A LOW-COST WEB-BASED ADMINISTRATION SYSTEM FOR SOLAR-INTEGRATED PALM SUGAR PRODUCTION

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ABSTRACT
Rural palm sugar producers increasingly combine traditional processing with photovoltaic systems, but production, quality, cost, and solar-use records often remain fragmented. This study designed and field-demonstrated a low-cost web-based administration system for Kelompok Tani Talaut Jaya in North Sulawesi, Indonesia. Following design science research, the study analyzed the group's paper forms, developed a Google Sheets and Google Apps Script prototype, demonstrated the artifact across several production cycles, and revised it through field observation and informal user feedback. The group leader and several producers used the system through four functional roles: operator, quality control, leadership, and administrator. The artifact integrates five modules: raw-material receiving, daily production, output quality, production-cost calculation, and solar-energy-use logging. Functional verification covered role-based access, transaction recording, automated calculation of Harga Pokok Produksi (HPP), and monthly PDF report generation. The evaluation was descriptive; exact user numbers, transaction volumes, task-completion times, error rates, and standardized acceptance scores were not formally recorded. The verified final forms contain six, six, six, five, and six data-entry fields, respectively. Only the production-cost module retained a documented initial count of ten fields, so the study does not claim a measured reduction across all modules. The solar-energy module documents utilization conditions but does not quantify energy savings or causal production effects. The findings support feasibility in one partner setting and require multi-site validation using formal usability, accuracy, time, and metered-energy measures.
Keywords: administration system, design science, palm sugar, rural micro-enterprise, solar-energy monitoring

INTRODUCTION

Granulated palm sugar (gula semut aren) is an important product for rural producer groups in Indonesia. It is made by tapping palm sap (nira) and concentrating it through a prolonged heating process. In the partner setting, photovoltaic equipment had begun to complement conventional energy inputs, creating an opportunity to modernize production while reducing dependence on fuel-intensive processing. However, technological modernization is not limited to installing equipment. Digital-transformation research distinguishes the conversion of analogue records into digital data from the deeper integration of digital technologies into organizational routines and value-creation processes (Verhoef et al., 2021; Vial, 2019). Research on digital agriculture likewise shows that benefits depend on connectivity, user capability, governance, and alignment with local work practices, not on hardware alone (Fielke et al., 2020; Klerkx et al., 2019). This issue has broad economic relevance because micro, small, and medium enterprises account for approximately 61% of Indonesia's gross domestic product and about 97% of employment (International Monetary Fund, 2024).

Administrative practice in the partner group had not advanced at the same pace as the photovoltaic installation. Raw-material intake, daily production, and quality checks were recorded on separate paper forms, while production-cost calculations were maintained in an unstructured spreadsheet whose formulas could be overwritten. In this study, Harga Pokok Produksi (HPP) refers to total production cost, comprising raw-material, labor, and other production costs; unit cost is obtained by dividing total HPP by the quantity produced. Fragmented recording reduces traceability between inputs, outputs, quality outcomes, cost calculations, and energy-use conditions. Information-systems research emphasizes that system quality and information quality are prerequisites for reliable use and organizational benefit (DeLone & McLean, 2003), while data-governance research highlights the need to clarify decision rights, accountability, and ownership of operational data (Khatri & Brown, 2010). These concerns are particularly relevant to micro-enterprises, where accounting practices are often simple and dependent on a limited number of personnel (Rafael & Biduri, 2025).

A solar-assisted producer group therefore needs an administrative mechanism that connects production, quality, cost, and solar-use records in a form that nontechnical users can operate. Before this study, the partner group had no integrated record linking photovoltaic-use conditions with daily production activities. The distinction between administrative logging and technical energy evaluation is important. Reviews of photovoltaic monitoring systems indicate that defensible performance assessment normally requires time-stamped electrical and environmental measurements, such as generated power, irradiance, temperature, operating status, and fault information (Madeti & Singh, 2017; Rahman et al., 2018). The present artifact focuses on structured monitoring and documentation. It does not estimate energy savings, avoided fuel use, profitability effects, or the photovoltaic installation's causal contribution to output unless metered energy data and an appropriate production baseline are available.

