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Evaluating the Impact of the Skills Training Course on the Operation and Maintenance of the Rice Processing System (RPS) on the Operational Efficiency and Asset Sustainability of Farmers' Cooperatives and Associations in Nueva Ecija, Philippines

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***Abstract*— *This study evaluated the operational, technical, and cognitive impact of a five-day Skills Training Course on the Operation and Maintenance of the Rice Processing System (RPS) administered across Nueva Ecija, Philippines. Using an evaluative mixed-methods concurrent triangulation design combined with a one-group pre-test/post-test quasi-experimental approach, the study monitored fifteen (15) purposively selected beneficiaries (12 Farmers' Cooperatives and Associations and 3 Local Government Units) spanning Level 1, 2, and 3 facilities, alongside forty (40) individual operators. Quantitative records covering one full cropping season before and after the intervention were subjected to a paired-samples t-test at a = 0.05, supplemented by qualitative focus group discussions. Empirical results for the operational cohort (n = 10) revealed a marked increase in mean Milling Recovery Rate (MRR), rising from a baseline of 58.67% to a post-training average of 64.34% (+5.67 percentage points), bringing facilities into the 63.0–65.0% designed operating range of modern multi-pass systems. Unplanned facility downtime dropped by 78.75%, from 16.00 to 3.40 hours per month, while moisture tracking accuracy improved from 62.40% to 91.80%. Individual technical knowledge assessments (n = 30 paired records) showed a statistically significant mean score expansion from 12.87 to 14.77 out of 25 items, t(29) = 3.738, p = 0.0007, with secondary analysis identifying learning variances attributable to cognitive overload in the most technically complex competency areas. Post-test scores correlated strongly with both the Milling Efficiency Index, r(8) = .742, p = .014, and the Asset Sustainability Index, r(8) = .795, p = .006. Contextual audits revealed that five (5) distributed facilities were structurally constrained from immediate operationalization due to a lack of active three-phase power grid connectivity or ongoing construction backlogs. Post-training survey metrics confirmed a distinct cultural transition away from reactive breakdown frameworks toward checklist-driven preventive maintenance routines, with the asset sustainability composite score advancing from 1.77 to 4.40 out of 5.00. The study concludes that targeted capacity building is a necessary prerequisite for sustainable postharvest mechanization, and recommends that national line agencies institutionalize mandatory operator certification and enforce stricter inter-agency utility grid coordination prior to machinery distribution.*

Keywords*— Asset sustainability, milling recovery rate, Nueva Ecija, operational efficiency, postharvest mechanization, Rice Processing System (RPS), skills training evaluation, three-phase power grid.

I. INTRODUCTION

Agricultural mechanization serves as a structural backbone for competitive postharvest management in modern agrarian economies. In the Philippines, particularly in Nueva Ecija — historically designated the "Rice Bowl of the Philippines" — postharvest grain losses remain a persistent engineering challenge. Traditional, non-mechanized handling, variable sun-drying on open roads, and single-pass milling systems collectively contribute to substantial physical and economic losses. To address these inefficiencies, the government has provided Rice Processing Systems (RPS) under the Rice Competitiveness Enhancement Fund (RCEF), equipping local farming groups with modern recirculating batch dryers and multi-pass rice milling facilities intended to accelerate production and preserve grain quality (Aquino & dela Cruz, 2021; De Guia & Sebastian, 2022).

However, machinery distribution alone addresses only part of the underlying problem. As capital investment in postharvest infrastructure has expanded, the operative constraint has shifted from equipment availability to the technical capacity to operate it. When advanced automated systems are transferred to Farmers' Cooperatives and Associations (FCAs) whose members have historically relied on traditional farming methods, a pronounced technical gap emerges. In the absence of formal mechanical training or structured troubleshooting skills, these machines are susceptible to miscalibration, accelerated wear, and prolonged operational downtime resulting from otherwise minor technical faults (Alavi & Leach, 2019; Mendoza & Ramos, 2023).

This gap between equipment capability and operator readiness represents a critical point of failure in engineering management terms: distributing hardware without a corresponding investment in operator training undermines the sustainability of the asset itself. A five-day Skills Training Course was developed to address this gap directly. This study evaluates the effectiveness of that training intervention in improving operational efficiency and supporting long-term asset sustainability across fifteen (15) designated RPS beneficiaries in Nueva Ecija.

1.1 Postharvest Mechanization Ecosystem in the Philippines

The structural transformation of agricultural systems relies heavily on deploying capital machinery to minimize systemic grain losses. Historically, the Philippine rice sector has lost an estimated 15% to 16% of total production during postharvest handling (Philippine News Agency, 2023). This is largely due to handling practices, traditional road-drying, and single-pass village-level hullers. Under national modernization mandates, state programs have accelerated the rollout of heavy industrial facilities (PHilMech, 2026).

These configurations are distributed based on a tiered infrastructure framework tailored to the processing scale of the recipient communities. An RPS Level 1 facility comprises one (1) unit of a multi-stage rice mill with a capacity of 1.5 tons per hour paired with two (2) units of recirculating dryers running at 6 tons per batch. Stepping up to mid-scale commercial production, an RPS Level 2 facility upgrades the setup to one (1) unit of a multi-stage rice mill with a capacity of 2 to 3 tons per hour, fed by two (2) units of higher-capacity recirculating dryers operating at 12 tons per batch. At the highest automated industrial scale, an RPS Level 3 facility leverages one (1) unit of a large multi-stage rice mill running at 4 to 5 tons per hour supported by three (3) units of 12-ton-per-batch recirculating dryers.

These setups reduce reliance on erratic weather and achieve high hulling efficiencies. However, empirical observations indicate that delivering complex engineering arrays does not automatically guarantee efficiency. Instead, long-term success depends on matching equipment drops with structured human operator capabilities (Japan International Cooperation Agency [JICA], 2025).

1.2 Mechanical Factors Driving Milling Recovery Rates

The Milling Recovery Rate (MRR) is a primary technical indicator of postharvest processing efficiency. Traditional field methods produce an MRR of 55% to 58%, resulting in high broken grain levels and heavy economic discounts (National Food Authority [NFA], 2024). Modern multi-pass systems — regardless of whether they operate at a Level 1 pace of 1.5 tons/hour or a Level 3 velocity of 4–5 tons/hour

— are engineered to achieve a target baseline MRR of 63.0% to 65.0% (NFA, 2024).

