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RESEARCH ARTICLE

HEALTHCARE SYSTEM CAPACITY, EFFICIENCY AND OBSTACLES SINCE CHINA'S 2009 REFORM: AN INTEGRATED TIME-SERIES ASSESSMENT OF REGIONAL DISPARITIES

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ABSTRACT

BACKGROUND

In 2009 China launched a new round of healthcare reform. This study aims to comprehensively evaluate the service capacity and efficiency of the Chinese healthcare system at both the national and regional levels since the reform's inception.

METHODS

We collected ten indicators of healthcare service capacity and efficiency from the China Health and Family Planning Statistical Yearbook and the China Health Statistical Yearbook for the period 2009-2023. This study employs the entropy weight method and the obstacle degree model in an integrated approach to comprehensively evaluate performance and diagnose the specific obstacles that constrain it.

RESULTS

Over the 16 years since the healthcare reform, the levels of healthcare service capacity and efficiency have generally shown an upward trend at the national level and across the eastern, central, and western regions. Specifically, the highest performance was observed in 2023, while the lowest was recorded in 2009. The main factors influencing healthcare service capacity and efficiency in China were identified as Inpatient Surgeries, Health Personnel, Hospital Beds, Medical Institutions, Average Length of Stay, and Total Patient Visits. However, the specific obstacle factors varied marginally among the national, eastern, central, and western regions.

CONCLUSIONS

Based on our comprehensive evaluation, it has been confirmed that healthcare service capacity and efficiency in China have demonstrated a pattern of gradual improvement since the 2009 healthcare reform. However, against the backdrop of ongoing socioeconomic development, demographic shifts, and other influencing factors, the Chinese government should continue to enhance healthcare capacity and efficiency nationwide to address the trend of diversifying future healthcare demands.

KEYWORDS

healthcare system; capacity and efficiency; obstacles; time-series

BACKGROUND

The Chinese Government has always prioritized the reform of the healthcare system [1]. In 2009, China launched its landmark healthcare reform through the Opinions of the Central Committee of the Communist Party of China and the State Council on Deepening the Reform of the Medical and Health System (Zhongfa [2009] No. 6). This ten-year plan aimed for universal basic healthcare coverage by 2020, with key efforts focused on expanding insurance, strengthening primary care, establishing an essential medicines system, improving public health services, and advancing public hospital reforms [2,3]. Over the past ten years, the reform has achieved remarkable outcomes [3,4]: China's healthcare service system has been steadily improved, universal health insurance coverage has been nearly fully achieved, the capacity of primary healthcare services has been consistently strengthened, and the equity in basic public health services has been further enhanced.

Despite the remarkable achievements in China's healthcare reform, significant challenges persist, driven by evolving socioeconomic conditions [5], demographic shifts [6], deteriorating environmental factors [7], changes in the disease spectrum [8], accelerated urbanization, rapid advances in medical technology, and the population's growing multi-tiered health demands. First, China's population aging is intensifying [9-11]. Projections indicate that by 2050, the population aged 60 and above will reach 522 million, while those aged 80 and above will total 133 million [12]. This profound demographic shift toward an older population structure is exacerbating pressure on the health insurance system and driving increased demand for healthcare and long-term care services.

Second, China's rapid socioeconomic development has been accompanied by a marked shift in its disease spectrum, evolving from a predominance of communicable diseases to a dual burden of both communicable and non-communicable diseases (NCDs) [13]. This transition presents substantial challenges to the healthcare system, necessitating long-term management strategies for NCDs and integrated approaches for the prevention and treatment of communicable diseases.

Third, China's ongoing urbanization has accelerated the demand for healthcare services and insurance coverage among rural and migrant populations [14]. This necessitates an integrated urban-rural and regionally coordinated healthcare system that ensures equitable access to basic medical security and continuous health services for these groups. Fourth, although the Chinese government has long been committed to optimizing the structure of healthcare resource allocation across the country and has implemented multiple initiatives to promote a more balanced distribution, significant regional disparities persist [15-18]. Gaps in the allocation of medical resources and variations in healthcare service capacity between regions still need to be further narrowed [19-20].

Confronted with these challenges, China's healthcare reform remains an ongoing and challenging endeavor, requiring the government and relevant authorities to implement comprehensive, systematic, and sustained reforms. Therefore, scientifically evaluating and analyzing the capacity and efficiency of China's healthcare services since the 2009 reform is crucial for health planners and policymakers. Such analysis will help health administrations adopt targeted measures to address existing issues and further optimize the national health system. To this end, this study collects data on healthcare service capacity and efficiency at both national and regional levels following the 2009 reform, longitudinally assesses the performance of China's health system from 2009 to 2023, and explores potential strategies for enhancing healthcare capacity and efficiency.

