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Original Paper

Modeling and Improvement Mechanism for the Applicability Evaluation of Work-Hour Allocation Standards in Modern Shipbuilding

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Abstract

This study proposes a data-driven applicability evaluation method for work-hour allocation standards in modern shipbuilding to address the lack of a systematic evaluation framework and the strong subjectivity of existing evaluation approaches. An evaluation index system covering the design, implementation, and feedback stages of the work-hour standard life cycle was established through literature analysis and questionnaire surveys. The indicators were standardized, and the K-means++ clustering algorithm was employed to objectively classify applicability levels based on historical work-hour data, thereby constructing a comprehensive evaluation model for identifying deficiencies in work-hour standards. A case study on the work-hour allocation standard for hull block manufacturing was conducted to validate the proposed method. The results show that the model effectively identifies weaknesses in data acquisition, standard implementation, and operational feedback, providing targeted guidance for standard improvement. The proposed evaluation framework enables objective applicability assessment and supports a closed-loop optimization process, offering a practical decision-making tool for the continuous improvement and lean management of shipbuilding work-hour standards.

Keywords

shipbuilding, work-hour allocation standard, applicability evaluation, evaluation index system

1. Introduction

With the continuous advancement of digital shipyards and lean manufacturing, shipbuilding enterprises have placed increasing demands on the refinement and standardization of work-hour management. As a fundamental basis for production organization, cost accounting, production planning, and performance evaluation, work-hour allocation standards directly affect production efficiency, resource allocation, and enterprise management performance. In recent years, large domestic shipbuilding enterprises have continuously promoted the establishment of work-hour standard systems. However, once these standards are implemented, systematic applicability evaluation mechanisms are generally lacking, making it difficult to identify deficiencies in the design, implementation, and operation of the standards in a timely manner or to establish a closed-loop process for continuous improvement. Therefore, developing a scientific and objective applicability evaluation method for work-hour allocation standards is of great theoretical significance and practical value for promoting the continuous optimization of shipbuilding work-hour standards.

Applicability evaluation has been widely adopted in equipment manufacturing, engineering construction, and safety assessment, where a variety of evaluation approaches have been developed. Mei et al. proposed a civil aircraft technology applicability evaluation framework by integrating the cloud model with the fuzzy comprehensive evaluation method, achieving multi-criteria comprehensive assessment; however, the indicator weights still relied on expert judgment, resulting in unavoidable subjectivity [1]. Wang et al. employed the fuzzy comprehensive evaluation method to assess the applicability of bucket-wheel excavator mining operations by constructing a hierarchical evaluation index system, but the weighting process also depended on expert experience [2]. To reduce human intervention, Guo et al. combined the coefficient of variation method with the linear weighted approach to develop a comprehensive Design for Wellbeing (DFW) evaluation model, thereby improving the objectivity of indicator weighting [3]. Chen et al. proposed a safety evaluation method for water conveyance tunnels based on the integration of K-means clustering and the cloud model, in which clustering was used to determine evaluation grades objectively, thereby improving the rationality and objectivity of grade classification [4].

Overall, existing studies on applicability evaluation have established several technical approaches, including fuzzy comprehensive evaluation, cloud models, and objective weighting methods. Nevertheless, two common limitations remain. First, indicator weighting generally depends on expert judgment, making evaluation results susceptible to subjective bias. Second, evaluation grades are commonly determined using empirical thresholds or manually predefined criteria without sufficient support from historical data, leading to limited objectivity. Compared with the conventional K-means algorithm, K-means++ optimizes the initialization of cluster centers, significantly reducing the probability of converging to local optima while improving clustering stability and classification accuracy. Consequently, it provides a promising data-driven solution for the objective determination of evaluation grade thresholds.