Achieving this recovery range requires precise operational calibrations. Operators must adjust clearances on the rubber rollers, set standard air flows in the aspiration chambers, and regulate counterweights on the friction whiteners. If operators do not master these technical factors, the multi-stage equipment can experience excessive structural friction. This friction breaks the rice kernels, negating the benefits of the capital investment.

1.3 Moisture Content Management Dynamics

Controlling the Moisture Content (MC) of incoming paddy is essential for preventing physical grain damage. For long-term storage and high-yield milling, rough paddy must be dried uniformly to a target MC of 14.0% (International Rice Research Institute [IRRI], 2022). Milling grain with an MC above 15.0% causes soft kernels to crack under pressure inside the whitening chambers, creating high volumes of broken rice and bran contamination. Conversely, over-drying paddy below 13.0% wastes furnace energy and causes grain fissures through thermal shock, which increases grain breakage during hulling (IRRI, 2022).

Operators must regularly use grain moisture meters to monitor drying curves and avoid over-drying across batch units, whether managing 6-ton batches at Level 1 or full 12-ton batches at Level 3. Effective moisture management requires a structured routine in which operators run multiple tests on grain lots before beginning operations. The governing paddy processing moisture curve proceeds from wet harvest (>24% MC), through recirculating batch drying, to target safe storage (14% MC), and finally to optimal multi-pass milling.

1.4 Asset Sustainability and Preventive Care Transitions

In engineering management, asset sustainability is defined as a facility's ability to maintain high operational availability while minimizing long-term component wear. Rural cooperative facilities often operate under a reactive repair framework, addressing equipment only after components fail. This approach leads to extended downtime and premature hardware failure.

Transitioning cooperatives toward preventive maintenance requires introducing daily pre-operation checklists, structured belt tensioning procedures, and scheduled gear lubrication routines. Teaching local operators to identify early signs of wear — such as loose elevator belts, vibrating bearings, or uneven screen wear — allows cooperatives to reduce unplanned downtime and operate independently of external technicians (JICA, 2025).

1.5 Cognitive Capacities and Training-to-Field Translation

Structured vocational training is essential for improving human capabilities in sociotechnical systems. However, transferring technical knowledge from a structured classroom to an open industrial floor can present challenges such as cognitive overload. This issue is common when training programs compress advanced mechanical, electrical, and thermal concepts into short timelines.

While short courses can successfully teach entry-level technical skills and safety procedures, they often fall short in teaching advanced troubleshooting diagnostics. Operators must understand complex engineering relationships, such as how rubber roller clearance affects hulling percentages or how screen wear changes the grading of milled rice. Evaluating this learning gap requires comparing baseline pre-tests with post-tests.

According to the foundational pedagogical framework established by Colt et al. (2010), the use of paired pre-test and post-test assessments serves as an objective, reliable tool for quantifying cognitive knowledge acquisition and measuring the immediate structural efficacy of short-term technical interventions. This methodology isolates intellectual growth from external field variations, providing engineering managers with clear verification of baseline competency development before technical operators are permitted to manage high-capital industrial assets.

1.6 Research Gap and Conceptual Framework

Existing literature establishes that agricultural mechanization and capital infrastructure investment reduce postharvest grain losses (PHilMech, 2026; Philippine News Agency, 2023). However, a distinct gap remains in the localized evaluation of human capacity interventions within FCAs; much of the existing literature emphasizes machinery adoption and funding allocation rather than post-implementation operator proficiency and its downstream effects on performance.

This study addresses that gap by applying the paired pre-test/post-test evaluation framework validated by Colt et al. (2010) within an industrial engineering management context. Rather than relying on machinery adoption statistics alone, this research links quantified operator learning gains directly to facility performance data across a full cropping cycle. By examining how training affects milling recovery rates, moisture content management, and facility downtime across Level 1, 2, and 3 setups, the study shifts the evaluative focus from equipment procurement toward the human–machine interactions that determine long-term asset sustainability (JICA, 2025; IRRI, 2022).

The evaluation is organized around an Input–Process–Output (IPO) model suited to engineering management interventions of this kind, presented in Fig. 1. The Input stage captures baseline facility and operator conditions: the starting conditions of the 15 designated RPS facilities, including their location, RPS level, building readiness, and operational status, along with operators' knowledge prior to training. The Process stage describes the delivery of the five-day training course and the tools used to measure its success, including paired t-tests on test score improvements, physical facility logbook audits, daily milling data monitoring, and correlation tests linking test scores to machine performance (Creswell & Creswell, 2018; Santos & Gamit, 2023). The Output stage identifies the resulting improvements in milling recovery, moisture content accuracy, reduction of sudden machine breakdowns, and the establishment of a proactive daily preventive maintenance habit (Mendoza & Ramos, 2023).

INPUT	PROCESS	OUTPUT
Baseline Profile of 15 RPS Facilities: • Geographical location and status • RPS Level (1, 2, or 3) • Infrastructure / building readiness • Operator baseline knowledge	Five-Day Skills Training Course Intervention; Mixed-Methods Evaluation: • Pre-test / post-test assessment • Paired-samples t-tests • Logbook and audit data • Daily milling metrics and correlation analyses	Improvements: • Higher milling recovery • Accurate moisture content • Fewer sudden machine breakdowns • Preventive maintenance culture

Fig.1: Conceptual framework of the study (Input–Process–Output model)

1.7 Objectives of the Study

The main objective of this study is to evaluate the impact of the Skills Training Course on the operational efficiency and asset sustainability of the fifteen (15) designated Rice Processing System (RPS) beneficiaries in Nueva Ecija. Specifically, it sought to answer the following questions:

1. What is the baseline profile of the fifteen (15) designated RPS beneficiaries in terms of (1.1) geographical location; (1.2) machine setup level (Level 1, Level 2, or Level 3); (1.3) infrastructure readiness; and (1.4) operational status?
2. What is the performance of the course participants in the Skills Training Course based on their baseline pre-test and final post-test technical assessment results?
3. What are the operational efficiency and asset sustainability of the RPS beneficiaries after the implementation of the skills training course in terms of (3.1) milling recovery rate; (3.2) moisture tracking accuracy; (3.3) unplanned downtime; (3.4) preventive maintenance compliance; and (3.5) troubleshooting capability?
4. Is there a significant relationship between the participants' technical assessment performance

and the operational efficiency and asset sustainability of the RPS beneficiaries?

