BUILDING DECISION SUPPORT SOFTWARE FOR OPTIMIZING THE MANAGEMENT OF EXISTING RESOURCES IN ELECTRICAL TESTING OPERATIONS

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Abstract - The Central Electrical Testing Company Limited (CPCETC) is currently facing challenges in managing limited resources (personnel, equipment, and transportation) due to manual workflows, resulting in inefficiency and data fragmentation. This paper proposes a Decision Support System (DSS) developed on the .NET MVC and SQL Server platforms to optimize production management. The system integrates GPS, Artificial Intelligence (AI), and EVN CA digital signatures to automate planning and resource allocation following the principle of "one-time input, multi-dimensional utilization." Practical implementation since January 2025 has demonstrated significant improvements: operational time reduced by 30–40%, operating costs decreased by 10–12%, productivity increased by 15–20%, profit rose by 22.5%, contract delays dropped by 31.2%, and acceptance quality was improved by 28.7%. The system thereby establishes a unified and robust data foundation for the company's digital transformation.

Key words - Decision Support Software; Resource Optimization; Mixed-Integer Programming; Electrical Testing; .NET MVC and SQL Server.

Tóm tắt - Công ty TNHH MTV Thí nghiệm Điện Miền Trung (CPCETC) hiện gặp khó khăn trong việc điều phối nguồn lực hữu hạn (nhân sự, thiết bị, vận tải) do quy trình thủ công, gây lãng phí và phân tán dữ liệu. Bài báo đề xuất hệ thống hỗ trợ ra quyết định (DSS) phát triển trên nền tảng .NET MVC và SQL Server nhằm tối ưu hóa điều hành sản xuất. Hệ thống tích hợp GPS, trí tuệ nhân tạo (AI) và chữ ký số EVN CA để tự động hóa lập kế hoạch và điều động nguồn lực theo triết lý "một lần nhập, khai thác đa chiều". Ứng dụng thực tế từ tháng 01/2025 cho thấy hiệu quả rõ rệt: thời gian điều hành giảm 30–40%, chi phí vận hành tiết kiệm 10–12%, năng suất tăng 15–20%, lợi nhuận tăng 22,5%, giảm chậm trễ hợp đồng 31,2% và cải thiện chất lượng nghiệm thu 28,7%, góp phần xây dựng nền tảng dữ liệu thống nhất cho chuyển đổi số doanh nghiệp.

Từ khóa - Phần mềm hỗ trợ ra quyết định; Quản lý nguồn lực; Tối ưu hóa; Lập trình số nguyên hỗn hợp; Thí nghiệm điện;.NET MVC và SQL Server.

1. Introduction

Electrical testing is a critical engineering discipline that ensures the safety, stability, and reliability of power systems. This field is highly specialized, requiring in-depth technical expertise, and its core outputs include test reports and legal documentation. Effective management of the process-from contracting and implementation to final acceptance-is vital to the success of the project.

In practice, contract management in the electrical testing sector in Vietnam still exhibits significant limitations. Most enterprises continue to rely on manual tools such as Excel spreadsheets and paper-based documentation, resulting in fragmented and inconsistent data. This manual management model introduces substantial risks, including loss of project control, ineffective change management, and constraints in information systems due to the absence of dedicated software solutions. These issues hinder the ability of enterprises to evaluate contract performance and ultimately lead to profit loss.

Globally, the optimization of scheduling and dispatching for technical services has been addressed using complex models. Numerous studies have applied mixed-integer programming (MIP) or meta-heuristic algorithms to incorporate constraints related to personnel, equipment, and routing problems (VRP). Additionally, multi-period and multi-echelon mixed-integer linear programming (MILP) models have been developed to minimize the costs of multi-level, multi-site, and multi-product supply chains, including transportation, inventory, processing, and administrative expenses [1–4]. However, the application of these models to the specific requirements of contract management in the electrical power sector - such as customer classification, contract administration, workforce and vehicle dispatching, equipment allocation, profit estimation, and integration with accounting processes - remains limited.

