MAPAN-JOURNAL ,
Publisher: METROLOGY SOC INDIA , NPL PREMISES,
Address: DR K S KRISHNAN MARG, NEW DELHI, INDIA,
ISSN / eISSN:0970-3950 / 0974-9853
Volume 25-Issue 1-(2025)
https://doi-001.org/1025/17634817393255

Independent Research Project of the 26th Batch of Key Research Topics on Health and Health Economics Management, Chinese Society of Health Economics (Project No. CHEACWZZ20252601)

Construction of an Early Warning Index System for Economic Operation Risk in Public Hospitals: Independent Research Project Report

First Author: Guan Xie, Chongqing Institute of Population and Family Planning Science and Technology

Co - First Author: Li Peng, Department of Pharmacy, People's Hospital Affiliated to Chongqing University

Second Author: Liu Fanyu, Chongqing Institute of Population and Family Planning Science and Technology

Corresponding Author: Zhang Ronggui, Chongqing Institute of Population and Family Planning Science and Technology；Email: 38476786@qq.com

October 2025

Contents

Chapter 1 Introduction
I. Research Background
(I) Establishing an effective risk early warning indicator system to promote sound economic operation of hospitals
(II) Current status of hospital economic operation risk early warning indicator systems in China and abroad
(III) Research Significance
II. Research Objectives
Chapter 2 Research Content and Methods
I. Research Content
II. Research Methods and Procedures
(I) Literature Review
(II) Group Discussion
(III) Delphi Expert Consultation
Expert Selection Criteria
Design of the Expert Consultation Questionnaire
Implementation of the Expert Consultation
Principles for Indicator Screening
(IV) Determination of Weights Using the Analytic Hierarchy Process (AHP)
Establishment of the Hierarchical Structure
Construction of Pairwise Comparison Judgment Matrices
Consistency Testing
III. Quality Control
IV. Technical Roadmap
Chapter 3 Results
I. Basic Framework of the Early Warning Indicator System for Economic Operation Risk in Public Hospitals
II. Results of Delphi Analysis
(I) Basic Characteristics of the Expert Panel
(II) Overview of the Expert Consultation

Expert Enthusiasm
Expert Authority Coefficient
Coordination of Expert Opinions
(III) Screening and Determination of Evaluation Indicators
Degree of Concentration of Expert Opinions in the First Round
Expert Opinions and Suggestions in the First Round
Indicator Screening and Revision
Degree of Concentration of Expert Opinions in the Second Round
Finalization of the Risk Indicator System
III. Determination of Indicator Weights by AHP
Chapter 4 Discussion
I. Discussion on the Components of the Early Warning Indicator System for Economic Operation Risk in Public Hospitals
II. Scientific Rationale for Using the Delphi Method and AHP to Construct the Early Warning Indicator System
(I) Composition of the Expert Panel
(II) Number of Consultation Rounds and Achievement of Expert Consensus
(III) Assignment of Weights
III. Significance of Constructing an Early Warning Indicator System for Economic Operation Risk in Public Hospitals
IV. Limitations of This Study
Chapter 5 Conclusion
Appendix
Revisions to the Evaluation Indicator System After the First Round
I. Basic Information of Experts
II. Importance Evaluation of First-Level Indicators [$\bar{x}_j,\sigma_j,CV_j,K_j$] (Matrix Scale Items)
III. Evaluation of Second-Level Indicators

The Formulation of an Early Warning Indicator Framework for Economic Performance in Public Hospitals

Abstract

Background ： With the deepening of healthcare system reforms, public hospitals in China are facing multiple challenges, including changes in medical insurance payment methods, the elimination of drug and consumable markups, and financial pressure. These factors have heightened the economic operational risks of public hospitals. Establishing a scientific and effective early warning indicator system is crucial for ensuring the stable operation and high-quality development of public hospitals. However, existing research often focuses on single financial risks and lacks a multi-dimensional and systematic early warning framework, making it difficult to comprehensively reflect the overall economic risks faced by hospitals.

Main Research Content ： This study aims to construct a scientific, systematic, and operable early warning indicator system for the economic operational risks of public hospitals. Through literature analysis and group discussions, a preliminary framework was established, covering seven dimensions: solvency, operational efficiency, profitability, development capacity, medical insurance policy, cost control, and medical quality and safety. Two rounds of Delphi expert consultations were conducted, involving 18 experts from hospital management, health economics, and medical insurance policy. The Analytic Hierarchy Process (AHP) was used to determine the weights of each indicator, resulting in a final system comprising 7 first-level indicators and 29 second-level indicators.

Results ： The constructed early warning indicator system is comprehensive, hierarchical, and practical. The weights of the first-level indicators show that "medical insurance policy risk" and "cost control risk" have the highest weights (both 0.2240), reflecting the critical impact of medical insurance policy implementation and cost management on hospital economic operations under the current reform context. Among the second-level indicators, "DRG/DIP grouping deviation rate," "cost consumption index," and "proportion of drug and consumable costs" are particularly prominent, highlighting the central role of medical insurance payment reforms and cost structure optimization in risk early warning. All indicators passed consistency tests, and the expert coordination coefficient was statistically significant ($P<0.05$), demonstrating the system's scientific rigor and authority.

Significance： This study fills a theoretical gap in multi-dimensional economic risk early warning systems for public hospitals, promoting the evolution of risk management from single financial indicators to comprehensive ecological models. In practice, the system provides hospital managers with a real-time, dynamic risk monitoring tool, facilitating a shift from reactive responses to proactive early warnings and enhancing resource allocation efficiency and operational resilience. Additionally, it offers a scientific basis for government departments to formulate precise compensation policies and optimize industry supervision, contributing significantly to the coordinated development of healthcare, medical insurance, and medicine, and supporting the high-quality development of public hospitals.

Keywords: Public hospital;Economic operation;Risk early warning; Indicator system; Delphi method; Analytic Hierarchy Process (AHP)

List of Main Symbols

Abbreviation	**Full Term (English)**	**Chinese Term**
CV	Coefficient of Variation	变异系数
W	Kendall's Coefficient of Concordance	肯德尔和谐系数
χ^2	Chi-square	卡方
CI	Consistency Index	一致性检验指数
CR	Consistency Ratio	随机一致性比率
P	Probability	概率

Chapter 1 Introduction

I. Research Background

(I) Establishing an effective early warning indicator system is crucial for the economic operation of public hospitals

Public hospitals are the core carriers of China’s healthcare service system, and the security of their economic operation is directly related to people’s well-being and social stability. As an essential component of the public health system, the stable and sustainable operation of public hospitals exerts a profound impact on population health and overall social order.

In recent years, with the deepening of healthcare reform, public hospitals have been exposed to emerging challenges and risks, including financial risk, operational risk, and debt risk, among others.[1] The economic performance of many hospitals remains suboptimal, and the level of risk management and development management needs further improvement.[2] Therefore, establishing an effective risk early warning indicator system is of great importance for the prevention and control of such risks.

Since 2020, the National Health Commission has continuously promoted the “Year of Economic Management of Public Medical Institutions” initiative, emphasizing refined operation and digital management centered on the integration of business and finance. However, the existing early warning mechanisms still suffer from shortcomings such as incomplete indicator systems and insufficient analysis of influencing factors.[3] Against this background, constructing a scientific and systematic early warning indicator system for economic operation risk in public hospitals has become an urgent task.

(II) Current status of early warning indicator systems for hospital economic operation risk at home and abroad

In Europe and the United States, hospitals have improved resource allocation and operational efficiency through refined management tools such as the ward/clinical unit manager system.[3] In Turkey, hospitals have been classified into 11 financial risk models, and six key variables influencing hospital financial risk were identified.[4] Other studies have applied approaches such as the DBMfS method to explore how healthcare organizations pursue sustainable performance from the perspective of sustainable business models, introducing corporate management concepts into healthcare management.[5]

International research has mainly focused on optimising hospital management, improving healthcare quality, and strengthening cost control. In contrast, studies specifically targeting the economic operation risk of public hospitals remain relatively limited. Nonetheless, with the advancement of globalisation and digitalisation, an increasing number of countries are paying attention to the modernisation of hospital management, and advanced concepts such as value-based management and lean management have gradually been introduced into public hospital practice.

Existing studies often focus on single financial risks, such as debt risk or advances of medical insurance funds, and lack a multidimensional, integrated early warning framework.[6] Some hospitals have attempted to build financial risk models (e.g. early warning models based on cluster analysis or neural networks), but these are rarely linked systematically with policy, operational, or governance risks.[7] In Henan Province, exploratory efforts have been made to construct an economic operation mechanism for public hospitals supported by the “integration of business and finance, discipline and finance, and data and finance,” with smart finance as the foundation, comprehensive budgeting as the core, and cost control and performance management as key instruments, thereby realising interconnection among modules and promoting high-quality development of hospitals.[8] These models provide scientific decision-making support for risk management to some extent, yet still face limitations such as insufficient practicality and constraints in data acquisition.

At the national level, the establishment of a “penetrating” regulatory mechanism for public medical institutions has been proposed, but its effective implementation relies on a unified, standardised, and operable indicator system for economic operation risk early warning.

(III) Research significance

1. Theoretical significance

This study aims to fill the theoretical gap in multidimensional economic operation risk early warning for public hospitals and to improve the theoretical framework of hospital risk management. By constructing an economic operation risk early warning indicator system, it systematically integrates financial risk, operational risk, policy risk, and other dimensions of risk, forming a management framework compatible with both the public welfare nature and quasi-market-oriented operation of public hospitals. This contributes to advancing risk management theory from a single financial-indicator perspective to a comprehensive ecological model.

Furthermore, the study deepens the analysis of the mechanisms of key influencing factors by examining the interaction between external factors—such as policy adjustment, cost structure, and medical insurance payment reform—and internal factors, including internal control and resource allocation efficiency. This supports the construction of a dynamic “environment–behaviour–outcome” analytical model,[10] providing a new theoretical lens for studying risk transmission pathways in public hospitals.

In terms of methodology, the study promotes innovation in risk early warning by advocating the introduction of big data analytics and machine learning techniques to overcome the limitations of traditional ratio analysis and to develop dynamic early warning models based on multi-source heterogeneous data. This supports the transformation of medical risk management from experience-driven to data-driven models.

2. Practical significance

This study provides a systematic and operable tool for government authorities and hospital managers to support precise policy-making, optimised resource allocation, and the achievement of "coordination among medical services, medical insurance, and pharmaceuticals" as well as the high-quality development of public hospitals.

Enhancing the risk resilience of public hospitals:

By establishing an early warning system incorporating key indicators such as asset-liability ratio, proportion of medical compensation, and cost-benefit ratio, hospitals can monitor risks such as debt default and low operational efficiency in real time and obtain accurate decision support. For example, when the asset-liability ratio exceeds the 50% threshold, the system can automatically trigger an early warning.

Optimising healthcare resource allocation efficiency:

By identifying critical risk points such as duplicate equipment procurement and excessive consumption of drugs and consumables, the system can guide hospitals to establish a cost-effectiveness-oriented resource management model.

Safeguarding the public welfare nature of public hospitals:

Under the background of Diagnosis-Related Groups (DRG) and Diagnosis-Intervention Packet (DIP) payment reforms, the early warning system can monitor indicators related to medical service efficiency and quality, preventing declines in care quality due to excessive pursuit of economic returns.

Addressing challenges arising from medical insurance policy reforms:

In response to income structure adjustments driven by reforms in medical insurance payment methods, the early warning system can dynamically evaluate indicators such as Case Mix Index (CMI) and low-risk mortality rates, helping hospitals maintain sustainable development under cost-containment pressure and improving modern hospital governance capacity.

Through the construction and application of this indicator system, the study contributes to improving the modern hospital management system and strengthening the governance capacity of public hospitals in China.

II. Research Objectives

This study responds to the current risk landscape and challenges confronting the economic operation of public hospitals. Drawing on extensive domestic and international research on the construction of evaluation indicator systems, it employs the Delphi method and Analytic Hierarchy Process (AHP) to develop a multidimensional, scientific, and feasible early warning indicator system for economic operation risk in public hospitals.

The objective of this system is to provide a structured solution for public hospitals to cope with complex challenges such as DRG-based payment reform and public health emergencies. It is intended to offer a practical tool for dynamic monitoring and early warning, thereby supporting high-quality development of public hospitals through proactive risk prevention and evidence-based decision-making.

Chapter 2 Research Content and Methods

I. Research Content

In line with the requirements of improving quality and efficiency in the economic operation of public hospitals, and considering their current risk profile and existing problems, this study focuses on assessing financial risk, operational efficiency, revenue structure, compliance risk, debt risk, resource, and sustainability. On this basis, a preliminary framework for the early warning indicators of economic operation risk in public hospitals was constructed.

