Research on the Standardization Path for Grade Evaluation of Inland River Smart Terminals

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Abstract: The intelligent construction of inland ports has long lacked a unified evaluation scale, making it difficult to implement graded construction and classified supervision. Based on the compilation practice of the "*Guidelines for the Evaluation of the Level of Inland River Smart Terminals*", this article discusses the standardization path of the level evaluation of inland river smart terminals. The study first examines the current construction status and standardization requirements of smart docks in inland rivers, sorts out the coverage scope and gaps of current standards, and then builds a level evaluation index system from five dimensions: facilities and equipment, production and operation, service coordination, green safety, and development guarantee. This article uses the Analytic Hierarchy Process to determine the weights of indicators and provides methods for fuzzy comprehensive evaluation and grade determination. The technical roadmap for standard preparation is organized into six stages: demand research, framework design, indicator construction, solicitation of opinions, review and release, and implementation and promotion. In addition, there are supporting implementation mechanisms such as publicity and training, pilot demonstrations, and dynamic maintenance. The path offers a unified evaluation scale and a technical basis for inland river smart terminals. It supports construction through evaluation and graded management, and it can also inform the compilation of evaluation standards for similar terminals.

Keywords: Inland River Smart Terminal; Grade Evaluation; Standardization Path; Indicator System; Standard Compilation

1. Introduction

Inland river shipping offers large capacity, low cost, and low energy consumption, and holds an important position in the comprehensive transportation system. To accelerate the building of a leading transportation nation and promote the high-quality development of inland river shipping, China has issued the *Outline for Building a Leading Transportation Nation* and the *Outline for the Development of Inland River Shipping*; both documents require raising the intelligence level of infrastructure such as waterways and ports. In recent years, technologies such as the Internet of Things, big data, and artificial intelligence have spread rapidly into the port sector, applications such as automated loading and unloading, smart gates, smart tallying, and intelligent scheduling have been widely adopted, and smart port construction has extended from coastal areas to inland rivers.

Research on smart port evaluation at home and abroad has largely followed two lines: evaluation indicator systems and methods, and standardization. Along the first line, early studies focused on what to evaluate. They built indicator systems from the connotative characteristics of smart ports and discussed methods of grade classification [1], and established indicator systems along three dimensions, namely port functions, theory, and technology, to assess the level of smart development of ports in Guangdong Province [2]. The focus then shifted to how to evaluate, introducing weight determination and quantitative models on top of indicator systems. The DPSIR model combined with the analytic hierarchy process was used to measure the level of smart port construction quantitatively [3]; improved matter-element theory combined with a cloud model was used to characterize the development level of ports [4]; the combination of KPI and AHP was used to compare the level of smart development among international ports [5]; and a hierarchical and graded indicator system based on ecological theory, together with

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grey entropy variable weights, advanced evaluation from static scoring to grade determination [6]. These studies differ in indicator dimensions and weighting approaches. Research along the standardization line remains limited. Existing reviews of standardization concentrate on automated container terminals in China and cover handling equipment and the handling process system [7], while practice at the inland river terminals of the Port of Shanghai provides a direct reference for inland river scenarios and advocates an overall implementation model of "construction first, assessment second" [8]. At the level of standard documents, the *Guidelines for Grade Evaluation of Smart Ports (Trial)* conducts grade evaluation of specialized terminals, port areas, or ports along four dimensions: digital foundation, production operations, operation management, and external services. Existing research and standards practice focus almost entirely on coastal specialized terminals and give insufficient consideration to differences among inland river terminals in waterway conditions, shoreline resources, and cargo structure. For inland river terminals, a targeted grade evaluation standard is still lacking, and evaluation criteria and grade classification have not been unified.

Based on the compilation of the *Guidelines for Grade Evaluation of Inland River Smart Terminals*, this paper first analyzes the standardization demands for grade evaluation of inland river smart terminals, then constructs a grade evaluation indicator system and method, and finally presents a technical route for standard compilation and implementation. The aim is to provide a unified evaluation scale and technical basis for the graded construction, classified regulation, and regional coordination of inland river terminals.