Moreover, existing studies primarily focus on optimizing individual components - such as personnel, equipment, or routing - without establishing an integrated multi-factor model suited to the operational characteristics of electrical testing, where technical, economic, and operational factors are highly interdependent.

In its comprehensive digital transformation strategy for the period 2021–2030, Vietnam Electricity (EVN) aims to become a "digital enterprise" by digitizing and automating all operational, production, and management processes. Representative solutions include the field management system (CityWork) implemented by Hanoi Power Corporation; the integration of geographic information systems (GIS), mobile platforms, and cloud technologies to support grid operation and maintenance; the digital signature and two-dimensional barcode (QR code) system adopted by the Northern Electrical Testing Company to ensure the security of technical documentation; the equipment management and on-site test report application deployed by the Central Power Service Company (CPSC) for bidding, inspection, and equipment calibration; and the integrated testing management system linking the technical management software (PMIS) and human resource management system (HRMS) of the National Power Transmission Corporation (EVNNPT), enabling full digitization of technical records [5–9]. Although significant progress has been made, these solutions primarily digitalize isolated operational functions and lack a fully integrated system that connects technical, financial, and field data.

At Central Electrical Testing Company Limited (CPCETC), despite the implementation of large-scale digitalization software (as shown in Figure 1), the system still lacks capabilities for cost analysis, cash flow, and existing resource management. Management of vehicles, fuel, and workdays remain fragmented, complicating operational management and resource optimization.

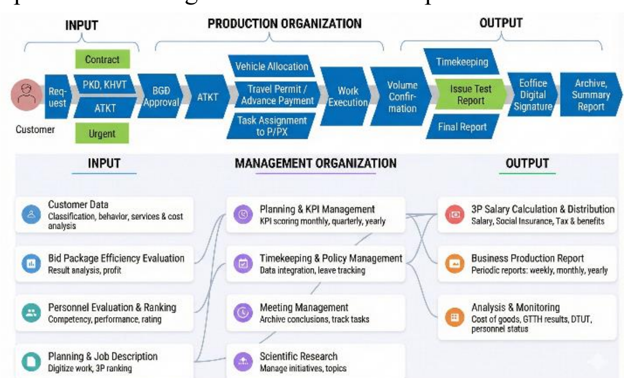

Figure 1. *CPCETC business production cycle*

Legend: *PKD: Business Department; KHVT: Planning and Materials Department; ATKT: Safety and Technical Department; BGĐ: Board of Directors; P/PX: Department/Workshop; ĐCT: Project Team; Eoffice: Electronic Office Software; KPI: Key Performance Indicators; 3P Salary: Three-factor salary system (position, individual, and performance/achievement).*

Therefore, this paper proposes the development of decision support software to simultaneously address the complex constraints faced by electrical testing units, optimizing production operations. The software is built on.NET MVC and SQL Server technologies, adhering to the "one-time input, multi-dimensional utilization" philosophy.

2. Integrated optimization model

After surveying and analyzing the contract management, production operations, and resource utilization processes at CPCETC, the research team proposes an integrated optimization model that simultaneously addresses real-time personnel, equipment, and vehicle dispatching, while accounting for contract priorities, costs, and capacity constraints.

2.1. Determination of estimated cost ($Z_{Estimate}$)

The estimated cost (denoted as $Z_{Estimate}$) serves as the breakeven point for bidding and initial financial evaluation of contracts.

According to Circular No. 13/2021/TT-BXD issued on August 31, 2021, by the Ministry of Construction, depreciation factors do not fully reflect the actual management practices at CPCETC and do not leverage existing data on equipment, vehicles, overtime, or resource quantity control.

Therefore, the estimated cost function is determined as follows:

$$Z_{Estimate} = C_{Depreciation} + C_{Personnel} + C_{Vehicle} + C_{Fixed} \quad (1)$$

Where:

- $C_{Depreciation}$: Depreciation cost of testing equipment based on actual asset value;

- $C_{Personnel}$: Average annual labor cost updated by the Finance and Accounting Department (TCKT);

- $C_{Vehicle}$: Operating cost for each type of vehicle (4–24 seats, crane/truck, etc.) according to fuel price fluctuations;

- C_{Fixed}: Fixed costs for management, general production, and finance.

