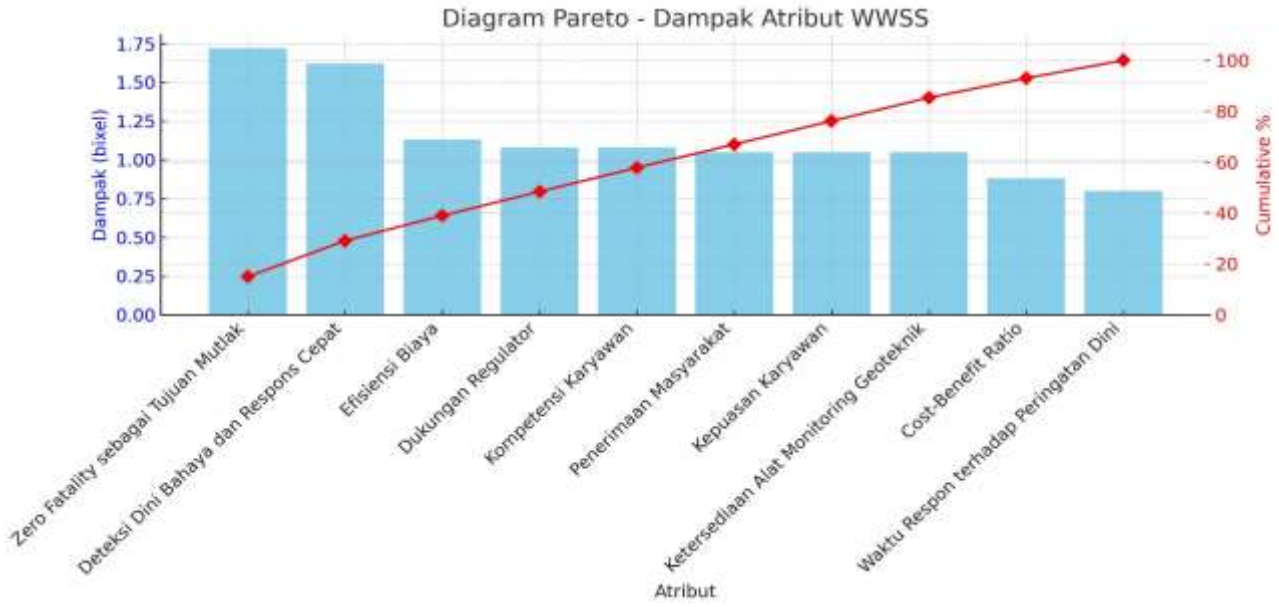

Diagram 3-1. Pareto Diagram of WWSS Attribute Impact

The Pareto diagram illustrates the distribution of impacts for each attribute in the WWSS Grasberg Project based on their level of significance. The results show that **Zero Fatality as an Absolute Goal** and **Early Hazard Detection and Rapid Response** are the two most critical attributes, each with an impact score above 1.6 (bi×ei). This highlights that occupational safety and geotechnical risk detection must remain the primary focus in slope stabilization strategies.

The cumulative Pareto line indicates that the top two to four attributes already account for more than 50% of the total impact. This finding supports the Pareto principle (80/20 rule), showing that managing a small number of key factors can strongly influence overall project success. Beyond the top safety-related factors, **Cost Efficiency, Regulatory Support, and Employee**

Competence also demonstrate significant contributions. These attributes emphasize that project sustainability depends not only on safety and environmental control, but also on financial efficiency, regulatory compliance, and human resource capabilities.

Overall, the interpretation confirms that the WWSS Project must prioritize its resources, monitoring technologies, and management policies toward the highest-impact attributes. Such prioritization enables budget allocation, human resource development, and performance evaluation to be directed more effectively in alignment with the strategic map of the Balanced Scorecard. Building on this analysis, a **strategic mapping of the WWSS Project** (Figure 4-5) is developed to present alternative optimal strategies.

