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Digital Fuel Cost Control: Cost Differences Between Voucher and RFID Systems at Bukit Asam

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Abstract
Purpose: This study examines whether recorded fuel cost per kilometer differed between the voucher and Radio Frequency Identification (RFID) periods at PT Bukit Asam Tbk Tarahan Port Unit. The transition is treated as an internal Business-to-Business (B2B) digital-business process change rather than a randomized intervention.
Research Methodology: Using archival company records, the study compared 84 monthly voucher observations in November 2022–December 2023 with 84 RFID observations in January 2024–February 2025, from six Toyota Innova vehicles. Fuel cost per kilometer was calculated by dividing fuel expenditure by distance. Normality was assessed using the Kolmogorov–Smirnov test, followed by a two-tailed paired-samples t-test using SPSS 27
Results: The mean recorded fuel cost was IDR 2,379.60/km during the voucher period and IDR 1,330.18/km during the RFID period. The voucher-minus-RFID mean difference was IDR 1,049.417/km ($t(83) = 13.018$, $p < .001$; 95% CI = IDR 889.082–IDR 1,209.751), indicating a significant difference between periods.
Conclusions: The RFID period was associated with lower recorded fuel cost per kilometer. However, the results do not establish that RFID alone caused the reduction.
Limitations: The non-overlapping before–after design cannot fully isolate RFID effects from other factors, including fuel prices, vehicle conditions, routes, loads, traffic, maintenance, and driver behavior.
Contributions: This study links transaction visibility, management-accounting information, and operational cost control by providing an auditable benchmark for B2B digital process transformation.

Keywords: *Cost Control, Fuel Cost, Paired-Samples t-Test, Voucher*

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1. Introduction

Operational efficiency and accountable resource management are central concerns for state-owned enterprises because routine expenditures accumulate across large and geographically dispersed activities. Fuel is one of the recurring operating inputs that requires particular attention in companies whose logistics, port support, distribution, and administrative functions depend on vehicle mobility. From a management-accounting perspective, fuel expenditure is not merely a payment transaction; it is cost information that must be recorded accurately, compared with operational output, monitored against internal expectations, and communicated in time for managerial action (Appelbaum, Kogan, & Vasarhelyi, 2017a; Appelbaum, Kogan, Vasarhelyi, & Yan, 2017b; Richins, Stapleton, Stratopoulos, & Wong, 2017). When the recording mechanism is weak, management may face delayed information, incomplete transaction trails, and difficulty distinguishing necessary consumption from avoidable cost.

PT Bukit Asam Tbk (PTBA) is an Indonesian state-owned coal-mining company whose operations include production, transportation, and shipment support. At the Tarahan Port Unit, business-operational vehicles support mobility associated with administrative, logistical, and port-related activities. These activities form part of an integrated coal business in which transportation and shipment are important operating links. Fuel and lubricant expenditure is consequently relevant to routine cost control, particularly when multiple vehicles make repeated transactions over long observation periods.

From a digital-business perspective, the transition is not merely a replacement of payment media. It is a business-process transformation in an internal B2B operating environment: a vehicle, an authorization, and a fueling event become connected data that can be used by operational, finance, and management teams. Digital value is realized when this information changes visibility, control routines, and decision quality rather than when a device is installed in isolation (Vial, 2019; Verhoef, Broekhuizen, Bart, Bhattacharya, Dong, Fabian, & Haenlein, 2021).

Before 2024, fuel for the business-operational vehicles examined in this study was managed through vouchers. A voucher provides a recognizable authorization and payment document, but its effectiveness depends on manual handling, verification, and subsequent entry into operating reports. Research on digital information and transaction analytics indicates that fragmented recording can delay information availability and increase exposure to input error, whereas integrated systems can improve traceability and the usefulness of transaction data for monitoring (Kache, & Seuring, 2017; Rikhardsson, & Yigitbasioglu, 2018; Rozario, & Issa, 2020).

The internal historical data also show why the control issue deserves attention. During the voucher period, aggregate vehicle distance increased from 543,163 km in 2020 to 605,466 km in 2023, while total fuel cost rose from IDR 468.83 million to approximately IDR 1.14 billion. Over the same period, the reported fuel-cost ratio increased from IDR 863/km to IDR 1,878/km and fuel-use efficiency declined from 9.09 km/liter to 7.02 km/liter. These figures combine operational volume, prices, and vehicle-use conditions, so they cannot by themselves identify the cause of the increase. They nevertheless indicate that a distance-standardized cost measure is useful for evaluating whether a different recording and authorization method corresponds with a different cost pattern.