A panel of consultation experts was established, comprising hospital managers (such as presidents and directors of finance), scholars in health economics, and experts engaged in medical insurance policy management and research. Through three rounds of expert consultation, the importance of each indicator was evaluated. Based on expert opinions and suggestions, and in accordance with predefined screening criteria, indicators were deleted, revised, or supplemented as appropriate. The Analytic Hierarchy Process (AHP) was then applied to construct judgment matrices, conduct consistency tests, and calculate indicator weights, ultimately forming the final early warning evaluation indicator system for economic operation risk in public hospitals.

II. Research Methods and Procedures

(I) Literature Review

Given the professional and comprehensive nature of the research topic, core search terms such as “public hospitals,” “economic operation,” “financial risk,” “operational efficiency,” “risk early warning indicators,” “sustainable development,” “compliance risk,” and “debt risk” were adopted.

Relevant studies were retrieved from major Chinese databases, including CNKI, Wanfang Data, and VIP, as well as international databases such as PubMed, Web of Science, and ScienceDirect. Journal articles and industry research reports published between 2018 and 2025 were included. Policy documents were also collected, including the Guiding Opinions on Strengthening Performance Appraisal of Tertiary Public Hospitals issued by the General Office of the State Council (GBF [2019] No. 4), and the requirements of the “Economic Management Year of Public Medical Institutions” campaign launched by the National Health Commission, to ensure coverage of theoretical research, practical experience, and policy orientation.

The literature review clarified the gaps this study intends to address. First, existing early warning indicators are predominantly concentrated on financial risk, with insufficient coverage of “compliance risk and alignment with medical insurance policies” and the linkage between “resource and sustainable development.” Second, some indicators lack direct alignment with the policy goal of improving quality and efficiency in public hospitals.

Based on these findings, seven primary indicator domains—financial risk, operational efficiency, revenue structure, compliance risk, debt risk, resource, and sustainable development—were preliminarily identified. These domains laid the foundation for constructing the preliminary early warning indicator framework for the economic operation of public hospitals and clarified the key issues to be further refined during the expert consultation process.

(II) Group Discussion

To enhance the scientific rigor and practicality of the early warning indicator system, a discussion group was formed, consisting of key personnel from hospital finance, operations management, and medical insurance liaison departments, as well as researchers in health economics.

The group focused on critical challenges encountered in current risk monitoring of public hospital economic operation, such as lagged financial data, fragmented operational efficiency indicators, and ambiguous definitions of compliance risk. The core objective of the discussions was to “evaluate the quality of economic operation monitoring in public hospitals and refine the early warning indicator framework.”

Discussions were conducted around the initially proposed indicator framework, following key principles including scientific relevance (clear linkage between indicators and risk dimensions), practicality (meeting management needs), operability (feasibility of data collection), and independence (avoiding redundancy and overlap among indicators).

During the process, existing deficiencies were systematically reviewed—for example, debt risk indicators previously focused only on liability ratios without fully reflecting debt-servicing capacity. Accordingly, the primary and secondary indicators were optimised: indicators such as “medical insurance settlement cycle” were added under compliance risk; “equipment utilisation rate” under resource was refined into “utilisation rate of large-scale equipment” and “turnover rate of conventional equipment.”

At the tertiary level, more specific indicators were defined, such as “current ratio” under “debt-paying capacity” and “consumable cost per 100 CNY of revenue” under “cost control.” This iterative refinement resulted in a logically coherent and practice-oriented first-round indicator system for the Delphi consultation.

(III) Delphi Expert Consultation

1. Expert Selection Criteria

Experts were selected from three key domains—hospital operation and management, health economics, and medical insurance policy—to ensure integration of theory and practice, and alignment of macro-level policy orientation with micro-level operational experience. The number of experts was controlled within 15–20.

(1) Hospital managers (e.g. hospital presidents, directors of finance)

Possess professional background in hospital operation management, financial management, or medical quality management, and are familiar with internal processes and risk control.

Have at least 5 years of experience in hospital management or related fields and hold middle-level or above managerial positions, enabling them to accurately identify practical risk points.

Hold associate senior or higher professional titles, or have a master's degree or above with significant achievements in hospital management.

(2) Health economics experts

Have expertise in health economics, medical cost accounting, or health policy evaluation, with the ability to analyse economic operation mechanisms from a theoretical perspective.

Have at least 5 years of experience in health economics research, cost analysis, or related work, and have participated in relevant projects or research reports.

Hold associate senior or higher titles, or a master's degree and representative achievements in the field, and are familiar with international research trends and applications.

(3) Medical insurance policy experts

Possess professional background in medical insurance policy formulation, payment management, or fund supervision, and are familiar with national and local policy systems and reform directions.

Have at least 5 years of experience in medical insurance policy research, implementation, or evaluation, and have participated in policy development, reform pilots, or guideline drafting.

Hold associate senior or higher titles, or middle-level or above positions in relevant administrative or research institutions, with in-depth understanding of payment reform and cost-containment policies.

2. Design of the Expert Consultation Questionnaire

The questionnaire consisted of five sections:

(1) Introduction

Clarifying the background, objectives, and contact information of the study and explaining the principles of anonymous and independent consultation.

(2) Expert Profile

Collecting information on age, specialty (hospital management, health economics/management research, medical insurance policy/management), years of experience (≥5 years), professional title/position (senior or associate senior title, administrative role), highest degree, and experience in relevant projects (e.g. economic evaluation, medical insurance policy design).

(3) Assessment of Expert Authority

To ensure methodological rigour, the authority coefficient (Cr) of each expert was calculated using two dimensions: judgment basis (Ca) and familiarity (Cs), where $Cr = (\text{mean } Ca + Cs) / 2$, and $Cr \geq 0.7$ was considered acceptable.

Judgment basis (Ca): Experts indicated the main sources underpinning their judgments, including theoretical analysis, practical experience, understanding of peers' work, and intuitive judgment. Corresponding scores of 0.9 (high), 0.6 (moderate), and 0.3 (low) were assigned, allowing higher weight for decisions grounded in theory and practical experience.

Familiarity (Cs): Experts rated their familiarity with economic operation risk indicators on a 5-level scale from "very familiar" to "unfamiliar," corresponding to values between 1.0 and 0.1. This captured their understanding of indicator connotations, calculation methods, and risk implications.

(4) Main Body of the Questionnaire

Structured around “multi-level indicators + clear definitions + unified scale + open comments.”

The indicator system covered 7 first-level dimensions and 21 second-level indicators, including debt-paying capacity, operational efficiency, profitability, development capacity, medical insurance policy, cost control, and medical quality and safety.

Each secondary indicator was accompanied by a definition and calculation formula (e.g. asset-liability ratio = total liabilities / total assets × 100%) to ensure consistent understanding.

A five-point Likert scale (1 = not important, 5 = very important) was used to rate indicator importance.

A free-text comment field was provided after each indicator for suggestions on definition refinement, calculation adjustment, or additional indicators.

(5) Comment Section

Experts could propose modifications, deletions, or additions to indicators, ensuring both standardisation and flexibility in the development of the system.

3. Implementation of the Expert Consultation

First round:

The first-round questionnaire, explanatory materials, and background information were distributed to the selected 15–20 experts. Experts were asked to:

Rate the importance of each indicator using the Likert 5-point scale based on its value in early warning of economic operation risk;

Propose additional indicators (including name, definition/formula, and rationale);

Complete the authority assessment (Ca and Cs).

Data were collated using Excel 2019 and analysed with SPSS 26.0. For each indicator, the mean score, standard deviation, and coefficient of variation were calculated; expert authority coefficients (Cr) were computed, and only opinions from experts with $Cr \geq 0.7$ were retained. Newly suggested indicators were summarised into an anonymised list. The aggregated results— including mean scores, standard deviations, and the list of proposed indicators—were fed back to experts anonymously to support independent reassessment in subsequent rounds.

Second round:

The second-round questionnaire included: (i) indicators with large disagreement in the first round (e.g. mean < 3.0 or standard deviation > 1.2), (ii) newly proposed indicators with clear definitions and formulas, and (iii) a summary of first-round results (means, standard deviations, and representative comments). Experts were invited to:

Reassess controversial indicators and provide reasons for adjustments where necessary;

Rate the importance of newly added indicators;

Refine indicator definitions and calculation methods.

According to the results, if Kendall's coefficient of concordance (W) exceeded 0.3 and its significance test showed $P < 0.05$, a final draft of the indicator system and a summary of the first two rounds (including W, P values, and screening rationale) were circulated for confirmation of completeness and rationality. If $W \leq 0.3$ or $P \geq 0.05$, a further round of consultation would be conducted, focusing on remaining controversial indicators and their underlying mechanisms, until greater consensus was achieved.

4. Indicator Screening Principles

Indicators were selected based on quantitative and qualitative criteria. An indicator was retained if it met all of the following conditions: arithmetic mean score ($\bar{x}$) ≥ 4.2, full-score ratio (K) > 0.20, and coefficient of variation (CV) < 0.25, indicating high perceived importance, strong central tendency, and good consensus among experts.

Indicators not meeting these thresholds were revised or removed according to expert suggestions. For indicators with substantial controversy or conflicting recommendations regarding deletion or addition, the final decision was made after collective discussion by the research team, ensuring that the resulting system was both scientifically rigorous and practically applicable.

Statistical Analysis of Expert Consultation Data

(1) Expert Enthusiasm Coefficient

The expert enthusiasm coefficient reflects the degree of engagement and concern of experts toward this study, and is measured by the questionnaire response rate and the suggestion rate. The calculation formulas are as follows:

$$\text{Questionnaire response rate} = \frac{\text{Number of questionnaires returned}}{\text{Number of questionnaires distributed}} \times 100\% \quad (1)$$

$$\text{Suggestion rate} = \frac{\text{Number of experts providing comments or suggestions}}{\text{Number of valid questionnaires returned}} \times 100\% \quad (2)$$

(2) Indicator Importance Scoring

The importance of each indicator was evaluated using a five-point Likert scale with the following categories: "very important," "important," "moderately important," "unimportant," and "very unimportant," assigned scores of 5, 4, 3, 2, and 1, respectively.

(3) Degree of Concentration of Expert Opinions

Arithmetic Mean：

$$\bar{x}_j = \frac{1}{m_j} \sum_{i=1}^{m} x_{ij} \qquad (3)$$

Where $\bar{x}_j$ denotes the mean evaluation score of indicator j; x_{ij} is the score given to indicator j by the i expert; and m is the total number of experts. A larger $\bar{x}_j$ indicates a higher perceived importance of indicator j .

Full-score ratio：

$$K_j = \frac{m_j}{M_j} \qquad (4)$$

where $m_j$represents the number of experts participating in the evaluation of indicator j ; m_j is the number of experts who assigned a full score (5 points) to indicator j. The full-score ratio K_j ranges from 0 to 1 and serves as a supplementary indicator to the mean score $\bar{x}_j$. The larger the K_j value, the higher the proportion of experts giving full scores, indicating greater perceived importance of indicator j.

Calculation of the Coefficient of Variation ：

$$CV_j = \frac{\sigma_j}{\bar{x}_j} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (5)$$

where: σ_j represents the standard deviation of indicator (j);

CV_j denotes the coefficient of variation for indicator (j), which reflects the degree of fluctuation in experts' evaluations of the relative importance of that indicator.

A smaller CV_j value indicates a higher level of consensus among experts regarding indicator (j).

Calculation of Kendall's Coefficient of Concordance:

$$W=\frac{12}{\mathrm{m}^2(\mathrm{n}^3\text{-}\mathrm{n})\text{-}\mathrm{m}\sum_{\mathrm{i}=1}^{\mathrm{m}} T_{\mathrm{i}} \sum_{\mathrm{j}=1}^{\mathrm{n}} \mathrm{d}_{\mathrm{j}}^2}\text{...........} \quad (6)$$

$$T_i=\sum_{i=1}^{L}\left(t_i^3\text{-}t_i\right)\text{...........} \quad (7)$$

where (n) denotes the number of indicators and (m) denotes the number of experts. $\sum_{j=1}^{n} d_j^2$ is the sum of squared deviations of the rank sums of all indicators from their mean; t_i is the tie-correction factor; L denotes the number of groups of tied ranks for expert i ; t denotes the number of indicators with the same rank in each tied group L .

The value of (W) ranges from 0 to 1. A larger (W) indicates a higher degree of concordance among experts. When all experts give completely consistent evaluations of the relative importance of all indicators, (W = 1); when their evaluations are entirely inconsistent, (W = 0).