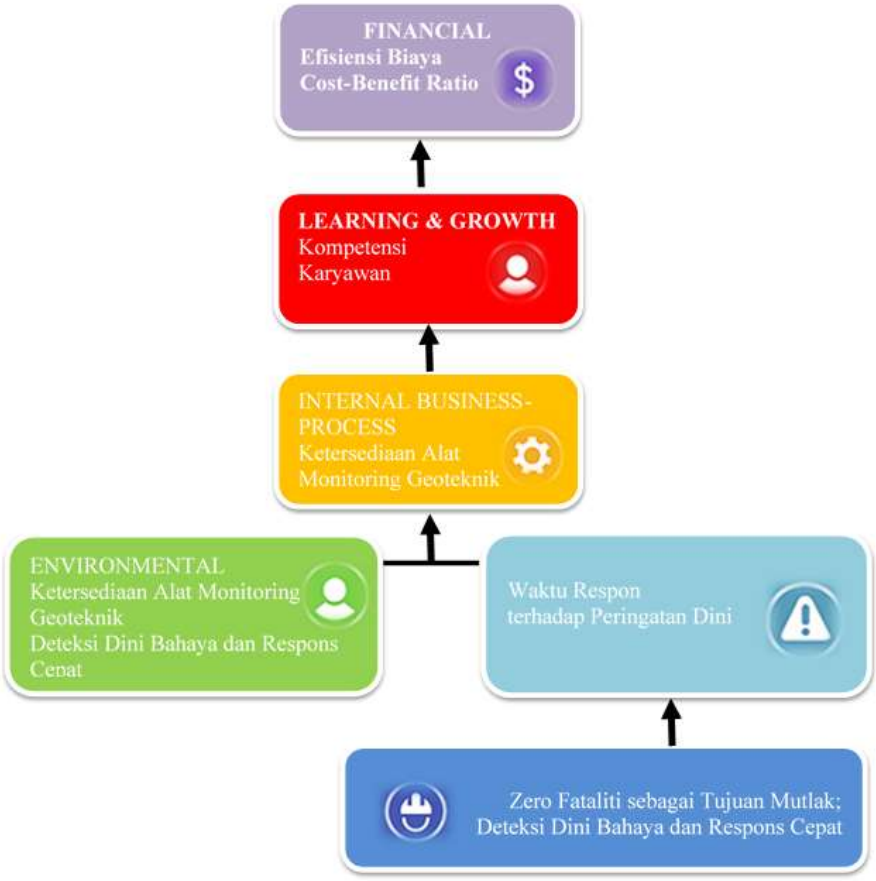

Figure 3-1. West Wanagon Slope Stability (WWSS) Project Mapping Strategy

3.3 Alternative Strategic Proposal for the West Wanagon Slope Stability Project (WWSS)

The West Wanagon Slope Stability (WWSS) Project at Grasberg is a vital initiative to ensure the long-term sustainability of open-pit mining operations under challenging geotechnical conditions, including steep slopes, high rainfall, and dynamic excavation activities. To address these risks, a strategic approach beyond technical interventions is required. This study employs the Balanced Scorecard (BSC) framework, which integrates five perspectives—Environmental & Social, Internal Business Process, Learning & Growth, External Stakeholders, and Financial—into a coherent strategic mapping process. Within this framework, Zero Fatality and Early Hazard Detection emerge as the core priorities forming the foundation for all subsequent initiatives.

The SWOT analysis highlights key strengths such as technological monitoring capabilities and corporate commitment to safety, balanced against weaknesses including skill gaps and high operational costs. Opportunities are identified in the application of advanced monitoring technologies and collaborative research, while threats relate to extreme geotechnical risks, reputational challenges, and cost fluctuations. Pareto analysis further indicates that most critical risks can be mitigated by focusing on early warning systems, emergency response, and capacity development.

Based on these findings, the proposed strategies emphasize technological innovation, competency-based training, risk-based budgeting, and proactive stakeholder engagement. These integrated approaches are expected to enhance slope stability, minimize human error, and strengthen sustainability in both technical and managerial dimensions of the WWSS Project.

Table 3-1. SWOT Matrix for the Grasberg WWSS Project

Strengths (S)	**Weaknesses (W)**
- Commitment to Zero Fatalities & Early Hazard Detection. - Clear mining regulatory support. - Experienced geotechnical personnel in large mines.	The availability of geotechnical monitoring tools is still limited. The response time for early warnings is not yet optimal. Human resource competence in new technologies still varies.
Opportunities (O)	**Threats (T)**
- IoT technology, radar, and deformation sensors are becoming more affordable. - Research collaboration with local universities and international vendors. - Slope stability budget schemes can be optimized based on risk.	The potential for extreme weather exacerbates the risk of landslides. - Stabilization costs will skyrocket if mitigation is not carried out in a timely manner. - Social conflict will arise if fatalities occur.