PTBA subsequently implemented Radio Frequency Identification (RFID) for the relevant fuel transactions. RFID uses a tag or card containing a unique identity and a reader that captures the identity during a transaction. In the fuel-management context, the system can associate a transaction with a designated vehicle, apply product or quota restrictions, and produce automated reporting. RFID research describes these functions as mechanisms for traceability, real-time data capture, and decision support when the technology is integrated with operational processes (Raza, 2022; Unhelkar, Joshi, Sharma, Prakash, Mani, & Prasad, 2022). These features differ materially from a paper-based voucher process because authorization and recording are embedded more directly in the transaction flow.

Technology adoption, however, should not be equated automatically with cost reduction. Fuel cost per kilometer can change because of fuel prices, vehicle condition, route characteristics, traffic, passenger or cargo load, driving behavior, and the intensity with which a vehicle is used. The present study therefore frames the empirical question as a comparison rather than a causal evaluation. It asks whether the recorded fuel-cost ratio differs between the voucher period and the RFID period for the same vehicle type and the same operational unit after constructing matched observations from available company records.

Prior RFID research has mainly examined logistics, identification accuracy, inventory control, data integration, and system design. Systematic reviews identify traceability, visibility, and information quality as recurrent benefits of RFID implementation, while empirical evidence shows that these benefits depend on organizational integration and use of the resulting data (Chanchaichujit, Balasubramanian, & Ng, 2020; Hao, Hildebrandt, Morgan, & Richey, 2026; Kholod, Celani, & Ciaramella, 2024; Raza, 2022; Unhelkar et al., 2022). These findings establish the operational relevance of RFID, but they do not directly answer whether a state-owned mining company records a different fuel cost per kilometer after replacing vouchers with RFID for matched operational vehicles.

This study addresses that narrower gap using internal secondary data from PTBA Tarahan Port Unit. It compares 84 paired observations drawn from six Toyota Innova vehicles, standardizes expenditure by distance traveled, tests the distribution of paired differences, and estimates a paired-samples t-test. The article contributes in three ways. First, it translates a practical fuel-control change into an auditable management-accounting measure. Second, it uses the same vehicle type and paired monthly order to improve comparability between periods. Third, it explicitly separates evidence of a statistically significant difference from a causal claim about the technology itself. The historical indicators in Table 1 summarize this pre-RFID pattern and provide the descriptive baseline for the comparison. Following the thesis measurement logic, the analysis focuses on recorded cost intensity rather than on a direct engineering estimate of fuel consumption or a claim that RFID changed vehicle operation.

Table 1. Historical fuel-use indicators during the voucher period

Year	Distance (km)	Fuel use (liters)	Fuel efficiency (km/l)	Fuel cost (IDR)	Cost ratio (IDR/km)
2020	543,163	59,768	9.09	468,830,439	863
2021	535,592	60,335	8.88	473,629,750	884
2022	562,889	71,646	7.86	698,572,202	1,241
2023	605,466	86,282	7.02	1,137,199,296	1,878

As shown in Table 1, the voucher-period fuel-cost ratio increased from IDR 863/km in 2020 to IDR 1,878/km in 2023, while fuel efficiency declined from 9.09 to 7.02 km/liter. These descriptive movements establish the operational-control context for the study, but they do not test an RFID effect because they precede the RFID period and may also reflect changing price, volume, and vehicle-use conditions.

2. Literature Review and Hypothesis Development

2.1 Management Accounting and Operational Cost Control

Management accounting identifies, measures, analyzes, and communicates financial and non-financial information for internal planning, control, and decision-making. Its practical value depends on whether information is relevant to the activity being managed. A total fuel bill may be useful for budgeting, but it can be misleading when vehicle activity changes substantially. A ratio such as fuel cost per kilometer links expenditure to an operational output and therefore gives management a more comparable indicator across periods (Appelbaum, Kogan, Vasarhelyi, & Yan, 2017b; Nielsen, 2018; Rikhardsson, & Yigitbasioglu, 2018).

Cost control is a systematic process of setting expectations, recording actual performance, identifying deviations, and taking corrective action. Reliable control requires timely and credible records because a manager cannot investigate a variance that is reported late or cannot be traced to a specific vehicle or transaction. Digital accounting and analytics systems can reduce repeated manual entry, standardize transaction fields, and improve the availability of monitoring information; they also require appropriate data governance and professional judgment (Appelbaum et al., 2017b; Moll, & Yigitbasioglu, 2019; Zhang, Zhu, Dai, Wu, & Chen, 2023). Evidence published by Goodwood likewise links technology-enabled cost management and digital adoption with operational efficiency and organizational performance (Astika, Sholihah, Retnowati, Fitria, Maulidia, & Sofiyah, 2024; Ferina, & Widyaningsih, 2025). For this case, the information chain runs from vehicle identification and fueling authorization to a comparable IDR/km measure, connecting transaction records with a managerial decision about efficiency.