1.8 Scope and Delimitation

This study focused on fifteen (15) purposively selected RPS beneficiaries across the congressional districts of Nueva Ecija, comprising twelve (12) registered FCAs and three (3) Local Government Units (LGUs). Analysis of individual operator learning was based on the 40 operators who completed the five-day training course; long-term field performance tracking, by contrast, was delimited to the subset of 10 facilities with active power infrastructure and complete cropping-season logbooks. This distinction in sample size across analyses is addressed further in Section II.

Field operational data was limited to one wet and one dry cropping season. Technical evaluation focused specifically on Milling Recovery Rate (MRR), operator accuracy in reaching the 14.0% target grain moisture standard, and total unplanned downtime hours recorded in facility logbooks. Broader cooperative finances, local rice price trends, and external market shifts fell outside the scope of this study.

1.9 Operational Definitions

Asset Sustainability Index. A composite metric measuring operator compliance with daily machine inspections, routine lubrication, and component calibrations (JICA, 2025).

Milling Recovery Rate (MRR). The percentage weight of clean, polished white rice obtained relative to the total weight of the raw paddy input.

Unplanned Downtime. The total number of hours per month a facility is non-operational due to mechanical failures or unexpected technical component breakdowns.

1.10 Significance of the Study

This research provides actionable insights for several agricultural stakeholders. For national agricultural line agencies, it provides empirical data to refine future machinery allocation frameworks and establish mandatory operator certification standards. For FCAs, it serves as an operational blueprint to shift localized facility management from reactive breakdown repairs to structured, preventive maintenance routines. For operators and engineers, it highlights the specific technical skills required to improve milling efficiency and prolong equipment lifespans. For future researchers, it offers an evaluative model and baseline field data for studying human–machine interfaces in agricultural engineering projects.

II. METHODOLOGY

2.1 Research Design

This study employed an evaluative mixed-methods concurrent triangulation design, integrated with a one-group pre-test/post-test quasi-experimental approach. Quantitative methods tracked shifts in technical test scores, mechanical downtime logs, and milling recovery data. Following the evaluative tracking model validated by Colt et al. (2010), the pre-test instrument was administered at the start of the training course to establish baseline cognitive competencies among the operator cohort, while an identical post-test instrument was administered upon course completion to isolate the extent of knowledge gained. Qualitative methods, conducted through focus group discussions (FGDs), contextualized the technical variations, infrastructure gaps, and behavioral transitions in maintenance practices identified in the quantitative data.

2.2 Locale of the Study

The research was conducted within the province of Nueva Ecija. This region is an ideal location for postharvest evaluations due to its high concentration of state-funded Rice Processing Systems across various municipal cooperatives and local government facilities.

2.3 Respondents and Sampling

The study drew on three overlapping but distinct samples, reflecting the different units of analysis addressed by the research questions:

RPS Beneficiaries (N = 15). Fifteen purposively selected regional entities — twelve (12) cooperatives and three (3) municipal LGUs — were profiled to establish the baseline infrastructure and operational status reported under Objective 1.

Technical Personnel (N = 40). Forty individual facility operators completed the five-day training course and the paired knowledge assessments; this group forms the basis for the item-level competency analysis in Objective 2 (Table 5). A subset of this group (n = 30) had complete, matched pre-test and post-test records and was used for the paired-samples t-test in Table 4.

Operational Tracking Subset (n = 10). Of the fifteen beneficiary facilities, ten maintained active three-phase power connections and complete, continuous processing logbooks across a full cropping cycle. Long-term operational and asset sustainability metrics (Objectives 3 and 4) were delimited to this subset, since the remaining five facilities lacked the infrastructure or logbook continuity needed for valid before/after comparison.

This layered sampling structure allows the study to draw on the full beneficiary and operator population where appropriate, while restricting causal before/after claims to facilities where operational data was complete and uncontaminated by infrastructure downtime unrelated to training.

2.4 Data Gathering Instruments

Data collection relied on four primary tools:

1. Standardized Technical Knowledge Assessments: a 25-item test measuring proficiency in machinery mechanics, multi-pass calibration rules, and diagnostic safety procedures adapted from industry training baselines.
2. Operational Logbooks: standardized logs tracking raw input weights, final polished rice yields, digital moisture readouts, and exact breakdown durations across specified mill sizes and dryer combinations.
3. Structured Asset Sustainability Surveys: a five-point Likert scale instrument measuring daily checklist usage, lubrication frequencies, and operator troubleshooting.
4. Focus Group Protocols: open-ended qualitative guidelines used to capture operational experiences, identify training-to-field knowledge transfer limitations, and document external infrastructure challenges.

2.5 Data Gathering Procedure

Data collection proceeded in three sequential phases:

1. Baseline Auditing: historical data extraction from existing cooperative records to log pre-training milling indices, baseline unplanned downtime, and facility infrastructure configurations.
2. Training and Knowledge Tracking: administering the standardized 25-item technical test immediately before and after the five-day training intervention to document operator learning gains (Colt et al., 2010).
3. Post-Implementation Monitoring: field tracking across a full cropping season to monitor post-training operational logs, compile survey metrics, and conduct qualitative focus group discussions.

2.6 Data Analysis Technique

Descriptive Statistics. Frequency distributions, percentages, and weighted means were used to characterize baseline cooperative attributes, assess site infrastructure readiness, and measure overall maintenance compliance levels.

Paired-Samples t-test. Applied to evaluate differences between operator test scores and monthly unplanned downtime before and after the training intervention, with significance set at $\alpha = 0.05$ and degrees of freedom reported alongside each t-value (Colt et al., 2010).

Pearson Product-Moment Correlation Coefficient (r). Used to determine the strength and direction of the relationship between operator technical scores and postharvest facility performance metrics, with degrees of freedom ($n - 2$) reported for each coefficient (Santos & Gamit, 2023).

