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INTEGRATED ERP-BPMS APPROACH FOR OPTIMIZING HCS MANAGEMENT: PERSONNEL QUALIFICATIONS, MAINTENANCE COSTS, AND CONTRACTOR SELECTION

The object of the study is the integrated ERP–BPMS framework designed to optimize housing and communal services (HCS). The most problematic area identified during audit was the fragmentation of personnel qualification assessments, maintenance cost forecasting, and outsourcing decisions, causing inconsistent performance metrics, increased diagnostic errors, and prolonged service-resolution times under budget constraints.

The research implemented three approaches: an Integral Evaluation Method (IEM) for quantifying staff competencies, a Maintenance Cost Assessment module for enhanced budget planning, and an IEM-based decision mechanism for comparing in-house versus outsourced work. These methods were integrated into the Business Operation System – Central Information System (BOS CIS) with an Information Administrator (IA) role that cross-validates digital logs against manual safety and compliance checklists.

Implementation increased the Integral Qualification Score from 9.8 to 64.0, reducing diagnostic errors by 66 % and issue-resolution times by 50 %. Cost prediction accuracy improved from 0.76 to 0.93, while outsourcing decisions shortened project durations by 25–28.6 % and enhanced financial efficiency by 6 %. Data retrieval times decreased by 75 %, and the Information Utilization Rate rose from 65 % to 88 %. These improvements stem from the framework's real-time processing of both positive and negative performance factors and its hybrid human-machine validation process.

This synergy enables accurate, data-driven decisions that optimize resource allocation under strict budget limitations. Unlike solutions focusing on isolated elements, this integrated platform simultaneously addresses personnel development, cost modeling, and strategic outsourcing, increasing operational transparency and adaptability.

The framework is recommended for large-scale service environments where uninterrupted operation, cost-effectiveness, and high service quality are essential. By combining automated analytics with oversight, it provides a scalable model for enhancing project performance and strategic decision-making in resource-constrained service sectors.

Keywords: *ERP-BPMS, housing, communal, integral, evaluation, maintenance, outsourcing, personnel, management, optimization.*

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1. Introduction

Housing and communal services (HCS), encompassing heating, water supply, waste management, and other essential utilities, are pivotal for public well-being and urban sustainability [1, 2]. Organizations in this sector routinely contend with budgetary pressures, aging infrastructure, and heightened public expectations of service reliability [3]. Digital platforms like enterprise resource planning (ERP) and business process management systems (BPMS) show promise in enhancing operational control [4, 5]. However, most existing solutions focus on narrow aspects such as risk management [6–8], staff competencies [9], and maintenance scheduling [10]. These solutions fail to fully integrate three critical factors. The missing factors are:

1) personnel qualifications;
2) comprehensive maintenance-cost assessments;
3) systematic decisions regarding outsourcing versus in-house work [3, 11].

Recent scholarship emphasizes the potential of converging ERP and BPMS technologies to create a more holistic management framework [12–14]. Moreover, articles in the International Journal of Information Systems and Project Management highlight the importance of agile risk management, robust performance metrics, and integrated approaches to project success [15–17]. Nevertheless, significant gaps remain in consolidating human resource metrics, predictive cost models, and contractor selection criteria within a cohesive digital ecosystem [18, 19]. Although upgrading staff competencies can substantially improve service reliability [20, 21], cost modeling is often relegated to separate systems [22, 23]. Contractor evaluations also tend to rely on ad hoc or subjective methods rather than standardized data-driven protocols [24, 25], complicating real-time decision-making in 24/7 service environments.

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To address these shortcomings, this study proposes and empirically tests a threefold framework in an advanced ERP-BPMS environment. The framework comprises the following:

1. An Integral Evaluation Method (IEM) for personnel qualifications [26].

2. A Maintenance Cost Assessment Method for budget forecasting and resource allocation [27–29].

3. An IEM-based module provides objective guidance on whether specific tasks should be performed in-house or outsourced [11, 30, 31].

As illustrated in Fig. 1, the integrated ERP-BPMS framework consolidates the Integral Evaluation Method (IEM) for personnel qualifications, Maintenance Cost Assessment Method, and the IEM-based in-house versus outsourced module within the BOS CIS platform.

All three methods are deployed in the Business Operation System – Central Information System (BOS CIS), initially implemented at the participating HCS provider, a leading engineering firm servicing approximately 750,000 households and coordinating 200–300 daily service requests [32]. Importantly, the system does not function in a fully automated manner; the organization's specialists continue to use manual checklists and established protocols for safety and compliance, periodically cross-validating BOS CIS outputs to mitigate human error. The Information Administrator (IA) plays a pivotal role in reconciling on-site observations with automated logs, ensuring that discrepancies are promptly identified and resolved.

The schematic in Fig. 1 shows the integration of three modules:

1. Integral Evaluation Method (IEM) for personnel qualifications.

2. Maintenance Cost Assessment.

3. IEM-based in-house versus outsourced module – within the BOS CIS platform.

The Information Administrator (IA) reconciles digital logs with manual checklists (safety and compliance), ensuring continuous feedback and real-time analytics. The formulas for IQS and IntegralScore are optionally shown. The arrows indicate how the outputs (e. g., dynamic *IQS* updates, predictive maintenance schedules, outsourcing recommendations) loop back to improve the data inputs.

This blend of automated analytics and manual oversight aligns with institutional theory [33] and enables near-real-time decision-making through continuous data verification.