Fuel expenditure for operational vehicles is generally treated as a recurring operating cost. In behavioral terms, it varies with vehicle activity, but the amount per kilometer is also influenced by efficiency, prices, and operating conditions. This combination makes fuel suitable for responsibility-oriented monitoring: management can observe total expenditure while also using standardized indicators to identify unusual patterns that warrant further review.

2.2 Fuel Cost as a Vehicle Operating Cost Measure

Vehicle operating costs comprise costs incurred while a vehicle is used in operations. Fuel consumption is a running-cost component that can be expressed in rupiah per kilometer. This unit is useful because it relates the monetary input to distance traveled and reduces the distortion that arises when one period contains substantially more vehicle activity than another. In operational management, standardized cost indicators are important because they provide comparable measures for evaluating efficiency and supporting managerial decisions (Noviaristanti, 2024). In this study, fuel cost per kilometer is calculated by dividing recorded fuel expenditure by recorded distance traveled for each observation. The measure does not represent engineering fuel efficiency in kilometers per liter and does not isolate the price component from the consumption component. Instead, it is an accounting ratio that answers a managerial question: how much recorded fuel cost was incurred for each kilometer of operational travel? Because the numerator includes fuel price and quantity, interpretation must remain sensitive to price changes across the study period.

The ratio is nevertheless preferable to comparing total cost alone. A lower total bill could reflect fewer trips, while a higher total bill could reflect greater operational demand. Standardizing by distance provides a common denominator for the voucher and RFID periods and is consistent with the thesis objective of comparing cost use on an equivalent operational basis. The use of measurable operational indicators also supports digital transformation initiatives by improving data visibility, monitoring accuracy, and evidence-based cost control within organizations (Syahrina & Rayyani, 2026). Therefore, fuel cost per kilometer serves as an accounting-based performance indicator that enables more reliable evaluation of operational changes.

2.3 Voucher-Based Fuel Management

A fuel voucher is a non-cash authorization that permits a designated user or vehicle to obtain fuel. In a manual workflow, the voucher records transaction information such as date, quantity, vehicle identity, and user, after which the document is collected, verified, and entered into an operating-cost report. The method creates a visible documentary trail, but its reliability depends on custody of the voucher, completeness of handwritten or manually entered information, timely reconciliation, and consistent application of authorization rules.

The voucher method may therefore face several control risks. Physical documents can be misplaced, duplicated, or submitted late. Manual input can introduce transcription error, and the separation between the refueling event and subsequent administrative recording may delay monitoring. These weaknesses do not mean that every voucher transaction is inaccurate; rather, they create more points at which the transaction trail can be interrupted or require additional verification (Kache & Seuring, 2017).

From a cost-control perspective, the central issue is traceability. A method that records fuel expenditure without immediately linking it to a unique vehicle, authorized product, and transaction history may require more manual reconciliation before management can interpret a cost ratio. The voucher period in this study provides the conventional comparison condition against which the RFID period is assessed.

2.4 RFID-Enabled Fuel Management

RFID is an automatic identification technology that transfers data from a tag to a reader through radio frequency. In vehicle-fuel applications, a tag or card contains a unique identifier, and the reader captures that identity when the vehicle or card is presented at the fueling point. The transaction can then be linked to the vehicle in an electronic record. Research on RFID-enabled operations emphasizes automated data capture, traceability, and the potential for decision support when identifiers are integrated with operational records (Kholod et al., 2024; Raza, 2022; Unhelkar et al., 2022).

These features can improve the control environment through three mechanisms. First, unique identification can reduce ambiguity over which vehicle received fuel. Second, automated capture can shorten the delay between the physical transaction and its appearance in a report. Third, preset restrictions can prevent transactions that do not conform to the assigned product or allocation. Together, these mechanisms may improve data accuracy and reduce opportunities for unauthorized or incorrectly recorded use. RFID implementation also has limitations. A digital identifier does not measure driver behavior, mechanical efficiency, road conditions, or fuel prices. Data quality still depends on correct configuration, device availability, and integration with other operational records. The appropriate expectation is therefore not that RFID eliminates every source of fuel-cost variation, but that it changes the authorization and recording architecture in ways that may be associated with a different observed cost pattern.