III. RESULTS AND DISCUSSION

This section presents, analyzes, and interprets the data gathered in the study. The presentation follows the exact sequence of the specific questions raised in the objectives of the study. Problem 1 establishes the baseline profile of the fifteen (15) designated RPS beneficiaries; Problem 2 reports the technical assessment performance of the training participants; Problem 3 presents the operational efficiency and asset sustainability outcomes of the beneficiary facilities; and Problem 4 tests the relationship between the two. Qualitative evidence drawn from the focus group discussions is integrated within the problem to which it directly pertains, consistent with the concurrent triangulation design described in Section II.

3.1 Baseline Profile of the Fifteen (15) Designated RPS Beneficiaries

The first research question sought to establish the baseline profile of the fifteen (15) designated RPS beneficiaries in terms of (1.1) geographical location, (1.2) machine setup level, (1.3) infrastructure readiness, and (1.4) operational status. An audit of official engineering asset logs revealed substantial variation across all four profile dimensions, summarized facility-by-facility in Table 1 and consolidated in frequency-and-percentage form in Table 2.

Table 1. Profile of Designated RPS Beneficiaries (N = 15)

No.	Name of RPS Beneficiary	Address	Setup Level	3-Phase Grid Status	Operational Status
1	City LGU of Cabanatuan	Kapitan Pepe, Cabanatuan City	Level 3	1 (Active)	Operational
2	Makabagong Magsasaka MPC	Palagay, Cabanatuan City	Level 1	1 (Active)	Operational
3	Cabanatuan City Seed Growers MPC	Dionisio S. Garcia, Cabanatuan City	Level 1	1 (Active)	Functional / Stagnant (Not Yet Trained)
4	Coop. Enterprise for True Economic Reform	Cabaruan, Guimba	Level 2	1 (Active)	Operational
5	Pakul Primary MPC	Pakul, Jaen	Level 2	1 (Active)	Operational
6	Bantug Agricultural MPC, Inc.	Bantug, Talavera	Level 2	1 (Active)	Operational
7	Kilusang Lima Para sa Lahat MPC	Maestrang Kikay, Talavera	Level 1	1 (Active)	Operational
8	South Nueva Ecija Seed Growers MPC	Poblacion, San Isidro	Level 1	1 (Active)	Operational
9	Provincial LGU of Nueva Ecija	Singalat, Palayan City	Level 1	0 (No Grid)	Functional / Delayed Grid Connection
10	SIPAG MPC	Poblacion, Aliaga	Level 1	0 (No Grid)	Functional / Stagnant (Not Yet Trained)
11	Licaong Agriculture Cooperative	Licaong, Science City of Muñoz	Level 1	0 (No Grid)	Functional / Stagnant (Not Yet Trained)
12	City LGU of Muñoz	Franza, Science City of Muñoz	Level 2	1 (Active)	Operational
13	Kasangga Ng Rang-Ay Irrigators' Assoc.	Gabaldon-Rangayan Rd, Muñoz	Level 1	1 (Active)	Operational
14	Caridad Sur Farmers MPC	Caridad Sur, Llanera	Level 1	1 (Active)	Operational
15	Talabutab Norte Primary MPC	Talabutab Norte, General Natividad	Level 2	1 (Active)	Functional / Stagnant (Not Yet Trained)

Table 2. Summary Distribution of the Baseline Profile Variables (N = 15)

Profile Variable / Category	Frequency (f)	Percentage (%)
1.1 Geographical Location		
Cabanatuan City	3	20.00
Science City of Muñoz	3	20.00
Talavera	2	13.33
Guimba, Jaen, San Isidro, Palayan City, Aliaga, Llanera, General Natividad (1 each)	7	46.67
1.2 Machine Setup Level		
Level 1 (1.5 t/hr mill + two 6 t/batch dryers)	9	60.00
Level 2 (2–3 t/hr mill + two 12 t/batch dryers)	5	33.33
Level 3 (4–5 t/hr mill + three 12 t/batch dryers)	1	6.67
1.3 Infrastructure Readiness (3-Phase Grid)		
Active 3-phase grid connection	12	80.00
No active 3-phase grid connection	3	20.00
1.4 Operational Status		
Operational	10	66.67
Functional / Stagnant (Not Yet Trained)	4	26.67
Functional / Delayed Grid Connection	1	6.67
Beneficiary Type		
Farmers' Cooperatives and Associations (FCAs)	12	80.00
Local Government Units (LGUs)	3	20.00

3.1.1 Geographical Location

The fifteen beneficiary facilities are distributed across ten (10) cities and municipalities spanning the congressional districts of Nueva Ecija. Cabanatuan City and the Science City of Muñoz each host three (3) facilities, or 20.00% apiece, while Talavera hosts two (2) or 13.33%. The remaining seven (7) facilities, representing 46.67%, are singly distributed across Guimba, Jaen, San Isidro, Palayan City, Aliaga, Llanera, and General Natividad. This dispersion reflects the allocation intent of the Rice Competitiveness Enhancement Fund, which distributes postharvest capacity across producing districts rather than concentrating it in a single processing hub.

3.1.2 Machine Setup Level

Level 1 configurations dominate the allocation at 60.00% (f = 9), followed by Level 2 multi-pass setups at 33.33% (f = 5), with only one facility, the City LGU of Cabanatuan, reaching the commercial automated Level 3 scale at 6.67% (f = 1). The concentration of grants at the Level 1 tier indicates that the prevailing capacity profile in the province is the 1.5-ton-per-hour mill paired with two 6-ton-per-batch recirculating dryers, a scale suited to cooperative-level rather than commercial-volume throughput.

3.1.3 Infrastructure Readiness

Infrastructure readiness was operationalized as the presence of an active three-phase power grid connection at the facility site, since the multi-stage mill and recirculating dryer motors cannot be energized without it. Twelve (12) facilities, or 80.00%, held active three-phase connections at the time of audit. Three (3) facilities, or 20.00% — the Provincial LGU of Nueva Ecija (No. 9), SIPAG MPC (No. 10), and Licaong Agriculture Cooperative (No. 11) — had no active three-phase grid connectivity at handover. This constitutes a pre-handover infrastructure mismatch: the capital asset was delivered and installed in advance of the utility service required to operate it, producing stagnation that is entirely independent of operator skill or training exposure.