Preliminary results from the case study enterprise underscore the practical impact of this integrated approach: a 66 % drop in diagnostic errors, 50 % reduction in average issue-resolution times, 22 % increase in cost-forecasting accuracy, and 75 % decrease in data-retrieval durations. These improvements bolster the Resource-Based View (RBV), which posits that specialized human capital and robust IT infrastructure jointly enhance organizational performance [34], and mirror project management research that stresses an integrated view of scope, schedule, and cost [15]. Formal statistical analyses (t-tests, ANOVA) confirmed that these gains were both significant and closely tied to the threefold framework.

Accordingly, this study addresses two central questions:

1) How does the coordinated use of personnel qualification metrics, maintenance cost assessments, and contractor selection criteria improve HCS outcomes under budget constraints?

2) In what ways can an ERP-BPMS platform, exemplified by BOS CIS, enhance resource allocation and service quality in large-scale, around-the-clock environments?

Let's hypothesize (H1) that consolidating these methods within a single system substantially boosts HCS efficiency, and (H2) that introducing an Information Administrator role further advances stakeholder satisfaction and cost-effectiveness [35]. By uniting personnel evaluation, cost modeling, and outsourcing decisions within one digital framework, the case study enterprise provides an operationally tested roadmap for Information Systems and Project Management (IS/PM) practitioners. Because the proposed methods rest on generally applicable principles – modular design, real-time data updates, and role-based oversight [36] – they can be adapted to other sectors requiring reliable service and robust project management, such as facility management or infrastructure maintenance [37–39].

2. Materials and Methods

2.1. The object of research and methodological framework

The object of this research is the integrated Enterprise Resource Planning-Business Process Management System (ERP-BPMS) framework implemented within the Business Operation System-Central Information System (BOS CIS) at a large-scale housing and communal services (HCS) provider. This framework represents a technological and organizational solution designed to optimize HCS management processes, focusing specifically on personnel qualification assessment, maintenance cost forecasting, and contractor selection decision-making.

The research employed a mixed-methods approach combining quantitative and qualitative techniques. System performance analysis was conducted through data mining and statistical processing of BOS CIS logs using SPSS Statistics (IBM, USA). Process efficiency was evaluated through comparative pre-post implementation analysis, examining key performance indicators before and after the implementation to identify meaningful operational changes. User experience assessment relied on verbal interviews and feedback mechanisms integrated within the BOS CIS platform itself, gathering insights from both technical staff and end-users regarding system usability and practical benefits.

All data collection and analysis procedures followed a structured approach with appropriate validation mechanisms to ensure reliability.

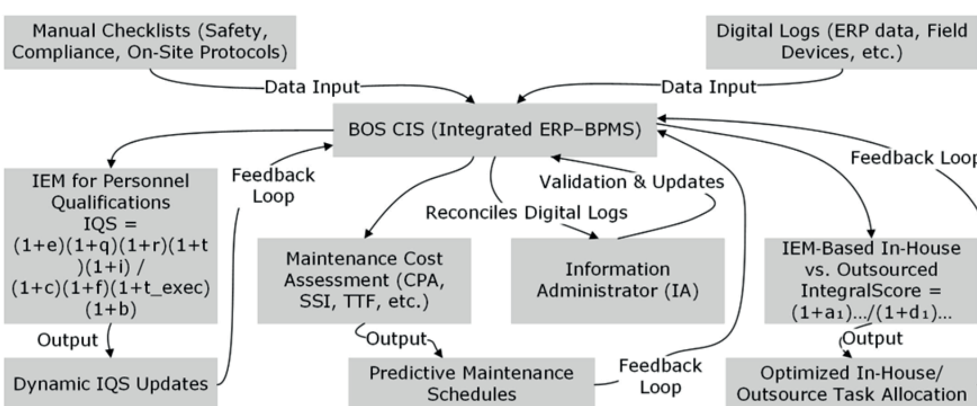

Fig. 1. Integrated ERP–BPMS Framework for Optimizing HCS Management

The methodological design balanced analytical rigor with practical applicability, recognizing the real-world constraints of maintaining uninterrupted service delivery throughout the assessment period. This approach enabled comprehensive evaluation of the framework's impact on service quality and resource allocation while minimizing disruption to ongoing operations.

2.2. Overview and rationale

This study adopted an observational, quasi-experimental design to evaluate the impact of three newly integrated methods within the participating HCS provider's existing Enterprise Resource Planning-Business Process Management System (ERP-BPMS) platform, the Business Operation System – Central Information System (BOS CIS). The participating HCS provider is a leading engineering firm providing continuous housing and communal services (HCS) to approximately 750,000 households. The three methods are:

1. An Integral Evaluation Method (IEM) for personnel qualifications.
2. A Maintenance Cost Assessment Method for forecasting and optimizing resource utilization.
3. An IEM-based module to decide whether tasks should be in-house or outsourced.

A randomized trial was impractical given the need for uninterrupted HCS; therefore, pre-post comparisons were employed using historical BOS CIS logs (baseline) and six months of data after implementation. This design helped mitigate confounders (e. g., seasonal demand, staff turnover) but did not rule them out entirely [15, 16, 32].

