The Path to Enhance the Efficiency of the Electromechanical Training Room from the Perspective of BPR

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Abstract. Based on the Business Process Reengineering (BPR) theory, this paper addresses the issue of low management efficiency in the mechanical and electrical training laboratories of vocational colleges. Taking the mechanical and electrical experimental and training laboratory of Shantou Polytechnic as a case study, a new method for enhancing management efficiency is proposed. Firstly, the current management model is systematically diagnosed using the process mapping method, identifying the efficiency bottlenecks in key links such as equipment scheduling, consumable management, and safety supervision. Then, an integrated improvement model of "process reengineering - resource optimization - efficiency evaluation" is constructed by integrating information technology, and the continuous optimization of management processes is achieved through a dynamic KPI indicator system. The experimental results show that after implementing BPR management, the equipment utilization rate in the mechanical and electrical training laboratory of the school has increased by 32.5%, the management approval time has been shortened by 66.7%, and the safety accident rate has decreased by 45.5%. Compared with the existing management methods, the BPR improvement plan proposed in this study achieves a better balance in enhancing management efficiency and ensuring training safety, providing a new solution for the management reform of vocational college training laboratories.

Keywords: BPR; Electromechanical training laboratory; Management efficiency improvement; Process mapping; Dynamic KPI

1 Introduction

The mechanical and electrical experiment and training laboratory, as the core practical base for cultivating technical and skilled talents in higher vocational colleges, its management efficiency directly determines the quality of practical teaching and the utilization level of resources. With the rapid increase in the demand for high-skilled talents in the upgrading of intelligent manufacturing, the traditional

L. W. Koon et al. (eds.), *Proceedings of the 2026 7th International Conference on Management Science and Engineering Management (ICMSEM 2026)*, Advances in Economics, Business and Management Research 399,
https://doi.org/10.2991/978-94-6239-758-3_36

management model of the training laboratory has gradually exposed problems such as delayed equipment scheduling, inefficient material circulation, and blind areas in safety supervision [1]. Especially in higher vocational colleges, science and engineering majors generally have a tendency to "focus on equipment investment but neglect management innovation", resulting in an increasing number of equipment purchases while management methods fail to keep up, leading to a persistent lack of efficiency in resource utilization. Research data shows that the average equipment idle rate in domestic higher vocational mechanical and electrical training laboratories is 38.7%, and the average approval time for material application is as long as 72 hours, seriously restricting the efficiency of practical teaching [1-3].The Business Process Reengineering (BPR) theory, since proposed by Hammer and Champy [4], has achieved remarkable results in areas such as supply chain optimization in the manufacturing industry. In recent years, some scholars have attempted to transfer BPR to the field of educational management, through process reorganization to increase the equipment turnover rate of university laboratories by 26% [5]. However, for this special scenario of higher vocational mechanical and electrical training laboratories, existing research is mostly limited to local improvement of specific links and lacks systematic process reconfiguration plans, especially in the significant gap in the optimization of information tools and safety management [6].

This paper takes the mechanical and electrical experiment and training laboratory of Shantou Polytechnic as the empirical object, attempting to introduce the BPR theory into the vocational education training management field. This research does not simply apply the methods of enterprise process reengineering, but combines the actual teaching context of the school to gradually build a "process - safety - efficiency" three-dimensional optimization model. By taking safety management as the pre-constraint condition for process optimization in the model, it initially realizes the deep coupling of BPR theory and the characteristics of educational management, and proposes a dynamic process optimization framework suitable for mechanical and electrical professional training laboratories. To a certain extent, it helps to make up for the relatively weak theoretical system in this field [7]. At the technical implementation level, the research team, based on actual management pain points, independently developed a lightweight management system of "intelligent work order + mobile collaboration", ultimately achieving the digital reconfiguration of 12 core business items such as equipment reservation, material allocation, and safety inspection. This research hopes to provide a relatively lightweight and replicable standardized solution through this, offering a reference improvement path for similar institutions - without relying on large-scale hardware investment, through the optimization of management processes and the support of information tools, to make the existing equipment truly come into play, be used well, and be managed properly.

