

## Fuel Management System as a Diagnostic Control Instrument for Fuel Cost Control: A Case Study at a Coal Mining Company in East Kalimantan, Indonesia

Windu Dharma Bakti<sup>1</sup>, Irwansyah<sup>2</sup>, Hariman Bone<sup>3</sup>

<sup>1,2,3</sup>*Master of Accounting, Universitas Mulawarman, Samarinda, Indonesia*

**ABSTRACT:** This study analyzes the implementation of a Fuel Management System (FMS) as an instrument supporting diagnostic control in fuel cost management at a mining services company in East Kalimantan, Indonesia, referred to here as “Mining Company X” to preserve its confidentiality. Fuel is one of the largest cost components in mining operations, yet manual recording practices often produce delayed and untraceable information. This study uses a qualitative case study approach at “Mining Company X”. Data were collected through semi-structured interviews with five informants, direct observation, and documentation, and analyzed using the interactive model of Miles, Huberman, and Saldaña. The findings show that FMS has shifted fuel recording from manual to digital, provides actual consumption data that supports monitoring, and enables the identification, verification, and follow-up of variances between actual and standard fuel consumption. FMS is positioned as a technology-based instrument that supports diagnostic control within the Levers of Control framework, rather than as a control mechanism in itself. This study does not, however, provide quantitative evidence of the causal cost savings attributable to FMS implementation.

**KEYWORDS :** *Diagnostic Control, Fuel Cost Control, Fuel Management System, Levers of Control, Management Control System*

### I. INTRODUCTION

Mining operations are characterized by high operational complexity and substantial fuel requirements. Within management accounting, fuel constitutes one of the primary cost drivers, as its use is closely tied to operational activity and the cost structure of mining companies [1], [2].

Industry reports indicate that fuel costs can account for approximately 30-50% of total operating costs in many mining companies, and in some operations more than 50% [3], [4]. The 2024 annual report of PT. Vale Indonesia Tbk recorded that the Fuel Oil & Lubricant component accounted for 22.82% of its cost of production [5]. This proportion indicates that controlling fuel consumption is a critical part of cost control in mining companies.

Effective fuel cost control requires a system capable of providing timely and traceable information on standards, actual consumption, and deviations, so that corrective action can be taken. In practice, however, many companies still rely on manual or semi-manual recording, which is prone to delays, recording errors, and difficulty in tracing consumption by unit, shift, or location.

Advances in information technology have enabled companies to adopt digital systems for managing fuel use, commonly referred to as a Fuel Management System (FMS). FMS utilizes sensors, the Internet of Things (IoT), and cloud-based data storage to support the recording, monitoring, and tracing of fuel consumption. Prior studies on FMS [6], [7] have shown that such systems improve the accuracy, transparency, and speed of fuel monitoring. However, these studies predominantly emphasize the technical and operational aspects of FMS and have not explicitly positioned FMS within the framework of diagnostic control as part of a management control system.

This gap is notable because the management accounting literature has long established that formal control systems including diagnostic control play an important role in ensuring that actual performance is measured against pre-established standards and that deviations are identified and followed up [8]. Positioning FMS within this framework extends the existing FMS literature beyond its technical-operational focus and offers a management-control perspective that has not been explicitly examined in prior studies.

Accordingly, this study aims to analyze the implementation of FMS as an instrument supporting diagnostic control in fuel cost management, focusing on three objectives: (1) to analyze the implementation of FMS as part of a Management Control System in a mining company; (2) to examine the role of FMS as diagnostic control in fuel cost control; and (3) to assess the contribution of FMS in detecting deviations between actual fuel consumption and management-established standards.

## II. LITERATURE REVIEW

### 2.1 *Management Control System and Diagnostic Control*

A Management Control System (MCS) is used by management to ensure that organizational activities and resources are directed toward achieving organizational objectives [9]. Within the Levers of Control framework, Simons [8] identifies diagnostic control systems as formal, information-based systems used by managers to monitor organizational outcomes and correct deviations from pre-set performance standards. A diagnostic control system operates through a cycle of establishing standards, measuring actual performance, comparing actual performance to standards, identifying variances, and taking corrective action when significant deviations occur.

