



Privacy by Design Business Intelligence for MSME Performance Management

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Article Info

Article history:

Received 22 August 2026

Received in revised form

September 2026

Accepted 26 September 2026

Keywords:

Business Intelligence

MSMEs

Privacy-By-Design

Data Warehouse

Kpi Dashboard

JEL Classification:

M15; M21; L26; O33; D83

Abstract

Micro, small, and medium enterprises increasingly generate sales, inventory, promotion, project, invoice, and payment data, yet these records often remain fragmented and underused for managerial decisions. This study develops a low-cost, privacy-oriented business intelligence design for Indonesian enterprises by combining a dimensional data warehouse, a scheduled data integration pipeline, a standardized performance-indicator dictionary, and role-based dashboards. The research applies a design science approach and reports the problem-diagnosis and artifact-design stages. A preliminary needs assessment involving ten enterprises in Solo Raya found that 70 percent still relied on manual records or basic spreadsheets, 80 percent had no performance dashboard, 60 percent lacked clear access restrictions, and 50 percent experienced delays in recognizing restocking, promotion, receivable, or project-status signals. These findings were translated into two analytical domains covering product-based and service-based enterprises. The resulting design integrates revenue, margin, inventory, lead conversion, project completion, receivables, repeat orders, and customer-service indicators while embedding data minimization, pseudonymization, role-based access, audit trails, retention rules, and backup controls. The study concludes that business intelligence for resource-constrained enterprises should be treated as an integrated management and governance capability rather than merely a visualization tool. Field implementation and before-and-after performance testing are recommended as the next research stage.

Introduction

Micro, small, and medium enterprises (MSMEs) are central to Indonesia's economic structure. Government information reports more than 64 million MSME units, a contribution of approximately 60 percent to national gross domestic product, and absorption of almost 97 percent of the workforce (Coordinating Ministry for Economic Affairs of the Republic of Indonesia, 2025). This economic importance makes managerial information quality a practical development issue. An enterprise that cannot quickly identify sales trends, margin erosion,

excess inventory, stock-outs, overdue invoices, or delayed projects may lose working capital and market opportunities even when demand remains available.

The growing use of digital channels expands both the quantity and variety of business records. Statistics Indonesia (2025) describes electronic commerce activities as businesses receiving orders or selling goods and services through the internet (Jusuf & Sarwono, 2025; Indiani et al., 2025; Zulvia & Fitri, 2026). Therefore, data-driven management is relevant not only to retailers and culinary enterprises but also to online resellers, creative businesses, website developers, training providers, and other service-oriented MSMEs. Their operational records may include leads, service packages, quotations, invoices, project milestones, revisions, payments, customer feedback, and service renewals. These records have economic value only when they are integrated into consistent indicators and interpreted within a managerial process (Prova, 2026; Shihab, 2025; Haningsih et al., 2026).

Recent research shows that digital transformation is not simply the adoption of individual applications. It involves organizational changes in strategy, processes, capabilities, and performance management (Kraus et al., 2022; Plekhanov et al., 2023). For MSMEs, transformation is shaped by limited resources, managerial knowledge, digital skills, and organizational readiness (Malodia et al., 2023; Clemente-Almendros et al., 2024; Sagala & Öri, 2024). Evidence also indicates that digitalization can improve firm performance when enterprises possess suitable orientation and competencies (Kallmuenzer et al., 2025). Consequently, an appropriate MSME solution must reduce technical complexity, preserve managerial usefulness, and avoid creating new administrative burdens.

Business intelligence offers a structured approach for converting operational records into decision-ready information (Chadni, 2025; Wahid & Rahmatullah, 2026; Sudipa et al., 2025). Its value for smaller enterprises lies in data integration, consistent measurement, and visualization of key conditions that require action (Champa & Segall, 2026; Rahman et al., 2025; Qisthani et al., 2026). Ragazou et al. (2023) emphasize the role of business intelligence in decision quality and competitive advantage among small and medium enterprises. However, a dashboard alone does not guarantee reliable decisions. If transaction files contain duplicates, product names are inconsistent, definitions of margin differ, or project statuses are updated irregularly, the dashboard merely presents inconsistent data more attractively. Recent performance-management research therefore supports flexible and data-driven measurement systems that connect technology with managerial adaptation (Cosa & Torelli, 2024).

