Comprehensive evaluation on bed utilization efficiency of public TCM hospitals in 17 cities of Hubei province

Xiaohua Wu¹, Shuanggui Tian²,*
¹School of Information Engineering, Hubei University of Chinese medicine, Wuhan, Hubei, 430065
²School of Information Engineering, Hubei University of Chinese medicine, Wuhan, Hubei, 430065

Corresponding author and e-mail: Shuanggui Tian, sunnytian610@hbtcm.edu.cn

Abstract. To evaluate the bed utilization efficiency of public TCM hospitals in 17 cities of Hubei Province, the date of the bed utilization of public TCM hospitals in 17 cities of Hubei Province in 2017 was collected. Then, the entropy weight method was used to determine the weight of evaluation indicators, and the method of TOPSIS and RSR were used to evaluate bed utilization efficiency. The bed utilization efficiency of public TCM hospitals in 17 cities of Hubei Province can be divided into three levels. Ezhou, Yichang were in lower range, Huanggang, Enshi, Jingmen, Huangshi, Tianmen, Wuhan, Qianjiang, Xiangyang, Xianning, Shiyan, Shenlongjia, Xiantao were in midrange and Jingzhou, Suizhou, Xiaogan were in higher range. The method of entropy weight TOPSIS and RSR can reflect the bed utilization efficiency of public TCM hospitals in different cities objectively and comprehensively, and the results are scientific and reliable. There is a big gap in the bed utilization efficiency of public TCM hospitals in cities of Hubei Province. It is suggested that cities with low bed utilization efficiency should give full play to the characteristics and advantages of TCM to improve the core competitiveness of hospitals and to enhance the attractiveness of hospitals to patients. At the same time, public TCM hospitals should deepen the integration of TCM and Internet, and optimize the medical service process of TCM to improve the bed utilization efficiency.

1. Introduction
The bed utilization efficiency of hospitals is an important evaluation indicator to reflect efficiency of work and utilization of resource in hospitals [1]. In recent years, many hospitals blindly pursue the scale of hospital beds and ignore the utilization efficiency of them, which leads to the waste of medical resources. In addition, for the bed utilization efficiency of hospitals, there are obvious differences between regions, this results in unbalanced allocation of hospital bed resources, which is specifically reflected in the area with low bed utilization efficiency, there is serious waste of bed resources, and in areas with high bed utilization efficiency, the hospital bed resources cannot even meet the needs of patients. As an important part of Chinese medical and health institutions, the research on the bed utilization efficiency of public TCM hospitals among regions is of great significance to the rational allocation of bed resources, the improvement of hospital work efficiency, management level of hospitals and the promotion of the development of TCM in China. As a major province of TCM in China, Hubei Province has rich resources and profound development foundation in TCM, the analysis
of the bed utilization efficiency of hospital in 17 cities in Hubei province is of great significance for rational allocation of hospital beds resources, narrowing the regional differences and promoting the development of TCM. Therefore, this study the Entropy TOPSIS and RSR method are used to analyze the bed utilization efficiency of public TCM hospitals in 17 cities of Hubei Province, and find the differences in the bed utilization efficiency of public TCM hospitals in different regions, analyzed the causes of the differences, and proposed targeted suggestions, so as to provide reference for reasonable allocation of bed resources and improve the bed utilization level in public TCM hospitals.

2. Sources and methods

2.1. Data sources

The original data of this study are obtained from the Comprehensive Statistical Management Platform of TCM in Hubei and the 2018 Statistical Yearbook of Hubei Statistics Bureau. Four indicators, which are the number of beds turnover (X1), the hospital bed working day (X2), the utilization rate of hospital beds (X3) and the average length of stay for discharged patients (X4), were selected to comprehensively evaluate the bed utilization efficiency of public TCM hospitals in 17 cities of Hubei Province in 2017. The basic information of evaluation indicators of per capita GDP and the utilization rate of hospital beds in 17 cities of Hubei Province in 2017 are shown in Table 1 (refer with: Table 1).