The software automatically consolidates input data (personnel, vehicles, equipment, projects) from relevant departments to calculate the breakeven point (Figure 2 illustrates the workflow).

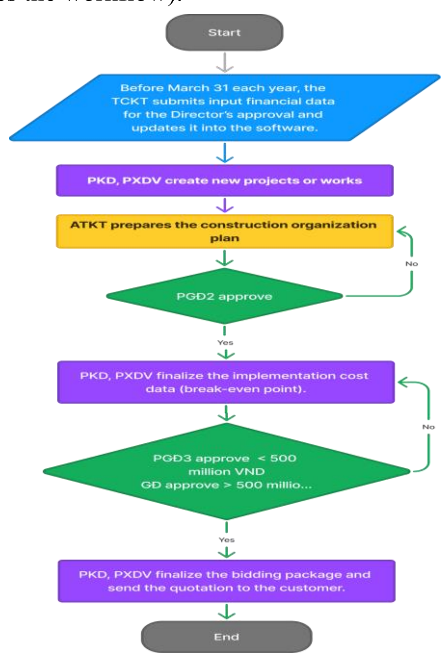

Figure 2. *Breakeven calculation flowchart*

2.2. Actual cost (Z_{Actual}) and dispatch optimization

In practice, CPCETC operates dozens of project teams daily at various locations domestically and internationally. The allocation of personnel, equipment, and vehicles must be optimized to minimize total costs while ensuring technical constraints and contract schedules.

The objective of the model is to minimize the overall operational cost Z_{Actual}:

$$\min \mathbf{Z}_{\mathbf{Actual}} = \sum Ci(xi,yi) \quad (2)$$

Subject to constraints: $Ax \leq b,\ x \in \{0,1\}$

Where:

x_i: binary variable representing the selection of personnel or vehicle i;

y_i: continuous variable representing workload or working time;

$Ax \leq b$: constraints on employee capacity and experience, energization time, vehicle fuel consumption standards, equipment inspection deadlines, and contract-specific workload and schedule requirements;

$C_i(x_i, y_i)$: incurred cost for each item (fuel, labor, depreciation, etc.).

The model is solved using Mixed Integer Programming (MIP), allowing simultaneous consideration of practical constraints such as personnel limits, equipment quantity, travel distance, and contract completion time.