Significance Test of the Degree of Concordance — Chi-square (χ^2) Test:

$$\chi_R^2=\frac{1}{mn(n+1)\text{-}\frac{1}{n\text{-}1}\sum_{i=1}^{m} K_i}\sum_{j=1}^{n} d_j^2 \ (\mathrm{v=n\text{-}1})\text{...........} \quad (8)$$

According to the degrees of freedom vvv and the significance level α=0.05， the critical value χ_α^2 is obtained from the chi-square distribution table. If $\chi_R^2 > \chi_\alpha^2$, the null hypothesis of random agreement is rejected, indicating that the concordance among experts is statistically significant, the degree of coordination is good, and the results are acceptable. If $\chi_R^2 < \chi_\alpha^2$, the consistency of expert opinions is considered not statistically reliable, the credibility of the evaluation is low, and the results are not suitable for adoption.

(5) **Expert Authority**

The degree of expert authority is expressed by the expert authority coefficient (c_r), which is determined by two components: the basis of the expert's judgment c_α and the expert's familiarity with the indicators c_s . The calculation formula is:

$$c_r = \frac{(c_\alpha + c_s)}{2} \quad \text{......................................} \ (9)$$

In this study, the judgment basis and familiarity of experts with each indicator were quantified (Table 2.1). When the resulting ， c_r is greater than 0.7, the conclusions drawn from the expert consultation are considered highly reliable and authoritative.

Table 2.1 Quantitative Scoring of Experts' Judgment Basis and Familiarity with Indicators [11]

Judgment basis	Quantified value	Familiarity level	Quantified value
Theoretical analysis	**0.9 / 0.6 / 0.3**	**Very familiar**	**1.0**
Practical experience	**0.9 / 0.6 / 0.3**	**Familiar**	**0.8**
Understanding of peers (domestic and international)	**0.9 / 0.6 / 0.3**	**Fairly familiar**	**0.6**

Judgment basis	Quantified value	Familiarity level	Quantified value
Intuition	**0.9 / 0.6 / 0.3**	**Slightly unfamiliar**	**0.3**
		Unfamiliar	**0.1**

IV . Determination of Weights Using the Analytic Hierarchy Process

The Analytic Hierarchy Process (AHP), proposed by the American operations researcher T. L. Saaty in the 1970s, is a multi-criteria decision-making method. Its core concept is to decompose complex decision problems (such as determining indicator weights or selecting optimal schemes) into a hierarchical structure consisting of a goal layer, a criteria layer, and an alternative/indicator layer. By conducting pairwise comparisons of the relative importance of elements at the same level with respect to the upper-level element, AHP constructs judgment matrices and, through mathematical computation, derives the weights of each element. This method enables a systematic analysis of decision problems and is particularly suitable for scenarios lacking sufficient quantitative data and relying heavily on expert judgment, such as assigning weights in the early warning indicator system for economic operation risks in public hospitals [11,12].

1. Establishment of the Hierarchical Structure

Goal layer (top level): To determine the weights of the indicators in the early warning system for economic operation risks in public hospitals.

Criteria layer (middle level): Core dimensions supporting the goal, such as debt-paying capacity, operational efficiency, profitability, development capacity, alignment with medical insurance policies, cost control, and medical quality and safety (i.e., the seven key risk dimensions identified through the Delphi method).

Indicator layer (bottom level): Specific early warning indicators under each criterion, for example, asset–liability ratio and current ratio under the "debt-paying capacity" dimension.

2. Construction of Pairwise Comparison Judgment Matrices

Experts compare elements at the same hierarchical level in pairs according to their relative importance with respect to the element in the upper level, and assign values using Saaty's 1–9 scale to construct the judgment matrices [13].

Table 2.2 Assignment of Values Using Saaty's 1–9 Scale

Scale	**Meaning**
1	Element *i* and element *j* are equally important.
3	Element *i* is slightly more important than element *j*.
5	Element *i* is clearly more important than element *j*.
7	Element *i* is strongly more important than element *j*.
9	Element *i* is extremely more important than element *j*.
2,4,6,8	Intermediate values between the adjacent judgements above.
Reciprocals (1/3, 1/5, 1/7, 1/9)	Element *j* is more important than element *i*.

3.Consistency Test

The eigenvector is normalized to obtain the weight vector, and the consistency index (CI) is then calculated. In general, a smaller CI indicates better consistency. The corresponding random index (RI) is determined according to the order of the matrix.

If (CR < 0.10), the consistency of the judgment matrix is considered acceptable, and the weight vector (W) can be adopted. If (CR \geq 0.10), the judgment matrix is deemed to have poor consistency and must be returned to the experts for revision of the pairwise comparisons until (CR < 0.10) is achieved.

Table 2.3 Average Random Consistency Index (RI) for 1–9 Order Matrices

Matrix order (n)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41

III. Quality Control

Quality control measures included: review of the hierarchical structure (recording names of pre-consultation experts, review dates, and revision suggestions); documentation of expert training and pilot testing results (including the list of participating experts and the accuracy rate of their understanding of the rating scale); detailed records of consistency testing (individual expert CR values, overall CR value, and number of adjustment rounds); documentation of weight calculation and validation (results obtained using different computational methods and corresponding correlation analysis reports); and archiving of de-identified original judgment matrices completed by experts together with user validation questionnaires, to ensure traceability and reproducibility of the study.

IV.Technical

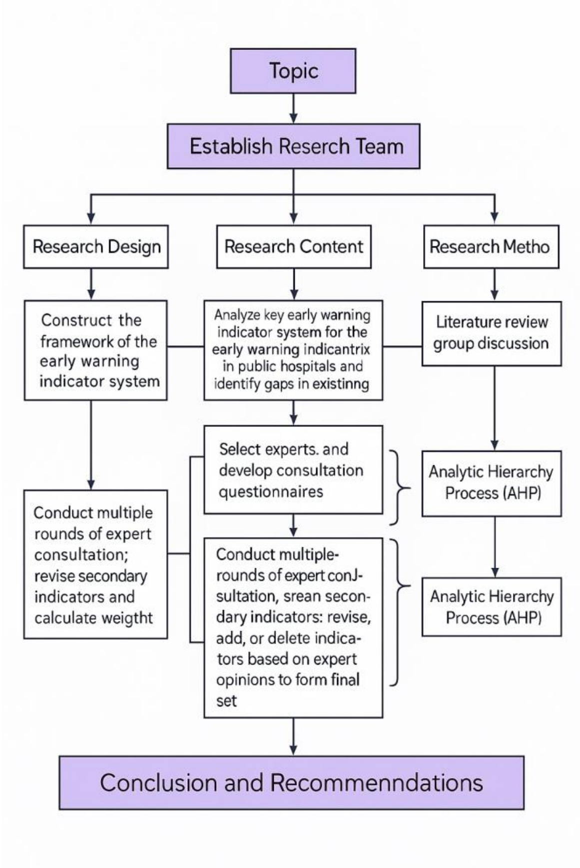

Figure 2.1 Technical Roadmap

Chapter 3 Results

I. Basic Framework of the Early Warning Indicator System for Economic Operation Risk in Public Hospitals

Using literature review and group discussion methods, this study initially constructed an early warning indicator system comprising 7 first-level indicators and 23 second-level indicators (see Figure 3.1). In this system, the "asset–liability ratio" indicator was developed with reference to the *Guiding Opinions on Strengthening the Operation Management of Public Hospitals* (Guo Wei Cai Wu Fa [2020] No. 27); "consumable cost per 100 CNY of medical revenue" was based on the *Opinions on Promoting the High-quality Development of Public Hospitals* (Guo Ban Fa [2021] No. 18); and the "proportion of drug and consumable expenditure" indicator followed the requirements of the *Cost Accounting Standards for Public Hospitals* (Guo Wei Cai Wu Fa [2021] No. 4).

Combined with findings from the literature and the latest industry standards such as the *Evaluation Standards for Tertiary Hospitals* (2025 edition), these indicators were discussed, screened, and finally incorporated into the early warning indicator system by the project team.

Table 3.1 Basic Framework of the Early Warning Indicator System for Economic Operation Risk in Public Hospitals

First-level Indicator	**Second-level Indicator**
1. Debt-paying capacity risk	1.1 Asset–liability ratio
	1.2 Current ratio
	1.3 Quick ratio
2. Operational efficiency risk	2.1 Turnover rate of medical receivables
	2.2 Service revenue per bed
	2.3 Bed occupancy rate
	2.4 Average length of stay

3. Profitability risk	3.1 Return on net assets
	3.2 Surplus rate of medical revenue
	3.3 Growth rate of medical revenue
4. Development capacity risk	4.1 Net fixed asset ratio
	4.2 Proportion of research funding
5. Medical insurance policy risk	5.1 Medical insurance settlement difference rate
	5.2 DRG/DIP grouping deviation rate
	5.3 Medical insurance claim denial rate
	5.4 Case Mix Index (CMI)
	5.5 Cost consumption index
6. Cost control risk	6.1 Consumable cost per 100 CNY of medical revenue
	6.2 Management expense ratio
	6.3 Proportion of drug and consumable expenditure
7. Medical quality and safety risk	7.1 Incidence of complications among surgical patients
	7.2 Patient satisfaction
	7.3 Average cost per discharged patient

II. Results of Delphi Analysis

(I) Basic Characteristics of the Expert Panel

A total of 18 experts were selected from primary healthcare institutions, municipal medical institutions, health administrative departments, and universities, all engaged in health economics research, health economic management, or hospital financial management. All experts were in their mid-career or younger, with 8 having more than 20 years of work experience (44.4%), indicating substantial practical expertise. In terms of professional background, 50% specialized in health economics/management research and 50% in hospital management. The overall professional rank was relatively high, with 66.0% holding senior titles and 27.8% intermediate titles. Most experts had prior experience in relevant projects, suggesting that the expert panel selected for this Delphi study was reasonably representative and possessed sufficient theoretical knowledge and practical experience. See Table 3.2.

Table 3.2 Basic Characteristics of Experts Participating in the Delphi Survey

Item	Number (n=20)	Percentage (%)
Age		
41–50 years	8	44.40
30–40 years	6	33.30
51–60 years	4	22.20
Years of Work Experience		
21–30 years	8	44.40
11–20 years	6	33.30
>30 years	3	16.70
5–10 years	1	5.60
Professional Background		
Health economics/management	9	50.00

Item	Number (n=20)	Percentage (%)
Hospital management related	9	50.00
Professional Title/Position		
Senior (full)	6	33.30
Intermediate	6	33.30
Associate senior	5	27.80
Division-level (department)	2	11.10
Section-level	1	5.60
Educational Background		
Others	5	27.80
Bachelor’s degree	5	27.80
Doctoral degree	4	22.20
Master’s degree	4	22.20
Project Experience		
With similar project experience	12	66.70
Without relevant experience	6	33.30

(II) Overview of the Delphi Consultation

1.Expert Enthusiasm

Two rounds of Delphi expert consultation were conducted in this study. To ensure continuity, experts who participated in the first round were invited to participate in the second round.

In the first round, 18 questionnaires were distributed and 18 valid questionnaires were returned; 8 experts provided additional comments or suggestions. The questionnaire response rate and suggestion rate were 100.00% and 40.00%, respectively.

In the second round, 18 questionnaires were distributed and all were returned, with a response rate of 100.00% and a suggestion rate of 11.11%.

These results indicate a high level of expert engagement and reflect the strong attention paid by the panel to the construction of the early warning indicator system.

2.Expert Authority Coefficient

Both rounds of the consultation included assessment of experts' familiarity with the indicators, the basis of their judgments, and their evaluation of indicator importance. The importance of each indicator was rated on a five-point scale (1–5), with higher scores indicating stronger representativeness and importance.

The expert authority coefficient（Cr）was determined jointly by the judgment basis （Ca） and familiarity （Cs）. Familiarity （Cs） was divided into five levels, while the judgment basis（Ca）was derived from four components: theoretical analysis, practical experience, reference to domestic and international literature, and intuitive judgment.

Based on the self-evaluation results and the scoring criteria shown in Table 2.1, the calculated authority coefficients for experts in both rounds were all greater than 0.7, indicating that the results of this Delphi process are reliable and that the participating experts have a solid understanding of the construction of an early warning indicator system for the economic operation risk of public hospitals. See Tables 3.3–3.7.