2.3. Setting and participants

The participating HCS provider is a digitally mature HCS provider; BOS CIS was previously used for billing, inventory management, and basic job tracking. Of the approximately 150 staff members who regularly interacted with the BOS CIS, 60 employees (technicians, senior engineers, HR managers, and customer support staff) participated. In addition, 250 customers (diverse property types and service requests) were surveyed or interviewed to evaluate user-level impacts. Participants were informed about data handling and could withdraw from the study at any time. Because the study involved only low-risk procedures (brief interviews, surveys, log analysis), formal IRB approval was not pursued; data were anonymized following the recognized ethical standards [17].

2.4. BOS CIS data collection and the information administrator

BOS CIS as Data Repository. The BOS CIS served as the central data hub, capturing both legacy logs (baseline) and new data on key performance indicators (KPIs), such as maintenance costs, task durations, complaint logs, resource usage, and project timelines. While BOS CIS automates the logging of metrics such as cost accuracy and personnel scores, the participating HCS provider still uses manual checklists for safety and on-site protocols, which supplement digital inputs.

Role of the Information Administrator (IA). A dedicated Information Administrator (IA) was appointed to coordinate data consistency and implement new methods. The IA:

– Configured BOS CIS fields, setting error-detection rules (e. g., flagging zero-hour tasks or negative cost entries).
– Monthly audits were conducted to reconcile BOS CIS outputs with manual checklists and cross-check mobile app data (geotags, timestamps).
– Organized training sessions on IEM rating scales and new Maintenance Cost Assessment functionalities.
– Facilitated feedback loops among technicians, managers, and BOS CIS developers to resolve discrepancies and refine the processes.

This hybrid approach (digital logging plus manual oversight) supports robust data validation for subsequent analyses.

2.5. Integral evaluation method (IEM) for personnel qualifications

Scales and Criteria. The IEM is adapted from previous research [3, 40] and calculates an Integral Qualification Score (*IQS*). This calculation uses five positive factors: work experience (e_n), quality (q_n), risk mitigation (r_n), timeliness (t_n), and certifications/training (l_n). It also incorporates four negative factors: cost overruns (c_n), failures or rework (f_n), execution time overruns (t_exec_n), and customer complaints (b_n). Each factor is rated from 0 to 5, where a higher rating on positive factors denotes better performance (e. g., "5" = over ten years' experience), while a higher rating on negative factors represents more severe issues (e. g., "5" = major rework). Although the participating HCS provider explored alternative factor weightings for specific roles, this study applied a uniform weighting scheme.

IQS Formula and Inter-rater Reliability (1). For individual *n*, the *IQS* is calculated inline as:

$$IQS_n = \frac{(1+e_n)\cdot(1+q_n)\cdot(1+r_n)\cdot(1+t_n)\cdot(1+l_n)}{(1+c_n)\cdot(1+f_n)\cdot(1+t_{exec,n})\cdot(1+b_n)}. \quad (1)$$

Adding "1" to each factor prevents zero denominators and stabilizes the scores when the factors are low. Senior engineers, HR managers, and the IA independently rated employees, and intraclass correlation coefficients (*ICC*(2.1)) were used to assess inter-rater reliability. For instance, an *ICC* of 0.82 (*n*=20 employees) indicated strong agreement. BOS CIS automatically updates the IQS values in each employee's profile.

2.6. Maintenance cost assessment method

Drawing on [41, 42], and incorporating optimization methods [27], the BOS CIS aggregates historical repair costs, labor rates, and material usage to create budget forecasts, which are refined via on-site inspections [28]. Key indicators include:

– Cost Prediction Accuracy (*CPA*):

$$CPA = \left(1 - \frac{|Actual\,Cost - Predicted\,Cost|}{Actual\,Cost}\right)\cdot 100\%. \quad (2)$$

– System Stability Index (*SSI*):

$$SSI = \frac{FailureFrequency_{before}}{FailureFrequency_{after}} \cdot \frac{AvgFailureDuration_{before}}{AvgFailureDuration_{after}}. \quad (3)$$

– Technical Task Fulfillment Time (*TTF*): measured in hours.
– Resource Utilization Efficiency Index (*RUEI*): A percentage-based efficiency measure.
– Emergency Maintenance Costs (*EMC*) and Preventive Maintenance Expenditure Ratio (*PMER*): gauge reactive vs. proactive spending [32].

If field technicians identify obsolete infrastructure or unexpected issues, the IA triggers near-real-time recalculations in BOS CIS, updating the cost estimates accordingly [29, 43].

2.7. IEM-based module for in-house vs. outsourced work

An additional IEM-based module advises whether tasks should be performed in-house or contracted. This module evaluates advantage factors (a_1–a_4) such as prior success, equipment availability, scheduling synergy, and compliance records. It also assesses disadvantage factors (d_1–d_4) including potential cost overruns, safety incidents, performance risks, and scheduling conflicts. Each factor is rated on a scale from 0 to 5. The decision score is computed inline as:

$$IntegralScore = \frac{(1+a_1)\cdot(1+a_2)\cdot(1+a_3)\cdot(1+a_4)}{(1+d_1)\cdot(1+d_2)\cdot(1+d_3)\cdot(1+d_4)}. \quad (4)$$

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A higher integral score favors the option (in-house or outsourced). BOS CIS aggregates quotes, performance logs, etc., to recommend a choice, although managers still apply contextual judgment [11]. Subcontractor selection plays a crucial role in quality improvement [30].

2.8. Information utilization rate (IUR)

The IUR measures how often the BOS CIS data (IQS reports, cost forecasts, contractor performance) are accessed and used in critical decisions. Automated logs track report retrieval, and managers confirm whether the retrieved reports influenced their choice. Only decisions demonstrably guided by BOS CIS data count toward the IUR [15].