Table 1. The basic information of evaluation indicators of per capita GDP and the utilization rate of hospital beds in 17 cities of Hubei province in 2017.

| City      | Per capita GDP(yuan) | X1(time) | X2(day) | X3(%) | X4(day) |
|-----------|----------------------|----------|---------|-------|---------|
| Wuhan     | 123111               | 31.9     | 319.3   | 87.5  | 10.1    |
| Huangshi  | 59883                | 34.4     | 317.1   | 86.9  | 9.3     |
| Shiyan    | 47757                | 31.1     | 360.4   | 98.7  | 11.7    |
| Yichang   | 93267                | 27.4     | 345.2   | 94.6  | 12.9    |
| Xiangyang | 71894                | 30.6     | 327.1   | 89.6  | 10.6    |
| Ezhou     | 84123                | 26.8     | 350.4   | 96.0  | 12.8    |
| Jingmen   | 57356                | 37.4     | 374.2   | 102.5 | 10.0    |
| Xiaogan   | 35447                | 36.6     | 313.2   | 85.8  | 8.6     |
| Jingzhou  | 34071                | 43.8     | 386.4   | 105.9 | 8.9     |
| Huanggang | 30308                | 36.4     | 328.1   | 89.9  | 8.9     |
| Xiantao   | 48711                | 30.0     | 317.2   | 86.9  | 10.5    |
| Suizhou   | 42331                | 38.3     | 339.6   | 93.0  | 8.8     |
| Enshi     | 23839                | 35.8     | 330.7   | 90.6  | 9.2     |
| Qianjiang | 62985                | 24.8     | 324.1   | 88.8  | 11.8    |
| Tianmen   | 41157                | 33.7     | 350.8   | 96.1  | 10.6    |
| Shenlongjia| 33216               | 17.1     | 135.1   | 37.0  | 7.8     |
2.2. Research methods
In this study, the entropy weight method is first used to determine the weight of evaluation indicators, and then the method of TOPSIS and RSR are used to evaluate the bed utilization efficiency of public TCM hospitals in 17 cities of Hubei Province. The calculation steps are as follows:
Step 1: The original data matrix $X_{ij} = x_{ij}(i=17, j=4)$ is standardized and the standardized matrix $R_{ij}=r_{ij}$ ($i=17, j=4$) is obtained.
If $x_{ij}$ is a positive indicator, then:
$$ r_{ij} = \frac{(x_{ij} - \min \{x_{ij}\})}{(\max \{x_{ij}\} - \min \{x_{ij}\})}; $$  (1)
If $x_{ij}$ is a negative indicator, then:
$$ r_{ij} = \frac{(\max \{x_{ij}\} - x_{ij})}{(\max \{x_{ij}\} - \min \{x_{ij}\})}. $$  (2)
Step 2: The proportion of the indicator value $y_{ij}$ is calculated.
$$ y_{ij} = \frac{r_{ij}}{\sum_{i=1}^{m} r_{ij}} $$  (3)
Step 3: The information entropy of the indicator $e_{i}$ and the redundancy of the indicator $d_{i}$ are calculated.
$$ e_{i} = (1 \times (1/LN(m))) \times (\sum_{i=1}^{m} y_{ij} \times LN(y_{ij})) $$  (4)
$$ d_{i} = 1 - e_{i} $$  (5)
Step 4: The weight of the indicator $W_{i}$ is calculated.
$$ W_{i} = \frac{d_{i}}{\sum_{i=1}^{n} d_{i}} $$  (6)
Step 5: The weighted distance $D_{i}^{+}$ and $D_{i}^{-}$ are calculated.
The optimal scheme $A^{+} = [1,1,\ldots,1]_{1 \times n}$ and $A^{-} = [0,0,\ldots,0]_{1 \times n}$ are chosen, then the formula of the weighted distances between all indicators of each evaluation objects and $A^{+}$ is as follows:
$$ D_{i}^{+} = \sqrt{\sum_{i=1}^{n} W_{i}(1 - r_{ij})^{2}} $$  (7)
The formula of the weighted distances between all indicators of each evaluation objects and $A^{-}$ is as follows:
$$ D_{i}^{-} = \sqrt{\sum_{i=1}^{n} W_{i}(0 - r_{ij})^{2}} $$  (8)
Step 6: The relative distance $C_{i}$ is calculated.
$$ C_{i} = D_{i}^{-}/(D_{i}^{+} + D_{i}^{-}) $$  (9)
The one with higher $C_{i}$ value is the better evaluation object.
Step 7: RSR is replaced by $C_{i}$ values and sorting them from smallest to largest. The corresponding frequencies $f$ of each $C_{i}$, downward cumulative frequency $\Sigma f$, rank $R$, average rank $\bar{R}$ are calculated. Then, the downward cumulative rate is calculated according to the formula $\left(\frac{\bar{R}}{n}\right) \times 100\%$. Finally, the percentage and probability unit comparison table is checked to find the Probit value corresponding to the downward cumulative rate.
Step 8: The regression equation $C_{i}(RSR) = a + b \times \text{Probit}$ is calculated, the bed utilization efficiency of hospital in 17 cities in Hubei province is classified and sorted according to the reasonable classification table and the best classification criteria for classification and sorting.