Table 3.3 Expert Authority in the Two Rounds of Consultation

Round	Judgment Coefficient (Ca)	Familiarity Coefficient (Cs)	Authority Coefficient (Cr)
First round	0.722222	0.916667	0.819444
Second round	0.744444	0.944444	0.844444

Table 3.4 Quantitative Assignment of Expert Judgment Basis

Judgment Basis (Ca)	Degree of Influence	Quantified Value
Practical experience	High	0.5
	Medium	0.4
	Low	0.3
Theoretical analysis	High	0.3
	Medium	0.2
	Low	0.1
Literature sources	—	0.1
Intuitive judgment	—	0.1

Table 3.5 Quantitative Assignment of Expert Familiarity

Familiarity Level	Quantified Value
Very familiar	0.9
Relatively familiar	0.7
Moderately familiar	0.5
Slightly unfamiliar	0.3
Very unfamiliar	0.1

Table 3.6 Authority Coefficients of Experts in the First Round

Expert	Cs (Familiarity)	Ca (Judgment)	Cr (Authority)
1	0.9	0.7	0.8
2	0.9	0.7	0.8
3	1.0	0.5	0.75
4	1.0	0.5	0.75
5	0.8	0.3	0.55
6	0.9	0.7	0.8
7	1.0	0.9	0.95
8	1.0	0.7	0.85
9	0.9	0.7	0.8
10	0.9	0.9	0.9
11	0.9	0.7	0.8
12	0.9	0.7	0.8
13	0.9	0.9	0.9
14	0.9	0.9	0.9
15	0.9	0.7	0.8
16	1.0	0.9	0.95
17	0.9	0.9	0.9
18	0.8	0.7	0.75
Mean	**0.916667**	**0.722222**	**0.819444**

Table 3.7 Authority Coefficients of Experts in the Second Round

Expert	**Ca (Judgment)**	**Cs (Familiarity)**	**Cr (Authority)**
1	0.8	0.7	0.75
2	0.9	0.7	0.8
3	1.0	0.9	0.95
4	1.0	0.7	0.85
5	0.9	0.7	0.8
6	0.9	0.7	0.8
7	0.9	0.7	0.8
8	1.0	0.9	0.95
9	1.0	0.9	0.95
10	1.0	0.9	0.95
11	0.9	0.7	0.8
12	1.0	0.7	0.85
13	1.0	0.5	0.75
14	0.9	0.9	0.9
15	1.0	0.9	0.95
16	0.9	0.3	0.6
17	0.9	0.7	0.8
18	1.0	0.9	0.95
Mean	**0.744444**	**0.944444**	**0.844444**

3.Degree of Coordination of Expert Opinions

The coordination of expert opinions on indicator importance in both rounds of consultation was assessed, and the P-values of Kendall's coefficient of concordance were all less than 0.05. This indicates that the results of both Delphi rounds are statistically significant and the degree of agreement among experts is reliable (see Table 3.7).

Table 3.8 Coordination Coefficients of the Two Rounds of Expert Consultation

Indicator Level	**First Round N**	**First Round W**	**First Round χ^2**	**First Round P**	**Second Round N**	**Second Round W**	**Second Round χ^2**	**Second Round P**
First-level	18	0.266	28.723	0.0001	18	0.222	24.000	0.001
Second-level	18	0.162	63.982	0.000	18	0.222	111.744	0.000

(III) Screening and Determination of Evaluation Indicators

1.Concentration of Expert Opinions in the First Round

For the seven first-level indicators, the arithmetic mean ($\bar{x}$) was ≥ 3.5, the coefficient of variation (CV) ≤ 0.2315, and the full-score ratio (K) ≥ 0.0556. Certain controversy remained regarding indicators under “development capacity risk” and “medical quality and safety risk,” for which the deletion or addition of specific items needed to be considered. For indicators under “operational efficiency risk,” “profitability risk,” and “medical insurance policy risk,” corresponding revisions were required based on expert comments. See Table 3.8.

Table 3.9 First-round Expert Ratings of First-level Indicators

Indicator	Mean	Standard Deviation	Coefficient of Variation	Full-score Ratio
1. Debt-paying capacity risk	4.50	0.366	0.0813	0.2222
2. Operational efficiency risk	4.0139	0.5654	0.1409	0.0556
3. Profitability risk	4.3889	0.5393	0.1229	0.1667
4. Development capacity risk	3.50	0.7475	0.2136	0.0556
5. Medical insurance policy risk	4.2889	0.6407	0.1494	0.1111
6. Cost control risk	4.2037	0.6777	0.1612	0.2778
7. Medical quality and safety risk	3.8889	0.9003	0.2315	0.1667

For the 23 second-level indicators, the arithmetic mean ($\bar{x}$) ranged from 3.6111 to 4.7222, the coefficient of variation (CV) ranged from 0.1039 to 0.4653, and the full-score ratio (K) ranged from 0.1111 to 0.7778. Among them, 10 indicators had ($\bar{x}$) < 4.20 and 3 indicators had (K < 0.20), indicating divergent expert opinions on their importance and a relatively low degree of coordination. See Table 3.9.

Table 3.10 First-round Expert Ratings of Second-level Indicators

Indicator	N	Min	Max	Mean	SD	CV	Full-score Ratio
1.1 Asset–liability ratio	18	4	5	4.6667	0.4851	0.1039	0.6667
1.2 Current ratio	18	3	5	4.3333	0.6860	0.1583	0.4444
1.3 Quick ratio	18	3	5	4.5000	0.6184	0.1374	0.5556
2.1 Turnover rate of medical receivables	18	3	5	3.9444	0.7254	0.1839	0.2222

Indicator	N	Min	Max	Mean	SD	CV	Full-score Ratio
2.2 Service revenue per bed	18	2	5	4.0556	0.8024	0.1978	0.2778
2.3 Bed occupancy rate	18	2	5	4.1667	0.8575	0.2058	0.3889
2.4 Average length of stay	18	2	5	3.8889	0.6764	0.1739	0.1111
3.1 Return on net assets	18	3	5	4.1111	0.7584	0.1845	0.3333
3.2 Surplus rate of medical revenue	18	3	5	4.7222	0.5745	0.1217	0.7778
3.3 Growth rate of medical revenue	18	2	5	4.3333	0.8402	0.1939	0.5000
4.1 Net fixed asset ratio	18	2	5	3.6111	0.8498	0.2353	0.1667
4.2 Proportion of research funding input	18	1	5	3.3889	0.9785	0.2887	0.1111
5.1 Medical insurance settlement difference rate	18	2	5	4.3889	0.8498	0.1936	0.5556
5.2 DRG/DIP grouping deviation rate	18	2	5	4.2778	0.8948	0.2092	0.5000
5.3 Medical insurance claim denial rate	18	2	5	4.2222	1.0033	0.2376	0.5556
5.4 Case Mix Index (CMI)	18	3	5	4.2222	0.6468	0.1532	0.3333
5.5 Cost consumption index	18	3	5	4.3333	0.6860	0.1583	0.4444
6.1 Consumable cost per 100 CNY of medical revenue	18	3	5	4.2222	0.8085	0.1915	0.4444
6.2 Management expense ratio	18	2	5	3.8889	1.0226	0.2630	0.3333

Indicator	N	Min	Max	Mean	SD	CV	Full-score Ratio
6.3 Proportion of drug and consumable expenditure	18	3	5	4.5000	0.6184	0.1374	0.5556
7.1 Incidence of complications in surgical patients	18	3	5	4.2222	0.8085	0.1915	0.4444
7.2 Patient satisfaction	18	1	5	3.3889	1.5770	0.4653	0.2778
7.3 Average cost per discharged patient	18	2	5	4.0556	0.9984	0.2462	0.3889

2.Expert Opinions and Suggestions in the First Round

In the first-round consultation, 8 experts provided comments and suggestions on certain indicators. Overall, the first-level indicators were considered reasonably designed. However, several issues were identified among the second-level indicators, including overlap and redundancy. For example, “consumable cost per 100 CNY of medical revenue” and “proportion of drug and consumable expenditure” were regarded as repetitive, as the former is already reflected within the latter. Experts recommended revising, adding, or removing some indicators. They suggested that the “proportion of research funding input” is not universally applicable, has limited evaluative value, and may lead to misjudgment; similarly, “patient satisfaction” is greatly influenced by patient expectations and individual factors, and under the current context of strained doctor–patient relationships and biased public opinion, may fail to accurately reflect hospital service quality and could be misleading.

In addition, optimization and substitution of some indicators were proposed. For instance, revising “surplus rate of medical revenue” to “medical surplus rate = (medical surplus − surplus from other items) / medical service revenue,” and replacing “net fixed asset ratio” with “total asset growth rate/net asset growth rate.” Experts also suggested adding new indicators at the second level, such as “number of months of cash reserve available.”

3.Indicator Screening and Revision

According to the predefined screening criteria and the experts’ feedback, several indicators were adjusted in terms of hierarchy or wording, as detailed in Table 3.10. The revised indicator system for the second-round consultation consisted of 7 first-level indicators (risk dimensions) and 29 second-level indicators (early warning indicators), as shown in Figures 3.11 and 3.12.

Table 3.11 Revisions to the Indicator Framework After the First-round Evaluation

Item	Number of Indicators	Level	Indicator Content
Deleted	**3**	**Second-level**	**4.2 Proportion of research funding input ； 7.2 Patient satisfaction ； 7.3 Average cost per discharged patient**
Added	**9**	**Second-level**	**1.4 Number of months of available cash reserves = ending balance of cash and cash equivalents ÷ average monthly rigid expenditures**
			1.5 Interest coverage ratio = (operating surplus + interest expenses) ÷ interest expenses
			2.5 Total asset turnover = medical revenue ÷ average total assets

Item	Number of Indicators	Level	Indicator Content
			2.6 Growth rate of discharges = (current-period discharges − previous-period discharges) ÷ previous-period discharges × 100%
			2.7 Growth rate of outpatient and emergency visits = (current-period visits − previous-period visits) ÷ previous-period visits × 100%
			5.6 Net impact of medical service price adjustment = (post-adjustment revenue of medical service items − pre-adjustment revenue) − (increase in patient out-of-pocket payments + increase in hospital costs)
			5.7 Dependence on government subsidies = annual total fiscal subsidy revenue ÷ absolute value of the annual hospital revenue–expenditure gap × 100%
			7.2 Total compensation for medical malpractice (sum of compensation amounts for malpractice events)
			6.4 Proportion of personnel expenses in operating expenses = personnel expenses ÷ operating expenses × 100%
Modified	3	Second-level	“3.2 Surplus rate of medical revenue” → “3.2 Medical surplus rate = (medical surplus − surplus from other items) ÷ medical service revenue”

Item	Number of Indicators	Level	Indicator Content
			“2.2 Service revenue per bed” → “2.2 Medical service revenue per bed = (operating revenue − drug revenue − consumables revenue) ÷ actual open beds” **“4.1 Net fixed asset ratio” → “4.1 Total asset growth rate ÷ net asset growth rate”**

Table 3.12 Revised Second-round Indicator System

First-level Indicator (Risk Dimension)	Second-level Indicator (Early Warning Indicator)	Definition / Calculation Formula
1. Debt-paying capacity risk	**1.1 Asset–liability ratio**	Total liabilities ÷ total assets × 100%; reflects long-term solvency. A higher ratio indicates higher risk.
	1.2 Current ratio	Current assets ÷ current liabilities; reflects short-term solvency. A low ratio suggests potential liquidity pressure.
	1.3 Quick ratio	(Current assets − inventories) ÷ current liabilities; more accurately reflects immediate short-term solvency.
	1.4 Number of months of available cash reserves	Ending balance of cash and cash equivalents ÷ average monthly rigid expenditures. Risk thresholds: 1 month (high risk), 2 months (at risk), 3 months (watch), 6 months (safe). Assesses the hospital’s capacity to cope

First-level Indicator (Risk Dimension)	Second-level Indicator (Early Warning Indicator)	Definition / Calculation Formula
		with large unexpected payments and reflects resilience of economic operation.
	1.5 Interest coverage ratio	(Operating surplus + interest expenses) ÷ interest expenses; measures the ability to cover interest payments with operating returns and warns of debt-servicing risk.
2. Operational efficiency risk	**2.1 Turnover rate of medical receivables**	Medical revenue ÷ average balance of medical receivables; reflects speed of receivables recovery. A low rate suggests high capital occupation risk.
	2.2 Medical service revenue per bed	(Operating revenue − drug revenue − consumables revenue) ÷ actual open beds; excludes the effect of “zero mark-up” on drugs and consumables to reflect the core service revenue capacity per bed.
	2.3 Bed occupancy rate	Actual occupied bed-days ÷ actual open bed-days × 100%; reflects utilisation efficiency of bed resources.
	2.4 Average length of stay	Total inpatient bed-days ÷ number of discharges; excessively long stays increase costs and reduce bed turnover.
	2.5 Total asset turnover	Medical revenue ÷ average total assets; reflects asset utilisation efficiency and helps identify idle or wasted resources, supplementing the coverage of receivables turnover.