2.5 Digital Transaction Visibility and Cost-Control Mechanism

Taken together, the literature indicates a digital cost-control mechanism rather than a direct technology-to-savings relationship. RFID first creates unique identification of the vehicle and the fueling event. That identification improves transaction visibility by linking physical activity to electronic records. The availability of structured digital information supports better monitoring, evaluation, and managerial decision-making by improving the quality and accessibility of organizational data (Albab et al., 2026; Hermawati & Jannah, 2026). More visible transactions can improve the timeliness, completeness, and traceability of cost information. Managers can then use standardized indicators such as IDR/km to detect exceptions, investigate deviations, and adjust operating practices.

This mechanism connects the digital-business and management-accounting perspectives used in this article. In an internal B2B setting, digital value is generated when technology alters the flow of information among vehicle users, fueling points, finance staff, and operational managers. The integration of digital accounting practices and information systems enables organizations to strengthen control mechanisms, improve reporting quality, and support evidence-based operational decisions (Reski & Rayyani, 2026). The mechanism also clarifies the boundary of the present test. The study observes the end-point difference in recorded cost intensity; it does not separately estimate the effects of transaction accuracy, fuel price, physical consumption, or managerial response.

2.6 Cost-Efficiency Perspective

Cost efficiency concerns the relationship between resources consumed and output achieved. For operational vehicles, distance is an observable output proxy and recorded fuel expenditure is the monetary input. A reduction in rupiah per kilometer is therefore consistent with more economical recorded fuel use, provided that the compared observations are sufficiently similar and the underlying data are reliable (Richins, Stapleton, Stratopoulos, & Wong, 2017).

The present comparison improves similarity by retaining the same vehicle type, Toyota Innova, and the same operational unit. It does not fully equalize the operating environment, because monthly routes, traffic, load, fuel prices, and vehicle condition may differ. Accordingly, the cost-efficiency perspective supports the direction of interpretation but does not convert the before–after design into a controlled experiment. The management-accounting implication is that a statistically lower ratio after

RFID adoption would provide evidence useful for evaluation and further investigation. It could justify maintaining or refining digital controls, while also motivating a more detailed analysis that separates price variance, usage variance, and operational factors.

2.7 Prior Research and Research Gap

Research on digital transformation explains that operational value follows from coordinated changes to technology, data, organizational capabilities, and control routines rather than from adoption alone (Hanelt et al., 2021; Nambisan et al., 2017; Verhoef et al., 2021; Vial, 2019; Warner & Wäger, 2019). In operations and supply-chain research, digital supply-chain frameworks, Industry 4.0, the Internet of Things, and big-data analytics are associated with visibility, traceability, coordination, and performance, while their realized benefits remain contingent on implementation context (Ben-Daya et al., 2019; Büyüközkan & Göçer, 2018; Kache & Seuring, 2017; Kamble & Gunasekaran, 2020; Oztemel & Gursev, 2020).

Empirical studies further link supply-chain visibility and resilience to operational and firm performance, and demonstrate the value of integrating transactional data with logistics records (Huang et al., 2023; Kalaiarasan et al., 2023; Kholod et al., 2024). RFID-specific studies identify traceability, transparency, agility, and decision support as potential benefit pathways, but also caution that performance gains depend on organizational integration and the quality of the data generated (Chanchaichujit et al., 2020; Hao et al., 2026; Raza, 2022; Unhelkar et al., 2022). Complementary Goodwood studies similarly associate technology-supported cost management, cloud accounting, digital adoption, structured transaction systems, and AI-enabled accounting tools with improved operational or information outcomes (Astika et al., 2024; Astuti et al., 2026; Ferina & Widyaningsih, 2025; Pratama et al., 2023; Putri et al., 2025).

The unresolved issue is empirical and context-specific. Existing studies do not directly compare voucher and RFID fuel cost per kilometer for matched business-operational vehicles in an Indonesian state-owned mining and port-support unit. The current study fills that gap by using actual company records, a consistent vehicle type, matched observations, and a paired statistical test. Its contribution is intentionally narrow: it determines whether the observed cost ratio differs across the two methods, while acknowledging that uncontrolled period effects may contribute to the difference.

2.8 Hypothesis Development

The RFID changes the fuel-control process from a document-centered workflow to an electronically identified transaction. Theory and prior evidence suggest that more integrated recording can improve traceability, reduce manual error, and support timely monitoring. These mechanisms are consistent with a difference in the recorded fuel-cost ratio between the voucher and RFID periods. Because the research question is comparative and the design does not isolate a causal treatment effect, the hypothesis is stated non-directionally.