METHODS

DATA SOURCES

China's new healthcare reform was launched nationwide in 2009. Accordingly, this study collected indicator data for evaluating medical service capacity and efficiency in China from the period following 2009. The data for the years 2010-2012 were obtained from the China Health Statistical Yearbook; data for 2013-2017 were sourced from the China Health and Family Planning Statistical Yearbook; and data for 2018-2024 came from the China Health Statistics Yearbook. These are the same yearbook, with the name changes due to the restructuring of national health institutions. Since the yearbooks compile statistical data from the preceding year, the study ultimately covers and analyzes indicator data for the period 2009-2023. The data encompass 31 provincial-level regions in mainland China, excluding Hong Kong, Macao, and Taiwan Province. The China Health Statistical Yearbook adopts the following regional classification: Eastern China comprises 11 provincial-level divisions, including Beijing, Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, and Hainan. Central China consists of 8 provinces: Shanxi, Jilin, Heilongjiang, Anhui, Jiangxi, Henan, Hubei, and Hunan. Western China encompasses 12 provincial-level divisions, namely the Inner Mongolia Autonomous Region, Guangxi Zhuang Autonomous Region, Chongqing, Sichuan, Guizhou, Yunnan, Tibet Autonomous Region, Shaanxi, Gansu, Qinghai, Ningxia Hui Autonomous Region, and Xinjiang Uygur Autonomous Region.

In accordance with the China National Health Statistics Survey System, all healthcare institutions at all levels and of all types, including hospitals, primary healthcare institutions, specialized public health institutions, and other healthcare institutions, are required to submit data related to medical services. These institutions report data through the National Health Statistics Network Direct Reporting System. The state mandates that the submitted data must be truthful, accurate, complete, and timely. After hierarchical review by health administrative departments at various levels, the National Health Commission is responsible for the final review and release of the national health statistics data.

INDICATOR SELECTION

The selection of scientific and rational indicators is crucial for evaluating medical service capacity and efficiency in China. The indicators in this study were chosen based on the following key considerations [21,22]: First, the representativeness and sensitivity of the indicators were taken into account. Drawing on the indicator selection practices used in similar studies on medical service capacity and efficiency evaluation in China, the choice of indicators in this research is guided by evidence-based approaches. Second, the selection adheres to fundamental principles such as scientific soundness, comprehensiveness, and data accessibility. Specific indicators were chosen from the medical service capacity and efficiency sections of the China Health Statistical Yearbook, China Health and Family Planning Statistical Yearbook, and China Health Statistics Yearbook. Based on the above principles and rationale, a comprehensive indicator system for evaluating medical service capacity and efficiency in China was constructed. This system consists of three hierarchical levels: the objective layer, the criterion layer, and the indicator layer (Table 1).

TABLE 1. A COMPREHENSIVE INDICATOR SYSTEM FOR EVALUATING MEDICAL SERVICE CAPACITY AND EFFICIENCY IN CHINA.

Objective layer	Criterion layer	Indicator layer	Indicator Naming	Attribute
Evaluating medical service capacity and efficiency	Healthcare Resources	Number of Medical Institutions	X1	Positive
		Number of Hospital Beds	X2	Positive
		Number of Health Personnel	X3	Positive
	Healthcare Services	Total Patient Visits	X4	Positive
		Outpatient and Emergency Visits	X5	Positive
		Hospital Discharges	X6	Positive
		Inpatient Surgeries	X7	Positive
	Healthcare Efficiency	Average Length of Stay	X8	Negative
		Bed Occupancy Rate	X9	Positive
		Daily Patient Load per Physician	X10	Positive

THE ENTROPY METHOD

The Entropy Method is an objective weighting approach originally proposed by Shannon and Weaver (1947) and later advanced by Zeleny (1982) [23]. Its fundamental principle involves evaluating the dispersion degree of indicators through the calculation of their entropy values. Specifically, a smaller entropy value for an indicator reflects greater data variability, which in turn conveys more useful information and carries greater significance in comprehensive evaluation systems. The specific calculation steps of the entropy weight method are as follows [24-27]:

Step 1: Data Standardization

Assuming there are n evaluation indicators and m evaluation years, the original data is first subjected to normalization and forward processing according to Equations (1) and (2).