Previous studies in the same setting examined renewable-energy-supported processing, business-model change, village-enterprise participation, and product marketing (Kumaat et al., 2023; Paendong et al., 2025a, 2025b). Other Indonesian palm-sugar initiatives have emphasized financial-report training, packaging, digital marketing, production management, and business feasibility (Cahyani et al., 2023; Ginting et al., 2025; Nurrahmawati et al., 2024; Setiyono et al., 2024; Utami et al., 2023), while equipment-oriented research has tested photovoltaic power for rural processing machinery (Asbanu et al., 2025). At a broader level, SMEs frequently face resource, skill, strategy, and implementation constraints during digitalization (Anatan & Nur, 2023; Eller et al., 2020). Evidence also suggests that digital tools create value when they are integrated with operational routines and business-model experimentation rather than adopted as isolated technologies (Bouwman et al., 2019). Cloud-based applications can lower infrastructure barriers for small firms, although adoption depends on relative advantage, compatibility, organizational readiness, security, and vendor conditions (Oliveira et al., 2014; Sultan, 2011). The unresolved gap is therefore not simply the absence of a digital form, but the absence of a low-cost, integrated, field-adjustable administrative workflow that links production, quality, HPP, and solar-use documentation in one rural producer-group setting.

The novelty of this study is a situated administrative artifact that combines five functions: raw-material receiving, daily production, output quality, HPP calculation, and solar-energy-use logging. The contribution is design-oriented rather than a technical evaluation of photovoltaic performance or a causal test of enterprise outcomes. Perceived usefulness and ease of use are treated as design rationales derived from Davis (1989), not as measured Technology Acceptance Model constructs, because no standardized acceptance instrument was administered. In design science, an artifact's contribution must be positioned in relation to both the practical problem and the existing knowledge base (Gregor & Hevner, 2013), and its evaluation strategy should match its maturity and intended claims (Venable et al., 2016). Accordingly, this study aims to design and implement a low-cost web-based system that integrates palm-sugar production administration with simple solar-energy-use monitoring and to document its initial field demonstration, including functional operation, field-driven simplification, implementation constraints, and requirements for more rigorous evaluation.

METHOD

The study employed design science research to create and demonstrate an information-system artifact addressing an identified administrative problem in the partner group (Hevner et al., 2004). The procedure was mapped to the stages proposed by Peffers et al. (2007): problem identification through review of existing records; definition of solution objectives and functional requirements; artifact design and construction; field demonstration; and descriptive evaluation followed by revision. This sequence also reflects the design-science principle that an artifact should be developed in relation to both its application environment and its knowledge contribution (Gregor & Hevner, 2013). The artifact was adjusted during field interaction, but the study does not claim a full action design research protocol because formal cycles of intervention, reflection, and learning were not systematically documented as required by Sein et al. (2011). Figure 1 summarizes the operational research sequence. The study did not employ an experimental or controlled before-and-after design, and the evidence should therefore be interpreted as an initial naturalistic demonstration rather than a comparative effectiveness test (Venable et al., 2016).