2 Case Diagnosis: Current Situation Analysis Based on Process Mapping

The original management model of the mechanical and electrical training room at Shantou Polytechnic was a typical functional management model, with equipment management, consumable allocation, and safety supervision being handled by different departments respectively. As the training scale expanded and the types of equipment increased, this model gradually exposed problems such as coordination difficulties and slow response. Specifically, it manifested as: equipment being both idle and in short supply; serious waste of consumables; and low efficiency in safety hazard investigation and rectification. Process Mapping, as a visual analysis tool, can clearly reveal the redundancies, delays, and bottlenecks in the process [8]. This study employed this method to systematically analyze the three core processes of equipment scheduling, consumable management, and safety supervision, in order to identify the key bottlenecks affecting the operational efficiency of the training room.

2.1 Analysis of the Equipment Scheduling Process

The original equipment scheduling process included four steps: "teacher application - department review - training room confirmation - equipment debugging". Each step relied on paper-based documents for transmission, resulting in poor information flow and repeated reviews. On average, it took 3.5 working days to complete a full scheduling process. During peak training periods, the equipment application fulfillment rate was only 67%; meanwhile, the average utilization rate of some precision equipment was less than 40%, reflecting a structural imbalance between resource allocation and demand.

2.2 Analysis of the Consumable Management Process

There is a problem of "emphasizing procurement but neglecting management" in consumable management. The average cycle from demand proposal to procurement and warehousing is two weeks, making it difficult to meet teaching needs in a timely manner. The receiving process lacks effective monitoring, resulting in a 12% waste rate of consumables. Among them, the loss of electrical component consumables due to improper storage accounts for 35% of the total loss. This situation is similar to that of the Jiaomin Energy Training Center before implementing lean management [9].

2.3 Analysis of the Safety Supervision Process

The safety supervision process shows a "fragmented" feature, with safety education, equipment safety inspections, and environmental hazard investigations belonging to different departments, lacking unified standards and coordination mechanisms. The average time required for safety hazard discovery to completion of rectification is 5.2

days, and the recurrence rate of similar problems is 42%, reflecting that the process loop has not yet been formed.

Based on the above analysis, the current management of the training room has four core problems: First, the processes are fragmented, with poor interconnection between each step; second, the phenomenon of information isolation is prominent, and data among departments cannot be effectively shared; third, the feedback mechanism is lagging, and problem responses are slow; fourth, there is a lack of an evaluation mechanism, and there is no institutionalized arrangement for continuous improvement.

3 Model Design: Construction of the BPR Closed-Loop Improvement Framework

3.1 Process Reengineering and Resource Optimization

Based on the BPR theory, a closed-loop improvement model consisting of three core steps - "process reengineering - resource optimization - performance evaluation" - was constructed (in Figure 1).