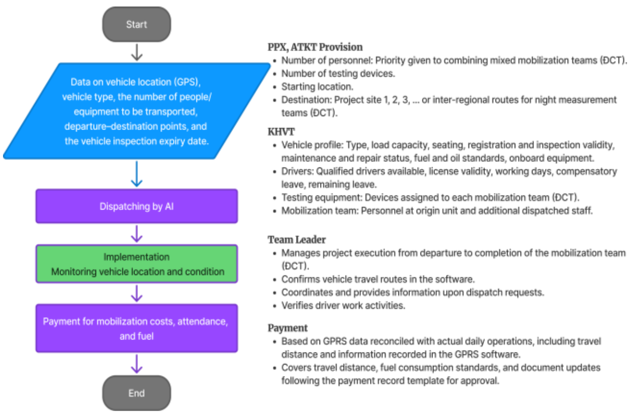

Figure 3. *Vehicle dispatch workflow chart*

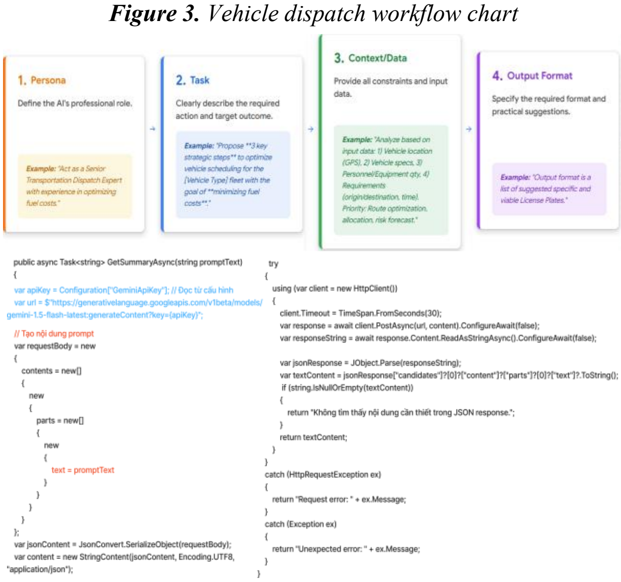

Figure 4. *Prompt structure diagram for Gemini API commands*

The software utilizes input data provided by the ATKT, P/PX, and KHVT departments. This dataset encompasses GPS locations, vehicle itineraries, and vehicle specifications (type, payload, seating capacity, inspection expiration, and fuel costs), alongside personnel and equipment quantities, and transit requirements (origin–destination, travel time). Subsequently, the AI module (integrated via the Gemini API) uses this data to suggest a cost-optimal vehicle dispatch plan. The optimization of the AI processing logic follows the prompt structure illustrated in Figure 4. Finally, the workflow proceeds to the Implementation and Cost/Fuel Payment stages (Figure 3), utilizing EVN CA digital signatures for the online approval of tasks (leave requests, overtime, timekeeping) via electronic workflow (Figure 5).

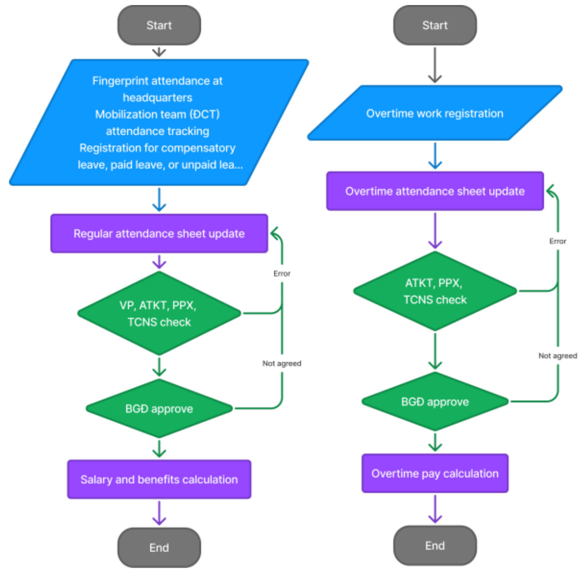

Figure 5. *Monthly timekeeping workflow chart*

2.3. Progress monitoring and test report management

In addition to resource optimization, the software provides tools for progress monitoring, asset management, and quality control of the output product - Test Reports (BBTN). Key modules include:

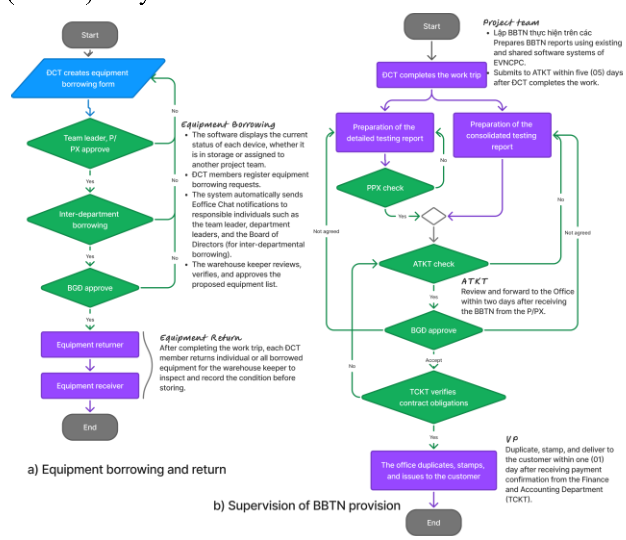

Figure 6. *Equipment borrow/return and test report status monitoring flowchart*

- Equipment Management: tracks information, calibration history, depreciation, and usage location (Figure 6a).