Compared with other industries, work-hour management in shipbuilding places greater emphasis on the rational formulation and continuous improvement of work-hour standards. Zhu et al. pointed out that some shipyards directly link work hours to employee income, resulting in widespread over-reporting of work hours, and therefore emphasized the importance of improving the accuracy of work-hour data collection [5]. Guo et al. reported that many shipyards still rely on manual reporting by production teams and lack comprehensive data acquisition and assessment mechanisms, highlighting the need to improve the completeness of work-hour data collection [6]. Wang et al. argued that inconsistencies between work-hour standards and actual labor intensity reduce employees' willingness to comply with the standards and proposed evaluating employee acceptance, implementation consistency, and the compatibility between work-hour standards and actual working conditions [7]. Shi et al. suggested that deviations between actual and standard work hours constitute important evidence for revising work-hour standards and recommended focusing on indicators such as the work-hour deviation rate and the proportion of processes with significant deviations [8]. Li et al. emphasized that a scientific work-hour quota system is essential for enterprise cost control and suggested that labor cost savings could be used to evaluate the effectiveness of work-hour standard implementation [9]. Li et al. also investigated the rationality of task package division in shipbuilding, providing useful insights for evaluating the design stage of work-hour standards [10]. Furthermore, to compensate for the fact that existing studies mainly emphasize objective operational data while overlooking frontline employees' subjective perceptions, this study incorporates questionnaire surveys and introduces two qualitative indicators—deficiencies in work-hour standard characteristics and perceived horizontal fairness—to better reflect the practical application of work-hour standards.

In summary, previous studies have explored applicability evaluation methods and work-hour management from different perspectives; however, several limitations remain. First, most existing applicability evaluation methods are designed for equipment, engineering, or safety assessment and lack a systematic evaluation framework tailored to work-hour allocation standards in shipbuilding. Second, current research on shipbuilding work-hour management mainly focuses on individual aspects such as work-hour data collection, standard formulation, or continuous improvement, without establishing a comprehensive evaluation index system covering the entire process of standard design, implementation, and feedback. Third, evaluation grades are still primarily determined by expert judgment or manually defined thresholds rather than objective historical data. Therefore, establishing a life-cycle-oriented evaluation framework and developing a data-driven method for objectively determining applicability levels remain critical issues for the continuous optimization of shipbuilding work-hour standards.

To address the above limitations, this study develops a life-cycle-oriented applicability evaluation framework covering the three stages of standard design, standard implementation, and standard feedback for shipbuilding work-hour allocation standards. Based on literature analysis and questionnaire surveys, an evaluation index system is established. Furthermore, the K-means++ clustering algorithm is introduced to achieve data-driven classification of applicability levels, and a closed-loop optimization mechanism integrating evaluation, diagnosis, and improvement is proposed to provide systematic methodological support for the continuous optimization of shipbuilding work-hour standards.

2. Construction of a Life-Cycle Applicability Evaluation Framework for Shipbuilding Work-Hour Allocation Standards

This study develops an applicability evaluation framework for shipbuilding work-hour allocation standards based on the life-cycle management concept of newly established work-hour standards. Guided by the complete life cycle of design, implementation, and iterative optimization, the proposed framework adopts a hierarchical structure consisting of life-cycle stages, evaluation dimensions, and specific evaluation issues. Through comprehensive life-cycle coverage, multi-dimensional assessment, and empirical support, the framework not only evaluates the effectiveness of work-hour standard implementation but also facilitates their continuous improvement, thereby providing a scientific tool for standardized work-hour management in high-value-added shipbuilding.

2.1 Construction of the Evaluation Framework Based on the Life Cycle of Work-Hour Standards

The value of a work-hour allocation standard is realized throughout its entire life cycle, including initial development, practical implementation, and iterative optimization. Accordingly, the evaluation framework is organized into three primary dimensions.

The standard design dimension evaluates the scientific validity and rationality of the work-hour standard itself, with particular emphasis on the design quality of work-hour data acquisition. The standard implementation dimension assesses employees' understanding, acceptance, and compliance with the work-hour standard during practical application, thereby reflecting its effectiveness in frontline production. The standard feedback dimension evaluates the operational performance of the standard after implementation, focusing on its economic benefits and the direction for subsequent improvement. These three dimensions are closely interconnected, forming a closed-loop process of rational design → effective implementation → continuous feedback and improvement.

In summary, the proposed evaluation framework covers the entire life cycle of work-hour allocation standards, from initial establishment through practical implementation to iterative optimization. By integrating the three evaluation dimensions of standard design, standard implementation, and standard feedback, the framework provides systematic support for the continuous evolution of work-hour standards from initial deployment to mature application.

2.2 Selection of Evaluation Indicators Based on Literature Review and Questionnaire Survey

Evaluation indicators are the fundamental units of the applicability evaluation framework, and each indicator should correspond directly to a specific evaluation objective and calculation method. To ensure both theoretical validity and practical applicability, indicator selection follows a dual-verification strategy that integrates literature analysis with questionnaire surveys. Literature analysis is employed to identify the core evaluation dimensions, whereas questionnaire surveys are used to refine the indicator design according to the practical perceptions of frontline employees. This approach ensures that every evaluation indicator is supported by both theoretical evidence and empirical data.

