INSTITUTO
UNIVERSITÁRIO
DE LISBOA

The Impact of the Nursing Practice Environment on Nursing Human Resources Efficiency: A case approach based on the theories of Human Capital and the Resource-Based View

XIONG Yong

Doctor of Management

Supervisors:
PhD Elisabeth Reis, Full Professor,
ISCTE University Institute of Lisbon
PhD Maria João Lopes, Assistant Professor
ISCTE University Institute of Lisbon

December, 2024

BUSINESS
SCHOOL

Marketing, Operations and General Management Department

The Impact of the Nursing Practice Environment on Nursing Human Resources Efficiency: A case approach based on the theories of Human Capital and the Resource-Based View

XIONG Yong

Doctor of Management

Supervisors:
PhD Elisabeth Reis, Full Professor,
ISCTE University Institute of Lisbon
PhD Maria João Lopes, Assistant Professor
ISCTE University Institute of Lisbon

December, 2024

BUSINESS
SCHOOL

Marketing, Operations and General Management Department

The Impact of the Nursing Practice Environment on Nursing Human Resources Efficiency: A case approach based on the theories of Human Capital and the Resource-Based View

XIONG Yong

Doctor of Management

Jury:

PhD Maria Fatima Jorge, Assistant Professor,
University of Évora
PhD Chichen Zhang, Professor,
SMU – Southern Medical University
PhD Dália Nogueira, Affiliated Member,
ISCTE University Institute of Lisbon
PhD Elizabeth Reis, Full Professor,
ISCTE University Institute of Lisbon
PhD Patrícia Costa, Assistant Professor,
ISCTE University Institute of Lisbon

December, 2024

INSTITUTO UNIVERSITÁRIO DE LISBOA

The Impact of the Nursing Practice Environment on Nursing Human Resources Efficiency: A case approach based on the theories of Human Capital and the Resource-Based View

XIONG Yong

[This page is deliberately left blank.]

Abstract

The nursing practice environment, as a core element of hospital organisational ecology, plays a pivotal role in optimising Nursing Human Resource Efficiency (NHRE). Grounded in human capital theory and the resource-based view, this study aims to explore the mechanisms through which the nursing practice environment influences NHRE and to propose scientific management strategies for hospital administrators.

Building on a literature review, a theoretical model on the impact of the nursing practice environment on NHRE was proposed, followed by empirical research. This study employed a mixed-methods approach, integrating Confirmatory Factor Analysis (CFA), Exploratory Factor Analysis (EFA), Data Envelopment Analysis (DEA), the Delphi expert consultation method, and semi-structured interviews. The research was conducted across 19 clinical nursing units in a tertiary Grade A general hospital in Guangdong Province, involving 670 nurses. The study spanned from 2020 to 2021, utilising a short term longitudinal tracking design.

The main innovations and contributions of this study include: (1) A five-subscale model of the Nursing Practice Environment Assessment Scale (NPEAS) was developed through CFA and EFA, and a questionnaire survey was administered to nurses. The five dimensions showed consistent trends, ranked from lowest to highest importance as follows: Job Autonomy, Compensation and Administrative Support, Management and Leadership Competences, Nurse-Physician Collaboration/Teamwork, and Training and Development; (2) An NHRE indicator system was constructed based on an input-output model, and eight key indicators were selected through the Delphi expert consultation method. The DEA model was used to analyse the NHRE of the 19 Decision Making Units (DMUs). (3) The sub-dimensions of the NPEAS positively influenced NHRE outcomes, allowing eight DMUs transitioned from inefficient to efficient; and (4) Three strategies have been proposed for hospital managers: strengthening leadership training for head nurses, building an intelligent nursing decision support system, and improving the multidimensional guaranteed mechanism for clinical nurses.

Keywords: nursing practice environment, nursing human resource efficiency, human capital theory, resource-based view, data envelopment analysis, Delphi expert consultation
JEL: I12, J28

[This page is deliberately left blank.]

Resumo

O ambiente de prática dos enfermeiros, como elemento central da ecologia organizacional dos hospitais, tem um impacto crucial na otimização da eficiência dos recursos humanos de enfermagem (Nursing Human Resource Efficiency, NHRE). Baseando-se na teoria do capital humano e na visão baseada em recursos, este estudo tem como principal objetivo explorar o mecanismo de influência do ambiente de prática dos enfermeiros na eficiência dos recursos humanos de enfermagem e propor estratégias científicas de gestão aos administradores hospitalares.

Com base na revisão da literatura, foi proposto um modelo teórico para a influência do ambiente de prática dos enfermeiros na eficiência dos recursos humanos de enfermagem, a que se seguiu uma investigação empírica. Este estudo adotou uma metodologia mista, integrando análise fatorial confirmatória (CFA), análise fatorial exploratória (EFA), análise envoltória de dados (DEA), método Delphi de consulta a especialistas e entrevistas semiestruturadas. O estudo foi realizado em 19 unidades de enfermagem clínica de um hospital geral de classe A na província de Guangdong, envolvendo 670 enfermeiros, com um desenho longitudinal de curto prazo que abrangeu os anos de 2020 e 2021.

As principais inovações e contribuições deste estudo incluem: (1) O desenvolvimento de um modelo de medida da NPEAS com cinco subescalas. As cinco dimensões apresentaram tendências consistentes, assim ordenadas de forma decrescente da importância: Autonomia no Trabalho, Remuneração e Apoio Administrativo, Competências de Gestão e Liderança, Colaboração Enfermeiro-Médico/Trabalho em Equipe, e Formação e Desenvolvimento. (2) A construção de um sistema de avaliação de NHRE com oito indicadores-chave selecionados através do método Delphi; (3) As subdimensões da escala de avaliação do ambiente de prática dos enfermeiros mostraram um impacto positivo nos resultados da NHRE, com oito DMUs a passaram de ineficientes a eficientes; (4) A proposta de três estratégias para os administradores hospitalares: fortalecer a formação em liderança das enfermeiras-chefe, construir um sistema inteligente de apoio à decisão em enfermagem e melhorar o mecanismo de garantia multidimensional para os enfermeiros clínicos.

Palavras-chave: Ambiente de prática dos enfermeiros, Eficiência dos recursos humanos de

enfermagem, Teoria do capital humano, Visão baseada em recursos, DEA, Método Delphi..
JEL: I12, J28

摘 要

护士执业环境作为医院组织生态的核心要素，对护理人力资源效率（Nursing Human Resource Efficiency, NHRE）的优化具有关键性影响。本研究基于人力资本和资源基础观，旨在探寻护士执业环境对护理人力资源效率的影响机制，并为医院管理者提供科学的管理策略。

在文献综述的基础上，提出了护士执业环境对 NHRE 影响的理论模型，并进行了实证研究。本研究采用了一种混合方法，整合了验证性因子分析（CFA）、探索性因素分析（EFA）、数据包络分析（DEA）、德尔菲专家咨询法和半结构化访谈。该研究在广东省一家三级甲等综合医院的 19 个临床护理单元进行，涉及 670 名护士。该研究从 2020 年到 2021 年，采用了短期纵向跟踪设计。

本研究的主要创新和贡献包括：（1）通过 CFA 和 EFA 开发了护士执业环境评估量表（NPEAS）的 5 个子量表模型，并对护士进行了问卷调查。5 个维度显示出一致的趋势，从低到高依次为：工作自主性、薪酬和行政支持、管理和领导能力、护医协作/团队合作以及培训和发展。（2） 基于投入—产出模型构建了 NHRE 指标体系，通过德尔菲专家咨询法确定了 8 个关键指标。采用 DEA 模型对 19 个决策单元（DMU）的 NHRE 进行了分析。（3） NPEAS 的子维度对 NHRE 结果产生了积极影响，使 8 个 DMU 从低效转变为高效。（4）为医院管理者提出了三项策略：加强护士长领导力培训，构建智能护理决策支持系统，完善临床护士多维保障机制。

关键词：护士执业环境，护理人力资源效率，人力资本理论，资源基础观，数据包络分析，德尔菲专家咨询。

JEL: I12, J28

[This page is deliberately left blank.]

Acknowledgement

The completion of my thesis has been a challenging journey, spanning five years and encompassing three years of the COVID-19 pandemic. During this time, my workplace also relocated from Guangzhou to Shenzhen. I have been incredibly fortunate to receive support from various professors, teachers, colleagues, and classmates, which enabled me to persevere in completing this thesis amidst my busy work schedule.

First and foremost, I would like to express my gratitude to my supervisors, Professors Elisabeth Reis and Maria João Lopes, for their guidance, care, and support. Whenever I encountered difficulties, I turned to Professor Elisabeth Reis for help. Her profound knowledge, approachable personality, and rigorous academic attitude have left a deep impression on me. For the sake of my thesis, she even invited Professor Maria João Lopes to provide specialized guidance on my data analysis. Professor Maria João Lopes' rigor, meticulousness, and professionalism in handling data have earned my deep respect and have greatly benefited me. Throughout every stage of my thesis, I consulted Professor Elisabeth Reis multiple times via email and video. She provided me with detailed guidance on topic selection, research design, model building, literature review, and the analysis of survey data in progress reports. Here, I want to express my most sincere thanks to Professors Elisabeth Reis and Maria João Lopes! The rigorous and conscientious academic attitudes I have learned from both supervisors will continue to guide my future work.

I would also like to extend my gratitude to Professors Virginia and Nelson for their patient explanations and valuable guidance during their professional courses and thesis supervision.

I am grateful to the leadership and faculty of the School of Health Management at Southern Medical University for their organization and guidance in my studies during my doctoral period, as well as for their reminders and support in the progress of my thesis.

I also want to thank my colleagues at the Third Affiliated Hospital of Southern Medical University, Mr. Han Dong, and all the head nurses, whose support facilitated the smooth completion of the data collection for this study.

Finally, I am deeply thankful to my family for their unwavering support in terms of time, finances, and encouragement, which enabled me to persevere through repeated setbacks.

Due to my limited academic capabilities, there are still many shortcomings in my thesis,

and I humbly welcome any corrections and guidance.

致 谢

我的毕业论文完成非常坎坷，跨越了 5 个年头，经过了 3 年新冠疫情，本人的工作地点也从广州调到深圳，非常幸运得到各位教授, 老师, 同事和同学的帮助，让我在繁忙的工作之余能坚持完成本论文。

首先感谢我的导师 Elisabeth Reis 和 Maria João Lopes 教授对我的指导, 关心和支持。每当我遇到困难时，我就向 Elisabeth Reis 教授求助，她渊博的知识, 平易近人的性格, 严谨的学术态度给我留下了深刻的印象。为了我的论文她还特意为我请来 Maria João Lopes 教授对我的数据分析进行专门指导。Maria João Lopes 教授对于数据的严谨, 认真, 专业让我肃然起敬，受益匪浅。在我的论文的每个阶段，我都曾多次通过电子邮件和视频咨询过 Elisabeth Reis 教授，她在课题选择, 研究方案, 模型构建, 文献综述, 进度报告中对问卷数据的分析等方面给了我非常详细的指导。在此，我要向 Elisabeth Reis 和 Maria João Lopes 教授表达我最诚挚的感谢！我也将从两位导师学习到的严谨认真的治学态度，继续应用在我未来的工作中。

感谢并将永远铭记 Virginia 教授和 Nelson 教授，在专业授课和论文辅导时的答疑解惑, 谆谆教导。

感谢南方医科大学卫生管理学院的领导, 教师对博士期间学习上的组织和指导，论文进度的提醒和帮助。

感谢南方医科大学第三附属医院的同事，韩栋老师, 各位护士长的帮助，让本研究的数据调查与收集得以顺利完成。

感谢我的家人在时间上, 经济上, 精神上给予我强大的支持，让我在一次次挫败中得以坚持。

由于我的学术水平有限，所写的论文中还存在很多不足，敬请指正。

[This page is deliberately left blank.]

Contents

List of Tables

[This page is deliberately left blank.]

List of Figures

[This page is deliberately left blank.]

List of Acronyms

AACN	American Association of Critical-Care Nurses
AIDES	Nursing Aides
AIN	Assistant in Nursing
ANCC	American Nurses Credentialing Center
ANCPRO	Auxiliary Non-Nursing Professionals
CAS	Compensation and Administration Support
Ca	Expert Familiarity Coefficient
CFA	Confirmatory Factor Analysis
CFI	Comparative Fit Index
CNA	Certified Nursing Assistant
CNKI	China National Knowledge Infrastructure
Cr	Judgment Basis Coefficient
CRS	Constant Returns to Scale
Cs	Authority Coefficient
CSPD	China Science Periodical Database
DEA	Data Envelopment Analysis
DEA- BCC	Data Envelopment Analysis with Banker, Charnes, and Cooper
DEA-CCR	Data Envelopment Analysis - Charnes,Cooper & Rhodes
DEA-SBM	Data Envelopment Analysis - Slack-Based Measure
DMUs	Decision Making Unit
DRG	Diagnosis Related Groups
EEN	Elementary Registered Nurse
EFA	Exploratory Factor Analysis
EN	Enrolled Nurse
FTE	Full-Time Equivalent
HCA	Health Care Nurse
HRDI	Health Resources Density Index
HRM	Human Resources Management
HWE	Healthy Work Environment

ICN	International Council of Nurses
IOM	Institute of Medicine
JA	Job Autonomy
KPI	Key Performance Indicator
LPN	Licensed Practical Nurse
ML	Maximum Likelihood
MLC	Management and Leadership Capabilities
NHPPD	Nursing Hours Per Patient Day
NM	Nurse Manager
NP	Nurse Practitioner
NPCT	Nurse-Physician Collaboration/Teamwork
NPEAS	Nurse Practice Environment Assessment Scale
NWI	Nursing Work Index
NWI-R	Revised Nursing Work Index
PES-NWI	Practice Environment Scale of the Nursing Work Index
PNWE	Perceived Nursing Work Environment
PTE	Pure Technical Efficiency
RBV	Resource-Based View
RMSEA	Root Mean Square Error of Approximation
RN	Registered Nurses
RSR	Rank-Sum Ratio
SE	Scale Efficiency
SFA	Stochastic Frontier Analysis
TCM	Traditional Chinese Medicine
TD	Training and Development
TE	Technical Efficiency
TFD	Transaction Flow Diagram
TFP	Total Factor Productivity
TLI	Tucker-Lewis Index
TOC	Theory of Constraints
TOP-SIS	Technique for Order Preference by Similarity to Ideal Solution
UAP	Unlicensed Assistant Personnel
VRS	Variable Returns to Scale

WHO	World Health Organization

[This page is deliberately left blank.]

Chapter 1: Introduction

1.1 Research background

Nurses are an essential part of the health system, and one of the most critical and dynamic health resources. As such, their allocation and use directly affect the nursing quality, patient safety, and overall operation efficiency of hospitals (Hinno et al., 2012). Following the onset of the Covid-19 epidemic in early 2020, Chinese nurses, serving as a crucial component of the healthcare sector, effectively carried out their duties (Sun et al., 2021). Nursing is a vital component of the healthcare system. Nurses play a crucial role within medicine and healthcare. They have a vital function in safeguarding lives, managing and averting illnesses, alleviating suffering, and enhancing well-being. Strengthening the development of nursing personnel, advancing health initiatives, promoting the Health China programme, and addressing the challenges posed by population ageing are all highly significant and have wide-ranging implications (NHC, 2020).

In 2020, Xi Jinping, General Secretary of Chinese Communist Party, fully affirmed the significant contributions made by nurses nationwide in the prevention and control of the pandemic and public protection and stressed the importance of caring for nurses and strengthening their training as an important basic work for healthcare development. He also underlined the significance of improving the incentive mechanism, publicising advanced models, and supporting the long-term retention of outstanding nurses.

The purpose of the management of hospital nursing human resources is to guarantee a sufficient number of nursing staff and maximise the efficiency of the existing workforce. In the context of health policy reform, the predominant strategies for ensuring the survival and growth of hospitals are centred on the implementation of talent strategies and the pursuit of low-cost human resource strategies within the broader framework of human resource management (Peng, 2004).

The global spotlight has been directed towards the strategic use of human resources, with particular emphasis on the development of nursing personnel (Buchan et al., 2015). Improving the efficiency of nursing human resources use is of great importance. Global nursing experts have suggested multiple efficient strategies for managing human resources, such as improving

nursing work conditions, establishing and improving salary incentive mechanisms, carefully considering nurse career planning, and strengthening professional skill training (T. Li & Li, 2018).

The State of The World's Nursing 2020 report highlights the importance of creating a favourable environment for professionals to address future workforce challenges. It is essential to improve the attractiveness and vitality of the nursing workforce, as well as to optimise their allocation and retention (WHO, 2020). Nurses operating in vulnerable and conflict-affected settings require special consideration. Furthermore, it is crucial to prioritise the resolution of problems related to sexual harassment, violence, and discrimination within the healthcare field. This should involve a strong focus on the implementation of effective solutions (de Raeve et al., 2023; Newman et al., 2023).

In 2020, Xi Jinping issued instructions on International Nurses Day to bolster the development of the nursing profession, guarantee the safety of nurses' practice, and enhance their provision of humanistic care. Moreover, he oversaw the implementation of specific strategies to reduce the workload of nurses, establish conducive conditions for their professional practice by addressing their urgent issues, and promote a societal environment in which they are valued and supported (X. Chen et al., 2021).

Drucker (2008) argued that the most important role of management is to guarantee an organisation's continuity and longevity. An efficient and properly organised structure can guarantee an organisation's resilience against any adversity. Simultaneously, it is imperative for management to capitalise on the chance to respond flexibly to rapidly- occurring global changes. Consequently, hospital nursing managers are now prioritising the establishment of a conducive practice environment. The objective is to augment nurses' professional satisfaction, stabilise nursing staff, and enhance the efficiency of nursing professionals (Weston, 2022).

1.2 Research problem

The shortage of nursing manpower has become an increasingly serious global issue (Herrick, 2024). Furthermore, the outbreak of the Covid-19 pandemic in 2020 presented an extra challenge for nursing personnel (Danesh et al., 2021; W. W. Liu et al., 2021).

The healthcare sector is undergoing significant changes due to China's social economy transformation, increased urbanisation, ageing population, and growing demand for high-quality medical services. Simultaneously, the discrepancy between the supply and demand for nursing staff is becoming increasingly apparent (Z. Z. W. Zhao et al., 2020).

Although there has been a general rise in the number of registered nurses and a higher nurse-to-patient ratio, these figures still fall significantly short of the desirable benchmark of a 1:2 ratio (A. Huang et al., 2018). This signifies a substantial deficit in the overall quantity of registered nurses and a critical state in the allocation of nursing human resources. In China, the current distribution of nursing personnel is primarily focused on broad measurements, such as the ratios of nurses to patients and beds to nurses, and per capita figures. However, these allocation methods neglect the practical usage of beds, the specific nursing requirements of various diseases, or the varying levels of care needed by patients. Strictly adhering to these ratios in nurse allocation may result in staffing shortages and wastage in clinical nursing (Y. Zhang, 2021). Furthermore, there is a prevalent scarcity of highly skilled individuals, which has largely been attributed to inadequate educational attainment and an insufficient quantity of specialised nurses (M. Xiao et al., 2020). Moreover, the regional distribution of nursing personnel is imbalanced, with significant disparities between urban and rural areas, and between the eastern and western regions of the country (F. Weng et al., 2019).

Given the shortage of nursing human resources, it is more practical and attainable to focus on improving the efficiency of current nursing personnel (Bowblis & Roberts, 2020). The lack of attention from hospital managers towards nursing efficiency and the use of outdated management concepts has resulted in a significant decrease in the efficient use of nursing human resources (R. Li et al., 2016). This problem has been exacerbated by a deficiency in inventive approaches to workforce planning and development, along with inadequate funding in technology and training programmes specifically designed for nurses (Zhang, 2021). Proper human resource management strategies could enhance hospital employee satisfaction and engagement (Cao et al., 2021). However, many studies conducted in various nations have disproven this claim, suggesting an indirect connection (Boxall et al., 2011; Gile et al., 2018; Marchal & Kegels, 2008). Moreover, the factors that are responsible for connecting this link are still not clearly understood (Karami et al., 2017).

From this, it is evident that the key challenges or dilemmas faced by hospitals are as follows: the crisis of nursing workforce shortages continues to intensify against the backdrop of public health emergencies and an ageing population. Healthcare institutions are confronted with the dual challenges of optimising the nursing practice environment and enhancing the efficiency of nursing human resources. However, these issues are further exacerbated by the widespread lag in evidence-based management practices among nursing administrators and their insufficient understanding of efficiency evaluation.

1.3 Research questions

To achieve the research objectives, the following questions need to be addressed:

(1) Which framework can be used to scientifically assess the nursing practice environment?

Understanding the nursing practice environment within hospitals and conducting regular evaluations and analyses provides hospital administrators with an objective basis and clear direction for ongoing improvements. Selecting objective and effective tools to assess the nursing practice environment is therefore crucial.

(2) How can an index system be utilized to evaluate the efficiency of nursing human resources?

Human resources efficiency is the extent to which these resources are effectively used. From the perspective of an enterprise, it is the extent to which these available resources contribute effectively to performance. The analysis is used to understand whether the enterprise's human resources are being fully capitalised upon and whether each employee is performing to their own potential, so that decision makers can take timely and effective measures to improve the efficiency of the enterprise's human resources use (F. Weng et al., 2019).

(3) Does the nursing practice environment influence the effectiveness of nursing personnel, and can a model be developed to explain this relationship?

The nursing practice environment can influence patient safety by affecting nurses directly. A positive work environment is directly related to the quality of nursing care (Amaliyah & Tukimin, 2021), and the nursing work environment significantly impacts patient safety outcomes (Nascimento et al., 2021). One of the primary reasons for the rising turnover rate among hospital nurses is a negative work environment. Such an environment reduces nurse performance and adversely impacts the quality of patient care, as well as the safety of both patients and healthcare workers (Ulusoy & Polatkan, 2016).

(4) What strategies can nurse managers employ to enhance the nursing practice environment and optimize the efficiency of nursing human resources?

Excellence in the nursing practice environment is essential for improving healthcare system performance. Nurses need a work environment where they can fully express their skills and knowledge. Identifying areas for improvement in the nursing work environment—by policymakers, administrators, nursing leaders, and educators—can significantly enhance patient outcomes (Hassanein et al., 2020).

1.4 Research purpose and steps

This study aims to explore the impact mechanism of the nursing practice environment on the efficiency of nursing human resources and to provide hospital administrators with scientifically grounded management strategies. Based on a comprehensive analysis of domestic and international literature, the research will be conducted through the following three steps:

(1) Assessment of the Nursing Practice Environment Across Different Study Units.

a) Selection of Assessment Tools: Various nursing practice environment assessment scales were identified through literature review, and their content and theoretical frameworks were compared. Following a thorough analysis, an appropriate assessment tool that matches the characteristics of the participants was selected.

b) Optimisation of the Assessment Tool: Exploratory factor analysis and confirmatory factor analysis were employed to refine the nursing practice environment assessment tool.

c) Development of a Survey Questionnaire: A survey questionnaire was designed and administered to nurses in the study units.

d) Statistical Analysis of Collected Data: The data collected were subjected to statistical analysis.

(2) Evaluation of Nursing Human Resources Efficiency Across Different Study Units.

a) Selection of Appropriate Evaluation Criteria: Data Envelopment Analysis (DEA) was chosen to assess the efficiency of nursing human resources, and the number of key indicators required for measurement was determined.

b) Construction of an Efficiency Indicator System for Nursing Human Resources: An input-output model was used to establish the efficiency indicator system for nursing human resources.

c) Screening of Key Indicators Using the Delphi Expert Consultation Method: The Delphi method was employed to identify the key indicators of nursing human resources efficiency.

d) Collection of Relevant Indicator Data from Study Units: Data on the relevant indicators were collected from the study units.

e) Comparison of DEA Models and Selection of the Optimal Model: Various DEA models were compared, and the Slacks-Based Measure (SBM) model was selected as the optimal model for analysis.

(3) Correlation Study Between the Nursing Practice Environment and Nursing Human Resources Management Efficiency.

a) Second Analysis Using the SBM Model: Each dimension of the nursing practice environment assessment scale was treated as an input indicator in the SBM model for a second

round of analysis.

b) Comparison of the Two Sets of Nursing Human Resources Efficiency Results: The results of the two analyses of nursing human resources efficiency were compared.

c) Interviews with Nurse Managers in the Study Units: Interviews were conducted with nurse managers in the study units.

d) Exploration of Factors Influencing Nursing Human Resources Efficiency: The study sought to identify the factors within the nursing practice environment that influence the efficiency of nursing human resources.

1.5 Structure of the thesis

This thesis is divided into six chapters:

Chapter 1: Introduction. Includes a brief description of the research background, clarification of research problem, research questions, research purpose and research steps, and thesis structure.

Chapter 2: Literature Review. Including the current situation of nursing human resources, concepts related to nursing human resource management, main contents of nursing human resource management, evaluation indexes and methods of nursing human resource efficiency, evaluation tools and application status of hospital nurses' practice environments, interactions between nurses' practice environments and nursing human resource efficiency, and theories related to this study (Human capital theory, Resource-Based View). By summarizing the literature and combining relevant management theories, a theoretical model of the impact of nursing practice environment on nursing human resource efficiency is proposed.

Chapter 3: Methods. Clarifies the research subjects and corresponding inclusion and exclusion criteria. Provides a detailed explanation of the research paths and methods for each of the three aspects: nurse practice environment, nursing human resource efficiency, and the relationship between nurse practice environment and nursing human resource efficiency.

Chapter 4: Results. The results of the data in 3 areas are presented: the results of the study of the nurse practice environment, the results of the establishment and application of the key indicators of nursing human resource efficiency, and the results of the study of the relationship between the nurse practice environment and nursing human resource efficiency.

Chapter 5: Discussion and Conclusion. After theoretical and empirical research, combined with research results, discussions and summaries are conducted, mainly targeting the research questions raised, identifying the theoretical and managerial contributions, objectively analyzing

the limitations of this study, and proposing future research direction. (1) Regarding the assessment tool for the nursing practice environment. The Nurse Practice Environment Assessment Scale (NPEAS), with its five sub-scale model, provides a reliable and effective structure for assessing the nursing practice environment, facilitating further research and practical application in nursing management in China. Existing tools for assessing the nursing practice environment evaluate the overall hospital environment (macro-environment). There is a need to develop scales specifically for evaluating smaller, department-specific environments (micro-environment) to increase precision and sensitivity in future studies. (2) Concerning the evaluation of nursing human resource efficiency. Eight indicators were determined using the Delphi method to evaluate nursing human resource efficiency, and the Slacks-Based Measure (SBM) model was used to analyze efficiency across 19 decision-making units (DMUs). Emphasis should be placed on the quality of indicators and data. A relative value system based on a quality perspective is worthy of reference and use in the nursing human resource efficiency indicator system. (3) A model was proposed and validated that assesses the impact of the nursing practice environment on nursing human resource efficiency (theoretical contribution). This theoretical model provides hospital managers with new ideas and insights into studying the nexus between the nursing practice environment and nursing human resource efficiency, offering good applicability and operability. It provides a model for hospital managers to assess and improve the nursing practice environment in their hospitals. (4) To improve the nursing practice environment and enhance nursing human resource efficiency, three optimization strategies were proposed: enhancing the management skills of supervisors (head nurses); improving nurses' leadership; and establishing a comprehensive clinical nurse support mechanism in hospitals. (5) The limitations of this study and directions for future research.

[This page is deliberately left blank.]

Chapter 2: Literature Review

A comprehensive literature review was performed using online resources, covering multiple databases, such as PUBMED, Medline, China National Knowledge Infrastructure (CNKI), and China Science Periodical Database (CSPD). We used the following keywords for our search: ’nursing human resources’, ’nursing human resource management’, ’nurse practice stability / nurse turnover rate’, ’nurse practice environment / nurse work environment’, and ’nursing human resource efficiency’. The aim of this systematic search was to gather relevant research papers, published in both Chinese and English, that are related to the mentioned keywords. Moreover, government reports and industry reports related to ’nursing human resources’ were also included in the search.

2.1 Current state of nursing human resources

The 2020 State of the World’s Nursing Report, a collaborative publication by the World Health Organization (WHO), the International Council of Nurses (ICN), and Nursing Now, highlights significant global challenges in the nursing workforce. According to the report, the total number of nurses worldwide falls short of 28 million, contributing to an alarming global deficit of approximately 5.9 million nurses. This shortage is particularly acute in low- and middle-income countries, where 5.3 million nurses—accounting for 89% of the gap—are needed. The most critical shortages are found in regions such as Africa, Southeast Asia, the Eastern Mediterranean, and parts of Latin America, which face increasing difficulties in meeting healthcare demands due to insufficient nursing staff (Zhang, 2021). In the United States and Europe, the average age of nursing teams is relatively high, with many nurses nearing retirement, leading to significant age gaps. This trend poses a challenge to the sustainability of the nursing workforce in these regions (Marć et al., 2019).

Nursing continues to be a profession predominantly occupied by women, with around 90% of the workforce identifying as female (Marć et al., 2019). This gendered composition of the field is accompanied by various systemic challenges, including gender biases, significant pay disparities, and other forms of discrimination that persist within healthcare settings (Zhang, 2021). As the largest sector of the global health workforce, nurses have been pivotal in responding to major health crises, particularly during the COVID-19 pandemic, where their

contributions were essential to managing the crisis and ensuring patient care (Zhang, 2021). Nurses play a crucial role in realizing the global commitment to “leave no one behind” and are central to the broader efforts aimed at achieving the United Nations Sustainable Development Goals (SDGs). However, there is currently no global nursing workforce that is adequately aligned with the demands of national health coverage and the SDGs (Cao et al., 2021).

In most countries worldwide, nurses account for approximately 0.5% of the population. According to the 2022 China Health Statistical Yearbook (NHC, 2020), by the end of 2021, China had 5,019,422 registered nurses, equating to 3.56 nurses per 1,000 population. This figure is notably lower than the EU benchmark of over 8 nurses per 1,000 population, the U.S. rate of 9.8 nurses per 1,000, and Japan's rate of 11.49 nurses per 1,000. The aging population in China further exacerbates this nursing shortage (Buchan et al., 2022).

There are significant regional disparities in the distribution of nursing staff within China, with the eastern regions having higher ratios than the central and western regions (M. Xiao et al., 2020). In 2018, the Health Resource Density Index of the eastern region was 1.66 times that of the central region and 3.24 times that of the western region (A. Huang et al., 2018). The Gini coefficient of nursing human resources in China is below 0.2 when based on economic factors, indicating a relatively fair distribution in terms of population and economic aspects. However, the coefficient rises to 0.66 when based on geographical regions, suggesting substantial inequality in distribution across regions (Y. Weng et al., 2019).

China is currently facing a shortage of nursing professionals, not only in overall numbers but also in the availability of advanced nursing talents, particularly those in leadership roles within the nursing discipline. Nursing education in China is primarily concentrated in secondary vocational schools, and higher nursing education started relatively late (A. Huang et al., 2018). The overall educational level of Chinese nursing personnel is relatively low, with only around 20% of nurses holding a bachelor’s degree or higher, likely reflecting the late development of higher nursing education in the country (Zhang & Song et al., 2021). In this context, the professional rank structure resembles a "pyramid" distribution—with a severe shortage of senior positions, and fewer than 20% of nurses holding an intermediate rank (Zhang & Song et al., 2021). This distribution does not align with the “olive-shaped” structure recommended by the World Health Organization (WHO, 2021). Furthermore, China's relaxation of birth policies in 2021 has led to short-term employment shortages and significantly extended training periods for nursing personnel, compounding the shortage of nursing human resources (Wei et al., 2020).

2.2 Concepts related to nursing human resource management

2.2.1 Human resource management

The concept of "human resource management" was introduced by E. Wighe Bakke in his 1958 book The Human Resources Function, where he elaborated on the functions of human resource management. He proposed that human resource management encompasses areas such as personnel administration, labour relations, interpersonal relations, and executive development.

Human resource management is a crucial field of study within management science, focusing on human resources as a unique economic and social asset. Specifically, it refers to the planning, organizing, directing, and controlling activities involved in the acquisition, development, retention, and utilization of human resources.

2.2.2 Hospital human resource management

Hospitals are specialised organisations with a significant number of staff members and the need for continuous, uninterrupted operations around the clock. Moreover, they are bound by distinct legal provisions concerning staff members. Health human resources are professionals in health settings who have achieved specific degrees, technical titles, or expertise in particular areas. This group comprises such medical professionals as physicians, chemists, nurses, technicians, examiners, and laboratory technicians, along with managers and administrative staff (Tulchinsky & Varavikova, 2014). We used this description, which includes all professionals employed by the hospital, to define hospital human resources. Hospital human resources are characterised by their intensity, specialisation, complexity, continuity, and adherence to mandatory regulations.

The field of human resource management in hospitals is currently confronted with several challenges due to advances in science, information technology, medical system reforms, and heightened competition (Tulchinsky & Varavikova, 2014). These challenges include a growing scarcity of skilled personnel, a sharp rise of employee turnover, and increasing costs and risks associated with managing human resources (Grabowski & Mor, 2020; Kelly et al., 2021).

The core of hospital human resource management is the effective administration of the value chain of human resources (Beaulieu & Bentahar, 2021), as well as the establishment of a strategic partnership between hospitals and employees with the dual bonds of labour and psychological contracts (Said et al., 2021). A new relationship model between hospitals and employees, as well as new guidelines for hospital human resource management focusing on

communication, trust, respect, innovation, learning, and cooperation, should also be established.

2.2.3 Nursing human resources management

While the concept of nursing human resources is widely used in the literature, a uniform definition is notably absent. Within the literature, "nursing human resources" is usually used in conjunction with "nursing workforce" and "nursing human power" (Lammintakanen et al., 2002).

Nursing human resources is the provision of a sufficient number of nurses of appropriate quality who are able to perform their jobs, and anticipate and respond to staff shortages, so as to ensure the proper functioning of the health organisation. Nursing human resource management includes recruitment, selection, induction, training, performance appraisal, remuneration, and safety (Čiarnienė et al., 2019).

The concept of nursing human resources has both broad and narrow conceptions. In the broad concept, it can refer to the sum of the number of people who have the ability to work in nursing, including active employees, those studying in schools and universities, and potential nursing staff. In a narrow sense, the concept refers to certified nurses who provide nursing services to patients in healthcare facilities (H. S. Cao, 2009). Nursing human resources refers to the nursing staff at all levels who are engaged in nursing work, and have certain knowledge, skills, and service quality –that is, nursing staff with secondary school education in nursing and above, who have passed the national nurse practice examination and obtained the nurse practice qualification certificate, and who provide nursing services directly to patients in medical institutions (Feng et al., 2013).

Population resources encompass the entire population of a country or region, forming the essential foundation from which all human resources institutions and human capital arise (D. Liu, 2023). The measurement of this concept is predominantly reliant on population statistics. Talent resources refer to individuals who possess advanced scientific knowledge and superior labour skills, and significantly contribute to the creation of value. Talent resources are a subset of human resources, consisting of exceptionally skilled and able individuals (Dessler, 2020). This study seeks to clarify concepts and connections between nursing staff, nursing human resources, and nursing talent resources by comparing them to those of population resources, human resources, and talent resources. According to Dessler (2020), the term 'nursing staff' refers to all individuals employed in the nursing profession. Nursing human resources pertain to the nursing workforce in a specific country or region, comprising individuals with specialised

knowledge and professional abilities who play a crucial role in value-creation process. Nursing talent resources are the elite subset of nursing human resources, characterised by their exceptional quality.

Accordingly, it is imperative to establish precise inclusion criteria for nursing human resources when conducting research and literature reviews. This will enhance the precision of calculations and allow for a significant comparison of outcomes.

Nursing human resource management adopts an economic perspective, focused on a "patient-centered" nursing service objective, to guide and implement activities that align resources with nursing roles. Its core functions include attracting, retaining, motivating, and developing nursing personnel through the identification, selection, hiring, training, and retention of nursing resources (X. Wu & Wang, 2021).

Nursing human resource management encompasses scientific structuring of nursing roles, classification-based hierarchical management, nurse staffing and allocation, personnel deployment, on-the-job training, advancement in professional titles, performance and compensation distribution, as well as effective utilization and potential development of nursing resources. The primary goals of nursing human resource management are: first, to ensure adequate nurse staffing, and second, to maximize the efficiency of the current workforce.

2.3 Key aspects of nursing human resource management

2.3.1 Characteristics of nursing human resources

As the largest and one of the most essential human resource groups in hospitals, nursing human resources exhibit the following characteristics:

(1) Subjective Initiative: Nurses demonstrate subjective initiative through their commitment to the nursing profession, positive attitude toward delivering healthcare services, and their personal control over the way they apply their skills and competencies.

(2) Variability: The capabilities of nursing staff are not fixed; hospitals and nursing departments can develop nurses' potential through post-graduate education and professional development programs.

(3) Synergy: Collaboration among nurses of varying ranks, experience, and educational backgrounds can produce outcomes greater than the sum of individual contributions (i.e., a 1+1>2 effect). Effective staffing and team composition are crucial aspects of human resource management.

(4) Exhaustibility: Idle human resources incur costs, necessitating basic support like wages and social benefits, including insurance and pension contributions.

(5) Mobility: Nursing personnel may transfer across departments, organizations, and regions.

2.3.2 Allocation management of nursing human resources

The allocation of nursing human resources refers to the strategic and efficient arrangement of different types of skilled staff in positions that align with the needs of nursing development. This is achieved through the use of various human resource management tools, with the aim of ensuring a proper fit between individuals and their roles, as well as integrating nursing human resources with other resources. Ultimately, this process forms an essential component of economic activity (X. Yang & Wu, 2008).

Nursing experts in various countries are constantly exploring ways to rationalise the allocation of nursing human resources, including professional judgement, volume-based methods (e.g., patient-to-nurse ratios), patient prototype/classification, and timed-task approaches (Aiken et al., 2014; Nelson III, 2017). The definition employed in this study, predicated on demand, focuses on three aspects: the patient dependency classification method, disease severity classification method, and nursing in- tensity measurement method (Adomat & Hewison, 2004). The allocation of nursing human resources in the US accurately reflects the use of nursing services by residents based on nursing demand. It prioritises the effective use of resources and follows the principle of demand-based staffing. This approach entails the objective measurement of nursing workload, the application of formulaic calculations, and the rational allocation of nursing human resources (Y. Y. Yang et al., 2023).

In China, the primary methods used to allocate nursing human resources are the bed-to-nurse ratio method, which is defined as the ratio of beds to full-time equivalent registered nurses in a unit to the total number of beds (Jiao et al., 2023), and the nursing workload measurement method. The latter uses various approaches, with the most frequently employed being the measuring of work hours. This involves the quantification of the duration allocated to various procedures and actions necessary for the successful completion of a given task. It functions as the primary approach for calculating the necessary labour, considering the overall duration of each operational step as the time expended by the work item being assessed (Han et al., 2018). The adoption of quantitative and scientific management of the allocation of nursing human resources has become a developmental trend in modern nursing (R. Li et al., 2016). The

application of computer technology for the allocation of nursing human resources is currently a feasible allocation method to maximise the effectiveness of limited human resources (P. F. Wang et al., 2015). This research trend involves developing a simple, standardised, and systematic allocation method that can reasonably allocate nursing manpower to different nursing units within and between hospitals. Therefore, it is of great practical importance to establish a patient classification system that is suitable for national conditions and to conduct scientific staff allocation according to standard nursing workload (Ma & Han, 2013).

Chinese Nursing Development Planning (2016-2020) clearly states that nursing teams should be effectively stabilised and developed, and nursing manpower should be allocated scientifically and reasonably to meet clinical work demands according to functional positioning, service radius, bed size, and clinical workload (Guo et al., 2015). Implementing evidence-based methodologies to allocate nursing personnel in a manner that a sufficient, exceptional quality and a reasonable structure is essential for enhancing the efficiency of these resources. However, this poses a substantial challenge for nursing managers (Katowa-Mukwato et al., 2021).

Nurse law is the legal guarantee of the allocation of the nursing human resources. In 1919, the UK became the first country to enforce The Nurses Registration Act (Bradshaw, 2000). In 1968, the ICN established an expert committee to develop a landmark document in the history of nursing legislation, the Apropos Guide for Formulating Nursing Legislation, which provides authoritative guidance on the content of nursing laws that must be designed in each country (Luo & Ma, 2021). On the 31st January, 2008, the Chinese Ministry of Health promulgated the Nurses Regulation, which stipulates that the number of nurses in medical institutions should not be lower than the conditions for nurses stipulated by the health department of the State Council, thus legally guaranteeing the allocation of nursing human resources (Zhang & Song et al., 2021).

At present, major adverse patient outcomes (e.g., morbidity and mortality) are mostly used as evaluation indicators to determine whether the allocation of nursing staffing is reasonable (Coster et al., 2018). In 2014, The Lancet published a study on nurse human resources in 300 hospitals in 9 European countries. The study found that, based on the patient-to-nurse ration, each additional patient cared for by nurses was likely to increase patient mortality by 7%; meanwhile, every 10% increase in nurses with bachelor's degrees was likely to decrease patient mortality by 7%; hospitals where 60% of nurses hold a bachelor's degree and care for an average of 6 patients have a nearly 1/3 lower risk of postoperative mortality compared to hospitals where 30% of nurses hold a bachelor's degree and care for an average of 8 patients (Aiken et al., 2014). Large, multi-centre studies of the association between nurse staffing and

patient outcomes have also been conducted in the US and Australia (Duffield et al., 2011). Their results have given a strong impetus to the legislative process of nurse staffing and nurse education. However, such studies are lacking in China, meaning that research should be conducted nationwide under the leadership of authoritative organisations to enhance the collection, analysis, and use of nursing human resource data, raise the awareness of health administrations, medical institutions, and the public about the importance of nurse staffing and structural allocation, increase investment in nurse staffing and nursing education, and promote relevant policy development (Zhang, 2021).

2.3.3 Hierarchical management of nursing human resources

According to the Report on the State of Nursing in the World in 2020, the global nursing workforce is approximately 27.9 million, of which 19.3 million are professional nurses, 6 million are certified professional nursing assistants, and 2.6 million are non-professional nurses (WHO, 2020). As such, these three personnel levels all belong to the category of nursing human resources. However, most studies on nursing human resources generally refer to registered nurses (RN) among nursing staff and the levels differ across countries.

The US: There are five levels of nurses in the US, mainly based on their education and work experience, from low to high: certified nursing assistant (CNA), licensed practical nurse (LPN), registered nurse (RN), nurse practitioner (NP), and nurse manager (NM). All nurses above the LPN level must pass the nursing licensure examination. Within the scope of their legal authority, those who do not pass cannot perform nursing evaluations and analyses, nor are they authorised to administer intravenous treatments to patients. CNAs are considered general labourers and are not required to pass a license examination, only a simple nursing skills exam and a certificate to work. Under the legal definition, they cannot perform injections, medication administration, or aseptic techniques. There is also a clinical category of people who work as CNAs but are not given the title of CNA, which is commonly referred to by hospitals as unlicensed assistant personnel (UAP) (Brunt & Morris, 2023).

The UK: There are eight grades of nurses in the UK from A to H (Fu, 2015), from low to high: A and B grade healthcare nurses, C grade registered nurses, D grade newly- qualified nurses, E grade experienced nurses (midwives generally start at this grade), F grade advanced nurses, G grade supervisor nurses (health advisors generally start at this grade), and H grade nurse practitioners and charge nurses. A and B grade nurses, without being trained in nursing school, are hired directly from non-professionals to the hospital with a short period of clinical

training. C grade registered nurses become D grade nurses when they achieve the required continuing education credits in two years. E and F grade nurses are engaged in supervision and guidance; H grade nurses are engaged in nursing management, the training of nurse practitioners and charge nurses, domestic and foreign consultations, and outpatient work of nursing specialists.

Australia: There are five levels of nurses in Australia (Dai & Zhang, 2013; Zhao et al., 2012), from low to high: assistant in nursing (AIN), enrolled nurse (EN), elementary registered nurse (EEN), registered nurse (RN), and nurse practitioner (NP), with clear educational requirements and scope of duties for each level. The career structure of registered nurses is further divided into Levels 1–6, and there are clear requirements for the professional roles that each can undertake. For instance, nurses at Level 3 or above can become clinical lead nurses and charge nurses, while those at Level 4 or above can become nurse practitioners, and nurses at Level 5 or above can become nurse directors and others. Singapore: There are three levels of nurses in Singapore, from low to high: health care nurse (HCA), enrolled nurse (EN) and registered nurse (RN). The division of labour is clear, with each having its own role and hierarchal rigid. Registered nurses, from the top down, includes the charge nurse, senior nurse, junior nurse, and nurse in training (Chua et al., 2019). Japan: Japan has three levels of nurses, from low to high: regular nurse, associate nurse, and care nurse. A regular nurse is a registered nurse, an associate nurse is a certified nursing assistant, and a care nurse is a healthcare nurse (Kanbara et al., 2017). Taiwan: In Taiwan, nurses are divided into four ranks: N1, N2, N3, and N4, and their titles include five ranks: deputy charge nurse, charge nurse, supervisor (department charge nurse), deputy director, and director. There is a strict promotion system for nurses, and each person must have a healthcare nurse or nurse practitioner license (healthcare nurse are specialist graduates who have studied for five years after graduating from junior high school; nurses are vocational school graduates who have studied for three years after graduating from junior high school), pass the training and specialist training, and achieve a grade of A or higher in the annual end-of-year examination before they are eligible to apply for promotion. N1 to N4 can be promoted by one grade after passing the examination for at least one year, and N3 and N4 can be promoted by passing the deputy charge nurse examination; deputy charge nurses can be promoted to charge nurse after two years; charge nurses can be promoted to nursing supervisor after three years upon passing the examination; and nursing supervisors can be promoted to nursing department (deputy) director after five years upon passing the examination. The promotion of nurses in Taiwan is institutionalised, with a focus on the accumulation of practical experience and facilitating the motivation to work on the front line

(C. C. Huang, 2024).

Hong Kong: Hong Kong. Nurses in Hong Kong are classified into five grades (Shi, 2015; G. Wang, 2003), from low to high: registered nurse, enrolled nurse, health attendant, trainee nurse and clerk. Registered nurses have a college or bachelor's degree and are awarded a certificate to practice if they pass the Hong Kong Unified Examination for Registered Nurses; registered nurses are trained in hospital-run nursing schools, equivalent to secondary school education, and are not awarded a nurse certificate to practice; and health attendants, trainee nurses, and clerks are required to complete a short training period. The administration of nursing posts follows a particular order: general manager of nursing, departmental operations manager, ward manager, charge nurse, registered nurse, enrolled nurse, health services assistant, and ward clerk.