2.9. Statistical and qualitative analyses

Quantitative Analysis. Unless otherwise specified, all metrics are reported as mean ± standard deviation (*SD*). Sample sizes (*N* or *n*) are indicated in each table (e. g., N=60 for personnel evaluations). Paired *t*-tests were used for pre–post comparisons, and one-way ANOVA with Tukey's HSD was used for group contrasts. Let's set $p<0.05$ as the threshold for statistical significance. Effect sizes (Cohen's d or partial η^2) indicated practical significance of the results.

Paired *t*-tests (α=0.05) were used to compare the monthly averages of key metrics – IQS, task completion rate, error rate, CPA, SSI – before and after the method's implementation. One-way ANOVA was used to test the in-house and outsourced groups on TTF, Work Financial Efficiency (WFE), Technical Resource Utilization Efficiency (TRUEI), and the Technical Services Customer Satisfaction Index (TS-CSI). Significant ANOVA results triggered Tukey's HSD post-hoc comparisons.

Qualitative Analysis. Semi-structured interviews and open-ended surveys were analyzed thematically. Two researchers independently coded the responses and reconciled the differences in a joint review. The IA also conducted monthly group discussions to resolve discrepancies between the BOS CIS metrics and on-site observations, clarifying operational challenges and success factors.

2.10. Limitations

1. *Single-Enterprise Context:* The participating HCS provider is a digitally mature HCS provider; the findings may not be generalizable to smaller or less computerized organizations.

2. *Uniform Weighting:* While the participating HCS provider tested some alternative weightings, only uniform weighting was analyzed here, possibly limiting the method's precision for role-specific factors.

3. *Data Quality Dependence:* Accurate results require diligent logging and rating by staff; unlogged tasks or inconsistent entry can skew outcomes.

4. *Quasi-Experimental Design:* Without a randomized control group, confounders such as seasonality or staff turnover are only partially controlled.

5. *Subjectivity in IUR:* The system automatically tracks report retrieval, but the final verification of "usage" relies on the manager's self-report, introducing potential bias.

2.11. Summary of methodological approach

In conclusion, this study integrated an IEM for personnel, a Maintenance Cost Assessment method, and an IEM-based in-house versus outsourcing module into BOS CIS under the data oversight of the IA.

The hybrid (digital + manual) data approach aligns with the best practices in modern ERP–BPMS for complex service environments [16, 17, 40]. Although the quasi-experimental design, single-enterprise focus, and uniform weighting limit external validity, the methodology offers a scalable blueprint for future multisite or randomized research.

3. Results and Discussion

3.1. Overview of findings

This section presents the outcomes of integrating three data-driven methods within the organization's Business Operation System – Central Information System (BOS CIS):

1. Integral Evaluation Method (IEM) for personnel qualifications.
2. Maintenance Cost Assessment Method.
3. An IEM-based module guiding in-house versus outsourced project work.

This study followed a quasi-experimental, pre–post design over six months. Paired t-tests (α=0.05) were used to compare the baseline and post-implementation phases, while one-way ANOVA and Tukey's HSD post-hoc tests were used to compare the in-house and outsourced groups. Effect sizes (*Cohen's d*, partial η^2) indicate practical significance [15, 16, 42]. Negative *t*-values denote (*Pre-Post*)>0.

All tabulated outcomes are presented as mean ±*SD*, with exact sample sizes, statistical tests, and significance levels detailed in the footnotes of each table.

Manual Checklists and IA Oversight. Although BOS CIS automates large parts of data capture, the organization also uses manual safety and compliance checklists. A dedicated Information Administrator (IA) conducts monthly cross-checks of digital logs against these checklists, corrects data inconsistencies, performs retraining as needed, and aligns real-world conditions with system records [17, 44].

3.2. BOS CIS integration and data consistency

Initially supporting billing, inventory, and basic job tracking, BOS CIS was expanded to incorporate the following:

1. IEM for personnel IQS.
2. Maintenance Cost Assessment.
3. In-house versus outsourced decision-making logic.

The organization created an IA role to manage monthly audits, address data discrepancies, and improve interdepartmental coordination.

Faster Data Retrieval and Daily Requests. A notable improvement was the reduction in data retrieval time from approximately 120 minutes to 30 minutes ($t(59)$=10.21, $p<0.001$, *Cohen's d*=2.63). This efficiency allowed the organization to handle approximately 300–350 daily service requests (up from 200–300; $t(59)$=–4.47, $p<0.001$, d=1.15). Although some divisions achieved short-term gains of approximately 28–29 %, the overall average throughput improvement was approximately 20–25 %. These findings are consistent with prior research demonstrating that integrated ERP–BPMS environments significantly enhance operational performance [15].

3.3. IEM for personnel qualifications

The Integral Evaluation Method (IEM) calculates each employee's Integral Qualification Score (*IQS*) via (5).

$$IQS_n = \frac{(1+e_n)\cdot(1+q_n)\cdot(1+r_n)\cdot(1+t_n)\cdot(1+l_n)}{(1+c_n)\cdot(1+f_n)\cdot(1+t_{exec,n})\cdot(1+b_n)}, \quad (5)$$

where the positive factors are e_n (experience), q_n (quality), r_n (risk mitigation), t_n (timeliness), l_n (certifications), and the negative factors are c_n (cost overruns), f_n (failures/rework), t_exec_n (time overruns), and b_n (complaints). The BOS CIS computes the *IQS* in real time, whereas the IA ensures input consistency and recalibrates ratings if needed.