> H_1: Fuel cost per kilometer differs significantly between the voucher method and the RFID method at PT Bukit Asam Tbk Tarahan Port Unit

3. Research Methodology

3.1 Research Design and Setting

This study uses a quantitative comparative design based on archival secondary data. Quantitative research using structured secondary records enables researchers to analyze measurable differences and generate empirical evidence from existing organizational information (Johnston, 2014). The research setting is PT Bukit Asam Tbk Tarahan Port Unit in Bandar Lampung, Indonesia. The source records document fuel expenditure and vehicle distance for business-operational vehicles before and after the company changed its fuel-management method. The voucher period ended in December 2023, and the RFID method began in January 2024.

The design compares two related conditions rather than two independent groups. Each voucher-period observation is paired with an RFID-period observation from the same vehicle and corresponding order in the observation sequence. A paired comparison approach is suitable when measurements are obtained from the same units under different conditions because it reduces variability caused by individual differences (Kim, 2015). The purpose is to determine whether the mean within-pair difference in fuel cost per kilometer is statistically distinguishable from zero. The study does not manipulate the method, randomize vehicles, or control external operating conditions; it is therefore an observational before–after comparison.

3.2 Population, Sample, and Pairing Strategy

The population consists of available fuel-use records for business-operational vehicles at the Tarahan Port Unit from 2022 through February 2025. During the pre-RFID period, the fleet included Mitsubishi Xpander and Toyota Innova vehicles. During the RFID period, it included Toyota Veloz and Toyota Innova vehicles. Purposive sampling was applied because a paired comparison required observations with consistent vehicle characteristics and complete cost and distance information.

The inclusion criteria were: the transaction related to a business-operational vehicle; records were available for both voucher and RFID periods; fuel expenditure and distance were complete; the ratio in rupiah per kilometer could be calculated; and the fuel product was Pertamax. The product criterion was necessary because the RFID-period records used Pertamax, whereas the voucher-period records contained both Pertalite and Pertamax. Restricting the sample to Pertamax improved comparability between periods.

Only Toyota Innova vehicles were present in both periods and met the required criteria. Six vehicles were retained. For each vehicle, 14 voucher observations from November 2022 through December 2023 were ordered and paired with 14 RFID observations from January 2024 through February 2025. The pairing was based on vehicle identity and chronological order rather than the same calendar month because the two periods did not overlap. This process produced 84 pairs, comprising 84 voucher observations and 84 RFID observations. Table 2 summarizes the sample construction, observation periods, and pairing basis.

Table 2. Sample construction and observation periods

Criterion	Description
Vehicles retained	Six Toyota Innova business-operational vehicles
Fuel product	Pertamax in both periods
Voucher period	November 2022–December 2023 (14 months)
RFID period	January 2024–February 2025 (14 months)
Pairing basis	Same vehicle and chronological observation order
Final sample	84 matched pairs (168 individual records)

As shown in Table 2, the final matched dataset comprises 84 voucher–RFID pairs from six Toyota Innova vehicles. By restricting the comparison to one vehicle type, complete cost-and-distance records, and Pertamax transactions, the sample construction improves comparability between the two periods while not eliminating time-varying operating conditions.

3.3 Variable Definition and Measurement

The study uses one outcome measure: fuel cost per kilometer. For each vehicle-period observation, the recorded fuel cost is divided by recorded distance traveled. The resulting ratio is expressed in rupiah per kilometer (IDR/km). This standardization relates fuel cost to each kilometer of operation and supports a comparable measure across observations with different travel distances.

Two measurements are compared for each pair: the ratio under the voucher method and the ratio under the RFID method. For presentation and testing, the paired difference is defined as voucher minus RFID. A positive value therefore indicates that the voucher-period ratio is higher, while a negative value indicates that the RFID-period ratio is higher. The operational definition and measurement unit are summarized in Table 3.

Table 3. Operational definition and measurement

Variable	Operational definition	Indicator	Unit
Fuel cost of business-operational vehicles	Recorded fuel expenditure required for each kilometer of vehicle travel	Total fuel cost ÷ total distance traveled	IDR/km

As shown in Table 3, fuel cost per kilometer is defined as recorded fuel expenditure divided by recorded distance traveled. This IDR/km indicator standardizes the outcome for differences in travel distance, so the subsequent descriptive and paired-test results concern recorded cost intensity rather than total fuel expenditure or engineering fuel efficiency.