Existing studies primarily focus on work-hour management methods and management models, while no dedicated evaluation index system has been established for assessing the applicability of work-hour allocation standards in shipbuilding. Most previous studies discuss only isolated issues rather than providing a systematic evaluation framework. Therefore, this study develops a comprehensive evaluation index system by considering the design objectives of work-hour allocation standards, existing practical problems, and employees' perceptions obtained from questionnaire surveys. The proposed indicators provide an effective evaluation tool for the continuous optimization of shipbuilding work-hour allocation standards.

To evaluate the consistency between recorded work-hour data and verification results and to reflect the accuracy of the work-hour data collection process, accuracy of work-hour data collection (S1) is selected as one of the key indicators for assessing the reliability of work-hour data. The indicator is calculated as

$$S_1=\frac{a_{11}}{a_{12}} \tag{1}$$

Where a_{11} denotes the number of verified work-hour records that are consistent with the inspection results during the construction of a specific ship type, and a_{12} denotes the total number of recorded work-hour entries for the same ship type.

To evaluate the coverage of standardized data acquisition equipment throughout all production or operational processes, completeness of work-hour data collection (S2) is adopted as an evaluation indicator. This indicator reflects the comprehensiveness of work-hour data acquisition and ensures that work-hour information from different production processes can be collected using standardized acquisition equipment. The indicator is calculated as

$$S_2=\frac{a_{21}}{a_{22}} \tag{2}$$

Where a_{21} denotes the number of production processes equipped with standardized work-hour data acquisition devices during the construction of a specific ship type, and a_{22} denotes the total number of production processes.

The work-hour deviation rate (S3) is introduced to measure the deviation between the total actual work hours and the total predefined standard work hours. A smaller deviation indicates that the predefined work-hour standard more accurately reflects actual production activities. The indicator is calculated as

$$S_3=\frac{|a_{31}-a_{32}|}{a_{32}} \tag{3}$$

Where a_{31} denotes the total actual work hours consumed during the construction of a specific ship type, and a_{32} denotes the total predefined standard work hours.

Among all production processes, those with a work-hour deviation rate exceeding 20% are identified as processes with significant work-hour deviations. The proportion of processes with significant work-hour deviations (S4) is adopted to quantify the percentage of high-deviation processes that require priority improvement. The indicator is calculated as

$$S_4=\frac{a_{41}}{a_{22}} \tag{4}$$

Where a_{41} denotes the number of production processes with a work-hour deviation rate greater than 20% during the construction of a specific ship type.

To evaluate employees' acceptance of the current work-hour allocation standard and their willingness to comply with it during practical implementation, consistency between work-hour acceptance and implementation (S5) is introduced. A higher value of this indicator implies stronger employee recognition of the work-hour standard and greater willingness to implement it, thereby reflecting the practical feasibility of the standard. The indicator is calculated as

$$S_5=\frac{a_{51}}{a_{52}} \tag{5}$$

Where a_{51} denotes the number of employees who consider the work-hour allocation standard to be reasonable or highly reasonable and report little or no negative attitude toward its implementation, anda_{52}denotes the total number of employees participating in the questionnaire survey.

The compatibility between work-hour standards and actual labor conditions (S6) is employed to evaluate employees' understanding of the work-hour allocation standard and the extent to which the standard reflects actual production tasks. A scientifically developed work-hour standard should not only be well understood by employees but also accurately represent the actual labor intensity and time consumption. Accordingly, this indicator serves as an important measure of the scientific validity of the work-hour allocation standard. The indicator is calculated as

$$S_6=\frac{a_{61}}{a_{52}} \tag{6}$$

Where a_{61} denotes the number of employees who have a basic or comprehensive understanding of the work-hour allocation standard and believe that it can or can fully reflect actual labor conditions.

To provide a more comprehensive assessment of problems encountered during the practical application of work-hour allocation standards, two qualitative indicators are further introduced for qualitative analysis. The corresponding evaluation criteria are presented in Table 1.