For positive indicators:

$$Y_{ij} = \left\{ \frac{M_{ij} - min\, M_{ij}}{max\, M_{ij} - min\, M_{ij}} \right. \tag{1}$$

For negative indicators:

$$Y_{ij} = \left\{ \frac{maxM_{ij} - M_{ij}}{max\, M_{ij} - min\, M_{ij}} \right. \tag{2}$$

Among them, M_{ij} represents the value of year (*i*) for indicator M_j, $maxM_{ij}$ denotes the maximum value of indicator M_j across all years (*i*), $minM_{ij}$ denotes the minimum value of indicator M_j across all years (*i*), and Y_{ij} represents the standardized indicator value after processing.

Step 2: Calculation of Characteristic Proportions:

Calculate the relative proportion P_{ij} of the *i-th* indicator value under the *j-th* indicator.

$$P_{ij} = \frac{Y_{ij}}{\sum_{j=1}^{n}} Y_{ij} \tag{3}$$

Step 3: Calculation of the Entropy Value e_j for the *j-th* Indicator

$$e_j = -k \sum_{i=1}^{m} P_{ij}\, ln(P_{ij}), k = 1/ln\, m \tag{4}$$

Where k=1/lnm>0 is a normalization constant ensuring [0, 1].

Step 4: Calculation of the Divergence Coefficient g_j for the *j-th* Indicator

$$g_j = 1 - e_j \tag{5}$$

Step 5: Determination of Indicator Weights

$$w_j = g_j / \sum_{j=1}^{n} g_j \tag{6}$$

WEIGHTED TOPSIS METHOD

As a classical multi-attribute decision-making approach, the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) was initially proposed by Hwang and Yoon in 1981[28]. The fundamental principle of this method involves identifying the optimal and worst solutions from a finite set of alternatives based on a normalized original data matrix, followed by calculating the relative closeness of each evaluation object to these ideal solutions for comprehensive assessment. The specific procedural steps are outlined as follows [29-30]:

Step 1: Construction of the Initial Evaluation Matrix

Assume there are *m* alternatives to be evaluated against *n* criteria, forming an initial evaluation matrix $X=(x_{ij})m\times n$, where represents the performance value of alternative *i* with respect to criterion *j*.

Step 2: Normalization of the Decision Matrix

The normalized matrix is constructed using Equation (7).

$$Z_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{n} x_{ij}^{2}}} \tag{7}$$

Step 3: Construction of the Weighted Normalized Matrix

The normalized matrix is weighted using the entropy weight method(w_j). Assuming the weighted matrix is denoted as V_{ij}, it is calculated as follows:

$$V_{ij} = w_j X_{ij} \tag{8}$$

Step 4: Determination of the Ideal and Negative-Ideal Solutions

$$v_j^{+} = \left(max\, v_{ij} \,/\, i = 1,2,3,\ldots,n\right) = \left(v_1^{+}, v_2^{+}, v_3^{+}, \ldots, v_n^{+}\right) \tag{9}$$

$$v_j^{-} = \left(min\, v_{ij} \,/\, i = 1,2,3,\ldots,n\right) = \left(v_1^{-}, v_2^{-}, v_3^{-}, \ldots, v_n^{-}\right) \tag{10}$$

Step 5: Calculation of Separation Measures

The Euclidean distances of each alternative from the ideal and negative-ideal solutions are calculated:

$$D_i^{+} = \sqrt{\sum_{j=1}^{m} \left(v_{ij} - v_j^{+}\right)^2} \qquad i = 1,2,3,\ldots,n \tag{11}$$

$$D_i^{-} = \sqrt{\sum_{j=1}^{m} \left(v_{ij} - v_j^{-}\right)^2} \qquad i = 1,2,3,\ldots,n \tag{12}$$

Step 6: Calculation of Relative Closeness to the Ideal Solution

$$C = \frac{D^{-}}{D^{+} + D^{-}} \tag{13}$$

The *C*-value indicates the relative closeness of each annual Euclidean distance to both the positive and negative ideal solutions, with its value ranging between 0 and 1. A higher numerical value signifies better performance.

OBSTACLE DEGREE MODEL

The Obstacle Degree Model (ODM) constitutes a methodological framework for assessing impediment effects through systematic deconstruction at the system level [31]. Developed upon comprehensive evaluation architectures, this model enables the identification of critical elements constraining system functionality. The core theoretical premise of ODM involves quantifying the obstructive impact of individual indicators on system development through precise measurement of deviation between observed values and ideal benchmarks. The main procedural formulas of the model are as follows [32-34]:

Step 1: Calculate Factor Contribution

$$F_j = w_j \times W_j \tag{14}$$

Where w_j represents the weight obtained through the entropy weight method, while W_j denotes the weight of the criterion layer.