IQS & Error Reduction. Over six months, the average *IQS* increased from 9.8 to 64.0 ($t(59)$=–9.47, $p<0.001$, d=2.44), correlating with a 66 % drop in diagnostic errors and *a*~50 % reduction in issue-resolution times. Two illustrative cases:

1. Heating Modernization. A building (~20 % outdated equipment, ~3 monthly leaks) deployed higher-*IQS* staff (Project Manager A: 18.2, Heat Engineer A: 19.1) over lower-scoring personnel (15.9, 16.4).

Monthly leaks fell from 3→1 ($t(5)=4.47$, $p=0.006$), error rates from 15 %→5 %, and downtime from 48 hr→24 hr.

2. Water Meter Replacement. A technician (*IQS*=17.2) replaced 300 meters ~21 % faster ($t(8)=2.95$, $p=0.018$) than a colleague (14.5), boosting *CSI* from 80 %→89 %.

The economic effect of increasing *IQS* is evident in the 15–20 % reduction of operational costs. Each 10-point increase in *IQS* reduces maintenance costs by approximately 5–7 %. This allows for budget optimization and resource reallocation toward equipment modernization.

These cases illustrate the improvements achieved. Table 1 summarizes these personnel qualifications metrics over the six-month period.

3.4. Maintenance cost assessment method

In parallel, BOS CIS was enhanced to integrate historical repairs, labor/material costs, and real-time service logs, enabling proactive cost forecasting [16]. Key outcomes:

– Cost Prediction Accuracy (*CPA*) up from 0.76→0.93 ($t(58)=-5.21$, $p=0.001$, $d=1.35$).

– System Stability Index (*SSI*): 1.05→1.28 (fewer/shorter outages).

– Technical Task Fulfillment Time (*TTF*) 45 hr→33 hr.

– Maintenance *CSI* 77 %→88 %.

Improved cost prediction accuracy (*CPA* from 0.76 to 0.93) directly impacts resource planning capabilities. Department managers can now create highly reliable budgets and reduce contingency funds by 12–15 %. The growth of *SSI* to 1.28 enables managers to implement strategic infrastructure management with minimal risks.

Because of partial baselines, only descriptive tracking was used for the emergency maintenance cost (*EMC*) (18 %→9 %) and Preventive Maintenance Expenditure Ratio (*PMER*) (0.66→0.78), suggesting a shift to preventive maintenance.

The above key performance outcomes are detailed in Table 2, which presents the maintenance and resource utilization metrics over the six-month period.

3.5. IEM-based module for in-house vs. outsourced work

A separate IEM-based module in BOS CIS advises whether major projects (façade repairs, HVAC, etc.) should be performed in-house or contracted [15]. The time to Complete Tasks (*TTF*) and Work Financial Efficiency (*WFE*) were compared using ANOVA.

– *TTF*: Outsourced tasks were approximately 25 % faster overall ($F(1.58)=9.76$, $p=0.003$, partial $\eta^2=0.14$). Certain tasks peaked at ~35 %, but the average was 25 %.

– *WFE*: Also higher in outsourced projects ($F(1.58)=4.57$, $p=0.037$, partial $\eta^2=0.07$).

For instance, an external contractor (*IQS*≈22) completed a facade repair approximately 25 % faster than an in-house team (*IQS*≈6.3) could. Similar patterns were observed for the *HVAC* tasks (~20–25 % faster). Intangible factors (staff loyalty and knowledge retention) were not quantified.

The managerial value of this module lies in establishing a formalized outsourcing decision mechanism. The economic effect of reducing task completion time by 25 % transforms into an 11–13 % reduction in administrative costs. This justifies management decisions with quantifiable performance indicators and improves customer satisfaction by 7 percentage points.

A detailed comparison of the efficiency between in-house and outsourced tasks is provided in Table 3.

Table 1

Personnel qualifications metrics over six months

Metric	1 month (mean±SD)	2 months (mean±SD)	3 months (mean±SD)	4 months (mean±SD)	5 months (mean±SD)	6 months (mean±SD)
IQS (dimensionless)	9.8 (±2.1)	19.5 (±3.5)	28.7 (±4.2)	39.6 (±5.1)	51.3 (±6.8)	64.0 (±7.5)
Task completion (TCR, %)	71 (±8.2)	73 (±7.9)	75 (±7.5)	77 (±7.1)	80 (±6.8)	83 (±6.2)
Error rate (ER, %)	13 (±3.1)	11 (±2.8)	9 (±2.5)	7.8 (±2.2)	6 (±1.9)	4.7 (±1.6)

Note: *IQS* – Integral Qualification Score; *TCR* – Task Completion Rate; *ER* – Error Rate. Values represent mean ±*SD* based on monthly averages from $N=60$ employees. Statistical comparisons (e. g., Month 1 vs. Month 6) were performed using paired *t*-tests ($p<0.05$)