- Test Report Monitoring: controls the progress of report creation, signing, and issuance; alerts delays and payment condition violations (Figure 6b).

2.4. Acceptance and contract performance evaluation

Figure 7 presents the process for verifying completed volumes and calculating the Return on Sales (ROS) ratio to evaluate economic efficiency. The volume and value verification process, depicted in Figure 7a, serves as the legal and financial basis for contract payment settlement. This process is standardized as follows:

Step 1: After each work period, the construction/testing contractor is responsible for preparing the detailed completed work volume table (Figure 8). This table must clearly indicate each work code (e.g., EA.21120 – 110kV transformer testing) according to the following parameters: Contract volume (estimated or bid), actual completed volume in the period, volume difference (if any), contract unit price and corresponding amount, total completed value for the period (denoted as DSj/GTTH).

Step 2: After preparation, the completed work volume table is submitted to the functional departments (such as ATKT and PKD). These departments, in coordination with the Project Management Board (BQLDA) or the investor's representative, conduct the review and verification process. This includes checking the validity and legality of the documents, comparing the accepted quantities with the actual on-site execution, and comparing the test results (where applicable) with the relevant technical standards.

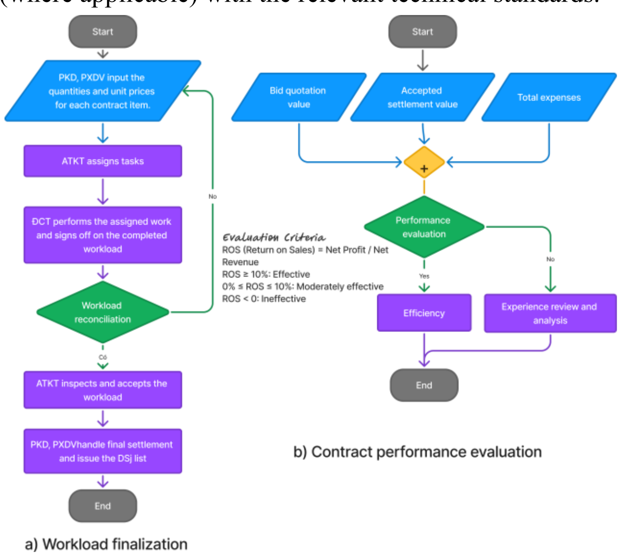

Figure 7. *Contract volume management and performance evaluation workflow*

No.	Description	Ref P/PX	Exec. Unit	Unit	Quantity					Unit Price		Contract Amount		
					Contract & Appx	Actual			Diff	Labor	Contract	Labor	DSi	Value
						Phase 1	Phase n	Accum.						
I	**Main Transformer Oil Testing**													
1	Density at 20°C	Petrochem	P9	Sample	1	1		1		170,010	302,455	170,010	170,010	302,455
2	Kinematic viscosity at 40°C	Petrochem	P9	Sample	1	1		1		317,465	657,521	317,465	317,465	657,521
3	Flash point (closed cup)	Petrochem	P9	Sample	1	1		1		317,465	611,100	317,465	317,465	611,100
4	Acid number	Petrochem	P9	Sample	1				-1	335,292	833,108	335,292	335,292	833,108
5	Water-soluble acid/base	Petrochem	P9	Sample	1				-1	353,120	635,281	353,120	353,120	635,281

Figure 8. *Detailed contract volume table*

Step 3: Only when the volume is fully confirmed and meets technical requirements is the acceptance dossier considered valid. This serves as input for the Finance and Accounting Department (TCKT) to process contractor payments according to contract terms.