Step 2: Compute Deviation Degree

Calculate the deviation degree of the *j-th* indicator in the *i-th* year.

$$I_{ij} = 1 - X_{ij} \qquad (15)$$

Step 3: Determine Obstacle Degree

Compute the obstacle degree (Oij) for each evaluation indicator.

$$Q_{ij} = \frac{F_j I_{ij}}{\sum_j F_j I_{ij}} \times 100\% \qquad (16)$$

The obstacle degree is calculated by integrating the factor contribution and the deviation degree, reflecting the extent to which each indicator hinders system development.

DATA ANALYSIS

MATLAB (Version R2020b; MathWorks, Natick, MA, USA) was employed to conduct analyses based on the Entropy Weight Method, Weighted TOPSIS, and the Obstacle Degree Model. The significance threshold was established at $p < 0.05$.

RESULTS

THE ENTROPY WEIGHT METHOD

The entropy weight method was applied to calculate the weight values of the ten evaluation indicators (X1-X10) under Healthcare Capacity and Efficiency for the national level as well as for the eastern, central, and western regions. We observe discernible regional variations in the assigned weights of the ten evaluation indicators (X1–X10) under Healthcare Capacity and Efficiency. For instance, at the national level, indicator X7 carries the highest weight (w = 0.1518), while X10 is assigned the lowest (w = 0.0527). In contrast, although X7 remains the most heavily weighted indicator in the western region (w = 0.1130), X1 receives the least weight (w = 0.0417). The complete set of entropy values (e), utility values (g), and weights (w) for all 10 indicators across the national, eastern, central, and western regions is reported in Table 2, with corresponding visualizations in Figure 1.

TABLE 2. ENTROPY WEIGHT METHOD CALCULATIONS FOR INDICATOR WEIGHTS OF HEALTHCARE CAPACITY AND EFFICIENCY.

Country/Region		X1	X2	X3	X4	X5	X6	X7	X8	X9	X10
	e	0.9351	0.9148	0.9070	0.9376	0.9376	0.9396	0.8879	0.9173	0.9377	0.9473
National	*g*	0.0649	0.0852	0.0930	0.0624	0.0624	0.0604	0.1121	0.0827	0.0623	0.0527
	w	0.0879	0.1154	0.1260	0.0846	0.0846	0.0819	0.1518	0.1120	0.0844	0.0714
	e	0.8909	0.9177	0.9078	0.9402	0.9402	0.9304	0.8851	0.9204	0.9375	0.9449
Eastern Region	*g*	0.1091	0.0823	0.0922	0.0598	0.0598	0.0696	0.1149	0.0796	0.0625	0.0551
	w	0.1390	0.1048	0.1175	0.0761	0.0762	0.0887	0.1464	0.1014	0.0797	0.0702
	e	0.9227	0.9112	0.9031	0.9379	0.9379	0.9436	0.8932	0.9082	0.9353	0.9332
Central Region	*g*	0.0773	0.0888	0.0969	0.0621	0.0621	0.0564	0.1068	0.0918	0.0647	0.0668
	w	0.0999	0.1148	0.1253	0.0802	0.0802	0.0729	0.1380	0.1187	0.0836	0.0864
	e	0.9583	0.9150	0.9072	0.9278	0.9279	0.9429	0.8870	0.9187	0.9374	0.9487
Western Regions	*g*	0.0417	0.0850	0.0928	0.0722	0.0721	0.0571	0.1130	0.0813	0.0626	0.0513
	w	0.0572	0.1166	0.1273	0.0990	0.0988	0.0784	0.1550	0.1115	0.0858	0.0703

FIGURE 1: PIE CHARTS OF TEN EVALUATION INDICATORS' WEIGHTS ACROSS THE NATIONAL, EASTERN, CENTRAL, AND WESTERN REGIONS.