3.1.4 Operational Status

Ten (10) facilities, or 66.67%, were classified as Operational, meaning they held active power, had completed operator training, and maintained continuous processing logbooks across the cropping cycle. These ten facilities constitute the operational tracking subset (n = 10) used in Problems 3 and 4, as delimited in Section II. Four (4) facilities, or 26.67%, were classified as Functional/Stagnant (Not Yet Trained), and one (1) facility, or 6.67%, as Functional/Delayed Grid Connection.

3.1.5 Non-Operational Facilities: A Distinct Structural Finding

Five (5) of the fifteen beneficiary facilities — 33.33% of distributed RPS assets — were not yet realizing operational value at the time of data collection, and were therefore excluded from the operational tracking analysis. The reasons for exclusion differ in kind and warrant separate treatment, as summarized in Table 3.

Table 3. Constraint Classification of Non-Operational RPS Facilities (n = 5)

No.	Facility	3-Phase Grid	Training Status	Governing Constraint
9	Provincial LGU of Nueva Ecija	None	Trained	Utility coordination (grid only)
10	SIPAG MPC	None	Not yet trained	Utility coordination + rollout schedule
11	Licaong Agriculture Cooperative	None	Not yet trained	Utility coordination + rollout schedule
3	Cabanatuan City Seed Growers MPC	Active	Not yet trained	Program rollout schedule only
15	Talabutab Norte Primary MPC	Active	Not yet trained	Program rollout schedule only

Three (3) of the five cases are governed wholly or partly by an absent three-phase grid connection, representing a pre-handover infrastructure failure situated outside the scope of the training intervention. The remaining two (2) facilities held active power but had simply not yet been scheduled into the training cycle at the time of data collection. This distinction matters for interpretation: grid-related stagnation reflects an inter-agency utility coordination failure, while training-related stagnation is a scheduling artifact of program rollout rather than evidence against the intervention's effectiveness. Neither category constitutes a negative training outcome.

The focus group discussions corroborate this reading. Under the theme Infrastructure Gaps, an operator assigned to a grid-constrained site reported that the facility remained idle notwithstanding completed instruction:

> *"Gusto sana nating i-apply agad yung natutunan sa training pero wala pa ring dumarating na 3-Phase power supply mula sa kooperatiba ng kuryente."*

The statement confirms that cognitive capacity had been successfully built at these sites, but that external utility deficits prevented that capacity from translating into regional processing volume. This finding is carried forward into the interpretation of Problems 2 and 3, where item-level mastery in dryer architecture is shown to coexist with zero field throughput at the affected facilities.

3.2 Performance of the Course Participants in the Skills Training Course

The second research question examined the technical assessment performance of the participants across the paired pre-test and post-test instruments. Two complementary analyses are presented: an aggregate paired-samples t-test on the matched score records (Table 4), and an item-by-item frequency and percentage distribution isolating the specific competency vectors in which learning occurred (Table 5).

3.2.1 Aggregate Knowledge Acquisition

Table 4. Paired t-test Analysis of Trainee Examination Scores (n = 30)

Evaluation Instrument	Mean Score	Net Change	t-value	p-value	Statistical Significance
Pre-Test Score (out of 25)	12.87	+1.90	t(29) = 3.738	0.0007	Highly Significant ($p < 0.01$)
Post-Test Score (out of 25)	14.77	—	—	—	—

Table 4 presents the paired-samples t-test comparing pre-test and post-test scores of the RPS operators with complete matched records. The baseline evaluation yielded a pre-test mean of 12.87 out of 25, indicating a moderate initial level of technical familiarity. Following the intervention, the post-test mean rose to 14.77 out of 25, a net change of +1.90 points. The analysis generated a computed value of $t(29) = 3.738$, $p = 0.0007$. Because the p-value falls substantially below the 0.01 threshold, the null hypothesis is rejected. The result is statistically highly significant, demonstrating that the skills training course produced a genuine, non-random improvement in the technical competencies of the FCA operators with respect to RPS operation and maintenance.

3.2.2 Item-Level Competency Distribution

Table 5. Frequency and Percentage Distribution of Operator Correct Responses (N = 40)

No.	Core Competency Vector	Pre-Test	Post-Test	Net Gain
1	Loss Factors Awareness (Moisture/Insects)	32 (80.0%)	39 (97.5%)	+17.5%
2	Postharvest Interaction System Matrices	28 (70.0%)	38 (95.0%)	+25.0%
3	Macro Anatomy of Paddy Grain Structures	25 (62.5%)	36 (90.0%)	+27.5%
4	Micro Structural Internal Component Anatomy	18 (45.0%)	29 (72.5%)	+27.5%
5	Target Safe Milling/Storage Moisture (14%)	14 (35.0%)	37 (92.5%)	+57.5%
6	Drying System Mechanics and Storage Theory	30 (75.0%)	39 (97.5%)	+22.5%
7	Mechanical Component Grouping	22 (55.0%)	35 (87.5%)	+32.5%
8	Commercial Dryer Layout Categorizations	16 (40.0%)	31 (77.5%)	+37.5%
9	Physical Grain Classification Standards	26 (65.0%)	38 (95.0%)	+30.0%
10	Primary Operator Accountability Mandates	34 (85.0%)	40 (100.0%)	+15.0%
11	Flatbed Dryer Architecture Classifications	15 (37.5%)	32 (80.0%)	+42.5%
12	External Postharvest Loss Factor Isolation	20 (50.0%)	34 (85.0%)	+35.0%
13	Warehouse Bag Stack Spacing Regulations	11 (27.5%)	28 (70.0%)	+42.5%
14	Moisture Testing Methodologies	13 (32.5%)	30 (75.0%)	+42.5%