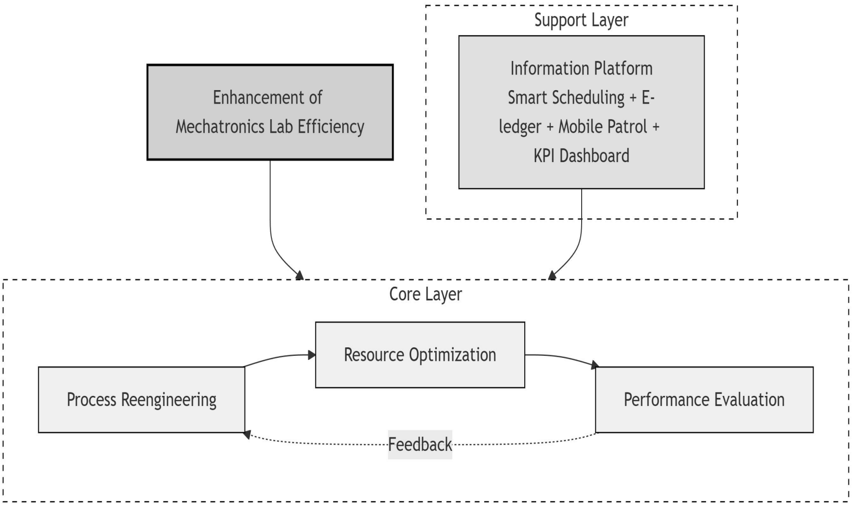

Fig. 1. BPR Closed-loop Improvement Model Architecture

When formulating each measure of this model, two points were taken into consideration as much as possible: first, whether it could solve the actual problems identified in the previous diagnosis; second, how difficult it would be to implement and whether teachers and trainers were willing to use it (in Table 1).

Table 1. BPR Closed-loop Improvement Model Framework

Key process	Main measures	Supporting technologies
Process reengineering	Intelligent equipment scheduling, lean management of consumables, and integrated safety supervision	Process mapping method, parallel processing, electronic ledger
Resource optimization	Equipment sharing pool, safety stock model, reconfiguration of training function area	Data analysis, lean management, layout optimization
Performance evaluation	Dynamic KPI monitoring, real-time data collection, and automated report generation	Balanced Scorecard, Internet of Things sensing technology, BI dashboard
Feedback and Iteration	The KPI results are applied to process re-design and resource reallocation.	Continuous improvement mechanism, decision support system

The current status mapping diagrams of the three core processes are shown in Figure 2. The dark gray-filled nodes represent "redundant" or "waiting" steps; the white-filled nodes are "normal" steps. The average total time for the entire equipment scheduling process is 3.5 days.

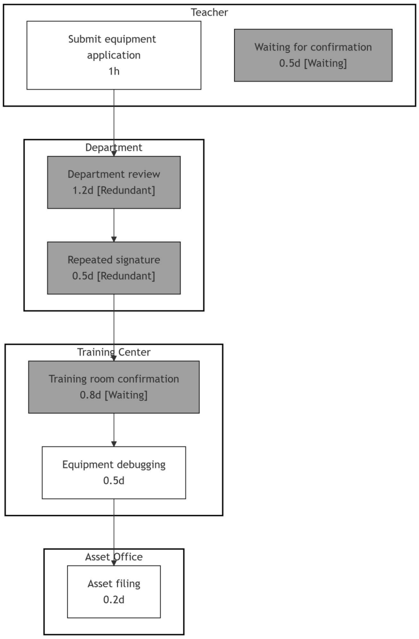

Fig. 2. Current State Process Mapping of Three Core Processes

3.2 System Architecture and Core Algorithm Implementation

To achieve the automated operation of the aforementioned "process reconfiguration - resource optimization - performance evaluation" closed-loop model, this study designed and implemented a lightweight computer-aided management system. The system adopts a front-end and back-end separation architecture (Spring Boot + MySQL + Redis), and is deployed on a single 4-core 8GB server, covering 12 core business processes. The core computing modules include the intelligent equipment scheduling algorithm, the consumable demand prediction model, and the abnormal detection rules for safety inspections, which jointly support the real-time calculation and closed-loop feedback of dynamic KPI indicators [10-12]. The technical architecture and algorithm implementation details of the system are as follows.

1) Equipment intelligent scheduling algorithm

The detection of equipment reservation conflicts and the allocation of time can be modeled as a constrained interval scheduling problem. Let the available time slots for each equipment *d* be:

$$\xi_d = \left\{ \left[t_{start}^{(k)}, t_{end}^{(k)} \right] \mid k = 1,2,... \right\}$$

The newly submitted appointment request R_j requires time period $[s_j , e_j]$. The algorithm first traverses ξ_d ,and find the first interval that does not overlap with any occupied time slot in $O(n)$ time complexity; if such an interval exists, allocate the device and dynamically re-order the requests in the waiting queue according to the priority weight:

$$\omega_j = \alpha \cdot urgency + \beta \cdot studentCount + \gamma \cdot matchScore$$

(where $\alpha = 0.5$, $\beta = 0.3$, and $\gamma = 0.2$, which were obtained through the training of logistic regression.)