2. Development Status of Inland River Smart Terminals and Standardization Demands

2.1 Current Status and Characteristics of Inland River Smart Terminals

There are significant differences in natural conditions, operational organization, and service targets between inland ports and coastal ports. Due to the constraints of waterway level and navigation conditions, the tonnage of berths at inland ports is generally small, and the shoreline resources are also relatively tight; The transportation organization presents the characteristics of short distance and multiple batches. Therefore, we believe that the intelligent construction of inland river terminals does not pursue large and fully automated terminals, but rather focuses on solving specific problems such as loading and unloading efficiency, safety management, and information collaboration with minimal investment.

Currently, the scale and hierarchy of inland river terminals vary greatly, with significant regional differences and limited investment capacity. The demands are also focused on cost reduction, efficiency improvement, and safety and green development. These characteristics determine the grading standards for inland ports and are not applicable to the practices of coastal ports.

2.2 Standardization Demands for Grade Evaluation

The main requirement is a unified evaluation scale. At present, there is no clear and universally accepted definition for smart docks. Therefore, various entities have vastly different evaluation dimensions, indicator standards, and data sources, making it easy for concepts to generalize and difficult to compare evaluation results. It is worth noting that it is necessary to clarify the objects, dimensions, and procedures of level evaluation through standards.

Evaluation scales are also needed to support hierarchical construction and classification supervision. The basic conditions of inland ports vary greatly. It is more appropriate to differentiate the development stages through level evaluation and guide the ports to transform step by step according to the gradient of basic, upgrading, and leading; The evaluation results can also provide a basis for classification guidance and differentiated management for port management departments.

Regional coordination and standard alignment are another demand. Inland river terminals are located in different provinces and cities, and their grade evaluation needs to align with the evaluation standards already established for coastal smart ports, so that the standard system does not fragment and evaluation results remain mutually recognized.

Standards should also guide investment and technology selection. Evaluation indicators need to clarify construction priorities and sequence, providing operable upgrading directions for small and medium-sized inland river terminals

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with limited investment capacity.

2.3 Review of Existing Standards and Gap Analysis

Existing standards related to the evaluation of port smart development are mainly the following. The China Ports and Harbours Association issued T/CPHA 9-2022, *Guidelines for Grade Evaluation of Smart Ports: Container Terminals*, and T/CPHA 27-2023, *Guidelines for Grade Evaluation of Smart Ports: Dry Bulk Terminals*; the Ministry of Transport issued the *Guidelines for Grade Evaluation of Smart Ports (Trial)*. The basic information of these standards and their applicability to inland river terminals are shown in Table 1.

Table 1 reveals three gaps in existing standards. First, the evaluation objects are mainly coastal specialized terminals, port areas, and ports, with insufficient consideration of the waterway, shoreline, and cargo conditions of inland river terminals. Second, the standards related to inland rivers are mostly association standards, whose coverage and binding force are limited, and whose grade names, score ranges, and evaluation procedures have not been unified. Third, the standards are not well connected in terms of indicator definitions and data requirements, so evaluation results are difficult to compare across regions and cargo types. These gaps point to a real practical need for standardization work on grade evaluation of inland river smart terminals.

Table 1. Review of Existing Standards and Gap Analysis

Standard (Name and Number)	Issuing Body	Main Evaluation Object	Dimensions and Grades	Applicability to Inland River Terminals
T/CPHA 9-2022 Guidelines for Grade Evaluation of Smart Ports: Container Terminals	China Ports and Harbours Association	Specialized container terminals	Container-terminal-related dimensions; graded evaluation	Oriented to coastal container terminals; limited applicability to inland rivers
T/CPHA 27-2023 Guidelines for Grade Evaluation of Smart Ports: Dry Bulk Terminals	China Ports and Harbours Association	Specialized dry bulk terminals for coal, ore, grain, and cement	Dimensions such as intelligent management, facilities and equipment, information technology, digital-intelligent services, and development mechanism	Oriented to specialized dry bulk terminals; inland river terminal conditions vary greatly
Guidelines for Grade Evaluation of Smart Ports (Trial)	Ministry of Transport	Specialized container and dry bulk terminals, port areas, or ports in operation for at least two years	Four dimensions: digital foundation, production operations, operation management, and external services; three grades	Mainly covers coastal ports; insufficient focus on inland rivers
T/ZGCX 016-2026 Guidelines for Smart Development Grade Evaluation of Inland River Terminals	Zhejiang Supply Chain and Warehousing Industry Association	Inland river terminals	Four dimensions: facilities and equipment, operation management, intelligent services, and sustainable development; three to five stars	Oriented to inland rivers, but it is an association standard with limited coverage and binding force