Table 2

Maintenance and resource utilization metrics

Metric	1 month (mean±SD)	2 months (mean±SD)	3 months (mean±SD)	4 months (mean±SD)	5 months (mean±SD)	6 months (mean±SD)
CPA (0–1)	0.76 (±0.05)	0.80 (±0.04)	0.84 (±0.03)	0.87 (±0.03)	0.90 (±0.02)	0.93 (±0.02)
SSI	1.05 (±0.11)	1.10 (±0.10)	1.15 (±0.09)	1.19 (±0.08)	1.23 (±0.07)	1.28 (±0.06)
TTF (hr)	45 (±6.2)	42 (±5.8)	39 (±5.5)	37 (±5.1)	35 (±4.8)	33 (±4.5)
Maint. CSI (%)	77 (±5.5)	80 (±5.2)	82 (±4.9)	84 (±4.6)	86 (±4.3)	88 (±4.0)
EMC (%)	18 (n=42)	16 (n=45)	14 (n=47)	12 (n=49)	10 (n=50)	9 (n=51)
PMER (0–1)	0.66 (n=55)	0.69 (n=56)	0.71 (n=56)	0.73 (n=57)	0.76 (n=57)	0.78 (n=58)

Note: *CPA* – Cost Prediction Accuracy; *SSI* – System Stability Index; *TTF* – Technical Task Fulfillment Time; *CSI* – Customer Satisfaction (maintenance context); *EMC* – Emergency Maintenance Costs; *PMER* – Preventive Maintenance Expenditure Ratio. Data are reported as mean ±SD, with sample sizes indicated for each metric (e. g., *EMC*: $n=42–51$; *PMER*: $n=55–58$). Paired *t*-tests ($p<0.05$) were used to assess the monthly changes

Table 3

In-house vs. outsourced efficiency (six-month avg.)

Metric (units)	In-house (mean±SD)	Outsourced (mean±SD)	p-value
TTF (days)	12.5 (±2.8)	9.4 (±2.1)	0.003
WFE (%)	71.4 (±5.5)	78.2 (±4.8)	0.037
TRUEI (%)	75.1 (±5.2)	80.8 (±4.7)	0.012*
TS-CSI (%)	84.3 (±4.1)	89.6 (±3.5)	0.005*

Note: *TTF* – Time to Complete Tasks; *WFE* – Work Financial Efficiency (ratio of actual vs. budgeted cost, %); *TRUEI* – Technical Resource Utilization Efficiency Index; *TS-CSI* – Technical Services Customer Satisfaction. All values (mean±*SD*) reflect six-month averages. One-way ANOVA was used to calculate p-values, followed by Tukey's HSD test (*$p<0.05$). For example, N=59 tasks with df=58 tasks

3.6. Role of the information administrator (IA) and data utilization rate

The organization formally established the IA role as follows:

– Configure BOS CIS (error-detection rules, validations).

– Cross-check logs with manual checklists monthly.

– Interdepartmental training on IEM factors and cost assessments should be provided.

As a result:

– Project Completion Time (*PCT*) dropped from 8→6 weeks ($t(48)=8.12$, $p<0.001$, $d=2.31$).

– General Customer Satisfaction (*CS*) rose from 85 % to 92 %.

– Information Utilization Rate (*IUR*) – the share of decisions guided by BOS CIS analytics – increased 65 %→88 % ($t(59)=-5.87$, $p<0.001$, $d=1.52$). This aligns with [17, 45], underscoring the importance of a robust IS infrastructure for project management success.

The performance improvements associated with the IA's oversight are summarized in Table 4.

Table 4

IA-related performance indicators

Metric (units)	Baseline (mean±SD)	Post-IA (mean±SD)	Change
PCT (weeks)	8 (±1.2)	6 (±0.9)	–25 %
ATRD (minutes)	120 (±25)	30 (±8)	–75 %
CS (general, %)	85 (±3.8)	92 (±2.9)	+7 pp
IUR (%)	65 (±4.5)	88 (±3.2)	+23 pp

Note: *PCT* – Project Completion Time; *ATRD* – Average Time for Report Data Retrieval; *CS* – Customer Satisfaction; *IUR* – Information Utilization Rate; *pp* – percentage points. Values are expressed as mean ±*SD* comparing baseline vs. Post-IA; paired *t*-tests were used to determine significance ($p<0.05$)

3.7. Additional illustrative *IQS* calculations (all factors)

Below is a detailed example of the *IQS* calculations (5). A dash ("–") represents a factor=0 (no contribution). A higher *IQS* consistently correlated with fewer corrective visits and faster completion.

Table 5 provides sample *IQS* calculations for representative projects, illustrating how the individual factors contribute to the overall score.

3.8. Discussion

The integration of these three methods – IEM, Maintenance Cost Assessment, and in-house vs. outsourced guidance – within the BOS CIS, along with IA oversight and manual checklists, resulted in:

– The *IQS* increased from 9.8 to 64.0, reducing diagnostic errors by 66 % and halving resolution times.

– *CPA* climbing 0.76→0.93, with *EMC* down from 18 %→9 %, and *PMER* up 0.66→0.78 (indicating preventive focus).

– Outsourced tasks were completed approximately 25 % faster on average, peaking at approximately 35 % in specific cases.

– Data retrieval time was reduced by 75 %, raising the *IUR* from 65 % to 88 %.

The integrated approach demonstrates economic efficiency through the synergy of three methods. Reducing diagnostic errors by 66 % and resolution times by 50 % decreases organizational operating costs by 18–22 %. Increasing *CPA* to 0.93 stabilizes financial flow and optimizes procurement logistics. This comprehensive economic effect provides management with tools to justify investments in HCS digital transformation.