Data governance and privacy must also be designed from the beginning (Martínez, 2025; Semantha et al., 2023). Data governance defines ownership, quality responsibilities, controls, and strategic actions that make data dependable (Zhang et al., 2022). Privacy-by-design extends this logic by requiring data minimization, purpose limitation, controlled access, traceability, and protection throughout the system life cycle (von Grafenstein et al., 2022; Del-Real et al., 2024). These requirements are especially relevant in Indonesia after the enactment of Law Number 27 of 2022 on Personal Data Protection. MSMEs may store customer names, telephone numbers, addresses, invoice records, and service histories, but managerial dashboards rarely need to expose these identities. A responsible design should therefore separate identity data from analytical data and display only information necessary for a user's role (Çetin et al., 2023; Alotaibi et al., 2023; Quince & Nikolic, 2026).

The proposal underlying this article identified a practical gap among prospective MSME partners in Solo Raya. A preliminary observation of ten businesses indicated extensive dependence on manual records or basic spreadsheets, limited use of standardized indicators, weak access restrictions, and delayed recognition of operational signals. The present study

translates those preliminary needs into an integrated artifact design. The research questions are: (1) what decision and data-management gaps appear in the preliminary MSME assessment; (2) what low-cost business intelligence architecture can address those gaps while embedding privacy controls; and (3) what performance-indicator structure can support both product-based and service-based enterprises? The contribution is a management-oriented design that combines data integration, performance measurement, and privacy governance in one replicable framework.

Method

This study employed a Design Science Research (DSR) approach because its primary objective was to identify practical data-management problems among micro, small, and medium enterprises (MSMEs) and translate these problems into a privacy-oriented business intelligence (BI) artifact. Design Science Research provides a systematic framework encompassing problem identification, definition of solution objectives, artifact design and development, demonstration, evaluation, and communication (Peppers et al., 2007). In accordance with this framework, the present study focused specifically on the problem-diagnosis and artifact-design stages. Therefore, the study did not evaluate post-implementation business performance; field deployment and comparative performance evaluation were reserved for subsequent research.

Preliminary Needs Assessment

The problem-diagnosis stage was conducted through a preliminary needs assessment involving ten MSMEs or prospective partner enterprises in Solo Raya. The enterprises represented both product-oriented and service-oriented business activities, including culinary and retail businesses, fashion or craft enterprises, online shops or resellers, digital services, and creative or mentoring services. Participants were selected purposively because the study required enterprises that routinely generated operational data but had not necessarily implemented an integrated analytical or BI system. To protect organizational confidentiality, the identities of participating enterprises were anonymized.

The preliminary assessment examined four operational and managerial conditions: (1) dependence on manual records or basic spreadsheets, (2) absence of a standardized key performance indicator (KPI) dashboard, (3) absence of clearly defined data-access restrictions, and (4) delays in identifying operational or financial signals. These indicators were selected because they directly represented the principal data-integration, performance-monitoring, and privacy problems identified during the preliminary observation. The assessment results were summarized descriptively using frequencies and percentages based on the ten participating enterprises. Accordingly, each enterprise represented 10% of the preliminary sample. The findings were subsequently used to identify the dominant decision-making gaps and determine the functional requirements of the proposed BI architecture.

In addition to the descriptive assessment, typical operational data sources and business processes were mapped to determine how data were generated, stored, processed, and potentially transformed into managerial information. The mapping differentiated between product-oriented enterprises, which commonly generate sales, inventory, product, supplier, channel, restocking, and promotional data, and service-oriented enterprises, which generate leads, service-package, project, milestone, invoice, payment, revision, and customer-feedback data.

Artifact Requirement Development

The artifact requirements were derived directly from the problems identified during the preliminary needs assessment. Each diagnosed problem was mapped to a corresponding design requirement. Fragmented records were addressed through scheduled data extraction, transformation, and loading procedures; inconsistent performance measures were addressed through standardized data and KPI dictionaries; delayed managerial signals were addressed through role-based dashboards and exception indicators; and privacy and governance risks were addressed through data minimization, pseudonymization, role-based access control, audit trails, retention rules, consent considerations, and backup mechanisms.

This problem-to-design mapping was used to ensure traceability between the empirical needs identified during the diagnostic stage and the architectural components presented in the resulting BI design. The artifact was consequently structured to accommodate two analytical domains—product-based and service-based MSMEs—while maintaining a common managerial framework for revenue, margin, cash collection, customer activity, and operational timeliness.