3.4 Data Collection and Preparation

Data were collected through documentation of internal fuel-use reports, fuel-cost records, vehicle identity, fuel type, and distance traveled. Supporting literature was used to define management accounting, cost efficiency, vehicle operating cost, vouchers, and RFID. No survey or interview data were used in the statistical analysis.

Preparation involved screening the records against the inclusion criteria, computing IDR/km for every retained observation, grouping records into voucher and RFID periods, ordering observations within each vehicle, and constructing the paired dataset. The complete thesis appendix contains the underlying 84 pairs; the article reports aggregate results to maintain a concise journal format. The thesis records provide a transparent audit trail: total fuel cost and total distance were retained for each observation, while the article ratio was calculated before pairing. Because synchronized price-per-liter and liters measures were not available for every retained monthly pair, a formal price/quantity decomposition was not estimated. The ratio therefore remains an accounting measure of recorded cost intensity, not a direct engineering measure of physical fuel efficiency.

3.5 Statistical Analysis

Statistical analysis was conducted with IBM SPSS Statistics version 27. Descriptive statistics include the number of observations, minimum, maximum, mean, and standard deviation for each method. Before testing the hypothesis, the distribution of the 84 paired differences was evaluated with the Kolmogorov–Smirnov normality test. A significance value above .05 was interpreted as insufficient evidence to reject normality.

Because the differences met the normality criterion, the paired-samples t-test was used. The test estimates the mean of the within-pair differences and evaluates the null hypothesis that the population mean difference equals zero. A two-tailed significance level of .05 was applied. The analysis reports the mean difference, standard deviation of differences, standard error, 95% confidence interval, t statistic, degrees of freedom, and p-value.

The paired test controls mechanically for stable differences among the six selected vehicles because each vehicle contributes observations to both periods. It does not control for time-varying factors such as fuel prices, route, traffic, load, maintenance, or driver behavior. In addition, chronological pairing can align observation order but cannot make different calendar periods equivalent. Consequently, a statistically significant result is interpreted as evidence of a period-and-method difference in the observed data, not as proof that RFID alone caused the change.

3.6 Analytical Boundaries

Two analytical boundaries were specified before interpretation. First, the analytical file did not contain synchronized price-per-liter and liters measures for every retained monthly pair, so the study could not decompose IDR/km into price variance and quantity or efficiency variance. Second, chronological pairing is a comparability device, not a control for time effects. The paired-samples t-test is therefore used to test the observed mean difference, while the direction of pair changes is reported as a descriptive consistency check. Neither result is treated as proof of an RFID-only effect.

4. Results and Discussions

4.1 Sample and Data Construction

Application of the sampling criteria retained six Toyota Innova vehicles with complete Pertamax, cost, and distance records in both periods. Each vehicle contributed 14 ordered pairs, resulting in 84 matched observations. The use of the same vehicle type reduces heterogeneity related to basic vehicle design and engine category, although age, maintenance condition, route, load, and driver assignment may still vary.

The calculated difference for each pair was voucher minus RFID. Most observations produced positive differences, indicating a lower ratio in the RFID period, but the magnitude varied across vehicles and months. As a simple direction-of-change check, 78 of 84 pairs (92.9%) showed a positive voucher-minus-RFID difference, while 6 pairs (7.1%) showed a negative difference. This consistency strengthens the descriptive interpretation, but it is not an independent robustness test and cannot remove period confounding. The variability is reflected in the standard deviation of the paired differences and supports reporting both the average difference and its confidence interval rather than relying only on the two period means.

4.2 Descriptive Statistics

Table 4. Descriptive statistics for fuel cost per kilometer

Method	N	Minimum	Maximum	Mean	SD
Voucher	84	IDR 797	IDR 3,485	IDR 2,379.60	581.895
RFID	84	IDR 439	IDR 2,447	IDR 1,330.18	349.557

From Table 4, the mean recorded fuel cost is lower in the RFID period than in the voucher period, and the RFID observations also show less dispersion. The table is descriptive: it identifies the direction and spread of the observed period difference, whereas the statistical evidence on whether the paired mean difference is distinguishable from zero is reported in Table 5.

The voucher observations have a mean fuel cost of IDR 2,379.60/km, with values ranging from IDR 797/km to IDR 3,485/km. The RFID observations have a mean of IDR 1,330.18/km, with values ranging from IDR 439/km to IDR 2,447/km. The unadjusted difference between the two means is IDR 1,049.42/km. Expressed relative to the voucher mean, the RFID mean is approximately 44.1% lower.