The relevance of a control system also depends on the context in which it is applied. Contingency-based perspectives on management control suggest that the design and use of control systems are influenced by organizational context, environment, technology, and the nature of operating activities [10], [11]. This perspective is used in the present study to help explain the contextual conditions such as network connectivity, data quality, and system reliability that accompany FMS implementation, without treating these conditions as statistically tested variables.

### 2.2 *Fuel Management System*

A Fuel Management System (FMS) is a technology-based information system used to record, monitor, and trace fuel receipt, distribution, and consumption. In the literature, FMS is described as an information system that can integrate sensors, IoT-enabled devices, and cloud-based data storage to provide more timely, accurate, and traceable information than manual recording methods [12], [13]. It should be noted that this description reflects the range of technologies associated with FMS in the literature; the extent to which a given implementation relies on automated sensors as opposed to application-based manual data entry is an empirical matter that varies across organizations and is examined for the present case in Section 4.1. Recent studies also indicate that FMS-type information systems can strengthen transparency and oversight of fuel use in operational settings [6], [7].

### 2.3 *Positioning FMS within Diagnostic Control*

Although prior studies have documented the technical capabilities of FMS, they have generally treated FMS as an operational recording tool rather than as an instrument embedded within a management control mechanism. This study addresses that gap by positioning FMS as a technology-based instrument that supports rather than substitutes for the diagnostic control mechanism described by [8]. In this view, FMS provides the actual consumption data required for the standard→actual→monitoring→variance→verification→corrective action cycle, while the interpretation of variances and the decision to act on them remain organizational and managerial processes involving procedures, physical verification, and the division of responsibility.

## III. RESEARCH METHOD

This study uses a qualitative approach with a case study design [14], [15], as it seeks to obtain an in-depth understanding of how FMS is implemented and used to support fuel cost control, rather than to test causal or statistical relationships. The case study was conducted at a coal mining services company in East Kalimantan, Indonesia, which has implemented FMS in its fuel management and distribution activities. To preserve its confidentiality, the company is referred to throughout this paper as “Mining Company X” and site-specific identifying details are not disclosed.

Five informants were selected using purposive sampling to represent technical, operational, managerial, and cost-control perspectives, as summarized in Table 1.

**Table 1.** Research Informants

| Code  | Position             | Relevance                                                                      |
|-------|----------------------|--------------------------------------------------------------------------------|
| IT-01 | Head of IT           | FMS implementation, system infrastructure, connectivity, and data validation   |
| SF-01 | Fuel Supervisor      | Fuel management, consumption monitoring, and variance follow-up                |
| DR-01 | Fuel Truck Driver    | FMS use and operational procedures for fuel filling and distribution           |
| MO-01 | Operations Manager   | Operational monitoring, evaluation of fuel use, and decision-making            |
| CC-01 | Admin / Cost Control | Reconciliation, variance analysis, and use of FMS information for cost control |

Data were collected through semi-structured interviews, direct field observation conducted on 10-11 August 2026, and documentation review, including standard operating procedures, consumption reports, and

FMS system reports. Data were analyzed using the interactive analysis model of [16], consisting of data condensation, data display, and conclusion drawing and verification. Each interview lasted approximately 45-60 minutes and followed a semi-structured interview guide covering FMS implementation, monitoring practices, and variance-handling procedures. The credibility of the findings was strengthened through source and method triangulation and member checking. All informants provided informed consent prior to participation, and their identities were kept confidential throughout the study.

#### IV. RESULTS AND DISCUSSION

##### 4.1 *Implementation of the Fuel Management System*

The findings show that fuel recording at Mining Company X has shifted from manual to digital recording through a mobile-based application (Fuel Apps). It should be emphasized that this shift reflects the digitization of recording rather than full sensor-based automation: fuel transactions are entered by the fuelman immediately after each fuel-filling activity, making consumption data available more quickly than under the previous manual system. Data are stored in the system and transmitted directly when network connectivity is available; when connectivity is unavailable, the system applies a buffer mechanism so that data are stored locally and transmitted once connectivity is restored.