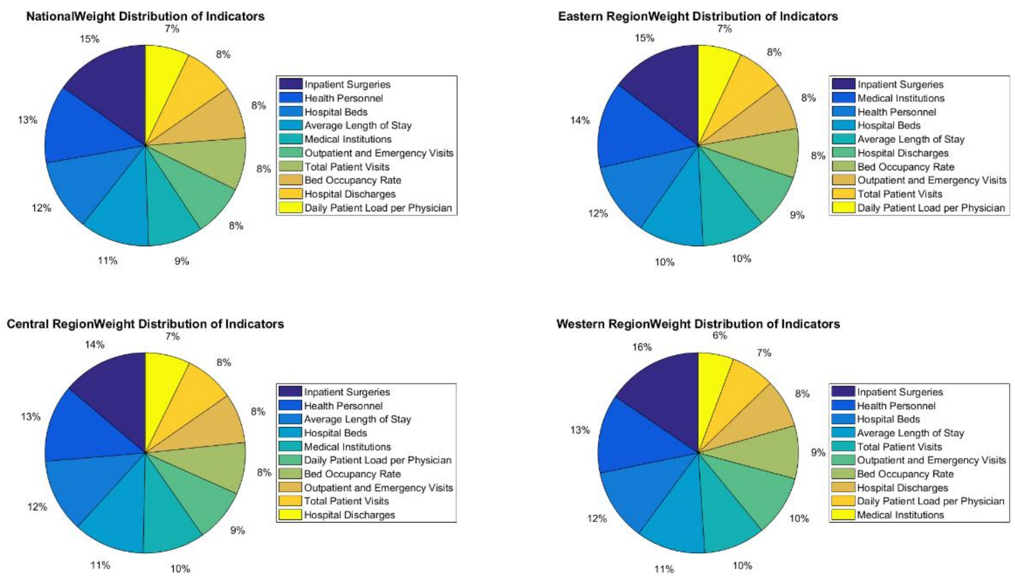


Figure 1 presents a series of pie charts illustrating the weight distributions of ten evaluation indicators (X1-X10) across the nation, eastern, central, and western regions. Each chart uses distinct colors to represent the proportional weights of different indicators. For instance, in the "National Weight Distribution of Indicators" chart, yellow corresponds to "Daily Patient Load per Physician," blue to "Health Personnel," and green to "Outpatient and Emergency Visits." Similar color schemes and interpretations apply to the regional charts for the eastern, central, and western areas.

The analysis reveals that the weight distributions of the ten evaluation indicators vary across regions, indicating that each indicator contributes different levels of meaningful information depending on the geographic context. These region-specific weight structures provide a valuable foundation for conducting comprehensive evaluations with enhanced accuracy and relevance.

WEIGHTED TOPSIS METHOD

In accordance with the steps of the weighted TOPSIS method, we computed the comprehensive evaluation scores (C-values) for the national, eastern, central, and western regions, and subsequently performed a ranking based on these values. While some differences exist in Healthcare Capacity and Efficiency across regions, their ranking trends remain largely similar. The detailed results are presented in Table 3 and Figure 2.

TABLE 3. EVALUATION OF HEALTHCARE CAPACITY AND EFFICIENCY IN CHINA SINCE THE 2009 HEALTHCARE REFORM USING THE WEIGHTED TOPSIS METHOD.

Year	National		Eastern Region		Central Region		Western Regions	
	C	*Rank*	*C*	*Rank*	*C*	*Rank*	*C*	*Rank*
2009	0.1825	15	0.1996	15	0.1483	15	0.1684	15
2010	0.2186	14	0.2294	14	0.1891	14	0.2037	14
2011	0.2695	13	0.2690	13	0.2596	13	0.2564	13
2012	0.3470	12	0.3353	12	0.3394	12	0.3339	12
2013	0.4007	11	0.3783	11	0.3946	11	0.4040	11
2014	0.4543	10	0.4290	10	0.4496	10	0.4518	10

2015	0.4791	9	0.4494	9	0.4877	9	0.4912	9
2016	0.5239	8	0.4925	8	0.5196	8	0.5248	8
2017	0.5771	6	0.5489	7	0.5667	6	0.5866	7
2018	0.6238	5	0.6021	5	0.5996	5	0.6373	5
2019	0.7023	2	0.6733	2	0.6646	4	0.7196	2
2020	0.5697	7	0.5703	6	0.5357	7	0.5982	6
2021	0.6648	4	0.6625	4	0.6674	3	0.6694	4
2022	0.6712	3	0.6729	3	0.6907	2	0.6838	3
2023	0.8255	1	0.8284	1	0.8366	1	0.8236	1