2.3. Introduction of the statistical analysis software
The software of EXCEL 2010 is used to sort out the relevant indicators which are used to evaluate bed utilization efficiency of public TCM hospitals in 17 cities of Hubei Province in 2017, calculate the relevant steps of TOPSIS and RSR method, and sort out and analyze the results. The software of SPSS 19.0 is used to analyze the variance of $C_{i}$ and Probit in step 8, to judge whether the correlation between $C_{i}$ and Probit is significant, and to determine whether the regression equation $C_{i}(RSR) = a + b \times \text{Probit}$ has statistical significance.
3. Results

3.1. The entropy weight method is used to determine the weight of evaluation indicators

The original data of the evaluation indicators of public TCM hospitals in 17 cities of Hubei Province in 2017 is collected, then, the original data is standardized according to the steps 1 (refer with: Eq. 1, Eq. 2). The result is omitted. The entropy value $e_j$ (refer with: Eq. 3, Eq. 4) and weight $W_j$ (refer with: Eq. 5, Eq. 6) are calculated according to step 2 ~ step 4 (refer with: Table 2).

Table 2. The normalized matrix and weight of each evaluation indicators in 17 cities of Hubei province in 2017.

| City      | X1  | X2  | X3  | X4  |
|-----------|-----|-----|-----|-----|
| Wuhan     | 0.5530 | 0.7329 | 0.7329 | 0.5455 |
| Huangshi  | 0.6500 | 0.7241 | 0.7241 | 0.7088 |
| Shiyan    | 0.5254 | 0.8965 | 0.8965 | 0.2347 |
| Yichang   | 0.3848 | 0.8359 | 0.8359 | 0.0000 |
| Xiangyang | 0.5070 | 0.7641 | 0.7641 | 0.4572 |
| Ezhou     | 0.3642 | 0.8566 | 0.8566 | 0.0140 |
| Jingmen   | 0.7598 | 0.9514 | 0.9514 | 0.5714 |
| Xiaogan   | 0.7307 | 0.7088 | 0.7088 | 0.8405 |
| Jingzhou  | 1.0000 | 1.0000 | 1.0000 | 0.7923 |
| Huanggang | 0.7220 | 0.7678 | 0.7678 | 0.7810 |
| Xianning  | 0.4826 | 0.7245 | 0.7245 | 0.4699 |
| Suizhou   | 0.7943 | 0.8136 | 0.8136 | 0.8035 |
| Enshi     | 0.7015 | 0.7783 | 0.7783 | 0.7182 |
| Xiantao   | 0.2892 | 0.7521 | 0.7521 | 0.2112 |
| Qianjiang | 0.4563 | 0.4733 | 0.4733 | 0.8225 |
| Tianmen   | 0.6215 | 0.8581 | 0.8581 | 0.4478 |
| Shenlongjia | 0.0000 | 0.0000 | 0.0000 | 1.0000 |

Table 3. Evaluation results of bed utilization efficiency of public TCM Hospitals in 17 cities of Hubei province in 2017 with TOPSIS method.

| City      | $D_i^+$ | $D_i^-$ | $C_i$ | Sorting |
|-----------|---------|---------|-------|---------|
| Wuhan     | 0.4006  | 0.6150  | 0.6055 | 9       |
| Huangshi  | 0.3019  | 0.7001  | 0.6987 | 7       |
| Shiyan    | 0.5562  | 0.5955  | 0.5171 | 13      |
3.3. The evaluation results of RSR method