China: In mainland China, Measures of the People's Republic of China for the Administration of Nurses promulgated a system of examination, registration and licensing of nurses for practice, and a division between trainee and registered nurses. The professional and technical titles of nursing staff are evaluated at three levels, from low to high, namely junior (nurse, nurse practitioner), intermediate (nurse practitioner in charge), and senior (deputy chief nurse practitioner, chief nurse practitioner). The nurse management system is divided into hospital nursing department director, department charge nurse (Level 3), and charge nurse. There is no unified grading system for nursing staff that reflects nurses' titles and positions, technical risks, and nurses' grades (Lu et al., 2021).

In 2013, the Health Commission of Guangdong Province issued the Implementation Plan for Post Management of Hospital Nurses in Guangdong Province (Trial and Guidance on Post Management of Nurses (Midwives) in Medical and Health Institutions in Guangdong Province (GHC, 2015). Guangdong Province established a hierarchical setting and promotion system for clinical nurses. According to the principle of correspondence of ability levels, each clinical nursing position is based on the professional ability and technical level of nurses as the main index, combined with their education, titles, and years of professional work. This enables the establishment of tiered positions, such as specialist nurses, senior charge nurses, charge nurses, and assistant nurses, which are then divided into 7 technical levels of N0 to N6 (J. Liu et al., 2021).

(1) Specialist nurses (specialist midwives, levels N5–6): Specialist, N6 nurses should hold a bachelor's or master's degree or above in nursing from national higher medical schools, receive standardised education of domestic and foreign specialist nursing diploma courses certified by the provincial specialist nursing development committee, have advanced nursing

practice ability, be competent for the duties of specialist nurse positions, and be certified as specialist nurses by the provincial specialist nursing development committee. N5 specialist nurses should hold a bachelor's degree or above in nursing, obtain the title of associate chief nurse or above and be appointed by the hospital, be engaged in clinical nursing for 20 years or more, be in this specialty field for 10 years or more, be trained in the core competencies of a specialist nurse, have rich clinical practice experience and advanced nursing practice ability, be competent to undertake the duties of a specialist nurse, independently undertake the specialist nursing clinic, and be certified as a specialist nurse by the hospital specialist nursing development committee.

(2) Senior responsible nurses (senior midwives, N3–4): Senior responsible N4 nurses should hold a bachelor's degree or above in nursing and the title of nurse practitioner in charge, complete the N4 level clinical nursing job training and pass the assessment, serve in the N3 level senior responsible nurse position for 2 years or more, be capable of performing the duties of the senior responsible nurse as either a nurse or midwife. In principle, senior responsible N3 nurses are nurses or midwives with a university degree or above in nursing, hold the title of super- vising nurse, or have 10 or more years' experience in clinical nursing. Moreover, they must have completed the N3 clinical nursing job training and passed the examination, served in the charge nurse position for 5 years or more, and been capable of performing the duties of the senior charge nurse position.

(3) (Primary) Responsible nurses (midwives, N1–2): Responsible N2 nurses should be nurses or midwives with an undergraduate degree or above in nursing, have obtained the professional and technical title of nurse and above, have been engaged in clinical nursing for 3 years or more, completed N2 level clinical nursing post training and passed the examination, and capable of performing the duties of the charge nurse. Responsible N1 nurses are nurses or midwives with a junior college degree or above in nursing, obtained the title of nurse, completed the N1 level clinical nursing post training and passed the examination after 3 years of the post-graduation clinical specialty rotation period, and can assume the post of responsible nurse.

(4) Certified nursing assistants (N0 level): Nursing assistants are nursing staff who have graduated in nursing, have not yet obtained a nurse practice certificate (or have done so but remain in the probationary period), and have passed the corresponding pre-service and post-training examination in the hospital.

There is no unified grading system for nursing staff that can reflect the title and position of nurses, technical risk, and nurse grade.

2.3.4 Vertical management of nursing human resources

Vertical nursing management refers to a centralized model in which the hospital's nursing department is directly responsible for overseeing the entire nursing management system. Typically, this model consists of a hierarchical structure involving the nursing department, head nurses of departments, and ward nurses, allowing direct line management of all nursing personnel within the hospital (Bu et al., 2023). It replaces the traditional cross-management model, which involved both department heads and the nursing department, unifying management of personnel, finances, and responsibilities (W. J. Zhou et al., 2016).

In nursing human resources vertical management, the nursing department centrally organizes human resource management based on a specific organizational structure (e.g., "Deputy Director of Nursing - Head of Nursing Department - Departmental Head Nurse - Ward Nurse - Staff Nurse"). This model has several key characteristics:

(1) Vertical Authority Distribution: Management authority is directly assigned by the higher-level administration, such as the appointment rights for head nurses, which are managed by the nursing department and reported to the HR department for appointment, reassignment, or dismissal.

(2) Unified Management and Allocation: The nursing department centrally plans and implements recruitment, hiring, allocation, and training activities to ensure rational and efficient use of nursing resources.

(3) Performance and Incentive Integration: A vertical performance distribution system aligns nursing staff performance with workload, role, and evaluation results. Performance evaluations are linked to compensation, promotion, and provide effective incentives to encourage nursing staff's productivity.

(4) Training and Development: The nursing department organizes professional training and skill development activities to ensure staff have the necessary nursing knowledge and skills. Programs such as rotational training and targeted development plans improve the team's overall quality and expertise

(5) Quality Control and Safety Management: A three-level quality and safety control system ensure nursing work quality and safety. Regular quality checks and assessments of nursing practices allow for prompt identification of issues and implementation of corrective actions.

Following the implementation of a vertical management model in a Grade III Class A hospital in Yunnan Province, the proportion of nurses with a bachelor's degree increased from 19.57% to 73.63%, with 75% of these nurses upgrading their education through adult education

motivated by vertical performance distribution and position management policies. The hospital also saw a rise in dynamic nursing resource allocation from 50 to 353 adjustments per year, saving up to 12 nursing positions annually. Nurse practice environment scores improved significantly, surpassing both provincial and national averages (H. Y. Li, 2023).

The vertical management model has had a substantial impact on nursing human resource allocation, promoting more efficient and scientific management practices. It enables better coordination across nursing units, allowing the nursing department to make informed staffing decisions based on real-time data. This flexibility reduces approval layers, speeding up resource allocation. Vertical management in nursing human resources provides a structured approach that improves efficiency, fairness, and responsiveness. By centralizing management processes and optimizing resource allocation, it enhances job satisfaction, lowers turnover, and supports professional growth among nursing staff. Future research should focus on evaluating the long-term impacts of vertical management in various healthcare settings and exploring further optimizations to enhance its effectiveness in improving nursing quality and patient outcomes (Bu et al., 2023).

2.3.5 Performance management of nursing human resources

Performance management of nursing human resources is a crucial component of hospital management. Effective nursing performance management can activate nurses' subjective initiative, enhance work efficiency, and improve the overall level of nursing human resource management.

Western scholars began studying nursing performance management early on, establishing a comprehensive set of standards for managing nursing performance. In 2006, the American Nurses Association implemented quantitative assessments across all nursing staff to enhance fairness and transparency in performance evaluation. Similarly, the Australian Nursing and Midwifery Board has continuously refined performance assessment indicators, providing guidance for safe nursing practices among Australian nurses and midwives. These standards have evolved into a competency analysis framework within Australia, focusing on dimensions such as professional practice, critical thinking and analysis, collaborative and therapeutic relationships, and nursing coordination. Each dimension includes multiple assessment items. Nurses first conduct self-assessments, followed by evaluations from managers.

Nikpeyma et al. (2014) proposed that performance management for nursing staff should be designed from a comprehensive perspective, assessing factors such as patient safety, teamwork,

patient satisfaction, nursing efficiency, and physician satisfaction. They also argued that performance evaluation should integrate evaluation results with a bonus distribution system, emphasizing feedback and maintaining transparency and openness of information. Supported by this holistic and efficient performance management model, nurses' attitudes toward work have shown significant improvement.

Allcock (2018) emphasized that performance evaluation indicators must align with the organization's specific circumstances to be effectively implemented. He pointed out that the stability of a talent team is closely related to a fair promotion mechanism and a reasonable salary and benefits system. Featheret al. (2015) suggested that in evaluating nursing staff, the impact of nurses' work outcomes on their respective departments is a key element.

Rachana (2019) analyzed Germany's performance-based pay system in healthcare institutions, observing that, following the introduction of performance-based pay, both doctors and nursing staff tended to prefer working with critically ill patients to achieve higher scores and subsequently receive higher performance pay. This incentive mechanism in Germany, as shown through statistical analysis by Najjar et al. (2020), significantly improved nursing quality. Hilko et al. (2023) argued that human resources are a primary objective of performance-based pay and are crucial in achieving the goals of performance incentive mechanisms. In most organizations in Europe and North America, performance-based pay typically targets three categories: employee value, human resources, and business outcomes. The absence of any performance objective could result in the organization failing to meet its predetermined goals.

Chinese scholars have started studying nursing performance management issues relatively recently. Some scholars have analyzed the current problems in nursing performance assessment in China, using real hospital conditions as a basis, aiming to help hospitals continuously improve nursing quality.

Q. He et al. (2020) argues that nursing performance management faces a range of issues, including a lack of diversity in assessment methods. The performance management process should adhere to principles of fairness and impartiality, focusing on enhancing nursing quality and patient satisfaction. Indicator settings should aim to improve nursing quality, meaning that a single nursing performance management system cannot be uniformly applied across all hospitals. Each hospital must develop a nursing performance management model that aligns with its unique strategies to genuinely achieve the goal of improving nursing service quality.

L. Chen (2021) emphasizes that nursing work varies significantly across different hospitals, especially in the composition of nursing staff. Hospital managers should adopt performance management methods suited to their specific circumstances to elevate nursing staff competency,

ultimately advancing institutional reform and improving management efficiency.

Su et al. (2023) conducted a survey on nursing performance management in 37 public hospitals, noting that domestic exploration of nursing performance management and reform in public hospitals remains in its early stages. Current practices primarily adopt generic human resource management methods without considering the specificities of medical work, resulting in a lack of unified, systematic, and mature nursing performance management systems. The main issues identified include:

(1) Unequal Pay for Equal Work: Nurses performing similar roles experience performance-based pay disparities due to differences in employment status, which impacts team harmony, raises turnover rates, and ultimately affects care quality.

(2) Unfair Performance Allocation: In secondary department-level distribution, seniority-based and equal distribution practices prevail, without fully incorporating workload, quality, risk, and difficulty as guiding factors, which negatively impacts team stability and motivation.

(3) Limited Coverage of Vertical Nursing Management: Recommendations include improving nursing position management systems, establishing a unified vertical management framework for nursing performance allocation, and creating a performance assessment system that highlights the value of nursing contributions.

In terms of the effectiveness of nursing performance management, Chinese scholars have conducted studies on nursing quality, nursing competence, and related aspects.

X. F. Peng (2020) suggested that organized nursing performance management helps nursing staff continuously improve their technical and theoretical skills, contributing to team stability and cohesion, and increasing job satisfaction among nurses.

G. Q. Song (2014) noted that implementing nursing performance management allows for evaluation and supervision of nursing staff in terms of work quality, job stress, and performance. This management approach effectively enhances nurses' initiative, improves service awareness, and consistently boosts work efficiency, ultimately leading to higher job satisfaction.

J. Liu et al. (2021) specifically proposed performance pay structures based on the “dual relationship” theory and dual-motivation theory. They offered recommendations on addressing detailed issues within nursing performance incentives, such as determining and managing performance disparities among nurses, setting pay for head nurses and nursing supervisors, handling performance differences between medical and nursing staff, conducting secondary allocation within departments, ensuring fairness, and implementing cost accounting.

Zhong et al. (2018), using the performance system at Sun Yat-sen University Cancer Prevention and Treatment Center as an example, proposed a shift from a full-cost accounting

performance allocation model toward a position-based performance management model that rewards effort proportionally. The center introduced innovative performance management schemes such as the KH model, personnel rate system, and unit price performance system. These initiatives, tailored to the center's unique needs, present a valuable reference for both public and private hospitals aiming to reform their performance management systems.

Reforming the nurse performance compensation system is a critical part of broader hospital compensation reform and is essential for the development of the nursing workforce and the nursing discipline. According to the National Nursing Development Plan (2021–2025), healthcare institutions are required to establish and improve nursing position management systems, taking into account both in-post and contract nurses and shifting from identity-based to position-based management. The plan emphasizes the establishment of an effective incentive mechanism for nursing staff, implementing a scientifically grounded system for nurse evaluation, appointment, and performance assessment. Performance evaluation results are linked to nurse appointment, performance-based pay distribution, awards, and recognition, with a preference for frontline and primary care nurses. This model rewards nurses based on workload and performance, effectively motivating them and ensuring that those who perform well are compensated accordingly.

2.4 Efficiency of nursing human resources

2.4.1 Concept of nursing human resource efficiency

Human resources efficiency is the extent to which these resources are effectively used. From the perspective of an enterprise, it is the extent to which these available resources contribute effectively to performance. The analysis is used to understand whether the enterprise's human resources are being fully capitalised upon and whether each employee is performing to their own potential, so that decision makers can take timely and effective measures to improve the efficiency of the enterprise's human resources use (F. Weng et al., 2019).

A wide range of studies have presented contrasting concepts regarding the effective- ness of nursing personnel. For example, El-Gazar and Zoromba (2021) defined the efficiency of nursing human resources as the application of human resources management practices to improve management efficiency and organisational effectiveness. Y. H. Wu et al. (2017) defined it as the number of nursing activities produced by a nursing unit after investing a certain amount of nursing human resources, which can reflect the unit's use of resources. According to F. Weng

et al. (2019), it is the main indicator of nursing work efficiency and resource use.

2.4.2 Indicator system for evaluating nursing human resource efficiency

The input-output theoretical model is one of the basic theories of health economics, and the indicators of the efficiency of nursing human resources at home and abroad are constructed based on this model (Worthington, 2004). The evaluation indicators are divided into two types: input and output indicators. The former specifically examine the allocation of resources for nursing management, encompassing such variables as staffing levels, materials, training and development, workload, and financial inputs (Babalola & Moodley, 2020; Mirmozaffari & Kamal, 2023; Okoroafor et al., 2022). Output indicators evaluate the consequences or achievements of nursing services, which include patient care quality, patient safety, healthcare use, staff satisfaction, and rates of burnout or turnover (Dubois et al., 2017; Endeshaw, 2021; Stemmer et al., 2022).

Based on the purpose of the study, the input and output indicators can differ. For instance, Dubois et al. (2017) conducted an in-depth review of performance indicators for nursing care, classifying them into three separate categories. These groups consist of 5 indicators pertaining to the acquisition, deployment, and maintenance of human and material resources; 9 indicators centred on the conversion of these resources into services; and 11 indicators devoted to assessing the capacity to bring about changes in patient conditions.

Y. Weng et al. (2019) used interviews and a literature review to initially establish an indicator system and conducted 2 rounds of expert correspondence with 30 experts through the Delphi method to construct an indicator system of the efficiency of nursing human resources with 8 primary indicators, 18 secondary indicators, and 50 tertiary indicators. The input level indicators included human, material, financial, and service inputs, while the output indicators included nursing service, nursing safety, nursing quality, and teaching and research outputs. This indicator system showed good reliability and scientificity, thus providing researchers with a basis from which to evaluate the efficiency of nursing human resources in a scientific and reasonable manner.

2.4.2.1 Evaluation of nursing human resources efficiency: Input indicators

(1) Nursing human resource input

This can be divided into two dimensions: quantity and structure.

Quantity of Nursing Staff: In Europe and the United States, nursing human resource inputs include Registered Nurses (RNs), Licensed Practical Nurses (LPNs), Nursing Aides (AIDES),

Certified Nursing Assistants (CNAs), and auxiliary non-nursing professional staff (ANCPRO). However, in China, nursing human resources predominantly consist of registered nurses. However, Qin et al. (2020) argue that the quantity of nursing human resources should include all nursing personnel, such as nursing aides, interns, and advanced nursing students.

Structure of Nursing Resources: Determined by professional titles, levels, and educational backgrounds rather than specific job functions, making this system different from those in Europe and the U.S. (Su et al., 2023).

(2) Nursing service input

Nurse workload is another critical input, typically evaluated based on nursing hours. Two primary methods are used to calculate these hours: Nursing Hours Per Patient Day (NHPPD) and Full-Time Equivalent (FTE) staffing numbers. NHPPD traditionally measures nursing output, whereas FTE provides a more straightforward metric for nursing efficiency (Griffiths et al., 2020). In China, the NHPPD method is commonly used to calculate nursing hours (Y. Y. Yang et al., 2023).

(3) Nursing material input

Key indicators reflecting material input in nursing units include consumables, equipment, and fixed assets. North et al. (2013) used bed count as a proxy for institutional scale and capital investment due to the complexities and variability in cost calculation across facilities. L. W. Zhang et al. (2019) view fixed assets as part of institutional material input. According to F. Weng et al. (2019), hospital beds are a critical resource determining hospital scale and serve as an essential indicator of hospital efficiency.

(4) Nursing financial input

Ongoing education and training for nursing staff are vital for maintaining high standards of patient care and ensuring nurse satisfaction. These training programs require highly skilled staff and financial resources, covering activities such as on-site training, certification courses, advanced degrees, and professional skills workshops (Suprapto et al., 2023). Financial inputs for nursing include human resource costs, training expenses, and research investment funds. Human resource costs are generally calculated based on the average annual pre-tax income per nurse (F. Weng et al., 2019).

2.4.2.2 Evaluation of nursing human resources efficiency: Output indicators

(1) Nursing service output

The number of discharged patients represents an output indicator based on productivity. In both Europe and the US, the number of discharged patients after adjustment by the case mix

index (CMI) is regarded as the main nursing human resources efficiency output indicator (Milstein & Schreyoegg, 2020). The CMI is here defined as a metric employed in the healthcare sector to evaluate the comprehensive intricacy and gravity of patient cases managed by a hospital or healthcare institution during a designated timeframe. Taiwan uses the hospitalisation classification system to determine the severity of patients' conditions, further divides patients into four levels, and uses the number of patients of different levels as the service output. China generally takes the number of patients admitted per year as an indicator of service output. F. Weng et al. (2019) used the number of discharged patients, bed occupancy rate, average length of stay in hospital, and the number of critically-ill patients as indicators of nursing service output.

(2) Nursing quality and safety output

Adverse nursing events is an important indicator for measuring nursing quality and safety. In Europe and the US, such adverse events as pain management, pressure ulcers, physical restraints, falls, and urinary tract infections are used as indicators of nursing quality and safety output, in which falls has the greatest impact on the efficiency value and thus is most widely used in efficiency evaluation (Labrague et al., 2020). The Joint Commission of United States Medical Institutions regards the incidence of falls as one of the important indicators for evaluating the safety of patients in medical institutions. It is a sensitive indicator of nursing care and has a significant impact on efficiency value (Dubois et al., 2017).

F. Weng et al. (2019) divided nursing quality and safety output into two Level-I indica- tors of nursing safety output and nursing quality output. Nursing safety output includes two Level-II indicators: the number of adverse nursing events and nurses' occupational exposure rate. The incidence of adverse nursing events involves several Level-III indicators, such as the incidences of falls or falls from a bed, inevitable pressure ulcers in the hospital, unplanned extubation, blocked intubation patients, drug extravasation, catheter-related bloodstream or urinary tract infections, and ventilator-related pneumonia, as well as the number of specimen errors, blood transfusion errors, medication errors, ID identification errors, and medical advice execution errors. Nursing quality output consists of four Level-II indicators: the assessment passing rate of nursing staff, the passing rate of nursing quality inspection, the success rate of rescue, and the satisfaction level. Satisfaction is divided into five Level-III indicators: patient satisfaction, nurse satisfaction, physician satisfaction, patient complaint rate, and nurse turnover rate.

(3) Nursing education and research output

F. Weng et al. (2019) divided nursing teaching and scientific research output into two Level-II indicators: nursing scientific research output and nursing talent training. Nursing scientific

research output includes three Level-III indicators: the number of innovative inventions and utility patents, the number of papers published per capita per year, and the number of new technologies applied and new businesses developed. Nursing talent training constitutes the number of specialist nurses at or above the provincial level, the number of people attending standardised training, and the number of graduates with higher education level.

2.4.3 Evaluation methods of the efficiency of nursing human resources

Various methodologies are currently employed to assess the efficiency of healthcare organizations, each offering distinct advantages depending on the context and specific objectives. Commonly utilized approaches include Data Envelopment Analysis (DEA), Stochastic Frontier Analysis (SFA), Rank-Sum Ratio (RSR), Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), and Comprehensive Evaluation Index ((Ahmed et al., 2019). Among these, Data Envelopment Analysis (DEA) is widely regarded as one of the most robust tools for assessing the operational efficiency of healthcare organizations (Ahmed et al., 2019).

2.4.3.1 Data envelopment analysis (DEA)

Data Envelopment Analysis (DEA) is a widely used non-parametric technique for assessing the relative efficiency of decision-making units (DMUs) within complex systems (Ahmed et al., 2019). DEA leverages mathematical models to evaluate the efficiency of production frontiers in economic and organizational contexts, making it particularly useful for assessing multi-input, multi-output systems where various resources and outcomes must be considered simultaneously.

The basic approach of DEA involves fixing either the input or output of a DMU and using mathematical programming to determine a relatively efficient production frontier. By projecting each DMU onto this DEA frontier, the relative efficiency of each DMU is assessed based on its deviation from the frontier. DEA constructs an efficiency frontier using optimal input-output combinations, with efficient points lying on the frontier and receiving an efficiency score of 1, while inefficient points lie outside the frontier and are assigned a relative efficiency score between 0 and 1.

As a linear programming-based non-parametric analysis method, DEA is particularly suitable for evaluating the relative efficiency of similar DMUs with multiple inputs and outputs. It intersects the fields of operations research, management science, and mathematical economics (Emrouznejad & Yang, 2018). In recent years, DEA has been widely applied to efficiency assessments in various fields such as financial investment, industrial manufacturing,

and healthcare services, revealing productivity changes primarily through efficiency shifts and technological changes (Y. Y. Zhao & Li, 2019).

DEA is regarded as one of the best methods for evaluating healthcare facility efficiency (Ahmed et al., 2019), largely due to its capability to handle multiple input and output variables effectively, offering a flexible and comprehensive assessment. This method allows for comparison of inputs and outputs without requiring predefined associations, which provides adaptability to the unique characteristics of healthcare services (Su et al., 2023). DEA uses efficient entities as benchmarks, setting clear targets that drive improvement. The evaluation process relies on the efficiency frontier derived from the dataset itself rather than external benchmarks (Zhu & He, 2023). By identifying inefficiencies and suggesting feasible resource allocation and process improvement strategies, DEA offers valuable insights to healthcare administrators and policymakers (Gavurova et al., 2021).

Key advantages of DEA include its non-reliance on predetermined weights for input and output indicators, the ability to directly calculate with the units of each indicator without requiring conversions, and the capacity to identify inefficiency sources and propose improvement measures for relatively inefficient decision-making units (H. H. Zhang et al., 2018). As an effective tool for evaluating resource allocation efficiency, DEA is especially advantageous in handling multi-input, multi-output metrics, making it widely applied in healthcare to assess the relative efficiency of decision-making units (DMUs) such as hospitals. DEA is a non-parametric approach that compares the ratio of inputs (e.g., human resources, costs) to outputs (e.g., services provided, economic benefits) to give relative efficiency scores, unaffected by variable units of measurement, which makes it ideal for evaluating healthcare facility performance (Jia & Feng, 2022).

2.4.3.2 DEA-CCR Model

The CCR model (Charnes-Cooper-Rhodes model) is the classic efficiency measurement model within DEA. Assuming constant returns to scale (CRS) for decision-making units (DMUs), the CCR model measures overall efficiency with a focus on maximizing outputs. The result, referred to as technical efficiency, provides an evaluation of total efficiency.

Key assumptions of the CCR model include:

(1) Homogeneous Data: The input and output data for all DMUs must be of the same type.

(2) Sample Size: The number of DMUs should be greater than the total number of input and output indicators.

(3) Dimensionless Data: Input and output indicators must be dimensionless, requiring

standardization.

(4) Input and Output Optimization: Inputs should ideally be minimized, and outputs maximized.

Applications of the CCR model and specific use cases are:

(1) Environmental Performance Management in Industrial Parks: The CCR model can evaluate the environmental performance of companies within industrial parks, helping to identify areas for improvement and enhance environmental performance management.

(2) Efficiency Evaluation of Technological Innovation in the Energy Industry: In the energy sector, the CCR model can assess the efficiency of technological innovations, identifying inefficient segments and suggesting improvement measures.

Limitations of the CCR model include when returns to scale are variable, the CCR model cannot accurately assess pure technical efficiency and scale efficiency, necessitating the use of the BCC model instead. The choice of input and output indicators significantly affects model outcomes, so selecting appropriate indicators is essential.

In summary, the CCR model holds substantial value in efficiency and performance evaluation; however, attention should be paid to its applicability and limitations.

2.4.3.3 DEA-BCC Model

In practice, decision-making units (DMUs) face unequal competition that inhibits them from achieving optimal operational scale. To address this issue, Banker, Charnes, and Cooper introduced an extension to the original DEA model in 1984, which was initially based on the assumption of constant returns to scale (CRS). Their modification, the BCC model (Banker-Charnes-Cooper model) (Jia & Feng, 2022), accounts for variable returns to scale (VRS), recognizing that a DMU's efficiency can be influenced by its scale of operation. This extension allows the DEA model to more accurately assess efficiency in contexts where DMUs may not be operating at the ideal scale. When a DMU is not operating at the optimal scale, its technical efficiency (TE) is impacted by scale efficiency (SE), which reflects how scale-related adjustments affect overall performance. The BCC model builds on the CCR model by incorporating additional constraints that allow for variable returns to scale across different DMUs. This means that the BCC model can accommodate three distinct types of scale behavior: increasing returns to scale, constant returns to scale, and decreasing returns to scale. In this framework, the production frontier is no longer static but reflects the varying efficiencies that result from different scales of operation.

A notable feature of the BCC model is its ability to decompose technical efficiency into

two key components: pure technical efficiency and scale efficiency. Pure technical efficiency measures how effectively a DMU utilizes its inputs to produce outputs at its given scale, independent of whether it is operating at an optimal size. In contrast, scale efficiency quantifies the degree to which a DMU could improve its performance by adjusting its operational scale to the most efficient level.

The BCC model is widely applied in efficiency evaluations across various fields, including corporate performance assessment, governmental agency efficiency evaluations, and healthcare resource allocation. In healthcare, the BCC model can assess resource utilization efficiency across different regions, providing a basis for resource allocation decisions.

Advantages of the BCC Model include:

(1) High Flexibility: The BCC model allows for variable returns to scale, offering a more accurate reflection of pure technical and scale efficiency for DMUs.

(2) Broad Applicability: Suitable for multi-input, multi-output systems without requiring a specific production function, and the evaluation process is free from subjective influence.

Limitations of the BCC Model include:

(1) High Data Requirements: The model needs a large amount of input-output data, and data quality directly impacts the accuracy of the evaluation.

(2) Limited Interpretability: While the model provides efficiency scores, it does not directly identify specific causes of inefficiency.

The BCC and CCR models represent the two primary frameworks in the DEA methodology. While both aim to evaluate efficiency, they differ in their assumptions about returns to scale and the level of detail they provide. The CCR model, which assumes constant returns to scale (CRS), focuses on assessing the overall technical efficiency (TE) of a DMU. It evaluates how efficiently a DMU transforms inputs into outputs under the assumption that its efficiency does not change with scale. On the other hand, the BCC model introduces the assumption of variable returns to scale (VRS), allowing for a more nuanced approach. In addition to calculating total technical efficiency, the BCC model separates this into two distinct components: pure technical efficiency (PTE) and scale efficiency (SE), where $TE=PTE\times SE$ (X. Q. Li, 2017).

The CCR model assumes constant returns to scale and is primarily used to evaluate overall efficiency. In contrast, the BCC model assumes variable returns to scale, allowing for a more detailed analysis of a decision-making unit's pure technical efficiency and scale efficiency.

2.4.3.4 Malmquist Index Model

The Malmquist Index, also known as the Total Factor Productivity (TFP) Index, was first

introduced in 1982 (Caves et al., 1982). This model decomposes the Total Factor Productivity Change Index (Tfpch) into the Technical Efficiency Change Index (Effch) and the Technological Change Index (Techch). Furthermore, the Technical Efficiency Change Index can be further divided into the Pure Technical Efficiency Change Index (Pech) and the Scale Efficiency Change Index (Sech).

The Malmquist Index measures the dynamic changes in TFP across multiple-input, multiple-output decision-making units (DMUs) over different periods, providing a comprehensive view of resource utilization, dynamic efficiency, technological progress, and management efficiency within a given study interval. This model is particularly suitable for analyzing panel data, making it widely applicable across various fields.

By capturing both efficiency and technology changes, the Malmquist Index offers valuable insights into the dynamic productivity growth and adjustments in resource allocation over time.

2.4.3.5 DEA-SBM Model

The SBM (Slacks-Based Measure) model assumes a monotonic linear relationship between inputs and outputs and uses linear programming to determine the relative efficiency of decision-making units (DMUs). The SBM model includes three types: input-oriented, output-oriented, and non-oriented. These types aim to minimize inputs for a given output, maximize outputs for a fixed input, or evaluate efficiency from both input and output perspectives simultaneously (Tone, 2002).

Characteristics of the SBM Model include:

(1) Non-Radial: Unlike radial models, the SBM model accounts for non-proportional relationships between inputs and outputs, avoiding biases that radial models may introduce.

(2) Consideration of Undesirable Outputs: The SBM model can handle undesirable outputs, such as environmental pollution, making it more practical for real-world economic issues.

(3) Flexibility: The SBM model can be set as input-oriented, output-oriented, or non-oriented, allowing users to choose the appropriate type based on specific needs.

Application Scenarios are:

(1) Industrial Economy Green Development Efficiency Analysis: The SBM model can address both economic benefits and environmental pollution issues, making it well-suited for green development studies.

(2) Regional Economic Performance Evaluation: Used to assess economic development efficiency across different regions, incorporating various input and output variables.

(3) Research Funding Efficiency Assessment: Evaluates the efficiency of research funding

use, considering the impact of different innovation environments on efficiency.

2.4.4 Applications of DEA in healthcare management

DEA was first applied to evaluate the efficiency of healthcare institutions in 1984 (Sherman, 1984), who assessed the economic efficiency of surgical departments across seven clinical teaching hospitals in Massachusetts, USA. The application of DEA in China began in 1986. This section will focus on DEA's applications in three key areas of healthcare management: medical resource allocation, healthcare institution operations management, and nursing human resource management.

2.4.4.1 Applications of DEA in medical resource allocation management

DEA has been widely applied in evaluating the efficiency of medical resource allocation across different regions and institutions. Notable studies include:

North et al. (2013) used DEA to assess the operational efficiency of 390 Italian public hospitals, identifying bed count and discharge rate as key factors affecting efficiency. Valdmanis et al. (2017) evaluated efficiency changes in 43 Scottish hospitals using DEA-Malmquist and time-series analysis, finding a general decline in total factor productivity over four years, primarily due to technological advancements.

Pérez-Romero et al. (2017) applied DEA and the Malmquist index to analyze technical efficiency and total factor productivity across 230 hospitals in Spain's National Health System. Results indicated high overall technical efficiency, though significant regional differences existed. They also used input-oriented DEA to study these hospitals from 2010-2012, finding a correlation between regional wealth and the likelihood of hospitals operating on the efficiency frontier.

Zheng et al. (2021) used an output-oriented DEA-VRS model to evaluate resource allocation efficiency in primary healthcare institutions across China. Findings suggested suboptimal efficiency levels, particularly in western provinces where resources were underutilized or oversupplied.

L. S. He (2023) conducted a static and dynamic analysis of the efficiency of primary healthcare resource allocation in Tianjin from both temporal and spatial dimensions, using the DEA-BCC model and the DEA-Malmquist Index model. The results indicated that from 2016 to 2020, most primary healthcare institutions in Tianjin exhibited low comprehensive technical efficiency, primarily influenced by scale efficiency. Additionally, total factor productivity was generally low, mainly due to limited progress in the technology advancement index.

Deng and Yao (2022) utilized the BCC model of DEA and the Malmquist Index model to measure the efficiency of healthcare resource allocation in the Beijing-Tianjin-Hebei region, the Yangtze River Delta, and the Greater Bay Area. This study provides data support for advancing healthcare development in these three major strategic regions.

B. Zhang et al. (2023) applied Data Envelopment Analysis (DEA) to assess the efficiency of healthcare resource allocation in maternal and child healthcare institutions in Anhui Province from 2010 to 2020. The results showed that, overall, these institutions achieved high resource allocation efficiency. However, a lag in medical technology levels did not align with the increasing scale of hospitals, an issue that hospital administrators should address.

Y. Y. Li et al. (2024) utilized Data Envelopment Analysis (DEA) and the Malmquist Index to evaluate the efficiency of Traditional Chinese Medicine (TCM) hospitals in China from 2012 to 2021. Their findings revealed an overall increase in the total resources allocated to TCM hospitals during this period, though the Total Factor Productivity (TFP) displayed irregular fluctuations. The study indicated that TCM hospitals generally exhibited low efficiency, with only six provinces achieving relatively effective overall efficiency in 2021. Additionally, significant interprovincial differences were observed in resource allocation, highlighting a clear redundancy in TCM hospital resources nationwide. Furthermore, a general decline in technical and organizational management levels in TCM hospitals was noted.

Z. Zhang and Li (2024) applied the BCC model of Data Envelopment Analysis (DEA) to evaluate the operational efficiency of 33 pilot tertiary hospitals in Tianjin participating in the 2023 DRG payment reform. The study found that the average comprehensive efficiency of these pilot hospitals was 0.889, indicating a relatively high level of overall efficiency. Among the hospitals, 15 (45.46% of the sample) achieved effective comprehensive efficiency, while 18 (54.54%) did not reach efficiency. The evaluation results showed significant variation in DRG operational efficiency across the pilot hospitals, with some hospitals not fully utilizing resources. The study suggests enhancing hospital resource allocation management, innovating resource management and development models, and promoting overall efficiency improvements under the DRG payment system.

2.4.4.2 Applications of DEA in healthcare operations management

Kadom et al. (2019) argued that technological advancements in radiology have improved diagnostic quality, reduced patient harm, supported clinical needs, and better served a diverse patient population. However, there remains debate over whether the value of these advancements outweighs the associated costs. Therefore, cost-effectiveness analysis is used to

compare healthcare technologies in radiology to optimize resource allocation.

L. Zhao et al. (2020) used DEA and the Malmquist Index to analyze the operational efficiency of Traditional Chinese Medicine (TCM) departments in secondary and higher-level public general hospitals across China. Their findings revealed significant regional disparities in TCM operational efficiency, indicating a need for increased support and guidance for underperforming provinces. While scale efficiency showed an overall upward trend, improvements in medical service capabilities and refined management practices are necessary to enhance overall operational efficiency.

Yu (2024) used the DEA-BCC model to evaluate indicators such as comprehensive efficiency, pure technical efficiency, scale efficiency, and returns to scale across 34 clinical departments in 2023. The results showed that 18 departments achieved DEA efficiency, 4 were in a weak DEA-efficient state, and 11 were DEA-inefficient. Additionally, 11 departments exhibited increasing returns to scale, while 5 showed decreasing returns to scale. The study suggests adopting a differentiated analysis strategy for medical resource allocation, with a focus on operational capacity analysis and enhancing refined management practices.

R. Zhou et al. (2024) utilized the CCR model of Data Envelopment Analysis (DEA) and the Malmquist Index to assess resource efficiency across 10 surgical departments in a tertiary hospital in Beijing. The results showed that only 2 departments achieved DEA efficiency, 2 departments had low pure technical efficiency, 2 departments were in decreasing returns to scale state, 2 remained constant, and the remaining departments exhibited increasing returns to scale. Except for the COVID-19 pandemic period, total factor productivity showed an overall upward trend. The efficiency levels varied significantly among departments, suggesting that departments not fully utilizing surgical resources should receive targeted guidance, while DEA-efficient departments should be given preferential resource allocation.

K. Liu et al. (2023) applied the DEA-BCC model to analyze input-output indicators of departments at the main and branch campuses of a tertiary hospital in 2021. The results showed an average comprehensive efficiency of 0.76 for departments at the main campus and 0.83 for those at the branch campus. The analysis provided a clear view of areas for improvement in input and output indicators for non-efficient departments. It was suggested that non-DEA-efficient departments optimize resource allocation based on actual conditions to enhance operational efficiency. The study demonstrated the feasibility of using Data Envelopment Analysis to evaluate departmental operational efficiency.

C. C. Huang (2024) used the BCC model of Data Envelopment Analysis (DEA) and the Malmquist Productivity Index to analyze the operational efficiency of clinical departments in a

multi-campus hospital. The results showed that efficiency varied across campuses for the same clinical departments, with lower efficiency generally attributed to suboptimal scale or inadequate organizational management. While branch campuses demonstrated significant technological progress in relevant departments, organizational management and economies of scale were temporarily affected. The study suggests leveraging leading departments to improve the organizational management of "non-efficient" departments, exploring optimal scale development, and aligning resource allocation with the functional positioning and developmental characteristics of each campus to support high-quality hospital development.

2.4.4.3 Application of DEA in nursing human resource management

Harrison and Rouse (2016) applied DEA and multiple regression analysis to evaluate the human resource efficiency of nursing units in 216 teaching hospitals in the United States. Their study found that nursing units with high-quality care also exhibited high overall efficiency. Enhancing nursing efficiency can be achieved through measures such as ensuring adequate staffing levels with appropriate skill mix, investing in specialized training to enhance nursing skills, and optimizing workflow processes to eliminate redundant tasks, all of which contribute to better patient recovery and improved clinical care quality. Additionally, the work style, philosophy, and overall competence of head nurses significantly influence nursing human resource efficiency.

Osman et al. (2011) used the DEA model to assess nursing workforce efficiency in the ICU of a large public hospital in Lebanon. The study demonstrated that DEA could effectively differentiate between high and low-performing nurses. The work behaviors of high-efficiency nurses can serve as internal benchmarks, helping to develop career plans and targeted training for less efficient nurses to improve their performance.

Based on the human resource evaluation framework established by F. Weng et al. (2019), Song et al. (2021) used R-based cluster analysis to streamline the evaluation indicators to seven key factors, facilitating a dynamic analysis of human resource changes. These factors include bed count, nurse-to-bed ratio, nursing staff numbers, number of discharged patients, bed occupancy rate, critical patient count, and adverse event count. They recommend that management focus on building a skilled nursing workforce, fostering innovative nursing talent, and optimizing internal human resource allocation based on departmental specialties to enhance nursing resource efficiency.

L. S. He (2023) developed a preliminary framework for assessing elderly nursing human resource efficiency using a literature review and in-depth semi-structured interviews. Through

expert consultation and cluster analysis, they finalized an evaluation framework based on DEA, which included four indicators: the number of specialized nurses as an input, and the proportion of specialized nurses, patient satisfaction, and nursing safety incident rate as outputs. Their findings showed that such a DEA-based framework can assist elderly care managers in conducting objective evaluations.

DEA has been selected for evaluating nursing human resource efficiency in critical care operating rooms, elderly care units (L. S. He, 2023), and cardiology (Song et al., 2021). Chinese researchers have used DEA to assess nursing status in hospitals (Cheng et al., 2020), conducting both dynamic and static analyses of nursing human resource efficiency (Song et al., 2021) and evaluating nursing efficiency across healthcare institutions in China's 31 provinces (Lan et al., 2020). All these studies demonstrate DEA's practicality as an evaluation tool. As a model suitable for multi-input, multi-output efficiency assessment, DEA is particularly effective for evaluating nursing units without being influenced by measurement units, and it does not require unit-free processing (M. Xu et al., 2019; W. Xu et al., 2018).

2.5 Nurse practice environment

2.5.1 The concept of the nurse practice environment

At present, there exists a lack of consensus regarding the precise definition of the nurse practice environment. However, it has been widely proposed that this definition should be approached from the aspects of nurses themselves and their organisational management.

Zelauskas and Howes (1992) proposed that the nurse practice environment is the context in which nurses, with the authority of managers, acquire more autonomy, control over their tasks, and accountability in delivering nursing care. The nurse practice environment refers to the organisational factors that promote or restrict the practice of nursing professions in the workplace (Lake, 2002).

Some scholars believe that the practice environment is divided into the hospital's internal and external practice environment (S. Zhang & Song et al., 2021). Nurse practice environment includes the physical and organisational environment the workplace of nurses (Zuo, 2006), as well as the characteristics of the work itself, such as its importance and complexity (Swiger et al., 2017). Other scholars have claimed that the nurse practice environment encompasses the interactions between nurses and their supervisors and other experts, the participation of nurses in decision making and enhancing quality (Mabona et al., 2022), and the presence of sufficient

staffing and resources for patient care (Lake et al., 2019).

2.5.2 The components of the nurse practice environment

In 2005, the American Association of Critical-Care Nurses launched the "Creating and Sustaining Healthy Work Environments" campaign, which outlined six key standards for fostering a healthy work environment in nursing. These standards include ensuring adequate staffing levels, supporting independent decision-making, facilitating effective communication, cultivating a collaborative atmosphere across multidisciplinary teams, providing reliable and supportive leadership, and recognizing the value of nursing work in the broader society (Lake et al., 2019).

In 2007, American nursing management expert Lake (2007) proposed that a healthy nursing practice environment includes autonomy in nursing practice, high-quality care, respect for nurses as professionals, empowered nursing leaders, a culture that promotes professional development, and effective communication among healthcare staff.

Qiao (2014) conducted a systematic review of the components of the nursing practice environment, identifying seven elements for building a healthy nursing practice environment: professional development, leadership, respect and recognition, communication and collaboration, system support, organization and management, and the need for autonomy. He suggested that interventions to create a healthy nursing practice environment could begin by focusing on these seven factors.

In summary, the fundamental components of a healthy nursing practice environment can be grouped into several broad categories. These include the opportunity for nurses to engage in hospital management decisions, the ability to practice with autonomy, organizational support at various levels, the equitable allocation of human and material resources, trustworthy leadership, collaborative and harmonious relationships among healthcare professionals, appropriate compensation and social recognition, and robust support for both professional growth and personal well-being.

2.5.3 Measurement tools for evaluating the nursing practice environment

Understanding the nursing practice environment within hospitals and conducting regular evaluations and analyses provides hospital administrators with an objective basis and clear direction for ongoing improvements. Selecting objective and effective tools to assess the nursing practice environment is therefore crucial.

A "Magnet Hospital" refers to a hospital that, despite facing a severe nursing shortage, can attract highly skilled nurses, reduce staff turnover, maintain a high-quality nursing workforce, and provide excellent patient care (McCaughey et al., 2020). The Magnet Hospital program includes a nursing management model aimed at improving the nursing practice environment and enhancing nurse satisfaction and productivity, ultimately raising the quality of patient care.

The following is an introduction to the current tools used domestically and internationally for evaluating the nursing practice environment.

2.5.3.1 Nursing Work Index (NWI)

The Nursing Work Index (NWI), developed by Kramer and Hafner (Kramer & Hafner, 1989), was designed to assess various organizational characteristics that influence nurses' job satisfaction, their ability to deliver quality care, and their overall perception of the work environment. The scale was developed through analysing the characteristics of the nurse practice environment in magnet hospitals and was made through qualitative interviews and literature reading with the nursing staff of such hospitals. The items must meet three conditions:

(1) Important for nurses' job satisfaction

(2) Vital for the implementation of high-quality nursing

(3) Can be reflected in the current work environment. The NWI is structured around five key dimensions: management style, leadership, organizational structure, professional practice behavior, and professional development. These dimensions are assessed through 65 items, each designed to capture different aspects of the nursing practice environment. Respondents are asked to rate each item on a 4-point scale, with the options ranging from 1 (completely disagree) to 4 (completely agree). The total score for the index can range from 65 to 260, with higher scores indicating a more favorable work environment. The α Cronbach coefficient for each dimension ranges from 0.89 to 0.95. The evaluation of content validity did not use statistical methods, but it was recognised by three of the four research experts of magnet hospitals at that time.

Aiken and Patrician (2000) stated that NWI itself was like the factors affecting job satisfaction and nursing quality in nurse practice environment in the 1980s. Furthermore, the NWI's items are all derived from the characteristics of magnet hospitals, meaning that it can only measure the extent to which the hospitals' nurse practice environments meet the standards of the professional practice environments. Lake (2002) argued that, despite its strong theoretical basis for measuring the practice environment, many of the NWI's items have not been empirically certified and the scale provides no reference values. Furthermore, for the subjects,

the NWI has many items, most of which can be considered time-consuming and laborious. In addition, the NWI has been used for over 20 years, meaning that some of its items are outdated and can no longer accurately reflect the status of the nurses' practice environment. Accordingly, it is rarely used nowadays.

2.5.3.2 Revised Nursing Work Index (NWI-R)

The NWI scale was revised by Aiken and Patrician (2000). Of the original 65 items, 56 were selected, and those with little relation to the practice environment of nurses were deleted and a new item related to team care was added. Compared with the fact that the inclusion of NWI items must meet three conditions, the inclusion of NWI-R items only needed to meet whether the content reflected in each item met this condition in the actual practice environment. The The NWI-R is organized into four key dimensions: nurses' job autonomy, control of practice, doctor-nurse relationships, and organizational support. These dimensions are assessed through a total of 57 items. Respondents are asked to rate each item on a 4-point scale, ranging from 1 (completely disagree) to 4 (completely agree), with higher scores indicating a more favorable work environment. The internal reliability of the NWI-R is notably strong, with an overall Cronbach's alpha coefficient of 0.96, indicating excellent consistency across all items. The alpha coefficients for each of the four dimensions range from 0.84 to 0.91, demonstrating solid reliability within each individual aspect of the scale.According to the results of validity tests, NWI-R scores of magnet hospitals are higher than those of non-magnet hospitals, thus showing its good discriminant validity.

Other scholars (Balsanelli & Cunha, 2015; Cho et al., 2013; Estabrooks et al., 2002; Roche et al., 2010) used the NWI-R, or the adapted version of the NWI- R to local conditions, to measure nurse practice environment. They all indicated that the NWI-R can accurately reflect the current nurse practice environment, organisational characteristics of the hospital, and nurses' job satisfaction. However, the scale has been criticised for having too many items.