Analysis of the Return on Sales (ROS) ratio and evaluation of contract economic efficiency after execution is mandatory [10]. This process is based on comparing estimated and actual cost data:

Estimated cost: Costs calculated during the bidding phase (personnel, vehicles, equipment; see section 2.1).

Actual cost (Finalization): Costs incurred during contract execution (labor, materials, fuel, testing costs, etc.), collected from the acceptance process (section 3.1) and the accounting system.

The software automatically generates analysis results (illustrated in Figure 7b), providing key quantitative data for management to assess bidding and project management effectiveness.

Remarks: The system ensures a closed-loop process from planning, operation, acceptance, and performance evaluation, forming a unified data foundation for comprehensive management and digital transformation.

3. Software development and experimental results

3.1. Hardware architecture

The system's hardware infrastructure is deployed on CPCETC's internal network platform.

The network utilizes two Internet connections (VNPT) routed through a central router, protected by a physical SRX550 firewall and two Layer 3 switches responsible for routing and IP address allocation.

The Wi-Fi system is centrally managed via a Wi-Fi Controller, ensuring stable connectivity for all endpoint devices.

The server subsystem includes virtual servers:

- ETC-DCT: dedicated to project team management software.

- AD-ETC: centralized user administration.

Data is backed up daily to a Synology NAS device, ensuring data safety and recovery capability in case of incidents.

Regarding information security, CPCETC applies a multi-layer security policy, including two-factor authentication (2FA), Wi-Fi access control via Active Directory accounts, regular malware signature updates on the Sophos software firewall, and established incident response procedures for risks such as ransomware or DDoS attacks.

3.2. Software architecture

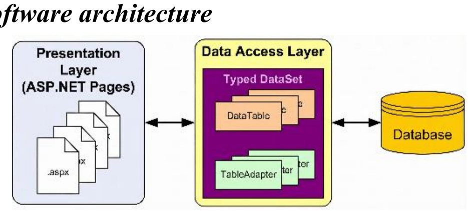

Figure 9. *System architecture overview*

The software is developed following a three-tier architecture, as shown in Figure 9, comprising:

- Presentation Layer: Web-based interface with detailed user role permissions across 9 pages.

- Business Layer: Handles operational logic, dispatching, approval, and API integration, with a total of 40 functions.

- Data Layer: Manages SQL Server databases with over 30 main tables.

Technologies used include: .NET MVC Framework, SQL Server 2019, AI Decision Engine, GPS Realtime API, and EVN CA digital signatures to ensure legal compliance and automate electronic approval processes. This integration allows users to: track vehicle locations in real time; manage online timekeeping, leave, and overtime; and electronically sign acceptance reports, contracts, and payments with internal digital signatures.

3.3. Implementation results

The software was piloted at CPCETC from January 2025 on more than 60 bidding packages for substation and power plant projects.

Figure 10 illustrates the digitalized interfaces for contract management, appendices, progress tracking, acceptance reports, and payments, all centrally stored and tagged with unique contract identifiers, reducing lookup time by 68% and completely eliminating paper records. The role-based access mechanism ensures safety, security, and traceability.