3. Construction of the Grade Evaluation Indicator System and Method

3.1 Design of the Evaluation Indicator System

3.1.1 Evaluation Dimensions and Indicator Selection

Indicator selection takes account of comprehensiveness, systematicness, representativeness, comparability, and operability [1,9]. Indicators should reflect the connotation and development direction of smart terminals and also adapt to the actual conditions of inland river terminals. In light of the main business processes of inland river terminals, grade evaluation sets five first-level dimensions. Smart facilities and equipment covers the intelligence level of handling equipment, sensing devices, and network and information infrastructure, while smart production and operations addresses the capabilities of automated operations, intelligent scheduling, and production control. Service and collaboration concerns online service handling, electronic documents, information sharing, and multimodal transport collaboration. Green and safety deals with energy consumption and emissions, safety management, and emergency response, and the development support mechanism captures supporting conditions such as planning, investment, talent, and standardization development. Each primary dimension is divided into several secondary indicators, and a three-level structure is constructed as a whole, including the target layer, dimension layer, and indicator layer. The basic framework is shown in Figure 1.

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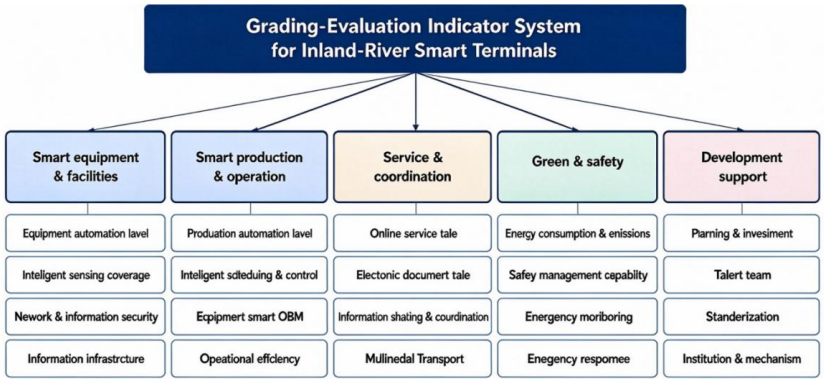

Figure 1. Framework of the Grade Evaluation Indicator System for Inland River Smart Terminals

3.1.2 Determination of Indicator Weights

Because indicators contribute differently to the level of smart development, their weights need to be determined separately. This paper uses the analytic hierarchy process. Indicators at the same level are first compared pairwise using a 1-9 scale to construct a judgment matrix; the maximum eigenvalue of the matrix and the corresponding eigenvector are then calculated, and a consistency test is carried out. When the consistency ratio is less than 0.10, the consistency of the judgment matrix is considered acceptable; otherwise it must be adjusted and recalculated [5]. We compare pairwise and obtain scores from experts in fields such as port operations, water transportation engineering, and standardization, and then summarize them to determine the weights of indicators at each level. If there are multiple dimensions with qualitative indicators, we can reduce subjective influence by increasing the number of experts and taking the mean of the results.

3.1.3 Compilation of Evaluation Criteria

In order to make the evaluation process reproducible and the evaluation results comparable, we quantify the indicators. Quantitative indicators are converted into standard scores according to scoring functions; qualitative indicators are given descriptive criteria at four levels, namely excellent, good, fair, and poor, each corresponding to a specific score. The definition of indicators, data sources, calculation methods, scoring rules, and criteria are compiled into a scoring table as a normative appendix to the standard. The scoring sheet can reduce subjective arbitrariness in evaluation and also provides evaluators with a unified operational basis.