Table 1. Qualitative Indicators and Classification Criteria

INDICATOR	DEFINITION	CLASSIFICATION CRITERIA
S7 Deficiencies in Work-Hour Standard Characteristics	This indicator is used to evaluate deficiencies in the work-hour allocation standard during practical application. It is determined according to employees' understanding of the standard, their	Level 1: Employees (excluding those who have never understood the work-hour standard) generally consider the standard unreasonable and identify four major deficiencies. Level 2: Employees who have a basic or comprehensive understanding of the standard consider it unreasonable and identify two to three deficiencies. Level 3: Employees who have a basic or comprehensive understanding of the standard consider it unreasonable and identify one deficiency.

INDICATOR	DEFINITION	CLASSIFICATION CRITERIA
	perception of its rationality, and the number of identified deficiencies, thereby providing guidance for subsequent standard improvement.	Level 4: More than 80% of employees (excluding those unfamiliar with the standard) consider the work-hour allocation standard reasonable and believe that no major deficiencies require improvement. Level 5: All surveyed employees consider the work-hour allocation standard completely reasonable, and more than 80% believe that no deficiencies require further improvement.
S8 Perceived Horizontal Fairness	This indicator evaluates employees' perceptions of fairness regarding work-hour allocation across different job positions and experience levels. It reflects whether the work-hour allocation standard appropriately differentiates between variations in job responsibilities and task difficulty, thereby measuring the fairness of the standard from a horizontal perspective.	Level 1: Employees across all experience levels (excluding those unfamiliar with the standard) generally consider the work-hour allocation among different positions and task difficulties to be very unfair. Level 2: More than 60% of employees with over three years of work experience who have a basic or comprehensive understanding of the standard consider the allocation unfair or very unfair. Level 3: More than 60% of employees with over three years of work experience who have a basic or comprehensive understanding of the standard consider the allocation fair or very fair. Level 4: More than 80% of employees across all experience levels (excluding those unfamiliar with the standard) consider the work-hour allocation among different positions and task difficulties fair or very fair. Level 5: All employees participating in the questionnaire consider the work-hour allocation among different positions and task difficulties to be very fair.

Based on the above indicator selection process, an applicability evaluation index system covering standard design, standard implementation, and standard feedback is established. The complete evaluation framework is illustrated in Figure 1.

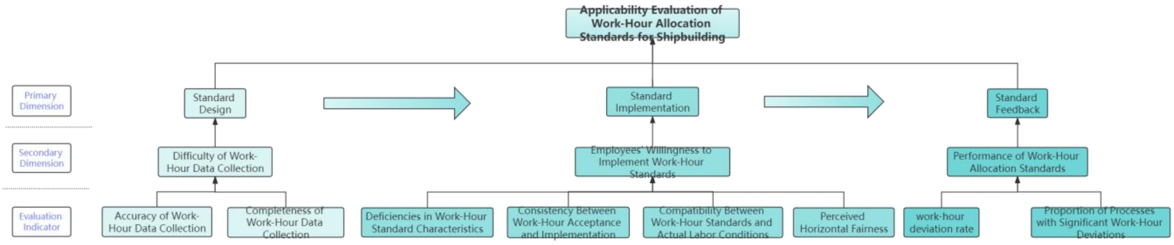

Figure 1. Evaluation Index System

3. Construction of a Data-Driven Applicability Evaluation Model

Following the principle of data-driven and objective evaluation, a three-stage applicability evaluation model consisting of indicator standardization, applicability level classification, and deficiency identification is developed. To eliminate the dependence on subjective experience inherent in conventional evaluation approaches, the K-means++ clustering algorithm is introduced to objectively determine applicability levels based on historical data. The proposed model not only provides an objective assessment of the applicability of work-hour allocation standards but also accurately identifies deficiencies, thereby supporting the continuous optimization of work-hour standards.

3.1 Indicator Standardization

The proposed evaluation system consists of six quantitative indicators and three qualitative indicators. The quantitative indicators are further classified into benefit-type indicators and cost-type indicators. To ensure consistency in the evaluation direction, all cost-type indicators are transformed into benefit-type indicators so that a higher indicator value always corresponds to a higher applicability level. The standardization principle is described as follows.

$$S_i=\frac{S_{max}-S_i}{S_{max}-S_{min}} \tag{7}$$

3.2 Applicability Level Classification and Deficiency Identification

Applicability level classification is a critical step that transforms standardized indicator scores into applicability levels. Its primary objective is to determine classification thresholds objectively based on historical data, thereby eliminating the subjective bias associated with conventional experience-based classification methods. Based on the findings of the literature review, the K-means++ clustering algorithm is employed to establish the applicability level classification model. The standardized indicator scores are classified into five applicability levels: Level 1 (Very Inapplicable), Level 2 (Inapplicable), Level 3 (Basically Applicable), Level 4 (Applicable), and Level 5 (Highly Applicable). The detailed procedure is described as follows.