Business Intelligence Architecture and Data Model

The proposed BI artifact was designed as a **five-layer architecture** comprising: (1) operational data sources, (2) a scheduled data-processing pipeline, (3) a dimensional data warehouse, (4) a KPI dictionary and semantic layer, and (5) role-based dashboards. Privacy and data-governance controls were incorporated across all layers rather than treated as separate post-development mechanisms.

A dimensional modeling approach was adopted to organize operational data into facts and descriptive dimensions. For product-oriented enterprises, the proposed sales fact contained quantity, net revenue, direct cost, discounts, and gross margin, linked to dimensions such as time, product, sales channel, and promotion. The inventory fact incorporated opening stock, stock receipts, stock issues, closing stock, stock-out events, and replenishment lead time. For service-oriented enterprises, lead and project facts incorporated lead source, conversion status, contract value, project milestones, completion status, invoice value, payment status, revisions, and customer feedback.

Data-processing rules were specified to improve the consistency and traceability of the analytical dataset. These rules included mandatory-field validation, date and identifier standardization, duplicate detection, reference validation, anomaly flagging, and processing logs. These procedures were designed to prevent inconsistent operational records from being transferred directly into managerial dashboards.

Performance Indicator Development

Performance indicators were selected according to three criteria: managerial relevance, traceability to available operational records, and interpretability by non-technical MSME users. The indicator structure was designed to reflect the different operational characteristics of product- and service-oriented enterprises while maintaining a common performance-management logic.

Shared indicators included net revenue and gross margin. Product-oriented indicators included stock-out rate and inventory days, whereas service-oriented indicators included lead conversion, on-time project completion, overdue receivables, and repeat-order rate. Inventory- and forecasting-related indicators were informed by previous studies concerning forecasting accuracy, inventory optimization, safety stock, and demand management (Koutsandreas et al.,

2022; Makridakis et al., 2022; Seyedan et al., 2023; Demiray Kırmızı et al., 2024). The formulas, units, managerial purposes, required source fields, and intended dashboard users were documented as part of the KPI dictionary.

Privacy-by-Design and Data-Governance Requirements

Privacy controls were incorporated into the artifact from the design stage. The proposed controls included data minimization, pseudonymization, role-based access, audit trails, retention rules, and backup and recovery procedures. Data minimization restricted analytical processing to information required for defined operational or KPI purposes, while pseudonymization separated direct customer identities from analytical records. Role-based access was designed to differentiate the information available to owners, operational staff, and mentors or researchers. Audit mechanisms were specified to record data-processing activities, changes, exports, errors, and user access.

These mechanisms were integrated into the BI architecture to ensure that managerial information could be generated without unnecessarily exposing identifiable customer or business information.

Design Evaluation and Traceability

At the current research stage, evaluation focused on the internal consistency, completeness, and traceability of the proposed artifact rather than on post-implementation performance effects. A traceability matrix was used to connect each identified business problem and managerial question with its corresponding source data, transformation rule, KPI formula, dashboard component, and authorized user role. This procedure was intended to verify that every major architectural and dashboard component could be traced back to an identified MSME requirement.

Synthetic and anonymized scenarios were specified for subsequent demonstration and technical validation so that confidential partner records and administrative credentials would not be required during initial testing. Future implementation will evaluate formula accuracy, dashboard usability, data-error reduction, decision timeliness, inventory outcomes, project delays, and receivable collection using field-based before-and-after assessment.

Result and Discussion

Preliminary MSME Needs

The preliminary assessment confirms that the core problem is not the total absence of digital records but the absence of an integrated decision-making process. Seventy percent of the businesses still depended mainly on manual records or basic spreadsheets, indicating that operational data were available but remained fragmented across separate files and recording practices. Eighty percent did not have a dashboard containing consistently defined performance indicators, suggesting that most enterprises lacked a standardized mechanism for translating operational records into comparable and actionable managerial information. Sixty percent had no clear restriction describing who could access operational or customer data, revealing a governance gap that could increase the risk of unnecessary data exposure and inconsistent access practices. Meanwhile, half of the businesses reported delays in recognizing signals such as restocking needs, promotion effectiveness, outstanding invoices, or project progress. This indicates that existing records were not yet being processed in a sufficiently timely and structured manner to support routine managerial decisions. Taken together, these findings show that the main challenge lies in integrating data, standardizing performance measures, controlling access, and improving the timeliness of business information rather than merely

increasing the use of digital tools. Accordingly, the identified gaps directly informed the design requirements for scheduled data integration, standardized KPI definitions, role-based dashboards, and privacy-oriented access controls. Figure 1 and Table 1 summarize these findings.