2.5.3.3 Practice Environment Scale of the Nursing Work Index (PES-NWI)

Lake (2002) revised the original NWI to develop the PES-NWI. The PES-NWI was developed based on magnet hospital research, the development and application of the NWI, and its theoretical foundation lies in the sociological characteristics of organisation and work. This makes it suitable for measuring the nurse practice environment. The objective of this adaptation was to develop a concise and reliable scale by incorporating empirically based subscales. The scale includes 5 dimensions (nurses' participation in hospital affairs, quality nursing foundation,

nursing manager's ability, leadership and support, sufficient manpower and material resources, and doctor-nurse cooperation) and 31 items. A 4-point answering scale is used for each item, ranging from '1=completely disagree' to '4=completely agree'. Average scores greater than 2.5 for 4 or more dimensions indicate a good nurse practice environment. Average scores greater than 2.5 for 3 or 3 dimensions indicate a medium nurse practice environment. An average score greater than 2.5 for just 1 dimension indicates a poor nurse practice environment. The overall Cronbach's α coefficient of the scale was 0.82, with Cronbach's α for each dimension ranging from 0.71 to 0.83, and the intraclass correlation coefficient (ICC) ranging from 0.88 to 0.97, indicating good inter-rater reliability. Validity testing showed that Magnet hospitals scored significantly higher than non-Magnet hospitals ($P<0.01$), demonstrating good discriminant validity.

By 2010, the PES-NWI had been adapted for use in five countries and translated into three languages. Studies consistently indicated that the nursing practice environment is influenced by the structural characteristics of the nursing workforce, patient demographics, and organizational factors (2002). Currently, the PES-NWI is the most widely utilized scale for assessing nurse practice environments and remains the primary tool referenced for research on magnet hospitals (2002).

In China, a study by L. Wang and Li (2002) tested the reliability and validity of the Chinese version of the PES-NWI. Their findings suggested that the scale exhibited relatively high reliability and validity, although they noted that the version did not address certain contemporary issues, such as nurse salary.

2.5.3.4 Perceived Nursing Work Environment (PNWE)

The Perceived Nursing Work Environment (PNWE) scale, originally developed by Choi et al. (2002), is an adaptation of the Nursing Work Index-Revised (NWI-R). It consists of 42 individual items, which are grouped into seven key dimensions: professional development and participation in decision-making, availability of human and material resources, nursing management, professional practice, collaboration between doctors and nurses, guarantees related to the clinical work system, and work scheduling. The scale employs a 4-point Likert-type response format, where responses range from '1=completely disagree' to '4=completely agree'. A higher score on this scale indicates a more favorable perception of the nursing practice environment.

In a significant study by Cimiotti et al. (2002), the PNWE scale was used to survey over 2,000 nurses working across three distinct types of hospitals: magnet hospitals, hospitals in the

process of obtaining magnet status, and non-magnet hospitals. The findings revealed that the PNWE is a reliable tool for assessing the characteristics of the nursing work environment, and it was effective in differentiating between the practice environments of magnet and non-magnet hospitals.

X. L. Chen et al. (2002) translated the PNWE scale into Chinese and applied it within the context of China. Their primary focus was to assess the overall state of the nursing work environment across various healthcare settings in China.

2.5.3.5 Nurse Practice Environment Assessment Scale (NPEAS)

The NPEAS was developed by the Nursing Center of the Institute of Hospital Management of the National Health Commission of China after organising experts to review relevant literature on the nurse practice environment (Ying et al., 2016). This scale was developed based on the original and Chinese versions of the PES-NWI.

The initial version of the scale was developed considering the specific Chinese context, including such factors as economic, social, and cultural background. Subsequently, it underwent a process of refinement and finalisation, which involved three rounds of expert consultation. To validate the scale, a questionnaire survey was conducted with nurses selected from 30 provinces, autonomous regions, and municipalities across China. The survey data were analysed using the multiple linear regression method. According to the measurements of the regression coefficients of each potential key component of the scale and the system, some items of the scale were modified, with certain meaningless items deleted. The final draft of the scale was formed after expert consultation. This scale includes 38 items, each with a score ranging from 0 to 100, with 0 referring to strongly disagree and 100 to strongly agree. The higher the score, the better the practice environment. L. W. Zhang et al. (2019) evaluated the reliability and validity of NPEAS, and subsequently completed a revised scale that included participation in hospital management, clinical nursing professionalism, leadership and communication, quality management, internal support, doctor-nurse cooperation, professional improvement, manpower, social status, and salary and other benefits. This revised version has 10 dimensions, 36 items, and 1 overall evaluation item. The National Nursing Quality Data Platform used this scale to develop a formal survey, which was completed by nurses online. The NPEAS was found to have good reliability and validity and can thus be used to evaluate the nurse practice environment in medical institutions in China.

Many Chinese scholars have used the NPEAS and found it to have good reliability and validity (Chen & Lv et al., 2021; Z. W. Zhao et al., 2020). At present, the NPEAS is used as a

tool of China's National Nursing Quality Data Platform to conduct regular surveys on grade-A tertiary hospitals.

2.5.4 Current applications of nursing practice environment evaluation

2.5.4.1 Assessment of the current state of the nursing practice environment

Suliman and Aljezawi (2018) investigated nurses' perceptions of the nursing work environment in Jordanian hospitals. Their findings showed that nurses working in public hospitals had a much more positive view of their work environment compared to those in private and university hospitals. Older nurses with lower educational qualifications were more likely to feel satisfied with their jobs. Additionally, nurses who perceived strong support from managers and colleagues, along with manageable workloads, were more likely to remain in their positions.

Ayaad et al. (2018) highlighted shared governance in nursing as a strategic tool that can enhance satisfaction for both nurses and patients, as well as improve nurses' work-life quality. They suggested that nursing departments adopt a shared governance model to improve nurses' quality of work life.

Jang and Choi (2020) emphasized that the work environment affects nurses' health and advocated for strategies to reduce ergonomic and psychosocial risk factors, which could improve nurses' health. They also noted that involving nurses in the Best Practice Spotlight Organization (BPSO) initiative and implementing best practice guidelines could positively shift nurses' perceptions of their work environment and attitudes toward evidence-based practice.

Ferreira et al. (2021) suggested that addressing a lack of familial and social support within the nursing work environment is crucial, as these factors influence the quality of care provided. They recommended fostering stronger family and social connections for nurses to prevent imbalances that could negatively impact the work environment and, subsequently, healthcare quality.

Chinese scholars H. Y. Zhang et al. (2017) applied the Nursing Practice Environment Scale, supported by the National Nursing Quality Data Platform, to survey 344,391 nurses from 764 tertiary hospitals across 30 provinces, autonomous regions, and municipalities in China. Valid responses (with at least 30 responses per hospital) were collected from 629 hospitals, totalling 326,769 nurses. The survey results indicated that the top five items in terms of scores were: "The hospital has a training program for new nurses," "Hospital management expects each nursing unit to provide high-standard care for patients," "The head nurse is an excellent manager and leader," "The hospital has a clear post-exposure management process that is effectively

implemented," and "Nurses within the team are competent in their nursing duties."

The lowest-scoring items were: "Nurses have opportunities to participate in hospital decision-making," "Nurses have opportunities to engage in internal hospital management," "Nurses have opportunities to participate in national and international academic activities," "Nurses' salaries are at a competitive level across social sectors," and "Nurses' work is recognized by society."

Similar surveys using the Nursing Practice Environment Scale were conducted in hospitals in Henan (Y. Q. Zhang et al., 2021), Hebei (Chen & Lv et al., 2021), Tianjin (W. Liu et al., 2021), Sichuan (Zeng et al., 2021), and Shandong (X. M. Zhang et al., 2020), yielding comparable results.

2.5.4.2 The importance of a healthy nursing practice environment

A healthy nursing work environment is one where safety, empowerment, and job satisfaction are prioritized, creating a setting in which nurses can perform effectively and deliver optimal care (2002). The significance of such environments extends beyond just the well-being of healthcare professionals; it plays a crucial role in the overall quality of patient care. This understanding is grounded in foundational work from the Institute of Medicine (IOM), a recognized authority on healthcare systems in the United States. The IOM's influential reports, To Err is Human: Building a Safer Health System and Crossing the Quality Chasm: A New Health System for the 21st Century, underscored alarming concerns about patient safety and nursing care quality within the U.S. healthcare system, calling attention to the systemic issues that contribute to preventable medical errors.The American Nurses Credentialing Center (ANCC) and the International Organization for Migration co-authored Keeping Patients Safe: Transforming the Work Environment of Nurses. This report advocated for systemic reforms to enhance nursing environments, recognizing that such improvements are integral to safeguarding patient care and ensuring high-quality nursing practice (ANCC, 2004).

Currently, medical errors are the third leading cause of death in the U.S. A healthy work environment and a stable nursing workforce are critical to preventing these errors. The current nursing turnover rate stands at 27%, with hospitals spending an estimated $5.13 million to $7.86 million annually on nurse turnover (Nursing Solutions, 2017).

The creation and maintenance of a healthy work environment (HWE) are fundamental to enhancing nurse satisfaction, improving retention, and ensuring that nurses are able to deliver high-quality patient care. Furthermore, a positive work environment is closely tied to the financial sustainability of healthcare organizations. Satisfied and stable nursing teams

contribute to both the quality of patient outcomes and the institution's overall efficiency (2002).

A healthy work environment is best understood as an integrated system encompassing people, organizational structures, and practices that together enable nurses to actively participate in providing top-tier care. In HWEs, nurses can make the most positive contributions to both their patients and the organization (Manning & Jones, 2021). An HWE empowers nurses to deliver high-quality care services (Cicolini et al., 2014). There is a significant correlation between nursing work environments, support for innovation, and nurses' innovative behaviours and outputs (Mahgoub et al., 2019).

To build and sustain these environments, nurse managers play a key role. They are responsible for cultivating a culture that promotes interdisciplinary collaboration, mutual respect, and shared decision-making. By fostering such a culture, nurse leaders can enhance the overall work environment, which in turn supports nurse well-being, improves patient safety, and ensures high-quality care (Mahgoub et al., 2019).

Excellence in the nursing practice environment is essential for improving healthcare system performance. Nurses need a work environment where they can fully express their skills and knowledge. Identifying areas for improvement in the nursing work environment—by policymakers, administrators, nursing leaders, and educators—can significantly enhance patient outcomes (Hassanein et al., 2020).

A healthy nursing practice environment benefits patients by increasing patient satisfaction (Aiken et al., 2012) and reducing hospital stays (Arai et al., 2012). For nurses, it raises job satisfaction (Cicolini et al., 2014; L. Wang et al., 2011) and lowers turnover rates (Feng et al., 2013). For organizations, it improves care quality (Kovner et al., 2016) and enhances safety in hospital care, ultimately increasing the efficiency of nursing human resources.

2.5.4.3 The role of the magnet nursing accreditation program in improving the nursing practice environment

The Magnet Nursing Accreditation Program, established by the American Nurses Credentialing Center (ANCC), is a prominent initiative designed to elevate the quality of the nursing practice environment and improve patient safety outcomes. This program identifies and accredits healthcare organizations that demonstrate excellence in nursing care, fostering environments that attract and retain skilled nursing professionals. Magnet certification is not only a recognition of high standards in nursing practice but also correlates with measurable improvements in patient care. Numerous studies have highlighted the superior safety outcomes associated with Magnet-certified hospitals. For example, research by Lake et al. (2011) revealed

that the rate of patient falls in Magnet hospitals was 5% lower than in non-Magnet hospitals, while McHugh et al. (2011) found that mortality and failure-to-rescue rates in Magnet hospitals were reduced by 14% and 12%, respectively, compared to their non-Magnet counterparts.

In a study by Kelly et al. (2011) involving 46 magnet hospitals and 521 non-magnet hospitals, it was found that hospitals with a healthy practice environment had higher job satisfaction, lower burnout rates, and reduced turnover compared to other hospitals.

The success of the Magnet Nursing Accreditation Program highlights the importance of a supportive nursing environment in ensuring patient safety. Research shows that when hospitals invest in improving their nursing practice environment, they not only enhance nurse job satisfaction and retention rates but also improve the quality of patient care and reduce the occurrence of adverse events (H. M. Wei et al., 2017). These findings underscore that the nursing practice environment is a modifiable factor that hospital administrators can optimize to improve both nurse and patient outcomes.

X. J. Wu et al. (2019) proposed that the magnet hospital concept is essential for establishing a quality nursing practice environment. A deep understanding of the magnet hospital's principles, along with learning from international experiences, can help integrate this management approach into high-quality nursing services. This integration supports the creation of a supportive nursing environment, inspires nurses' innovation and creativity, unites team efforts, and improves the quality and efficiency of nursing management.

Lu et al. (2021) investigated the current magnet level in four tertiary hospitals in Xinjiang, finding that the total score ranged from 45 to 100 (average score 97.31 ± 21.38), with a scoring rate of 54.06%, indicating room for improvement. Key factors affecting the Magnet level included nurses' organizational commitment, psychological resilience, psychological contract, educational background, employment type, and age.

L. Zhang et al. (2022) applied magnet hospital principles to enhance the nursing practice environment for Traditional Chinese Medicine (TCM) nurses by promoting a magnet nursing culture. After implementing these principles, the scores for TCM nurses' practice environment and satisfaction were significantly higher than before ($P<0.05$). The application of magnet hospital principles in nursing management proved highly effective, significantly improving the practice environment, raising the overall quality of hospital nursing care, and increasing patient satisfaction.

2.6 The association between nursing practice environment and nursing human resource efficiency

2.6.1 Analysis of factors influencing the nursing practice environment

H. Y. Zhang et al. (2017) analysed factors affecting the nursing practice environment primarily based on the nurses' general demographics. Key influencing factors include gender, education level, years of experience, and employment type. Male nurses scored significantly lower than female nurses, possibly due to societal biases against male nurses in China, which affects their self-efficacy and sense of organizational support, leading to dissatisfaction with the practice environment. Nurses with higher educational backgrounds perceived their practice environment more negatively. As education level increases, nurses typically have stronger professional and logical reasoning skills, and higher expectations for career autonomy and self-worth. If institutions fail to provide appropriate empowerment or support, this can negatively impact the perception of their work environment.

Nurses aged 30–39, holding positions of "Nurse Practitioner" or "Head Nurse," and with 5–9 years of experience scored the lowest in practice environment assessments. This group is often in a career development phase and considered key personnel within departments, carrying heavy work responsibilities, including teaching roles. They are also central to family life, balancing significant family and work demands, leading to high stress levels, an increased likelihood of turnover, and a more negative perception of their work environment. Nurses with formal employment contracts scored higher than those on contract terms, as the formality of their role provided greater confidence, initiative, and access to better resources, leading to a more positive experience within the practice environment.

H. T. Guo et al. (2018) identified three primary factors influencing the nursing practice environment: work pressure, compensation, and career development. Work pressure is a major determinant, as poor working conditions lead to psychological issues, burnout, and even fatigue, all of which increase the likelihood of errors, reduce nursing quality, and may cause serious healthcare incidents. Key sources of work pressure include relationships with patients and colleagues, excessive workload, and frequent night shifts. Low compensation is a leading factor in decreased job satisfaction within the nursing environment, reducing work motivation and increasing turnover rates. Career development opportunities reduce burnout, while a lack of support and recognition in this area exacerbates it. Additional influences include the healthcare environment, national healthcare policies, support from colleagues and management, and

individual skills and abilities.

Corresponding Analysis of Influencing Factors Based on Nursing Human Resource Efficiency Input Indicators

(1) Nursing Human Resource Input:

Insufficient nursing staff can lead to high workloads and excessive night shifts for nurses, increasing stress and reducing their efficiency. Ensuring adequate staffing levels is essential to prevent burnout and maintain sustainable shift patterns.

(2) Nursing Service Input:

A high workload and excessive demands on nurses can lead to fatigue, impacting both physical and mental health, and increasing the likelihood of burnout. This, in turn, negatively affects the quality of patient care and reduces nurses' ability to work efficiently.

(3) Nursing Material Input:

Adequate provision and quality of nursing tools and equipment are vital for supporting and improving nurses' work efficiency. Hospital bed count, as a measure of the institution's scale and capital investment, is critical in determining the appropriate nurse-to-bed ratio for efficient resource allocation and optimal patient care.

(4) Nursing Financial Input:

Financial investment in nursing includes costs associated with human resources, training, and research. The primary expense is typically the annual pre-tax income per nurse (F. Weng et al., 2019). Compensation is a crucial factor in the nursing practice environment, as inadequate salaries can decrease job satisfaction and increase turnover. Specialized training and continuing education are essential to enhance nurses' professional skills, uphold high patient care standards, and ensure job satisfaction, supporting nurses' career development through adequate recognition and support.

2.6.2 The impact of the nursing practice environment on patient safety and care quality (output indicators)

The nursing practice environment plays a crucial role in influencing patient safety outcomes. It encompasses both the physical and organizational conditions within the nurse's work setting, such as staffing levels, leadership, autonomy, quality management, interprofessional relationships, and opportunities for professional development (J. Zhang et al., 2018).

Patient safety is defined as the prevention of errors and adverse effects associated with healthcare services (WHO, 2017). Common patient safety issues include hospital-acquired

infections, medication errors, falls, and pressure ulcers—preventable events that can result in serious harm or even death. According to WHO's 2017 report on patient safety, approximately 1 in 10 hospitalized patients globally experiences harm, with nearly half of these adverse events being preventable (J. Zhang et al., 2018). This underscores the need for systematic improvements in healthcare environments, particularly the nursing practice environment, as nurses are the frontline caregivers directly interacting with patients.

Research shows a strong correlation between a positive nursing practice environment and improved patient safety outcomes. For instance, Aiken et al. (2009) found in a study of 168 hospitals in Pennsylvania that better nursing environments were associated with a 14% reduction in inpatient mortality rates. Similarly, Kelly et al. (2013) reported that hospitals with favourable work environments had infection rates 36% to 41% lower than those with poorer environments. These studies suggest that improving the nursing practice environment can directly reduce the incidence of adverse events such as infections, medication errors, and patient falls.

Further research has identified several key elements of the nursing practice environment that impact patient safety outcomes, including adequate nurse staffing levels, strong nursing leadership, interprofessional collaboration, access to necessary resources, and a supportive organizational culture (Min et al., 2018). For example, inadequate staffing is closely linked to nurse burnout, increased turnover rates, and a higher risk of errors in patient care. In contrast, a supportive environment that provides sufficient staffing, continuous professional development opportunities, and allows nurses to participate in decision-making is associated with lower mortality and infection rates and overall improved patient outcomes (J. Zhang et al., 2018).

Given the substantial evidence supporting the link between the nursing practice environment and patient safety, healthcare institutions should prioritize creating and maintaining a healthy work environment for nurses. This includes addressing key areas such as adequate staffing, fostering leadership and decision-making autonomy, strengthening interprofessional relationships, and offering continuous professional development opportunities. Additionally, adopting evidence-based frameworks like the Magnet Nursing Accreditation Program for benchmarking nursing management and implementing best practices is essential.

Future research should explore the specific mechanisms by which different elements of the nursing practice environment impact patient safety. More longitudinal studies are needed to understand how changes in the nursing environment over time affect nurse outcomes and patient safety. Moreover, studies should consider cultural and organizational differences across

various healthcare settings to develop targeted interventions that can effectively improve nursing environments on a global scale.

The nursing practice environment can influence patient safety by affecting nurses directly. A positive work environment is directly related to the quality of nursing care (Amaliyah & Tukimin, 2021), and the nursing work environment significantly impacts patient safety outcomes (Nascimento et al., 2021). Improving the practice environment has become a crucial strategy for infection prevention. In a survey conducted by Kelly et al. (2021) involving 3,217 nurses across 320 hospitals, it was found that hospitals with a healthy practice environment had infection rates 36% to 41% lower than those with poorer environments.

A healthy nursing practice environment can also reduce patient mortality rates. McHugh et al. (2013) compared 564 hospitals with different practice environments and found that hospitals with a healthy environment had 14% lower patient mortality rates and 12% lower failure-to-rescue rates within a month compared to hospitals with less favourable environments. Similarly, data from the Pennsylvania trauma research database involving 73,830 patients were analyzed and it was found that hospitals with healthy practice environments had a 20% lower patient mortality rate compared to other hospitals (Evans et al., 2014).

Bolton and Aronow (2009) conducted a study in a large hospital and found that, over a four-year period from 2004 to 2008, reducing patient fall rates saved $7.9 million, and decreasing the incidence of stage III and IV pressure ulcers saved $59.3 million. Investment by healthcare institutions in a supportive nursing work environment and professional development for nurses can improve care quality, thereby enhancing patient outcomes.

2.6.3 The impact of the nursing practice environment on nurse turnover rate (output indicator)

One of the primary reasons for the rising turnover rate among hospital nurses is a negative work environment. Such an environment reduces nurse performance and adversely impacts the quality of patient care, as well as the safety of both patients and healthcare workers (Ulusoy & Polatkan, 2016).

The nursing practice environment affects nurses' work engagement. Van Bogaert et al. (2013) surveyed 357 nurses and found that the nursing practice environment can influence nurses' work engagement, subsequently impacting job satisfaction, turnover rates, and quality of care. Carthon et al. (2021) further demonstrated that high levels of nurse burnout are associated with lower patient satisfaction. They suggested that hospitals could reduce nurse

burnout and improve patient satisfaction by investing in a supportive work environment. X. Wang (2012) surveyed 750 clinical nurses and found that reducing role stress, increasing organizational support, and fostering a positive practice environment could enhance nurses' work engagement and reduce burnout.

The nursing practice environment also influences job satisfaction among nurses. Lee et al. (2014) conducted a survey of 3,096 nurses across 60 hospitals and similarly concluded that the practice environment significantly affects nurses' job satisfaction.

The nursing practice environment significantly affects the incidence of occupational injuries among nurses. Clarke et al. (2002) demonstrated through a series of studies that when resources are allocated inefficiently, the incidence of needlestick injuries is more than three times higher than usual, and poor personnel management or understaffing doubles the likelihood of such injuries. Cho et al. (2013) suggested that reducing needlestick injury rates requires increasing staffing and resource allocation, reducing emotional exhaustion, and enhancing the use of safety equipment. Roche et al. (2010) found that good interprofessional relationships, high levels of nurse autonomy, and strong nursing leadership are associated with lower rates of workplace violence.

The nursing practice environment also impacts nurse turnover rates, which significantly add to hospital staffing costs. North et al. (2013) conducted a 12-month study across 22 wards and found a nurse turnover rate of 44.3%, costing a total of $23,711. Turnover also increases patient care costs. Bolton and Aronow (2009) reported that, in a large hospital, reducing nurse turnover over a four-year period from 2004 to 2008 saved $5.6 million.

High turnover rates are a major contributor to nursing shortages. N. Guo et al. (2015) examined the profiles and reasons for nurse turnover in a tertiary hospital and concluded that establishing a supportive practice environment and promoting a “Magnet” management philosophy are essential for enhancing job satisfaction, professional development, reducing turnover, and stabilizing the nursing workforce. Similarly, H. F. Zhang et al. (2015) surveyed 330 nurses and found that workplace support is the primary factor in reducing turnover intentions. They recommended that hospitals and nursing managers create a positive practice environment and department atmosphere and provide substantial work support to reduce turnover.

2.7 Relevant management theories

2.7.1 Human capital theory

Human Capital Theory, rooted in the field of economics, was first conceptualized by American economists Theodore Schultz and Gary Becker during the 1960s. This framework introduced a novel way of understanding human productive capacity by treating individuals' knowledge, skills, and health attributes as a form of capital. Within this theory, physical capital encompasses tangible assets such as buildings, machinery, equipment, raw materials, land, financial assets, and other economic resources. In contrast, human capital refers to the intangible, yet vital, investments in individuals that contribute to their productive capabilities. These investments include the costs associated with education, vocational training, and the opportunity costs individuals bear during their educational journeys. Human capital is reflected in the stock of knowledge, technical skills, managerial abilities, and health characteristics possessed by individuals.

Human capital is a concept in Western economics, also known as "intangible capital," in contrast to "material capital." It represents the capital embodied in workers, such as their knowledge, skill levels, cultural and technical expertise, and health status. Its main characteristic is its intrinsic link to individual freedom, meaning it does not transfer with the sale of products. Human capital is primarily developed through investment in people, which includes: (1) expenditures on education; (2) expenditures on healthcare; (3) expenditures on internal labour mobility; and (4) expenditures on immigration. Education expenditures are particularly significant, as they create educational capital. Education enhances labour quality, workforce competence, and technical skills, thereby boosting labour productivity. This growth in human capital, especially through education expenditures, is recognized as one of the key drivers of economic growth (Goldin, 2024).

Content of Human Capital Theory include:

(1) Human Resources as Primary Resources: Human resources are considered the most critical resource in the economic landscape, positioning human capital as a fundamental focus within economic theory.

(2) Greater Role of Human Capital in Economic Growth: In the context of economic growth, human capital is often recognized as having a more significant impact than physical capital. While investments in tangible assets such as machinery and infrastructure are important, it is the investment in human capabilities—through education, training, and health—that drives

more rapid increases in national income. As the stock of human capital expands, it leads to greater labor productivity, which in turn accelerates economic development at a rate that outpaces the growth of physical capital.

(3) Core of Human Capital - Enhancing Population Quality: At the heart of human capital theory is the notion that improving the quality of the population is essential to maximizing economic potential. Education plays a pivotal role in this process, serving as the primary means by which human capital is developed and enhanced. Investment in education is not merely an expense but a long-term investment that yields returns far surpassing those associated with physical capital. The theory posits that, rather than being a consumable resource, human capital should be seen as a renewable asset, where each investment in education and skill development contributes to a more skilled, knowledgeable, and productive workforce.

(4). Market-Driven Educational Investment: The theory also suggests that investments in education should align with market demands, following the principles of supply and demand. The fluctuating "prices" of human capital—represented by wages, labor mobility, and skill requirements—serve as indicators for where educational investments should be directed.

2.7.2 Resource-Based View

The Resource-Based View (RBV) is a pivotal theoretical framework in the field of strategic management, initially proposed by Jay Barney in 1991. It seeks to explain how firms can achieve and sustain competitive advantage through their unique resources and capabilities (Barney, 1991). The core premise of this theory is that a firm's competitive advantage stems from the heterogeneity and inimitability of its internal resources, rather than from external market conditions or industry structure. The RBV posits that a firm is a collection of unique resources and capabilities, which form the foundation of its competitive advantage (Barney, 1991; Grant, 1991).

The Resource-Based View provides firms with a theoretical framework for understanding competitive advantage from the perspective of internal resources. By emphasising the heterogeneity, inimitability, and non-substitutability of resources, the RBV helps firms identify and leverage their unique resources and capabilities to achieve and sustain competitive advantage in highly competitive markets (Barney, 1991). With the continuous evolution of market environments, the concept of dynamic capabilities further extends the applicability of the RBV, enabling firms to better address future challenges (Teece et al., 1997).

The key components of the Resource-Based View are:

(1) Resource Heterogeneity: A central assumption of the RBV is that resources are heterogeneous across firms. Different firms possess distinct resource portfolios, and these differences determine their performance in the market (Barney, 1991). Heterogeneous resources are those that are scarce and difficult for competitors to acquire. For instance, some firms may hold unique technological patents or possess strong brand reputations, which are classic examples of heterogeneous resources (Peteraf, 1993).

(2) Resource Inimitability: The inimitability of resources is another critical concept in the RBV. Even if competitors recognise the importance of certain resources, they may find it challenging to replicate them (Barney, 1991). The inimitability of resources can arise from various factors, such as the complexity of the resources, path dependency (i.e., the historical context in which the resources were developed), and causal ambiguity (i.e., the difficulty in identifying the exact reasons for the success of the resources) (Dierickx & Cool, 1989). For example, a firm's organisational culture or managerial capabilities may be difficult to imitate due to their unique historical development.

(3) Resource Non-Substitutability: Non-substitutability refers to the absence of equivalent alternatives for certain resources in the market. Even if competitors cannot imitate specific resources, they might still achieve similar outcomes through substitute resources (Barney, 1991). Therefore, the non-substitutability of resources is also a crucial factor in sustaining competitive advantage. For instance, a firm's supply chain management capabilities may be difficult to substitute, as they rely on specific supplier networks and long-term relationships (Amit & Schoemaker, 1993).

(4) Resource Accumulation and Integration: The RBV also emphasises that firms must not only possess unique resources but also effectively integrate and utilise them (Grant, 1991). The process of resource accumulation and integration is a vital component of a firm's capabilities. By combining and optimising different resources, firms can create new competitive advantages. For example, a firm may integrate its technological and market resources to develop more competitive products (Teece et al., 1997).

(5) Dynamic Capabilities: As market environments evolve, firms must continuously adjust and update their resource portfolios to address new competitive challenges. Dynamic capabilities, an important extension of the RBV, refer to a firm's ability to adapt its resource base to external environmental changes through continuous learning and innovation (Teece et al., 1997). Dynamic capabilities enable firms to maintain competitive advantage in rapidly changing markets.

The RBV is widely applied in various areas of business management, particularly in

strategy formulation, performance management, and innovation management (Hesterly & Barney, 2014). Firms can use the RBV to identify their core resources and capabilities and develop strategies to maximise the potential of these resources. For instance, firms can analyse the heterogeneity and inimitability of their internal resources to determine the sources of their competitive advantage in the market (Grant, 1991).

2.8 Theoretical model

The theoretical model for this study (see Figure 2.1) integrates concepts of nursing human resource management, efficiency evaluation, and the nurse practice environment. It aims to explore the relationships between these elements and provide actionable strategies for improving nursing resource utilization and enhancing the overall healthcare environment.

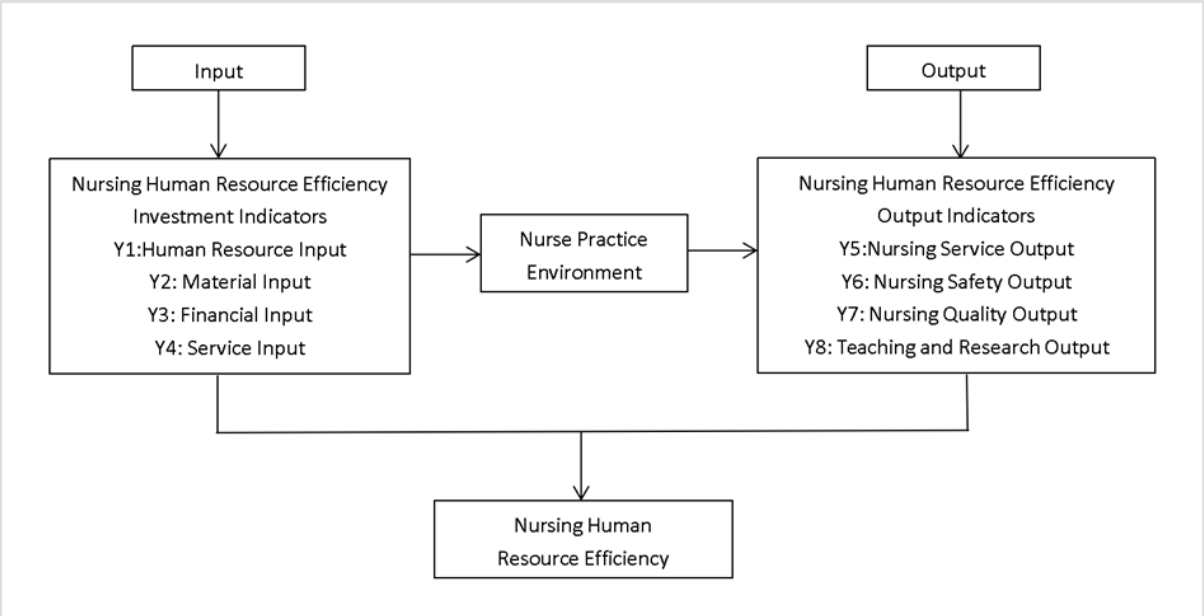

Figure 2.1 Theoretical model on the impact of the nursing practice environment on nursing human resources efficiency

According to the input-output theoretical model, the input index and output index of nursing human resource efficiency of the research unit are listed respectively, and DEA is used to measure the nursing human resource efficiency of the research unit; then the nursing unit's practice environment evaluation score is used as one of the input indicators, and DEA is used to measure the nursing human resource efficiency of the research unit. This paper attempts to find the relationship or influence between the nursing practice environment and nursing human resource efficiency, as well as what intermediate variables exist between the two.

Through an extensive literature review of nursing human resource management, efficiency

evaluation, and nursing practice environments, it is evident that no studies currently explore the relationship between the nursing practice environment and nursing human resource efficiency, their influence on each other, or potential intermediary variables. Therefore, constructing a model to assess the impact of the nursing practice environment on nursing human resource efficiency holds valuable significance. This study aims to select suitable tools for evaluating the nursing practice environment, identify key indicators for assessing nursing human resource efficiency, establish an evaluation system, and explore correlations between factors or indicators of the nursing practice environment and human resource efficiency. The findings aim to provide nursing managers with strategies for improving the practice environment to enhance resource efficiency.

Despite the theoretical model based on a broad literature review and the comprehensive exploration of the relationship between nursing human resource efficiency and the practice environment, certain limitations remain. First, although the literature review covers a wide range of relevant studies, there may still be omissions, particularly with regard to recent or unpublished research. Additionally, while nursing practice environment evaluation tools are widely used, their applicability and validity may vary across cultural contexts, potentially impacting the generalizability of the findings. Finally, the proposed theoretical model requires validation in subsequent empirical research to ensure its applicability and feasibility.

Chapter 3: Research Methods

3.1 Research object

For the convenience of research, the subject of this study is the hospital where the researcher works.

Survey Hospital: The basic information of the hospital is that A Hospital in Guangdong Province, is a tertiary comprehensive hospital with 1100 beds, 2100 staff members, and a total of 715 nurses. Hospitals in mainland China implement a hierarchical management system: ① By Scale: Hospitals are classified into three levels: Level I, Level II, and Level III. ② By Medical Standards and Service Quality: Hospitals are graded into two categories: Grade A and Grade B. ③ By Type: Hospitals are divided into two main types: general hospitals and specialized hospitals. A Grade III, Class A general hospital represents the highest level and most comprehensive institution, typically integrating medical care, teaching, and research. These hospitals possess complete medical departments and professional teams, capable of providing high-level medical services and treating complex and challenging conditions. The hospital in question is a Grade III, Class A general hospital, located in a city where both the economic and medical standards rank among the highest in China. As a result, the data from this hospital is highly representative.

Research Unit: Convenience sampling method was used to screen the clinical nursing units of the hospital. Inclusion criteria: ①Homogeneity, all are inpatient wards, each nursing unit admits inpatients and provides nursing services and treatment according to service standards; ② A clinical nursing unit that is willing to participate in this study after training and has complete and reliable data. Exclusion criteria: ①Nursing units without inpatient beds, such as outpatient clinics, endoscopy centers, medical imaging departments, and neurology departments; ② Special departments such as emergency department, ICU, delivery room and other nursing units; ③ Clinical nursing units with incomplete research data. According to the above standards, a total of 19 clinical nursing units were selected as research units.

Investigated nurses: Screening of nurses from clinical nursing units included in the study. Selection criteria: ① Registered nurse with at least 1 year of employment; ② Engaged in

clinical nursing work or nursing management work; ③ Voluntarily participate in this study; ④ No previous or current mental illness or consciousness disorders. Exclusion criteria: ① Unregistered nurses such as intern nurses, trainee nurses, and regulated nurses; ② Engaged in clinical nursing work in our hospital for less than 1 year; ③ During the investigation period, employees who are absent from work due to sick leave, personal leave, maternity leave, or going out for further studies. According to the above standards, the total number of nurses in 19 research units in 2020 was 358, with 336 eligible nurses for the survey; In 2021, the total number of nurses in 19 research units was 357, with 334 eligible nurses for the survey. Cluster sampling was used, and nurses who met the survey criteria were distributed survey questionnaires and included in this survey.

3.2 Nursing practice environment

3.2.1 Evaluation of nursing practice environment

Figure 3.1 shows overview of the phases involved in evaluating the nursing practice environment.

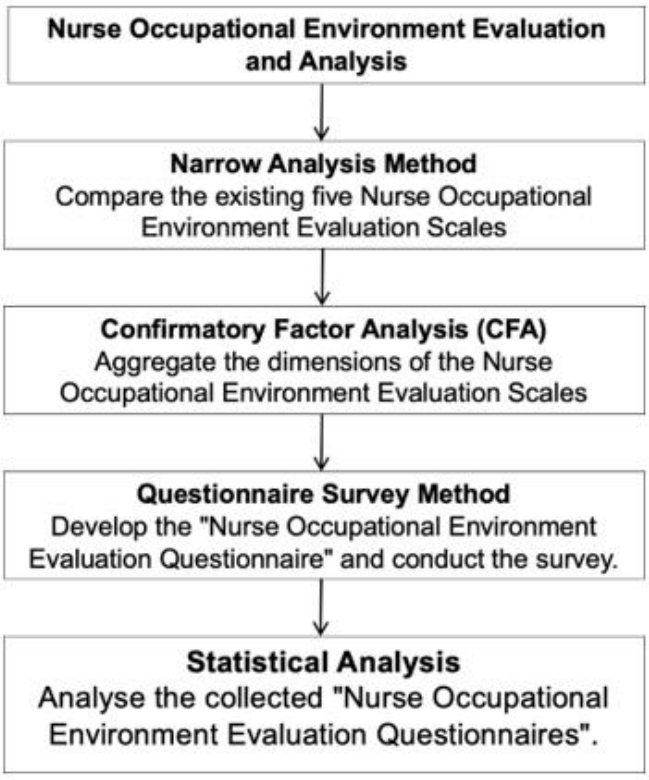

Figure 3.1 Theoretical model of nursing practice environment

Phase 1: Comparative analysis

The initial phase involves a comparative analysis of five existing nursing practice environment evaluation scales. Comparative analysis is a commonly used research method that compares two or more sets of data to determine their similarities and differences. By connecting the subject of study with other relevant subjects, we can identify its essential attributes through a thorough, systematic comparison. This step identifies the strengths and weaknesses of each scale to select the most appropriate one for the study.

Phase 2: Confirmatory factor analysis (CFA) and Exploratory Factor Analysis (EFA)

Confirmatory Factor Analysis (CFA) is used to measure the correspondence between factors and measurement items (scale items) to verify if they align with the researcher's predictions. It is a statistical technique developed by Jöreskog (1969). The mathematical model for CFA is: $x = \Lambda x\xi + \delta$, where x represents the observable variable vector, Λx represents the factor load matrix, ξ represents the latent common factor vector, and δ is the measurement error vector. This step ensures that the chosen scale's dimensions are robust and reliable for further analysis.

Exploratory Factor Analysis (EFA) is a technique used to identify the essential structure of multivariate observed variables and perform dimensionality reduction. EFA can synthesize variables with complex relationships into a few core factors.

Phase 3: Survey methodology

A questionnaire is developed based on the validated dimensions from the CFA and EFA. The questionnaire survey method involves distributing questionnaires to the target population to collect relevant information and data. The questionnaires typically include a series of questions that respondents answer based on their actual situation. This method is characterized by standardization, high efficiency, large information volume, and flexibility. The survey collects data on the nursing practice environment from various hospitals.

Phase 4: Statistical analysis

The collected survey data are subjected to rigorous statistical analysis to identify key indicators and assess their relevance. The results provide a comprehensive understanding of the current nursing practice environment and its impact on nursing human resources.

3.2.2 Comparative analysis of nurse practice environment evaluation scales

Comparative analysis is a commonly used research method that involves comparing the data of two or more objects or categories to determine their similarities and differences. An object

cannot be understood in isolation; it must be examined in connection with other objects. Through comparative analysis, the essential attributes among numerous properties can be identified.

The basic principle of the comparative analysis method is to contrast the characteristics and performance of different objects to identify their differences. By comprehensively and systematically comparing these differences, we can better understand their strengths and weaknesses, providing strong support for decision-making.

A comprehensive review of existing literature was conducted to identify and evaluate various theoretical models that describe the nursing practice environment. This review focused on widely recognized frameworks and models that have been used in previous research to assess the nursing practice environment. The databases searched included PUBMED, Medline, China National Knowledge Infrastructure (CNKI), and the China Science Periodical Database (CSPD). Keywords such as nurses, work/practice environment, evaluation/assessment, and questionnaire/scale/model/tool were used to ensure a broad and inclusive search.

The literature review findings were comprehensively analyzed to identify the strengths and limitations inherent in each of the assessment frameworks. This process involved a thorough comparison of the various dimensions covered by each tool, assessing their relevance and applicability to the objectives of the current study. Five key instruments emerged from the review: the Nursing Work Index (NWI), the Revised Nursing Work Index (NWI-R), the Practice Environment Scale of the Nursing Work Index (PES-NWI), the Perceived Nursing Work Environment (PNWE), and the Nurse Practice Environment Assessment Scale (NPEAS).

The Perceived Nursing Work Environment (PNWE) scale, developed by Choi et al. in 2004, builds on the NWI-R and offers a more comprehensive approach to assessing the nurse practice environment. This scale examines nurses' perceptions of key environmental factors that impact their work, such as organizational culture, job autonomy, and professional relationships. Finally, the Nurse Practice Environment Assessment Scale (NPEAS) was created by the Nursing Center of the Institute of Hospital Management, under the National Health Commission of China, following extensive expert review and analysis of relevant literature. Drawing from both the original and Chinese versions of the PES-NWI, the NPEAS was specifically designed to assess the unique characteristics of the nurse practice environment within Chinese healthcare settings (1969). A detailed comparison of these assessment tools, including their specific dimensions and relevance to the current study, is presented in Table 3.1.

Table 3.1 Assessment tools for the nursing practice environment

Assessment tools	Country	Dimensions	Number of items	Basic theory	Cronbach 's α
Nursing Work Index (NWI) (Kramer & Hafner, 1989)	USA	5 dimensions 1) nursing management, 2) leadership, 3) organizational structure, 4) professional practice 5) professional development	65	Characteristics of nurse practice environment in magnet hospitals	0.85
Revised Nursing Work Index (NWI-R) (Aiken & Patrician, 2000)	USA	4 dimensions 1) autonomy of nurses, 2) control over the nursing activities, 3) relationship between physicians and nurses, 4) support of organizations	57	Revised based on the NWI	0.88
Practice Environment Scale of the Nursing Work Index (PES-NWI) (Aiken & Patrician, 2000)	USA	5 dimensions 1) nurse participation in hospital affairs, 2) nursing foundations for quality of care, 3) nurse manager ability, leadership, support of nurses, 4) staffing and resource adequacy, 5) collegial nurse–physician relations	31	The magnet hospital research, the development and application of the NWI, and the sociological characteristics of organization and work.	0.91
Perceived Nursing Work Environment (PNW) (Choi et al., 2004)	USA	7 dimensions 1) Professional practice, 2) nursing management, 3) staffing and resources adequacy, 4) nursing process, 5) nurse/physician collaboration, 6) nursing competence, 7) positive scheduling climate.	42	Revised based on the NWI-R	0.87
Nurse Practice Environment Assessment Scale (NPEAS) (Ying et al., 2016)	China	10 dimensions 1) nurse participation in hospital affairs, 2) Professional practice, 3) leadership and communication, 4) quality management, 5) internal support, 6) nurse/physician collaboration, 7) professional development, 8) staffing adequacy, 9) Social Status, 10) compensation and benefits	36	Revised based on PES-NWI and the Chinese version of PES-NWI	0.89

After comparing 5 scales, the scale used in this study was selected based on the following 4 principles: (1) Reliability: The consistency of the tool in measuring the nursing practice

environment across different settings and times. (2) Validity: The extent to which the tool measures what it purports to measure. (3) Comprehensiveness: The ability of the tool to cover all relevant dimensions of the nursing practice environment. (4) Applicability: The suitability of the tool for use in the Chinese healthcare context, considering cultural and organizational differences.

Given the complexity of the nursing practice environment, especially in the context of Chinese healthcare system, selecting the most appropriate scale is crucial for accurately capturing various factors that affect the efficiency of nursing human resources.

Five widely recognized scales: Nursing Work Index (NWI), Revised Nursing Work Index (NWI-R), Nursing Work Index Practice Environment Scale (PES-NWI), Perceived Nursing Work Environment (PNWE), and Nursing Practice Environment Assessment Scale (NPEAS). The evaluation of each scale is based on its ability to measure key dimensions of the nursing practice environment, such as nurse autonomy, leadership, nurse physician relationships, and resource adequacy, as well as its relevance to specific challenges faced by Chinese hospitals.

Although the Nursing Work Index (NWI) and the revised version of the Nursing Work Index (NWI-R) have historical significance and are widely used in Western medical environments, research has found that they are not very suitable for the current development of nursing practice in China. NWI was developed in the 1980s for measuring tissue characteristics in magnet hospitals but has since been criticized for lacking attention to the evolving nursing role and interdisciplinary collaboration. Although NWI-R has improved on the original scale, focusing on nurses' autonomy and control over practice, it still fails to capture the multidimensional aspects of leadership and teamwork that are essential in modern nursing environments, especially in high-pressure and resource limited environments like China.

Perceived Nursing Work Environment (PNWE) provides a comprehensive understanding of the nursing practice environment by measuring seven dimensions. However, PNWE has not been widely adopted in research beyond its initial development background. In pilot studies conducted in Chinese hospitals, its reliability was low, with Cronbach's alpha being 0.87. Its dimensional scope is broader, so it does not pay much attention to specific factors such as management leadership and resource adequacy, but these factors are crucial for understanding nursing efficiency in the Chinese context.

The Nursing Work Index Practice Environment Inventory (PES-NWI), with Cronbach's alpha of 0.91, shows the highest reliability, indicating strong internal consistency in its five core dimensions: nurse participation in hospital affairs, nursing quality foundation, nurse manager competence and leadership, staffing and resource adequacy, and colleague relationships

between nurses and doctors. PES-NWI focuses on management leadership and staffing adequacy, which is particularly relevant to the objectives of this study as these factors are crucial for understanding how to effectively utilize nursing resources in hospitals with varying levels of complexity and patient sensitivity.

The Nursing Practice Environment Assessment Scale (NPEAS) was developed based on the original and Chinese versions of PES-NWI, effectively retaining the advantages of PES-NWI. This scale was specifically developed for Chinese medical institutions, and its initial design considered the specific situation in China, including economic, social, and cultural factors, providing a way to evaluate the nursing practice environment in China within the context of Chinese culture. Afterwards, the scale underwent a process of improvement and refinement, which included three rounds of expert consultation. Conduct a questionnaire survey on nurses from 30 provinces, autonomous regions, and municipalities directly under the central government in China, and analyze the survey data using multiple linear regression method. Based on the regression coefficients of each possible key component of the scale and system, adjustments were made to certain items of the scale, and the final version of the scale was developed. Revised Nurse Practice Environment Assessment Scale with 36 items and 1 overall evaluation item. The score range for each item is 0 to 100. A score of 0 indicates' strongly disagree ', and a score of 100 indicates' strongly agree'. The higher the score, the better the practical environment. NPEAS has shown high reliability (Cronbach's alpha 0.89) and good effectiveness in addressing the unique organizational and cultural factors of Chinese hospitals. At present, the Nurse Practice Environment Assessment Scale is regularly used as a tool for the Chinese National Nursing Quality Data Platform to conduct research on tertiary hospitals.