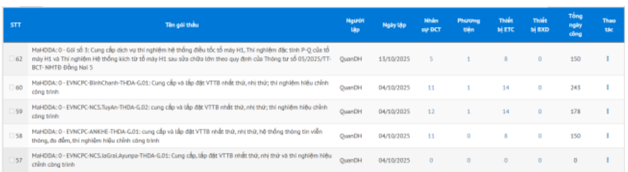

Figure 10. *Contract management*

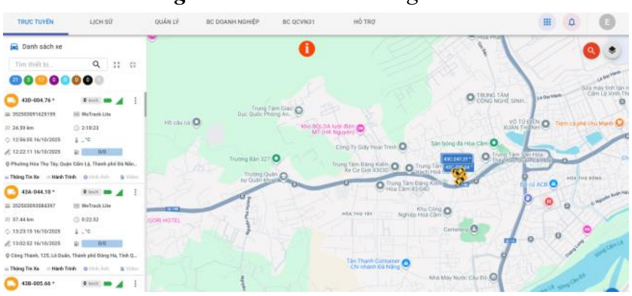

Figure 11. *GPS-based vehicle management*

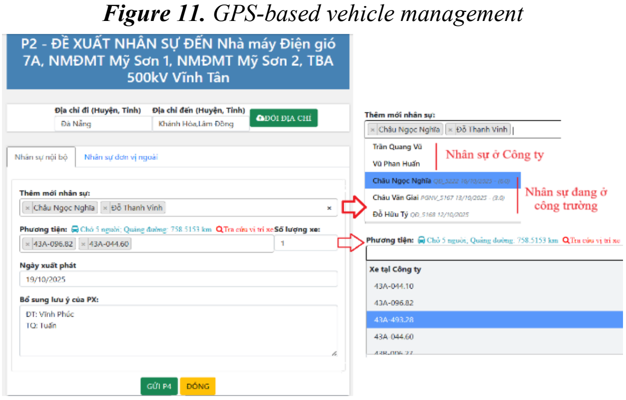

Figure 12. *AI-assisted personnel and vehicle dispatching*

Figures 11–15 present modules for vehicle management, timekeeping, progress monitoring of test report (BBTN) delivery, and completed work volume. For example, when a project team needs to travel from Da Nang to Khanh Hoa and Lam Dong (as shown in Figure 12), the department fills in the number of personnel as 5 (excluding drivers) and 23 devices/materials for testing. The AI does not suggest passenger cars (4–5 seats) but instead recommends from the company's vehicle list and selects the optimal solution with the lowest fuel cost: truck/pickup 43A-044.60 for 23 devices and 7-seat 43A-096.82 for 4 people. Moreover, the software indicates whether the driver is at the worksite or the company for convenient dispatching.

Data from project teams is synchronized in real time, enabling fast and accurate executive decisions. Compared to the pre-deployment phase, the time to complete management tasks decreased significantly - from an average of 60 minutes to just 5 minutes - resulting in substantial administrative labor savings. The approval and payment process is standardized with electronic signatures, shortening document processing time by 35% and reducing accounting discrepancies. Fuel control for 28 testing vehicles saves an average of 12.3% in fuel costs per kilometer compared to 2024.