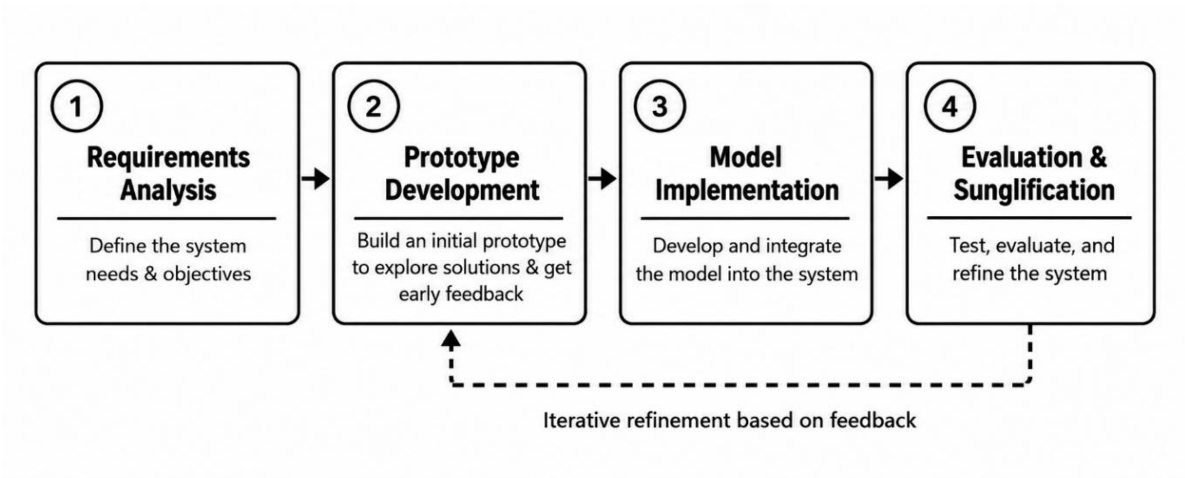

Figure 1. Research Stages (Adapted from Peffers et al., 2007)

The study was conducted with Kelompok Tani Talaut Jaya, a palm sugar producer group operating a solar-supported production process in Talaitad Utara Village, South Minahasa District, North Sulawesi. The group leader and several producers participated in requirements identification and field use. User access was organized into four functional roles—operator, quality control, leadership, and administrator—but the exact number of individual users and the number of completed production cycles were not formally logged. This reporting gap is acknowledged as a limitation rather than being replaced with an estimated value.

Figure 2. Field Data Collection with Kelompok Tani Talaut Jaya during Solar-Supported Palm Sugar Production

Requirements were derived primarily from the group's existing paper forms for raw-material receiving, daily production, output quality, and HPP calculation. Each field was reviewed to identify information that was regularly completed, omitted, misunderstood, duplicated, or already captured automatically by the login account. Field observation and informal conversations with the group leader and producers were used to refine labels, remove redundant inputs, convert selected free-text fields into controlled choices, and add a separate solar-energy-use module. This iterative adjustment is consistent with the design-science view that artifacts are shaped through interaction with their organizational context (Sein et al., 2011). Nevertheless, because the conversations were not recorded through a standardized interview guide, transcribed, or coded, the evidence is reported as practical design feedback rather than formal qualitative thematic data.

The artifact uses a three-part low-code architecture: a browser-based interface for data entry, Google Apps Script for application logic and report generation, and Google Sheets for structured data storage. Cloud-based services can be attractive to SMEs because they reduce the need for locally managed infrastructure and support flexible access, but their value depends on organizational readiness, compatibility, security, and continued service availability (Oliveira et al., 2014; Sultan, 2011). Form-level checks support basic input validation, role permissions limit access to relevant modules, and records retain the username associated with each entry. Passwords are stored as salted hashes rather than plain text; however, the study did not conduct an independent penetration test or disclose code-level security parameters. The evaluated version also lacked automated backup and recovery. Consistent with data-governance principles, continuity therefore depends on clearly assigned account ownership, decision rights, backup responsibilities, and account succession procedures (Khatri & Brown, 2010).

Data collection proceeded through four stages. First, the researchers examined existing forms and workflow problems to define the initial data structure, user roles, and functional requirements. Second, a prototype was built in Google Sheets and Google Apps Script with four core administrative modules and role-based multi-user access. Third, the prototype was demonstrated in the partner's production environment across several production cycles. Fourth, the artifact was revised in response to observed use and informal feedback: wording was simplified, redundant fields were removed or merged, selected responses were standardized, and a fifth module was added to document solar-energy use. The procedure generated field notes, retained form versions, screenshots, functional checks, and the final artifact. Exact implementation dates, transaction volume, frequency of individual use, and the number of completed report cycles were not systematically captured.

Evaluation was descriptive and functional. The researchers checked whether authorized roles could access the intended modules, whether transactions could be saved and retrieved, whether the embedded HPP formula produced the expected result from entered values, and whether monthly records could be compiled into a printable PDF report. This verification established that specified functions operated in the demonstrated setting, but it did not constitute a complete information-systems success assessment. Such an assessment would require evidence concerning system quality, information quality, use, user satisfaction, and net benefits (DeLone & McLean, 2003). Likewise, perceived usability was not measured with a standardized instrument such as the System Usability Scale (Lewis, 2018). No task-timing protocol, controlled error test, audited cost analysis, security test, or metered photovoltaic-performance evaluation was conducted. The partner group's adoption statement was treated as administrative evidence of willingness to continue use, not as an independent measure of effectiveness or sustained adoption. Organizational collaboration was documented, but formal ethics-approval and individual-consent records were unavailable in the retained study files; no personal participant data are reported.