No.	Core Competency Vector	Pre-Test	Post-Test	Net Gain
15	Chemical Degree Testing (Bran Staining)	8 (20.0%)	22 (55.0%)	+35.0%
16	Sizing/Grading Separation Mechanics	21 (52.5%)	35 (87.5%)	+35.0%
17	First-Line Warehouse Sanitation Defenses	29 (72.5%)	39 (97.5%)	+25.0%
18	Phase-Sequencing of Milling Processes	19 (47.5%)	33 (82.5%)	+35.0%
19	Warehouse Fumigation Protective Measures	12 (30.0%)	26 (65.0%)	+35.0%
20	Field Sample Replication Testing Frequencies	10 (25.0%)	29 (72.5%)	+47.5%
21	Cross-Infestation Biosecurity Vulnerabilities	14 (35.0%)	31 (77.5%)	+42.5%
22	Milling Extraction Grading Profiles	9 (22.5%)	24 (60.0%)	+37.5%
23	Husker Rubber Roller Clearance Settings (50%)	6 (15.0%)	23 (57.5%)	+42.5%
24	Inventory Control Management Logic (F.I.F.O.)	31 (77.5%)	40 (100.0%)	+22.5%
25	Fluid-Air Velocity Calibration Diagnostics	7 (17.5%)	25 (62.5%)	+45.0%
	Cumulative Mean	**47.00%**	**81.30%**	**+34.30%**

Table 5 shows the evaluation matrix across the twenty-five (25) core competency vectors comprising the assessment instrument. Prior to the intervention, cumulative baseline knowledge was deficient, yielding a mean pre-test score of 47.00%. This low baseline exposes systemic technical vulnerabilities in local postharvest handling, particularly in advanced diagnostic calibrations and chemical testing metrics. Following the training course, the cumulative mean post-test score advanced to 81.30%, a net knowledge gain of +34.30%.

The most pronounced breakthrough occurred in Item 5, Target Safe Milling/Storage Moisture (14%), which surged by +57.5% to a mastery level of 92.5%. Perfect mastery (100.0%) was recorded for both Item 10, Primary Operator Accountability Mandates, and Item 24, Inventory Control Management Logic (F.I.F.O.), indicating that operators thoroughly absorbed institutional accountability frameworks and warehouse structural flows. These three items are the competency vectors most directly implicated in the operational outcomes reported under Problem 3.

3.2.3 Residual Competency Gaps and Cognitive Calibration Overload

Notwithstanding uniformly positive net gains, residual deficiencies persist within advanced technical and chemical diagnostic workflows. Item 15, Chemical Degree Testing via Bran Staining Reagents (55.0%), and Item 23, Husker Rubber Roller Clearance Settings (57.5%), lagged materially behind all other categories, indicating that these competencies require a longer learning curve than a five-day format allows.

Focus group data under the theme Cognitive Overload and Calibration Limits explains the lag directly:

> *"Mabilis naituro yung chemical testing (bran staining) pero nalilito pa rin kami, pati rin sa porsyento ng clearance ng rollers lalo na kapag paiba-iba ang laki ng palay."*

Operators reported that biochemical testing procedures were clearly presented during lecture, but that applying that knowledge proved substantially more difficult. Specifically, operators struggled to compute percentage clearances on rubber rollers because incoming raw grain dimensions varied continuously. This pattern suggests that fixed-parameter training templates do not fully prepare operators for highly variable field conditions, and that a five-day window provides insufficient time to build adaptive troubleshooting skill.

Left unaddressed, these gaps carry a direct operational risk. As established in Section I, improper roller clearance increases structural friction and grain breakage inside the husking chamber. This finding should therefore be read as a specific, actionable design constraint on future training cycles rather than as a general shortfall of the intervention.

3.3 Operational Efficiency and Asset Sustainability After the Training Course

The third research question evaluated the operational efficiency and asset sustainability of the beneficiary facilities following the intervention, across five indicators: (3.1) milling recovery rate, (3.2) moisture tracking accuracy, (3.3) unplanned downtime, (3.4) preventive maintenance compliance, and (3.5) troubleshooting capability. Consistent with the delimitation established in Section II, this analysis covers the ten (10) facilities holding active power connections and complete cropping-season logbooks. Indicators 3.1 through 3.3 are drawn from operational logbook records and presented in Table 6; indicators 3.4 and 3.5 are drawn from the structured asset sustainability survey and presented in Table 7.

Table 6. Postharvest Processing Efficiencies and Operational Status (n = 10)

Metric	Pre-Training	Post-Training	Net Shift	Implication
3.1 Milling Recovery Rate (MRR)	58.67%	64.34%	+5.67 pp	Higher profitability, reduced raw grain waste
3.2 Moisture Tracking Accuracy	62.40%	91.80%	+29.40 pp	Precise pricing, mold prevention, optimized storage
3.3 Unplanned RPS Downtime	16.00 hrs/mo	3.40 hrs/mo	−78.75%	Extended machine lifespan, continuous operations

3.3.1 Milling Recovery Rate

The Milling Recovery Rate, the primary technical indicator of postharvest processing efficiency, advanced from a baseline of 58.67% to a post-training level of 64.34%, a net yield increase of +5.67 percentage points. This post-training figure falls squarely within the target MRR range of 63.0% to 65.0% established for modern multi-pass systems (NFA, 2024) and discussed in Section I, indicating that trained operators brought facility performance up into the equipment's designed operating envelope. The baseline of 58.67%, by contrast, sat at the upper edge of the 55% to 58% band characteristic of traditional field methods, meaning that prior to training the facilities were operating modern multi-pass equipment at effectively traditional recovery levels.

3.3.2 Moisture Tracking Accuracy

Moisture tracking accuracy improved by +29.40 percentage points, from a baseline of 62.40% to 91.80%, ensuring closer alignment with the 14.0% target moisture standard and materially reducing spoilage risk during storage. This is the largest proportional gain among the operational indicators, and it corresponds directly to the largest item-level knowledge gain reported under Problem 2 (Item 5, +57.5%). Focus group evidence under the theme Moisture Control Shift traces the mechanism:

> *"Dati sa kalsada kinapakapa lang namin kung tuyo na ang palay. Noong nalaman namin yung saktong 14%, mas kaunti na ang nadudurog na bigas sa loob ng whiteners."*

Operators noted that their historical baseline routine relied on subjective physical assessment of paddy on open roads rather than instrument-based verification. Replacing that habit with objective moisture testing at the 14% threshold produced an immediate, visible reduction in grain fracturing inside the milling equipment. This rapid workplace feedback loop reinforced classroom learning and helps explain why this competency was internalized faster than any other. The convergence between the +57.5% item gain, the +29.40 pp accuracy gain, and the elevated MRR of 64.34% constitutes the strongest evidentiary chain in the study, linking a single discrete cognitive gain to a measurable physical yield outcome.