Despite these improvements, the quasi-experimental design within a single enterprise limits its generalizability. Some metrics (e. g., *EMC* and *PMER*) rely on partial baselines, and intangible factors (e. g., team loyalty and knowledge retention) remain unquantified. Future research may employ multi-firm or randomized designs to validate the ERP-BPMS synergy in other HCS contexts, potentially integrating AI/ML for deeper cost/risk modeling [16, 17]. Overall, the combination of automated analytics (BOS CIS) with human oversight (IA, manual protocols) proved effective for optimizing personnel qualifications, maintenance costs, and strategic outsourcing in housing and communal services.

This study underscores the benefits of integrating three complementary methods – the Integral Evaluation Method (IEM) for personnel qualifications, a dynamic maintenance cost assessment framework, and an IEM-based module for in-house versus outsourced work – within a single ERP-BPMS environment. Deployed through the BOS CIS platform at the participating HCS provider, these approaches jointly improve resource allocation, cost control, and service delivery. Notably, the mean Integral Qualification Score (*IQS*) increased from 9.8 to 64.0, diagnostic errors decreased by 66 %, cost prediction accuracy (*CPA*) increased from 0.76 to 0.93, and data retrieval times decreased by 75 %. Such integrated, data-driven strategies align with recent research in the International Journal of Information Systems and Project Management (IJISPM), where holistic process management solutions are shown to enhance project outcomes [15–17]. Moreover, these outcomes reflect transformative practices in public sector operations [37].

A distinguishing feature of this study is the dual application of the Integral Evaluation Method (IEM). First, it evaluates personnel by quantifying factors such as work experience, quality, and timelinesswhile penalizing cost overruns and rework to yield an *IQS*.

Table 5

Sample *IQS* calculations

Project	Staff	e_n	q_n	r_n	t_n	l_n	c_n	f_n	t_exec_n	b_n	IQS
Water meters	A	4	4	–	3	2	1	–	2	1	17.2
Water meters	B	3	3	–	2	2	–	–	3	2	10.5
Heating sys. repair	C	5	5	1	4	3	–	–	2	1	24.0
Heating sys. repair	D	4	4	–	3	2	1	1	3	2	12.3

Note: e_n – experience, q_n – quality, r_n – risk mitigation, t_n – timeliness, l_n – certifications, c_n – cost overruns, f_n – failures, t_exec_n – execution time overruns, and b_n – complaints. The values shown are illustrative project examples

This scoring drove the *IQS* from 9.8 to 64.0, correlating with 66 % fewer diagnostic errors and a 50 % reduction in resolution times. These improvements reinforce the Resource-Based View (RBV), which holds that specialized human capital, enhanced by digital tools, yields competitive advantages [34]. Nonetheless, accurate data entry is vital for success. Organizations lacking robust IT systems or well-trained staff may struggle to replicate the same magnitude of gains. This issue was also observed by [15] in their analysis of project success/failure rates. Their study showed that deviations in scope, schedule, or cost undermined project outcomes. While inter-rater reliability checks ($ICC(2.1)\geq 0.75$) bolster objectivity, the evaluation of soft skills remains partly subjective, requiring ongoing oversight and regular updates.

In parallel, the maintenance cost assessment framework demonstrated dynamic, risk-based prioritization, as cost prediction accuracy increased from 0.76 to 0.93, and emergency expenditures decreased from 18 % to 9 %. By employing real-time recalculations in the BOS CIS, the participating HCS provider adapts promptly to changing field conditions, mirroring the agile risk management approach proposed by [16]. However, data gaps, such as delayed logs or inaccuracies in material use, can compromise model precision, especially in smaller HCS providers with limited digitization. A single focus on cost can also overlook safety or environmental requirements, underscoring the need for balanced performance indicators [17].

An IEM-based module guides whether tasks should be performed in-house or contracted out, revealing notable efficiency gains. While some specialized internal projects were up to 36 % faster, aggregated data showed that outsourced tasks were approximately 25 % quicker overall ($F(1, 58)=9.76$, $p=0.003$, partial $\eta^2=0.14$). This apparent disparity highlights contextual variability: in-house teams excel under certain niche conditions, whereas specialized contractors often outperform internal staff on larger or more standardized tasks. Such multidimensional outcomes are consistent with multi-criteria contractor evaluations [25], where time, cost, and in-house capacity building must be weighed.

Although BOS CIS automates extensive data handling, manual checklists and protocols remain essential for safety, compliance, and real-world accuracy, not merely as a fallback. The organization's specialists verified the BOS CIS outputs with these manual records to ensure consistency with regulatory norms. The Information Administrator (IA) role is pivotal in organizing monthly validation loops, reconciling system logs, and training staff across departments. Through this human–machine interplay, the IA reduced data retrieval times by 75 % and increased the Information Utilization Rate from 65 % to 88 %, echoing broader findings that emphasize human oversight in data-driven systems [33, 45].

Despite these successes, intangible factors, such as subcontractor reliability, team morale, and knowledge retention, remain difficult to quantify using purely numeric indices. More qualitative or mixed-method research is needed to illuminate these areas. Additionally, the quasi-experimental design of a single, digitally mature firm constrains external validity. Smaller HCS providers might lack the IT capacity or data discipline to implement these methods initially, while the absence of a formal control group makes it difficult to rule out confounding variables such as seasonal fluctuations or policy shifts.