3.4 Implementation of the WWSS Reclamation Project Strategy

The West Wanagon Slope Stability (WWSS) reclamation project at Grasberg mine represents PT XZY commitment to sustainable post-mining land management. The project aims to restore overburden slopes to a stable and productive condition in alignment with the approved AMDAL 300K and in compliance with the Ministry of Energy and Mineral Resources Regulation No. 7/2014 on reclamation and post-mining practices. Implementation follows a structured process comprising five-year planning, land preparation, revegetation, and periodic monitoring audited by regulatory authorities.

A central approach is revegetation using native alpine species such as Deschampsia klossii and shrub varieties, applied through manual planting and hydro-seeding to achieve rapid ground cover. Field practices include nursery propagation, tissue culture for seedling multiplication, organic composting, and the use of hydro-seeder equipment. Between 2015 and 2024, reclamation progress exceeded planned targets, achieving 338.32 hectares compared to the target of 275 hectares, demonstrating both quantitative and qualitative success.

Monitoring integrates assessments of plant growth, soil fauna, and drainage systems, with operational challenges such as machine breakdowns mitigated through improved site design and planting patterns. The WWSS reclamation initiative not only fulfills regulatory requirements but also contributes to biodiversity conservation in highland alpine ecosystems. By involving local communities, applying appropriate technologies, and ensuring long-term monitoring, the project is positioned as a model of sustainable reclamation, supporting ecological restoration before final land handover to the government.

Figure 3-2. Planting Deschampsia klossii seedlings on a slope

3.5 Implementation of the Human Resource Strengthening Strategy for the West Wanagon Slope Stability (WWSS) Project

The training and certification program for Slope Stability Engineers, including software training in Slope/W and Plaxis, is designed to enhance technical competence and safety in mining operations. The training status diagram indicates significant differences between the two vendors. Petrosea-Pratama demonstrates stronger progress, with approximately 100 employees having completed the program and about 30 still pending, reflecting the company's commitment to workforce readiness. In

contrast, Freeport-Staff shows relatively fewer participants, with nearly equal proportions of completed and not completed status, highlighting the need for accelerated training initiatives.

Software proficiency in Slope/W and Plaxis is particularly critical, as it enables engineers to conduct numerical slope stability analyses, assess factors of safety, and simulate geotechnical conditions. The incomplete training status therefore requires immediate follow-up through rescheduled sessions and intensive mentoring.

Overall, the program serves as a strategic measure to mitigate slope failure risks, strengthen operational efficiency, and enhance the professional credibility of geotechnical engineers. Achieving 100% completion across both vendors is essential for ensuring project sustainability and compliance with mine safety standards.

Diagram 3-2. Human Resource Training per Vendor

IV. CONCLUSION

Based on the findings of this study, the following conclusions can be drawn:

1. The application of the Balanced Scorecard (BSC) in the West Wanagon Slope Stability (WWSS) project at PT Freeport Indonesia has proven effective in evaluating project performance from a holistic, multi-perspective approach.
2. The optimization strategies for BSC implementation in the WWSS project enhance operational efficiency, project sustainability, and overall performance through the following key actions:

- **Zero Fatality & Early Detection Strategy**: Focused on strengthening occupational safety systems through the use of real-time deformation radar, emergency response simulations, and reclamation activities, reaffirming safety as the project's top priority.
- **Monitoring Modernization**: Directed toward the adoption of additional geotechnical monitoring tools and integration of real-time dashboards, demonstrating a commitment to advanced digital surveillance for faster and more accurate risk detection.
- **Human Resource Development Strategy**: Implemented through training and certification of slope stability engineers as well as capacity building in geotechnical software (Slope/W, Plaxis), thereby enhancing technical competence and analytical reliability.

- **Project Cost Control Strategy**: Executed using risk-based budgeting and cost-benefit ratio audits to improve budget efficiency, ensuring effective and sustainable project execution.

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