3.3.3 Unplanned Downtime

Unplanned RPS downtime decreased from an average of 16.00 hours per month to 3.40 hours per month, a reduction of 78.75%. This finding is consistent with the asset sustainability literature reviewed in Section I (JICA, 2025), which links structured preventive maintenance routines to reduced component failure rates. The magnitude of the reduction observed here suggests that daily pre-operational inspection habits and first-line troubleshooting capability were the primary drivers of continued operational continuity for the multi-million-peso RPS asset. Expressed in operating terms, the facilities recovered approximately 12.6 productive machine-hours per month, a recovery of particular consequence during peak harvest windows when drying and milling capacity is rate-limiting.

Table 7. Behavioral Maintenance Metrics and Asset Sustainability Indices (n = 10)

Asset Care Vector	Pre-Training	Post-Training	Shift	Behavioral Shift
3.4 Daily Pre-Operation Checklist Execution	1.40 (Poor/Reactive)	4.60 (Excellent)	+3.20	Rare to Highly Consistent
3.4 Systematic Lubrication & Belt Tensioning	1.80 (Marginal)	4.50 (Excellent)	+2.70	Neglected to Routinely Conducted
3.5 Independent Plant Failure Troubleshooting	2.10 (Marginal)	4.10 (Compliant)	+2.00	External-Dependent to Autonomous
Composite Asset Care Index	**1.77 (Marginal)**	**4.40 (Compliant)**	**+2.63**	**Reactive Upkeep to Preventive Care**

3.3.4 Preventive Maintenance Compliance

Preventive maintenance compliance was measured through two behavioral vectors. Daily Pre-Operation Checklist Execution registered the single most notable behavioral evolution in the study, rising by +3.20 points from a baseline mean of 1.40 (Poor/Reactive) to a post-intervention mean of 4.60 (Excellent). Systematic Lubrication and Belt Tensioning advanced from 1.80 (Marginal) to 4.50 (Excellent), a shift of +2.70 points, indicating that previously neglected scheduled tasks are now routinely integrated into daily operations.

Focus group evidence under the theme Maintenance Culture Shift documents the underlying institutional change:

> *"Hindi na namin hihintayin na maputol ang elevator belt bago ayusin. Ngayon, bago magpaandar sa umaga, sinusunod na namin yung checklist sa tensyon at langis."*

Rather than relying on reactive, breakdown-driven repairs, operators reported actively institutionalizing structured pre-shift protocols, running standardized oiling, tensioning, and sequential inventory checklists each morning before activating machinery. This behavioral internalization corresponds to the perfect post-test mastery recorded for Items 10 and 24 under Problem 2, and directly explains the movement of the Composite Asset Care Index from 1.77 (Marginal) to 4.40 (Compliant), which relocates the institutional culture into the Compliant behavioral threshold.

3.3.5 Troubleshooting Capability

Independent Facility Failure Troubleshooting rose from 2.10 (Marginal) to 4.10 (Compliant), a shift of +2.00 points. While this vector registered both the lowest post-training mean and the smallest absolute gain among the three behavioral indicators, the shift nonetheless signifies a meaningful reduction in dependency on external technicians and a transition from an externally dependent to a substantially autonomous maintenance posture.

The comparatively restrained gain in this vector is internally consistent with the residual competency gaps identified under Problem 2. Troubleshooting is the behavioral expression of exactly those diagnostic competencies — roller clearance calibration (Item 23, 57.5%) and chemical degree testing (Item 15, 55.0%) — that remained least mastered at post-test. The two findings converge on the same interpretation: routine, rule-based maintenance behaviors transferred readily from classroom to plant floor, whereas adaptive, judgment-dependent diagnostic behaviors transferred only partially within the five-day window.

3.4 Relationship Between Technical Assessment Performance and Facility Outcomes

The fourth research question tested whether a significant relationship exists between the operator competency established under Problem 2 and the facility-level outcomes established under Problem 3. A Pearson product-moment correlation coefficient was computed between operators' post-test scores and two institutional metrics: the Milling Efficiency Index and the Asset Sustainability Index.

Table 8. Correlation Matrix — Participant Performance vs. Facility Efficiencies (n = 10)

Correlated Variables	Pearson r	p-value	Inference
Post-Test Scores vs. Milling Efficiency Index	r(8) = .742	0.014	Strong Positive (Significant)
Post-Test Scores vs. Asset Sustainability Index	r(8) = .795	0.006	Strong Positive (Highly Significant)

The relationship between operators' post-test scores and RPS milling efficiency is strong, positive, and statistically significant, $r(8) = .742$, $p = .014$. Because the p-value falls below the conventional $\alpha = .05$ threshold, the null hypothesis is rejected, indicating that higher post-training technical competency is strongly associated with improved milling recovery, lower broken-grain rates, and reduced downtime during peak harvest.

The correlation between post-test scores and the Asset Sustainability Index is stronger still, $r(8) = .795$, $p = .006$, a highly significant relationship at the $\alpha = .01$ level. This suggests that technical competence is a critical determinant of machinery longevity: operators with higher proficiency scores demonstrate stronger adherence to preventive maintenance schedules, more precise troubleshooting, and more consistent calibration, directly reducing the risk of premature equipment depreciation.

That the competency–sustainability association exceeds the competency–efficiency association is itself interpretively significant. Milling recovery is jointly determined by operator skill and by exogenous variables outside the operator's control, including incoming paddy variety, harvest maturity, and field moisture at intake. Maintenance behavior, by contrast, is almost wholly operator-determined. The stronger coefficient on the sustainability index therefore reflects the indicator on which operator competency exerts the most direct causal leverage.

Taken together, these coefficients provide statistical evidence that targeted technical skills training is a meaningful driver of both immediate operational efficiency and long-term asset sustainability for agricultural cooperatives in Nueva Ecija. It should be noted, consistent with the delimitation in Section II, that the correlation is computed on the ten-facility operational subset, and that association at this sample size does not by itself establish causal direction.

3.5 Convergence of Quantitative and Qualitative Findings

Consistent with the concurrent triangulation design, the qualitative themes derived from the focus group discussions were coded and mapped against the research problem to which each pertains. Table 9 presents the consolidated coding matrix, integrating the verbatim field transcripts discussed under Problems 1 through 3.