RESULTS AND DISCUSSION

System Modules and Data-Entry Indicators

The artifact is named Sistem Administrasi Produksi Gula Semut Terintegrasi Photovoltaic (Palm Sugar Production Administration System Integrated with Photovoltaic). The dashboard shown in Figure 3 summarizes monthly production, quality, raw-material intake, cost, and recorded solar-energy-use information before users open an individual module.

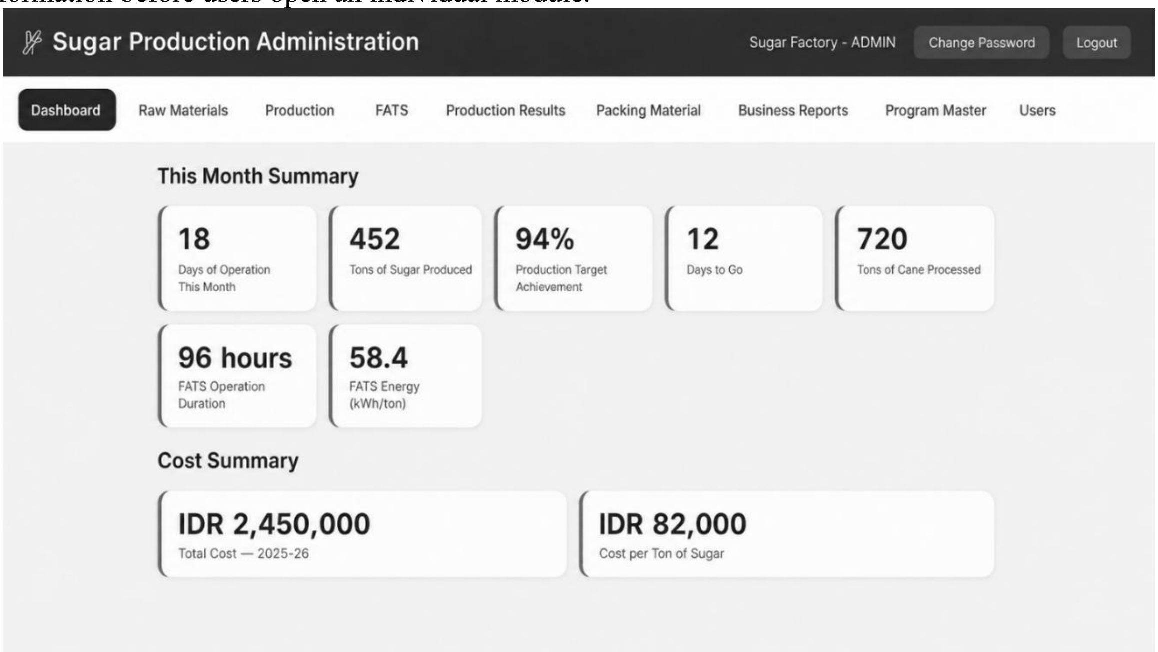

Figure 3. Dashboard View of the Palm Sugar Production Administration System

The system comprises five modules: raw-material receiving, daily production, output quality, production-cost (HPP) calculation, and solar-energy-use logging. The first four modules were derived from existing administrative forms, whereas the solar-energy module was added during field revision. Simplification involved removing duplicated identity fields, merging related inputs, shortening labels, and replacing selected free-text entries with limited-choice responses. Table 1 reports only field counts that can be verified from the retained documentation.