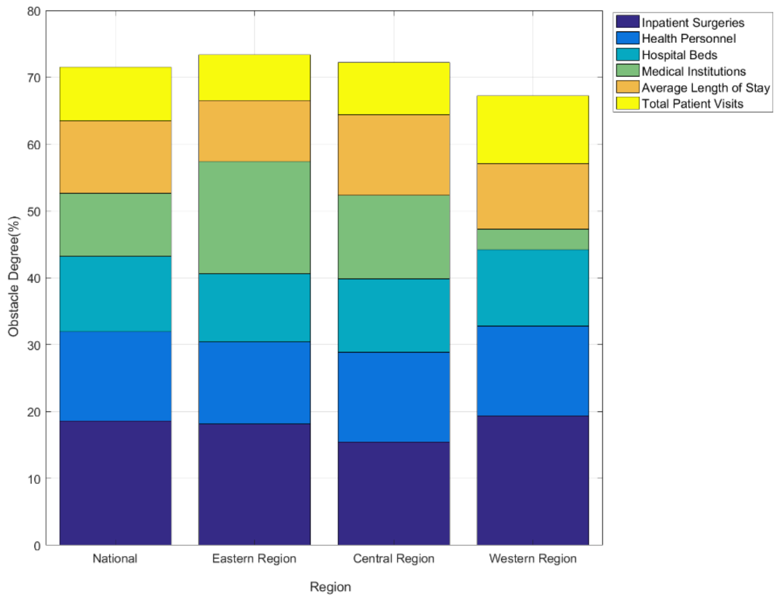
FIGURE 2. MEDICAL SERVICE CAPACITY EVALUATION (2009-2023) FOR THE NATIONAL, EASTERN, CENTRAL, AND WESTERN REGIONS.

Figure 2 illustrates the comprehensive evaluation results of medical service capacity across the national, eastern, central, and western regions since the initiation of the new healthcare reform in 2009. Distinct colors represent the different regions, and the addition of trend lines allows for a clear discernment of the overall trajectory.

OBSTACLE DEGREE MODEL

Based on calculations from the Obstacle Degree Model, we identified the six indicators with an obstacle degree value as the primary obstacle factors. These factors are: Inpatient Surgeries, Health Personnel, Hospital Beds, Medical Institutions, Average Length of Stay, and Total Patient Visits (Figure 3-4).

FIGURE 3. MAIN OBSTACLE INDICATORS FOR MEDICAL SERVICE CAPACITY ACROSS REGIONS.



In Figure 3, the color scheme represents the obstacle degree values for each indicator. Based on the values represented by this color scheme, the six indicators from each region were identified as the primary obstacle factors.

To further the analysis, we present the specific obstacle degrees of all ten indicators for each region. This allows for a visual comparison that immediately reveals the primary constraining factors of the Medical Service Capacity evaluation in different areas. The detailed results are shown in Figure 4.

FIGURE 4. DETAILED PRESENTATION OF OBSTACLE DEGREES FOR THE TEN INDICATORS ACROSS REGIONS.

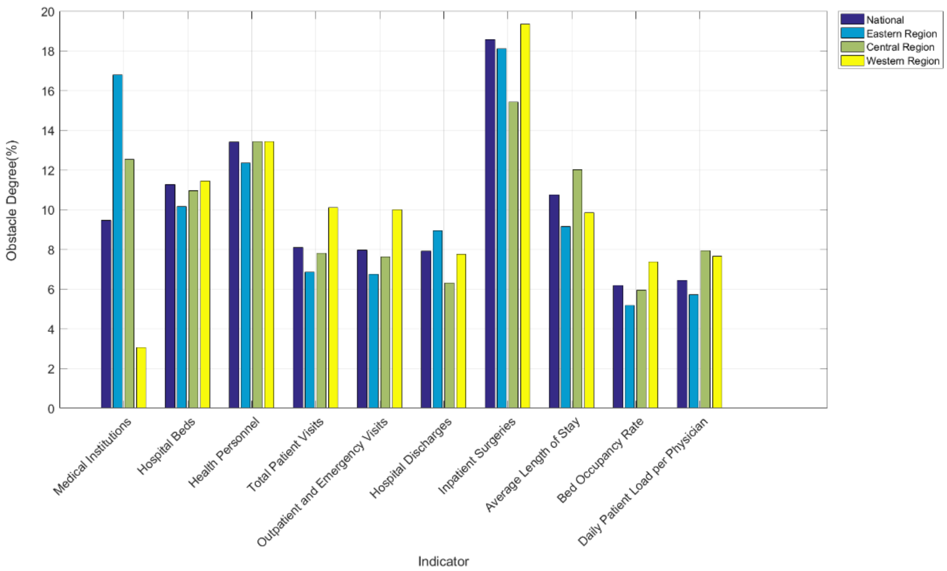


Figure 4 employs a color code to represent the different regions. The results clearly illustrate that the constraining effects of the various indicators on the Medical Service Capacity evaluation differ across these regions.