3.2 Grade Evaluation Method and Grade Classification

3.2.1 Normalization of Evaluation Data

Because the indicators of inland river terminals have different dimensions and magnitudes, normalization is carried out first. For positive indicators, where a larger value is better, the extremum method is used for normalization and the result is multiplied by a coefficient of 100; for negative indicators, where a smaller value is better, normalization is performed in the opposite direction [6]. After normalization, indicator values fall within the same interval, which facilitates subsequent weighted aggregation. Take the automation level of handling equipment as an example: a higher value indicates a higher degree of smart development, so it is a positive indicator, whereas energy consumption per unit and ship berthing time are the opposite and are negative indicators.

3.2.2 Fuzzy Comprehensive Evaluation and Grade Determination

On the basis of indicator normalization and weight determination, the comprehensive score is obtained by combining weighted aggregation with fuzzy comprehensive evaluation. The scores of the first-level dimensions are first derived by weighting the second-level indicators, and the comprehensive score is then obtained by weighting the first-level dimensions. Because smart development is fuzzy in some qualitative indicators, fuzzy comprehensive evaluation is introduced: experts give membership judgments for qualitative indicators, which are combined with quantitative scores to determine the comprehensive score [4].

We divide the inland smart dock into three levels based on the comprehensive score and the compliance requirements of key indicators: those with a comprehensive score of 60 or above and qualified key indicators are classified as level three, which is the basic type; A score of 75 or

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above is a second level and belongs to the promotion type; A score of 90 or above is the first level, which is the leading type. Grading is not only based on the total score, but also sets hard thresholds for key indicators such as safety and environmental protection to prevent the core links from not meeting the standards even though the total score is sufficient. The evaluation process refers to the current evaluation method of smart ports, which consists of four steps: the terminal first evaluates itself, then the industry association or third-party organization reviews and evaluates it, and then publishes the results and implements dynamic management. The results of the evaluation can be used as a reference for port planning, capital investment, and demonstration project application.

4. Compilation and Implementation Path of the Guidelines

4.1 Principles and Technical Route of Standard Compilation

4.1.1 Principles of Standard Compilation

This standard mainly follows four principles:

First, both scientific and progressiveness. The indicators set should not only be in line with the development direction and technological trend of intelligent inland ports, but also rely on data that can be obtained and easily verified, without creating unrealistic and hollow indicators.

Secondly, highlight applicability and operability. Fully considering the characteristics of small scale and significant differences in conditions among inland ports, the number of indicators should not be too many, the division should not be too detailed, and the scoring method should be simple to facilitate on-site implementation and use.

Thirdly, pay attention to coordination and openness. This standard should be aligned with the "*Guidelines for the Evaluation of Smart Port Grades*" and existing evaluation standards for container and dry bulk terminals, maintaining consistency in terminology, evaluation dimensions, and statistical caliber, while leaving interfaces for easy integration with upstream and downstream standards.

Fourth, adhere to dynamism and scalability. When there are changes in the categories of inland waterway freight and the application of new technologies in the future, the indicators and score thresholds can be adjusted and updated regularly to keep up with the pace of industry development.

4.1.2 Standard Compilation Process

In the stage of demand research and pre research, we have sorted out the current construction status, management requirements, and existing relevant standards of inland river terminals, and clarified the positioning and scope of application of this standard; During the framework design phase, the evaluation object, evaluation dimensions, and level classification were determined; During the indicator construction phase, the indicators were screened, weights were determined, and the scoring table was completed; During the consultation stage, opinions were widely solicited from port enterprises, industry regulatory departments, and research institutions, and expert discussions were organized for controversial content; During the review stage, the expert group reviewed the scientific, applicable, and normative aspects of the standards; After approval and release, it will be officially launched and promoted. This process also aligns with the goal oriented and systematic approach emphasized by the comprehensive standardization method. [10].