The historical data of the previous work-hour allocation standard are selected as the clustering samples because the previous standard has been applied in enterprise production over an extended period, accumulating a large amount of representative practical data covering the full spectrum of applicability, from poor to excellent. Based on these historical samples, the K-means++ algorithm is applied to perform clustering analysis.

After clustering, each cluster corresponds to one applicability level. The minimum standardized indicator score within each cluster is calculated to determine the threshold interval for each of the five applicability levels. Subsequently, a comprehensive evaluation procedure consisting of overall applicability score calculation, individual indicator level determination, and deficiency identification is performed to diagnose the applicability of the new work-hour allocation standard comprehensively. The evaluation results provide a quantitative basis for the iterative optimization and continuous improvement of the work-hour allocation standard.

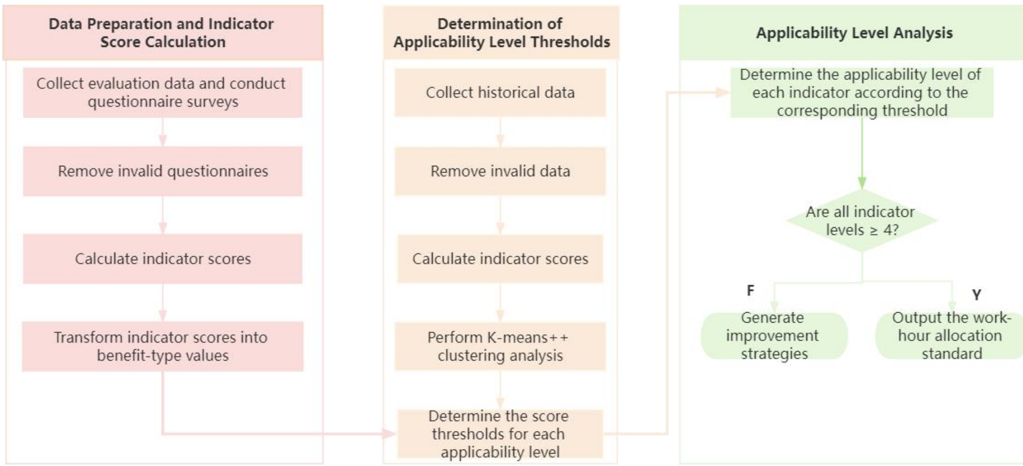

Figure 2. Flowchart of the Applicability Evaluation Process

4. Case Study

To validate the effectiveness and practical applicability of the proposed evaluation method, a case study is conducted using the hull block manufacturing stage of shipbuilding. Based on the established evaluation index system and the K-means++ clustering algorithm, a complete applicability evaluation is performed following the proposed evaluation framework.

After preprocessing and calculating the historical data, the K-means++ clustering algorithm is employed to classify the standardized indicator scores into five applicability levels . The resulting classification thresholds for each evaluation indicator are presented in Table 2.

Table 2. Thresholds for the Applicability Levels of Evaluation Indicators

INDICATOR	THRESHOLDS FOR EACH APPLICABILITY LEVEL				
	Level 1	Level 2	Level 3	Level 4	Level 4
accuracy of work-hour data	(0,0.2272)	(0.2272,0.3451)	(0.3451,	(0.6209,0.8176,)	(0.8176,

collection (S1)			0.6209)		1)

INDICATOR	THRESHOLDS FOR EACH APPLICABILITY LEVEL				
	Level 1	Level 2	Level 3	Level 4	Level 4
completeness of work-hour data collection (S2)	(0, 0.2055)	(0.2055, 0.4469)	(0.4469, 0.6438)	(0.6438, 0.8097)	(0.8097, 1)
the work-hour deviation rate (S3)	(0, 0.1871)	(0.1871, 0.4279)	(0.4279, 0.6212)	(0.6212, 0.8459)	(0.8459, 1)
the proportion of processes with significant work-hour deviations (S4)	(0, 0.3018)	(0.3018, 0.4856)	(0.4856, 0.6997)	(0.6997, 0.8144)	(0.8144, 1)
consistency between work-hour acceptance and implementation (S5)	(0, 0.1681)	(0.1681, 0.4108)	(0.4108, 0.6209)	(0.6209, 0.7671)	(0.7671, 1)
the compatibility between work-hour standards and actual labor conditions (S6)	(0, 0.1173)	(0.1173, 0.4329)	(0.4329, 0.6238)	(0.6238, 0.8890)	(0.8890, 1)