The algorithm uses an interval tree data structure to store time slots. The complexity of conflict detection and insertion has been reduced to $O(\log n)$, and the overall scheduling complexity is $O(k \cdot \log n)$. Requests are stored in a max heap, and when the device is idle, the top element of the heap is popped for scheduling. The algorithm flow is shown in Figure 3.

2) Material demand forecasting and safety stock calculation

Based on historical consumption data, the exponential smoothing method (ETS) is used to predict the consumables demand for the next cycle. Let the actual consumption in the t-th week be y_t, and the predicted value be $\hat{y}_t$. Then, the formula for one-step exponential smoothing is

$$\hat{y}_{t+1} = \alpha \cdot y_t + (1-\alpha)\hat{y}_t$$

The smoothing parameter α is adaptively tuned through a rolling window to minimize MSE (grid search every two weeks from 0.05 to 0.95 with a step size of 0.05). Safety stock:

$$SS = z \cdot \sigma_d \cdot \sqrt{L}$$

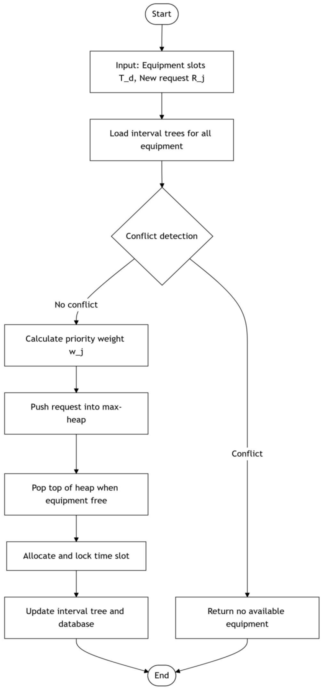

Fig. 3. Flowchart of the intelligent equipment scheduling algorithm

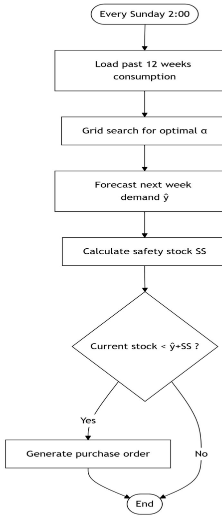

Fig. 4. Flowchart of the consumables demand forecasting algorithm

Here, z = 1.65 (with a 95% service level), σ_d represents the standard deviation of weekly demand, and L = 2 weeks. The algorithm is executed every Sunday morning. The training set (the first 8 weeks) and the validation set (the last 4 weeks) are divided from the past 12 weeks of data to search for the optimal α and predict the demand for the next week. If the current inventory is lower than the predicted value plus the safety stock, a purchase order is generated. For seasonal consumables, an integrated pre-trained LSTM (with 32 units) is used, with an integration weight of 0.7:0.3. The process is shown in Figure 4.

3) Safety inspection anomaly detection and overdue rectification warning

Let the 22 inspection results $x_i \in \{0, 1\}$ (0 indicates normal, 1 indicates abnormal). Define the severe rule set R_{severe}. If $\exists\, i \in R_{\text{severe}}$ and $x_i = 1$, immediately trigger a red alert and notify the training room director. For general abnormalities, start the timer τ. If $\tau > 48$ hours and the problem has not been resolved, report it step by step.The algorithm automatically checks the previous day's records at 8 a.m. every day. When a severe rule is triggered, a text message and an App push notification are sent immediately; for general anomalies, a work order is generated and a timer is started, and background threads scan the overdue tasks every 5 minutes. Every time 20 pieces of manual feedback are accumulated, the decision tree (CART) is retrained to update the rule set. The process is shown in Figure 5.