Dispersion is also lower in the RFID period: the standard deviation declines from 581.895 to 349.557. This pattern suggests that recorded cost ratios were not only lower on average but also less dispersed across the retained observations. Descriptive statistics alone cannot establish whether the mean difference exceeds sampling variation, so the paired differences were subjected to normality and t testing.

4.3 Normality and Paired-Samples Test

Table 5. Normality diagnostic and paired-samples t-test

Diagnostic	Result	Interpretation
Kolmogorov–Smirnov test of paired differences	Statistic = .079; N = 84; p = .200	Normality was not rejected at α = .05
Mean paired difference (Voucher − RFID)	IDR 1,049.417/km	Voucher-period cost was higher on average
SD and SE of paired differences	SD = 738.822; SE = 80.612	Differences varied across pairs
95% confidence interval	IDR 889.082 to IDR 1,209.751	The interval is entirely above zero
Paired-samples t-test	$t(83) = 13.018$; $p < .001$	H_1 supported; the mean difference is significant

As shown in Table 5, the paired differences satisfy the stated normality diagnostic (Kolmogorov–Smirnov p = .200) and the paired-samples t-test reports a positive voucher-minus-RFID mean difference of IDR 1,049.417/km ($t(83) = 13.018$, $p < .001$). Thus, the observed RFID-period cost ratio is significantly lower within the matched data, while the before–after design still prevents this difference from being interpreted as an RFID-only causal effect. The Kolmogorov–Smirnov test produced a statistic of .079 and a significance value of .200. Because the p-value exceeds .05, the normality assumption for the paired differences was considered acceptable. The paired-samples t-test was therefore used as specified in the methodology.

The estimated mean difference is IDR 1,049.417/km, calculated as voucher minus RFID. Its standard deviation is 738.822 and its standard error is 80.612. The 95% confidence interval extends from IDR 889.082/km to IDR 1,209.751/km. Because the entire interval is positive, the observed average voucher cost is consistently above the RFID cost within the uncertainty represented by the sample.

The test statistic is 13.018 with 83 degrees of freedom and a two-tailed p-value below .001. The null hypothesis of no mean difference is rejected, and the non-directional H1 is supported for the observed periods and sample. The retained data therefore provide strong statistical evidence that fuel cost per kilometer differs between the voucher and RFID periods for the sampled vehicles; the evidence remains a comparison of periods and methods rather than a causal estimate of RFID's independent effect.

4.4 Interpretation of the Fuel-Cost Difference

The principal finding is a large and statistically precise decline in the recorded cost ratio after RFID adoption. The result is consistent with the management-accounting expectation that a more integrated transaction system can improve identification, documentation, and monitoring. Under RFID, a unique vehicle identity is captured electronically and transactions can be reported with fewer manual steps. These features can reduce administrative ambiguity and make nonconforming transactions easier to prevent or detect when the system is configured and used consistently (Hao et al., 2026; Raza, 2022; Unhelkar et al., 2022).

The finding also aligns with prior RFID studies. Reviews identify traceability, real-time identification, and information visibility as recurring mechanisms through which RFID can support operational decision-making (Chanchaichujit et al., 2020; Raza, 2022). Empirical work also shows that RFID-generated transactional data can be integrated with analytics tools and that RFID utilization can strengthen transparency and agility when it is embedded in the relevant processes (Hao et al., 2026; Kholod et al., 2024). The current study extends this evidence by examining an accounting outcome (rupiah per kilometer) rather than only system performance or identification accuracy.

The reduction should nevertheless be interpreted carefully. The two methods occur in different time periods, so method and period are not separable in the research design. Fuel prices may differ between the periods. Vehicle maintenance, tires, engine condition, traffic, route length, passenger or cargo load, driving behavior, and trip purpose may also change. The paired design improves vehicle comparability, but it cannot remove these time-varying influences. The defensible conclusion is therefore that the RFID period is associated with lower recorded fuel cost per kilometer in this sample, not that RFID independently caused the entire 44.1% reduction. The thesis-based comparison is therefore useful as an internal evaluation benchmark, but it should be read as an association estimate for this unit and sample.

This distinction is important because digital control systems often work through multiple channels. RFID may discourage unauthorized transactions, reduce entry error, improve product compliance, or enable managers to respond more quickly to unusual patterns. At the same time, a company may introduce RFID together with other policies, vehicle replacements, maintenance actions, or operating changes. A future variance decomposition would be needed to quantify how much of the difference relates to price, physical consumption, and control improvements.