Field data were collected through on-site investigations. The scores of the six quantitative indicators, namely S1, S2, S3, S4, S5, and S6, were calculated and subsequently subjected to benefit-oriented transformation and normalization. The qualitative indicators were evaluated based on questionnaire survey results. The resulting indicator scores are presented below.

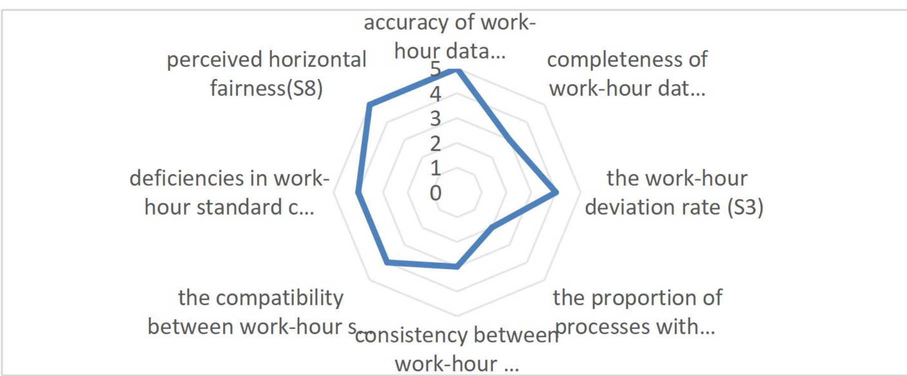

Figure 3. Evaluation Indicator Scores

The evaluation results indicate that four quantitative indicators are classified below Level 4, suggesting that the applicability of the proposed work-hour allocation standard still requires improvement in several aspects. Within the standard design dimension, the relatively low level of S2 (Completeness of Work-Hour Data Collection) indicates insufficient coverage in the design of the work-hour data collection system. Within the standard implementation dimension, the relatively low levels of S5 (Consistency Between Work-Hour Acceptance and Implementation) and S6 (Compatibility Between Work-Hour Standards and Actual Labor Conditions) reveal deficiencies in employees' understanding of and willingness to implement the work-hour allocation standard. Within the standard feedback dimension, the low level of S4 (Proportion of Processes with Significant Work-Hour Deviations) indicates that a relatively high proportion of production processes still exhibit significant deviations after the implementation of the new standard. These findings demonstrate that targeted improvements are required in data collection system design, frontline implementation, and deviation control.

The ultimate objective of the applicability evaluation is to establish a closed-loop mechanism of evaluation–deficiency identification–continuous improvement. Based on the identified deficiencies, hierarchical improvement strategies are proposed according to the priority sequence of standard design → standard implementation → standard feedback.

Standard design: The insufficient performance of S2 suggests inadequate completeness of work-hour data collection. Therefore, the deployment of data acquisition equipment should be optimized, and a performance assessment mechanism for work-hour data collection completeness should be established.

Standard implementation: The relatively low levels of S5 and S6 indicate insufficient employee acceptance and inadequate compatibility between the work-hour standards and actual production practices. Accordingly, training on work-hour standards should be strengthened, employee feedback channels should be improved, and field-measured production data should be incorporated to calibrate the work-hour standards. For the identified deficiencies in work-hour standard characteristics, phased optimization plans should be formulated according to the priorities reflected in employee questionnaire responses.

Standard feedback: The low level of S4 indicates that the proportion of processes with significant work-hour deviations remains high. Therefore, the root causes of these deviations should be systematically investigated, including unreasonable work-hour standards, process modifications, and workforce differences, followed by the implementation of targeted corrective measures.

Closed-loop iteration: After the improvement measures have been implemented, a new round of work-hour data should be collected, and the applicability evaluation model should be executed again. By comparing the applicability levels before and after improvement, effective measures can be incorporated into the standard system, whereas deficiencies that remain unresolved should be further analyzed and addressed through iterative strategy refinement, thereby promoting the continuous evolution of the work-hour allocation standard from usable, to effective, and ultimately to lean.