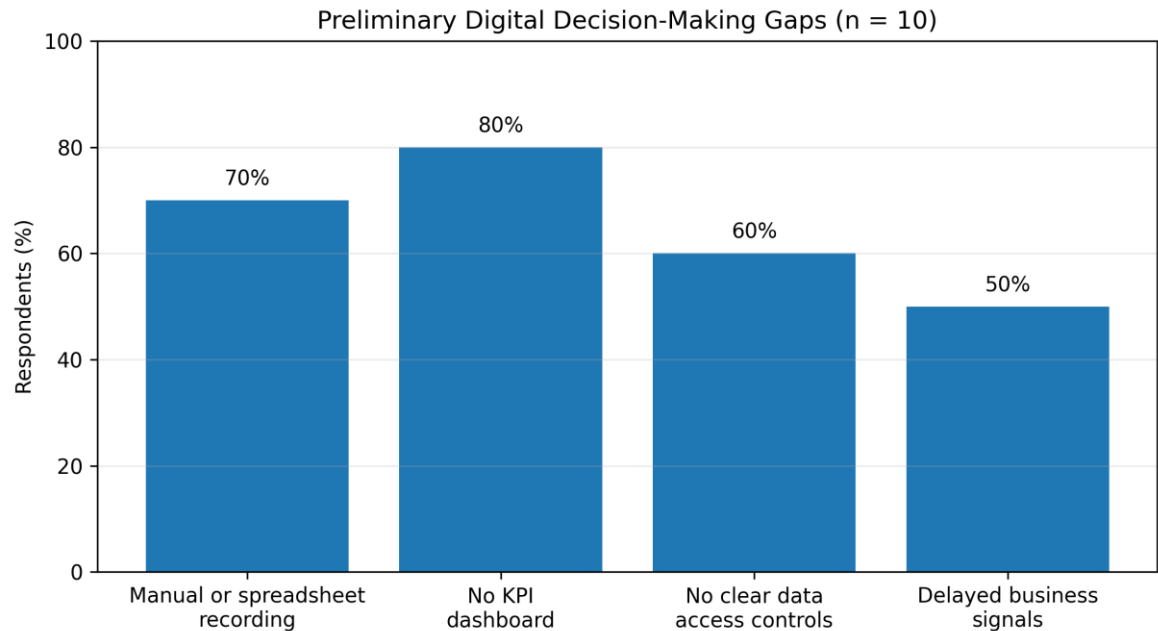


Figure 1. Preliminary MSME decision-making gaps

Table 1. Preliminary needs and design implications

Observed condition	Share	Design implication
Manual records or basic spreadsheets	70%	Scheduled imports, standardized identifiers, and data-quality checks
No standardized KPI dashboard	80%	KPI dictionary, formulas, units, thresholds, and role-based visual summaries
No clear access restrictions	60%	Role-based access, pseudonymized analytical keys, and audit logs
Delayed business signals	50%	Exception indicators for stock, promotions, invoices, and project milestones

Source: Authors’ preliminary observation, 2025.

The high proportion without dashboards indicates a performance-measurement gap, but the solution should not begin with visualization. It should begin with metric definitions and source-data discipline. This finding is consistent with the broader literature stating that successful digital transformation requires alignment among technology, organizational capabilities, strategy, and performance outcomes rather than isolated application adoption (Kraus et al., 2022; Sagala & Öri, 2024; Kallmuenzer et al., 2025). For MSMEs, a concise indicator dictionary can function as a managerial contract: each user understands what an indicator means, where it comes from, how frequently it is updated, and what action should follow.

Integrated Architecture

The resulting architecture consists of five connected layers. The first layer contains operational sources such as spreadsheets, comma-separated files, forms, and exports from point-of-sale or project applications. The second layer is a scheduled data pipeline that validates mandatory fields, standardizes dates and identifiers, removes duplicates, and records errors. The third layer is a dimensional data warehouse that separates transactional facts from descriptive dimensions. The fourth layer is a semantic layer containing the performance-indicator dictionary, formulas, units, thresholds, refresh frequency, and interpretation. The fifth layer presents role-based dashboards for owners, operational staff, and mentors or researchers. Privacy and governance controls apply across all layers, as shown in Figure 2.