Table 1. Data-Entry Fields per Module After Indicator Simplification

Module	Data-Entry Fields
Raw-material receiving	6
Daily production	6
Output quality	6
Production cost (HPP)	5

The retained records support a verified reduction only for the production-cost module, from ten data-entry fields to five. Complete pre-simplification counts for the other original modules were not systematically retained, and the solar-energy module had no initial paper-form equivalent because it was added during field revision. The manuscript therefore withdraws the earlier claim that every module lost more than half of its fields. The defensible finding is that the final forms are shorter, more structured, and organized around routine entry, while the magnitude of simplification across all modules cannot be quantified from the available documentation. This cautious interpretation separates observable artifact characteristics from unmeasured claims about efficiency or usability.

The solar-energy-use module contains six fields: date, weather condition, panel-use duration, generated energy in kilowatt-hours when a meter reading is available, equipment problems, and an optional note. The module is intentionally designed for observational logging by producers rather than technical photovoltaic assessment. When kilowatt-hour data are unavailable, the record documents use conditions only. Reviews of photovoltaic monitoring show that performance and fault analysis require systematic electrical and meteorological measurements at defined intervals (Madeti & Singh, 2017; Rahman et al., 2018). Consequently, the current module cannot independently determine energy savings, avoided firewood use, cost reductions, efficiency losses, or causal effects on production output.

Cost Structure and Automated HPP Calculation

The cost module calculates Total HPP as Raw-Material Cost + Labor Cost + Other Production Costs, and Cost per Unit as Total HPP divided by the quantity produced. For illustration only, raw-material costs of IDR 1,400,000, labor costs of IDR 450,000, and other costs of IDR 150,000 yield a Total HPP of IDR 2,000,000. For 25 kilograms of output, the calculated cost is IDR 80,000 per kilogram. These figures are a test case used to explain the formula; they are not audited field results. Functional checking confirmed that the system reproduced the expected result and prevented users from directly overwriting the embedded formula, although it could not eliminate errors in the values entered by users.

Data Governance and Multi-User Access

Each account is assigned one functional role—operator, quality control, leadership, or administrator—and each record retains the username associated with data entry. Operators record production activities, quality-control personnel record output-quality results, leadership users enter cost information and review reports, and administrators manage accounts. The login page is shown in Figure 4. An administrator can deactivate an account or reset a password without deleting previous records, and a separate confirmation step is required before transactional data are cleared for a new reporting cycle. These controls support basic accountability by linking data-entry authority to defined roles, a central concern in data-governance design (Khatri & Brown, 2010). They should not, however, be interpreted as a complete information-security, privacy, audit, or disaster-recovery framework.

Figure 4. Login Page of the Palm Sugar Production Administration System

Field Implementation and Technology Readiness

The artifact was demonstrated in the partner group's operational environment across several production cycles. The available evidence confirms that users in different roles could enter raw-material, production, quality, cost, and solar-use records and that the system could compile those records into a monthly PDF report. The report contains target and actual output, quality-rejection information, raw-material receipts, HPP results, solar-energy-use entries, and a signature block for administrative approval. Exact implementation duration, number of transactions, report cycles, task-completion times, and error frequencies were not logged; therefore, the manuscript no longer characterizes use as continuous or daily in a quantitatively verified sense.

The evidence supports an initial field demonstration in the relevant operating environment: the artifact was not tested only in isolation, and the partner group accepted it for continued use. Nevertheless, the information required to distinguish adjacent Technology Readiness Levels—such as a documented verification protocol, duration and volume of use, failure records, repeatability, and independently assessed performance—was not collected. The manuscript therefore does not assign a definitive numerical TRL. Future assessment should map explicit technical and operational evidence to the criteria proposed by Mankins (1995) and distinguish artifact demonstration from validated effectiveness.

Discussion

The study's principal scholarly contribution is the design and initial field demonstration of an integrated, low-cost administrative artifact rather than a new photovoltaic technology or a controlled test of enterprise performance. Earlier work in the same setting emphasized processing technology, business-model transformation, marketing, and institutional support (Kumaat et al., 2023; Paendong et al., 2025a, 2025b), while other palm-sugar initiatives concentrated on training, packaging, financial reporting, marketing, production management, or feasibility analysis (Cahyani et al., 2023; Ginting et al., 2025; Nurrahmawati et al., 2024; Setiyono et al., 2024; Utami et al., 2023). The present artifact differs by placing production, quality, HPP, and solar-use records in one operational workflow and revising that workflow in response to observed field use. In the terminology of design science, the contribution is best understood as a contextually demonstrated instantiation with situated design lessons, not a fully generalized design theory (Gregor & Hevner, 2013).