First-level Indicator (Risk Dimension)	Second-level Indicator (Early Warning Indicator)	Definition / Calculation Formula
	2.6 Growth rate of discharges	(Current-period discharges − previous-period discharges) ÷ previous-period discharges × 100%; together with outpatient/emergency growth reflects changes in core service volume and warns of contraction risk.
	2.7 Growth rate of outpatient and emergency visits	(Current-period outpatient and emergency visits − previous-period visits) ÷ previous-period visits × 100%; monitors changes in service workload.
3. Profitability risk	**3.1 Return on net assets**	Net profit ÷ average net assets × 100%; reflects earning efficiency of net assets. Negative or very low values indicate higher profitability risk.
	3.2 Medical surplus rate	(Medical surplus − surplus from non-medical items) ÷ medical service revenue; accurately reflects the profit/loss risk of core medical activities by excluding non-medical income effects.
	3.3 Growth rate of medical revenue	(Current-period medical revenue − previous-period medical revenue) ÷ previous-period medical revenue × 100%; reflects stability of revenue growth.
4. Development capacity risk	**4.1 Total asset growth rate ÷ net asset growth rate**	Assesses overall development scale and asset appreciation capacity, and warns of excessively rapid expansion or stagnation.

First-level Indicator (Risk Dimension)	Second-level Indicator (Early Warning Indicator)	Definition / Calculation Formula
5. Medical insurance policy risk	**5.1 Medical insurance settlement difference rate**	(Payable amount by insurance − actual settlement amount) ÷ payable amount by insurance × 100%; reflects fluctuation risk in medical insurance payment.
	5.2 DRG/DIP grouping deviation rate	Misclassified or disputed cases ÷ total cases × 100%; reflects the risk of mismatch with DRG/DIP payment rules.
	5.3 Medical insurance claim denial rate	Amount of denied claims ÷ declared insurance amount × 100%; reflects compliance risk in medical insurance operations.
	5.4 Case Mix Index (CMI)	Core DRG/DIP indicator reflecting case complexity; a low CMI may lead to insufficient insurance reimbursement.
	5.5 Cost consumption index	DRG/DIP indicator reflecting cost efficiency for similar conditions; a high index indicates inadequate cost control.
	5.6 Net impact of medical service price adjustment	(Revenue from medical service items after adjustment − revenue before adjustment) − (increase in patient out-of-pocket payments + increase in hospital costs); quantifies the net financial impact of price reforms.
	5.7 Dependence on government subsidies	Annual total fiscal subsidy revenue ÷ absolute value of the annual hospital revenue–expenditure gap × 100%; reflects reliance on government subsidies.

First-level Indicator (Risk Dimension)	Second-level Indicator (Early Warning Indicator)	Definition / Calculation Formula
6. Cost control risk	**6.1 Consumable cost per 100 CNY of medical revenue**	Consumables expense ÷ medical revenue × 100; reflects control over consumable costs. Higher values indicate greater cost pressure.
	6.2 Management expense ratio	Administrative/management expenses ÷ total expenditure × 100%; reflects efficiency of administrative operations. Higher ratios suggest management cost inefficiency.
	6.3 Proportion of drug and consumable expenditure	(Drug expenses + consumable expenses) ÷ total operating revenue × 100%; reflects risk associated with drug and consumable cost control.
	6.4 Proportion of personnel expenses in operating expenses	Personnel expenses ÷ operating expenses × 100%; balances cost control with staff motivation and human resource sustainability.
7. Medical quality and safety risk	**7.1 Incidence of complications among surgical patients**	Number of surgical patients with complications ÷ total number of surgical discharges in the same period × 100%; high rates increase additional costs and dispute risks.

First-level Indicator (Risk Dimension)	Second-level Indicator (Early Warning Indicator)	Definition / Calculation Formula
	7.2 Total compensation for medical malpractice	Total compensation paid for confirmed medical malpractice cases; directly reflects risks related to medical quality and fault-induced costs.

4.Convergence of Expert Opinions in the Second Round

For the seven first-level indicators, the arithmetic mean ($\bar{x}$) was ≥ 4.6111, the coefficient of variation (CV) ≤ 0.1088, and the full-score ratio (K) ≥ 0.6111, indicating a high level of consensus and strong recognition of the revised first-level indicators (Table 3.13).

Table 3.13 Second-round Expert Ratings of First-level Indicators

Indicator	N	Min	Max	Mean	SD	CV	Full-score Ratio
Debt-paying capacity risk	18	4	5	4.9444	0.2357	0.0477	0.9444
Operational efficiency risk	18	4	5	4.9444	0.2357	0.0477	0.9444
Profitability risk	18	4	5	4.9444	0.2357	0.0477	0.9444
Development capacity risk	18	4	5	4.6111	0.5016	0.1088	0.6111
Medical insurance policy risk	18	5	5	5.0000	0.0000	0.0000	1.0000
Cost control risk	18	5	5	5.0000	0.0000	0.0000	1.0000
Medical quality and safety risk	18	4	5	4.7778	0.4278	0.0895	0.7778

For the 29 second-level indicators, the arithmetic mean ranged from 4.3333 to 5.0000, the CV ranged from 0.0000 to 0.1770, and the full-score ratio ranged from 0.5000 to 1.0000. These results indicate high consistency, strong concentration, and low dispersion of expert opinions. All indicators had a full-score ratio ≥ 0.5, suggesting that experts generally agreed on the high importance of the revised second-level indicators (Table 3.14).

Table 3.14 Second-round Expert Ratings of Second-level Indicators

Indicator	**N**	**Min**	**Max**	**Mean**	**SD**	**CV**	**Full-score Ratio**
1.1 Asset–liability ratio	18	5	5	5.0000	0.0000	0.0000	1.0000
1.2 Current ratio	18	4	5	4.7778	0.4278	0.0895	0.7778
1.3 Quick ratio	18	5	5	5.0000	0.0000	0.0000	1.0000
1.4 Number of months of available cash reserves	18	5	5	5.0000	0.0000	0.0000	1.0000
1.5 Interest coverage ratio	18	4	5	4.5556	0.5113	0.1122	0.5556
2.1 Turnover rate of medical receivables	18	4	5	4.8889	0.3234	0.0661	0.8889
2.2 Medical service revenue per bed	18	5	5	5.0000	0.0000	0.0000	1.0000
2.3 Bed occupancy rate	18	5	5	5.0000	0.0000	0.0000	1.0000

2.4 Average length of stay	18	4	5	4.7222	0.4609	0.0976	0.7222
2.5 Total asset turnover	18	4	5	4.8333	0.3835	0.0793	0.8333
2.6 Growth rate of discharges	18	5	5	5.0000	0.0000	0.0000	1.0000
2.7 Growth rate of outpatient and emergency visits	18	5	5	5.0000	0.0000	0.0000	1.0000
3.1 Return on net assets	18	4	5	4.6667	0.4851	0.1039	0.6667
3.2 Medical surplus rate	18	5	5	5.0000	0.0000	0.0000	1.0000
3.3 Growth rate of medical revenue	18	4	5	4.9444	0.2357	0.0477	0.9444
4.1 Total asset growth rate / net asset growth rate	18	3	5	4.3333	0.7670	0.1770	0.5000
5.1 Medical insurance settlement difference rate	18	3	5	4.7222	0.5745	0.1217	0.7778
5.2 DRG/DIP grouping deviation rate	18	5	5	5.0000	0.0000	0.0000	1.0000
5.3 Medical insurance claim denial rate	18	4	5	4.6667	0.4851	0.1039	0.6667
5.4 Case Mix Index (CMI)	18	4	5	4.8889	0.3234	0.0661	0.8889
5.5 Cost consumption index	18	5	5	5.0000	0.0000	0.0000	1.0000
5.6 Net impact of medical service price adjustment	18	4	5	4.9444	0.2357	0.0477	0.9444

5.7 Dependence on government subsidies	18	3	5	4.5000	0.7071	0.1571	0.6111
6.1 Consumable cost per 100 CNY of medical revenue	18	4	5	4.9444	0.2357	0.0477	0.9444
6.2 Management expense ratio	18	3	5	4.5556	0.6157	0.1352	0.6111
6.3 Proportion of drug and consumable expenditure	18	5	5	5.0000	0.0000	0.0000	1.0000
6.4 Proportion of personnel expenses in operating expenses	18	4	5	4.8889	0.3234	0.0661	0.8889
7.1 Incidence of complications among surgical patients	18	4	5	4.7778	0.4278	0.0895	0.7778
7.2 Total compensation for medical malpractice	18	4	5	4.5556	0.5113	0.1122	0.5556

5.Finalization of the Risk Indicator System

Based on the statistical analysis of the second-round Delphi consultation, all indicators met the predefined screening criteria for mean ($\bar{x}$), coefficient of variation (CV), and full-score ratio (K), and no indicators were excluded. Kendall’s coefficients of concordance for all indicator levels were statistically significant ($P < 0.05$), indicating good consistency among expert opinions.

In the second round, two experts proposed refinements concerning individual indicators. After reviewing relevant literature and consulting the research team, the indicator “5.7 Dependence on government subsidies” was revised to “5.7 Dependence on fiscal subsidies.”

The final early warning indicator system is shown in Table 3.15.

Table 3.15 Final Early Warning Indicator System for Economic Operation Risk in Public Hospitals

First-level Indicator (Risk Dimension)	Second-level Indicator (Early Warning Indicator)
1. Debt-paying capacity risk	1.1 Asset–liability ratio
	1.2 Current ratio
	1.3 Quick ratio
	1.4 Number of months of available cash reserves
	1.5 Interest coverage ratio
2. Operational efficiency risk	2.1 Turnover rate of medical receivables
	2.2 Medical service revenue per bed
	2.3 Bed occupancy rate
	2.4 Average length of stay
	2.5 Total asset turnover
	2.6 Growth rate of discharges
	2.7 Growth rate of outpatient and emergency visits
3. Profitability risk	3.1 Return on net assets
	3.2 Medical surplus rate
	3.3 Growth rate of medical revenue
4. Development capacity risk	4.1 Total asset growth rate / net asset growth rate
5. Medical insurance policy risk	5.1 Medical insurance settlement difference rate
	5.2 DRG/DIP grouping deviation rate
	5.3 Medical insurance claim denial rate
	5.4 Case Mix Index (CMI)
	5.5 Cost consumption index

First-level Indicator (Risk Dimension)	Second-level Indicator (Early Warning Indicator)
	5.6 Net impact of medical service price adjustment
	5.7 Dependence on fiscal subsidies
6. Cost control risk	6.1 Consumable cost per 100 CNY of medical revenue
	6.2 Management expense ratio
	6.3 Proportion of drug and consumable expenditure
	6.4 Proportion of personnel expenses in operating expenses
7. Medical quality and safety risk	7.1 Incidence of complications among surgical patients
	7.2 Total compensation for medical malpractice

III. Determination of Indicator Weights Using AHP

(I) Procedure for Determining Weights with the Analytic Hierarchy Process

The Analytic Hierarchy Process (AHP) is a systematic and hierarchical method that combines qualitative judgement with quantitative analysis. It is highly practical and effective for solving complex decision-making problems. The basic steps include: establishing the hierarchical structure model, constructing pairwise comparison matrices, calculating weight vectors and conducting consistency tests, and deriving the combined weight vector.

In this study, AHP was applied to determine the weights of the indicators. The specific procedures are as follows:

Construction of judgment matrices:

$$\mathbf{A} = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix}$$

In the judgment matrix, each element a_{ij} represents the relative importance of element (i) compared with element (j). If the former is more important, then (a_{ij} > 1); if they are equally important, then a_{ij} = 1.

Importance judgment of matrix elements

Table 3.16 Scale of Relative Importance

Scale	Meaning
1	Two factors are equally important.
3	When comparing two factors, the former is slightly more important.
5	When comparing two factors, the former is clearly more important.
7	When comparing two factors, the former is strongly more important.
9	When comparing two factors, the former is extremely more important.
2,4,6,8	Intermediate values between the judgments above.
Reciprocals of the above	When the order of comparison is reversed, the importance is the reciprocal of the original value.

Calculation of the Indicator Weight Vector

First, normalize the judgment matrix using the following formula:

$$b_{ij} = \frac{a_{ij}}{\sum_{i=1}^{n} a_{ij}} \quad (i, j = 1, 2, \cdots n) \quad \ldots\ldots\ldots\ldots\ldots\ldots \text{（10）}$$

where a_{ij} is the element in row (i), column (j) of the judgment matrix (A), and b_{ij} is the corresponding element in row (i), column (j) of the normalized matrix.

Second, sum the elements in each row of the normalized matrix.

$$\overline{w_i} = \sum_{j=1}^{n} b_{ij} \quad (i, j = 1, 2, \cdots n) \ldots\ldots\ldots\ldots\ldots\ldots \text{（11）}$$

Third, normalize the row sums obtained above to derive the weight vector：

$$w_i = \frac{\overline{w_i}}{\sum_{i=1}^{n} \overline{w_i}} \quad (i = 1, 2, \cdots n) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{（12）}$$

where w_i is the weight of the (i)-th indicator.