Proposed Privacy-by-Design Business Intelligence Architecture

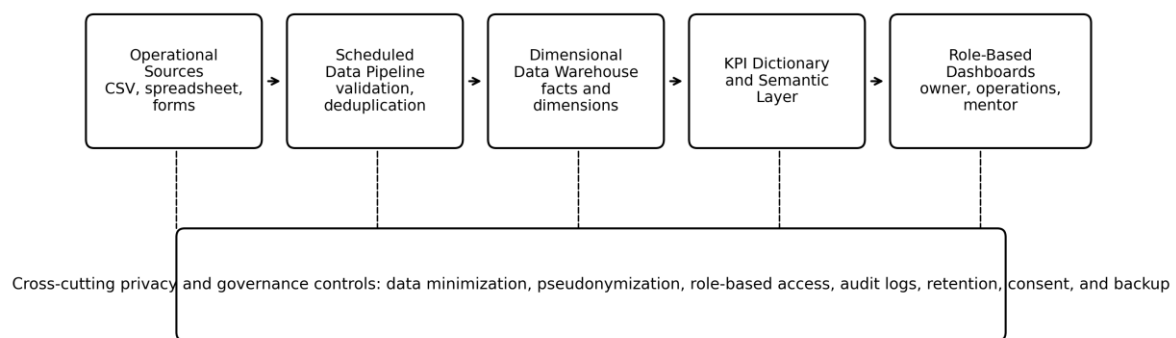


Figure 2. Privacy-by-design business intelligence architecture

The architecture is intentionally modular and low-cost. A small enterprise can begin with spreadsheet exports and a limited set of monthly indicators, then increase refresh frequency and data-source integration as its capabilities grow. This staged approach is important because resource constraints and heterogeneity strongly affect digital transformation among MSMEs (Clemente-Almendros et al., 2024; Malodia et al., 2023). The design therefore avoids requiring advanced automation at the first stage. Scheduled loading can initially run daily or weekly, while a simple error report enables the business owner to correct missing product codes, inconsistent service categories, or duplicated invoices.

Core Performance-Indicator Dictionary

The proposed indicator set distinguishes product and service economics while preserving a shared managerial structure. Both domains require revenue, margin, cash collection, customer activity, and operational timeliness. Product-based enterprises additionally need stock availability, inventory days, and replenishment indicators. Service enterprises need lead conversion, project completion, overdue receivables, revision intensity, and repeat orders. Table 2 presents the recommended core indicators. This design supports the argument that digital performance measurement should be flexible enough to reflect different business

models while maintaining comparable managerial logic (Cosa & Torelli, 2024; Costa Melo et al., 2023).

Table 2. Core performance indicators for product and service MSMEs

Domain	Indicator and calculation	Primary managerial use
Shared	Net revenue = gross sales less discounts and returns	Monitor market activity and income trend
Shared	Gross margin (%) = $(\text{revenue} - \text{direct cost}) / \text{revenue} \times 100$	Assess pricing, cost control, and profitability
Product	Stock-out rate = $\text{stock-out events} / \text{total item-days} \times 100$	Identify lost-sales and service-level risk
Product	Inventory days = $\text{average inventory} / \text{cost of sales} \times \text{period days}$	Control working capital and slow-moving stock
Service	Lead conversion (%) = $\text{won leads} / \text{qualified leads} \times 100$	Evaluate marketing and sales effectiveness
Service	On-time completion (%) = $\text{on-time completed projects} / \text{completed projects} \times 100$	Assess delivery reliability and capacity
Service	Overdue receivables (%) = $\text{overdue invoice value} / \text{outstanding invoice value} \times 100$	Identify liquidity and collection risk
Service	Repeat-order rate (%) = $\text{returning clients} / \text{active clients} \times 100$	Monitor relationship continuity and service value

Source: Authors' design based on the research proposal and reviewed literature.

For product-oriented enterprises, gross margin is more informative than revenue alone because increased sales can coincide with declining profitability. Stock-out rate and inventory days connect service availability with working-capital use. Recent inventory studies show that demand variation, safety-stock policy, and forecasting quality materially influence inventory cost and service levels (Seyedan et al., 2023; Demiray Kırmızı et al., 2024). When forecasting is added, mean absolute percentage error or symmetric mean absolute percentage error may be displayed as supporting indicators, but they should be interpreted carefully because no single accuracy measure is universally suitable (Koutsandreas et al., 2022). The M5 competition likewise demonstrates the managerial value of systematic retail forecasting while highlighting the importance of method selection and evaluation (Makridakis et al., 2022).