DISCUSSION

To our knowledge, this is the first study to conduct a longitudinal, comprehensive assessment of China's healthcare service capacity and efficiency following the implementation of the new medical reform. The insights gained are crucial for informing evidence-based policies aimed at enhancing service delivery and overall system effectiveness.

In this study, a rigorous screening process prioritizing representativeness, sensitivity, and data availability was first conducted, leading to the selection of ten key indicators. Subsequently, the entropy weight method was applied to objectively determine the relative importance and calculate the weights for these indicators. These calculated weights were then integrated into the TOPSIS model to perform a comprehensive time-series evaluation of healthcare capacity and efficiency at the national, eastern, and western regional levels. Furthermore, to pinpoint the specific factors impeding performance, the obstacle degree model was employed to identify the primary obstacles across these different regions. Based on the methodological analysis, the entropy weight method was first employed as an objective approach to calculate indicator weights. By determining weights through information entropy, this method effectively minimizes subjective bias, thereby ensuring the objectivity of the weighting process and avoiding the arbitrariness inherent in subjective assignment [35-37]. Subsequently, the TOPSIS method was applied due to its notable advantages, including computational simplicity, strong applicability, and objective results. It imposes minimal restrictions on data distribution and sample size [38-40]. Through data normalization and vector scaling, it eliminates the effects of different measurement units, which significantly enhances the accuracy of the comprehensive evaluation. The weights derived from the entropy weight method were directly integrated into this step to calculate the evaluation results. Thus, the entropy-weighted TOPSIS method can fully leverage the respective advantages of each model to yield a more robust and objective assessment [41, 42]. Furthermore, to diagnose the specific factors limiting system development, the obstacle degree model was introduced [43]. This tool quantifies key obstacles, allowing for the identification of the primary factors affecting healthcare capacity and efficiency. Finally, the sequential and combined application of these three methods formed a comprehensive analytical framework. This integrated approach provided a systematic analysis of both the longitudinal evolution and the key obstacles in China's healthcare capacity and efficiency following the new medical reform.

Our findings indicate an overall upward trend in healthcare capacity and efficiency rankings since the inception of China's new healthcare reform in 2009. This trend was observed despite slight variations among the national, eastern, central, and western regions. In China, the eastern, central, and western regions exhibit distinct healthcare supply and demand patterns: supply is dense in the east, moderate in the center, and sparse in the west [44]. On the supply side, the eastern region benefits from higher population density and stronger socioeconomic development, ensuring better resource availability [45]. The western region, in contrast, is sparsely populated and under-resourced relative to the central and eastern regions. On the demand side, the east's advanced medical technology and capacity generate strong demand for complex, severe, and life-cycle care. Meanwhile, patients with complex conditions from the central and western regions frequently seek cross-regional referrals to the east, exacerbating supply-demand imbalances [46, 47].

We analyze the specific reasons as follows. On one hand, since the inception of the new healthcare reform in 2009, China has undertaken a systematic restructuring of its medical and health system through top-level national design. This integrated approach has not only enhanced the overall capacity of the national healthcare service but has also improved medical service efficiency, thereby driving high-quality development in the sector [3,4]. On the other hand, following the new healthcare reform, China has actively promoted the coordinated reform of pharmaceuticals, medical insurance, and healthcare delivery, a mechanism known as the "Triple Linkage." The government has consistently increased healthcare investment, with total health expenditure rising from 4.85% of GDP in 2010 to 7.19% in 2023 [48]. Concurrently, continuous expansion of insurance coverage and improvements in the medical service system have effectively stimulated the growing healthcare demands of the population. This is evidenced by China's Medical Insurance Information Systems (MIISs), which now connect over 700,000 medical institutions across all levels and cover more than 1.35 billion people [49]. Collectively, these factors have driven the enhancement of China's healthcare capacity and efficiency.

In addition, digital health, technological advancements, and modern health service management have emerged as key drivers of improvement in China's healthcare system [50, 51]. For example, with the development of telemedicine in China, healthcare service supply has expanded, inter-regional and inter-city service efficiency has significantly improved, and healthcare accessibility for rural populations has therefore been markedly enhanced [52, 53]. Meanwhile, the application of electronic health records and artificial intelligence in healthcare services has further driven and enhanced medical service efficiency in China [54]. For instance, AI-assisted diagnostic technologies have strengthened both the capacity and efficiency of primary healthcare services [55]. Furthermore, modern management practices, including hospital accreditation, lean hospital management, and national performance-based assessments of public hospitals, have been progressively implemented across the country, thereby strengthening healthcare service capacity, quality, and efficiency [56, 57]. The implementation of these measures has jointly contributed to the improvement of China's healthcare service capacity, efficiency, and quality.