The resulting data are used by supervisors and the operations manager to monitor fuel use by unit and activity. Nevertheless, digital recording has not eliminated physical verification: flow meters, tank-level gauges, and dipstick sounding continue to be used to cross-check the accuracy of digital data. Notably, these instruments support physical volume measurement rather than automatic transaction capture, so that the recording process as a whole remains a hybrid of manual data entry and instrument-assisted verification rather than a fully automated, sensor-driven system. This indicates that FMS implementation is best understood as a technology-based information infrastructure embedded within a broader mechanism of operational procedures, physical measurement, and managerial oversight, consistent with the contingency-based view that the effectiveness of a control system depends on the operational context in which it is used [11].

##### 4.2 *The Role of FMS as an Instrument Supporting Diagnostic Control*

As illustrated in Figure 1, FMS supports a diagnostic control cycle consisting of six stages: standard, actual, monitoring, variance, verification, and corrective action. Management establishes a fuel consumption standard or target; FMS then provides actual consumption data used for monitoring. When actual consumption deviates from the standard, FMS generates variance information. Consistent with the diagnostic control logic proposed by [8], a variance is not immediately interpreted as fuel loss; rather, it functions as a signal that requires verification.

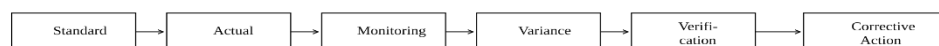


**Fig. 1.** *The Diagnostic Control Cycle Supported by FMS [8]*

An illustrative case is a variance identified on 30 June 2026, in which the FMS "Refueling Summary" report showed a balance of 237,146 liters against an ending stock of 136,939.923 liters, producing a variance of 100,206.077 liters exceeding the company's 0.05% SOP tolerance threshold. Verification, conducted by cross-checking system data against transaction documents and clarifying with the relevant personnel, revealed that the variance stemmed from a fuel withdrawal that had not yet been receipted in the system, compounded by a shift/time-recording difference, rather than an actual physical loss of fuel. This case illustrates how FMS enables the identification of a deviation, while the verification and interpretation of that deviation remain a data-supported managerial judgment rather than an automated conclusion supporting the diagnostic control cycle rather than replacing it.

##### 4.3 *Contribution of FMS in Detecting Fuel Consumption Variances*

The findings further indicate that FMS contributes to fuel cost control through several interrelated capabilities: providing timely actual consumption data, accelerating monitoring, enabling traceability by unit, operator, shift, and location, accelerating reconciliation, supporting variance detection and verification, facilitating follow-up action, and providing information that supports managerial decision-making.

These findings support the study's central proposition that FMS functions as an instrument supporting diagnostic control rather than as diagnostic control itself: the value of FMS lies not merely in its capacity to generate data, but in how that data is embedded in the monitoring, verification, and corrective-action processes carried out by the organization. At the same time, this study does not find sufficient quantitative evidence to

state the magnitude of cost savings causally attributable to FMS implementation; the qualitative case-study design used here is not intended to establish such causal, statistically generalizable claims.

## V. CONCLUSION

This study concludes that the Fuel Management System at Mining Company X has evolved from a transaction-recording tool into an information instrument that supports the implementation of diagnostic control in fuel cost management. Theoretically, this study extends the Levers of Control framework by demonstrating how a technology-based information system such as FMS can operationalize diagnostic control in resource-intensive operational settings. Practically, the findings suggest that mining companies seeking to strengthen fuel cost control should not treat FMS adoption as a purely technical upgrade, but should embed it within clear standard operating procedures for variance verification and corrective action, supported by periodic physical cross-checking. FMS implementation is reflected in the shift from manual to digital, traceable recording, supported by physical verification and a validation-and-follow-up mechanism. FMS supports diagnostic control by supplying actual consumption data that can be compared against standards, facilitating variance identification, enabling verification, and providing the basis for corrective action, as illustrated by the 30 June 2026 variance case. FMS also contributes to detecting fuel consumption deviations by improving the timeliness, traceability, and verifiability of consumption information.