Table 9. Qualitative Coding Matrix for Transcribed Operator Responses

Theme	Related Problem	Typical Verbatim Statement (Tagalog Field Transcript)	Operational Management Meaning
1. Infrastructure Gaps	Problem 1 (1.3, 1.4)	"Gusto sana nating i-apply agad yung natutunan sa training pero wala pa ring dumarating na 3-Phase power supply mula sa kooperatiba ng kuryente."	Explains why infrastructure variables limit immediate field efficiency despite strong Item 8 mastery; utility delays stall automated storage rollout.

Theme	Related Problem	Typical Verbatim Statement (Tagalog Field Transcript)	Operational Management Meaning
2. Cognitive Overload & Calibration Limits	Problem 2 (2.3)	"Mabilis naituro yung chemical testing (bran staining) pero nalilito pa rin kami, pati rin sa porsyento ng clearance ng rollers lalo na kapag paiba-iba ang laki ng palay."	Confirms that a short training window provides insufficient time to master precision settings under variable load inputs; explains the lag in Items 15 and 23.
3. Moisture Control Shift	Problem 3 (3.1, 3.2)	"Dati sa kalsada kinapakapa lang namin kung tuyo na ang palay. Noong nalaman namin yung saktong 14%, mas kaunti na ang nadudurog na bigas sa loob ng whiteners."	Validates the statistical jump in Item 5; connects empirical moisture management to higher MRR and fewer broken grains.
4. Maintenance Culture Shift	Problem 3 (3.4, 3.5)	"Hindi na namin hihintayin na maputol ang elevator belt bago ayusin. Ngayon, bago magpaandar sa umaga, sinusunod na namin yung checklist sa tensyon at langis."	Explains the structural shift behind the Asset Sustainability Index jump; reinforces mastery of Items 10 and 24.

The mapping demonstrates that the qualitative data does not merely restate the quantitative findings but explains their distribution. Themes 3 and 4 account for where gains were largest, Theme 2 accounts for where gains were smallest, and Theme 1 accounts for where gains could not be expressed in field performance at all. The convergence across both strands supports the validity of the overall evaluative conclusion while identifying, with precision, the two boundaries — cognitive and infrastructural — that constrained it.

IV. CONCLUSION

This study evaluated the impact of a five-day Skills Training Course on the operation and maintenance of the Rice Processing System upon the operational efficiency and asset sustainability of fifteen (15) designated RPS beneficiaries in Nueva Ecija, comprising twelve (12) registered Farmers' Cooperatives and Associations and three (3) Local Government Units, encompassing forty (40) trained operators. Drawn in the sequence of the research problems, the study concludes that:

1. The baseline allocation of RPS assets in Nueva Ecija is skewed toward cooperative-scale Level 1 configurations and is not synchronized with local utility readiness. One-fifth of distributed facilities lacked the three-phase grid service required to energize the equipment at handover, and one-third of all assets were not yet generating operational value at the time of study. Capital distribution has therefore outpaced both the utility coordination and the training rollout necessary to activate it, leaving idle assets whose stagnation is attributable to program sequencing rather than to recipient capability.
2. The five-day Skills Training Course produced a statistically highly significant and non-random improvement in operator technical competency, but the gain is not uniform across competency types. Rule-based and threshold-based knowledge — target moisture, accountability mandates, inventory logic — was acquired to near or full mastery, whereas adaptive, judgment-dependent diagnostic competencies involving chemical assessment and mechanical clearance under variable grain loads remained substantially unmastered. A compressed timeline is sufficient to establish standards but insufficient to build calibration judgment.
3. The training intervention translated into measurable operational and behavioral gains at the facility level across all five indicators. Milling recovery moved from traditional-method performance into the equipment's designed

operating range, moisture accuracy and downtime improved substantially, and cooperative maintenance culture shifted from a reactive breakdown framework to a structured, checklist-driven preventive regime. The comparatively restrained gain in independent troubleshooting mirrors the diagnostic learning gap identified above, confirming that field behavior tracks the specific structure of what was learned rather than the aggregate fact of training.

4. Operator technical competency is a statistically significant correlate of both operational efficiency and asset sustainability, with the stronger association attaching to asset sustainability. Structured human capacity building is therefore not an adjunct to postharvest mechanization but a determinant of whether distributed machinery achieves its designed performance and its intended service life. Procurement and distribution of high-capital machinery without matched investment in operator proficiency constitutes a systemic engineering management gap.

V. RECOMMENDATIONS

Proceeding from the conclusions above, the following are recommended:

1. To national line agencies and program implementers: mandate pre-handover infrastructure readiness audits. Physical machine allocation should be synchronized with local utility capability, with active three-phase electrical service verified and energized prior to equipment distribution and operator training. Formal coordination instruments with local electric cooperatives should be executed at the site-selection stage rather than after installation, and training schedules should be sequenced to follow rather than precede facility commissioning.
2. To training implementing units: extend training windows and provide focused refresher modules. Future interventions should expand the course timeline or offer specialized hands-on follow-up sessions targeting the specific competencies shown here to resist short-format transfer — adaptive rubber roller clearance adjustment under variable grain dimensions and chemical bran staining diagnostics. Instruction in these areas should employ variable-parameter practice on live equipment rather than fixed-parameter classroom templates.
3. To Farmers' Cooperatives and Associations and managing stakeholders: institutionalize standardized compliance and accountability frameworks. Formal internal monitoring systems should mandate continuous use of daily pre-operation checklists, routine lubrication schedules, and continuous logbook accounting, so that the behavioral gains recorded here are sustained beyond the immediate post-training period and survive operator turnover.
4. To national line agencies: institutionalize mandatory operator certification as a precondition of asset custody. Given the demonstrated correlation between operator competency and both processing efficiency and asset longevity, certification of at least one qualified operator per facility should be established as a formal requirement prior to the transfer of custody of high-capital postharvest equipment.
5. To future researchers: extend the evaluative window beyond a single cropping cycle to test the durability of the observed behavioral gains, and replicate the design in provinces with differing utility-readiness profiles to isolate the infrastructure effect from the training effect.

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