Fourth, calculate the maximum eigenvalue $\lambda_{\max}$ of the judgment matrix (A).

$$\lambda_{\max} = \frac{1}{n} \sum_{i=1}^{n} \frac{(Aw)_i}{w_i} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{（13）}$$

where (n) is the order of the matrix, (A) is the judgment matrix, w_i is the weight of （5.1 the (i)-th indicator, and $\lambda_{\max}$ is the maximum eigenvalue of the judgment matrix (A).

For consistency testing, the previously obtained weight vector and eigenvalue are used to assess whether the judgment matrix is logically consistent. If the consistency test is passed, the matrix is considered reasonable and has explanatory validity.

Let (CI) denote the consistency index. It is calculated as follows:

$$CI = \frac{\lambda_{\max} - n}{n-1} \quad \text{(14)}$$

Table 3.17 Random Consistency Index (RI)

Matrix order (n)	RI
1	0
2	0
3	0.52
4	0.89
5	1.12
6	1.26
7	1.36
8	1.41
9	1.46
10	1.49
11	1.52
12	1.54
13	1.56
14	1.58
15	1.59

The RI value is determined according to the matrix order (n), and the consistency ratio (CR) is then calculated. When (CR < 0.10), the consistency of the judgment matrix is considered acceptable.

(II) Construction of Judgment Matrices and Determination of Weights in This Study

1.Judgment Matrix and Weights for First-level Indicators

Based on the finalized indicator system and using the above-mentioned 1–9 scale, experts in the relevant fields were invited to score the relative importance of the first-level indicators through a structured Delphi questionnaire. The scoring results were further discussed and summarized within the research team to construct the final judgment matrix (see Table 3.17).

Table 3.17 Judgment Matrix for First-level Indicators

	1. Debt-paying Capacity	**2. Operational Efficiency**	**3. Profitability**	**4. Development Capacity**	**5. Medical Insurance Policy**	**6. Cost Control**	**7. Medical Quality & Safety**
1. Debt-paying capacity	**1**	**1**	**1**	**3**	**1/2**	**1/2**	**2**
2. Operational efficiency	**1**	**1**	**1**	**3**	**1/2**	**1/2**	**2**
3. Profitability	**1**	**1**	**1**	**3**	**1/2**	**1/2**	**2**

	1. Debt-paying Capacity	2. Operational Efficiency	3. Profitability	4. Development Capacity	5. Medical Insurance Policy	6. Cost Control	7. Medical Quality & Safety
4. Development capacity	1/3	1/3	1/3	1	1/3	1/3	1/2
5. Medical insurance policy	2	2	2	3	1	1	2
6. Cost control	2	2	2	3	1	1	2
7. Medical quality & safety	1/2	1/2	1/2	2	1/2	1/2	1

First, calculate the maximum eigenvalue of the judgment matrix. Then, conduct the consistency test by computing the consistency index (CI):

$$CI = \frac{\lambda_{\max} - n}{n-1} = \frac{7.1275-7}{7-1} = 0.0212$$

the average random consistency index (RI).

the consistency ratio (CR):

$$CR = \frac{CI}{RI} = \frac{0.0212}{1.36} = 0.0156 < 0.10$$

Since (CR < 0.1), the judgment matrix is considered consistent and reasonable; therefore, the weights of the first-level indicators were calculated accordingly (see Table 3.18).

Table 3.18 Weights of First-level Indicators

Indicator	Weight
1. Debt-paying capacity risk	0.1363
2. Operational efficiency risk	0.1363
3. Profitability risk	0.1363
4. Development capacity risk	0.0544
5. Medical insurance policy risk	0.2240
6. Cost control risk	0.2240
7. Medical quality and safety risk	0.0886

2.Judgment Matrices and Weights for Second-level Indicators

(1) Debt-paying Capacity Risk: Judgment Matrix and Weights

Using the Analytic Hierarchy Process, a pairwise comparison judgment matrix was constructed to determine the weights of the second-level indicators under debt-paying capacity risk, as shown in Table 3.19.

Table 3.19 Judgment Matrix for Indicators 1.1–1.5

	1.1 Asset–liability ratio	1.2 Current ratio	1.3 Quick ratio	1.4 Months of available cash reserves	1.5 Interest coverage ratio
1.1 Asset–liability ratio	1	2	1	1	3
1.2 Current ratio	1/2	1	1/2	1/2	2
1.3 Quick ratio	1	2	1	1	3
1.4 Months of available cash reserves	1	2	1	1	3
1.5 Interest coverage ratio	1/3	1/2	1/3	1/3	1

First, calculate the maximum eigenvalue of the judgment matrix. Then, perform the consistency test by computing the consistency index (CI):

$$CI = \frac{\lambda_{\max} - n}{n - 1} = \frac{5.0100 - 5}{5 - 1} = 0.0025$$

average random consistency index (RI)

consistency ratio (CR):

$$CR = \frac{CI}{RI} = \frac{0.0025}{1.12} = 0.0022 < 0.10$$

Since (CR < 0.1), the judgment matrix is considered consistent and reasonable; therefore, the weights of the secondary indicators 1.1–1.5 were calculated (Table 3.20).

Table 3.20 Weights of Secondary Indicators 1.1–1.5

Indicator	Weight
1.1 Asset–liability ratio	0.2599
1.2 Current ratio	0.1383
1.3 Quick ratio	0.2599
1.4 Number of months of available cash reserves	0.2599
1.5 Interest coverage ratio	0.0822

(2) Operational Efficiency Risk: Judgment Matrix and Weights

Using the Analytic Hierarchy Process, a pairwise comparison judgment matrix was constructed for the second-level indicators under operational efficiency risk, as shown in Table 3.21.

Table 3.21 Judgment Matrix for Indicators 2.1–2.7

	2.1 Turnover rate of medical receivables	**2.2 Medical service revenue per bed**	**2.3 Bed occupancy rate**	**2.4 Average length of stay**	**2.5 Total asset turnover**	**2.6 Growth rate of discharges**	**2.7 Growth rate of outpatient & emergency visits**
2.1 Turnover	1	1/2	1/2	2	2	1/2	1/2

	2.1 Turnover rate of medical receivables	2.2 Medical service revenue per bed	2.3 Bed occupancy rate	2.4 Average length of stay	2.5 Total asset turnover	2.6 Growth rate of discharges	2.7 Growth rate of outpatient & emergency visits
rate of medical receivables							
2.2 Medical service revenue per bed	2	1	1	3	2	1	1
2.3 Bed occupancy rate	2	1	1	3	2	1	1
2.4 Average length of stay	1/2	1/3	1/3	1	1/2	1/3	1/3
2.5 Total asset turnover	1/2	1/2	1/2	2	1	1/2	1/2
2.6 Growth	2	1	1	3	2	1	1

	2.1 Turnover rate of medical receivables	**2.2 Medical service revenue per bed**	**2.3 Bed occupancy rate**	**2.4 Average length of stay**	**2.5 Total asset turnover**	**2.6 Growth rate of discharges**	**2.7 Growth rate of outpatient & emergency visits**
rate of discharges							
2.7 Growth rate of outpatient & emergency visits	2	1	1	3	2	1	1

First, calculate the maximum eigenvalue of the judgment matrix. Then, perform a consistency test by computing the consistency index (CI):

$$CI = \frac{\lambda_{\max} - n}{n-1} = \frac{7.0642 - 7}{7-1} = 0.0107$$

average random consistency index (RI).

consistency ratio (CR):

$$CR = \frac{CI}{RI} = \frac{0.0107}{1.36} = 0.0079 < 0.10$$

Since (CR < 0.1), the judgment matrix is considered consistent and reasonable; therefore, the weights of the indicators were calculated as shown in Table 3.22.

Table 3.22 Weights of Secondary Indicators 2.1–2.7

Indicator	**Weight**
2.1 Turnover rate of medical receivables	0.1095
2.2 Medical service revenue per bed	0.1858
2.3 Bed occupancy rate	0.1858
2.4 Average length of stay	0.0575
2.5 Total asset turnover	0.0899
2.6 Growth rate of discharges	0.1858
2.7 Growth rate of outpatient and emergency visits	0.1858

(3) Profitability Risk: Judgment Matrix and Weights for Secondary Indicators

Using the Analytic Hierarchy Process, a pairwise comparison judgment matrix was constructed for the secondary indicators under profitability risk (Table 3.23).

Table 3.23 Judgment Matrix for Indicators 3.1–3.3

	3.1 Return on net assets	**3.2 Medical surplus rate**	**3.3 Growth rate of medical revenue**
3.1 Return on net assets	1	1/3	1/3
3.2 Medical surplus rate	3	1	2

	3.1 Return on net assets	**3.2 Medical surplus rate**	**3.3 Growth rate of medical revenue**
3.3 Growth rate of medical revenue	3	1/2	1

First, calculate the maximum eigenvalue of the judgment matrix. Then, perform the consistency test by computing the consistency index (CI):

$$CI = \frac{\lambda_{\max} - n}{n-1} = \frac{3.0538-3}{3-1} = 0.0269$$

average random consistency index (RI).
consistency ratio (CR):

$$CR = \frac{CI}{RI} = \frac{0.0269}{0.52} = 0.0517 < 0.10$$

Since (CR < 0.10), the judgment matrix is considered consistent and reasonable; therefore, the weights of the indicators were determined as shown in Table 3.24.

Table 3.24 Weights of Secondary Indicators 3.1–3.3

Indicator	**Weight**
3.1 Return on net assets	0.1416
3.2 Medical surplus rate	0.5247
3.3 Growth rate of medical revenue	0.3338

(4) Medical Insurance Policy Risk: Judgment Matrix and Weights for Secondary Indicators

Using the Analytic Hierarchy Process, a pairwise comparison judgment matrix was constructed for the secondary indicators under medical insurance policy risk, as shown in Table 3.25.

Table 3.25 Judgment Matrix for Indicators 5.1–5.7

	5.1 Medical insurance settlement difference rate	**5.2 DRG/DIP grouping deviation rate**	**5.3 Medical insurance claim denial rate**	**5.4 Case Mix Index (CMI)**	**5.5 Cost consumption index**	**5.6 Net impact of medical service price adjustment**	**5.7 Dependence on fiscal subsidies**
5.1 Medical insurance settlement difference rate	1	1/3	2	1/2	1/3	1/2	2
5.2 DRG/DIP grouping deviation rate	3	1	3	2	1	2	3
5.3 Medical	1/2	1/3	1	1/2	1/3	1/3	2

	5.1 Medical insurance settlement difference rate	5.2 DRG/DIP grouping deviation rate	5.3 Medical insurance claim denial rate	5.4 Case Mix Index (CMI)	5.5 Cost consumption index	5.6 Net impact of medical service price adjustment	5.7 Dependence on fiscal subsidies
insurance claim denial rate							
5.4 Case Mix Index (CMI)	2	1/2	2	1	1/2	1/2	3
5.5 Cost consumption index	3	1	3	2	1	2	3
5.6 Net impact of medical service price adjustment	2	1/2	3	2	1/2	1	3
5.7 Dependence on fiscal subsidies	1/2	1/3	1/2	1/3	1/3	1/3	1

First, calculate the maximum eigenvalue of the judgment matrix. Then, perform a consistency test by computing the consistency index (CI):

$$CI = \frac{\lambda_{\max} - n}{n-1} = \frac{7.2091 - 7}{7-1} = 0.0348$$

average random consistency index (RI).
consistency ratio (CR):

$$CR = \frac{CI}{RI} = \frac{0.0348}{1.36} = 0.0256 < 0.10$$

Since (CR < 0.10), the judgment matrix is considered consistent and reasonable; therefore, the indicator weights were determined as shown in Table 3.26.

Table 3.26 Weights of Secondary Indicators 5.1–5.7

Indicator	**Weight**
5.1 Medical insurance settlement difference rate	0.0915
5.2 DRG/DIP grouping deviation rate	0.2391
5.3 Medical insurance claim denial rate	0.0721
5.4 Case Mix Index (CMI)	0.1323
5.5 Cost consumption index	0.2391
5.6 Net impact of medical service price adjustment	0.1700
5.7 Dependence on fiscal subsidies	0.0559

(5) Cost Control Risk: Judgment Matrix and Weights for Secondary Indicators

Using the Analytic Hierarchy Process, a pairwise comparison judgment matrix was constructed for the secondary indicators under cost control risk, as shown in Table 3.27.