This study is subject to several limitations. As a qualitative single-case study, its findings are context-bound and are not intended for statistical generalization; transferability to other mining sites should therefore be assessed by readers in relation to similarities in operational scale, technology infrastructure, and organizational context. In addition, this study does not statistically test the causal relationship between FMS implementation and cost savings. Future research could extend this study by employing a quantitative design to measure the impact of FMS on fuel cost control for example, by comparing fuel cost per unit of production, fuel consumption ratios, and variance levels before and after FMS implementation or by comparing FMS implementation across multiple mining sites or companies.

## REFERENCES

- [1] C. T. Horngren, S. M. Datar, and M. V. Rajan, *Cost Accounting A Managerial Emphasis*, 14th ed. Upper Saddle River, N.J.: Pearson Prentice Hall, 2012.
- [2] C. Drury, *Management and Cost Accounting, 11th Edition*. Annabel Ainscow, 2021.
- [3] Indonesia Mining Association (IMA), “Biaya Bahan Bakar Pertambangan Sampai 35%, Penggunaan EV Dinilai Jadi Solusi,” Indonesia Mining Association. [Online]. Available: <https://ima-api.org/kontak/>
- [4] PERHAPI, “Dampak Kenaikan BBM pada Biaya Operasional (2026).” [Online]. Available: <https://perhapi.or.id/>
- [5] PT. Vale Indonesia Tbk, *Annual Report Summary*. 2024. [Online]. Available: <https://www.vale.com/in/indonesia>
- [6] M. Mwinyi, Angela-Aida K, and Runyoro, “Effect of Fuel Management Information Systems ( FMIS ) on the Operational Performance of Government Vehicles in Tanzania,” vol. 6, no. 2, pp. 23–31, 2025.
- [7] M. L. Widianoto and Nurhadi., “Analysis of Fuel Tank Level Monitoring System Design for Generator Set,” vol. 8, no. 2, pp. 226–233, 2024, doi: 10.31289/jmemme.v8i2.10110.
- [8] R. Simons, *Levers of Control*. Harvard Business School Press, 1995.
- [9] K. A. Merchant and W. A. Van der Stede, *Management Control Systems Performance Measurement, Evaluation, and Incentives Fourth Edition*. Pearson, 2017.
- [10] D. Otley, “The contingency theory of management accounting and control: 1980–2014,” *Manag. Account. Res.*, pp. 1–18, 2016, doi: 10.1016/j.mar.2016.02.001.
- [11] R. H. Chenhall, “Management control systems design within its organizational context: findings from contingency-based research and directions for the future,” *Accounting, Organ. Soc.*, 2003, [Online]. Available: [https://doi.org/10.1016/S0361-3682\(01\)00027-7](https://doi.org/10.1016/S0361-3682(01)00027-7)
- [12] A. W. Hapsari, H. Prastowo, and T. Pitana, “Real-Time Fuel Consumption Monitoring System Integrated With Internet Of Things (IOT),” vol. 18, no. 2, pp. 88–100, 2021.
- [13] K. S. A. Khuwaja, A. A. Brohi, V. O. Mihalca, and R. C. Țarcă, “Automatic fuel tank monitoring , tracking & theft detection system,” vol. 02011, pp. 1–4, 2018, doi: <https://doi.org/10.1051/mateconf/201818402011>.
- [14] J. W. Creswell, *Research Design Qualitative, Quantitative, and Mixed Methods Approaches*. SAGE Publications, Inc, 2014.
- [15] R. K. Yin, *Case Study Research and Applications*. SAGE Publications, Inc, 2018.
- [16] M. B. Miles, A. M. Huberman, and J. Saldana, *Qualitative Data Analysis: A Methods Sourcebook (3rd ed.)*. SAGE Publications, Inc, 2014.