However, our observation using the obstacle degree model was that the obstacles to improving healthcare capacity and efficiency were universal across the national, eastern, central, and western regions. These primary obstacles are: Inpatient Surgeries, Health Personnel, Hospital Beds, Medical Institutions, Average Length of Stay, and Total Patient Visits. Among these obstacles, the resource-based indicators of Health Personnel, Hospital Beds, and Medical Institutions can be more directly addressed through governmental resource reallocation. In contrast, improvements in the service-oriented indicators, Inpatient Surgeries and Average Length of Stay, depend on nationwide advancements in medical technology, service delivery, and consistent quality enhancement, representing a longer-term endeavor. In optimizing health resource allocation, China's key challenge lies in the inequitable distribution across regions, with the western region being less equitable than the central and eastern regions, and rural areas less equitable than urban areas. Therefore, priority must be given to improving resource allocation levels in the western region and rural areas [16, 17]. In advancing medical technology and service quality, China's key initiative was the 2019 "Pilot Program for Regional Medical Center Construction" jointly launched by national authorities, involving the establishment of 125 national and 114 provincial regional medical centers aimed at standardizing service quality and elevating care standards. However, this program represents a complex, multi-domain systemic project whose implementation faces challenges primarily in management systems, human resources, and clinical capabilities [58]. Therefore, focused efforts to address these issues are crucial for enhancing China's medical technology and service levels. In strengthening medical quality, China has established medical quality control centers at the national, provincial, and municipal levels, forming a three-tier quality control network. However, the monitoring and evaluation of medical quality still lack effective integration and supplementation, with insufficient dynamic monitoring and assessment of the healthcare service process [59]. Therefore, enhancing the dynamic monitoring of clinical care processes should be the highest priority in future medical quality improvement efforts. Our study has certain limitations. First, while the selection of indicators was based on representativeness, sensitivity, and availability, these indicators cannot fully reflect healthcare capacity and efficiency. For example, the number of Diagnosis-Related Groups is a crucial metric in evaluating healthcare capacity but could not be included in the analysis due to data unavailability. Similarly, indicators reflecting healthcare quality and safety, such as medical adverse events and unplanned readmissions or reoperations, were also excluded. Second, although the entropy weight method applied in this study produced valuable findings in assessing healthcare capacity and efficiency across national, eastern, central, and western regions, the method itself has inherent drawbacks. For instance, it calculates weights based solely on data statistics and cannot incorporate prior knowledge or expert judgment. Therefore, in future research, we will first attempt to collect data on indicators such as DRG numbers, medical adverse events, and unplanned readmissions or surgeries to improve the healthcare capacity and efficiency indicator system and achieve a more comprehensive evaluation. Furthermore, we will explore integrating the Delphi method and the Analytic Hierarchy Process to determine indicator weights, thereby incorporating prior knowledge and expert experience into the analytical framework. Third, regarding the limitations of data analysis, this study focused more on data at the regional level in China. However, the China Health Statistics Yearbook also provides facility-level data disaggregated by type of health care institution (e.g., hospitals, community health centers), which could offer more granular insights. These data were not included in this study due to concerns about longitudinal consistency. Future research should explore these disaggregated indicators as data availability improves.

CONCLUSIONS

In this study, we evaluate the evolution of healthcare service capacity and efficiency in China since the 2009 healthcare reform and identify the key constraints influencing their development. The findings offer valuable insights for informing future healthcare reform policies. While the results indicate an overall improvement in healthcare service efficiency since the reform, China continues to face multiple challenges. These include accelerated population aging, which is expected to drive sustained growth in medical service demand, as well as persistent disparities in healthcare service levels and resource allocation across regions. Looking ahead, China should focus on enhancing the healthcare service system, optimizing the distribution of medical resources among regions, improving medical technology and quality management, advancing the Healthy China Initiative, and ultimately elevating the overall health status of the population.

CONFLICT OF INTERESTS

We declare that we have no conflict of interest.

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None.

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ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Not applicable. Data were obtained from publicly accessible sources. Formal ethical approval was not required for this study.

AUTHOR CONTRIBUTIONS

Conceptualization: DZ and SCP
Data curation: DZ
Formal analysis: DZ
Writing–original draft: DZ and SCP
Writing-review & editing: DZ and SCP

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