Table 3.27 Judgment Matrix for Indicators 6.1–6.4

	6.1 Consumable cost per 100 CNY of medical revenue	**6.2 Management expense ratio**	**6.3 Proportion of drug and consumable expenditure**	**6.4 Proportion of personnel expenses in operating expenses**
6.1 Consumable cost per 100 CNY of medical revenue	1	3	1/2	2
6.2 Management expense ratio	1/3	1	1/3	1/3
6.3 Proportion of drug and consumable expenditure	2	3	1	2
6.4 Proportion of personnel expenses in operating expenses	1/2	3	1/2	1

First, calculate the maximum eigenvalue of the judgment matrix. Then perform the consistency test by computing the consistency index (CI):

$$CI = \frac{\lambda_{\max} - n}{n - 1} = \frac{4.1219 - 4}{4 - 1} = 0.0406$$

average random consistency index (RI).
consistency ratio (CR):

$$CR = \frac{CI}{RI} = \frac{0.0406}{0.89} = 0.0456 < 0.10$$

Since (CR < 0.10), the judgment matrix is considered consistent and reasonable; therefore, the weights of the indicators were determined as shown in Table 3.28.

Table 3.28 Weights of Secondary Indicators 6.1–6.4

Indicator	**Weight**
6.1 Consumable cost per 100 CNY of medical revenue	0.2875
6.2 Management expense ratio	0.0981
6.3 Proportion of drug and consumable expenditure	0.4063
6.4 Proportion of personnel expenses in operating expenses	0.2081

(6) Medical Quality and Safety Risk: Judgment Matrix and Weights for Secondary Indicators

Using the Analytic Hierarchy Process, a pairwise comparison judgment matrix was constructed for the secondary indicators under medical quality and safety risk (Table 3.29).

Table 3.29 Judgment Matrix for Indicators 7.1–7.2

	7.1 Incidence of complications among surgical patients	**7.2 Total compensation for medical malpractice**
7.1 Incidence of complications among surgical patients	1	2
7.2 Total compensation for medical malpractice	1/2	1

For a 2×2 matrix, consistency is guaranteed; thus no consistency test is required. The resulting weights are shown in Table 3.30.

Table 3.30 Weights of Secondary Indicators 7.1–7.2

Indicator	**Weight**
7.1 Incidence of complications among surgical patients	0.6667
7.2 Total compensation for medical malpractice	0.3333

(7) Weights of the Early Warning Indicator System for Economic Operation Risk in Public Hospitals

Table 3.31 Early Warning Indicator System and Overall Weights

First-level Indicator	Weight	Second-level Indicator	Weight	Overall Weight
1. Debt-paying capacity risk	0.1363	1.1 Asset–liability ratio	0.2599	0.0354
		1.2 Current ratio	0.1383	0.0189
		1.3 Quick ratio	0.2599	0.0354
		1.4 Number of months of available cash reserves	0.2599	0.0354
		1.5 Interest coverage ratio	0.0822	0.0112
2. Operational efficiency risk	0.1363	2.1 Turnover rate of medical receivables	0.1095	0.0149
		2.2 Medical service revenue per bed	0.1858	0.0253
		2.3 Bed occupancy rate	0.1858	0.0253
		2.4 Average length of stay	0.0575	0.0078
		2.5 Total asset turnover	0.0899	0.0123
		2.6 Growth rate of discharges	0.1858	0.0253
		2.7 Growth rate of outpatient and emergency visits	0.1858	0.0253
3. Profitability risk	0.1363	3.1 Return on net assets	0.1416	0.0193
		3.2 Medical surplus rate	0.5247	0.0715
		3.3 Growth rate of medical revenue	0.3338	0.0455

First-level Indicator	Weight	Second-level Indicator	Weight	Overall Weight
4. Development capacity risk	0.0544	4.1 Total asset growth rate / net asset growth rate	1.0000	0.0544
5. Medical insurance policy risk	0.2240	5.1 Medical insurance settlement difference rate	0.0915	0.0205
		5.2 DRG/DIP grouping deviation rate	0.2391	0.0536
		5.3 Medical insurance claim denial rate	0.0721	0.0162
		5.4 Case Mix Index (CMI)	0.1323	0.0296
		5.5 Cost consumption index	0.2391	0.0536
		5.6 Net impact of medical service price adjustment	0.1700	0.0381
		5.7 Dependence on fiscal subsidies	0.0559	0.0125
6. Cost control risk	0.2240	6.1 Consumable cost per 100 CNY of medical revenue	0.2875	0.0644
		6.2 Management expense ratio	0.0981	0.0220
		6.3 Proportion of drug and consumable expenditure	0.4063	0.0910
		6.4 Proportion of personnel expenses in operating expenses	0.2081	0.0466
7. Medical quality and safety risk	0.0886	7.1 Incidence of complications among surgical patients	0.6667	0.0591
		7.2 Total compensation for medical malpractice	0.3333	0.0295

Chapter 4 Discussion

I. Discussion of the Contents of the Early Warning Indicator System for the Economic Operation of Public Hospitals

With the deepening of health-care system reform, public hospitals face multiple challenges, including insufficient fiscal input, the removal of drug and consumable mark-ups, and reforms to medical insurance payment mechanisms. These factors place higher demands on the economic operation of public hospitals. As key providers of medical services, the stability and efficiency of public hospitals directly affect the quality and sustainability of health services. Accordingly, constructing a scientific and reasonable early warning indicator system for economic operation is essential to identify and prevent potential risks in a timely manner and to ensure the healthy development of public hospitals.

Cai Shanshan [16] noted in Construction of an Evaluation Index System for Asset Operation Efficiency in Public Hospitals that building such a system helps optimize asset allocation and improve asset security and integrity. Xu Jiajie [17], Hu Xiaomei [187] and others (2024) developed a hospital operation efficiency evaluation system using an input–output framework; Chen Yaoxuan [19] and Huang Guangcheng et al. [20] proposed systems covering operational efficiency, risk control, revenue–expenditure structure, and development capacity, emphasizing the importance of evaluation indicators from a high-quality development perspective. Hu Xiaomei’s work further highlighted the impact of reforms in medical insurance payment methods on hospitals’ economic operation. However, existing studies still suffer from insufficient integration of operations and finance, single evaluation methods, and a lack of early-warning functionality.

The system developed in this study is organized around “risk identification — quantitative assessment—targeted early warning,” comprising seven first-level risk dimensions and 29 second-level early-warning indicators. It features comprehensive coverage, clear hierarchy, practical operability, policy alignment, focused core indicators, goal balancing, quantitative objectivity, and linkage between quality and economy:

1. The system is closely aligned with current reform priorities—especially medical insurance payment reform—and designs targeted early-warning indicators to help hospitals respond to economic risks arising from policy changes.

2. It covers the full chain of economic risks in public hospital operations. Seven first-level dimensions (risk categories) comprehensively span core economic risks—solvency, operations, profitability, and development—while extending to medical insurance policy, cost control, and medical quality and safety, thereby forming a complete matrix in which "economic risks are primary and associated risks are supplementary."

3. No abstract qualitative indicators are used. The logic progresses step by step, and all indicators are designed to be "measurable, assessable, and actionable," directly serving practical early-warning needs.

4. Rather than pursuing a "single optimum," indicator design balances multiple, sometimes competing, operational goals to ensure long-term sustainability. Over 90% of indicators are quantitative, replacing subjective judgment with data calculation and thus substantially improving objectivity and accuracy.

II. Scientific Rationale for Using the Delphi Method and AHP to Build the Indicator System

(i) Composition of the Expert Panel

The Delphi method, which reaches consensus through multiple rounds of expert consultation, is commonly used to construct evaluation systems. It effectively integrates expert opinions, reduces subjective bias, and enhances scientific validity and practicality. Studies show that prediction accuracy in Delphi increases with participant numbers within a reasonable range; a panel of 10–40 experts generally yields ideal prediction performance [21–23]. Too many experts complicate organization and coordination, while too few may undermine representativeness and reliability. For example, Liu Li from the Pharmacy Department of Tibet Autonomous Region People's Hospital invited 10 experts from medicine, pharmacy, and hospital management for two rounds of consultation, ultimately establishing an index system for off-label drug-use management with 3 first-level, 14 second-level, and 52 third-level indicators [24]. Chen Yinan of the Zhejiang Patriotic Health Development Center consulted 20 domain experts in two rounds to build a Healthy Rural Zhejiang monitoring index system comprising 6 first-level, 17 second-level, and 55 third-level indicators [25].

In this study, two rounds of consultation were conducted with 18 experts from primary and municipal medical institutions, health administrative departments, and universities who have substantive achievements in health economics research, health economic management, and hospital financial management. Eight experts had more than 20 years of experience (44.4%). Professional backgrounds were evenly split between health economics/management research and hospital management. The majority held senior or intermediate professional titles (66% senior; 27.8% intermediate) and had relevant project experience, enabling comprehensive, multidimensional understanding of early warning indicators for economic operation risks in public hospitals.

(ii) Number of Rounds and Achieving Expert Consensus

The number of Delphi rounds is flexible and depends on study objectives, degree of convergence in expert views, and feedback efficiency [26–28]. Typically, two or three rounds are used [29–31]. In Round 1, experts respond to open questions and evaluate/supplement preliminary indicators based on background materials [28,29]. In Round 2, they re-evaluate after feedback—especially on items with large divergence.

When ≥70% of experts agree on the strength and direction of recommendations, consensus is considered reached [32]. This approach minimizes unnecessary rounds while ensuring full expression and integration of expert opinions, emphasizing progressive convergence rather than a fixed number of rounds.

Here, front-line managers and researchers served as experts. After extensive review of literature and policies related to economic risks and early-warning indicators in public hospitals, the team drafted a preliminary indicator set and conducted two consultation rounds, both with a 100% response rate. Mean expert authority coefficients exceeded 0.7 in both rounds, and P-values for Kendall's W were <0.05 in both rounds—indicating sufficient attention and permitting statistical analysis. Arithmetic means, coefficients of variation, and full-score ratios for indicators all met the screening thresholds, suggesting broad expert recognition of the evaluation system.

Currently, no unified international or domestic standard exists for Delphi-based indicator screening criteria. Prior studies have adopted thresholds such as mean importance >3.5 or >4 [33–34,36]; coefficient of variation (CV) <0.25 for consistency [34,37]; and full-score ratio >20% or >30% [33,34]. When only part of the criteria are met (e.g., mean >3.5 but CV ≥0.25 or full-score ratio ≤20%), expert opinions and team discussion should guide retention or removal [34,37]. Regarding authority and reliability, the expert authority coefficient （Cr）is typically calculated as Cr=(Ca+Cs)/2 (judgment basis （Ca） and familiarity （Cs）, with (Cr>0.7) generally required. A response rate (enthusiasm coefficient) >70% is commonly expected [35,37]. In this study, indicators were selected using mean ≥4.2, CV <0.25, and full-score ratio >0.20, while also incorporating experts' revision suggestions. Ultimately, 7 first-level risk dimensions and 29 second-level early-warning indicators were retained.

(iii) Weight Assignment

Weighting methods are commonly categorized as subjective, objective, and hybrid. In health-economic indicator selection, each has pros and cons. Subjective methods—such as AHP, Delphi ranking, and preference ordering—leverage expert knowledge to model logic or ranking for multi-criteria decisions but may be biased; AHP is systematic yet computationally involved. Objective methods—such as entropy weighting, principal component analysis (PCA), and CRITIC—use data variability or correlation and thus are more objective but may neglect substantive meaning; entropy is sensitive to outliers, and PCA can lose original information. Hybrid methods (e.g., AHP–entropy) seek balance but are more complex operationally. In general, simple scenarios (e.g., single cost analyses) suit entropy; complex systems (e.g., policy evaluation) benefit from methods combining expertise and data.

AHP has distinct advantages for health-economic indicator selection due to its systematic structure, flexibility, and ability to coordinate multiple objectives. First, AHP decomposes complex problems via a hierarchical model (goal–criteria–alternatives), clarifying relationships among indicators (e.g., cost, effectiveness, equity) and compensating for objective methods' neglect of inter-indicator relations. Second, by integrating expert judgment with consistency checks (e.g., CR), AHP preserves experiential insight while reducing arbitrariness, striking a balance between the roughness of Delphi and the mechanical nature of purely data-driven methods. Third, AHP allows dynamic weight adjustment to reflect policy shifts (e.g., prioritizing "emergency efficiency" during public health emergencies) and quantifies trade-offs among multiple goals (e.g., "cost control" vs. "quality improvement"), aiding decision-makers.

Given the two-tier structure and the relatively large number of second-level indicators in this study, combining the Delphi method with AHP for weight determination was appropriate. Results show that "medical insurance policy risk" and "cost control risk" received the highest weights (both 0.2240). Within these, "DRG/DIP grouping deviation rate" and "cost consumption index" carry the highest weights under medical insurance policy risk, while “proportion of drug and consumable expenditure” ranks highest under cost control risk. This indicates expert consensus that indicators related to cost containment and to monitoring the impacts of medical insurance policy are crucial for early warning of economic operation risks in public hospitals.