The field-driven simplification illustrates a practical design response to limited administrative capacity, but it should not be confused with measured usability improvement. Removing duplicate identity fields, protecting formulas, and replacing selected free-text inputs with controlled choices can reduce opportunities for inconsistent entry; however, the study did not quantify task time, cognitive effort, completion rates, or user satisfaction. The dashboard and monthly report therefore represent improved information visibility and process integration at the artifact level, not proven organizational performance. This distinction is consistent with the DeLone and McLean (2003) model, which treats system quality, information quality, use, satisfaction, and net benefits as related but empirically distinct dimensions. It also aligns with SME digitalization research showing that technology adoption alone does not guarantee financial or operational gains without complementary skills, strategy, and implementation capability (Bouwman et al., 2019; Eller et al., 2020).

Transfer to another agro-processing group would require an internet-connected phone or computer, access to the Google cloud platform, locally understandable form labels, a designated account administrator, and basic competence in browser-based data entry. These requirements are consistent with research showing that digitalization in small enterprises depends on technological resources, employee capability, organizational strategy, and the fit between the technology and established routines (Eller et al., 2020; Vial, 2019). The spreadsheet and script structure can be adapted to different products, but production, quality, cost, and reporting fields must be revalidated with each group. Data ownership should be assigned to an institutionally controlled account rather than an individual account, and local procedures are needed for backup, recovery, account succession, and connectivity interruptions. Cloud adoption research similarly emphasizes relative advantage, compatibility, readiness, security, and provider dependence (Oliveira et al., 2014; Sultan, 2011).

The solar-energy module is transferable primarily as a documentation template. In rural digitalization, useful systems must remain understandable to local users while retaining enough structure to support later analysis (Fielke et al., 2020; Klerkx et al., 2019). For a stronger photovoltaic evaluation, future versions should automatically time-stamp meter readings and, where feasible, capture generated energy, power, weather or irradiance conditions, equipment status, and faults. These data should then be linked to production quantity, processing duration, fuel use, and cost records. Without that expanded measurement design, the system can establish when solar equipment was reported as used but cannot determine its technical efficiency or economic contribution.

The principal limitations are the single-group setting, absence of a formally logged implementation period and transaction volume, incomplete retention of initial field counts, reliance on observation and informal feedback, and lack of standardized usability, accuracy, timing, security, and energy-performance tests. Formal ethics and consent documentation were also unavailable in the retained study records. Accordingly, the study demonstrates that the artifact can operate in one field setting, but it does not establish how much time, error, energy, or money it saves, whether users find it easy to use, or whether the approach will scale without adaptation. Future research should use a multi-site design; retain complete baseline forms and system logs; measure task-completion time, error rates, data completeness, report accuracy, and sustained use; administer an appropriate acceptance or usability instrument (Davis, 1989; Lewis, 2018); assess system and information quality together with user satisfaction and net benefits (DeLone & McLean, 2003); test backup and security controls; and relate metered photovoltaic data to production and cost outcomes using accepted monitoring variables (Madeti & Singh, 2017; Rahman et al., 2018). A staged evaluation strategy would also allow formative findings to guide revision before broader summative testing (Venable et al., 2016).

CONCLUSION

This study designed and field-demonstrated a low-cost web-based administration system that integrates raw-material receiving, daily production, quality control, HPP calculation, and solar-energy-use logging for one rural palm sugar producer group. The artifact operated through role-based accounts, generated an automated monthly PDF report, and produced the expected HPP result in functional testing. The verified final forms contain six, six, six, five, and six fields across the five modules, but complete baseline counts were unavailable for most modules; therefore, no overall percentage reduction is claimed. The solar component provides structured utilization records rather than a quantitative measure of energy contribution or cost savings. The evidence supports feasibility and initial field use in one setting, not definitive Technology Readiness Level classification or general scalability. More rigorous multi-site evaluation is needed before conclusions can be drawn about usability gains, recording accuracy, sustained adoption, economic benefit, or photovoltaic performance.

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