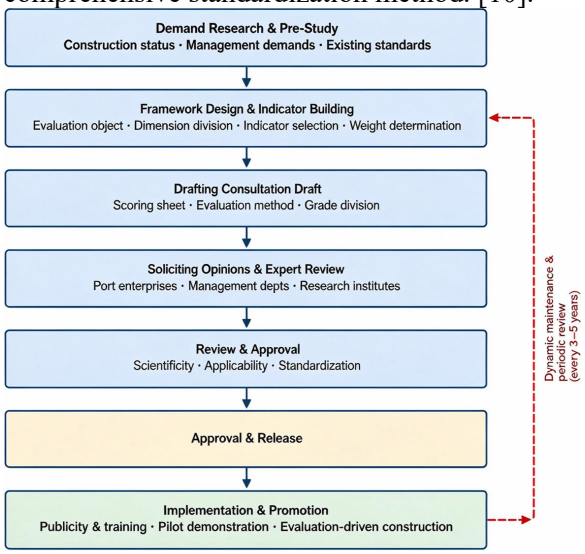

Figure 2. Technical Route of the Standardization Path for Grade Evaluation of Inland River Smart Terminals

4.2 Core Content of the Standard and Its Implementation and Promotion

4.2.1 Framework of the Core Content

The main text of the "Guidelines for Evaluating the Level of Inland River Smart Terminals" is divided into eight parts. The scope of application has been clarified, and the guidelines are applicable to the level evaluation of specialized

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inland ports and port areas; The terms and definitions have defined core concepts such as smart docks and grade evaluation; The evaluation object proposes the basic requirements for the production period and data preparation of the participating docks; The evaluation index system provides a three-level index structure and index description, as shown in Table 2.

The evaluation method specifies data standards, weight settings, and calculation rules for comprehensive scores; The evaluation program determines the implementation process of self-evaluation, verification, result disclosure, and dynamic management; The classification of levels specifies the names, score ranges, and criteria for achieving key indicators for each level; The appendix includes a scoring table and evaluation report format template.

4.2.2 Implementation and Promotion Mechanism

The value of standards ultimately depends on their implementation, so it is necessary to establish a supporting promotion mechanism.

Firstly, do a good job in publicity and training. Conduct standard interpretation and practical training for inland river terminals and port management departments, and unify everyone's evaluation criteria.

Secondly, promote pilot demonstrations. Select typical inland river terminals of different types and scales for pilot evaluation, test whether the indicators are effective, and summarize the experience and practices that can be promoted.

Thirdly, adhere to promoting construction through evaluation. Link the evaluation results with port planning, technological renovation projects, and demonstration applications, guide the dock to compare the evaluation results, identify the direction of renovation, and arrange the construction sequence reasonably.

Fourth, implement dynamic maintenance. Establish a standard regular review and feedback mechanism, with a principle of review every 3-5 years, and adjust indicators and thresholds in a timely manner based on the development of inland smart terminals. The relevant practices of data governance also demonstrate that unified data standards and evaluation processes are the foundation for achieving business collaboration [11].

5. Conclusions

Based on the compilation of the *Guidelines for Grade Evaluation of Inland River Smart Terminals*, this paper studies the standardization path for grade evaluation of inland river smart terminals. The main work covers three aspects.

First, it analyzes the construction status and standardization demands of inland river smart terminals, reviews the coverage and gaps of existing standards, and explains the necessity of standardizing grade evaluation.

Second, it constructs a grade evaluation indicator system from five dimensions: facilities and equipment, production and operations, service and collaboration, green and safety, and development support. It determines indicator weights with the analytic hierarchy process and establishes a fuzzy comprehensive evaluation method with three-grade classification.

Third, it proposes a technical route for standard compilation covering demand research, framework design, indicator construction, public consultation, review and release, and implementation and promotion, and presents implementation mechanisms covering publicity and training, pilot demonstration, and dynamic maintenance.

Inland rivers have diverse cargo types and pronounced regional differences. As technology advances, data-driven evaluation methods can be introduced to improve the objectivity and efficiency of evaluation, and alignment with coastal smart port evaluation standards and international benchmarking can be deepened, so that the grade evaluation standard system for inland river smart terminals is gradually improved.

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