III. Significance of Constructing an Early Warning Indicator System for the Economic Operation of Public Hospitals

For public hospitals themselves, establishing an economic operation risk early warning indicator system serves as a core driver for connotative development and refined management reform. The system transforms hospital management from traditional *ex post accounting* and *passive response* to *ex ante warning* and *proactive management*. By integrating key indicators—such as cash flow, asset–liability structure, cost-effectiveness, and resource utilization efficiency—it functions as a real-time, dynamic “health check” of the hospital’s economic status.

When early signals emerge—for example, tightening cash flows, slower turnover of drug inventories, or abnormal increases in the proportion of personnel expenses—the system can promptly trigger alerts. This not only provides management with a critical decision-making buffer to prevent potential financial crises and operational interruptions, but also anchors decisions in objective data rather than subjective experience, promoting a shift from extensive management to data-driven, refined governance. It helps identify weak points in cost control, optimizes allocation of key resources (personnel, finance, equipment), and provides an evidence base for major strategic decisions such as discipline construction and equipment investment, thereby supporting a transition from scale expansion to quality- and efficiency-oriented development on the basis of operational safety and sustainability.

For patients and the general public, the system is an important safeguard for upholding the public welfare nature of public hospitals and ensuring the quality and safety of medical services. The legitimacy of public hospitals lies in their 公益性;

financial distress can erode this foundation. Under economic pressure, hospitals may be driven to pursue excessive revenue generation, increasing the risk of over-prescription and over-examination, which aggravates patients' financial burden and undermines doctor–patient trust. By promoting internal cost reduction and efficiency improvement, the early warning system provides material support for maintaining the public welfare bottom line under stable operation.

Moreover, the economic health of a hospital is closely linked to medical quality and safety. Institutions facing financial crisis are more likely to encounter talent loss, delayed equipment renewal, and shortages of drugs and consumables, all of which directly threaten service capacity and patient safety. The early warning system thus acts as a "firewall": by ensuring stable and resilient economic operation, it indirectly but effectively safeguards the reliability and safety of medical services, curbs unreasonable cost escalation, and contributes to reducing the overall social burden of medical expenditure, enabling the public to continuously access high-quality, affordable public medical services.

For government and regulatory authorities, constructing a unified early warning system is a key instrument for intelligent regulation, optimized macro-level resource allocation, and strengthened public health emergency preparedness. The system provides health, finance, and medical insurance authorities with a standardized and visualized monitoring tool, enabling them to track in real time the overall operation profile and common risk patterns of public hospitals, and to shift from supervising "people and processes" to supervising "performance and capital".

Through large-scale data analysis, policymakers can accurately identify systemic losses caused by policy factors (such as price adjustments or payment reform), thus providing robust evidence for determining fiscal compensation, dynamically adjusting service prices, and optimizing insurance payment policies, thereby enhancing the precision and effectiveness of health policies. Based on early warning results, governments can implement more targeted resource allocation—rewarding efficient, low-risk hospitals and focusing regulatory support and intervention on high-risk institutions—to guide medical resources toward more efficient and high-need areas. Ultimately, a financially sound and operationally robust public hospital system is a cornerstone of national public health emergency capacity, and an essential foundation for building a strong public health system and advancing the "Healthy China" strategy.

IV. Limitations of This Study

This study has several limitations, primarily due to funding constraints, which affect both the construction and application of the indicator system.

First, the coverage and representativeness of the expert panel are limited. Given resource constraints, the consultation mainly involved managers from tertiary hospitals, scholars in health economics, and key staff from provincial medical insurance departments, with insufficient participation from primary and grassroots medical institutions. As a result, the sensitivity of the indicator system to regional heterogeneity and institutional-level differences may be inadequate.

Second, the mechanism for dynamic adjustment of indicators remains underdeveloped. Due to funding limitations, a long-term tracking and evaluation platform has not yet been established. The study primarily focuses on constructing a static indicator system and does not include empirical validation or the development of intelligent data collection and automated early warning functions.

Third, there are methodological limitations. Although AHP was employed to determine indicator weights and all consistency tests met the required standards, the results remain influenced by the subjective judgments of a limited number of experts within specific regions. This may lead to deviations between the derived weights and the actual priority structure of economic operation risks in different types of public hospitals. Further empirical testing, expansion of expert diversity, and integration with objective weighting methods are needed to enhance the robustness and generalizability of the indicator system.

Chapter 5 Conclusion

This study developed a comprehensive and scientifically grounded early warning indicator system for the economic operation risk of public hospitals. The system consists of seven primary risk dimensions and twenty-nine secondary early warning indicators, forming a structured, multi-dimensional evaluation framework. This design not only reflects methodological rigor and logical coherence, but also ensures broad coverage of key economic, managerial, and policy-related risk factors faced by public hospitals under ongoing health system reform.

The proposed system enables the timely identification of potential risks arising in the course of hospital economic operation. By monitoring indicators related to solvency, operational efficiency, profitability, development capacity, medical insurance policy, cost control, and medical quality and safety, hospitals can detect warning signals at an early stage and initiate targeted interventions, thereby reducing the likelihood of financial distress and operational disruption.

In addition, the indicator system provides a practical tool for internal cost containment and efficiency improvement. Through continuous monitoring and quantitative assessment, hospitals are encouraged to optimize the allocation of human, financial, and material resources, refine cost management, and enhance the input–output efficiency of medical services. This contributes to the transition from extensive growth driven by scale expansion to connotative development oriented toward quality and value, while safeguarding the stability and resilience of hospital operations.

At the macro level, the system also supports a more rational and efficient allocation of health resources. Early warning information derived from this framework can assist health authorities and payers in understanding the operational risk profile of public hospitals, guiding differentiated regulation, performance-based support, and evidence-based policy adjustment. In doing so, it helps channel medical and health resources toward institutions and services with higher efficiency and greater need, thereby improving the overall effectiveness and equity of the health system.

In summary, the early warning indicator system constructed in this study serves as a systematic, objective, and operable tool for risk identification, performance monitoring, and decision support in public hospitals. It holds important implications not only for enhancing the refined management and sustainable development of individual hospitals, but also for strengthening the governance capacity and high-quality development of the public health care system as a whole.

References

1.Lin ZJ, Nie DD. Mechanism for prevention and mitigation of economic operation risks in public hospitals. Health Economics Research 2025;42(4):85–86.

2.Li YT, et al. Empirical study on the monitoring and evaluation index system of economic operation in public hospitals in Guangzhou. Chinese Health Economics 2024;43(1):72–76.

3.He J, Du WJ. Study on financial risk early warning of public hospitals from the perspective of the government accounting system. Fiscal Supervision 2022;(20):94–99.

4.Tomietto M, Oikarinen A, Tuomikoski AM, Kärsämänoja T, Oikarainen A. The ward manager role in the context of nursing and midwifery students' clinical learning: Testing a model. Journal of Nursing Management 2022;30(1):144–153.

5.Koyuncugil AS, Ozgulbas N. Early warning system for financially distressed hospitals via data mining application. Journal of Medical Systems 2012;36(4):2271–2287.

6.Sun RJ, Li TS. Construction and application of a financial risk early warning model for public hospitals. Chinese Health Economics 2023;42(11):73–77.

7.Xie JL, Xu MQ, Zheng YH. Construction and empirical study of a debt risk model for public hospitals based on factor analysis. Chinese Health Economics 2024;43(2):79–83.

8.Jiang R, et al. Discussion on the economic operation mechanism of large public hospitals in Henan Province. Chinese Hospital Management 2024;44(3):17–20.

9.Cosenz F, Noto G, Cavadi G, Bivona E, Scirè G. Pursuing sustainable performance in healthcare organizations: A sustainable business model perspective. Journal of Health Organization and Management 2024;38(5):741–759.

10.Xu BL, Wang SQ, Shao XY. Status analysis of behavior modeling and simulation in dynamic environment coupling. Computer and Information Technology 2021;29(4):26–29.

11.Zhang YF, Chai JJ, Hu BS, et al. Construction and application of an outpatient medical quality control index system in modern hospitals based on Delphi method and analytic hierarchy process. Chinese Hospital 2021;25(3):36–39.

12.Sun ZQ, Xu YY. Medical Statistics. 4th ed. Beijing: People’s Medical Publishing House; 2017. p.402–421.

13.Liu NN. Study on the evaluation index system of traditional Chinese medicine health tourism destinations from the perspective of consumers. Beijing: Beijing University of Chinese Medicine; 2020.

14.Cai SS. Construction of an evaluation index system for asset operation efficiency in public hospitals. Chinese Hospital President 2023;(20):87–89.

15.Xu JJ, Wang LN. Review of research on the economic operation evaluation index system of public hospitals in China. Chinese Health Resources 2021;24(2):190–193.

16.Hu XM, Su D, Jiang D, Huang W, Huang L. Construction of a hospital operation efficiency evaluation index system under medical insurance payment reform. Chinese Hospital 2024;28(4):6–9.

17.Chen YX. Construction of an economic operation evaluation index system for hospitals from the perspective of high-quality development. Economist 2023;(6):223–224.

18.Huang GC, Zhang YN, Jiang H, et al. Construction of an economic operation monitoring and evaluation index system for public hospitals based on high-quality development. Health Economics Research 2022;39(5):63–66.

19.Ru H, Xu XY, Wang X, et al. Study on performance appraisal index system for shared research wards. Chinese Health Quality Management 2024;31(9):73–76.

20.Chen JN, Deng YY, Yang B, et al. Expert consensus on selection of competency evaluation indicators for psychological assistance hotline professionals. Chinese Journal of Mental Health 2025;39(6):490–495.

21.Xin Y, Song RM, Hao J, et al. A methodological quality assessment framework for health economic evaluation based on pragmatic clinical trials. Chinese Health Economics 2025;44(5):5–11.

22.Liu L, Ze B, Danzen LJ, et al. Construction of an index system for hospital off-label drug use management based on the Delphi method. China Pharmacy 2025;36(17):2182–2186.

23.Chen YN, Wang XL, He SH, et al. Construction of a healthy village monitoring indicator system in Zhejiang Province based on the Delphi method. Chinese Journal of Public Health 2025;41(9):1106–1111.

24.Li YY, Chen WJ. Application status of the Delphi method in nursing management. Nursing Research 2018;32(21):3339–3341.

25.Chang YY, Ma YT, Chu Y. Application status of the Delphi method in the study of dual competencies of intern nursing students. Vocational Technology 2010;(7):53.

26.He Y, Tian J, Yang XZ, Zhu J, Zhao XD. Construction of a professional quality cultivation system in pediatric medical talent training. Modern Vocational Education 2021;(6):226–227.

27.Chen JX. Analysis of the knowledge self value-added mechanism of the Delphi method. Chinese and Foreign Entrepreneurs 2005;(3):88–91.

28.Wang SN, Dong R, Xie H, Jia XJ. Application progress of the Delphi method and its use in constructing index systems. Journal of Bengbu Medical College 2016;41(5):695–698.

29.Hu CP, Yang J. Application of the Delphi method in constructing government performance index systems: A case study of township governments. Journal of Shaanxi Administration Institute 2007;(4):12–15.

30.Wang XF, Su YZ, Liao X, et al. Determination of clinical questions in the "Expert consensus on TCM prevention and treatment of novel coronavirus infection". Chinese Journal of Traditional Chinese Medicine Emergency 2024;33(3):377–382.

31.Shi JY, Song QF, Wang Y, et al. Research on the construction of a modern hospital management training system in China. Chinese Hospital 2025;29(10):25–28.

32.Wei X, Yin YH, Wang X, et al. Evaluation index system for bone health service capacity of primary medical and health institutions based on the Delphi method. Chinese General Practice 2025;28(19):2354–2362.

33.Chongqing Medical Association; Chongqing Pharmacy Management Quality Control Center; Expert Consensus Working Group on Quality Control of Home Pharmacy Services in the Sichuan–Chongqing Regional Medical Consortium. Expert consensus on quality control of home pharmacy services in the Sichuan–Chongqing closely integrated regional medical consortium. China Pharmacy 2025;36(14):1689–1696.

34.Li XX, Feng YN, Zhuang W, et al. Expert consensus on the evaluation of shortage proprietary Chinese medicines in medical institutions. China Medicine 2025;20(5):641–647.

35.Jing TY, Cui LY, Li YK, et al. Expert consensus on diagnostic items for phlegm–blood stasis interlocking pattern in hypertension based on Delphi method. Journal of Traditional Chinese Medicine 2025;1–15. (online ahead of print, 29 Oct 2025).