The research subjects of this study are in China, and the Nurse Practice Environment Assessment Scale (NPEAS) has high reliability and effectiveness when used in tertiary hospitals in China, therefore it has been determined as the tool used in this study. It should be noted that this scale has 10 dimensions, although comprehensive, its length and complexity will pose certain challenges to research.

3.2.3 Validation of the Nurse Practice Environment Evaluation Scale

Confirmatory Factor Analysis (CFA) is a statistical technique used to test the hypothesis that a relationship between observed variables and their underlying latent constructs exists. Unlike Exploratory Factor Analysis (EFA), which explores the possible underlying factor structure without a preconceived theory, CFA is used to confirm or reject the hypothesized factor

structure.

The theoretical foundation of CFA is based on the common factor model. The basic CFA model can be represented by the equation 3.1:

$$\mathbf{x}=\mathbf{\Lambda}\boldsymbol{\xi}+\boldsymbol{\delta} \tag{3.1}$$

where:

x is a p × 1 vector of observed variables,

Λ is a p × n matrix of factor loadings,

ξ is an n × 1 vector of latent variables (factors),

δ is a p × 1 vector of measurement errors.

In CFA, the researcher specifies the number of factors, and the pattern of factor loadings based on theoretical considerations or previous research. The specified model is then tested to see if it fits the observed data.

For instance, in the context of the Nursing Practice Environment Assessment Scale (NPEAS), we hypothesize that there are several underlying factors such as nurse participation, professional practice, leadership, quality management, internal support, nurse/physician collaboration, professional development, staffing adequacy, social status, and compensation and benefits.

The model can be written as in equation 3.2:

$$\mathbf{x}=\mathbf{\Lambda}\boldsymbol{\xi}+\boldsymbol{\delta} \tag{3.2}$$

with

$$\Lambda = \begin{bmatrix} \lambda_{11} & 0 & \cdots & 0 \\ 0 & \lambda_{22} & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & \lambda_{10,10} \end{bmatrix}$$

The parameters of the CFA model, including factor loadings, variances, and covariances, are typically estimated using the Maximum Likelihood (ML) method. ML estimation aims to find parameter estimates that maximize the likelihood of observing the sample data given the specified model.

To evaluate how well the model fits the observed data, several fit indices are commonly used:

Chi-square test: A statistical test to assess the fit of the model. A non-significant Chi-square value suggests a good fit.

Root Mean Square Error of Approximation (RMSEA): Values less than 0.08 indicate a reasonable fit, while values less than 0.05 indicate a close fit.

Comparative Fit Index (CFI): Values greater than 0.90 are indicative of a good fit.

Tucker-Lewis Index (TLI): Values greater than 0.90 are indicative of a good fit.

CFA can be performed using various statistical software packages such as AMOS, LISREL, or Mplus. These packages provide tools for specifying the model, estimating parameters, and assessing model fit.

In the context of this study, CFA is used to validate the factor structure of the Nursing Practice Environment Assessment Scale (NPEAS). The NPEAS includes ten dimensions: nurse participation in hospital affairs, professional practice, leadership and communication, quality management, internal support, nurse/physician collaboration, professional development, staffing adequacy, social status, and compensation and benefits.

3.2.4 Using questionnaire survey method to evaluate the nursing practice environment

Questionnaire survey method refers to the method of collecting data by developing detailed and thorough questionnaires and requiring respondents to answer based on them. Questionnaire survey method is a commonly used tool for collecting data in social survey research activities. According to the different carriers, it can be divided into paper questionnaire surveys and online questionnaire surveys. Questionnaire survey is a valuable research tool, but it also has certain limitations: (1) Response bias: respondents may not always provide accurate or truthful answers. (2) Low response rate: Surveys, especially those distributed via email or online, may have low response rates, which may affect the representativeness of the data. (3) Limited depth: Questionnaire surveys typically provide quantitative data, which may lack the depth and background of qualitative data. When conducting a questionnaire survey, researchers should also consider ethical issues and achieve: (1) informed consent: ensuring that all respondents fully understand the purpose of the survey and agree to participate. (2) Confidentiality: Ensure the identity and answers of the respondents are kept confidential and only used for research purposes. (3) Voluntary participation: Ensure that participation is voluntary and respondents can withdraw at any time without penalty.

This study used a questionnaire survey method to systematically collect data on various aspects of the nursing practice environment. Follow the steps below to conduct the questionnaire survey.

The first step is to develop a Nurse Practice Environment Assessment Survey Questionnaire.

(1) Design of survey questionnaire. To ensure the scientificity and operability of the survey, the questionnaire design strictly follows the principles of probability and statistics, achieving

rationality, generality, logicality, clarity, non-inducement, and ease of organization and analysis. The basic structure of this survey questionnaire is divided into three parts, namely the beginning, background, and main body. The beginning section includes greetings, filling instructions, and acknowledgements. The background section contains personal information, including gender, age, education level, years of work experience, monthly personal pre tax income, staffing category, professional title, position, marital status, fertility status, monthly night shifts, department, etc. The main body, which is the core part of the survey questionnaire, is the Nurse Practice Environment Assessment Scale (NPEAS), consisting of 36 items and 1 overall evaluation item, with scores ranging from 0 to 100 for each item. A score of 0 indicates ‘strongly disagree’, and a score of 100 indicates 'strongly agree'.

(2) Validation and preliminary testing of the survey questionnaire. To ensure the validity and reliability of the questionnaire, preliminary testing was conducted on 30 nursing professionals. The feedback received during this testing phase will help improve the questionnaire, especially in enhancing the clarity of certain items. This verification process is crucial to ensure the achievement of the expected goals of nursing practice environment assessment.

(3) Create a survey questionnaire. Using the form of a questionnaire star, after completing the online production, generate a QR code for the questionnaire and conduct an online survey.

The detailed information on the "Nurse Practice Environment Assessment Survey Questionnaire" can be found in Appendix 1.

The second step is to distribute and collect the "Nurse Practice Environment Assessment Survey Questionnaire".

This study takes a tertiary hospital in Guangdong Province as an example, where the researcher works in the nursing department and is responsible for the hospital's nursing management. All 19 nursing units included in this study have head nurses.

Conduct training before distributing survey questionnaires. The researchers trained 19 head nurses, who then trained the nurses in their respective departments to ensure accuracy in filling out information.

Distribute survey questionnaires after training. Send the questionnaire star link or QR code of the "Nurse Practice Environment Assessment Survey Questionnaire" to the head nurse, and send it to the nurse for anonymous filling.

Questionnaire collection. The process lasted for two weeks. During this period, researchers can view the completion status of the questionnaire on the Wenjuanxing system, and promptly encourage and remind nurses to complete the survey. This method produces a robust response

rate, further improving the reliability of the research results.

After the survey was completed, the researchers exported all questionnaire data in Excel format through the Wenjuanxing system.

The third step is to statistically analyze and collect the "Nurse Practice Environment Assessment Survey Questionnaire".

Use Excel 2010 to build the database and use SPSS 22.0 statistical software package for data entry and statistical analysis. Count data is described using frequency and percentage; For metric data that conforms to a normal distribution, describe them as belonging and standard deviation, and use independent sample t-test for inter group comparison.

3.3 Nursing human resource efficiency

3.3.1 Research path for nursing human resource efficiency

Figure 3.2 shows an overview of the phases involved in analyzing nursing human resource efficiency.

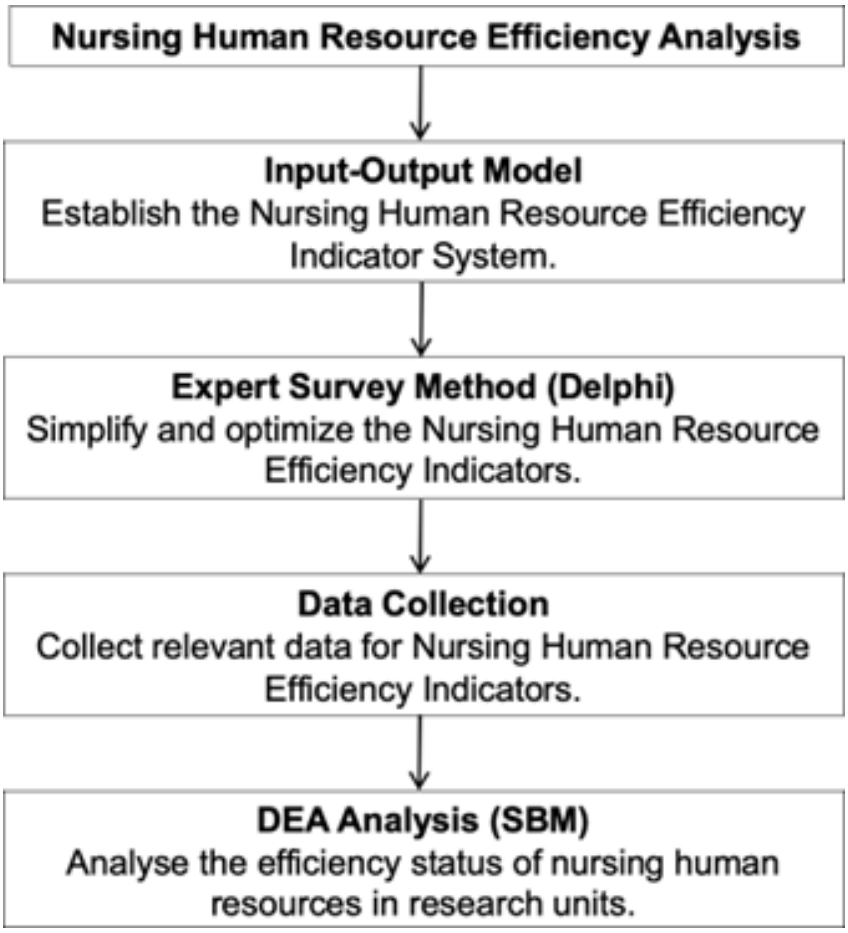

Figure 3.2 Research path of nursing human resource efficiency

Phase 1: Input-output model construction

An input-output model is established to construct a nursing human resource efficiency index system. Originating in the 1930s and pioneered by Wassily Leontief, this model describes and analyzes the interrelationships between different industries within an economic system. Modern input-output models have expanded to include complex economic systems and have been applied to fields such as environmental assessment, resource allocation, and policymaking. This model helps in quantifying the resources allocated and the outputs generated in the nursing sector.

Phase 2: Delphi method (expert consultation)

The Delphi method, also known as expert consultation, is employed to simplify and optimize the nursing human resource efficiency indicators. Experts provide feedback to refine these indicators, ensuring they are comprehensive and practical.

Phase 3: Data collection

Data relevant to the nursing human resource efficiency indicators are collected. This includes quantitative metrics such as staffing levels, patient outcomes, and resource utilization.

Phase 4: DEA analysis (SBM)

Data Envelopment Analysis (DEA) using the Slack-Based Measure (SBM) model is conducted. DEA is a non-parametric method based on linear programming that evaluates the relative efficiency of multiple input and output decision-making units (DMUs). This analysis evaluates the efficiency of nursing human resources across different units, providing insights into areas that require improvement.

3.3.2 Construction of nursing human resource efficiency system using input-output model

Nursing human resource efficiency is a comprehensive concept, and any single indicator can only reflect one aspect of nursing human resource efficiency. Building a sound input-output indicator system is the basis for scientifically and comprehensively evaluating nursing human resource efficiency.

The input-output theoretical model is one of the basic theories of health economics, and the indicator construction of nursing human resource efficiency at home and abroad is based on this model (Worthington, 2004). Evaluation indicators are divided into two categories: input indicators and output indicators. The former mainly examines the resource allocation of nursing management, including variables such as personnel allocation, materials, training and

development, workload, and financial investment (Babalola & Moodley, 2020; Okoroafor et al., 2022). Output indicators evaluate the outcomes or achievements of nursing services, including patient care quality, patient safety, healthcare use, employee satisfaction, and job burnout or turnover rates (Dubois et al., 2017; Endeshaw, 2021; Stemmer et al., 2022).

According to the research objectives, input and output indicators may vary. For example, Dubois et al. (2017) conducted an in-depth evaluation of nursing performance indicators, dividing them into three independent categories. These categories include 5 indicators related to the acquisition, allocation, and maintenance of human and material resources; 9 indicators focused on transforming these resources into services; and 11 indicators dedicated to evaluating patients' ability to change their condition.

Y. Weng et al. (2019) established a preliminary indicator system based on the input-output theory model through interviews and literature review. They conducted two rounds of expert inquiries with 30 experts using the Delphi method and constructed a nursing human resource efficiency indicator system consisting of 8 primary indicators, 18 secondary indicators, and 50 tertiary indicators. The input level indicators include human, material, financial, and service inputs, while the output indicators include nursing services, nursing safety, nursing quality, and teaching and research outputs. This indicator system demonstrates good reliability and scientificity, providing a basis for researchers to scientifically and reasonably evaluate the efficiency of nursing human resources.

Based on the construction of the nursing human resource efficiency index system by Weng Yanling and others, this study mainly combines relevant nursing index data from the China National Nursing Quality Management Center to further improve and modify it.

Based on the construction of the nursing human resource efficiency index system by Weng Yanling et al., this study mainly combined relevant nursing index data from the China National Nursing Quality Management Center to further improve and modify it. A nursing human resource efficiency index system with 60 indicators was established, including 17 input indicators and 43 output indicators (see Annex B).

Investment indicators: 1. Number of practicing nurses; 2. Number of nursing interns and trainees; 3. Number of nursing staff; 4. Proportion of nurses with different educational backgrounds; 5. Proportion of nurses with different professional titles; 6. Proportion of nurses with different years of work experience; 7. Proportion of nurses at different levels; 8. Proportion of specialized nurses; 9. Patient nurse ratio; 10. Bed protection ratio; 11. Medical staff ratio; 12. Proportion of nurses on sick and maternity leave; 13. Actual number of open beds; 14. Annual per capita pre tax income of nurses; 15. Funds for nurses to participate in continuing education

and training; 16. Funds allocated for nurses to conduct scientific research; 17. Average 24-hour nursing hours per hospitalized patient.

Output indicator: 18. Number of discharged patients; 19. Bed utilization rate; 20. Average length of hospital stay; 21. Number of critically ill patients; 22. Number of adverse nursing events; 23. Incidence of falls/bed falls; 24. The incidence of non-inevitable pressure ulcers in the hospital; 25. Unplanned extubation incidence rate; 26. Incidence of tube blockage in patients undergoing intubation; 27. Number of occurrences of drug extravasation in patients; 28. The number of errors in patient specimens; 29. Number of transfusion errors in patients; 30. Number of medication errors made by patients; 31. Number of patient identification errors; 32. Number of errors in the execution of nursing orders; 33. Incidence of catheter-related bloodstream infections in patients; 34. Incidence of catheter-related urinary tract infections in patients; 35. Incidence of ventilator-associated pneumonia in patients; 36. Number of occupational exposures among nurses; 37. Nurse theoretical assessment pass rate; 38. Qualification rate of nurses' operational skills assessment; 39. Nurse emergency response (including emergency plans) assessment pass rate; 40. Qualification rate of clinical competence assessment for nurses; 41. Patient first level nursing qualification rate; 42. Nursing qualification rate for critically ill patients; 43. The intact rate of emergency drugs and equipment; 44. Qualification rate of high-risk drug use and safety management; 45. Qualification rate of nursing document writing; 46. Implementation rate of health education; 47. Disinfection and isolation qualification rate; 48. Implementation qualification rate of nursing core system; 49. Patient rescue success rate; 50. Patient satisfaction; 51. Nurse satisfaction; 52. Doctor satisfaction; 53. Patient complaint rate; 54 nurse turnover rate; 55. Number of innovative inventions and practical patents for nurses; 56. Annual average number of papers published by nurses; 57. The number of nurses carrying out new technologies and services; 58. Number of specialized nurses at or above the provincial level; 59. Number of nurses who have completed standardized training; 60. Increase the number of graduates with nursing education.

3.3.3 Delphi method for screening nursing human resource efficiency indicators

Based on the 60 indicators system of nursing human resource efficiency constructed on the input-output model, taking into account the availability and effectiveness of indicator data, the Delphi method was used to simplify and optimize the nursing human resource efficiency indicators. This method involves a structured communication process, in which a selected group of experts provide feedback through multiple rounds of questionnaires, gradually refining

indicators until consensus is reached.

This study, based on the nursing human resource efficiency index system constructed by scholars such as Weng Yanling, considers the availability and effectiveness of index data, and uses the Delphi method to simplify and optimize the nursing human resource efficiency index. This method involves a structured communication process, in which a selected group of experts provide feedback through multiple rounds of questionnaires, gradually refining indicators until consensus is reached.

The first step is to select consulting experts.

Strictly select consulting experts based on research objectives and corresponding content to ensure the authority and reliability of this study. The selection criteria are: ① Working in a tertiary Grade A comprehensive hospital, medical school, professional academic institution, or health administrative department; ② The majors include nursing, hospital management, and medical statistics Experts are willing to participate in this research. Fourteen experts from tertiary hospitals, medical schools, provincial nursing associations, provincial health commissions, municipal nursing associations, and municipal health commissions were selected as survey experts. The sources of experts are shown in Table 3.2, and the overview of experts is shown in

Table 3.2 Expert list

Expert ID	Institution	Specialty	Title	Position
1	Hospital A	Nursing Management	Associate Senior	Head Nurse
2	Hospital B	Hospital Management	Intermediate	Director of HR Department
3	Hospital C	Nursing Management	Senior	Head Nurse
4	Hospital D	Nursing Management	Senior	Director of Nursing Department
5	Hospital E	Nursing Management	Associate Senior	Head Nurse
6	Hospital F	Nursing Management	Senior	Deputy Director of Nursing Department
7	Hospital G	Nursing Management	Senior	Director of Nursing Department
8	Hospital H	Financial Management	Senior	Chief Financial Officer
9	Hospital I	Hospital Management	Associate Senior	Vice President
10	Medical University J	Medical Statistics	Intermediate	Researcher
11	Provincial Nursing Society K	Nursing Management	Associate Senior	Committee Member
12	Provincial Health Commission L	Medical Statistics	Associate Senior	Director of Statistics Office

13	City Nursing Society D	Nursing Management	Senior	Deputy Director Committee
14	City Health Commission G	Hospital Management	Senior	Deputy Director

Basic information of 14 experts. Age:<40 years old, 3 people; 40-50 years old, 6 people 50 years old, 5 people. Education background: 5 undergraduate students, 8 master's students, and 1 doctoral student; Professional technical titles: 2 intermediate, 7 deputy senior, and 5 senior. Work experience:<10 years, 2 people; 10-20 years, 2 people 20 years, 10 people.

The second step is expert interviews.

Collect indicator data from the hospitals where two consulting experts are located according to the nursing human resource efficiency index system constructed by Y. Weng et al. (2019), and conduct interviews with these two experts. Draft interview outline: (1) How familiar are you with these indicators? (2) How do you assess these indicators? (3) How easy is it to collect these indicators? (4) How accurate are these indicator data? (5) Do you have anything else you would like to add besides the content covered in this interview? Due to the epidemic, online video communication was adopted.

Develop the first version of the inquiry questionnaire based on expert interviews.

Step three, expert inquiry.

After the finalization of the inquiry questionnaire, it will be stored in electronic format and distributed to experts via email. The research leader is required to provide detailed explanations to the experts on the background, basic methods, principles and implementation of the Delphi method, and design principles of the indicator system. Experts are asked to evaluate the importance and rationality of each indicator based on the questionnaire filling instructions, assign weights and importance scores to the indicators, and provide suggestions for modification, deletion, or supplementation until there is no feedback or revision content.

Round 1: Distribute the first version of the inquiry questionnaire electronically to experts and ask them to rate the importance of various indicators of nursing human resource efficiency on a scale of 1 to 5 according to the Likert scale. Experts can also provide opinions and propose new indicators.

Second round: Based on the feedback from the first round, the inquiry questionnaire was revised to form the second version, and the improved indicators were submitted to experts for further evaluation. This round of consultation aims to reach a consensus among experts on the most critical indicators.

The fourth step is statistical analysis.

Use SPSS 22.0 software to analyze research data, with count data represented as n/% and

metric data represented as (x ± s). The main statistical indicators include expert familiarity coefficient (Cs), judgment basis coefficient (Ca), authority coefficient (Cr), Kendall coordination coefficient, effective response rate, indicator weight, etc. $P<0.05$ indicates statistical significance of the difference.

3.3.4 DEA analysis of nursing human resource efficiency index data

Data Envelopment Analysis (DEA), introduced by A. Charnes and colleagues in 1978, is a widely recognized non-parametric technique used to assess the relative efficiency of decision-making units (DMUs) in systems with multiple inputs and outputs. This method is particularly valuable in evaluating the performance of complex organizations, such as healthcare institutions, where numerous resources contribute to diverse outcomes. DEA employs mathematical models and linear programming to construct a production frontier, which represents the optimal relationship between inputs and outputs. The analysis involves selecting various input and output data points from the Decision Unit and determining whether each point lies on or outside the efficiency frontier. In DEA, those units that lie on the production frontier are deemed "efficient" and are assigned an efficiency score of 1, signifying their optimal performance. Conversely, units that fall outside the frontier are considered "inefficient" and are given an efficiency score between 0 and 1, reflecting their relative inefficiency compared to the best-performing units. DEA is considered one of the best methods for evaluating the efficiency of healthcare institutions (Ahmed et al., 2019). This is mainly attributed to its ability to effectively handle multiple input and output variables simultaneously, providing a flexible and comprehensive evaluation. Based on the characteristics of data envelopment analysis, this study will use the data envelopment analysis method to analyze the efficiency of nursing human resources in the research unit.

The first step is to determine the research unit.

Convenience sampling method was used to screen the clinical nursing units of the hospital. Inclusion criteria: ① Homogeneity, all are inpatient wards, each nursing unit admits inpatients and provides nursing services and treatment according to service standards; ② A clinical nursing unit that is willing to participate in this study after training and has complete and reliable data. Exclusion criteria: ① Nursing units without inpatient beds, such as outpatient clinics, endoscopy centers, medical imaging departments, and neurology departments; ② Special departments such as emergency department, ICU, delivery room and other nursing units; ③ Clinical nursing units with incomplete research data. According to the above standards, a total

of 19 clinical nursing units were selected as research units, as shown in Table 3.3. A total of 19 clinical nursing units were selected as research units, as shown in Table 3.3.

Table 3.3 The 19 distinct decision-making units (DMUs)

DMU	Department
DMU1	Sports Medicine
DMU2	Spine Surgery (Division I)
DMU3	Spine Surgery (Division II)
DMU4	Pediatric Orthopedics
DMU5	Orthopaedics
DMU6	Shoulder and Elbow and Vascular Surgery
DMU7	Foot and Ankle Oncology
DMU8	General Surgery
DMU9	Gynecology
DMU10	Urology
DMU11	Pediatrics
DMU12	Neurology Physiatry
DMU13	Respiratory
DMU14	Cardiology Hematology
DMU15	Neurosurgery Rheumatology
DMU16	Gastroenterology
DMU17	Endocrinology Metabolism
DMU18	Thoracic surgery Traumatology
DMU19	Nephrology

The second step is to determine the indicators to measure nursing human resources efficiency.

A nursing human resource efficiency index system with 60 indicators was constructed based on the input-output model, and the Delphi method was used to simplify and optimize the nursing human resource efficiency indicators.

The research data will be calculated using the Data Envelopment Analysis method. According to the principle, the total number of input and output indicators should be less than half of the decision-making unit.

According to the above method, determine the indicators of nursing human resource efficiency for this study.

The third step is to collect data on nursing human resource efficiency indicators for the research unit.

Collection method: Based on the attributes of the indicators, relevant departments such as the Human Resources Department, Finance Department, Nursing Department, and Science and Education Department will be consulted.

Collection time: Data from 2020 and 2021.

Step four, determine the DEA analysis model.

When evaluating the efficiency of nursing human resources, the DEA method was chosen

to do achieve this goal by the literature review. Since its introduction by Charnes, Cooper, and Rhodes in 1978, data envelopment analysis (DEA), also known as the DEA-CCR model, has been widely utilized across various fields (Charnes et al., 1978). It treats the DMU as a black box and ignores the entire transformation process. The traditional DEA cannot provide sufficient management information for managers and decision-makers to evaluate their competitive strategies. Researchers have developed numerous modified DEA models based on the original CCR model. These modifications, also known as extensions, enable analysts to customize the DEA program according to the specific characteristics of the gathered data and the unique intricacies of the environment under investigation.

The CCR model is the most classic efficiency measurement model in DEA models. The CCR model assumes that the DMU is under a fixed scale reward and is used to measure overall efficiency. The CCR model focuses on maximizing output, and the measured data is called technical efficiency, which can evaluate overall efficiency.

The theoretical foundation of DEA is based on the concept of relative efficiency, comparing the performance of each DMU against the best performing ones. The general form of the linear programming DEA-CCR, which was the first DEA model, for DMU_0 is given in equation 3.3:

$$\textbf{Maximize } \theta = \sum_{r=1}^{s} u_r y_{r0} \tag{3.3}$$

$$\textbf{subject to}$$

$$\sum_{i=1}^{m} v_i x_{i0} = 1$$

$$\sum_{r=1}^{s} u_r y_{rk} - \sum_{i=1}^{m} v_i x_{ik} \leq 0 \quad \textbf{for k=1, 2, …, n}$$

$$v_1, \ldots, v_m \geq 0$$

$$u_1, \ldots u_m \geq 0$$

where:

θ is the efficiency score,

m and s are the number of inputs and outputs, respectively,

y_{rk} is the amount of output r produced by DMU k,

x_{ik} is the amount of input i used by DMU k,

u_r and vi are weights assigned to output r and input i, respectively,

The value of θ is not greater than 1. If θ is equal to 1 then DMU_0 is efficient, otherwise DMU_0 is inefficient.

In reality, unequal competition and inefficient allocation of resources can result in certain decision-making units (DMUs) not operating at their optimal scale. To address this issue, Banker, Charnes, and colleagues expanded the original DEA framework—which assumed fixed

economies of scale—by introducing the Banker-Charnes-Cooper (BCC) model in 1984. The BCC model relaxes the assumption of constant returns to scale and instead assumes that DMUs may operate under variable returns to scale (VRS). This model divides technical efficiency into two distinct components: pure technical efficiency and scale efficiency. Pure technical efficiency reflects the ability of a DMU to achieve the best possible output given a specific input level, independent of its size. In contrast, scale efficiency assesses whether a DMU is operating at an optimal scale, i.e., whether it is producing the maximum output at the most efficient scale of operation.

The Malmquist index, also referred to as the Total Factor Productivity (TFP) index, measures the changes in total factor productivity (TFP) across multiple periods. The Malmquist index decomposes the overall TFP change into two key components: technical efficiency change (Effch) and technological progress (Techch). Further decomposition of the efficiency change reveals two additional indexes: the pure technical efficiency change (Pech) and the scale efficiency change (Sech). This allows for a detailed examination of how productivity evolves over time, considering not only shifts in technology but also variations in the efficiency with which resources are utilized. The Malmquist index is particularly useful for analyzing dynamic changes in efficiency across decision-making units that involve multiple inputs and outputs, offering a comprehensive view of changes in resource utilization, technological advancements, and managerial improvements within a specified time frame.

Another widely used model for evaluating efficiency is the Slack-Based Measure (SBM), which assumes a monotonic linear relationship between inputs and outputs. The SBM model employs linear programming techniques to assess the relative efficiency of decision-making units. This model is particularly advantageous because it does not require the assumption of proportionality between inputs and outputs. The SBM model can be applied in three distinct orientations: input-oriented, output-oriented, and non-oriented. The input-oriented SBM seeks to minimize inputs while maintaining a fixed level of output, aiming to reduce resource usage. The output-oriented SBM, on the other hand, aims to maximize outputs while holding inputs constant, emphasizing productivity gains.

Table 3.4 lists the detailed information of these models and the reasons for selecting or not selecting each model.

Table 3.4 Modified DEA models and their selection rationale

Name of the modified DEA model	Strength of the model	Reason why choose or not choose this model
The Banker, Charnes, and Cooper (BCC) model	Enables more accurate evaluations of efficiency by considering the ideal scale size of DMUs during operation	Due to the limited and non-revisable DMUs in this study, this model was not suitable.
Slacks-Based Measure (SBM) Model	Enables a more detailed and nuanced examination of efficiency by directly measuring slack, hence offering valuable insights into specific inefficiencies within the inputs and outputs	This could help measure the input and output indicator with different units of measure, identify the key indicators and fits the objective of this study question.
Range-Adjusted Measure (RAM) Model	Boosting the applicability of Data Envelopment Analysis (DEA) in datasets with a wide range of values.	Due to the limited number of DMUs, the number of indicators is also restricted, making this model unsuitable.
Dynamic DEA Model	Well-suited for evaluating the progression of efficiency over time, a particularly advantageous aspect in longitudinal investigations	The main purpose of this study is not to examine changes in the efficiency of DMUs over time.
Fuzzy DEA Model	Handle uncertainty in input and output data in unpredictable contexts.	Since the context of this study is a stable hospital environment, this model is not suitable.

In this study, the SBM-DEA model was chosen. The inclusion of categorical inputs and outputs is another valuable expansion, addressing scenarios where DMUs operate under diverse conditions or provide distinct services that are not easily comparable. By classifying these inputs and outputs, the DEA model can examine each category separately, enhancing the relevance and significance of the efficiency evaluation. This model considers positive values for inputs and outputs and can handle both good and bad outputs, which may be separable or non-separable. Assuming independence between inputs and outputs, we consider a model with separable outputs. This model generalizes a non-oriented Slacks-Based Model for good outputs, and by differentiating between discretionary and nondiscretionary variables, it offers a more precise evaluation of a Decision-Making Unit's (DMU) efficiency within its operational limitations.

The Slacks-Based Measures (SBM) model, proposed by Tone (2001), enhances the traditional DEA making its efficiency evaluation invariant to the units of measure used for the different inputs and outputs. It directly incorporates slacks into the efficiency measurement. In this model, the objective is to minimize the slack variables, which represent input excesses and output shortfalls. The SBM efficiency measure, for DMU_0, is defined as equation 3.4:

$$\textbf{Minimize } \rho = \frac{1 - \frac{1}{m}\sum_{i=1}^{m} s_i^- / x_{i0}}{1 + \frac{1}{s}\sum_{r=1}^{s} s_r^+ / y_{r0}} \quad (3.4)$$

$$\textbf{subject to}$$

$$x_0 = \lambda X + s^-$$
$$y_0 = \lambda Y - s^+$$
$$\lambda \geq 0, s^- \geq 0, s^+ \geq 0$$

where:

ρ is the SBM efficiency score,

λ are the intensity variables,

X and Y are the input and output matrixes, respectively,

s^- and s^+ are the input and output slacks, respectively,

x_0 and y_0 are the inputs and outputs for DMU_0.

In case of separable good and bad outputs, the SBM model takes the form in 3.5:

$$\textbf{Minimize } \rho = \frac{1 - \frac{1}{m}\sum_{i=1}^{m} s_i^- / x_{i0}}{1 + \frac{1}{(s_1+s_2)}\left[\sum_{r=1}^{s_1} s_r^g / y_{r0}^g + \sum_{r=1}^{s_2} s_r^b / y_{r0}^b\right]} \quad (3.5)$$

subject to

$$x_0 = \lambda X + s^-$$
$$y_0^g = \lambda Y^g - s^g$$
$$y_0^b = \lambda Y^b + s^b$$
$$\lambda \geq 0, s^- \geq 0, s^g \geq 0, s^b \geq 0$$

where:

ρ is the SBM efficiency score,

s_1 and s_2 are the number of good and bad outputs, respectively,

λ are the intensity variables,

X, Y^g and Y^b are the input, the good and the bad output matrixes, respectively,

s^-, s^g and s^b are the input, the good output and the bad output slacks, respectively,

x_0, and y_0^b are the inputs, good outputs and bad outputs for DMU_0, respectively.

The SBM models presented equation 3.4 and 3.5 are not linear due to the objective functions. For the model involving good and bad outputs, the transformation proposed by Charnes et al. (1978), which consists in multiply the decision variables λ, s^-, s^g, s^b by t, obtaining $\lambda t = \Lambda, s^- t = S^-, s^g t = S^g, s^b t = S^b$,, allows to obtain the linear model:

$$\tau^* = \textbf{min } t - \frac{1}{m}\sum_{i=1}^{m} S_i^- / x_{i0} \quad (3.6)$$

subject to

$$1 = t + \frac{1}{(s_1+s_2)}\left[\sum_{r=1}^{s_1} S_r^g / y_{r0}^g + \sum_{r=1}^{s_2} S_r^b / y_{r0}^b\right]$$

$$x_0 t = X\Lambda + S^-$$
$$y_0^g = Y^g\Lambda - S^g$$
$$y_0^b = Y^b\Lambda + S^b$$
$$\Lambda \geq 0, S^- \geq 0, S^g \geq 0, S^b \geq 0, t > 0$$

The optimal objective value of this model is equal to its corresponding non-linear programming model. So, if $\tau^* = 1$ then DMU0 is efficient.

Step five, statistical analysis.

DEAP2.1 software from the University of Queensland was used to analyze and process the collected data on various nursing human resource indicators from 19 research units.

3.4 The relationship between nursing practice environment and nursing human resource efficiency

This section uses the quantitative and qualitative data collected in the previous sections to explore the complex relationship between nursing practice environment and nursing human resource efficiency.

Understanding the nurse practice environment is crucial for optimizing performance as it can directly impact the operational dynamics and resource allocation within hospital departments. By exploring and integrating various input indicators, such as dimensions of nursing practice environment assessment, and using advanced data analysis methods such as Data Envelopment Analysis (DEA), the aim is to identify factors that significantly affect the efficiency of nursing human resources.

3.4.1 Research path on nursing practice environment and nursing human resource efficiency

Figure 3.3 shows the research path for analyzing the relationship between nurse practice environment and nursing human resource efficiency.

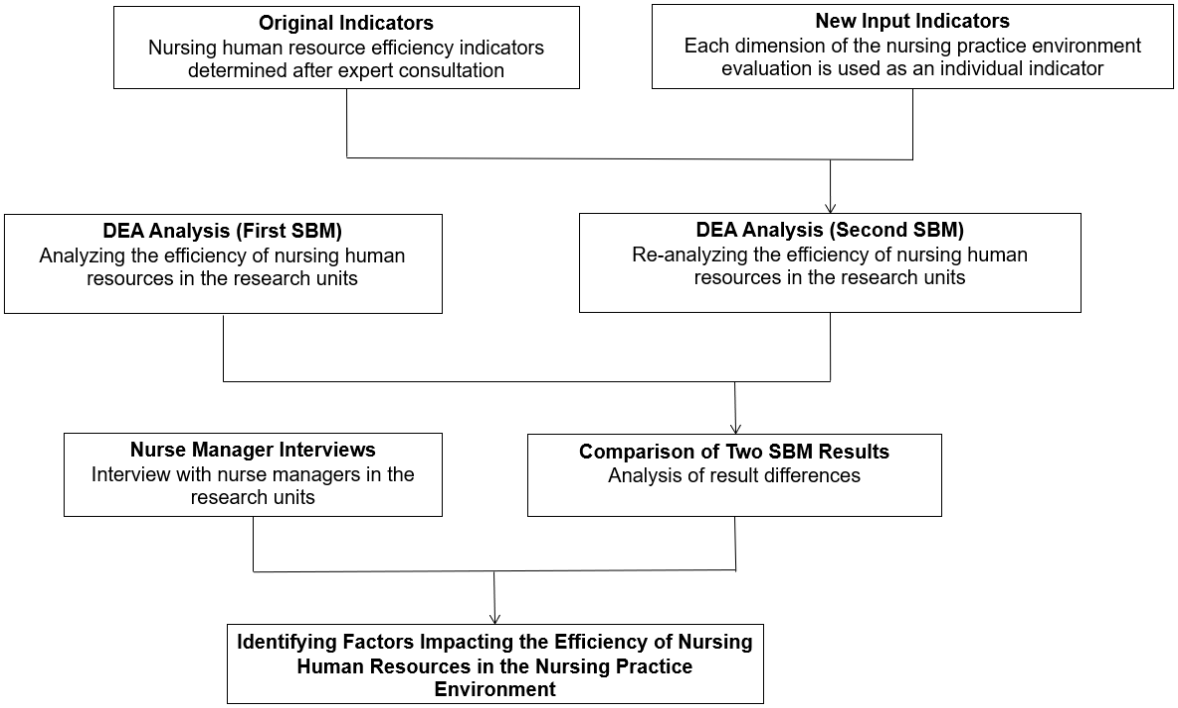

Figure 3.3 Research path on the relationship between nurse practice environment and nursing human resource efficiency

Step 1: To use the DEA SBM model for the second analysis of the nursing practice environment evaluation scale, which includes each dimension as one input indicator, four input indicators, and four output indicators determined by expert consultation.

Step 2: Compare the results of the second analysis of nursing human resource efficiency using the DEA SBM model with the results of the first analysis.

Step 3: Conduct interviews with head nurses from 19 research units.

Step 4: To compare the results of human resource efficiency data and explore the influencing factors of nursing practice environment on nursing human resource efficiency, based on the interviews with head nurses in 19 research units.

3.4.2 DEA second analysis of nursing human resource efficiency index data

The specific analysis method is the same as 3.3.4

This time, an additional investment indicator has been added. Using the DEA SBM model for the second analysis, each dimension of the nurse practice environment assessment scale is taken as one input indicator, and four input indicators and four output indicators are determined through expert consultation.

To evaluate the efficiency of nursing human resources, Data Envelopment Analysis (DEA) is conducted in two stages, each using slack based measurement (SBM) methods. The first DEA

analysis focused on evaluating the current efficiency levels within 19 decision units (DMUs). After preliminary analysis, new input indicators related to the nursing practice environment were introduced and a second DEA analysis was conducted to re-evaluate the nursing human resource efficiency of 19 DMUs, considering additional environmental factors.

Using the dimensions of the nursing practice environment as input can provide a more detailed understanding of the efficiency of nursing human resources. The comparison between the results of the first and second DEA analyses (SBM) shows that there may be differences in the effectiveness of DMU due to the inclusion of nurse practice environment factors that alter the efficiency score of nursing human resources.

3.4.3 Conduct interviews with head nurses from 19 research units

The interview method is a widely employed research technique that involves direct, oral communication between the researcher and the participants. It serves as a valuable tool for obtaining objective, factual information from respondents. This method is particularly effective in capturing the diverse perspectives of individuals, especially when addressing complex research questions that require a deep understanding of various viewpoints and experiences.

The relationship between the nursing practice environment and the efficiency of nursing human resources is a complex research question. The head nurse of the research unit, as the direct manager of the department and nursing team, has the best understanding of the actual situation on the clinical front line. Therefore, interviews were conducted with head nurses from 19 research units. The characterization of the head nurses is shown in Table 3.5

Table 3.5 Basic information of the head nurse on the 19 DMUs

DMU	Department	No.	Gender	Age	Education	Title
DMU1	Sports Medicine	1	Female	38	Bachelor's Degree	Associate Chief Nurse
DMU2	Spine Surgery(Division I)	2	Female	41	College Diploma	Nurse-in-Charge
DMU3	Spine Surgery(Division II)	3	Female	40	Bachelor's Degree	Nurse-in-Charge
DMU4	Pediatric Orthopedics	4	Female	32	Bachelor's Degree	Nurse-in-Charge
DMU5	Orthopaedics	5	Female	40	Bachelor's Degree	Nurse-in-Charge
DMU6	Shoulder and Elbow Vascular Surgery	6	Female	50	College Diploma	Nurse-in-Charge
DMU7	Foot and Ankle Oncology	7	Female	38	Bachelor's Degree	Associate Chief Nurse
DMU8	General Surgery	8	Female	36	Bachelor's Degree	Nurse-in-Charge

DMU9	Gynecology	9	Female	38	Bachelor's Degree	Nurse-in-Charge
DMU10	Urology	10	Female	40	Bachelor's Degree	Nurse-in-Charge
DMU11	Pediatrics	11	Female	30	Bachelor's Degree	Nurse-in-Charge
DMU12	Neurology Physiatry	12	Female	36	Bachelor's Degree	Nurse-in-Charge
DMU13	Respiratory	13	Female	40	Bachelor's Degree	Nurse-in-Charge
DMU14	Cardiology and Hematology	14	Female	38	Bachelor's Degree	Nurse-in-Charge
DMU15	Neurosurgery and Rheumatology	15	Female	35	Bachelor's Degree	Nurse-in-Charge
DMU16	Gastroenterology	16	Female	42	Bachelor's Degree	Nurse-in-Charge
DMU17	Endocrinology and Metabolism	17	Female	48	Bachelor's Degree	Nurse-in-Charge
DMU18	Thoracic surgery and Traumatology	18	Female	38	Bachelor's Degree	Nurse-in-Charge
DMU19	Nephrology	19	Female	52	Bachelor's Degree	Associate Chief Nurse

The first step is to determine the interview method.

Interview methods can be divided into structured interviews and unstructured interviews. The former is characterized by conducting interviews according to targeted standard procedures, usually using questionnaires or survey forms; The latter refers to free conversation without standardized procedures. This head nurse interview adopts a semi-structured interview.

The second step is to evaluate the interviewee.

The interviewees for this interview are head nurses from 19 research units. The 19 head nurses interviewed were all female, aged between 30 and 52, with an average age of 40; 2 people have a college degree and 17 people have a bachelor's degree; 16 with intermediate professional titles and 3 with senior professional titles; Responsible for the nursing management work of this research unit, with rich experience in nursing management.

Step three, develop an interview plan.

The purpose of the interview is to understand the head nurse's understanding of the nursing practice environment, nursing human resource management, and corresponding management measures or methods in this department.

The interview time is 45-60 minutes for each head nurse, and the plan is to complete interviews with 19 head nurses within 2 months.

The interview method can be conducted face-to-face or via video conference depending on the head nurses' situation.

Step four, develop an interview outline.

The selection of semi-structured interview format is to ensure consistency in the data collection process, while allowing respondents to flexibly elaborate on topics particularly relevant to their department. The purpose of this interview is to understand the head nurse's understanding of the nursing practice environment, nursing human resource management, and corresponding management measures or methods in this department. Develop a structured outline that includes open-ended questions on the following topics:

Nursing human resource efficiency: views on the results of nursing human resource efficiency in this department; Explore how to analyze the reasons and improvement measures for the efficiency results of nursing human resources in this department.

Personnel configuration and workload management: The issue focuses on the number of nurses assigned to each shift, the ratio of nurses to patients, and the task allocation among staff.

Challenges in nursing human resources mainly include nurse turnover rate, nurse burnout, and difficulties in recruiting nurses.

Nurse career development support: The interview also covered the availability of training programs, career development opportunities, and support provided for continuing education.

Nursing management practice: understanding the management strategies of head nurses, communication with employees, solving employee problems, and improving job satisfaction.

Step five, conduct a formal interview.

Obtain the consent of the head nurse before conducting the interview and choose the interview time and method according to the head nurse's personal wishes. Each interview lasts for 45 minutes to 1 hour and can be conducted face-to-face or via video conference. All interviews were recorded word for word and transcribed for analysis.

Step six, organize interview materials, analyze interview results, and draw interview conclusions.

The interview data was collected within two months, with sufficient time to schedule and conduct interviews with all 19 participants. Classify and organize the interview materials according to the interview outline. Interviews provide rich qualitative data, which is crucial for understanding the complex contextual factors that affect the professional environment of nurses in different hospital departments.

[This page is deliberately left blank.]

Chapter 4: Results

4.1 Results of the nursing practice environment

4.1.1 Confirmatory Factor Analysis (CFA) and Improvement of the Nurse Practice Environment Assessment Scale（NPEAS）

Initially, CFA was performed on the Chinese version of the NPEAS scale, which included 36 items across ten subscales:

Nursing Management (3 items): Items 2, 5, 32

Professional Practice (2 items): Items 3, 36

Leadership and Communication (4 items): Items 8, 12, 22, 29

Quality Management (6 items): Items 4, 10, 11, 13, 19, 25

Internal Support (5 items): Items 6, 21, 26, 31, 35

Nursing Competence and Work System (2 items): Items 7, 22

Improvement of Profession (4 items): Items 9, 24, 28, 34

Equipment of Manpower (5 items): Items 14, 15, 16, 17, 20

Social Status (2 items): Items 18, 27

Salary and Benefits (3 items): Items 30, 33, 37

Confirmatory Factor Analysis (CFA) was employed to verify the factor structure of the Nurse Practice Environment Assessment Scale (NPEAS). The initial model comprised ten subscales based on a previous exploratory factor analysis. However, the initial CFA showed a poor fit, necessitating further analysis to refine the model.

EFA was applied to identify the number of subscales (dimensions) present in the data. KMO value is excellent (KMO= 0.989) and the hypothesis the correlation matrix is an identity matrix is rejected (p-value=0.000 for Bartlett test of sphericity), so the data is adequate for this type of analysis. Varimax rotation was applied and loadings equal or greater than 0.4 were considered adequate for the interpretation of each subscale. The internal consistency of the construction was analyzed using the Alfa Cronbach coefficient, and a value greater than 0.70 is acceptable. Therefore, exploratory factor analysis (EFA) should be applied to determine the optimal number of subscales.

4.1.1.1 Analysis 1: 7 subscales

The first analysis allows the identification of 7 subscales which were named according to the variables with highest loadings in each subscale. The item situation, differences, and internal consistency of the 7 subscales are shown in Table 4.1.

Table 4.1 Items, differences, and consistency of the 7 subscales

Subscales	Number of items	Items	% Variance explained	Cronbach α
1. Nurse Participation in Hospital Management (NPHM)	5	5,2,32,24,6	16,9	0,936
2. Training and Quality Procedures (TQP)	7	34,35,36,20,13,31,9	15,5	0,941
3. Salary, Benefits and Working Conditions (SBWC)	7	37,30,33,16,14,26,28	13,1	0,958
4. Management Ability and Leadership (MAL)	7	29,12,23,8,19,25,21	11,9	0,962
5. Nursing Foundation for Care Quality (NFQC)	4	4,10,11,3	11,0	0,923
6. Nurse-Physician Collaboration (NPC)	4	7,22,27,18	8,1	0,921
7. Nurse Competence (NC)	2	15,17	5,2	0,854
Total	36		81,7	0,988

EFA revealed a seven-subscale solution that explained 81.7% of the total variance with high internal consistency (Cronbach's $\alpha > 0.85$ for all subscales). Further analysis using the rotation component matrix is in Table 4.2.