For service-oriented enterprises, a pipeline from lead to paid invoice is the analytical equivalent of a product flow. Lead conversion indicates marketing effectiveness, on-time completion reflects delivery reliability, overdue receivables show liquidity risk, and repeat-order rate provides a simple indicator of relationship continuity. These indicators enable owners to distinguish a demand problem from a delivery or collection problem. A business may generate many leads but convert few of them, complete many projects but collect slowly, or grow revenue while revisions and delays reduce effective margin. Integrating these indicators

supports better resource allocation and reinforces the role of data-driven capabilities in MSME competitiveness (Ragazou et al., 2023).

Privacy and Data-Governance Controls

Privacy-by-design changes the architecture from a reporting tool into a governed management capability. Table 3 specifies the principal controls. Data minimization limits collection to fields required for a defined indicator or operational purpose. Pseudonymization replaces direct customer identities with analytical keys. Role-based access separates owner, operational, and mentor views. Audit logs record access and processing events, while retention rules prevent indefinite storage of detailed records. These controls reflect recent privacy-by-design research emphasizing proactive, life-cycle protection rather than corrective measures after deployment (von Grafenstein et al., 2022; Del-Real et al., 2024). They also support compliance with Indonesia's personal-data protection framework.

Table 3. Privacy-by-design controls and operational purposes

Control	Implementation	Managerial and compliance purpose
Data minimization	Collect only fields required for defined operational and KPI purposes	Reduce exposure, cost, and unnecessary processing
Pseudonymization	Replace customer or client identities with analytical keys	Enable analysis without routinely exposing direct identities
Role-based access	Separate owner, operations, and mentor or researcher permissions	Apply least-privilege access to dashboards and detailed data
Audit trail	Record data loads, errors, changes, exports, and access events	Support accountability and traceability
Retention rules	Archive or delete detailed records according to defined periods	Prevent indefinite storage and reduce data risk
Backup and recovery	Maintain scheduled encrypted backups and documented restoration tests	Protect operational continuity and data availability

Source: Authors' design.

Managerial Implications and Limitations

The design has three managerial implications. First, it treats data quality as an economic issue because inaccurate products, invoices, or project statuses can lead to poor purchasing, pricing, staffing, and collection decisions. Second, it treats the indicator dictionary as a governance mechanism, reducing disagreement over formulas and enabling traceability from a dashboard number to its source. This is consistent with the strategic view of data governance developed by Zhang et al. (2022). Third, it allows gradual digitalization: enterprises can begin with a small, understandable indicator set and expand only when data discipline and managerial use have matured.

The study is limited by its preliminary sample and design-stage evaluation. The percentages describe the ten observed businesses and should not be generalized to all Indonesian MSMEs.

The architecture has not yet been evaluated through longitudinal before-and-after indicators, user-adoption metrics, or cost-benefit analysis. The next stage should implement the artifact with synthetic or anonymized records, verify formula accuracy and traceability, test dashboard readability with participating enterprises, and compare decision timeliness, data-error rates, inventory outcomes, project delays, and receivable collection before and after use. These steps are necessary to convert a plausible design into validated evidence of business value.

Conclusion

The study identifies an integrated management problem among the preliminary MSME participants: operational records exist, but they are fragmented, inconsistently defined, weakly governed, and slow to generate actionable signals. The proposed privacy-by-design business intelligence architecture responds through scheduled data integration, a dimensional data warehouse, a standardized indicator dictionary, and role-based dashboards for product and service enterprises. Its central contribution is the integration of performance management and data governance, ensuring that revenue, margin, inventory, lead, project, invoice, and customer indicators remain traceable and proportionate to user needs. MSMEs should begin with a limited set of high-value indicators and expand the system gradually as data discipline improves. Future research should deploy the artifact with anonymized partner data, conduct usability and formula-validation tests, measure before-and-after managerial outcomes, and evaluate whether improved information timeliness produces measurable gains in working capital, service reliability, collections, and business performance.

Acknowledgment

The authors thank Universitas Muhammadiyah Surakarta and the prospective MSME partners in Solo Raya for institutional and preliminary needs-assessment support. This manuscript was developed from the competitive research proposal entitled “Ethically-Aligned Business Intelligence for MSMEs: A Privacy-by-Design Data Warehouse, Scheduled ETL, and KPI Dashboards.”

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