5. Conclusion

This study proposes an applicability evaluation method for work-hour allocation standards in shipbuilding. Rather than merely applying the K-means++ clustering algorithm, the proposed method establishes a comprehensive applicability evaluation framework guided by the concept of life-cycle management of work-hour allocation standards. The framework covers three key stages, namely standard design, standard implementation, and standard feedback. Compared with conventional evaluation approaches that primarily focus on work-hour deviations or implementation performance, the proposed framework extends the evaluation scope to encompass the quality of standard design, implementation effectiveness, and operational feedback. Consequently, the evaluation results not only reflect the current applicability of work-hour allocation standards but also identify critical deficiencies during their implementation, thereby providing a scientific basis for the continuous optimization of work-hour allocation standards.

Compared with existing applicability evaluation studies, the proposed method exhibits several distinctive characteristics. First, regarding the evaluation framework, most existing studies employ methods such as the fuzzy comprehensive evaluation method or the analytic hierarchy process (AHP) to evaluate engineering systems or equipment, where the evaluation indicators are largely derived from expert experience. Few studies have developed a dedicated evaluation index system specifically for work-hour allocation standards in shipbuilding. In this study, literature analysis, historical work-hour data, and questionnaire surveys of shipyard employees are comprehensively integrated to establish an evaluation index system that simultaneously incorporates objective operational data and employees' subjective perceptions. Consequently, the proposed framework provides a more comprehensive representation of the actual performance of work-hour allocation standards in production practice.

Second, regarding the evaluation methodology, conventional applicability levels are generally determined according to expert judgment or predefined thresholds, which may lead to inconsistencies among different evaluators. In contrast, this study utilizes historical enterprise work-hour data and the K-means++ clustering algorithm to identify the natural distribution characteristics of evaluation indicators and determine applicability level thresholds in a data-driven manner. This approach effectively reduces the subjectivity introduced by manually defined thresholds, improves the consistency and reproducibility of evaluation results, and enhances the practicality of the evaluation model in industrial applications.

Furthermore, the proposed evaluation framework emphasizes not only the evaluation results themselves but also their integration with the continuous improvement of work-hour allocation standards. By mapping the evaluation results to the three stages of standard design, standard implementation, and standard feedback, the framework facilitates the identification of key factors affecting the applicability of work-hour allocation standards and establishes a closed-loop optimization mechanism consisting of evaluation, deficiency identification, improvement, and verification. Consequently, the applicability evaluation evolves from a conventional assessment tool into a management tool that supports the continuous optimization of work-hour allocation standards. Owing to its flexibility, the proposed framework can be adapted to different shipyards, ship types, and production organization modes through appropriate adjustments to the evaluation indicators and evaluation criteria, thereby satisfying the applicability evaluation requirements under various industrial scenarios.

Nevertheless, several limitations should be acknowledged. First, the applicability level classification depends on historical work-hour data. When the historical sample size is insufficient or data quality is poor, the clustering results may be affected, indicating that the reliability of the proposed model relies on the continuous and standardized accumulation of enterprise work-hour data. Second, the case study was conducted only for the hull block manufacturing stage of a single shipyard. Since production organization, manufacturing processes, and work-hour management practices vary across shipyards, both the evaluation indicators and applicability level thresholds should be further adapted to specific application scenarios. In addition, the proposed framework currently focuses on applicability evaluation and deficiency identification, whereas a quantitative mapping between evaluation results and the automatic revision of work-hour allocation standards has not yet been established. This issue deserves further investigation in future research.

Future research will focus on expanding the historical work-hour datasets by incorporating multiple shipyards and different ship types to validate the proposed framework under diverse industrial scenarios and improve its generalization capability. Furthermore, dynamic data-driven techniques, such as dynamic clustering and online learning, will be integrated to develop an adaptive evaluation model capable of continuously updating applicability level thresholds as historical work-hour data accumulate. Finally, by combining the proposed evaluation framework with work-hour allocation standard optimization models, future studies will investigate the automatic mapping between evaluation results and standard revision strategies, thereby establishing an integrated continuous improvement system that combines evaluation, diagnosis, and optimization and provides theoretical support and technical guidance for the intelligent management of work-hour allocation standards in digital shipyards and smart manufacturing.

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