Table 4.2 Factor loadings rotated component matrix (7 subscales)

Items	Factor loadings	Subscale
5. Nurses have the opportunity to decide hospital affairs	,839	NPHM
2. Nurses have the opportunity to participate in the internal management of the hospital	,813	
32. Nurses have the opportunity to become a member of the hospital or nursing committee	,759	
24. Nurses have the opportunity to participate in academic activities at home and abroad	,551	
6. The functional management department of the hospital can support the work of nurses	,485	
34. The hospital has systematic training for new nurses	,797	TQP
35. The hospital has clear procedures to deal with nurses' occupational exposure, and can effectively implement them	,727	
36. The clinical work of the hospital can reflect the professionalism of nursing	,516	
20. Under normal circumstances, the backbone nurses of the department are not frequently transferred	,514	
13. The hospital management department expects each nursing unit to provide patients with high-standard nursing services	,507	
31. Nurses can obtain corresponding occupational protection at work	,476	
9. The hospital conducts continuing education for nurses based on job needs	,470	
37. Nurses can enjoy statutory benefits (such as: statutory holidays shifts or overtime subsidies, holidays, and insurance)	,601	SBWC
30. The hospital's salary allocation system is reasonable	,597	

33. The salary of nurses is at an appropriate level compared with workers in various industries of society	,584	
16. Existing working hours and intensity are appropriate	,564	
14. The nurse configuration of the nursing unit can meet the needs of clinical nursing work	,551	
26. The clinical support system allows nurses more time to take care of patients	,455	
28. The hospital has a clear career development path or professional title promotion system for nurses	,454	
29. When nurses make mistakes, nurse managers pay more attention to guiding and improving them instead of criticizing them blindly	,604	MAL
23. Nursing managers will discuss daily work issues with nurses	,603	
12. Nursing managers support nurses to make correct decisions	,580	
8. Nurses obtain encouragement and recognition when completing their work satisfactorily	,519	
19. The nursing team often discusses patients' nursing problems and seeks ways to improve	,492	
25. Nurses' scheduling is beneficial to continuous care of patients	,475	
21. The provision of nursing devices in the hospital is conducive to improving the efficiency of nurses	,402	
4. The responsibilities of each nursing position are clear	,697	NFQC
10. There is a perfect working system	,632	
11. There is thorough and directive workflow that is easy to implement	,590	
3. Nurses can evaluate patients in clinical nursing, and perform personalized nursing care based on the evaluation results	,448	
7. There is harmonious working relationship between physicians in the department and nurses	,668	NPC
22. Physicians in the department and nurses can perform their duties and work together	,535	
27. Nurses can feel the trust and respect of patients towards them at work	,481	
18. Nurses can be recognized by society	,462	
15. Nurses in the work team are competent for nursing work	,524	NC
17. Nurse scheduling considers nurses' competence and position level	,453	

Note: Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.
a. Rotation converged in 14 iterations.

4.1.1.2 Analysis 2: 5 subscales

The second analysis allows the identification of 5 subscales which were named according to the variables with highest loadings in each subscale. The item situation, differences, and internal consistency of the 5 subscales are shown in Table 4.3

Table 4.3 Items, Differences, and Consistency of the 5 subscales

Subscales	Number of items	Items	% Variance explained	Cronbach α
Management Ability and Leadership (MAL)	16	4,12,23,10,11, 29,19, 8,25,17, 13,36,3,20,15,31	22,9	0,977
Salary, Benefits and Working Conditions (SBWC)	12	30,33,16,14,37, 18,26,24,6,27, 28,21	19,7	0,972
Nurse Participation in Hospital Management (NPHM)	3	5,2,32	15,4	0,933
Training and Quality Procedures (TQP)	3	34,35,9	14,1	0,878

Nurse-Physician Collaboration (NPC)		2	7,22	7,3	0,883
Total		36		79,3	0,988

EFA revealed a five-subscale solution that explained 79.3% of the total variance with high internal consistency (Cronbach's $\alpha > 0.85$ for all subscales). Further analysis using the rotation component matrix is in Table 4.4.

Table 4.4 Factor loading rotated component matrix (5 subscales)

Item	Subscale
4. The responsibilities of each nursing position are clear	MAL
12. Nursing managers support nurses to make correct decisions	
23. Nursing managers will discuss daily work issues with nurses	
10. There is a perfect working system	
11. There is thorough and directive workflow that is easy to implement	
29. When nurses make mistakes, nurse managers pay more attention to guiding and improving them instead of criticizing them blindly	
19. The nursing team often discusses patients' nursing problems and seeks ways to improve	
8. Nurses obtain encouragement and recognition when completing their work satisfactorily	
25. Nurses' scheduling is beneficial to continuous care of patients	
17. Nurse scheduling considers nurses' competence and position level	
13. The hospital management department expects each nursing unit to provide patients with high-standard nursing services	
36. The clinical work of the hospital can reflect the professionalism of nursing	
3. Nurses can evaluate patients in clinical nursing, and perform personalized nursing care based on the evaluation results	
20. Under normal circumstances, the backbone nurses of the department are not frequently transferred	
15. Nurses in the work team are competent for nursing work	
31. Nurses can obtain corresponding occupational protection at work	
30. The hospital's salary allocation system is reasonable	SBWC
33. The salary of nurses is at an appropriate level compared with workers in various industries of society	
16. Existing working hours and intensity are appropriate	
14. The nurse configuration of the nursing unit can meet the needs of clinical nursing work	
37. Nurses can enjoy statutory benefits (such as: statutory holidays shifts or overtime subsidies, holidays, and insurance)	
18. Nurses can be recognized by society	
26. The clinical support system allows nurses more time to take care of patients	
24. Nurses have the opportunity to participate in academic activities at home and abroad	
6. The functional management department of the hospital can support the work of nurses	
27. Nurses can feel the trust and respect of patients towards them at work	
28. The hospital has a clear career development path or professional title promotion system for nurses	
21. The provision of nursing devices in the hospital is conducive to improving the efficiency of nurses	
5. Nurses have the opportunity to decide hospital affairs	NPHM
2. Nurses have the opportunity to participate in the internal management of the hospital	
32. Nurses have the opportunity to become a member of the hospital or nursing committee	
34. The hospital has systematic training for new nurses	TQP
35. The hospital has clear procedures to deal with nurses' occupational exposure, and can effectively implement them	
9. The hospital conducts continuing education for nurses based on job needs	

7. There is harmonious working relationship between physicians in the department and nurses	NPC
22. Physicians in the department and nurses can perform their duties and work together	

Note: Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.
a. Rotation converged in 11 iterations.

4.1.1.3 Comparison of the two solutions

The software program of IBM SPSS Amos 29.0 was to be utilized for this goal. There are many indicators of model fit, but none is regarded as the single best one (Davcik, 2014). Indices such as the χ2/df, CFI, GFI, RMSEA with 90% CI and MECVI, are generally considered to be reflective of the model's goodness of fit and are widely in use (Raykov & Marcoulides, 2006). These criteria are listed in the following table as well as their acceptable threshold levels. If the proposed theoretical model showed satisfactory results for most of them, the model could be deemed to have good fit. When comparing different models, the model with the lowest MECVI shows the best external validity. The fit indices and their acceptable thresholds are listed in Table 4.5.

Table 4.5 Fit indices and acceptable threshold levels

Fit Indices	Acceptable Threshold Levels	Sources
χ2/df	<5.0	Wheaton (1977)
RMR	<0.08	Hu and Bentler (1999)
GFI	>0.90	Tabachnick (2007)
AGFI	>0.90	Tabachnick (2007)
CFI	>0.90	Bentler (Bentler, 1990)
RMSEA	Very good if < 0.05 Good if < 0.08	Cudeck (2000)

The goodness-of-fit indices for the two models (seven-subscale and five-subscale solutions) are summarized in Table 4.6. Both models are acceptable, but the five-subscale model showed slightly higher fit values.

Table 4.6 Goodness-of-fit indices for the models

Indices	Model 1-5 Subscales	Model 2-7 Subscales
χ2/df	7.635	8.277
CFI	0.959	0.956
GFI	0.891	0.885
RMSEA	0.056	0.059
RMSEA 90% CI	0.055-0.058	0.057-0.060
MECVI	2.169	2.316

In Figure 4.1, The CFA results confirmed the suitability of the five-subscale model for the Chinese version of the NPE scale. This model provides a reliable and valid structure for assessing the nurse practice environment, facilitating further research and practical applications in nursing management.

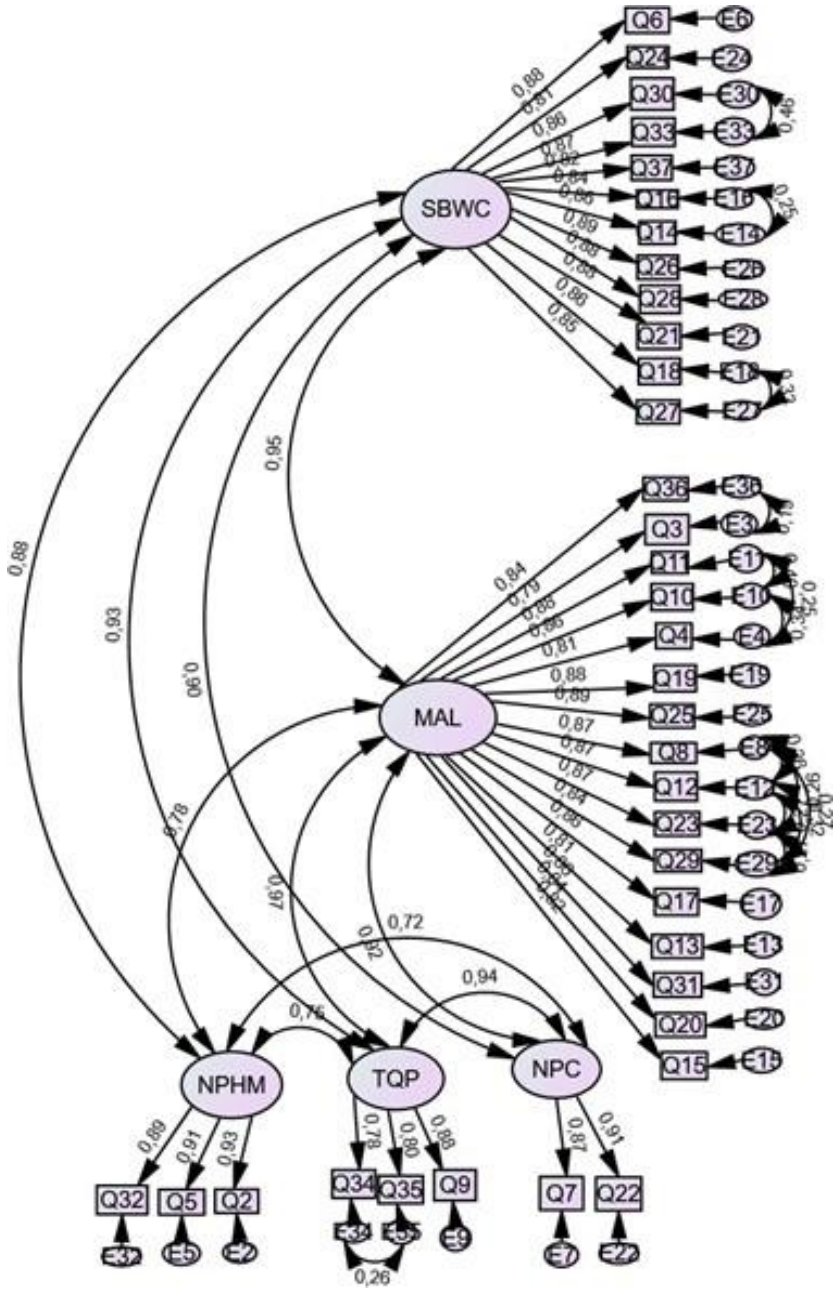

Figure 4.1 Five subscales measurement model

Based on these results, this study selected 5 subscale models for further analysis and application. The subscales included in the model are:

Management Ability and Leadership (MAL)

Salary Benefits and Working Conditions (SBWC)

Nurse Participation in Hospital Management (NPHM)

Training and Quality Procedures (TQP)

Nurse-Physician Collaboration (NPC)

To align with the concepts of Human Resource Management (HRM) and the Resource-Based View (RBV), and to ensure that these terms better reflect the essence of the items within

these subscales, the concept of organisational capabilities from the RBV has been emphasised. Consequently, the names of these five subscales have been optimised as follows:

Management and Leadership Capabilities (MLC)

Compensation and Administration Support (CAS)

Job Autonomy (JA)

Training and Development (TD)

Nurse-Physician Collaboration/Teamwork (NPCT).

4.1.2 Results of the Nurse Practice Environment Evaluation Scale for nineteen DMUs

A survey was conducted on nurses from 19 decision-making units (DMUs) using the Nurse Practice Environment Assessment Scale (NPEAS) to collect data on various aspects of the nurse practice environment. According to the optimized Nurse Practice Environment Assessment Scale (NPEAS) model (5 subscale models: Management and Leadership Capabilities (MLC), Compensation and Administration Support (CAS), Job Autonomy (JA), Training and Development (TD), Nurse-Physician Collaboration/Teamwork, (NPCT)), data statistical analysis was conducted.

A survey was conducted on nurses from 19 decision-making units (DMUs) using the Nurse Practice Environment Assessment Scale (NPEAS) to collect data on various aspects of the nurse practice environment. According to the optimized Nurse Practice Environment Assessment Scale (NPEAS) model (5 subscale models), namely Management Ability and Leadership (MAL), Salary, Benefits and Working Conditions (SBWC), Nurse Participation in Hospital Management (NPHM), Training and Quality Management (TQP), and Medical Collaboration (NPC), data statistical analysis was conducted.

In 2020, the total number of nurses in 19 research units was 358, with 336 eligible nurses for the survey. 336 survey questionnaires were distributed, 334 were collected, with a response rate of 99.4%. 331 qualified questionnaires were distributed, with a pass rate of 98.5%.

In 2021, the total number of nurses in 19 research units was 357, with 334 eligible nurses for the survey. 334 survey questionnaires were distributed and collected, with a 100% response rate. 332 qualified questionnaires were distributed, with a 99.4% pass rate.

4.1.2.1 Total scores

Figure 4.2 shows the total scores of the Nursing Practice Environment Assessment for 2020 and 2021. The scores indicate the overall perception of the nursing practice environment among the respondents.

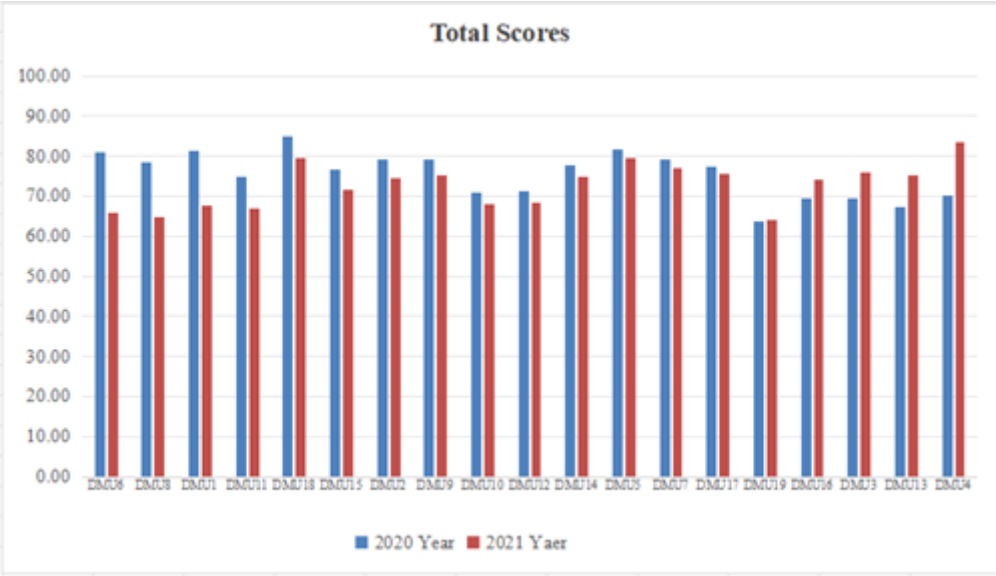

Figure 4.2 2020-2021 nursing practice environment assessment total scores

There are a total of 14 research units showing a downward trend, ranked in descending order of magnitude as follows: DMU6, DMU8, DMU1, DMU11, DMU18, DMU15, DMU2, DMU9, DMU10, DMU12, DMU14, DMU5, DMU7, DMU17.

There are a total of 4 research units showing an upward trend, ranked in descending order from low to high: DMU16, DMU3, DMU13, and DMU4.

There is one research unit that is basically flat, which is DMU19.

4.1.3 Management and Leadership Capabilities (MLC)

The scores for Management and Leadership Capabilities (MLC) for 2020 and 2021 are presented in Figure 4.3. These scores reflect the effectiveness of management and leadership within the nursing practice environment.

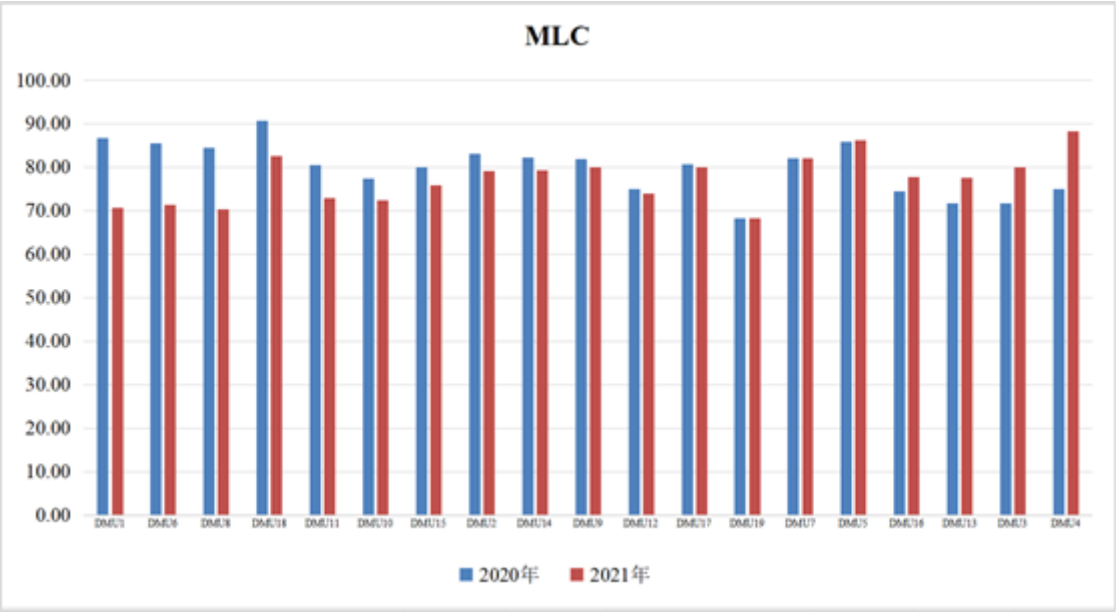

Figure 4.3 2020-2021 nursing practice environment assessment MLC scores

There are a total of 12 research units showing a downward trend, ranked in descending order of magnitude as follows: DMU1, DMU6, DMU8, DMU18,D MU11, DMU10, DMU15, DMU2, DMU9, DMU12, and DMU17.

There are a total of 4 research units showing an upward trend, ranked in descending order from low to high: DMU16, DMU13, DMU3,and DMU4.

There are three research units that are basically equal, namely DMU19, DMU7, and DMU5.

4.1.4 Nurse-Physician Collaboration/Teamwork (NPCT)

Figure 4.4 illustrates the scores for Nurse-Physician Collaboration/Teamwork (NPCT) for 2020 and 2021. These scores highlight the level of collaboration and communication between nurses and physicians.

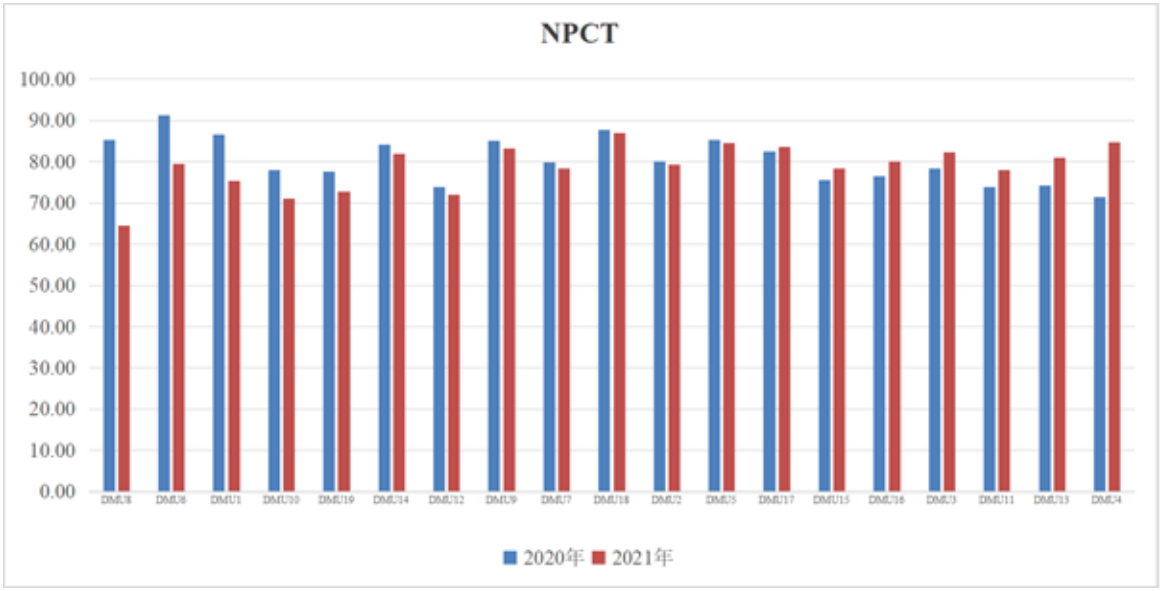

Figure 4.4 2020-2021 nursing practice environment assessment NPCT scores

There are a total of 14 research units showing a downward trend, ranked in descending order of magnitude as DMU8, DMU6, DMU1, DMU10, DMU19, DMU14, DMU12, DMU9, DMU7, DMU18, DMU2, and DMU5.

There are a total of 5 research units showing an upward trend, ranked in descending order from low to high: DMU17, DMU15, DMU16, DMU3, DMU11, DMU13, and DMU4.

4.1.5 Job Autonomy (JA)

The scores for Job Autonomy (JA) for 2020 and 2021 are depicted in Figure 4.5. These scores assess the degree to which nurses are involved in hospital management and decision-making processes.

Figure 4.5 2020-2021 nursing practice environment assessment JA scores

There are a total of 11 research units showing a downward trend, ranked in descending order of magnitude as follows: DMU9, DMU6, DMU1, DMU8, DMU11, DMU2, DMU15, DMU7, DMU17, DMU19, and DMU18.

There are a total of 7 research units showing an upward trend, ranked in descending order from low to high: DMU12, DMU5, DMU10, DMU3, DMU13, DMU4, and DMU16.

There is one research unit that is basically flat, which is DMU14.

4.1.6 Compensation and Administration Support (CAS)

Figure 4.6 presents the scores for Compensation and Administration Support (CAS) for 2020 and 2021. These scores reflect the satisfaction of nurses with their salary, benefits, and overall working conditions.

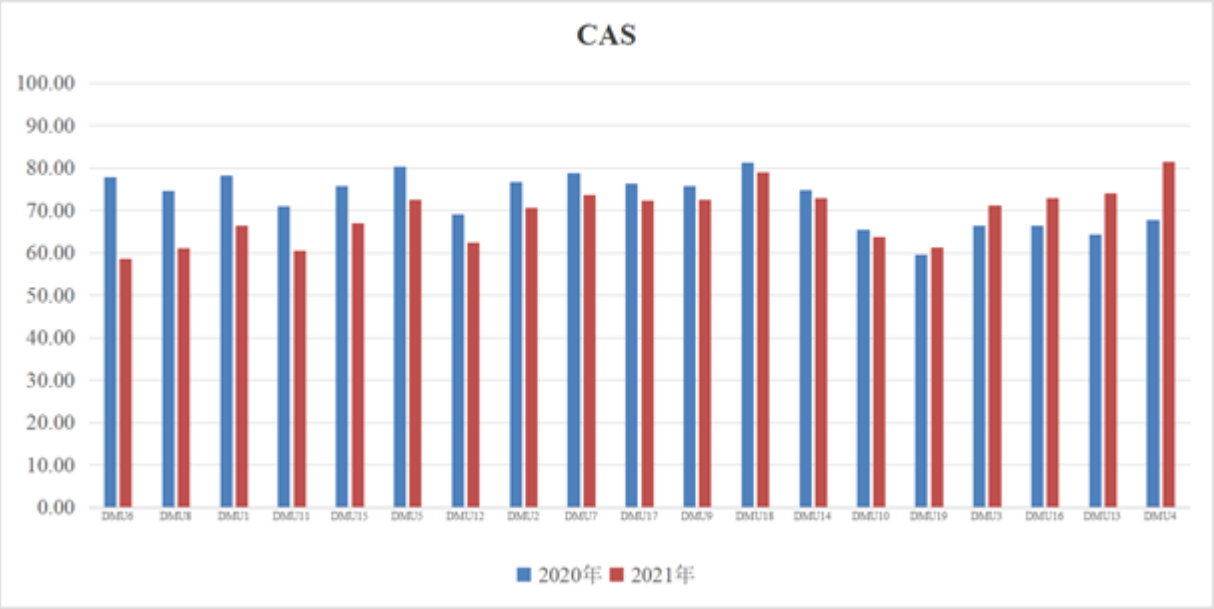

Figure 4.6 2020-2021 nursing practice environment assessment CAS scores

There are a total of 14 research units showing a downward trend, ranked in descending order of magnitude as follows: DMU6, DMU8, DMU1, DMU11, DMU15, DMU5, DMU12, DMU2, DMU7, DMU17, DMU9, DMU18, DMU14, and DMU10.

There are a total of 5 research units showing an upward trend, ranked in descending order from low to high: DMU19, DMU3, DMU16, DMU13, and DMU4.

4.1.7 Training and Development (TD)

The scores for Training and Development (TD) for 2020 and 2021 are shown in Figure 4.7. These scores evaluate the quality and availability of training and professional development opportunities for nurses.

Figure 4.7 2020-2021 nursing practice environment assessment TD scores

There are a total of 11 research units showing a downward trend, ranked in descending order of magnitude as follows: DMU1, DMU8, DMU18, DMU6, DMU11, DMU9, DMU14, DMU10, DMU16, DMU5, and DMU12.

There are a total of 7 research units showing an upward trend, ranked in descending order from low to high: DMU2, DMU17, DMU15, DMU19, DMU3, DMU4, and DMU13.

There is one research unit that is basically flat, which is DMU7.

4.1.8 Comparison of five dimensions in 2020 and 2021

Figures 4.8 and 4.9 provide a comparison of the Nursing Practice Environment Assessment scores across the five dimensions for the years 2020 and 2021.

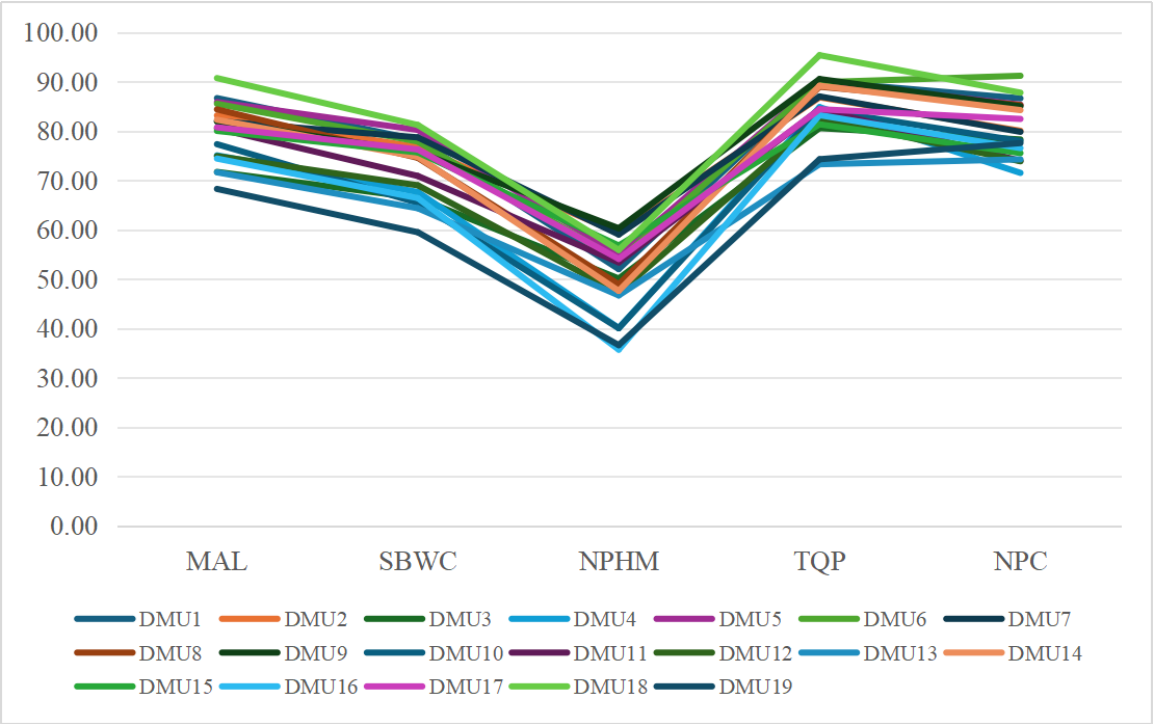

Figure 4.8 2020 nursing practice environment assessment scores based on five dimensions

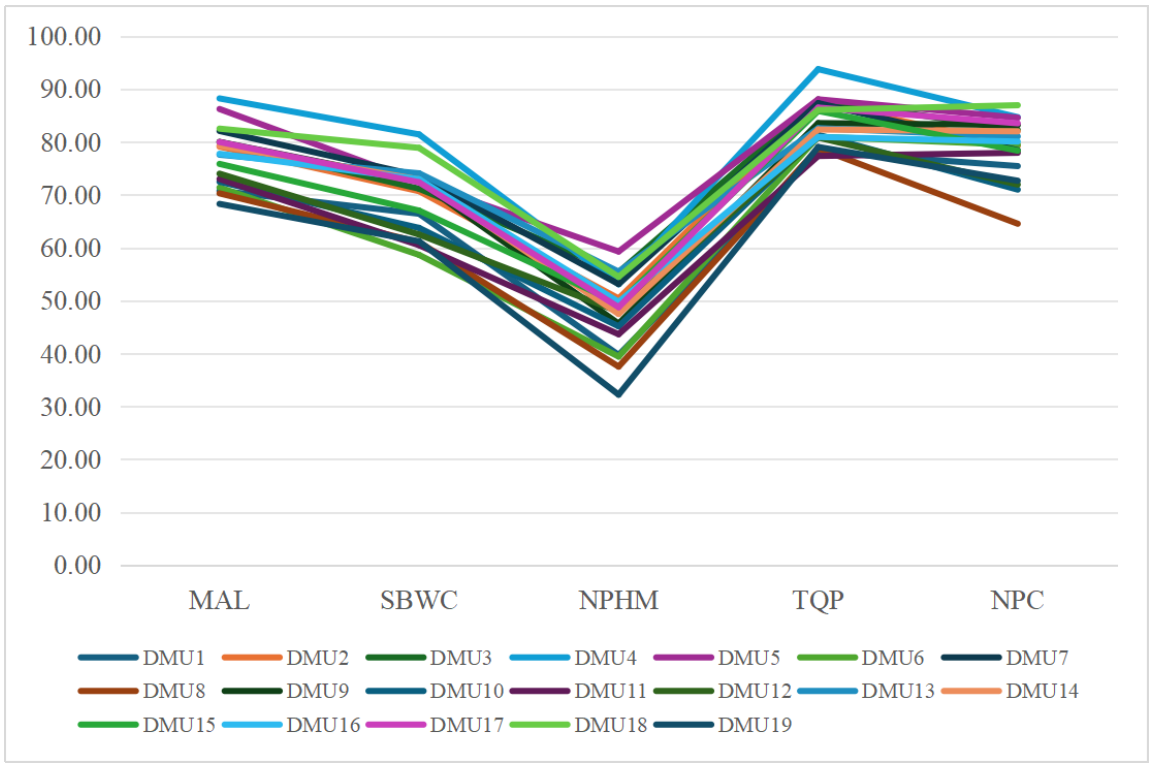

Figure 4.9 2021 nursing practice environment assessment scores based on five dimensions

The scores of the 5 dimensions from 2020 to 2021 show a consistent trend, sorted from low to high, as follows: JA, CAS, MLC, NPCT, TD.

4.1.9 Radar chart of nurse practice environment assessment scores for 19 research units from 2020 to 2021

Figures 4.10 and 4.11 show the radar charts of nurse practice environment assessment scores for 19 research units.

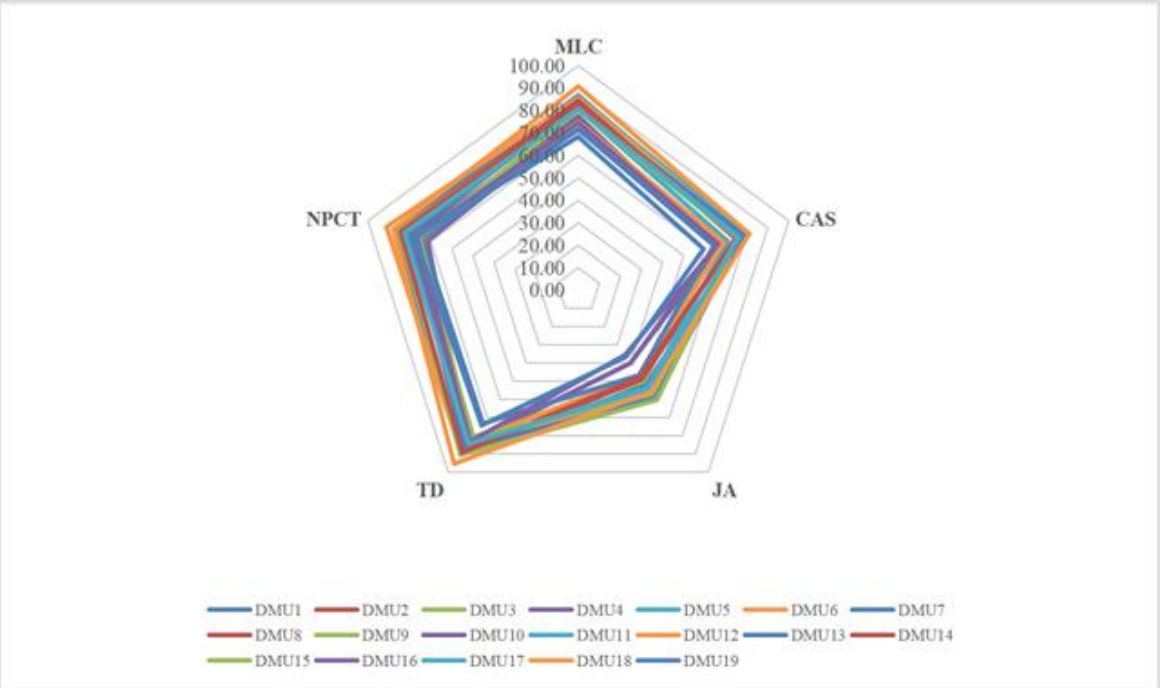

Figure 4.10 Radar chart of nurse practice environment evaluation scores for 19 research units in 2020

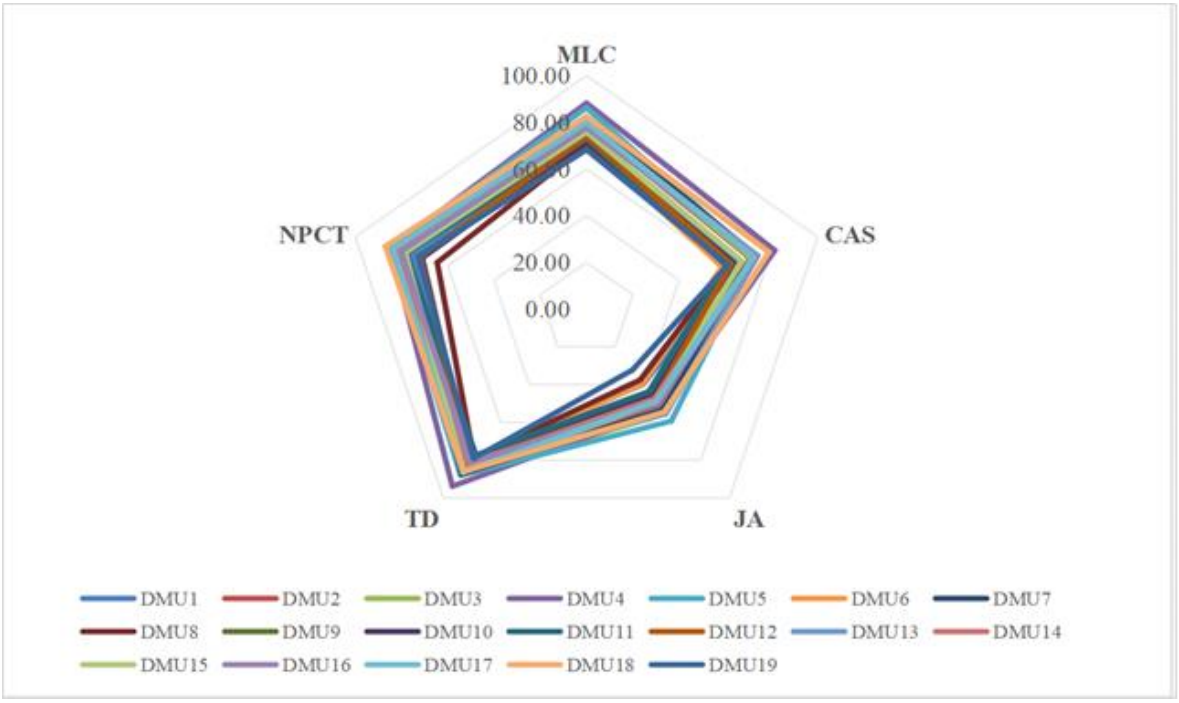

Figure 4.11 Radar chart of nurse practice environment evaluation scores for 19 research units in 2021

The scores of the 5 dimensions from 2020 to 2021 show a consistent trend, sorted from low

to high, as follows: JA, CAS, MLC, NPCT, TD.

4.2 Nursing human resource efficiency

4.2.1 Results of screening nursing human resource efficiency indicators using Delphi method

The Delphi method was employed in this study to refine the indicators for evaluating nursing human resource efficiency. Through a structured process involving multiple rounds of feedback from experts, a consensus was reached on the key performance indicators (KPIs) essential for assessing nursing efficiency across different hospital departments. The expert panel consisted of nursing leaders, hospital administrators, and healthcare policy experts, all of whom provided valuable insights during the iterative consultation process.

This study employs the questionnaire response rate to assess expert engagement. When the response rate is > 50%, it indicates that the collected data is suitable for analysis. If the response rate reaches 70%, it signifies a high level of expert participation, and the data quality is considered good. In this study, 14 inquiry questionnaires were distributed in both rounds, with a 100% response rate achieved in both rounds. In the first round, there was 1 invalid questionnaire, resulting in an effective response rate of 92.8%. In the second round, there were no invalid questionnaires, leading to a 100% effective response rate. Four individuals and one individual provided comments and suggestions in first and second round respectively.

Coefficient of reliability (Cr) is calculated as the arithmetic mean of coefficient of sense (Cs) and coefficient of adjudication (Ca). It is generally accepted that a Cr value of ≥ 70% is considered acceptable. Through calculations, for this round of expert consultations, the Cs value is 0.81, the Ca value is 0.86, and the Cr value is 0.84. This indicates that the experts participating in this study hold a high level of authority within the scope of this research field.

The degree of concentration of expert opinions on the importance of individual indicators is generally represented using the standard deviation (S), the mean of assigned importance values ($\overline{X}$), and the retention ratio. A smaller standard deviation, along with larger mean and retention rate, indicates a higher concentration of expert opinions, and thus, greater importance of the indicators.

The final set of key performance indicators agreed upon by the expert group includes input and output indicators that comprehensively measure the efficiency of nursing human resources. These indicators are designed to be applicable to different departments and hospitals, ensuring

broad relevance to various clinical environments. There are a total of 8 evaluation indicators for the efficiency of nursing human resources, including 4 input indicators: the number of practicing nurses, the actual number of open beds, the annual per capita pre-tax income of nurses, and the average 24-hour nursing hours per hospitalized patient. There are 4 output indicators: the number of discharged patients, the number of critically ill patients, the occurrence of nursing adverse events, and the nurse turnover rate. The specific calculation situation is shown in Table 4.7.

.

Table 4.7 Results of nursing human resources efficiency indicators

Category	Indicators	Retention Rate (%)	Importance			Accuracy		
			Mean ($\bar{X}$)	Standard deviation (SD)	Coefficient of variation (cv)	Mean ($\bar{X}$)	Standard deviation (SD)	Coefficient of variation (cv)
Input	Number of Licensed Nurses	84.62	4.73	0.65	0.14	5.00	0.00	0.00
	Active Beds	53.85	4.71	0.49	0.10	4.43	0.53	0.12
	Average Pre-tax Income per Nurse per Year	53.85	4.71	0.49	0.10	4.57	0.53	0.12
	Average Nursing Hours per 24 Hours per Inpatient	53.85	5.00	0.00	0.00	4.00	0.82	0.20
Output	Number of Discharged Patients	53.85	4.57	0.53	0.12	5.00	0.00	0.00
	Number of Critically ill patients	63.23	4.33	0.71	0.16	4.78	0.44	0.09
	Number of Nursing Adverse Events	100	4.62	0.51	0.11	4.62	0.51	0.11
	Nurse Turnover Rate	53.85	4.57	0.53	0.12	4.43	0.53	0.12

4.2.2 Results of nursing human resource efficiency in 19 research units

The first stage of DEA (Data Envelopment Analysis) uses indicators confirmed after Delphi expert consultation to evaluate the nursing human resource efficiency of 19 DMUs. The input indicators included the number of licensed nurses, active beds, average pre-tax income per nurse per year, and average nursing hours per 24 hours per inpatient. Output indicators, on the other hand, captured good outputs such as the number of discharged patients and the number of critically ill patients, while bad outputs included nursing adverse events and the nurse turnover rate. SBM model is used for analysis.

Explanation of Indicator Definition:

(1) Number of practicing nurses refers to the total number of on-the-job nurses who participated in nursing services in the department

(2) Actual number of open beds refers to the number of beds provided by the department for the treatment and nursing of patients.

(3) Annual per capita pre-tax income of nurses refers to the per capita amount of income of nurses in the department before tax (in 10000 yuan).

(4) Average nursing hours per hospitalized patient per 24 hours: The average nursing hours provided by nurses per hospitalized patient within 24 hours.

(5) Number of discharged patients refers to the total number of discharged patients during the department's investigation period.

(6) Number of critically ill patients refers to the number of critically ill cases classified as type D in the department during the investigation period.

(7) Number of nursing adverse events refers to the total number of nursing adverse events occurring within the department during the investigation period.

(8) Nurse turnover rate refers to the ratio of the number of nurses leaving a department during the survey period to the average number of nurses at the beginning and end of the department.

Explanation of numerical meaning:

(1) Input value: A value of 0 indicates the optimal utilization of resources. An input value greater than 0 indicates that the utilization rate is not ideal enough.

(2) Output value: Good output: Positive values indicate a beneficial impact on DMU efficiency. The number of discharged patients and critically ill patients are good output indicators. Bad output: Positive values indicate adverse effects on DMU efficiency. The number

of nursing adverse events and nurse turnover rate are poor output indicators. For efficient DMUs, the output values are equal to 0.

(3) Efficiency: A measure of the efficiency of nursing human resources in research units, where 1 represents complete efficiency and values below 1 indicate varying degrees of efficiency.

4.2.2.1 Results of nursing human resource efficiency in 19 decision-making units in 2020

Table 4.8 shows the efficiency results of nursing human resources in 19 decision-making units in 2020, specifically:

Table 4.8 Results of nursing human resource efficiency for each DMU in 2020

DMU	Number of Active Beds Licensed Nurses		Average Pre-tax Income per Nurse per Year	Average Nursing Hours per 24 Hours per Inpatient	Good output: Number of Discharged Patients	Good output: Number of Critically ill patients	Bad output: Number of Nursing Adverse Events	Bad output: Nurse Turnover Rate	Efficiency
1	0	0	0	0	0	0	0	0	1
2	5,7464	19,679	13,648	1,4487	0	117,78	0	0	0,0594
3	0	0	6,4267	0,0395	0	79,625	0	0,0474	0,1773
4	0	0	0	0	0	0	0	0	1
5	0	0	0	0	0	0	0	0	1
6	0	0	0	0	0	0	0	0	1
7	0	0	0	0	0	0	0	0	1
8	0	0	0	0	0	0	0	0	1
9	0,2223	0	3,3332	1,3439	0	44,836	8,2224	0,1261	0,2729
10	0	6,669	0,7729	0,4161	0	33,281	0	0	0,5792
11	0	0	0	0	0	0	0	0	1
12	0	0	0	0	0	0	0	0	1
13	0	0	0	0	0	0	0	0	1
14	0	0	0	0	0	0	0	0	1
15	0	0	0	0	0	0	0	0	1
16	5,836	1,1293	6,3136	0,6337	0	0	0,3359	0,0541	0,5708
17	5,4268	17,839	6,6212	1,0198	0	0	1,6506	0	0,5145
18	4,5739	26,142	7,4253	1,2606	0	0	3,1931	0,1686	0,3187
19	0	6,1529	4,1861	1,0941	0	0	0,9976	0,0463	0,64

(1) The nursing human resource efficiency result (=1) showed that there were 11 DMUs, including DMU1, DMU4, DMU5, DMU6, DMU7, DMU8, DMU11, DMU12, DMU13, DMU14, and DMU15, accounting for 57.89%.

(2) The nursing human resource efficiency result (<1) showed that there were 8 DMUs, including DMU2, DMU3, DMU9, DMU10, DMU16, DMU17, DMU18, and DMU19, accounting for 42.11%.

From the perspective of input indicators: all the 8 inefficient decision-making units (DMUs) show positive slack in both "annual pre-tax income per nurse" and "average nursing hours per hospitalized patient every 24 hours," indicating an excess in average income and nursing time inputs. Six DMUs (DMU2, DMU10, DMU16, DMU17, DMU18, DMU19) have positive slack in "actual number of open beds," suggesting that the number of beds in operation exceeds the necessary amount in these units. Five DMUs (DMU2, DMU9, DMU16, DMU17, DMU18) exhibit positive slack in "number of practicing nurses," indicating that the number of nurses exceeds the required number in these units.