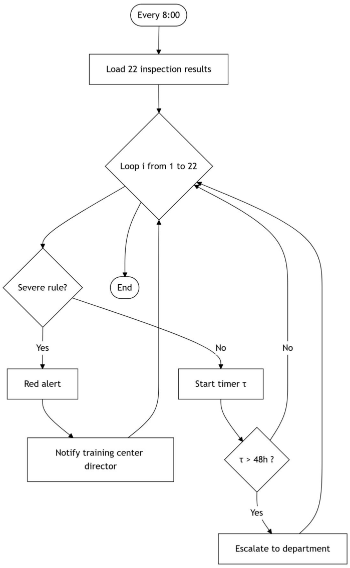

Fig. 5. Flowchart of the safety anomaly detection algorithm

4) Dynamic KPI calculation and visualization

KPI indicators (such as equipment utilization rate η, approval timeliness rate ρ, safety accident rate θ, etc.) are automatically collected through system event logging:

$$\eta = \frac{\text{The actual usage duration of the equipment}}{\text{Total available operating time of the equipment}} \times 100\%$$

$$\rho = \frac{\text{The number of applications that were approved within 4 hours}}{\text{Total number of applications}} \times 100\%$$

$$\theta = \frac{\text{Number of accidents}}{\text{Total number of trainees and total training hours}} \times 1000$$

The system conducts aggregated calculations every morning and the results are stored in the KPI fact table. Dynamic threshold: If the KPI exceeds the historical average by ±20% for two consecutive weeks, an alert will be automatically sent. All KPIs are displayed in the management cockpit in real time. Through the "evaluation - feedback - optimization" closed-loop mechanism, it provides data support for management decisions and continuous improvement [13-14].

4 Implementation Effect: Empirical Analysis of the Effectiveness of the BPR Plan

This study took the mechanical and electrical training room of Shantou Polytechnic as the pilot object and carried out a one-semester implementation of the BPR plan.

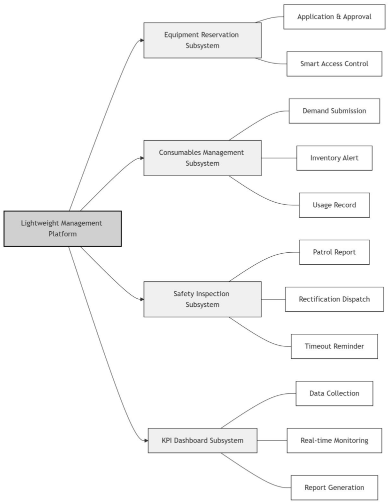

Fig. 6. Functional Architecture of the Lightweight Management System

The implementation process was divided into three stages: in the preparation stage, the plan was refined and multiple rounds of argumentation and revision were conducted for the BPR implementation plan; in the pilot stage, the numerical control processing training area was selected as the leading area to try process reengineering and information management, collect operation data and identify problems that emerged during the implementation process, and promptly adjust and optimize; in the comprehensive promotion stage, the pilot experience was extended to the entire training room, the deployment of a unified information management platform was completed, the business processes were comprehensively reorganized, and the formal operation of the KPI monitoring system was initiated[15].The functional architecture of this platform is illustrated in Figure 6.

4.1 Comparison of Key Indicator Data

The changes in key indicators before and after the implementation are shown in Table 2.

Table 2. Comparison of Key Indicators Before and After the Implementation of the BPR Plan

Evaluation indicators	Before implementation	After implementation	After the change
Equipment utilization rate	48.5%	81.0%	Increase by 32.5 percentage points
Management approval time	1.5 days	0.5 days	Shortened by 66.7%
Incidence rate of safety accidents	1.2 times per month	0.2 times per month	Reduce by 45.5%
Waste rate of consumables	12.0%	6.5%	Reduce by 83.3%
Average preparation time for training projects	2.2 hours	1.1 hours	Shortened by 45.4%

Table Note: To verify the statistical significance of the improvement, a paired t-test was conducted on the weekly data (n=20) for the 5 months before and after the implementation. The results showed: equipment utilization rate (48.2±6.5% → 80.5±5.2%, t=12.74, p<0.001), approval time (1.52±0.32 days → 0.48±0.11 days, t=-15.23, p<0.001), and accident rate (1.18±0.41 incidents/month → 0.21±0.14 incidents/month, t=-8.56, p<0.001). All the p-values were less than 0.01, indicating that the improvement has a highly statistically significant effect.