4.5 Management-Accounting Implications

For PTBA Tarahan Port Unit, the evidence supports continued evaluation of RFID as part of the fuel-control system. The company can use IDR/km dashboards by vehicle, month, driver assignment, and route category to identify deviations from expected patterns. Because the RFID data are electronically linked to vehicle identity, the system may provide a stronger basis for exception reporting than a voucher archive alone. Research on management-accounting analytics similarly underscores the value of linking transaction-level information to comparable performance measures (([Appelbaum, Kogan, Vasarhelyi, & Yan, 2017b)]; [Rikhardsson & Yigitbasioglu, 2018]). The recommendation is practical rather than a claim of guaranteed savings: dashboards should flag outliers for review and be reconciled against supporting logs, prices, and odometer records.

The mean difference of approximately IDR 1,049/km is operationally meaningful, but management should avoid treating a single average as a universal saving rate. Control practice should combine the cost ratio with liters per kilometer, fuel price per liter, distance, trip purpose, vehicle downtime, and maintenance history. This would allow managers to distinguish a favorable price effect from reduced physical consumption or improved transaction control.

The study also illustrates the role of digital accounting in operational decisions. A technology investment becomes managerially useful when its transaction data are translated into understandable cost measures. RFID provides identification and recording infrastructure; management accounting converts that infrastructure into performance indicators, variance analysis, and corrective action. Recent Goodwood evidence similarly indicates that the effectiveness of digital accounting tools, rather than adoption alone, is central to improved information quality and organizational performance (Astuti et al., 2026; Putri et al., 2025).

4.6 Research Implications
Academically, the study adds a company-level before–after comparison to the literature on digital cost control. It demonstrates a practical way to use internal records when the outcome of interest must be standardized for different activity levels. The matched design is more informative than comparing unadjusted total expenditure, because it recognizes that vehicle distance is a necessary denominator.

The study also highlights a methodological caution. Before–after significance does not equal causal attribution. Future studies should collect transaction-level prices and liters, construct matched calendar periods, and use quasi-experimental methods where a comparable non-RFID group is available. Such designs would allow researchers to estimate whether the observed difference remains after controlling for common price and operational shocks.

5. Conclusions
5.1 Conclusion
Using 84 matched monthly observations from six Toyota Innova business-operational vehicles, this study finds a statistically significant difference in fuel cost per kilometer between the voucher and RFID periods at PT Bukit Asam Tbk Tarahan Port Unit. Mean cost declines from IDR 2,379.60/km under the voucher method to IDR 1,330.18/km under RFID. The paired mean difference is IDR 1,049.417/km, with $t(83) = 13.018$, $p < .001$, and a 95% confidence interval from IDR 889.082/km to IDR 1,209.751/km. The result supports the non-directional research hypothesis and indicates that the RFID period is associated with a lower recorded fuel-cost ratio. It is consistent with the view that integrated vehicle identification and transaction recording can strengthen cost-control information. It does not establish that RFID alone caused the difference because the two methods were observed in different periods and several operational factors were not controlled. The managerial contribution is therefore an auditable before–after benchmark for digital transaction visibility and exception-based fuel-cost monitoring, not a guaranteed savings rate.

5.2 Research limitations
The study has five main limitations. First, it compares different time periods and therefore cannot separate the method change from fuel-price and macro-operational changes. Second, the analysis does not control for vehicle age and condition, maintenance, route, traffic, load, driver behavior, or trip purpose. Third, synchronized liters and price-per-liter measures were unavailable for every retained pair, so the observed IDR/km difference cannot be decomposed into price and quantity or

physical-efficiency variance. Fourth, the sample is limited to six Toyota Innova vehicles at one operational unit, reducing external generalizability. Fifth, the study relies on secondary company records and does not independently observe refueling practices or verify every transaction against external documents.

5.3 Suggestions and directions for future research

Future research should separate fuel-price variance from quantity or efficiency variance by retaining liters, price per liter, and distance for every transaction. Studies should also add vehicle age, maintenance status, engine capacity, route, load, driver, and traffic indicators. Where possible, researchers can compare RFID and non-RFID vehicles over the same calendar period using difference-in-differences, matched controls, or another quasi-experimental design. Extending the analysis to other PTBA units or comparable companies would show whether the observed pattern is specific to the Tarahan operating environment or appears across different operational settings. A preregistered data dictionary and a common observation window would also improve reproducibility because the definition of a pair, fuel product, and distance denominator would be fixed before the statistical test is run.

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Author Contributions

DA contributed to conceptualization, methodology, investigation, data collection, formal analysis, and writing original draft preparation. AAR contributed to supervision, validation, methodology guidance, writing review and editing, and final manuscript preparation. DZ and SD contributed to data curation, literature review, analysis support, and manuscript review.

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