From the perspective of output indicators: none of the inefficient decision-making units show slack in "number of discharged patients," hence the quantity of discharged patients does not fall below the appropriate level when compared to efficient units. However, four inefficient DMUs (DMU2, DMU3, DMU9, DMU10) have positive slack in "number of critical patients," implying that the number of critical patients in these units is lower than expected when compared to efficient units. Five inefficient DMUs (DMU9, DMU16, DMU17, DMU18, DMU19) show positive slack in "number of nursing adverse events," suggesting that these units have a higher number of nursing adverse events than expected. Lastly, five inefficient DMUs (DMU3, DMU9, DMU16, DMU18, DMU19) have positive slack in "nurse turnover rate," indicating that these units have higher nurse turnover rates than expected when compared to efficient units.

(3) The DEA analysis of 2020 revealed a significant variation in the efficiency of the DMUs. Out of the 19 DMUs, 11 were classified as efficient with an efficiency score of 1, representing full efficiency. In contrast, 8 DMUs were found to be inefficient, with efficiency scores below 1, indicating suboptimal utilization of nursing resources. Among the inefficient DMUs, DMU2 and DMU3 were the least efficient, with scores of 0.0594 and 0.1773, respectively, reflecting challenges related to resource allocation and workload distribution in high-demand departments.

(4) Among the 19 DMUs, the proportion of efficient decision-making units is only 57.89%, which has not reached 80%, reflecting the overall low efficiency of nursing human resources in the hospital's inpatient ward and insufficient utilization of nursing resources.

4.2.2.1 Results of nursing human resource efficiency in 19 decision-making units in 2021

Table 4.9 shows the efficiency results of nursing human resources in 19 decision-making units in 2021, specifically:

Table 4.9 Results of nursing human resource efficiency for each DMU in 2021

DMU	Number of Licensed Nurses	Active Beds	Average Pre-tax Income per Nurse per Year	Average Nursing Hours per 24 Hours per Inpatient	Good output: Number of Discharged Patients	Good output: Number of Critically ill patients	Bad output: Number of Nursing Adverse Events	Bad output: Nurse Turnover Rate	Efficiency
1	4,3941	27,274	4,9344	0	0	253,3	0,8771	0	0,0486
2	10,706	25,485	13,288	1,2879	0	65,928	0	0,0571	0,0426
3	0,9572	0	9,0018	0,8658	0	251,56	0,2479	0	0,0476
4	0	8,4125	5,031	0,288	0	160,35	0,34	0	0,0582
5	0,9935	9,9853	7,3681	0,6179	0	217,67	0,285	0,0182	0,1558
6	6,0808	17,102	2,3288	1,2693	0	48,373	1	0,0645	0,3584
7	0	0	0	0	0	0	0	0	1
8	0	0	0	0	0	0	0	0	1
9	0	0	0	0	0	0	0	0	1
10	0	0	0	0	0	0	0	0	1
11	0	0	0	0	0	0	0	0	1
12	0	0	0	0	0	0	0	0	1
13	0	0	0	0	0	0	0	0	1
14	0	0	0	0	0	0	0	0	1
15	11,151	17,568	0	0,7855	0	0	3,0777	0,0456	0,5936
16	7,3157	3,9505	1,5829	0,2767	0	20,497	2	0,0541	0,5074
17	5,5186	19,146	4,9306	0,8609	0	0,8609	0	0,0741	0,3783
18	2,8725	17,329	3,1007	0,5391	365,96	0	0	0,2857	0,5191
19	6,5704	20,992	9,1544	1,0544	0	0	1,8667	0,0657	0,3454

(1) The nursing human resource efficiency result (=1) showed that there were 8 DMUs, including DMU7, DMU8, DMU9, DMU10, DMU11, DMU12, DMU13, and DMU14, accounting for 42.11%.

(2) The nursing human resource efficiency result (<1) showed that there were 11 DMUs, including DMU1, DMU2, DMU3, DMU4, DMU5, DMU6, DMU15, DMU16, DMU17, DMU18, and DMU19, accounting for 57.89%.

From the input indicators perspective, 10 decision-making units (DMU1, DMU2, DMU3, DMU5, DMU6, DMU15, DMU16, DMU17, DMU18, DMU19) have positive slack in "number of practicing nurses." Therefore, in these units, the number of practicing nurses is higher than necessary. 10 decision-making units (DMU1, DMU2, DMU4, DMU5, DMU6, DMU15, DMU16, DMU17, DMU18, DMU19) have positive slack in "actual number of open beds." Thus, in these units, the actual number of open beds is higher than required. 10 decision-making units (DMU1, DMU2, DMU3, DMU4, DMU5, DMU6, DMU16, DMU17, DMU18, DMU19) have positive slack in "average pre-tax annual income per nurse." Therefore, there is an input surplus in "average pre-tax annual income per nurse" in these units. 10 decision-making units (DMU2, DMU3, DMU4, DMU5, DMU6, DMU15, DMU16, DMU17, DMU18, DMU19) have positive slack in "average nursing hours per inpatient per 24 hours." Consequently, there is an input surplus in nursing hours in these units.

Turning to the output indicators, certain units demonstrate a positive slack that indicates their performance exceeds expectations in specific areas. For example, one inefficient unit (DMU18) shows positive slack in the "number of discharged patients", meaning it has performed better in this area compared to its peers, discharging more patients than expected.In contrast, six inefficient units (DMU1, DMU3, DMU4, DMU5, DMU15, DMU19) show positive slack in the "number of adverse nursing events", meaning these units have a higher incidence of such events compared to their more efficient counterparts. Finally, eight inefficient units (DMU2, DMU5, DMU6, DMU15, DMU16, DMU17, DMU18, DMU19) demonstrate positive slack in "nurse turnover rate". This indicates that these units experience a higher rate of nurse turnover than would be expected.

(3) The DEA analysis of 2021 revealed a significant variation in the efficiency of the DMUs. Out of the 19 DMUs, 8 were classified as efficient with an efficiency score of 1, representing full efficiency. In contrast, 11 DMUs were found to be inefficient, with efficiency scores below 1, indicating suboptimal utilization of nursing resources. Among the inefficient DMUs, DMU2, DMU3, DMU1 and DMU4 were the least efficient, with scores of 0.0426, 0.0476, 0.0486 and

0.0582, respectively, reflecting challenges related to resource allocation and workload distribution in high-demand departments.

(4) Among the 19 DMUs, the proportion of efficient decision-making units is only 42.11%, which has not reached 50%, reflecting the overall low efficiency of nursing human resources in the hospital's inpatient ward and insufficient utilization of nursing resources.

4.2.2.3 Comparison of nursing human resource efficiency results among 19 decision-making units in two years

Table 4.10 shows a comparison of the efficiency results of nursing human resources in 19 decision-making units from 2020 to 2021, specifically:

Table 4.10 Comparison between two years

	2020	**2021**
DMU	Eff.	Eff.
1	1	0,0486
2	0,0594	0,0426
3	0,1773	0,0476
4	1	0,0582
5	1	0,1558
6	1	0,3584
7	1	1
8	1	1
9	0,2729	1
10	0,5792	1
11	1	1
12	1	1
13	1	1
14	1	1
15	1	0,5936
16	0,5708	0,5074
17	0,5145	0,3783
18	0,3187	0,5191
19	0,64	0,3454

(1) DMU with unchanged efficiency results in nursing human resources the past two years

The results of the two-year nursing human resource efficiency were all (=1), and the effective decision-making units were DMU7, DMU8, DMU11, DMU12, DMU13, and DMU14, totaling 6, accounting for 31.58%.

The results of the two-year nursing human resource efficiency were all (<1), and the decision-making units with low efficiency are DMU2, DMU3, DMU16, DMU17, DMU18, And DMU19, a total of 6, accounting for 31.58%.

(2) DMU with changed efficiency results in nursing human resources for the past two years

The results of nursing human resource efficiency have changed from (=1) to (<1), from efficient to inefficient.The decision-making units are DMU1, DMU4, DMU5, DMU6, and

DMU15, totaling 5, accounting for 26.31%.

The results of nursing human resource efficiency have changed from (<1) to (=1), from inefficient to efficient. The decision-making units are DMU9 and DMU10, totaling 2, accounting for 10.53%.

In 2021 the nursing human resource efficiency result (=1) showed that there were 8 DMUs, a decrease of 3 compared to 2020. In 2021 the nursing human resource efficiency result (<1) showed that there were 11 DMUs, an increase of 3 compared to 2020. It can be reflected that the efficiency of nursing human resources in the inpatient ward of the hospital has decreased in 2021, and the utilization of nursing resources is seriously inadequate.

4.3 Relationship between nurse practice environment and nursing human resource efficiency

4.3.1 Application of nurse practice environment evaluation results in nursing human resource efficiency evaluation

4.3.1.1 Comparison of nursing human resource efficiency results between the 19 research units

Follow the steps below: (1) Use the scores of the five dimensions of the annual nurse practice environment assessment as one new input indicator (the fifth input indicator) and conduct a second DEA analysis together with the original eight indicators to obtain five new results. (2) 2020 and 2021 will be recalculated according to the above distribution. (3) Compare the results of the first SBM analysis with the results of the second SBM analysis each year.

Compare the results of the first SBM analysis in 2020 and 2021 (without including the nurse practice environment assessment score) with the results of the second SBM analysis (including the nurse practice environment assessment score) before and after, as shown in Table 4.11.

Table 4.11 Comparison of SBM analysis in 2020 and 2021

DMU	2020 The first analysis of Eff.	The second analysis of Eff.					2021 The first analysis of Eff.	The second analysis of Eff.				
		MAL	SBWC	NPHM	TQP	NPC		MAL	SBWC	NPHM	TQP	NPC
DMU1	1	1	1	1	1	1	0,0486	1	1	1	1	1
DMU2	0,0594	0.07265	0.07253	0.07072	0.07319	0.07324	0,0426	0.07292	0.07289	0.07254	0.07242	0.07303
DMU3	0,1773	0.20902	0.21002	0.20855	0.20707	0.20443	0,0476	0.20434	0.20393	0.2018	0.20338	0.20176
DMU4	1	1	1	1	1	1	0,0582	1	1	1	1	1
DMU5	1	1	1	1	1	1	0,1558	1	1	1	1	1
DMU6	1	1	1	1	1	1	0,3584	1	1	1	1	1
DMU7	1	1	1	1	1	1	1	1	1	1	1	1
DMU8	1	1	1	1	1	1	1	1	1	1	1	1
DMU9	0,2729	1	1	1	1	1	1	1	1	1	1	1
DMU10	0,5792	0.52873	0.53516	0.54994	0.52552	0.52835	1	0.52311	0.52078	0.51733	0.52035	0.51917
DMU11	1	1	1	1	1	1	1	1	1	1	1	1
DMU12	1	1	1	1	1	1	1	1	1	1	1	1
DMU13	1	1	1	1	1	1	1	1	1	1	1	1
DMU14	1	1	1	1	1	1	1	1	1	1	1	1
DMU15	1	1	1	1	1	1	0,5936	1	1	1	1	1
DMU16	0,5708	0.49684	0.49761	0.51937	0.49344	0.49438	0,5074	0.48464	0.47807	0.47851	0.48951	0.47831
DMU17	0,5145	1	1	1	1	1	0,3783	1	1	1	1	1
DMU18	0,3187	0.01357	0.01368	0.01374	0.01356	0.01368	0,5191	0.01376	0.01362	0.01359	0.01385	0.01372
DMU19	0,64	0.5736	0.57869	0.58753	0.5741	0.56149	0,3454	0.5708	0.5681	0.60312	0.56371	0.56413

The results of two SBM analyses (between the first and the second analysis) in 2020 showed that:

(1) There is no change compared to before and after:

There are a total of 11 DMUs that are efficient both times, namely DMU1, DMU4, DMU5, DMU6, DMU7, DMU8, DMU11, DMU12, DMU13, DMU14, DMU15.

There are a total of 6 DMUs that are both inefficient, namely DMU2, DMU3, DMU10, DMU16, DMU18, DMU19.

(2) There have been changes before and after:

There are two DMUs that have transformed from low efficiency to high efficiency, namely DMU9 and DMU17.

There is one DMU with reduced efficiency, which is DMU18. DMU18 efficiency has reduced significantly. It has become the most inefficient DMU.

The results of two SBM analyses (between the first and the second analysis) in 2021 showed that:

(1) There is no change compared to before and after:

There is a total of 7 DMUs that are efficient both times, namely DMU7, DMU8, DMU9, DMU11, DMU12, DMU13, DMU14.

There are a total of 5 DMUs that are both inefficient, namely DMU2, DMU3, DMU16, DMU18, DMU19.

(2) There have been changes before and after:

There are a total of 6 DMUs that have transformed from low efficiency to high efficiency, namely DMU1, DMU4, DMU5, DMU6, DMU15, DMU17.

There is one DMU that has changed from high efficiency to low efficiency, DMU10.

There is one DMU with reduced efficiency, which is DMU18.

The results of two SBM analyses in 2020 and 2021 showed that:

(1) There has been no change compared to two years ago:

There are a total of 6 efficient DMUs, namely DMU7, DMU8, DMU11, DMU12, DMU13, DMU14.

There are four inefficient DMUs, namely DMU2, DMU3, DMU16, DMU19.

There is one DMU with a two-year efficiency decrease, which is DMU18.

(2) There have been changes before and after two years:

In 2020, there were two DMUs that went from low efficiency to high efficiency, namely DMU9 and DMU17.

In 2021, there were a total of 6 DMUs that went from low efficiency to high efficiency,

namely DMU1, DMU4, DMU5, DMU6, DMU15, DMU17.

In 2021, there was one DMU that went from being efficient to being inefficient, DMU10..

4.3.1.2 Correspondence analysis between the evaluation results of nursing practice environment and the efficiency results of nursing human resources

(1) The sub-dimensions of the Nurse Practice Environment Assessment Scale have an impact on the results of nursing human resources efficiency.

a) The impacts generated are mostly positive.

In 2020, 2 DMUs changed from low efficiency to high efficiency, and in 2021, 6 DMUs changed from low efficiency to high efficiency, for a total of 8 DMUs. Only 1 DMU changed from high efficiency to low efficiency in 2021.

The five sub dimensions of the Nurse Practice Environment Assessment Scale are: Management and Leadership Capabilities (MLC), Compensation and Administration Support (CAS), Job Autonomy (JA), Training and Development (TD), Nurse-Physician Collaboration/Teamwork (NPCT). The higher the score, the better the nurse practice environment. A good nursing practice environment can improve the efficiency and quality of nursing work, reduce the occurrence of patient safety (adverse) events, and thus have a positive effect on the efficiency of nursing human resources.

b) The impacts generated are limited.

There were 16 DMUs that remained unchanged around 2020, accounting for 84.2%; There are 11 DMUs that have remained relatively unchanged around 2021, accounting for 57.89%.

The second SBM analysis consists of 9 indicators. There are 8 initial evaluation indicators for the efficiency of nursing human resources, including 4 input indicators: number of practicing nurses, actual number of open beds, annual per capita pre tax income of nurses, average 24-hour nursing hours per hospitalized patient, and 4 output indicators: number of discharged patients, number of critically ill patients, occurrence of nursing adverse events, and nurse turnover rate. The sub dimensions of the Nurse Practice Environment Assessment Scale are only used as one newly added input indicator for measurement.

(2) The total score of the nurse practice environment assessment matches the efficiency results of nursing human resources

The total score of nurse practice environment assessment: ① The average total score of 19 research units in 2020 was (75.46 ± 16.32), including 4 decision-making units with a total score of ≥ 80, 11 research units with a total score of 70-79.99, and 4 research units with a total score<70. ② The average total score of 19 decision-making units in 2021 is (72.75 ± 14.63),

including 1 decision-making unit with a total score ≥ 80, 11 research units with a total score of 70-79.99, and 7 decision-making units with a total score<70 The total scores for both years were lower than the Chinese average (79.97 ± 18.21). The overall score of the nurse practice environment assessment is low, indicating a poor nurse practice environment.

Results of nursing human resource efficiency: ① Among the 19 DMUs in 2020, the proportion of efficient decision-making units was only 57.89%, which did not reach 80%; ② Among the 19 DMUs in 2021, the proportion of efficient decision-making units is only 42.11%, which has not reached 50% The overall efficiency of nursing human resources in the past two years is not high, and the utilization of nursing resources is not high.

From this, the overall score of the nurse practice environment evaluation in the inpatient ward of the hospital is low, the nurse practice environment is poor, and the efficiency of nursing human resources is also not high.

4.3.2 Results of interviews with nurse managers

By analyzing the interview records of 19 head nurses, we found that all of them reported the results as helpful for their nursing management work. They also expressed a desire for specialized training on the indicators, analysis methods, and application of nursing human resource efficiency results. We gained a deep understanding of the head nurses' overall impressions and views on the efficiency results. The interviews covered not only their evaluations of current efficiency but also their analyses of the potential factors affecting these results. We explored the underlying reasons for variations in nursing human resource efficiency and discussed possible measures for improvement with the head nurses to enhance overall efficiency.

4.3.2.1 Head nurses' views on 8 indicators of nursing human resource efficiency

Eight indicators were selected for this study, and the head nurses generally expressed their approval. These indicators include the number of practicing nurses, the number of actual open beds, the annual per capita pre-tax income of nurses, the average nursing hours per inpatient in 24 hours, the number of discharged patients, the number of critically ill patients, the number of adverse nursing events, and the nurse turnover rate.

Regarding investment indicators, the following three proposals are put forward:

(1) The number of provincial and above specialist nurses was initially one of the indicators identified through the Delphi method. However, due to its minimal impact on the results in the DEA statistics, it was ultimately excluded from the analysis. This decision has been

communicated to the head nurses, who have understood and acknowledged it. One head nurse mentioned that although the short-term impact of provincial and above specialist nurses on the direct human resource efficiency of the department is not significant, it has a positive effect on improving long-term human resource efficiency. The nursing human resource structure, which includes the ratio of senior, intermediate, and junior nurses, is a better measurement indicator that helps to fully understand the overall quality of the nursing team.

(2) The head nurse pointed out that the number of practicing nurses and the actual number of open beds are the basic and important indicators of nursing human resource efficiency, but the rationality and effective utilization rate of the actual number of open beds need further exploration. The number of practicing nurses is allocated according to a certain proportion based on the actual number of open beds, and this allocation method also deserves further discussion and improvement.

(3) The annual per capita pre-tax income of nurses is the most important lever for nursing human resource management within the department. The average nursing hours per inpatient in 24 hours is an important basis for determining the pre-tax income of nurses. Recording the nursing hours of each nurse is also one of the main tasks of daily nursing management. Head nurses ensure the rational allocation and utilization of nursing resources through daily scheduling and nursing work records. However, the annual per capita pre-tax income of nurses in this study hospital is mainly related to the operational efficiency of the specialist medical group.

Regarding output indicators, the following two proposals are put forward:

The accuracy and sensitivity of output indicators are insufficient. Indicators such as the number of discharged patients, the number of critically ill patients, the number of adverse nursing events, and the nurse turnover rate can reflect the actual situation of clinical nursing work from multiple dimensions. However, head nurses believe that although these indicators are scientific, they cannot accurately measure results consistent with reality, nor can they effectively reflect the problems.

To address this, they have put forward some suggestions for improvement. First, the indicator of the number of discharged patients should be changed to the number of discharged patients per 100 beds or the number of bed days occupied by inpatients. Secondly, the indicator of the number of critically ill patients should be changed to the number of critically ill patients per 100 beds or the number of days requiring special nursing care. Finally, the indicator of adverse nursing events should be changed to the number of adverse nursing events of level 2 or above per 100 beds. These adjustments aim to improve the accuracy and practicality of the

indicators and more effectively reflect the actual situation of clinical nursing work.

Regarding the collection of indicators data, it is proposed that:

The results of nursing human resource efficiency evaluation are closely related to data quality, so the objectivity and authenticity of the data also need to be considered. All data should be derived from the hospital's existing specialized statistics to avoid adding extra workload and to ensure the convenience of data collection. They also emphasized that the data collection process should be simplified as much as possible to avoid excessive manual recording. It was suggested to use existing information systems and technical means to improve the efficiency and accuracy of data collection.

4.3.2.2 Nurses' views on the efficiency results of departmental nursing human resources

Seventeen head nurses' self-evaluations were consistent with the actual data results, accounting for 89.47% of the total. Among them, 1 person said they strongly agreed, 12 people said they agreed, 4 people said they relatively/basically agreed, and 2 people said they disagreed/reserved their opinions, accounting for 10.53%. These data show that most head nurses' self-evaluations of the efficiency of nursing human resources in their departments are relatively accurate, although there are still a few deviations.

For departments that have been effective in nursing human resource efficiency for both years, head nurses unanimously believe the main reasons are that the department's business is stable or heavy, the nursing workload is large, and nurses often work overtime. Additionally, nurses' salaries are moderate or lower than those in similar departments.

For departments that have improved from ineffective to effective, head nurses attribute this change to an increase in the number of beds and business volume without a corresponding increase in nursing manpower, a decrease in nursing adverse events, and a reduction in the nurse turnover rate. Work efficiency has been improved through the enhancement of work processes and support from department directors.

For departments where nursing human resource efficiency was ineffective for both years, the head nurses believed the main reason was the instability of the department's business. The number of open beds in the department was unreasonable, as it was allocated by the hospital leadership team, nursing department, and personnel department, leaving the head nurses unable to intervene. This resulted in low efficiency per bed and low nurse efficiency. Additionally, the head nurses of three departments believed this inefficiency was related to the characteristics of the discipline, such as some departments focusing on chronic disease management and having fewer critically ill patients.

For departments that changed from effective to ineffective, head nurses believed the main reasons were an increase in the number of beds and nurses in the department, accompanied by a decrease in nurses' salaries. Additionally, the number of discharged patients and critically ill patients decreased, adverse events increased, and the nurse turnover rate rose. One head nurse expressed reservations about the nursing efficiency results because, in addition to the above reasons, the department involved many specialties, resulting in high work pressure for the nurses. Compared with a single specialty, nurses needed to master more specialized knowledge and skills, and the requirements for nurses were higher, but the salary did not reflect this. As a head nurse, she felt helpless and powerless.

The only participant who completely disagreed with the result was the head nurse of DMU15, who believed there might be an error in the data analysis and that it needed to be recalculated. She pointed out that the number of people in the department remained the same, the department's business increased, good output indicators increased, and bad output indicators decreased. Therefore, she objected to the result and believed it needed to be assessed.

4.3.2.3 Suggestions from the head nurse to the hospital's senior management regarding nursing management

In nursing management, head nurses believe that multiple factors affect the management of human resources. These factors can be divided into those that promote the effectiveness of nursing human resources and those that hinder it. Head nurses have put forward a series of relevant suggestions for addressing these factors.

Factors that promote effective nursing human resources

(1) Nursing Quality Management and Process Optimization

The head nurses unanimously agreed that optimizing nursing quality management methods and work processes is an effective strategy for enhancing nursing human resource efficiency. By streamlining nursing processes and improving the quality of care, the utilization efficiency of nursing resources can be significantly increased. This involves developing scientific nursing standards and operating procedures, ensuring each nursing step has clear guidelines and standards, reducing ineffective operations, and improving the standardization and efficiency of nursing tasks.

The head nurses emphasized the need for these processes to be ongoing. For instance, regular evaluations of nursing care quality should be conducted, problems should be identified and addressed promptly to ensure continuous improvement of nursing services. Additionally, they recommended holding regular quality analysis meetings to share successful experiences

and improvement strategies to foster continuous enhancement of nursing quality.

(2) Physician and Nursing Collaboration

During the interviews, head nurses highlighted the importance of medical-nursing collaboration, especially in departments with efficient nursing human resources. They noted that effective medical-nursing cooperation is a critical factor in improving nursing efficiency. Strengthening communication and collaboration between doctors and nurses can enhance work efficiency, improve nursing quality, and reduce medical errors and nursing incidents. It is recommended that hospitals regularly organize joint medical-nursing training and team-building activities to enhance trust and collaboration among medical and nursing staff.

Moreover, most head nurses stressed the importance of support from department directors in promoting medical-nursing teamwork and enhancing work efficiency. Department directors should actively participate in nursing management, support head nurses' initiatives, provide necessary resources, and ensure the smooth progress of nursing operations. Regular communication between department directors and head nurses is essential to understand the actual situation and challenges in nursing work and to jointly develop improvement plans.

(3) Positive Working Environment

Head nurses generally agreed that a positive working environment can enhance human resource efficiency, particularly in departments where nursing human resource efficiency has been effective for consecutive years. When defining a positive working environment, head nurses identified key factors such as salary and benefits, doctor-nurse relationships, nursing team atmosphere, and career development opportunities.

They suggested improving the medical-nursing collaboration and the working environment within departments. Organizing team-building activities can strengthen cohesion and cooperation among department members, improving the working atmosphere. Department directors play a crucial role in fostering positive medical-nursing relationships. Head nurses who have achieved effective nursing human resource efficiency emphasized the importance of the department director's understanding and support for the nursing team in resource allocation, communication, and conflict resolution. They recommended that head nurses actively communicate with department directors to seek their support. Regarding career development, head nurses believe that good career prospects can attract and retain excellent nursing talent. Providing more career development opportunities and training, enhancing nurses' professional skills and overall quality, and boosting their professional identity and job satisfaction are essential measures.

Factors hindering nursing human resources

(1) Decision-Making Authority Over Human Nursing Resource Allocation

The lack of decision-making authority over human resource allocation is a significant hindrance to human resource efficiency, according to head nurses. Those who experienced a decline or consistently low efficiency in human resource management attributed it to irrational bed allocations, leading to uneven workload distribution across hospital departments. It is recommended that hospitals plan bed allocations more reasonably, limiting the number to 50 per department to ensure more efficient human resource allocation.

Due to limitations in bed and nurse numbers, some departments face tight human resources, impacting the normal development of nursing work. Head nurses advocate for flexible resource allocation to improve human resource utilization efficiency and reduce waste. Establishing a flexible resource allocation mechanism, such as a mobile nurse pool and vertical management system, can help adjust resources based on actual departmental needs. However, this approach may face fairness issues, requiring reasonable system design and effective communication to ensure equitable and rational resource distribution.

(2) Rationality of the Nursing Structure

The rationality of the nursing structure has been a longstanding concern for head nurses, who noted that achieving a balanced ratio of senior, intermediate, and junior nurses is challenging. The lack of decision-making power in nursing human resource management exacerbates this issue. Head nurses can only submit personnel requests to the human resources and nursing departments, with final decisions made by the hospital leadership.

Given the limited overall human resources, departmental efficiency directly influences approval of resource requests. Hospital development strategies, such as prioritizing certain departments, also affect recruitment processes. Increasing head nurses' involvement in nursing human resource management decisions and optimizing nurse allocation scientifically, especially during recruitment, is recommended.

Currently, the nursing team structure is predominantly an unreasonable pyramid shape, which should transition to a more efficient spindle shape. A balanced echelon structure, particularly the ratio of junior to senior nurses, can enhance team stability and professionalism. Providing more training and development opportunities can improve nurses' professional abilities and job satisfaction, reducing turnover rates.

(3) Nurses' Remuneration

Unreasonable salary and benefits were cited by all head nurses from ineffective departments as the primary factor for low human resource efficiency. Compensation is key to influencing nurses' work enthusiasm and satisfaction. A fair salary structure can motivate nurses

to improve efficiency and reduce turnover.

Head nurses suggested implementing reasonable performance appraisals to encourage nurses to enhance work quality and efficiency. Establishing performance bonuses and reward mechanisms can motivate nurses to continuously improve their skills and service quality, increasing their enthusiasm and initiative. The current salary structure is primarily based on working hours, with factors such as performance, workload, and nursing difficulty considered, but these are difficult to quantify, making the performance appraisal system complex and opaque. A transparent performance appraisal system is needed to ensure fair evaluation and recognition of each nurse's efforts.

The hospital uses salary as a significant lever, making evaluation indicators the most crucial performance measures. The existing salary structure is financially oriented, lacking lean management. High surgical charges contrast with low service charges, resulting in low incomes for departments like internal medicine. Nurse risk intensity is not adequately considered. Optimizing the salary structure, raising standards for nursing charges, and providing better compensation, especially in high-difficulty nursing departments, are recommended.

By addressing the above factors, head nurses believe nursing human resource efficiency can be effectively improved by optimizing quality management, enhancing medical-nursing cooperation, rationally planning remuneration, and improving department atmosphere and nursing environment. To overcome obstacles, hospitals should adopt flexible decision-making, listen to head nurses' opinions, and ensure rational human resource allocation. These measures can improve nursing service quality, patient satisfaction, and treatment outcomes. These suggestions provide a vital reference for future nursing management improvements and lay a solid foundation for enhancing nursing service levels. Head nurses unanimously believe that by continuously optimizing and improving nursing management, they can better address challenges, elevate overall nursing standards, and ultimately achieve comprehensive improvements in medical service quality.

Chapter 5: Discussion and Conclusions

The main purpose of this study is to investigate the impact of the practice environment on nursing human resource efficiency and to provide nursing managers with strategies on how to improve the former to benefit the latter. To achieve the research objectives, the following questions need to be addressed: □Which framework can be used to scientifically assess the nursing practice environment? ②How can an index system be utilized to evaluate the efficiency of nursing human resources? ③Does the nursing practice environment influence the effectiveness of nursing personnel, and can a model be developed to explain this relationship? ④What strategies can nursing managers employ to enhance the nursing practice environment and optimize the efficiency of nursing human resources? After theoretical and empirical research, this section will discuss and summarize the research results:

5.1 Assessment-optimization-application of nurse practice environment assessment tools

5.1.1 Evaluation and optimization of nurse practice environment assessment tool

Zelauskas and Howes (1992) suggested that a nurse practice environment is one in which nurses are empowered by their managers to gain more autonomy, control over their tasks, and responsibility in the delivery of nursing care. Nurse practice environments have organizational factors that facilitate or limit the practice of nursing in the workplace (Lake, 2002). The nurse practice environment includes the physical and organizational environment of the nurse's workplace (Zuo, 2006), as well as the characteristics of the work itself, such as its importance and complexity (Swiger et al., 2017).

According to the research of domestic and foreign scholars on the components of the practice environment, the connotations of a healthy nurse practice environment can be summarized as follows: the opportunity to participate in the management of hospital affairs, autonomy of nurses in their work, organizational support, reasonable allocation of nursing manpower and material resources, reliable leadership and management, harmonious health care relationship, reasonable remuneration and social status, and favourable to the development of

the profession and personal development.

Hospital administrators understand the situation of the nurse practice environment in hospitals, and regular measurement and analysis of the nurse practice environment can provide an objective basis and a clear direction for continuous improvement of the nurse practice environment. Therefore, it is very important to choose an objective and effective assessment tool for nurse practice environment.

In this study, the results of the literature review were synthesized and analyzed, and five nurse practice environment assessment tools were identified, including the Nursing Work Index (NWI), the Revised Nursing Work Index (NWI-R), the Practice Environment Scale for the Nursing Work Index (PES-NWI), the Perceived Nursing Work Environment (PNW), and the Nurses' Practice Environment Assessment Scale (NPEAS).

The underlying theories, dimensions, number of entries, Cronbach's alpha coefficients, use, and research on five nurse practice environment assessment instruments were and compared in detail through comparative analysis to identify the strengths and limitations of each scale. The selection of the scale to be used in this study was then carried out based on the following four principles: ① Reliability: the consistency of the instrument in measuring the practice environment of nurses in different settings and time. ② Validity: the extent to which the tool measures what it claims to measure. ③ Comprehensiveness: the ability of the tool to cover all relevant dimensions of the nurse practice environment. ④ Applicability: the applicability of the tool in the Chinese healthcare environment, taking into account cultural and organizational differences.

Given the complexity of the nurse practice environment, especially in the context of the Chinese healthcare system, the selection of the most appropriate scale is critical to accurately capture the several dimensions that influence the efficiency of nursing human resources. The Nursing Work Index Practice Environment Scale (PES-NWI), with a Cronbach's α of 0.91, was shown to have the highest reliability. Its five core dimensions: nurses' involvement in hospital affairs, nursing quality base, nurse manager competence and leadership, staffing and resource adequacy, and collegiality between nurses and physicians are particularly relevant to the objectives of this study. The Nursing Practice Environment Assessment Scale (NPEAS) was developed based on the original and Chinese versions of the PES-NWI and retains the PES-NWI advantages well. The NPEAS was developed specifically for Chinese healthcare organizations and was initially designed to take into account the specific conditions of China, including economic, social, and cultural factors, to provide a means of assessing the practice

environment for nurses in China within the Chinese culture. The NPEAS was identified as the instrument to be used in this study because of its high reliability and validity for use in tertiary hospitals in China.

The NPEAS consisted initially of 10 dimensions: nurses' involvement in hospital affairs, professional practice, leadership and communication, quality management, internal support, nurse/physician collaboration, professional development, job adequacy, social status, and compensation and benefits. The dimensions of the scale are very comprehensive, but its length and complexity need to be emphasized by the researcher. Therefore, Validated Factor Approach Analysis (CFA) and Exploratory Factor Analysis (EFA) were used to further optimize the Nurse Practice Environment Assessment Scale (NPEAS).

Confirmatory factor analysis (CFA) was used to validate the factor structure of the NPEAS, which showed poor fit for its 10 subscales. Exploratory factor analysis (EFA) was applied to determine the optimal number of subscales. The analysis was conducted according to the 7-subscale model and the 5-subscale model, and the results showed that both models were acceptable, but the 5-subscale model had a slightly higher goodness-of-fit index (the goodness-of-fit indices included the $\chi 2/df$, CFI, GFI, RMSEA with 90% CI, and MECVI). CFA was then used to validate the 5-subscale models with results. The CFA confirmed the applicability of the 5-subscale model to the Chinese version of the NPEAS scale.

The final confirmation of the 5-subscale model of NPEAS contained the subscales: Management and Leadership Capabilities (MLC), Compensation and Administration Support (CAS), Job Autonomy(JA), Training and Development (TD), Nurse-Physician Collaboration/Teamwork (NPCT). In this study, five subscale models were selected to apply and analyze the NPEAS in 19 decision-making units, showing good internal consistency and stability, validity and accuracy of the measurements.

The 5-subscale model of the NPEAS provide a reliable and valid structure for assessing the practice environment of nurses and promote further research and practical application of nursing management in China and, in this way answer research question ① Which framework can be used to scientifically assess the nursing practice environment.

5.1.2 Analysis of the evaluation results of nurses' practice environment

The Nurse Practice Environment Assessment Scale (NPEAS) was applied to evaluate the nurse practice environment of 19 decision-making units. In the results of this study, it was found that:

① The total score of nurse practice environment assessment: The average total scores for

the two years were (75.46 ± 16.32) and (72.75 ± 14.63), respectively, both lower than the Chinese average (79.97 ± 18.21, 81.27 ± 19.92). The overall score of the nurse practice environment assessment is low. The study is a cross-sectional survey in 2020 and 2021. It is just in the critical period of the novel coronavirus epidemic in China, and hospitals, departments and nurses are facing more and more emergencies and pressure. Therefore, the results may be affected by the novel coronavirus epidemic, and there are some deviations caused by uncontrollable factors. On the whole, however, there is little difference from the average in China. With the improvement of the epidemic situation of novel coronavirus, it may increase. Suggestion: Hospitals still need to regularly evaluate the nursing practice environment, providing objective basis and clear direction for hospital managers to continuously improve the nursing practice environment.

② The sub dimensions of the Nurse Practice Environment Assessment Scale have limited impact on the efficiency results of nursing human resources. The proportion of nursing human resource efficiency that remained unchanged before and after the two-year evaluation was 84.2% and 57.89%, respectively. The second SBM analysis consists of 9 indicators. There are 8 initial evaluation indicators for nursing human resource efficiency, and the sub dimension of the nurse practice environment evaluation scale is only used as one newly added input indicator for measurement, which may limit its influence on data output. In addition to the above reasons, it is also necessary to consider the existing nursing practice environment evaluation tools, which evaluate the overall nursing practice environment of the hospital (macro environment), and whether they are suitable for reducing the evaluation target unit to evaluate the nursing practice environment of a specific department (micro environment). In future research, it is possible to explore the development of a specialized nurse practice environment scale for evaluating departments (small environments), which can be more accurate and sensitive.

5.2 An indicator system for the evaluation of nursing human resource efficiency

5.2.1 Selection of efficiency evaluation indicators for nursing human resources

Nursing human resource efficiency is a comprehensive concept, and any single indicator can only reflect one side of nursing human resource efficiency. Constructing a perfect input-output indicator system is the basis for scientific and comprehensive evaluation of nursing human resource efficiency. The input-output theoretical model is one of the basic theories of health

economics, and the construction of indicators of nursing human resource efficiency at home and abroad is based on this model (Worthington, 2004). Assessment indicators are divided into two categories: input indicators and output indicators. Input indicators examine the resource allocation for nursing management, including variables such as staffing, supplies, training and development, workload, and financial inputs (Babalola & Moodley, 2020; Okoroafor et al., 2022). Output indicators, on the other hand, assess the outcomes or achievements of nursing services, including quality of patient care, patient safety, health care utilization, employee satisfaction, and burnout or turnover rates (Dubois et al., 2017; Endeshaw, 2021; Stemmer et al., 2022).

Y. Weng et al. (2019) initially established an indicator system based on the input-output theoretical model through interviews and literature review and conducted two rounds of expert correspondence with 30 experts through the Delphi method to construct a nursing human resource efficiency indicator system including 8 level 1 indicators, 18 level 2 indicators, and 50 level 3 indicators. The input level indicators include human, material, financial and service inputs, while the output indicators include nursing services, nursing safety, nursing quality, and teaching and research outputs.

Based on the nursing human resource efficiency indicator system constructed by Y. Weng et al. (2019) and mainly combining the relevant nursing indicator data from the China National Center for Nursing Quality Management, this study carried out one step of improvement and modification to establish a nursing human resource efficiency indicator system with 60 indicators, including 17 input indicators and 43 output indicators. The Delphi method was used to simplify and optimize the nursing human resource efficiency indicators, taking into account the availability and validity of the indicator data. The Delphi method was used to simplify and optimize the nursing human resource efficiency evaluation indicators. Through a structured process involving multiple rounds of expert feedback, a consensus was reached on the key performance indicators (KPIs) necessary to assess nursing human resource efficiency in different departments of the hospital. A total of eight nursing human resource efficiency evaluation indicators were identified, including four input indicators: number of practicing nurses, number of actual open beds, annual per capita pre-tax income of nurses, and 24-h average nursing hours per hospitalized patient, and four output indicators: number of discharged patients, number of critically ill patients, occurrence of adverse nursing events, and nurse turnover rate.

5.2.1.1 Number of active beds in departments

The number of active beds indicates the facility's potential patient capacity. Human resource allocation, particularly nursing staff, is determined based on this number to ensure that every patient receives adequate care (Wynendaele et al., 2019). Maintaining active beds incurs costs, not just in terms of equipment and space but also the human resources needed to serve patients in those beds. Efficient allocation of nurses to active beds ensures optimal financial management (Giancotti et al., 2017).

In China, while laws dictate a basic patient-to-nurse ratio, the essence of nursing human resource management is allocating limited resources efficiently across departments (Du et al., 2023). On January 30, 2022, Guiding Principles for the Planning of Medical Institutions (2021-2025) was issued (NHC, 2020). The plan clearly states that the establishment of medical institutions is subject to macro-control based on major indicators such as medical service demand, medical service capacity, number of beds per thousand people (number of beds for traditional Chinese medicine per thousand people), number of doctors per thousand people (number of traditional Chinese medicine doctors per thousand people) and number of nurses per thousand people. The specific indicator values are determined by provinces, autonomous regions and municipalities directly under the central government based on actual conditions. Among them, among the main indicators of the national medical institution establishment plan in 2025, the guiding requirements for the number of beds per thousand people in 2025 are 7.4 to 7.5 beds; the number of practicing (assistant) doctors per thousand people is 3.2 people; the proportion of geriatric medicine departments in secondary and above general hospitals is not less than 60%; the appropriate bed scale of county-run general hospitals is 600 1000 beds; the appropriate bed scale of municipal-run general hospitals is 1000 1500 beds; the appropriate bed scale of provincial-run and above general hospitals is 1500 3000 beds. Hospitals should achieve the transformation from large-scale hospitals to quality hospitals in order to achieve optimal benefits.

In the hospital where the study was implemented, the number of open beds in a department is adjusted by hospital management based on the hospital development strategy and the department's bed utilization rate from the previous year, and is generally relatively fixed. In this study, DMU1 was expanded from 56 to 85 beds; DMU8 was expanded from 48 to 85 beds; DMU9 was expanded from 36 to 66 beds; DMU12, 65 beds, DMU14, 63 beds; DMU15, 73 beds. Public hospitals should reasonably set the number of the beds of every departments according to their functional positioning and service capabilities. In China's public hospital

system, the emphasis isn't just on cost-effectiveness but also patient safety and healthcare equity. Allocating more resources to high-revenue departments isn't viable. The number of beds in each department should not exceed 50. Management of wards exceeding this size should be strengthened.

Hospital beds are essential resources that must be efficiently allocated and fully utilized. Thus, bed management has consistently been a critical issue in hospital administration. Bed resources possess a unique attribute: they are non-storable. When the functions and services associated with bed resources are not immediately utilized, hospital beds are essential resources that must be effectively allocated and fully utilized. Therefore, bed management has always been a key issue in hospital administration. Bed resources have a unique attribute: they are non-storable. When the functions and services associated with bed resources are not immediately utilized, their time value cannot be quickly realized. The effective planning and allocation of bed resources are important indicators of a hospital's service capacity and management level. Effective planning and allocation of bed resources are vital indicators of a hospital's service capacity and management level.

General hospitals usually have a comprehensive discipline system. However, due to the varying nature and developmental stages of different departments, there is often an imbalance in departmental activity, resulting in both bed waste and vacancies. This imbalance highlights a characteristic issue within the medical market: the coexistence of insufficient and wasted health resources. The failure to fully utilize bed resources not only leads to their wastage but also delays the treatment of patients requiring hospitalization (J. Liu et al., 2021). Keeping beds available at all times is the key, and timely release of bed resources is a shortcut to improve efficiency (Tulchinsky & Varavikova, 2014). In response to this contradiction between demand and waste, most hospitals in the early years alleviated it by expanding and increasing the scale of beds. However, the problem of bed waste in some departments has not been solved by external expansion, and blind expansion will also cause more management problems (Hua et al., 2018). The Theory of Constraints (TOC), one of the three major management theories in the world, suggests that enterprise management should be system-based. By focusing on improving bottlenecks, enterprises can achieve synchronous and overall enhancement of all system components, rather than blindly attempting to promote expansion (Mabin & Balderstone, 2020). Therefore, in recent years, hospital managers have applied the core ideas of this theory to the issue of bed management (Bacelar-Silva et al., 2022).

General hospitals typically have a comprehensive disciplinary system. However, due to the varying nature and development stages of different departments, departmental activities are

often imbalanced, leading to bed wastage and vacancies. This imbalance highlights a typical issue in the medical market: traditional management methods usually involve department heads or doctors controlling bed resources. The root cause of this dilemma, as identified, lies in the localized management of department beds, which leads departments to retain their own "reserved areas" to expand the number of beds (Dong et al., 2021). Additionally, traditional performance accounting systems focus on revenue and expenditure, failing to reflect or incentivize cross-departmental patient admissions. This has resulted in reluctance and an inability to implement a "hospital-wide single bed" management model.

To scientifically coordinate hospital-wide bed resources and improve bed utilization efficiency, some tertiary general hospitals have implemented the “one bed for the entire hospital” management model. “One bed for the entire hospital” refers to breaking down the barriers between departmental beds, ensuring medical safety, and following the principles of proximity in building and specialty to centrally allocate hospital bed resources. This allows for the management of patients across departments, reducing patient admission waiting times. For patients admitted across departments, the hospital arranges for specialist doctors to conduct regular ward rounds and provide treatment, ensuring that services follow the patient wherever they go, truly achieving “patient-centered care” (Lan et al., 2023). Based on the integrated medical concept, this approach fully considers the current state of hospital beds, specialty development, disease characteristics, and patient needs. By establishing an admission preparation center and promoting interdepartmental collaboration within the hospital, guided by national assessments, hospitals efficiently integrate bed and management resources (Hua et al., 2018).

This model breaks down the barriers preventing the allocation of beds between departments, enabling dynamic bed management and resource sharing. It maximizes patient satisfaction, reduces admission waiting times, enhances the patient experience, and better reflects the hospital’s public welfare and patient-centered service philosophy. The “Notice of the National Health Commission on the Issuance of the ‘Tertiary Hospital Evaluation Standards (2022 Edition)’ and Its Implementation Rules” mandates centralized bed management, with departments or dedicated personnel responsible for coordinating hospital-wide bed resources. Therefore, the “one bed for the entire hospital” management model is being promoted as a new management approach (Lan et al., 2023).

5.2.1.2 Number of nurses

The number of nurses directly affects a healthcare facility’s service delivery, impacting the

patient-to-nurse ratio, workload, wait times, and care quality (Stalpers et al., 2015). Studies link nurse staffing to patient outcomes. Low staffing correlates with higher patient morbidity, mortality, longer stays, and more adverse events (Griffiths et al., 2019). Overloading nurses due to understaffing can lead to dissatisfaction (L. Wang & Li, 2011), burnout (Nelson III, 2017), and high turnover (Pérez-Francisco et al., 2020). A balanced nurse staffing is crucial for consistent patient care (Griffiths et al., 2020). In healthcare, nursing often constitutes a major part of operational costs. A balanced number of nurses ensures quality care without financial strain.

The rational allocation of nursing human resources is the cornerstone for improving nursing quality, ensuring work efficiency, stabilizing the nursing workforce, and promoting the sustainable development of nursing disciplines (Shi, 2006). Currently, the nursing human resource allocation system and structure in China require improvement. In terms of allocation policy, the regulation of nursing human resources in China started relatively late but has developed rapidly. China's first draft on this matter was introduced in 1978. With economic development and increased national attention to healthcare, since 2001, China has not only issued allocation policies for different departments but also formulated a series of strategic plans for the development of nursing (Feng et al., 2013). However, China's policies on nursing human resource allocation mainly consist of drafts, notices, plans, and guidelines, lacking mandatory constraints, whereas other countries have incorporated nursing human resource allocation into their legal frameworks (Dessler, 2020; P. F. Wang et al., 2015). Therefore, it is necessary to strengthen the binding force of policies and further incorporate the allocation of nursing human resources into a legal management track.

Regarding nursing human resource allocation indicators and levels, both China and the UK use the nurse-to-bed ratio, but China's allocation level is much lower than that of the UK (A. Huang et al., 2018). The Provisional Draft of Organizational Compilation Principles for General Hospitals issued by China's former Ministry of Health proposed a bed-to-nurse ratio of 1:0.4 for staffing nursing positions. However, as the scope and content of nursing work expand, allocating nursing staff based solely on the nurse-to-bed ratio fails to accurately reflect nurses' workload (Feng et al., 2013). Y. Y. Yang et al. (2023) proposed establishing a nursing human resource allocation model for hepatobiliary surgery based on case mix index and nursing hours.