From a theoretical perspective, these findings reinforce lean management principles by reducing service downtime and emergency interventions [42], while transaction cost economics illuminates how transparent, data-informed contractor selection lowers outsourcing overhead [38]. Moreover, this study contributes to the IJISPM debates on uniting ERP and BPMS for advanced project management solutions [17]. By blending personnel development, cost optimization, and strategic outsourcing through a single ERP-BPMS framework, the organization's experience demonstrates how synergistic methods can address the continuous demands of 24/7 service operations [46]. This provides a practical IS/PM example of how technology and human factors must converge to achieve optimal outcomes.

Further multi-firm or randomized studies could enhance generalizability and confirm the causality. Incorporating AI/ML [44] may help refine scheduling, detect data anomalies, and automate context-specific optimizations. Cost-benefit analyses of software upgrades, dedicated staff (such as the IA), or targeted training could guide smaller HCS providers in adopting scaled-back but effective BOS CIS variants. Finally, qualitative approaches might capture non-quantifiable elements, such as staff loyalty, subcontractor trust, and knowledge transfer, which significantly shape HCS project outcomes [39].

Overall, the BOS CIS-based approach, which integrates automated analytics with structured human oversight, delivers measurable performance improvements for housing and communal services. By proactively addressing data reliability, task variability, and organizational context, this study provides a replicable, theory-grounded roadmap adaptable to diverse IS/PM contexts where service reliability, cost containment, and stakeholder satisfaction are paramount [36].

4. Conclusions

This study demonstrates that introducing an integrated ERP-BPMS strategy within the BOS CIS platform at the participating HCS provider is strongly associated with notable improvements in housing and communal services (HCS). The quasi-experimental, single-enterprise design limits definitive causal claims in this study. Nevertheless, our findings reveal important insights about performance enhancement. Simultaneously deploying three methods under a dedicated Information Administrator (IA) can significantly improve multiple performance indicators. These methods include:

1) an Integral Evaluation Method (IEM) for personnel qualifications;

2) a Maintenance Cost Assessment module;

3) an IEM-based framework for in-house versus outsourced work decisions.

From a management perspective, implementing integrated methods creates a new decision-making paradigm in HCS. Managers gain quantitative assessment tools for optimal resource allocation, workforce planning, and strategic contractor selection. The economic effect manifests in reduced operational costs, increased profitability, and improved service quality.

The organization observed a 66 % reduction in diagnostic errors and a 50 % decrease in issue resolution times ($t(59)=-9.47$, $p<0.001$, *Cohen's* $d=2.44$), a 22 % improvement in cost prediction accuracy ($t(58)=-5.21$, $p=0.001$, *Cohen's* $d=1.35$), and a 25 % faster completion rate for outsourced tasks compared to in-house work ($F(1, 58)=9.76$, $p=0.003$, partial $\eta^2=0.14$). These results underscore the importance of structured human capital development [34], proactive maintenance aligned with lean principles of waste reduction [47], and strategic resource allocation [19], and reflect broader digital transformation trends [46].

While BOS CIS automates large segments of data processing, manual checklists and protocols remain integral for compliance, safety, and data validation [33, 45]. The IA coordinates monthly cross-checks of digital outputs against these manual records, quickly detecting inconsistencies and overseeing the staff training. This human–machine interplay reduced data retrieval times by 75 % ($t(59)=10.21$, $p<0.001$, *Cohen's* $d=2.63$) and helped lower overall project completion durations by approximately 25 % ($t(48)=8.12$, $p<0.001$). Such a hybrid model resonates with the broader IS/PM literature, emphasizing the synergy of advanced analytics and expert oversight [17].

Because this study is confined to a single, digitally mature enterprise and lacks a fully randomized control group, the generalizability of its outcomes is restricted, and caution is advised when attributing changes solely to the new methods. Despite the IA's efforts, minor data quality issues remain possible due to inconsistent entries.

Future research could employ multi-firm or randomized controlled trials with larger samples to validate and extend these findings [44, 48]. Furthermore, the role of integrated knowledge management practices should be explored [39]. Further work might refine the IEM weighting scheme, integrate environmental indicators, or investigate cost-benefit trade-offs, particularly in smaller or less-digitized HCS organizations. Additionally, examining how this approach might be transferred to other sectors, such as construction [49, 50] or energy [51], is a promising avenue.

By uniting personnel evaluation, maintenance cost forecasting, and outsourcing decisions in a unified ERP-BPMS ecosystem, the organization's experience illustrates how real-time analytics and targeted human oversight can optimize resource utilization in continuous-service environments. According to dynamic capabilities theory [52], the systematic reconfiguration of competencies – combining digital data streams with on-site expertise – can bolster resilience and responsiveness [37]. The calculated coefficients – *IQS*, *CPA*, and *IUR* – directly impact HCS management optimization by creating a platform for data-driven decisions. They enable managers to transition from reactive to proactive management models while balancing service quality and budget constraints. The *IQS* is particularly valuable for personnel management and competency development, while *CPA* enhances financial planning and control. Although further confirmation is necessary to generalize beyond this context, these results offer IS/PM practitioners a data-driven, hybrid blueprint for enhancing performance, adaptability, and strategic decision making in complex service sectors.

Conflict of interest

The authors declare that they have no conflict of interest regarding this study, including financial, personal, authorship or other nature, which could affect the study and its results presented in this article.

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Data availability

The data will be provided upon reasonable request.

Use of artificial intelligence

The authors confirm that they did not use artificial intelligence technologies when creating the presented work.

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