The corresponding frequencies $f$ of each $C_i$, downward cumulative frequency $\sum f$, rank $R$, average rank $\bar{R}$, and downward cumulative rate $P_i$ are calculated according to steps 6 and the corresponding Probit value was searched in Percentage and probability unit comparison table (refer with: Table 4).

| City       | $C_i$ | $f$ | $\sum f$ | $R$ | $\bar{R}$ | $P_i$ | Probit |
|------------|-------|-----|----------|-----|-----------|-------|--------|
| Yichang    | 0.7276| 0.5152| 0.4146  | 17  |            |       |        |
| Xiangyang  | 0.4512| 0.5863| 0.5651  | 11  |            |       |        |
| Ezhou      | 0.7223| 0.5228| 0.4199  | 16  |            |       |        |
| Jingmen    | 0.3058| 0.7599| 0.7130  | 6   |            |       |        |
| Xiaogan    | 0.2374| 0.7730| 0.7650  | 3   |            |       |        |
| Jingzhou   | 0.1359| 0.9168| 0.8709  | 1   |            |       |        |
| Huanggang  | 0.2388| 0.7627| 0.7615  | 4   |            |       |        |
| Xianning   | 0.4587| 0.5689| 0.5536  | 12  |            |       |        |
| Suizhou    | 0.1955| 0.8046| 0.8045  | 2   |            |       |        |
| Enshi      | 0.2680| 0.7346| 0.7327  | 5   |            |       |        |
| Xiantao    | 0.6400| 0.4746| 0.4258  | 15  |            |       |        |
| Qianjiang  | 0.4200| 0.6435| 0.6051  | 10  |            |       |        |
| Tianmen    | 0.4149| 0.6493| 0.6102  | 8   |            |       |        |
| Shenlongjia| 0.7559| 0.6547| 0.4641  | 14  |            |       |        |
The analysis of correlation and regression shows that $C_i$ and Probit have a high correlation ($R^2=0.963$). The regression equation is $C_i(\text{RSR}) = -0.103 + 0.141 \times \text{Probit}$. The results of variance analysis show that $F$ is equal to 393.910 and $P$ is less than 0.01, it indicates that the regression equation has statistical significance. The values of Probit are substituted into the regression equation to calculate the value of $C_i$. Then according to the estimated value of $C_i$ and the reasonable classification table and the best classification criteria for classification and sorting, the bed utilization Efficiency of Public TCM Hospitals in 17 Cities of Hubei Province in 2017 is divided into three grades: very good, good and poor (refer with: Table 5).

**Table 5.** Sorting and classification of $C_i(\text{RSR})$ of bed utilization efficiency of public TCM hospitals in 17 cities of Hubei province in 2017.

| Grade   | $P_x$  | Probit | $C_i(\text{RSR})$ | Classification and sorting                  |
|---------|--------|--------|-------------------|--------------------------------------------|
| poor    | $<$15.866 | $<$4.00 | $<$0.461          | Ezhou, Yichang                             |
|         |        |        |                   | Huanggang, Enshi, Jingmen, Huangshi,        |
|         |        |        |                   | Tianmen, Wuhan, Qianjiang, Xiangyang,       |
|         |        |        |                   | Xiangning, Shiyang, Shenlongji, Xiantao     |
| good    | P15.866 $\sim$ | 4.00 $\sim$ | 0.461 $\sim$     | Tianmen, Wuhan, Qianjiang, Xiangyang,       |
|         |        |        |                   | Xiangning, Shiyang, Shenlongji, Xiantao     |
| very good | $>$84.134 | $>$6.00 | $>$0.743          | Jingzhou, Suizhou, Xiaogan                 |

4. Discussion

4.1. Analysis of evaluation methods
Entropy weight method is a method to assign objective weights to evaluation indicators according to their variation. To some extent, it can avoid the influence of subjective factors and make the evaluation results more scientific, objective and applicable [2]. TOPSIS method can make full use of the information of the original data, eliminate the influence of dimension, and quantitatively evaluate the pros and cons of different evaluation indicators, but it cannot classify the evaluation results. RSR method can make up the shortcoming of TOPSIS method, and replacing RSR value with $C_i$ avoid the problem of missing information in the process of transforming data into rank with RSR method [3]. The method of entropy weight TOPSIS and RSR can reflect the bed utilization efficiency of public TCM hospitals in different cities objectively and comprehensively, and the results are scientific and reliable. Therefore, in this study, TOPSIS and RSR were used to comprehensively evaluate the bed utilization efficiency of public TCM hospitals based on the entropy weight method in 17 Cities of Hubei Province in 2017, so as to achieve complementary effects and make the evaluation results more scientific and reliable.