The rational allocation structure of nursing human resources needs improvement. A scientifically designed nursing staff structure can reduce nursing costs, decrease infection rates, and shorten hospital stays (B. Y. Yang et al., 2014). Enriching the nursing human resource structure is essential for its rational allocation. Several countries/regions employ a nursing staff

structure that includes both registered nurses and unregistered nurses. In terms of qualification requirements for nursing staff, most of the countries/regions have clear certification management systems for registered nurses (McKenzie-Green, 2003). However, only the United States and Germany have mandatory requirements for the qualification certification of unregistered nurses (Rafferty et al., 2019). In China, unregistered nurses primarily refer to nursing assistant. The Training and Standard Management Requirements for Nursing assistant was issued in 2019, but their management and qualification certification remain unclear (R. Li et al., 2016; X. Yang & Wu, 2008).

Regarding the nursing staff structure ratio, the 1978 standard of a 3:1 ratio of registered nurses to caregivers has been consistently used, which is relatively high compared to other countries. While a higher proportion of registered nurses can reduce the risk of adverse nursing events, an excessively high proportion increases hospitalization costs for patients and operational costs for healthcare institutions (X. M. Liu & Wang et al., 2023; X. Yang & Wu, 2008). This nursing staff structure serves as a general indicator, but the United States and Victoria, Australia, adjust it according to different departments, and Germany optimizes it based on different shifts. As the healthcare sector develops and institutional settings become increasingly sophisticated, departmental specialization is maturing (Feng et al., 2013). Consequently, a single set of standards cannot meet the needs of all departments and shifts. In clinical nursing practice, it is necessary to flexibly adjust the nursing staff structure according to the specific requirements of different departments and shifts to ensure the rational allocation of nursing human resources (Ma & Han, 2013).

5.2.1.3 Nurse salary

Average Pre-tax Income per Nurse per Year provides a direct snapshot of the economic contribution of each nurse, facilitating a clearer understanding of human resource value. This metric allows healthcare facilities to benchmark against competitors or industry standards, helping identify areas of efficiency or underperformance. As a significant chunk of healthcare expenses is associated with human resources, this metric aids in discerning the financial implications of staffing decisions and resource deployment (Cantor & Poh, 2018). A higher average income per nurse often suggests effective resource utilization and high productivity, whereas a lower average might indicate potential inefficiencies (Rumbold et al., 2015).

It aids in designing competitive compensation and incentive structures, ensuring that remuneration is in line with the value delivered by the nursing staff (Wan et al., 2018). For budgeting, expansions, or service modifications, understanding the income generated per nurse

is essential to make informed, strategic decisions.

In most hospitals in China, the distribution of nursing performance-based pay follows a departmental accounting model, where performance bonuses are tied to the department's economic benefits. This method of distribution is heavily finance-oriented, with bonuses for nursing staff allocated based on departmental levels or in proportion to doctors' bonuses, lacking a clear mechanism for assessing the quality of nursing service (Chen & Lv et al., 2021). The "one-size-fits-all" distribution within departments means that performance among nurses in the same department is indistinguishable, leading to a discrepancy between actual workload and performance rewards. There is also a lack of cost control awareness, resulting in varying degrees of waste (C. Liu, 2024).

The China Nursing Development Plan (2016-2020) (NHC, 2016) mandates that hospitals should expedite the improvement of nursing performance evaluations and establish a scientific system for nurse performance assessments and compensation distribution. This system should prioritize positions with heavy clinical nursing workloads, high risks, and high technical requirements, reflecting the principles of more work for more pay and better pay for better performance. P. F. Wang et al. (2015) developed a nursing performance-based pay reform plan under the vertical management system of the nursing department. By using historical data and survey interviews, they calculated and adjusted the indicators and weights in the reform plan and developed an information system to visualize the data, implementing the nursing performance-based pay reform in practice.

The reform under the vertical management system achieved the goals of more work for more pay and better pay for better performance. Compared to the period before the reform, the resignation rate and job transfer rate of nursing staff decreased, while job satisfaction among nurses and patient satisfaction increased. This reform boosted the enthusiasm of nursing staff, standardized nursing post management, improved the quality of nursing services, and proved to be operationally feasible, providing a reference for nursing performance-based pay reform in public hospitals.

5.2.1.4 Average nursing hours per inpatient per 24 hours

The average nursing hours per inpatient per 24 hours refers to the average number of nursing hours each inpatient receives daily. There is a certain correlation between patient care outcomes and the nursing hours received. Monitoring the average nursing hours per inpatient per 24 hours helps managers understand the average nursing hours patients receive. It links to patient outcomes and other quality indicators, analyzing factors that affect the quality of patient

outcomes and whether the nursing hours received are reasonable. This metric is crucial for appropriately staffing nursing personnel and for quality improvement.

5.2.1.5 Number of discharged patients

The number of discharged patients is a tangible metric reflecting the volume of patients who have completed their care cycle. It provides a direct insight into the throughput managed by the nursing staff, illustrating their capacity to handle and process patient care (Min et al., 2018). A higher rate of successful discharges, when viewed alongside other quality metrics like readmission rates or patient satisfaction scores, can indicate efficient and effective care. It suggests that patients are being treated effectively and safely under the care of the nursing team (Kunjumen et al., 2022). A larger number of discharges may indicate effective interdepartmental collaboration and proficient nursing practices. The number of discharged patients can act as a comparative metric against industry benchmarks or peer institutions, offering insights into the relative efficiency and performance of a healthcare facility's nursing staff.

5.2.1.6 Number of critically ill patients

Critically ill patients demand a higher level of care and attention. Managing a large number of such patients underscores the proficiency and effectiveness of the nursing staff, as it reflects their capacity to handle more complex and intensive care needs (Kunjumen et al., 2022). Attending to critically ill patients requires advanced clinical skills, timely decision-making, and in-depth knowledge. A higher number of critically ill patients under care indicates the advanced skill set and capabilities of the nursing team (F. Weng et al., 2019).

5.2.1.7 Number of adverse events

At its core, nursing aims to provide safe and effective patient care. A low number of adverse events indicate efficient and safe nursing practices. Effective management and allocation of nursing resources can help reduce adverse events (Cho et al., 2013). Thus, this metric provides insights into how well resources are being managed to ensure patient safety. Adverse events can lead to extended hospital stays, additional medical interventions, and legal implications, all of which have operational and financial consequences. Efficient nursing practices, reflected by fewer adverse events, can reduce these associated costs and operational challenge.

5.2.1.8 Nurse turnover rate

High turnover rates can disrupt continuity of care. Consistent staffing ensures patients receive

care from nurses familiar with their medical histories, improving outcomes (Griffiths et al., 2019). Frequent staff changes can negatively impact team cohesion and morale, which can, in turn, affect patient care quality and further exacerbate turnover. High turnover rates mean recurrent expenses related to recruitment, orientation, and training, which can strain budgets (Labrague et al., 2020). Elevated turnover leads to repeated recruitment, orientation, and training expenses, burdening budgets (Duffield et al., 2014).

5.2.1.9 Control of indicator quality and data quality

In interviews with 19 head nurses, it was pointed out that the accuracy and sensitivity of the output indicators are insufficient, and there is a need to improve the indicators. Suggestions were made: the number of discharged patients indicator should be changed to the number of discharged patients per 100 beds or the number of bed days occupied by hospitalized patients. The indicator for the number of critically ill patients should be changed to the number of critically ill patients per 100 beds or the number of days requiring special care. The indicator for nursing adverse events should be changed to the number of nursing adverse events of level 2 or above per 100 beds The results of nursing human resource efficiency evaluation are closely related to data quality, so the objectivity and authenticity of the data also need to be considered. All data should come from the hospital's existing professional statistical data to avoid additional workload and ensure the convenience of data collection. They also emphasized that the data collection process should be simplified as much as possible to avoid excessive manual recording. Suggest utilizing existing information systems and technological means to improve the efficiency and accuracy of data collection.

When studying the efficiency evaluation indicators of innovative enterprises, Luo et al. (2018) established and compared an absolute numerical system based on the quantity perspective and a relative value system based on the quality perspective. The verification results showed that the enterprise innovation efficiency evaluation system based on the quality perspective is more scientific and reasonable, and the evaluation results are more practical. This study is worthy of reference and use in the efficiency index system of nursing human resources.

5.2.2 Evaluation methods and models for nursing human resources efficiency

Data Envelopment Analysis (DEA) was first proposed by Charnes et al. (1978). DEA is a non-parametric method using mathematical tools to evaluate the effectiveness of the production frontier of an economic system and is adapted to the performance evaluation of multi-input and multi-output multi-objective decision-making units. Data Envelopment Analysis constructs

data envelopment curves by selecting multiple input data and output data of a decision-making unit (DMU) and utilizing linear programming to take the optimal inputs and outputs as the production frontier. In this case, the efficient points will be located on the frontier surface and the efficiency value is calibrated to 1. The inefficient points will be located outside the frontier surface and will be assigned a relative efficiency value greater than 0 but less than 1. DEA is considered as one of the best methods for assessing the efficiency of healthcare organizations (Ahmed et al., 2019).

According to the needs of this thesis, five models for DEA improvement are compared and analyzed, and the rationale for model selection is clarified. a). The BCC model is a model that allows for a more accurate assessment of efficiency by taking into account the ideal size of DMUs during operation (Han et al., 2021). There are only 19 DMUs in this study, which are limited in number and not modifiable, so this model is not applicable. b). RAM model to improve the applicability of DEA in datasets with a wide range of values (P. Chen & Zhao et al., 2021). This model is not appropriate due to the limited number of DMUs and the number of indicators in this study. c). The dynamic DEA model is well suited to assess changes in efficiency over time, which is a particularly favourable aspect in longitudinal investigations (Ren et al., 2022). The main purpose of this thesis is not to examine changes in DMU efficiency over time, so this model was not chosen. d). The fuzzy DEA model deals with uncertainty in input and output data in an unpredictable environment (Ji et al., 2019). Since the context of this thesis is a stable hospital environment, this model is not appropriate. e). The SBM model directly measures idle time, allowing for a more detailed and precise examination of efficiency (Zhang & Chen, 2018). This provides valuable insights into specific inefficiencies in inputs and outputs. It helps measure input and output indicators with different units of measurement, identifies key indicators, and aligns with the objectives of this study.

The SBM model was ultimately chosen for this study to analyze the efficiency of nursing human resources in 19 DMUs. The inclusion of categorical inputs and outputs in the SBM model is another valuable extension that addresses situations where DMUs operate under different conditions or provide different services that are not easily comparable. By categorizing these inputs and outputs, the DEA model can examine each category separately, thereby enhancing the relevance and significance of the effectiveness assessment. The model takes into account the positive values of the inputs and outputs and can deal with good and bad outputs, which can be separable or non-separable. The model generalizes a model based on undirected relaxation to obtain good outputs and allows for a more accurate assessment of the efficiency of the DMUs within its operational constraints by distinguishing between free and non-free

variables.

In summary, answer question ②: How to establish an indicator system to evaluate the efficiency of nursing human resources?

Based on the input-output theory model, eight key indicators for evaluating the efficiency of nursing human resources were determined through Delphi expert consultation. Compare the five DEA models and choose the SBM model to evaluate the efficiency of nursing human resources.

5.3 The proposed model for the efficiency of nursing human resources (theoretical contribution)

5.3.1 The impact of nursing practice environment on nursing human resource efficiency

From the literature review, the nurse practice environment is influenced by three aspects: Job stress. Nurses' work stress has become a major influence on their practice environment. Because a poor practice environment will make nurses have psychological problems, slack work, and even a sense of work fatigue, leading nurses to make errors in their work, so that the level of quality of nursing work decreases, and in serious cases, cause medical and nursing accidents. Interpersonal relations and workload from the nurse-patient, medical and nursing, and the excessive frequency of night shifts are the main reasons for nurses' high work pressure. Remuneration package. Lower remuneration package will greatly reduce nurses' work motivation and initiative, thus affecting nurses' turnover rate and job satisfaction. Career development. The more career development nurses get, the lower the burnout is. On the contrary, the lack of sufficient support and recognition for nurses' career development will strengthen their burnout. In addition to this, the influencing factors are the healthcare environment, the national healthcare policy system, the support of hospital colleagues and management, and their own quality and ability.

The influencing factors of nurses' practice environment are sorted out according to the input indicators of nursing human resource efficiency: ① Nursing human resource input. Insufficient input of nursing manpower can lead to high workload of nurses and excessive frequency of night shifts. ② Nursing service input. If the workload of nurses is too large, it will easily lead to nurse fatigue, which will easily lead to mental and physical health problems and burnout. ③ Nursing material input. Well-equipped and sufficient nursing appliances can support and improve nurses' work efficiency. The number of beds serves as a measure of the size and capital

investment of a healthcare organization, and it is important to reasonably allocate the number of nurses according to the number of beds. ④ Nursing financial inputs. Nursing financial investment includes nursing human resource costs, training costs for nursing staff, and research investment funds. Nursing human resource costs are mostly based on the annual per capita pre-tax income of nurses (Y. Weng et al., 2019). Compensation package is an important factor that affects the nursing practice environment. Healthcare organizations invest in special training costs for nursing staff and ensure post-graduation continuing education and training for nursing staff, which is essential for nurses to improve their professional skills, maintain a high standard of patient care, and ensure satisfaction of nurses, so that they are fully supported and recognized in their career development.

The impact of the nurse practice environment on the output indicators of nursing human resource efficiency is mainly reflected in the outputs of nursing safety and the outputs of nursing quality. Common patient safety issues include events such as hospital-acquired infections, medication errors, falls, and pressure sores. Nurse practice environments can influence patient safety and quality of care through their impact on nurses. Improving the nurse practice environment can directly reduce the incidence of adverse events such as infections, medication errors, and patient falls. A large body of evidence supports the link between nursing practice environments and patient safety, and healthcare organizations should prioritize the creation and maintenance of healthy work environments for nurses. The environment in which nurses work has been shown to affect their levels of commitment to their work, their satisfaction with their work, and the incidence of occupational injuries among nurses. The provision of support at work is the most significant factor in reducing the likelihood of nurses leaving their jobs. Hospitals and nursing managers can help to create a positive work environment for nurses by providing them with a supportive work environment and by increasing their job satisfaction. Various factors, including organisational factors, social factors, personal characteristics, and the work environment, can influence nurses' intentions to leave their jobs. However, these intentions can be reduced by improving the work environment. The nursing practice environment affects the turnover rate of nurses, and the turnover of nurses increases the cost of nursing manpower in hospitals.

The results of the survey of the working environment and human resources efficiency of the 19 DMUs in Guangdong Provincial A Hospital indicate that:

a). The sub-dimensions of the nurse practice environment assessment tool have a significant impact on the efficiency of human resources, with the majority producing a positive effect. In the second SBM analysis, 8 DMUs changed from low efficiency to high efficiency from 2020

to 2021. The five sub dimensions of the Nurse Practice Environment Assessment Scale: Management and Leadership Capabilities (MLC), Compensation and Administration Support(CAS), Job Autonomy (JA), Training and Development (TD), Nurse-Physician Collaboration/Teamwork (NPCT), the higher the score, the better the nurse's professional environment. A positive impact on the nurses' working environment can lead to increased efficiency and quality of care, as well as a reduction in adverse events for patients. This, in turn, has a positive effect on the utilisation of human resources in healthcare.

b). The total score for the nurses' working environment assessment correlates with the results of the assessment of the efficiency of human resources in healthcare. The total score of nurse practice environment assessment: The average total scores for the two years were (75.46 ± 16.32) and (72.75 ± 14.63), respectively, both lower than the Chinese average (79.97 ± 18.21, 81.27±19.92). The overall score of the nurse practice environment assessment is low, indicating a poor nurse practice environment. The efficiency results of nursing human resources: The number of efficient DMUs in two years accounted for 57.89% and 42.11% respectively. The overall efficiency of nursing human resources in two years was not high, and the utilization of nursing resources was not high. From this, the overall score of the nurse practice environment evaluation in the inpatient ward of the hospital is low, the nurse practice environment is poor, and the efficiency of nursing human resources is also not high. The overall efficiency of the nurse human resource utilization was high. This indicates that the hospital's inpatient department had a high nurse-to-patient ratio. The total score for the nurse practice environment assessment was low, indicating that the environment for nurses was unsatisfactory. Furthermore, the efficiency of human resources in nursing was also not optimal.

c). The sub dimensions of the NPEAS have limited impact on the efficiency results of nursing human resources. The proportion of cases where there was no change in the efficiency of human resources in nursing in 2020 and 2021 was 84.2% and 57.89%, respectively. In the second SBM analysis, there were nine indicators. The initial efficiency of human resources in nursing assessment indicators included eight items, and the sub-dimensions of the nurse practice environment assessment scale were used as a single additional indicator. The input indicators were evaluated, which may have resulted in limitations in the data output.

This study proposed a theoretical model, "The Impact of Nurse Work Environment on Nursing Human Resources Efficiency," which was then tested in a quasi-experimental study at A Hospital with 19 DMUs. This theoretical model provides new ideas and insights for hospital managers to study the nurse practice environment and nursing human resource efficiency and has good applicability and operability. Provides a model for hospital managers to evaluate and

improve the nursing practice environment in our hospital.

5.3.2 Ideas for managing nursing human resource efficiency from the perspective of human capital

Marxist labour value theory and Western economists' utility value theory both assert that human capital inherently possesses value. Human capital refers to the ability of workers, as carriers of human capital, to create value through their labour. This includes physical strength, knowledge, skills, and experience. Human capital can be divided into static and dynamic value. Static value is the stock of human capital formed through long-term investments by individuals and society, such as knowledge and skills. Dynamic value refers to the potential value that human capital can realise, such as values, mental reserves, and initiative (Garegnani, 2018).

Human capital is characterised by its centrality, concealment, innovativeness, scarcity, and high returns. Schultz classified the economically valuable capabilities of human capital into five categories: learning ability, working ability, cultural and athletic abilities, creativity, and the ability to cope with imbalances. The level of Human capital is reflected and measured through human capital investment costs and economic value. From an investment cost perspective, the level of Human capital refers to all expenses necessary to maintain the reproduction of human capital. These include: 1. Living expenses of human capital owners. 2. Costs incurred by human capital owners in healthcare, education, training, and migration. 3. Opportunity costs of human capital investment by owners. 4. Investment costs in human capital by the state, society, and enterprises (M. X. Zhang, 2015). From an economic value perspective, the level of Human capital includes both its investment costs and the present value of its future returns. The more developed a country is, the higher its level of Human capital tends to be. Human capital plays an increasingly important role in economic development. China, despite being rich in human resources, has a relatively low level of human capital value. M. X. Zhang (2015) identifies the main factors affecting the enhancement of Human capital in China as conceptual factors, institutional factors, and financial factors. Conceptual factors refer to misunderstandings about the importance of enhancing Human capital for economic development, resulting in insufficient emphasis on human capital investment. Traditional economic growth perspectives focus solely on GDP as the indicator of economic growth, neglecting other important indicators, including culture, environment, and resources. Overemphasis on material wealth growth while ignoring the enhancement of human value inevitably leads to a lack of emphasis on human capital investment (J. L. He, 2015).

Institutional barriers are the fundamental reason for the low level of Human capital in China.

These barriers are divided into investment and allocation barriers. Key investment barriers include a single investment entity, misalignment between education investment structure and labour market demand, unreasonable education investment proportions, and a disconnect between educational theory and job requirements. Major allocation barriers include low human capital mobility, lack of a clear human capital property rights system, single incentive methods for human capital, and unreasonable compensation systems.

Financial constraints are also a crucial reason for China's high human resource abundance but low Human capital level. The government, as the main channel for enhancing human capital value, is constrained by fiscal revenue. Enterprises and residents' investments in enhancing Human capital are limited by income levels and returns. China's fiscal investment in enhancing Human capital remains insufficient. In 2012, China's national fiscal education expenditure accounted for 4.28% of GDP, while in 1997, the proportions of total public education expenditure to GDP were 5.2%, 5.8%, 4.5%, and 4.4% in the United States, France, Germany, and South Korea, respectively (Y. Zhang & Su, 2024). Nursing human resources, as an important category of human resources, need financial and institutional support, as well as updated societal and individual perceptions, to fully reflect their Human capital and improve efficiency.

5.3.3 Ideas for managing the efficiency of nursing human resources from an economic perspective

Human resource efficiency in economics refers to the degree of effective utilization of human resources. From a business perspective, it indicates the extent to which human resources contribute effectively to the company's performance. The main factors influencing human resource efficiency include system factors, quality factors, matching factors, and incentive factors. System factors reflect the impact of organizational structure on human resource efficiency. Quality factors represent the influence of the human resources' own quality structure on their efficiency. Matching factors show the impact of the degree of matching between personnel skills and job requirements on efficiency. Incentive factors indicate the extent to which individuals consciously or unconsciously utilize their potential. The survey used the NPEASS which includes ten dimensions: 1) nurse participation in hospital affairs, 2) Professional practice, 3) leadership and communication, 4) quality management, 5) internal support, 6) nurse/physician collaboration, 7) professional development, 8) staffing adequacy, 9) Social Status, 10) compensation and benefits. These dimensions reflect the system, quality, matching, and incentive factors to some extent (Ying et al., 2016).

Based on these four major influencing factors, experts have proposed strategies to improve human resource efficiency: promoting optimization, simplification, standardization, and regulation of corporate management and employee behavior through scientific management; enhancing the sharing and replicability of knowledge and skills; advancing professional behavior among employees to ensure correct and professional work conduct; engaging in valuable work activities and eliminating both explicit and implicit waste of human resources; and establishing standardized systems for fundamental human resource elements, such as creating a clear repository of standard responsibilities based on business development, with clear standards for duty delineation. Furthermore, analyzing and classifying the various capabilities required by the company according to strategic and business development needs to form standardized capability and knowledge bases. These strategies are valuable for managing nursing human resource efficiency (M. X. Zhang, 2015).

With the development of the digital economy, there are two trends in human resource management thinking: one is to treat human resources as a cost and take corresponding measures to reduce human resource cost expenditures, in order to explore competitive advantages. The second is to treat human resources as assets and maximize their value to enhance competitive advantage. The transformation of human resource management thinking has led to changes in organizational form, increasing the pressure of cost control in human resource management. Propose strategies for controlling human resource management costs from an economic perspective Build a scientific and dynamic salary and welfare mechanism to improve employee work efficiency Control employee turnover rate and reduce opportunity costs caused by employee turnover Optimize human resource allocation and improve employee performance. As the largest group in hospitals, the total cost of nursing personnel also accounts for a significant portion of the hospital's labor costs. Nursing human resource managers and senior hospital managers utilize economic knowledge to improve the management model of nursing human resources, achieve rational allocation and utilization of nursing human resources, and thus assist in the intelligent transformation of nursing human resources, achieving maximum efficiency of nursing human resources.

5.3.4 Perspectives on nursing human resources efficiency management from the Resource-Based View

The Resource-Based View (RBV) posits that a firm's competitive advantage stems from the heterogeneity and inimitability of its internal resources (Barney, 1991). Nursing human resources are not only a critical asset for hospitals but also a fundamental guarantee of the

quality of healthcare services.

The heterogeneity of nursing human resources is reflected in the skills, experience, and attitudes of nurses. Significant differences exist among nurses in areas such as clinical operations, communication skills, and emergency response capabilities. This heterogeneity determines the overall performance of the nursing team. Hospital administrators should ensure that the nursing team possesses diverse skills and experiences through scientific recruitment and training mechanisms to cope with the complex healthcare environment.

The inimitability of nursing human resources lies in their professional knowledge and team collaboration capabilities. The professional knowledge and clinical experience of nurses are accumulated through long-term learning and practice, making them difficult for competitors to replicate. In addition, the collaborative ability and tacit understanding of the nursing team are also important resources that cannot be imitated. Hospitals should enhance the cohesion and collaboration of the nursing team by fostering a positive team culture and implementing incentive mechanisms.

The non-substitutability of nursing human resources is evident in their unique role in patient care. Despite the increasing application of technological advancements and automated equipment in healthcare, the humanistic care and personalised services provided by nurses remain irreplaceable. Hospitals should improve nurses' job satisfaction and working conditions to reduce turnover rates and ensure the stability of the nursing team.

Dynamic capabilities are manifested in the nursing team's ability to quickly adapt and adjust to new medical technologies and patient needs. Hospitals should enhance nurses' professional skills and adaptability through continuous training and education. Furthermore, hospitals should encourage nurses to participate in research and innovation activities to elevate their academic standards and innovative capabilities.

Therefore, from the perspective of the Resource-Based View, strategies for managing the efficiency of nursing human resources include: ① Optimising Human Resource Allocation: Hospitals should allocate nursing human resources rationally based on the characteristics of the nursing team and patient needs. Through scientific scheduling and task allocation, hospitals can ensure that each nurse's workload is reasonable, avoiding overwork and resource wastage. Additionally, hospitals should leverage information technology to streamline nursing workflows and improve efficiency. ② Enhancing Nurses' Comprehensive Competencies: Hospitals should implement systematic training and development programmes to enhance nurses' professional skills and overall competencies. Moreover, hospitals should provide career

development pathways to help nurses achieve their personal career goals, thereby increasing their sense of belonging and job satisfaction. ③ Fostering a Positive Organisational Culture: A strong organisational culture is crucial for improving the efficiency of nursing human resources. Hospitals should build an uplifting team culture to enhance the cohesion and collaboration of the nursing team. For example, regularly organizing team building activities to enhance trust and understanding among nurses. Additionally, hospitals should establish incentive mechanisms to recognise outstanding nurses, setting examples and motivating the entire nursing workforce.

In summary, answer question③:Does the nursing practice environment influence the effectiveness of nursing personnel, and can a model be developed to explain this relationship? Based on literature research, a theoretical model of the impact of nursing practice environment on nursing human resource efficiency is proposed, and a research path is designed for empirical research. After empirical research, this theoretical model provides new ideas and insights for hospital managers, and has good applicability and operability.

5.4 Optimization strategies for improving the nursing practice environment and the efficiency of nursing human resources (managerial contributions)

The final evaluation of the nursing practice environment in this thesis was conducted using the five subscales of the NPEAS, namely: Management and Leadership Capabilities (MLC), Compensation and Administration Support (CAS), Job Autonomy (JA), Training and Development (TD), Nurse-Physician Collaboration/Teamwork (NPCT). The scores of the 5 subscales from 2020 to 2021 show a consistent trend, sorted from low to high, as follows: JA, CAS, MLC, NPCT, TD. Therefore, in improving the nursing practice environment, the key improvement issues are: ① promoting nurses' participation in hospital management and decision-making; ② Provide support in terms of manpower and equipment, improve the working conditions of nurses, and increase their salaries and benefits; ③ Improve the management ability of head nurses and the leadership of nurses themselves.

The results of the nurse practice environment assessment and nursing human resource efficiency for 19 decision-making units (DMUs) were shared with the 19 head nurses, followed by in-depth interviews. The head nurses provided suggestions for hospital nursing management from two dimensions:

From the perspective of promoting factors, improve nursing quality management and

optimize work processes, strengthen medical and nursing collaboration, and foster a positive working environment within departments. From the perspective of restricting factors, decision-making authority over nursing human resource allocation to ensure the rationality and timeliness of staffing decisions. The rationality of nursing human resource structure. Nurse compensation, salary structure, and distribution schemes.

Based on these findings, Based on the above research results, the following strategies are proposed and answered question④: What strategies can nursing managers employ to enhance the nursing practice environment and optimize the efficiency of nursing human resources?

Strategy 1: Enhance the Management Capabilities of Nurse Managers

Nurse managers (head nurses) are the grassroots leaders and organizers of the hospital's nursing team. They are the direct leaders and directors of department nursing work. The quality of departmental nursing is directly related to the nurse manager's own quality and management level. The effectiveness, qualifications, and capabilities of nurse managers will directly impact the hospital's nursing quality and management level. Nursing management is a crucial part of hospital management, and head nurses are the main subjects of nursing management. Therefore, improving the management capabilities of nurse managers should be a priority.

The head nurse takes the initiative to participate in management training and accepts advanced management concepts. Specifically in the nursing practice environment and nursing human resources management, takes the initiative to cooperate with the development of vertical management of hospital nursing, to promote and implement the management of "one bed for the whole hospital", and actively carry out the construction of magnetic departments.

Nurse managers should be fully aware of the importance of establishing a healthy nursing practice environment management model and will continue to optimize the nursing practice environment. Make efforts to create a participatory management atmosphere and authorize nurses to participate in the development of relevant decisions, such as the development of nursing quality improvement measures, interns and new nurses training program development and implementation. Establishing various channels and pathways to help nursing staff communicate effectively at the level of hierarchy or above and below, such as encouraging nurses to participate in nursing committees and join labor unions. Create a nursing work environment with mutual respect and a sense of belonging to enhance nurses' job satisfaction and sense of value.

Nurse managers need to manage nurses according to their abilities, hierarchy and needs, considering both health care and motivational factors. Nurses belong to the grassroots of the hospital, focusing on health care factors: systematic training for new nurses; establishment of

comprehensive and instructive workflows that are easy to implement; nurse scheduling that considers the nurses' competence and position level; and establishment of a reasonable performance allocation program for the department. Regarding motivational factors, assisting nurses to develop career planning, providing nurses with clear promotion paths and training opportunities, and helping staff career development; allowing nurses to gain a sense of accomplishment in their work, giving nurses a certain degree of autonomy, and stimulating nursing staff's innovation and creativity, such as encouraging nurses to carry out new projects and new technologies, innovative inventions, and clinical nursing research.

Strategy 2: Enhance Nurses' Leadership.

Nurse leadership is the ability of the general nurse to integrate care and promote positive patient outcomes by influencing and coordinating patients, families, and members of the healthcare team in the clinical setting. The World Health Organization (WHO) mentions in The State of the World's Nursing 2020 that enhancing nurse leadership can effectively drive the development of the nursing team, improve the quality of care, and provide safer, more efficient, and personalized care to patients. The defining attributes of nurse leadership include clinical competence, self-awareness, influence, and change management ability, and the antecedent factors include demographic characteristics, education and training, and organizational empowerment, and the outcomes of having nurse leadership are to promote self-development, enhance patient satisfaction, increase team cohesion, and promote nursing talent.

Hospitals should establish a long-term mechanism for systematic training of nurses' leadership, and effectively improve nurses' awareness and ability of leadership. Nursing managers should create a working environment that supports communication and teamwork, encourage nurses to communicate with patients and healthcare team members to discuss their conditions and treatment plans, and promote the formation and realization of a common vision; at the same time, managers should provide nurses with sufficient resources and support and encourage nurses to participate in clinical decision-making, which will help enhance their influence on patients and healthcare team members and effectively improve their clinical leadership.

First, nurses should pay attention to the development of their own leadership, improve self-awareness, enhance self-efficacy, and improve mental toughness. Secondly, nurses should continuously improve their clinical ability, do a good job on patient health education, promote patient recovery, and strengthen clinical risk identification and emergency response ability. In clinical nursing, patients are centered, patients and families are encouraged to participate in accomplishing nursing goals, and patients are educated and empowered with knowledge. Build

trusting relationships during ongoing interactions with others, share knowledge and resources with coworkers, communicate timely feedback with members of the multidisciplinary team, and assume responsibility for solving patient care problems. Promote students' personal growth while imparting knowledge and skills, giving full play to the role of mentor. Third, with the complexity of today's healthcare environment, nurses need to learn to utilize digital healthcare resources, improve their information literacy, and identify changes and challenges in the nursing field. Learn to make good use of the initiative and autonomy at hand to demonstrate to others the value of addressing challenges and implementing change. Maintain the ability to be flexible and cope in the midst of change and improve their own change management skills.

Strategy 3: Establish a comprehensive clinical nurse support mechanism in hospitals.

The National Nursing Career Development Plan (2021-2025) points out that medical institutions should increase their efforts to improve nursing services from multiple perspectives, such as human, financial, and material resources, strengthen the manpower of nurses, improve and perfect the incentive mechanism, strengthen the support of information technology, and improve the logistical support system, so as to ensure that nurses are maximally engaged in clinical nursing services, and that patients have a better medical experience and feeling.

Guarantee of nursing human resources. Reasonable allocation of nursing manpower to guarantee the needs of routine clinical nursing work. A pool of mobile nurses has been set up as a manpower reserve for emergencies. Carry out vertical nursing management and “one bed for the whole hospital” management to improve the flexible deployment of nursing manpower and beds. Improve the logistic support system to reduce the non-nursing work of nurses. Equip hospitals with adequate nursing equipment to improve nurses' work efficiency. Building an intelligent clinical nursing information system to improve clinical nursing decision-making.

The hospital establishes a good colleague support system, organizational support system and social support system, improves the humanistic environment of the hospital, and builds a magnetic hospital.

5.5 Limitations and future research directions

This study emphasizes the crucial role of the nurse practice environment in influencing the efficiency of nursing human resources, and the importance of creating a positive nurse practice environment to improve the efficiency of nursing human resources. Key strategies have been proposed to improve the nursing practice environment, with a focus on areas such as management support, professional development opportunities, and organizational culture. By

addressing identified areas of improvement and leveraging their strengths, healthcare institutions can create a more supportive and favourable working environment for nurses, ultimately leading to better patient outcomes and organizational performance.

Although this study provides valuable insights, its limitations must be acknowledged. Firstly, the empirical study of this research was only conducted in a tertiary hospital in Guangdong Province, and limited data may limit the generalizability of the research results in other environments. Secondly, this study is a cross-sectional study that provides information on the nurse practice environment and nursing human resource efficiency at specific time points, which may not capture the long-term trends and impacts of these variable changes. Third, the empirical research time of this study is 2020 and 2021, and its results may be affected by the epidemic situation of novel coronavirus, and there are some deviations caused by uncontrollable factors.

Future research can build on the results of this study by further examining the development and implementation of interventions designed to enhance the quality of care practice environments. Potential interventions may include leadership training programs, strategies to enhance collaboration between nurses and physicians, and strategies to improve work conditions and job satisfaction. In terms of research scope, it would be beneficial to consider a broader range of hospitals and regions, thereby increasing the generalizability of the findings. In terms of time, longitudinal studies could be conducted to track changes over time. A comprehensive understanding of the factors influencing the efficiency of healthcare personnel is essential. Longitudinal studies can provide deeper insights into the long-term impact of changes in the working environment on human resources efficiency. Additionally, they can investigate external factors influencing human resources efficiency, such as policy changes, economic conditions, and technological advancements. In terms of research tools, it is possible to explore the development of a specialized nurse practice environment scale for evaluating departments (small environments), improve hospital information systems, and achieve intelligent analysis of nursing human resource efficiency data.

In conclusion, this study provides a more comprehensive evaluation of the impact of the working environment on human resources efficiency. The findings offer valuable insights for healthcare managers, policy makers, and researchers, emphasizing the significance of a supportive work environment in improving healthcare outcomes and quality of care.

Bibliography

Adomat, R., & Hewison, A. (2004). Assessing patient category/dependence systems for determining the nurse/patient ratio in ICU and HDU: A review of approaches. *Journal of Nursing Management*, *12*(5), 299-308.

Ahmed, S., Hasan, M. Z., MacLennan, M., Dorin, F., Ahmed, M. W., Hasan, M. M., Hasan, S. M., Islam, M. T., & Khan, J. A. (2019). Measuring the efficiency of health systems in Asia: A data envelopment analysis. *British Medical Journal Open*, *9*(3), e022155.

Aiken, L. H., Clarke, S. P., Sloane, D. M., Lake, E. T., & Cheney, T. (2009). Effects of hospital care environment on patient mortality and nurse outcomes. *The Journal of Nursing Administration*, *39*(7/8), S45-S51.

Aiken, L. H., Sermeus, W., Van den Heede, K., Sloane, D. M., Busse, R., McKee, M., Bruyneel, L., Rafferty, A. M., Griffiths, P., & Moreno-Casbas, M. T. (2012). Patient safety, satisfaction, and quality of hospital care: cross sectional surveys of nurses and patients in 12 countries in Europe and the United States. *British Medical Journal*, *344*, 12-17.

Aiken, L. H., Sloane, D. M., Bruyneel, L., Van den Heede, K., Griffiths, P., Busse, R., Diomidous, M., Kinnunen, J., Kózka, M., & Lesaffre, E. (2014). Nurse staffing and education and hospital mortality in nine European countries: a retrospective observational study. *The Lancet*, *383*(9931), 1824-1830.

Aiken, L. H., & Patrician, P. A. (2000). Measuring organizational traits of hospitals: the Revised Nursing Work Index. *Nursing Research*, *49*(3), 146-153.

Allcock, A. (2018). Effective performance management in healthcare. *Journal of Health Organization and Management*, *32*(5), 678-690.

Amaliyah, E., & Tukimin, S. (2021). The relationship between working environment and quality of nursing care: An integrative literature review. *British Journal of Healthcare Management*, *27*(7), 194-200.

Amit, R., & Schoemaker, P. J. (1993). Strategic assets and organizational rent. *Strategic Management Journal*, *14*(1), 33-46.

Arai, H., Ouchi, Y., Yokode, M., Ito, H., Uematsu, H., Eto, F., Oshima, S., Ota, K., Saito, Y., & Sasaki, H. (2012). Toward the realization of a better aged society: Messages from gerontology and geriatrics. *Geriatrics & Gerontology International*, *12*(1), 16-22.

Ayaad, O., Alloubani, A., Thiab, F., Yousef, D., & Banat, B. (2018). Adopting a shared governance model to improve nurses' working environments. *British Journal of Healthcare Management*, *24*(12), 594-602.

Babalola, T. K., & Moodley, I. (2020). Assessing the efficiency of health-care facilities in Sub-Saharan Africa: A systematic review. *Health Services Research and Managerial Epidemiology*, *7*, 1513512244.

Bacelar-Silva, G. M., Cox III, J. F., & Rodrigues, P. P. (2022). Outcomes of managing healthcare services using the TOC: A systematic review. *Health Systems*, *11*(1), 1-16.

Balsanelli, A. P., & Cunha, I. C. K. O. (2015). Nursing leadership in intensive care units and its relationship to the work environment. *Revista Latino-Americana De Enfermagem*, *23*, 106-113.

Barney, J. (1991). Firm resources and sustained competitive advantage. *Journal of Management*, *17*(1), 99-120.

Beaulieu, M., & Bentahar, O. (2021). Digitalization of the healthcare supply chain: A roadmap to generate benefits and effectively support healthcare delivery. *Technological Forecasting*

and Social Change, *167*, 120717.

Bentler, P. M. (1990). Comparative fit indexes in structural models. *Psychological Bulletin*, *107*(2), 238.

Bolton, L. B., & Aronow, H. U. (2009). The business case for TCAB. *The American Journal of Nursing*, *109*(11), 77-80.

Bowblis, J. R., & Roberts, A. R. (2020). Cost-effective adjustments to nursing home staffing to improve quality. *Medical Care Research and Review*, *77*(3), 274-284.

Boxall, P., Ang, S. H., & Bartram, T. (2011). Analysing the "black box" of HRM: Uncovering HR goals, mediators, and outcomes in a standardized service environment. *Journal of Management Studies*, *48*(7), 1504-1532.

Bradshaw, A. (2000). Competence and British nursing: A view from history. *Journal of Clinical Nursing*, *9*(3), 321-329.

Brunt, B. A., & Morris, M. M. (2023). Nursing professional development evidence-based practice. In W. B. Ackley & T. S. Adolphe (Eds.), *StatPearls* (pp. 102-134). StatPearls Publishing.

Bu, M. M., Tian, Z. R., Li, Y., & Hou, J. (2023). 垂直管理模式下护理人力资源管理实践 [Practice of nursing human resource management under vertical management mode]. *Chinese Nursing Management*, *23*(12), 1864-1867.

Buchan, J., Catton, H., & Shaffer, F. (2022). Sustain and retain in 2022 and beyond. *International Council of Nurses*, *71*, 1-71.

Buchan, J., Twigg, D., Dussault, G., Duffield, C., & Stone, P. W. (2015). Policies to sustain the nursing workforce: An international perspective. *International Nursing Review*, *62*(2), 162-170.

Cantor, V. J. M., & Poh, K. L. (2018). Integrated analysis of healthcare efficiency: A systematic review. *Journal of Medical Systems*, *42*, 1-23.

Cao, H. S. (2009). *Investigation of nursing workload in NCU and analysis of related factors* [Master's thesis]. Jilin University.

Cao, J., Jia, Z., Zhu, C., Li, Z., Liu, H., Li, F., & Li, J. (2021). Nurses' turnover intention and associated factors in general hospitals in China: A cross-sectional study. *Journal of Nursing Management*, *29*(6), 1613-1622.

Carthon, J. M. B., Hatfield, L., Brom, H., Houton, M., Kelly-Hellyer, E., Schlak, A., & Aiken, L. H. (2021). System-level improvements in work environments lead to lower nurse burnout and higher patient satisfaction. *Journal of Nursing Care Quality*, *36*(1), 7-13.

Caves, D. W., Christensen, L. R., & Diewert, W. E. (1982). The economic theory of index numbers and the measurement of input, output, and productivity. *Econometrica*, *3*, 1393-1414.

Charnes, A., Cooper, W. W., & Rhodes, E. (1978). Measuring the efficiency of decision making units. *European Journal of Operational Research*, *2*(6), 429-444.

Chen, L., Lv, S. M., Liang, J. L., Li, J., Zhao, B., & Li, L. Y. (2021). 河北省三甲医院护士执业环境测评分析 [Evaluation and analysis of the nurses' working environment in the tertiary hospitals in Hebei Province]. *Journal of Hebei Medical University*, *42*(1), 99.

Chen, P., Zhao, T., & Liu, J. (2021). Improving RAM model applications in healthcare efficiency analysis. *International Journal of Health Management*, *36*(7), 987-1002.

Chen, X., Xu, Q., & Li, X. (2021). 新时代护士护理健康专题研讨（上）：习近平总书记关怀中国护理界讲话汇编 [Special discussion on nurses' care and health in the new era (part one): A compilation of President Xi Jinping's attention to the Chinese nursing community]. *Chinese Journal of Critical Care Medicine*, *41*(8), 645-646.

Cheng, L. H., Song, Y. L., Bai, Y. M., Wen, Y. L., & Xu, G. H. (2020). 基于数据包络分析的护理效率评价与影响因素研究 [Study on evaluation and influencing factors of nursing

efficiency based on data envelopment analysis]. *Journal of Nursing*, *35*(15), 60-62.

Cho, E., Lee, H., Choi, M., Park, S. H., Yoo, I. Y., & Aiken, L. H. (2013). Factors associated with needlestick and sharp injuries among hospital nurses: A cross-sectional questionnaire survey. *International Journal of Nursing Studies*, *50*(8), 1025-1032.

Choi, J., Bakken, S., Larson, E., Du, Y., & Stone, P. W. (2004). Perceived nursing work environment of critical care nurses. *Nursing Research*, *53*(6), 370-378.

Chua, W. L., Legido-Quigley, H., Ng, P. Y., McKenna, L., Hassan, N. B., & Liaw, S. Y. (2019). Seeing the whole picture in enrolled and registered nurses' experiences in recognizing clinical deterioration in general ward patients: A qualitative study. *International Journal of Nursing Studies*, *95*, 56-64.

Čiarnienė, R., Suprikienė, R., Čiutienė, R., Daunorienė, A., & Riklikienė, O. (2019). Managing human resources in nursing: the relationship of nurses' working time and patients' independence level. *Journal of Business Economics and Management*, *20*(1), 192-207.

Cicolini, G., Comparcini, D., & Simonetti, V. (2014). Workplace empowerment and nurses' job satisfaction: A systematic literature review. *Journal of Nursing Management*, *22*(7), 855-871.

Clarke, S. P., Sloane, D. M., & Aiken, L. H. (2002). Effects of hospital staffing and organizational climate on needlestick injuries to nurses. *American Journal of Public Health*, *92*(7), 1115-1119.

Coster, S., Watkins, M., & Norman, I. J. (2018). What is the impact of professional nursing on patients' outcomes globally? An overview of research evidence. *International Journal of Nursing Studies*, *78*, 76-83.

Cudeck, R. (2000). Exploratory factor analysis. In H. E. Tinsley & S. D. Brown (Eds.), *Handbook of applied multivariate statistics and mathematical modeling* (pp. 265-296). Elsevier.

Dai, F. M., & Zhang, X. (2013). 澳大利亚公立医疗集团护士岗位管理的借鉴与思考 [Reference and reflection on nurse job management in Australian public medical groups]. *Chinese Journal of Nursing*, *48*(11), 1011-1013.

Danesh, M. K., Garosi, E., & Golmohamadpour, H. (2021). The COVID-19 Pandemic and nursing challenges: A review of the early literature. *Work*, *69*(1), 23-36.

Davcik, S. N. (2014). The use and misuse of structural equation modeling in management research: A review and critique. *Journal of Advances in Management Research*, *11*(1), 47-81.

de Raeve, P., Xyrichis, A., Bolzonella, F., Bergs, J., & Davidson, P. M. (2023). Workplace violence against nurses: Challenges and solutions for Europe. *Policy, Politics, & Nursing Practice*, *24*(4), 255-264.

Deng, X. X., & Yao, Z. J. (2022). 我国三大重大战略区域的卫生资源配置效率分析 [Analysis on the efficiency of health resource allocation in three major strategic regions of my country]. *Modern Preventive Medicine*, (9), 49.

Dessler, G. (2020). *Fundamentals of human resource management*. John Wiley & Sons.

Dierickx, I., & Cool, K. (1989). Asset stock accumulation and sustainability of competitive advantage. *Management Science*, *35*(12), 1504-1511.

Dong, L. M., Shi, L. N., Yang, Y., & Ren, H. M. (2021). 基于数据包络分析的产房护理效率评价指标的构建 [Construction of evaluation indicators for delivery room nursing efficiency based on data envelopment analysis]. *Nursing Research*, *35*(5), 4.

Drucker, P. (2008). *Management challenges for the 21st century*. Routledge.

Du, M. C., Wang, H., Liu, Y., & Zeng, T. Y. (2023). 护理人力资源配置评价指标的范围综述 [A review of the scope of evaluation indicators for nursing human resource allocation]. *Chinese Journal of Nursing*, *58*(3), 100.

Dubois, C. A., D'Amour, D., Brault, I., Dallaire, C., Déry, J., Duhoux, A., Lavoie Tremblay, M., Mathieu, L., Karemere, H., & Zufferey, A. (2017). Which priority indicators to use to evaluate nursing care performance? A discussion paper. *Journal of Advanced Nursing*, *73*(12), 3154-3167.

Duffield, C. M., Roche, M. A., Blay, N., & Stasa, H. (2011). Nursing unit managers, staff retention and the work environment. *Journal of Clinical Nursing*, *20*(1-2), 23-33.