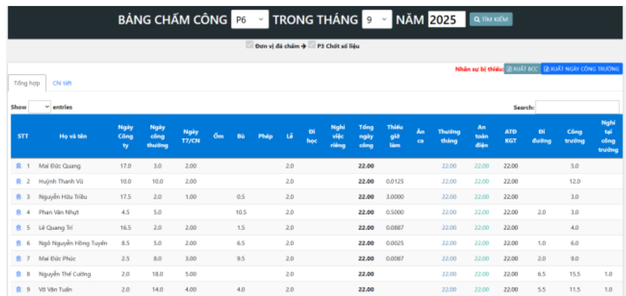

Figure 13. *Timekeeping management*

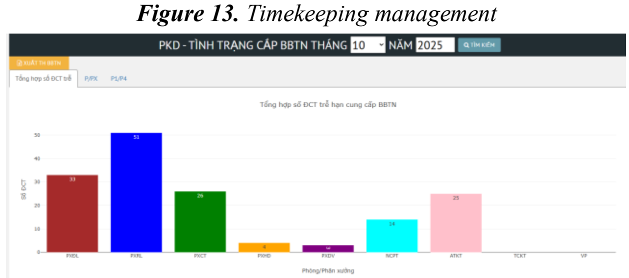

Figure 14. *Test report (BBTN) status management*

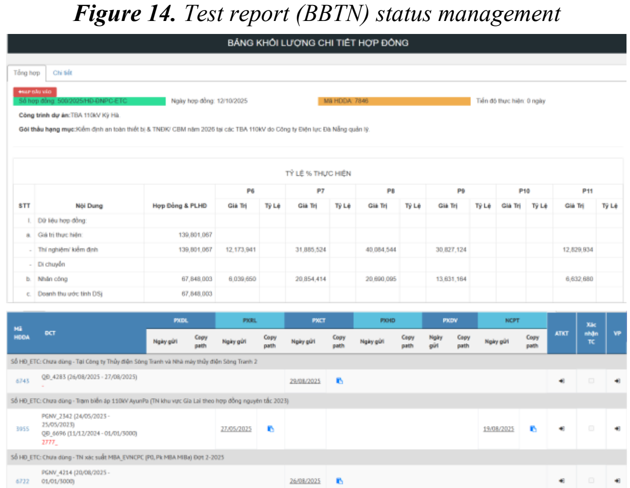

Figure 15. *Work volume management*

The contract performance evaluation module allows comparison of estimated and actual costs, automatically updating discrepancies for each bidding package. For instance, the inspection and electrical equipment testing package for A Luoi Hydropower Plant and Cu Jut Solar Power Plant in 2025 (Figure 16) shows:

$$ROS = \frac{Net\ profit\ after\ tax}{Net\ revenue} \times 100\% = \frac{58,696,082}{410,040,116} = 14.31\%$$

ROS = 14.31%, reflecting a high profitability compared to the general average for electrical technical service contracts (typically ranging from 6–10%).

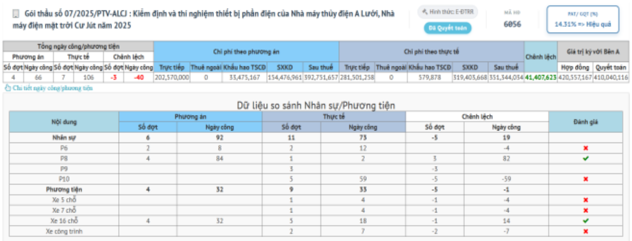

Figure 16. *Package performance evaluation*

Profit exceeding the plan: Saving 41,407,623 VND compared to estimates directly increased final profit.

Total personnel workdays: Saved 19 days, completed with 73 workdays, more efficient than the planned 92 days.

Total vehicle workdays: Used 33 vehicle workdays, 1 day more than the planned 32 days.

Similar implementation for all pilot packages from January 2025, totaling more than 60 packages, is summarized in Table 1 compared to 2024 data.

Table 1. *Comparative effectiveness before and after DSS software implementation*

Evaluation Criteria	Before Implementation	After Implementation	Improvement Rate
Average operational time	100%	60 - 70%	Reduced 30 - 40%
Vehicle operating cost	100%	88 - 90%	Reduced 10 - 12%
Labor productivity	100%	115 -120%	Increased 15 - 20%
Average profit	100%	122.5%	Increased 22.5%
Acceptance delay time	100%	68.8%	Reduced 31.2%
Acceptance quality	100%	128.7%	Increased 28.7%

In summary, the system facilitates the establishment of a 'Single Source of Truth', ensuring transparency and traceability while supporting data-driven decision-making throughout the entire contract lifecycle.

4. Conclusion

This paper proposes an integrated Decision Support System (DSS) framework, addressing the gap in optimizing electrical testing operations, where personnel, equipment, and vehicles interact in complex and tightly coupled ways. Based on the analysis of management processes at CPCETC, the authors developed and implemented the DSS on the .NET MVC and SQL Server platform, integrating Artificial Intelligence (AI), GPS tracking, and EVN CA digital signatures. The system enables optimized resource allocation, automated operations, and real-time contract performance evaluation.

Practical deployment results demonstrate significant effectiveness: reducing operational time by 30–40%, saving 10–12% in operating costs, increasing labor productivity by 15–20%, and enhancing acceptance quality by 28.7%. Furthermore, the system forms a centralized and unified data source, providing a crucial foundation for enterprise digital transformation.

However, the research has so far only been piloted at a single unit and has not been scaled across the industry. In the next phase, the authors plan to expand the DSS model to other EVN units and integrate deep learning algorithms to forecast demand and dynamically schedule resources in real time, aiming to further improve operational efficiency and intelligent decision-making capabilities.

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