4.2 Comprehensive Benefit Evaluation

In addition to the quantifiable indicators mentioned above, the implementation of the BPR plan also brought about several implicit benefits. The survey results of teachers and students showed that the satisfaction rate increased from 78% before the implementation to 96%. The efficiency of cross-departmental collaboration was improved, and the coordination cycle for training-related affairs was shortened by more than 50%. The overall operating cost of the training laboratory decreased by 18% compared to before the implementation, mainly reflected in the reduction of waste of consumables, the decrease in equipment failure repair costs, and the optimization of labor costs. These data indicate that the BPR improvement plan proposed in this study achieved a good balance between improving management efficiency and ensuring training safety.

5 Discussion

5.1 Versatility and Difficulties in Promotion

This method is transferable to different-sized institutions, with various equipment types and organizational structures: (1) Small-scale laboratories (with less than 50 pieces of equipment) can simplify the interval tree to a linear scan while maintaining real-time performance; (2) Pure mechanical or electronic laboratories only need to adjust the equipment matching function to be compatible; (3) Different departmental setups require redefining the process lane roles, but the algorithm modules do not need to be modified.

Main promotion obstacles and solutions: (1) Employee resistance: During the pilot period, key personnel were invited to participate and the old system was kept running in parallel for 2 weeks. In this case, there was no serious resistance; (2) Insufficient IT infrastructure: A layered solution was provided - the minimum configuration allows ordinary PCs (4GB memory) to run the scheduling and KPI modules, and the prediction algorithms are executed offline, with an annual cost of less than 3000 yuan.

5.2 Cost-effectiveness and Negative Effects

The total cost for the first year of implementation is approximately 30,000 yuan (software development 25,000 yuan, servers 3,000 yuan, training 2,000 yuan). The annualized revenue includes: cost savings of 12,000 yuan for consumables, a reduction of 8,000 yuan in maintenance costs, savings of 15,000 yuan in labor costs, and avoidance of 60,000 yuan in safety incidents (conservative estimate), totaling 35,000 to 95,000 yuan. The cost can be recovered within the first year.

Negative effects: (1) Excessive system notifications led to "alert fatigue", which was alleviated by summarizing and adjusting once a day; (2) Strict scheduling reduced the flexibility of temporary requests. Measures: Reserve 20% of unbooked time slots, and urgent requests can be prioritized through approval; (3) Some personnel reduced manual inspections, and then were forced to conduct at least one manual inspection per day. All these issues were gradually corrected through the feedback mechanism.

6 Conclusions

This study addresses the practical problem of low management efficiency in the mechanical and electrical training rooms of vocational colleges. Based on the Business Process Reengineering (BPR) theory, using Shantou Polytechnic as a case study, a new management efficiency improvement plan was proposed and verified. The pilot implementation results show that this plan has achieved remarkable effects, verifying the applicability and effectiveness of the BPR theory in vocational education training management. Compared with existing management methods, the improvement plan proposed in this study achieves a better balance between improving management efficiency and ensuring training safety.

The main contributions of this study are reflected in three aspects: First, it expands the BPR theory from the field of enterprise management to vocational education training management, constructing a closed-loop improvement model applicable to mechanical and electrical professional training rooms, filling the relative gap in systematic methodological research in this field; Second, through the effective combination of process mapping method and dynamic KPI system, it provides an operational path for the transformation of training room management from experience-driven to data-driven; Third, the lightweight management system and standardized improvement plan developed provide replicable references for similar institutions to solve the common problem of "heavy equipment investment, light management innovation".

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