Duffield, C. M., Roche, M. A., Homer, C., Buchan, J., & Dimitrelis, S. (2014). A comparative review of nurse turnover rates and costs across countries. *Journal of Advanced Nursing*, *70*(12), 2703-2712.

El-Gazar, H. E., & Zoromba, M. A. (2021). Nursing human resource practices and hospitals' performance excellence: The mediating role of nurses' performance. *Acta Bio Medica: Atenei Parmensis*, *92*(S2), e2021022.

Emrouznejad, A., & Yang, G. (2018). A survey and analysis of the first 40 years of scholarly literature in DEA: 1978–2016. *Socio-Economic Planning Sciences*, *61*, 4-8.

Endeshaw, B. (2021). Healthcare service quality-measurement models: A review. *Journal of Health Research*, *35*(2), 106-117.

Estabrooks, C. A., Tourangeau, A. E., Humphrey, C. K., Hesketh, K. L., Giovannetti, P., Thomson, D., Wong, J., Acorn, S., Clarke, H., & Shamian, J. (2002). Measuring the hospital practice environment: A Canadian context. *Research in Nursing & Health*, *25*(4), 256-268.

Evans, T., Rittenhouse, K., Horst, M., Osler, T., Rogers, A., Miller, J. A., Martin, C., Mooney, C., & Rogers, F. B. (2014). Magnet hospitals are a magnet for higher survival rates at adult trauma centers. *Journal of Trauma and Acute Care Surgery*, *77*(1), 89-94.

Feather, R. A., Ebright, P., & Bakas, T. (2015). Nurse manager behaviors that RN s perceive to affect their job satisfaction. *Nursing Forum*, *50*(3), 125-136.

Feng, L., Chen, H., & Yang, R. (2013). 我国护理人力资源配置现状分析 [Analysis on the current situation of nursing human resources allocation in my country]. *Hospital Management in China*, (8), 69-71.

Ferreira, M., Vidal, D. G., Ferreira, C., & Gregório, S. (2021). The impact of lack of affection and poor social ties in the nurses work environment: Evidence from a Portuguese sample. *European Journal of Public Health*, *31*(Supplement 2), 10.

Fu, L. P. (2015). 英国护士的分级管理及高级护理实践 [Grading management and advanced nursing practice of nurses in the UK]. *Chinese Journal of Modern Nursing*, (20), 2479-2480.

Garegnani, P. (2018). On the labour theory of value in Marx and in the Marxist tradition. *Review of Political Economy*, *30*(4), 618-642.

Gavurova, B., Kocisova, K., & Sopko, J. (2021). Health system efficiency in OECD countries: dynamic network DEA approach. *Health Economics Review*, *11*, 1-25.

Giancotti, M., Guglielmo, A., & Mauro, M. (2017). Efficiency and optimal size of hospitals: Results of a systematic search. *PLoS One*, *12*(3), e0174533.

Gile, P. P., Buljac-Samardzic, M., & Klundert, J. V. D. (2018). The effect of human resource management on performance in hospitals in Sub-Saharan Africa: A systematic literature review. *Human Resources for Health*, *16*, 1-21.

Goldin, C. (2024). *Human capital*. Springer.

Grabowski, D. C., & Mor, V. (2020). Nursing home care in crisis in the wake of COVID-19. *Jama-Journal of the American Medical Association*, *324*(1), 23-24.

Grant, R. M. (1991). The resource-based theory of competitive advantage: Implications for strategy formulation. *California Management Review*, *33*(3), 114-135.

Griffiths, P., Ball, J., Drennan, J., & Jones, J. (2019). Nurse staffing levels and continuity of care: An international perspective. *International Journal of Nursing Studies*, (92), 1-10.

Griffiths, P., Saville, C., Ball, J., Jones, J., Pattison, N., Monks, T., & Group, S. N. C. S. (2020). Nursing workload, nurse staffing methodologies and tools: A systematic scoping review and discussion. *International Journal of Nursing Studies*, *103*, 103487.

Guo, H. T., Qi, X. R., Li, Y. L., Gong, Y. L., & Fu, C. (2018). 中国护士执业环境研究进展 [Research progress on the professional environment of Chinese nurses]. *Modern Clinical Nursing*, *17*(6), 5.

Guo, N., Zhang, L., & Lu, X. (2015). 应用Mobley模型分析护理人员流失原因及对策 [Analysis on nursing staff turnover by using Mobley Model: Reasons and countermeasures]. *Hospital Administration Journal of Chinese People's Liberation Army*, *22*(5), 433-435.

Han, B., Chen, X., & Li, Q. (2018). 病例组合指数在护理人力资源配置中的应用 [Application of case mix index in the allocation of nursing human resources]. *Journal of Nursing Management*, *26*(6), 647-652.

Han, X., Zhang, L., & Wang, Y. (2021). Efficiency evaluation using the bcc model: Applications in healthcare organizations. *Operations Research in Medicine*, *15*(2), 123-135.

Harrison, J., & Rouse, P. (2016). DEA and accounting performance measurement. In S. N. Hwang, H. S. Lee, & J. Zhu (Eds.), *Handbook of operations analytics using data envelopment analysis* (pp. 385-412). Springer.

Hassanein, E. H., El-Hawary, M. A., Abdel-Aziz, M. A., & Mehany, M. M. (2020). Effect of designing Educational Program on NursesPerformance for Immediate care of post cystectomy Patients at Intensive Care Unit. *Assiut Scientific Nursing Journal*, *8*(20), 114-123.

He, J. L. (2015). *Research on the role of human capital value enhancement in the transformation of economic development mode and its implementation mechanism* [Master's thesis]. Hunan University.

He, L. S. (2023). *Research on the efficiency and influencing factors of resource allocation in grassroots medical and health institutions in Tianjin* [Master's thesis]. Tianjin University of Traditional Chinese Medicine.

He, Q., Fu, Y., Su, Y., & Luan, Y. (2020). 了解中国的护理教育和实践，以发展国际护理伙伴关系 [Understanding Chinese nursing education and practice for developing international nursing partnerships]. *Journal of Transcultural Nursing*, *31*(4), 406-412.

Herrick, C. (2024). Problems of past anticipations of the future: The case of medical manpower. *The Geographical Journal*, *190*(2), e12564.

Hesterly, W., & Barney, J. (2014). *Strategic management and competitive advantage*. Pearson.

Hilko, A., Smith, J., & Brown, L. (2023). Aligning human resource strategies with performance-based pay systems in healthcare. *International Journal of Human Resource Management*, *34*(2), 256-270.

Hinno, S., Partanen, P., & Vehviläinen Julkunen, K. (2012). Nursing activities, nurse staffing and adverse patient outcomes as perceived by hospital nurses. *Journal of Clinical Nursing*, *21*(11-12), 1584-1593.

Hu, L. T., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling*, *6*(1), 1-55.

Hua, H., Zhang, W. Y., & Zhang, Y. (2018). 统一床位管理优化住院流程的服务模式探索 [Exploration of service model for unified bed management and optimization of hospitalization process]. *Chinese Hospital*, *22*(10), 3.

Huang, A., Fang, P., Tao, S., Chen, M., Shen, M., & Le, H. (2018). 2011年与2016年中国护理人力资源配置公平性比较研究 [Comparative study on equity of Chinese nursing human resource allocation in 2011 and 2016]. *Chinese Health Economics*, *37*(1), 70-73.

Huang, C. C. (2024). *Relationships among organizational context, structure, and medication errors in Taiwanese nursing units* [Doctoral dissertation]. The University of North Carolina.

Jang, H., & Choi, E. (2020). The impacts of nurses' working environment on health problems. *Korean Journal of Occupational Health Nursing*, *29*(1), 1-7.

Ji, W., Sun, H., & Zhao, F. (2019). Application of Fuzzy DEA models in unpredictable hospital environments. *European Journal of Operational Research*, *277*(4), 987-995.

Jia, S. J., & Feng, H. J. (2022). 某三级甲等医院护士执业环境现状调查分析 [Investigation and analysis of the current situation of nursing practice environment in a tertiary hospital]. *Evidence-Based Nursing*, (7), 8-10.

Jiao, H., Li, J., Liu, L., & Zhao, H. (2023). Study on the rationalization of human resources allocation in hospitals in the post-epidemic era. *Applied Mathematics and Nonlinear Sciences*, *9*(1), 1-16.

Jöreskog, K. G. (1969). A general approach to confirmatory maximum likelihood factor analysis. *Psychometrika*, *34*(2), 183-202.

Kadom, N., Itri, J. N., Trofimova, A., Otero, H. J., & Horný, M. (2019). Cost-effectiveness analysis: An overview of key concepts, recommendations, controversies, and pitfalls. *Academic Radiology*, *26*(4), 534-541.

Kanbara, S., Yamamoto, Y., Sugishita, T., Nakasa, T., & Moriguchi, I. (2017). Japanese experience of evolving nurses' roles in changing social contexts. *International Nursing Review*, *64*(2), 181-186.

Karami, A., Farokhzadian, J., & Foroughameri, G. (2017). Nurses' professional competency and organizational commitment: Is it important for human resource management? *Public Library of Science One*, *12*(11), e0187863.

Katowa-Mukwato, P., Mwiinga-Kalusopa, V., Chitundu, K., Kanyanta, M., Chanda, D., Mwelwa, M. M., Ruth, W., Mundia, P., & Carrier, J. (2021). Implementing evidence based practice nursing using the PDSA model: Process, lessons and implications. *International Journal of Africa Nursing Sciences*, *14*, 100261.

Kelly, D., Kutney-Lee, A., Lake, E. T., & Aiken, L. H. (2013). The critical care work environment and nurse-reported health care-associated infections. *American Journal of Critical Care*, *22*(6), 482-488.

Kelly, L. A., Gee, P. M., & Butler, R. J. (2021). Impact of nurse burnout on organizational and position turnover. *Nursing Outlook*, *69*(1), 96-102.

Kelly, L. A., McHugh, M. D., & Aiken, L. H. (2011). Nurse outcomes in magnet and non-magnet hospitals. *The Journal of Nursing Administration*, *41*(10), 428-433.

Kovner, C. T., Djukic, M., Fatehi, F. K., Fletcher, J., Jun, J., Brewer, C., & Chacko, T. (2016). Estimating and preventing hospital internal turnover of newly licensed nurses: A panel survey. *International Journal of Nursing Studies*, *60*, 251-262.

Kramer, M., & Hafner, L. P. (1989). Shared values: Impact on staff nurse job satisfaction and perceived productivity. *Nursing Research*, *38*(3), 172-177.

Kunjumen, T., Okech, M., Diallo, K., Mcquide, P., Zapata, T., & Campbell, J. (2022). Global experiences in health workforce policy, planning and management using the Workload Indicators of Staffing Need (WISN) method, and way forward. *Human Resources for Health*, *19*(S1), 152.

Labrague, L. J., De Los Santos, J. A. A., Tsaras, K., Galabay, J. R., Falguera, C. C., Rosales, R. A., & Firmo, C. N. (2020). The association of nurse caring behaviours on missed nursing care, adverse patient events and perceived quality of care: A cross-sectional study. *Journal of Nursing Management*, *28*(8), 2257-2265.

Lake, E. T. (2002). Development of the practice environment scale of the nursing work index. *Research in Nursing & Health*, *25*(3), 176-188.

Lake, E. T. (2007). The nursing practice environment. *Medical Care Research and Review*, *64*(S2), 104S-122S.

Lake, E. T., Sanders, J., Duan, R., Riman, K. A., Schoenauer, K. M., & Chen, Y. (2019). A

meta-analysis of the associations between the nurse work environment in hospitals and 4 sets of outcomes. *Medical Care*, *57*(5), 353-361.

Lammintakanen, J., Saranto, K., Kivinen, T., & Kinnunen, J. (2002). The digital portfolio: a tool for human resource management in health care? *Journal of Nursing Management*, *10*(6), 321-328.

Lan, J., Diao, G. F., & Zhang, H. Q. (2023). "全院一张床"提高床位效率和效益的管理措施探讨 [Discussion on the management measures of "one bed for the whole hospital" to improve the efficiency and benefit of beds]. *Business Information*, (36), 121-124.

Lan, Y. Y., Kan, L., & Niu, H. Y. (2020). 基于 DEA 的我国医疗机构护理效率的综合评价 [Comprehensive evaluation of nursing efficiency of medical institutions in my country based on DEA]. *China Health Statistics*, *37*(4), 595-598.

Lee, S., Kim, C., Kang, J., Yoon, T., & Kim, C. S. (2014). Influence of the nursing practice environment on job satisfaction and turnover intention. *Journal of Preventive Medicine and Public Health*, *47*(5), 258.

Li, H. Y. (2023). *Analysis of the operation status and effectiveness of nurse post management in a third class hospital in Yunnan Province based on vertical management* [Master's thesis]. Kunming Medical University.

Li, R., Liang, G., Xu, Y., & Zhuang, L. (2016). 我国护理人力资源配置研究进展 [Research progress on nursing human resources allocation in China]. *Chinese Nursing Research*, *30*(15), 1799-1802.

Li, T., & Li, G. (2018). 针对护理人力资源流失的干预措施的回顾 [A review of interventions against loss of nursing human resources]. *Journal of Nursing Science*, *33*(4), 107-110.

Li, X. Q. (2017). 基于数据包络分析的福建省科技创新效率研究 [Research on the efficiency of scientific and technological innovation in Fujian Province based on data envelopment analysis]. *Journal of Xiamen University of Technology*, *25*(6), 8.

Li, Y. Y., Zhao, J., & Xu, P. P. (2024). 2012-2021年全国中医医院卫生资源配置效率分析 [Analysis of the efficiency of health resource allocation in traditional Chinese medicine hospitals in China from 2012 to 2021]. *Soft Science of Health*, *38*(2), 70-75.

Liu, C. (2024). 经济学视角下人力资源管理成本分析及控制策略 [Human resource management cost analysis and control strategies from an economic perspective]. *Modernization of Business Market*, (18), 98-100.

Liu, D. (2023). 人口大国现代化的中国道路：价值内涵、现实路径与现实选择 [Chinese path to modernization with a huge population size: Value connotation, realistic approach and practical choice]. *Contemporary Economic Research*, (9), 39-45.

Liu, J., Liu, X., Zheng, J., Liu, K., Wu, Y., Wang, J., Li, M., & You, L. (2021). Changes over 10 years in the nursing workforce in Guangdong province, China: Three-wave multisite surveys. *Journal of Nursing Management*, *29*(8), 2630-2638.

Liu, K., Luan, J., Zhang, T. T., & Fan, W. Y. (2023). 基于数据包络分析的某三甲医院科室效率分析与探讨 [Analysis and discussion on the efficiency of a tertiary hospital department based on data envelopment analysis]. *Hospital Management Forum*, *40*(9), 46-49.

Liu, W., Guo, Y. N., Feng, X. R., Zhang, H. F., & Zou, P. (2021). 天津市三级甲等综合儿科医院护士执业环境现状分析及对策 [Analysis on the current situation and countermeasures of nurses' working environment in tertiary grade A comprehensive pediatric hospitals in Tianjin]. *Tianjin Nursing*, *29*(1), 16.

Liu, X. M., Wang, J., Xin, X., & Li, J. Q. (2023). 陕西省护士执业环境现状调查与影响因素分析 [Investigation on the current situation of nursing practice environment in Shaanxi Province and analysis of influencing factors]. *Chinese Health Quality Management*, *30*(1),

44-48.

Lu, H., Hou, L., Zhou, W., Shen, L., Jin, S., Wang, M., Shang, S., Cong, X., Jin, X., & Dou, D. (2021). Trends, composition and distribution of nurse workforce in China: A secondary analysis of national data from 2003 to 2018. *British Medical Journal Open*, *11*(10), e047348.

Luo, L. H., Hu, X. J., & Feng, J. (2018). 企业创新效率评价指标体系实证比较研究 [Empirical comparative study on the evaluation index system of enterprise innovation efficiency]. *Scientific Research Management*, *39*(2), 6.

Luo, Y., & Ma, Z. (2021). 比较法视角下的国际护士立法及其启示 [International nurse legislation from perspective of comparative law and its enlightenment]. *Journal of Nursing*, *18*(28), 74-78.

Ma, Y. X., & Han, L. (2013). 护理人力资源配置方法的研究进展 [Study on methods of nursing human resources allocation]. *Journal of Nursing Science*, (4), 92-95.

Mabin, V. J., & Balderstone, S. J. (2020). *The world of the theory of constraints: A review of the international literature*. CRC Press.

Mabona, J. F., van Rooyen, D. R., & Ten Ham-Baloyi, W. (2022). Best practice recommendations for healthy work environments for nurses: An integrative literature review. *Health SA Gesondheid*, *27*(1), 17-24.

Mahgoub, A. E., Mostafa Shazly, M., & Mohammed El-sayed, S. (2019). Relationship between work environment and innovative behavior among staff nurses. *Egyptian Journal of Health Care*, *10*(3), 64-76.

Manning, J., & Jones, N. (2021). Improving healthy work environments through specialty nursing professional development. *Journal of Radiology Nursing*, *40*(3), 241-245.

Marć, M., Bartosiewicz, A., Burzyńska, J., Chmiel, Z., & Januszewicz, P. (2019). A nursing shortage: A prospect of global and local policies. *International Nursing Review*, *66*(1), 9-16.

Marchal, B., & Kegels, G. (2008). Focusing on the software of managing health workers: What can we learn from high commitment management practices? *The International Journal of Health Planning and Management*, *23*(4), 299-311.

McCaughey, D., McGhan, G. E., Rathert, C., Williams, J. H., & Hearld, K. R. (2020). Magnetic work environments: Patient experience outcomes in Magnet versus non-Magnet hospitals. *Health Care Management Review*, *45*(1), 21-31.

McHugh, M. D., Kelly, L. A., Smith, H. L., Wu, E. S., Vanak, J. M., & Aiken, L. H. (2013). Lower mortality in magnet hospitals. *Medical Care*, *51*(5), 382-388.

McKenzie-Green, B. A. (2003). *Shifting focus: how registered nurses in residential aged care organise their work: A grounded theory study* [Doctoral dissertation]. Auckland University of Technology.

Milstein, R., & Schreyoegg, J. (2020). The relationship between nurse staffing levels and nursing-sensitive outcomes in hospitals: Assessing heterogeneity among unit and outcome types. *Health Policy*, *124*(10), 1056-1063.

Min, A., Scott, L. D., Park, C., Vincent, C., Ryan, C. J., & Lee, T. (2018). Impact of M edicare A dvantage penetration and hospital competition on technical efficiency of nursing care in US intensive care units. *The International Journal of Health Planning and Management*, *33*(3), 733-745.

Mirmozaffari, M., & Kamal, N. (2023). The application of data envelopment analysis to emergency departments and management of emergency conditions: A narrative review. *Healthcare 2023*, *11*(18), 2541.

Najjar, M. E., Hamdan, M., & Baillien, E. (2020). The impact of performance-based payment on nurses' performance: A cross-sectional study in Palestinian hospitals. *Journal of Nursing Management*, *28*(5), 1104-1112.

Nascimento, A., de Jesus, É., de Almeida, S. P., & Nunes, E. (2021). Validation and psychometric assessment of the Practice Environment Scale of the Nursing Work Index in the Portuguese hospital context. *Journal of Nursing Measurement*, *29*(2), 269-282.

Nelson III, K. E. (2017). Nurse manager perceptions of work overload and strategies to address it. *Nurse Leader*, *15*(6), 406-408.

Newman, C., Nayebare, A., Gacko, N. M. N. N., Okello, P., Gueye, A., Bijou, S., Ba, S., Gaye, S., Coumba, N. D., & Gueye, B. (2023). Systemic structural gender discrimination and inequality in the health workforce: Theoretical lenses for gender analysis, multi-country evidence and implications for implementation and HRH policy. *Human Resources for Health*, *21*(1), 37.

Nikpeyma, N., Abed Saeedi, Z., Azargashb, E., & Alavi Majd, H. (2014). Problems of clinical nurse performance appraisal system: A qualitative study. *Asian Nursing Research*, *8*(1), 15-22.

North, N., Leung, W., Ashton, T., Rasmussen, E., Hughes, F., & Finlayson, M. (2013). Nurse turnover in New Zealand: Costs and relationships with staffing practises and patient outcomes. *Journal of Nursing Management*, *21*(3), 419-428.

Okoroafor, S. C., Ahmat, A., Osubor, M., Nyoni, J., Bassey, J., & Alemu, W. (2022). Assessing the staffing needs for primary health care centers in Cross River State, Nigeria: A workload indicators of staffing needs study. *Human Resources for Health*, *19*(Supplement 1), 108.

Osman, I. H., Berbary, L. N., Sidani, Y., Al-Ayoubi, B., & Emrouznejad, A. (2011). Data envelopment analysis model for the appraisal and relative performance evaluation of nurses at an intensive care unit. *Journal of Medical Systems*, *35*, 1039-1062.

Peng, G. (2004). The counter-measures and status of the management of nursing human resource in Guangdong province. *Chinese Nursing Management*, *4*(2), 14-19.

Peng, X. F., Gao, X. H., & Sun, J. (2020). 医院绩效工资分配的问题及对策分析 [Analysis on the problems and countermeasures of performance wage distribution in hospitals]. *China Medical Guide*, *18*(3), 384-385.

Pérez-Francisco, D. H., Sáez-Rubio, M. A., & Fernández-López, A. (2020). High turnover and its effects on nursing workforces. *Journal of Nursing Management*, *28*(7), 1523-1532.

Pérez-Romero, C., Ortega-Díaz, M. I., Ocaña-Riola, R., & Martín-Martín, J. J. (2017). Análisis de la eficiencia técnica en los hospitales del Sistema Nacional de Salud español. *Gaceta Sanitaria*, *31*(2), 108-115.

Peteraf, M. A. (1993). The cornerstones of competitive advantage: A resource-based view. *Strategic Management Journal*, *14*(3), 179-191.

Qiao, Y. (2014). *The elements of healthy nursing working environment* [Mater's thesis]. Zhe Jiang University.

Qin, H., & Hua, H. (2020). On the definition of nursing human resource quantities. *Journal of Health Policy Research*, *12*(4), 45-52.

Rachana, S. (2019). Performance-based pay in healthcare: A comparative study of Germany and the UK. *Health Policy*, *123*(10), 915-920.

Rafferty, J., Mattson, G., Earls, M. F., Yogman, M. W., Gambon, T. B., Lavin, A., Wissow, L. S., & Health, C. O. P. A. (2019). Incorporating recognition and management of perinatal depression into pediatric practice. *Pediatrics*, *1*, 143.

Raykov, T., & Marcoulides, G. A. (2006). On multilevel model reliability estimation from the perspective of structural equation modeling. *Structural Equation Modeling*, *13*(1), 130-141.

Ren, L., Gao, M., & Zhang, X. (2022). Dynamic DEA models for efficiency analysis over time: Case studies in hospital operations. *Journal of Operational Research*, *48*(1), 112-127.

Roche, M., Diers, D., Duffield, C., & Catling Paull, C. (2010). Violence toward nurses, the work environment, and patient outcomes. *Journal of Nursing Scholarship*, *42*(1), 13-22.

Rumbold, B. E., Smith, J. A., Hurst, J., Charlesworth, A., & Clarke, A. (2015). *Health*

economics, policy and law. Cambridge.

Said, H., Ali, L., Ali, F., & Chen, X. (2021). COVID-19 and unpaid leave: Impacts of psychological contract breach on organizational distrust and turnover intention: Mediating role of emotional exhaustion. *Tourism Management Perspectives*, *39*, 100854.

Sherman, H. D. (1984). Hospital efficiency measurement and evaluation: Empirical test of a new technique. *Medical Care*, *22*(10), 922-938.

Shi, L. (2006). *Managing human resources in health care organizations*. Jones & Bartlett Publishers.

Shi, R. (2015). 香港护理教育概况与启示 [General situation and enlightenment of nursing education in Hong Kong]. *Contemporary Educational Practice and Teaching Research*, (5), 238.

Song, G. Q., Huang, L., Qin, Y. X., & Huang, J. L. (2014). 基于护理岗位管理的护士队伍成效建设 [Effectiveness construction of nursing team based on nursing post management]. *Journal of Nursing: General Edition*, *29*(4), 4.

Song, S., Wei, L., Liu, Y., Wang, Q., Luo, R., & Lin, M. (2021). 应用数据包络分析法评价心内科护理人力资源效率的研究 [Application of Data Envelopment Analysis in evaluation human resources efficiency of nursing in department of cardiology]. *Chinese Nursing Management*, *21*(5), 745-749.

Stalpers, D., de Brouwer, B. J., Kaljouw, M. J., & Schuurmans, M. J. (2015). Associations between characteristics of the nurse work environment and five nurse-sensitive patient outcomes in hospitals: A systematic review of literature. *International Journal of Nursing Studies*, *52*(4), 817-835.

Stemmer, R., Bassi, E., Ezra, S., Harvey, C., Jojo, N., Meyer, G., Özsaban, A., Paterson, C., Shifaza, F., & Turner, M. B. (2022). A systematic review: Unfinished nursing care and the impact on the nurse outcomes of job satisfaction, burnout, intention-to-leave and turnover. *Journal of Advanced Nursing*, *78*(8), 2290-2303.

Su, W., Hou, Y., Huang, M., Xu, J., Du, Q., & Wang, P. (2023). Evaluating the efficiency of primary health care institutions in China: An improved three-stage data envelopment analysis approach. *Bmc Health Services Research*, *23*(1), 995.

Suliman, M., & Aljezawi, M. (2018). Nurses' work environment: Indicators of satisfaction. *Journal of Nursing Management*, *26*(5), 525-530.

Sun, S., Xie, Z., Yu, K., Jiang, B., Zheng, S., & Pan, X. (2021). COVID-19 and healthcare system in China: Challenges and progression for a sustainable future. *Globalization and Health*, *17*, 1-8.

Suprapto, S., Lalla, N. N., Mulat, T. C., & Arda, D. (2023). Human resource development and job satisfaction among nurses. *International Journal of Public Health*, *12*(3), 1056-1063.

Swiger, P. A., Patrician, P. A., Miltner, R. S. S., Raju, D., Breckenridge-Sproat, S., & Loan, L. A. (2017). The Practice Environment Scale of the Nursing Work Index: An updated review and recommendations for use. *International Journal of Nursing Studies*, *74*, 76-84.

Tabachnick, B. G. (2007). *Experimental designs using ANOVA*. Oxford Press.

Teece, D. J., Pisano, G., & Shuen, A. (1997). Dynamic capabilities and strategic management. *Strategic Management Journal*, *18*(7), 509-533.

Tone, K. A. (2002). Slacks-based measure of super-efficiency in data envelopment analysis. *European Journal of Operational Research*, *143*(1), 32-41.

Tulchinsky, T. H., & Varavikova, E. A. (2014). Human resources for health. *The New Public Health*, *1*, 729.

Ulusoy, H., & Polatkan, R. (2016). Assessment of the nurses' work environment using the nursing work index scale. *Cumhuriyet Medical Journal*, *38*(4), 246-257.

Valdmanis, V. G., Rosko, M. D., Leleu, H., & Mukamel, D. B. (2017). Assessing overall, technical, and scale efficiency among home health care agencies. *Health Care Management*

Science, *20*, 265-275.

Van Bogaert, P., Wouters, K., Willems, R., Mondelaers, M., & Clarke, S. (2013). Work engagement supports nurse workforce stability and quality of care: Nursing team-level analysis in psychiatric hospitals. *Journal of Psychiatric and Mental Health Nursing*, *20*(8), 679-686.

Wan, Q., Li, Z., Zhou, W., & Shang, S. (2018). Competitive compensation structures in healthcare and their impact on staff retention. *International Journal of Nursing Studies*, *85*, 10-17.

Wang, G. (2003). 香港医院护理工作管理特点 [Characteristics of nursing management in Hong Kong hospitals]. *Shandong Medical Journal*, *43*(14), 64-65.

Wang, L., Tao, H., & Liu, X. H. (2011). 护士留职意愿与工作满意度的相关性研究 [Study on the correlation between nurses' willingness to stay and job satisfaction]. *Chinese Journal of Nursing*, *46*(1), 19-22.

Wang, L., & Li, L. Z. (2011). 中文版护理工作环境量表的信效度研究 [Reliability and validity of Chinese version of the Practice Environment Scale]. *Chinese Journal of Nursing*, *46*(2), 121-123.

Wang, P. F., Zhang, H., Li, R., Ji, H., & Zhang, P. (2015). 医院护理人力资源管理系统的设计与应用 [Design and application the nursing human resource information system in hospital]. *Chinese Nursing Management*, *15*(1), 74-76.

Wang, X. (2012). *Research on work engagement and its influencing factors of clinical nurses* [Master's thesis]. Nankai University.

Wei, H. K., Nian, M., & Li, L. (2020). China's strategies and policies for regional development during the period of the 14th five-year plan. *Chinese Journal of Urban and Environmental Studies*, *8*(2), 2050008.

Wei, H. M., Liao, Y., & Guo, J. X. (2017). 护理执业环境现状的研究进展 [Research progress on the current situation of nursing practice environment]. *Journal of Nursing Administration*, *17*(10), 3.

Weng, F., Bai, Y., & Tao, L. (2019). 国内外护理人力资源效率指标研究进展 [Research advances on human resource efficiency indicators of nursing in China and abroad]. *Journal of Nursing Research*, *33*(12), 2049-2052.

Weng, Y., Tao, L., Chen, L., & Bai, Y. (2019). 国内外护理人力资源效率指标的研究进展 [Research advances on human resource efficiency indicators of nursing in China and abroad]. *Chinese Nursing Research*, *33*(12), 2049-2052.

Weston, M. J. (2022). Strategic planning for a very different nursing workforce. *Nurse Leader*, *20*(2), 152-160.

Wheaton, B. (1977). *Assessing reliability and stability in panel models*. Jossy-Bass.

Worthington, A. C. (2004). Frontier efficiency measurement in health care: A review of empirical techniques and selected applications. *Medical Care Research and Review*, *61*(2), 135-170.

Wu, X. J., Zhu, C., & Jiao, J. (2019). 磁性医院理念:创造优质的护理执业环境 [Magnetic hospital concept: creating a high quality nursing practice environment]. *Journal of Nursing Administration*, *19*(5), 4.

Wu, X., & Wang, Y. (2021). *护理管理学* [Nursing management]. People's Health Publishing House.

Wu, Y. H., Liu, C., & Zheng, Y. Z. (2017). 数据包络分析法在我院护理工作效率评价中的应用 [Application of data envelopment analysis in assessment of nursing efficiency of a general hospital]. *Modern Clinical Nursing*, *16*(3), 60-63.

Wynendaele, H., Willems, R., & Trybou, J. (2019). Systematic review: Association between the patient–nurse ratio and nurse outcomes in acute care hospitals. *Journal of Nursing*

Management, *27*(5), 896-917.

Xiao, M., Cooke, F. L., Xu, J., & Bian, H. (2020). To what extent is corporate social responsibility part of human resource management in the Chinese context? A review of literature and future research directions. *Human Resource Management Review*, *30*(4), 100726.

Xu, M., Zhong, H., Li, Y., Shan, L., & An, X. (2019). 基于 DEA 模型的我国三级医院科研效率评价研究 [Chinese Hospital Management]. *China Hospital Management*, *39*(9), 55-58.

Xu, W., Wang, M., Bai, Y., Huang, F., Wang, D., & Song, Y. (2018). 数据包络分析应用于护理人力资源效率评价的研究进展 [Data envelopment analysis in nursing human resource efficiency evaluation: A literature review]. *Nursing Management in China*, *18*(3), 396-399.

Yang, B. Y., Guo, C. Y., Ye, W. Q., & Li, L. (2014). 国内外护理人力资源配置政策的现况及思考 [Current situation and reflections on nursing human resource allocation policies at home and abroad]. *PLA Nursing Journal*, *31*(2), 42-43, 52.

Yang, X., & Wu, Q. (2008). *现代医院护理人力资源管理* [Nursing human resource management in modern hospital]. Military Medical Science Press.

Yang, Y. Y., He, M., Yang, Y., Liu, Q., Liu, H., Chen, X., Wu, W., & Yang, J. (2023). Construction and application of a nursing human resource allocation model based on the case mix index. *Bmc Nursing*, *22*(1), 466.

Ying, X., Zhang, H. Y., Jian, W. Y., & Mo, L. (2016). 护士执业环境的研究现状 [Research status of nursing practice environment]. *Chinese Nursing Management*, (6), 6.

Ying, X., Zhang, H., Shang, W., Li, J., Jian, W., Yao, L., & Feng, Z. (2016). 5家大型医院护士执业环境测评结果分析 [Nurses' perceptions of professional practice environment: A cross-sectional study]. *Chinese Nursing Management*, *16*(7), 873-878.

Yu, K. X. (2024). 基于DEA-BCC模型的某公立医院临床科室运行效率研究 [Research on the operational efficiency of clinical departments in a public hospital based on DEA-BCC model]. *Jiangsu Science and Technology Information*, (16), 128-132.

Zelauskas, B., & Howes, D. G. (1992). The effects of implementing a professional practice model. *The Journal of Nursing Administration*, *22*(7/8), 18-23.

Zeng, J., Liang, R., Zhang, D., Li, Q., Ming, X., Chen, C., & Ding, Y. (2021). 四川省 52 所三级医院护士执业环境现状及影响因素研究 [Analysis on the current situation and influencing factors of nurse practice environment in 52 tertiary hospitals in Sichuan Province]. *Journal of Nursing Administration*, *21*(5), 313-317.

Zhang, B., Zhang, L. X., Sun, S. W., & Liu, H. (2023). 基于数据包络分析法的安徽省妇幼保健机构资源配置效率评价与分析 [Evaluation and analysis of resource allocation efficiency of maternal and child health care institutions in Anhui province based on data envelopment analysis]. *Chinese Primary Health Care*, *37*(4), 51-55.

Zhang, H. F., Liu, Y. H., Yang, Y., & Liu, J. Y. (2015). 在职护士离职倾向相关因素分析 [Analysis of factors related to turnover tendency of employed nurses]. *Chinese Journal of Nursing*, *50*(2), 6.

Zhang, H. Y., Liang, J., Yao, L., Jian, W., Wu, Z., Shang, W., & Ying, X. (2017). 我国三级医院护士执业环境的现况研究 [Status of practice environment among nurses in 3-level hospitals of China]. *Journal of Nursing Administration*, *17*(5), 308-311.

Zhang, H., Xu, Y., Cheng, K., Zhang, R., & Yin, C. (2018). 数据包络分析研究热点综述 [Summary of research hotspots of data envelopment analysis]. *Computer Engineering and Applications*, *54*(10), 219-228.

Zhang, J., Pi, X. F., Lin, J., Liang, B. H., Fang, S., & Chen, Y. (2018). 不同级别医院护士执

业环境现状及影响因素的对比研究 [A comparative study on the current status of nursing practice environments and influencing factors among nurses in hospitals of different levels]. *Contemporary Nurses: Comprehensive Edition (First Edition)*, (9), 22-25.

Zhang, L. W., Zeng, Y., & Fang, Y. (2019). Evaluating the technical efficiency of care among long-term care facilities in Xiamen, China: Based on data envelopment analysis and Tobit model. *Bmc Public Health*, *19*, 1-9.

Zhang, L., Zheng, L. F., & Zhou, Y. F. (2022). 磁性医院理念在优化中医护士执业环境中的作用 [The role of magnetic hospital concept in optimizing the practice environment of traditional Chinese medicine nurses]. *Journal of Traditional Chinese Medicine Management*, (1), 30.

Zhang, M. X. (2015). 浅析影响我国人力资本价值提升的因素 [A brief analysis of the factors affecting the improvement of human capital value in my country]. *Knowledge Economy*, (3), 2.

Zhang, S., Song, J., Hu, J., Liu, J., Zhang, L., & Chen, L. (2021). Exploring the role of nurses in national health management. *Chinese Nursing Management, 5*(21), 656-658.

Zhang, X. M., Ma, X., Liu, Y., & Li, Z. (2020). Investigation on nurses practice environment in tertiary hospitals in Shandong Province. *Chinese Journal of Nursing*, *55*(11), 1680-1684.

Zhang, Y. Q., Zhang, H. M., & Song, B. Y. (2021). 河南省三级综合医院护士执业环境现状调查 [Investigation on the status quo of nurses practice environment in tertiary general hospitals of Henan province]. *Chinese Nursing Research*, *35*(4), 734-736.

Zhang, Y. (2021). 新时期大型公立医院职能定位下护理人力资源配置的思考 [Reflection on allocating human resources for nursing based on the functional orientation of large public hospitals in the new era]. *Shanghai Nursing*, *21*(1), 1-5.

Zhang, Y., & Chen, W. (2018). SBM Models in detailed efficiency measurement for hospital operations. *Health Economics Review*, *30*(5), 354-369.

Zhang, Y., & Su, F. X. (2024). 从国际比较的视角观照我国财政性教育经费支出占GDP比重的适切性 [The appropriateness of the proportion of my country's fiscal education expenditure to GDP from the perspective of international comparison]. *Education and Economy*, *40*(3), 79-87.

Zhang, Z., & Li, X. F. (2024). 基于DEA-BCC模型的天津市三级医院DRG运行效率研究 [Research on DRG operational efficiency of tertiary hospitals in Tianjin based on DEA-BCC model]. *Chinese Public Health Management*, *40*(3), 334-338.

Zhao, B., Zhou, K., & Zhu, J. Y. (2012). 澳大利亚护士分层管理对我国护理发展的启示 [Enlightenment of hierarchical management of nurses in Australia to nursing development in China]. *Nursing Practice and Research*, *9*(24), 106-107.

Zhao, L., Jiang, X., Huang, Y., Lu, Y., Mo, Y., & Guan, J. (2020). 广东省江门市4所二级综合医院护士职业环境评价现状及影响因素 [Evaluation status and influencing factors of nurses' professional environment in four secondary general hospitals in Jiangmen, Guangdong Province]. *Nursing of Integrated Traditional Chinese and Western Medicine*, *6*(9), 118-122.

Zhao, Y. Y., & Li, L. Q. (2019). 基于DEA-Malmquist指数模型的政府医疗卫生投入绩效分析研究 [Research on the performance analysis of government medical and health investment based on DEA-Malmquist index model]. *China Health Economics*, *38*(12), 4.

Zhao, Z. W., Jia, H., & Chen, M. (2020). Major socioeconomic driving forces of improving population health in China: 1978–2018. *Population and Development Review, 46*(4), 643-676.

Zheng, C. C., Zhang, W., Wen, X. M., & Wang, X. N. (2021). 基于DEA的全国基层医疗卫生资源配置效率分析 [Analysis on the efficiency of allocation of national primary medical

and health resources based on DEA]. *Health Soft Sciences*, *35*(3), 57-61.

Zhong, J. X., Zhai, H. W., & Peng, W. Q. (2018). 建立公立医院员工分级分类绩效评价体系的探讨——以中山大学肿瘤防治中心为例 [Discussion on establishing a hierarchical and classified performance evaluation system for public hospital employees: Taking the Cancer Prevention and Treatment Center of Sun Yat-sen University as an example]. *Chinese Cancer*, *27*(8), 7.

Zhou, R., Huang, Y., & Zhang, Y. Q. (2024). 基于DEA的三级公立医院手术科室效率研究 [Study on the efficiency of surgical departments in tertiary public hospitals based on DEA]. *Chinese Journal of Social Medicine*, *41*(2), 253-257.

Zhou, W. J., Gu, S., Shang, S. M., & Luo, J. K. (2016). 垂直管理在护理岗位管理应用中的质性研究 [Qualitative study on the application of vertical management in nursing position management[]. *Journal of Nursing*, *31*(6), 4.

Zhu, N., & He, K. (2023). The efficiency of major industrial enterprises in Sichuan province of China: A super slacks-based measure analysis. *Journal of Industrial & Management Optimization*, *19*(2), 397.

Zuo, J. Y. (2006). 工作环境对护士生活质量影响的研究进展 (综述) [Research progress on the impact of working environment on nurses' quality of life (review)]. *Chinese Journal of Urban and Rural*, *21*(6), 64-65.

Other References

ANCC. (2004). *Keeping patients safe: Transforming the work environment of nurses*.

GHC. (2015). *Notice on printing and distributing the implementation plan for post management of hospital nurses in Guangdong Province (for trial implementation)*.

NHC. (2016). *National nursing career development plan (2016-2020)*.

NHC. (2020). *Notice of the NHC of PRC on further strengthening the construction of nursing staff in studying and implementing the spirit of general secretary Xi Jinping's important instructions*.

Nursing Solutions. (2017). *National healthcare retention and RN staffing report*.

Oracle. (2017). *The cost of nurse turnover and its impact on healthcare systems*.

WHO. (2017). *Patient safety: Making health care safer*.

WHO. (2020). *State of the world's nursing 2020: Executive summary*.

WHO. (2021). *Global strategic directions for nursing and midwifery 2021-2025*.

[This page is deliberately left blank.]

Annex A: Nurse Practice Environment Assessment Scale

(1) General information

1. Name of the medical institution: _____

2. Level of the medical institution: _____

3. Is it a university hospital: Yes £ No £

4. Category of the hospital: Public £ Private £ Other £

5. Department that you are working in: _____

6. Gender: Male £ Female £

7. Age:

8. Working years:

9. Title: Nurse £ Senior nurse £ Supervisor nurse £ Co-chief superintendent nurses £ Chief superintendent nurse £ Other £

10. Position: Nurse £ Deputy Head Nurse £ Head Nurse £ Deputy Director of Nursing Department £ Director of Nursing Department £

Deputy Dean (Assistant Dean) £ Other £

11. Highest educational level: Doctor £ Master £ Bachelor £ Junior college £ Technical secondary school £ Others £

12. Do you have a budgeted post: Yes £ No £

(2) Nurses Practice Environment Assessment Scale

The purpose of the questionnaire is to understand the factors affecting the practice environment of nurses. There are 37 items in this questionnaire. “0” means very dissatisfied or extremely disagree, “100” means very satisfied or extremely agree. Please choose the appropriate one according to your personal experience.

1. Your overall evaluation of the practice environment of hospital nurses

2. Nurses have the opportunity to participate in the internal management of the hospital

3. Nurses can evaluate patients in clinical nursing, and perform personalized nursing care based on the evaluation results

4. The responsibilities of each nursing position are clear

5. Nurses have the opportunity to decide hospital affairs

6. The functional management department of the hospital can support the work of nurses
7. There is harmonious working relationship between physicians in the department and nurses
8. Nurses obtain encouragement and recognition when completing their work satisfactorily
9. The hospital conducts continuing education for nurses based on job needs
10. There is a perfect working system
11. There is thorough and directive workflow that is easy to implement
12. Nursing managers support nurses to make correct decisions
13. The hospital management department expects each nursing unit to provide patients with high-standard nursing services
14. The nurse configuration of the nursing unit can meet the needs of clinical nursing work
15. Nurses in the work team are competent for nursing work
16. Existing working hours and intensity are appropriate
17. Nurse scheduling considers nurses' competence and position level
18. Nurses can be recognized by society
19. The nursing team often discusses patients' nursing problems and seeks ways to improve
20. Under normal circumstances, the backbone nurses of the department are not frequently transferred
21. The provision of nursing devices in the hospital is conducive to improving the efficiency of nurses
22. Physicians in the department and nurses can perform their duties and work together
23. Nursing managers will discuss daily work issues with nurses
24. Nurses have the opportunity to participate in academic activities at home and abroad
25. Nurses' scheduling is beneficial to continuous care of patients
26. The clinical support system allows nurses more time to take care of patients
27. Nurses can feel the trust and respect of patients towards them at work
28. The hospital has a clear career development path or professional title promotion system for nurses
29. When nurses make mistakes, nurse managers pay more attention to guiding and improving them instead of criticizing them blindly
30. The hospital's salary allocation system is reasonable
31. Nurses can obtain corresponding occupational protection at work
32. Nurses have the opportunity to become a member of the hospital or nursing committee
33. The salary of nurses is at an appropriate level compared with workers in various industries of society

34. The hospital has systematic training for new nurses

35. The hospital has clear procedures to deal with nurses' occupational exposure, and can effectively implement them

36. The clinical work of the hospital can reflect the professionalism of nursing

37. Nurses can enjoy statutory benefits (such as: statutory holidays shifts or overtime subsidies, holidays, and insurance)

[This page is deliberately left blank.]

Annex B：Content of nursing human resource efficiency index system

Level-I indicator Level-II indicator Level-III indicator

Y1 Input of human resources Number Number of nurse practitioner

Number of nursing interns and advanced students

Number of health care nurse

Staffing structureProportion of nurses with different academic qualifications

Proportion of nurses with different professional titles

Proportion of nurses of different working years

Proportion of nurses at different levels

Proportion of specialist nurses

Nurse-to-patient ratio

Bed-to-nurse ratio

Physician-to-nurse ratio

Proportion of nurses on sick or maternity leave

Y2 Input of materials Actual number of open beds

Y3 Input of financial support Annual per capita income of nurses before tax

Teaching and scientific research funds Continuing education and training funds

Scientific and research funds

Y4 Input of service Nursing Hours per Patient Day

Y5 Output of nursing service Number of discharged patients

Bed occupancy rate

Average length of stay

Number of critically ill patients

Y6 Output of nursing safety Number of adverse nursing events Incidence of falls/falls from the bed

Incidence of non-inevitable pressure ulcers in hospital

Incidence of unplanned extubation

Incidence of tube blockage in intubated patients

Incidence of drug extravasation

Number of specimen errors

Number of blood transfusion errors

Number of medication errors

Number of ID identification errors

Number of medical advice execution errors

Incidence of catheter-related bloodstream infection

Incidence of catheter-related urinary tract infection

Incidence of ventilator-related pneumonia

Occupational exposure of nurses

Y7 Output of nursing quality Assessment passing rate of nursing staff Passing rate of theoretical assessment

Passing rate of operation skill assessment

first aid (including emergency plan) assessment pass rate

Passing rate of nurses' clinical ability assessment

Passing rate of nursing quality inspection qualified rate of primary care

Qualified rate of care for critically ill patients

Proportion of emergency medicines and equipment in good condition

Qualified rate of high-risk drug use and safety management

Qualified rate of nursing document writing

Health education implementation rate

Qualified rate of sterilization and isolation

Qualified rate of nursing core system implementation

Rescue success rate

Satisfaction Patient satisfaction

Nurse satisfaction

Physician satisfaction

Patient complaint rate

Nurse turnover rate

Y8 Output of teaching and scientific research Scientific research output Number of innovative inventions and utility patents

Annual number of papers published per capita

Number of new technologies applied and new businesses developed

talent development Number of specialist nurses at provincial level and above

Staffing structure	Number of people attending standardized training
	Number of graduates with higher education level

[This page is deliberately left blank.]