4.2. There is a big gap in the bed utilization efficiency of public TCM hospitals in cities of Hubei province
The bed utilization efficiency of public TCM hospitals in Ezhou, Yichang was in lower range, Huanggang, Enshi, Jingmen, Huangshi, Tianmen, Wuhan, Qianjiang, Xiangyang, Xiangning, Shiyang, Shenlongji, Xiantao was in midrange and Jingzhou, Suizhou, Xiaogan were in higher range. The reasons could be that the cities which bed utilization efficiency is high, the population is more too, but the per capita GDP is low and the economic development falls behind relatively. Those lead to poor
development of urbanization level and traffic conditions in these cities. Therefore, patients generally choose hospitals close to home for medical treatment [4]. In addition, these cities are not rich in medical resources, and patients have relatively few choices for medical treatment, so the bed utilization efficiency of public TCM hospitals in those cities is relatively high. Take Jingzhou as an example. The number of permanent residents in Jingzhou was 5,641,700 (refer with: Figure 1), ranking fourth in Hubei province in 2017, while per capita GDP of Jingzhou was 3407.94yuan (refer with: Figure 2), ranking fourth from the bottom. The results show that the number of beds turnover, the hospital bed working day, utilization rate of hospital beds of public TCM hospitals in Jingzhou are all high, the average length of stay for discharged patients is low, and the bed utilization efficiency is high (refer with: Figure 3).

On the contrary, the cities which bed utilization efficiency is low, the population is less too, but the per capita GDP is high and the economic development is high relatively. Those lead to poor development of urbanization level and traffic conditions in these cities. Therefore the overall medical resources in these cities are rich, and TCM hospitals are in fierce competition with other non-TCM hospitals [5-6]. Besides, there is the convenient transportation, so, patients have more choices of medical treatment and the bed utilization efficiency is low. In addition, the low bed utilization efficiency in public TCM hospitals may also be related to the unreasonable allocation of hospital beds, the irregular medical service process [7], the lack of outstanding TCM characteristic services and obvious TCM advantages, and the lack of attraction to patients.

![Figure 1. Population in 17 Cities of Hubei province in 2017.](image1)

![Figure 2. Per capita GDP in 17 Cities of Hubei province in 2017.](image2)
5. Suggestions

5.1. Give full play to the characteristics and advantages of TCM to improve the core competitiveness of hospitals

With the change of disease spectrum, the arrival of aging society and the change of health concept, the unique advantages of TCM in disease prevention, treatment and rehabilitation have become more and more obvious, and its scientificity and progressiveness have been paid more and more attention by academia and industry [8]. As a major province of TCM in China, Hubei Province has rich resources and profound development foundation in TCM [9]. In recent years, Hubei Provincial Party Committee and provincial government have issued a series of policy documents which all set the goal of building Hubei Province into a strong province of TCM.

It is suggested that public TCM hospitals in Hubei province, especially in the cities which economic development level is high, but the bed utilization efficiency is low, give full play to the characteristics and advantages of TCM. They should apply modern science technology and medical equipment under the guidance of TCM theory to enhance the level of clinical diagnosis and treatment, focus on the development of special diseases, promote appropriate technology, build the characteristic brand, improve the core competitiveness and service capabilities of TCM hospitals, so as to attract more patients.

5.2. Deepen the integration of TCM with the Internet and optimize the process of TCM medical services

With the development of Internet + TCM modal, public TCM hospitals should adapt to the development of the Times and make full use of artificial intelligence, mobile internet, internet of things, big data and cloud computing and other information technologies to optimize the TCM medical service process so that both doctors and patients can use the terminal applications of tablet computers and smart phones to seamlessly connect with the hospital system, so as to meet the service requirements that inquires the inspection and inspection report and the inpatient daily clearing details, achieve bedside settlement [10]. In this way, the waiting time of patients in examination, surgery, payment and other aspects can be shortened, the hospitalization days of patients can be reduced, the turnover of hospital beds can be Speeded up and the utilization rate of hospital beds will be improved.

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