



Analysis of Operation Efficiency of Local Museums Based on DEA and Malmquist Method

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Abstract. This paper analyzes the social education operation efficiency and the dynamic change process from 2019 to 2021 of museums in Hechi area by DEA method and Malmquist index method. The data show that the overall scale efficiency of museums is insufficient, the comprehensive efficiency of type museums is higher than that of comprehensive museum, and the technical efficiency is difficult to be fully realized due to the impact of scale efficiency. Local museums should make more efforts in scale, differentiation and digital development.

Keywords: Museum · Operational efficiency · DEA method · Malmquist index method

1 Introduction

At present, the research on efficiency evaluation of cultural institutions is a very rich field both in theory and application [1]. Their value is often difficult to show through the actual effect on the market. Although it is difficult to quantify the effectiveness of cultural facilities so far, there is a consensus on improving the efficiency of public facilities management [2]. As a cultural institution, the research on measuring the efficiency of museums has attracted more and more attention in the past decades. Mairesse and Eckaut analyzed the technical efficiency and scale efficiency of museums, and proposed a global evaluation method for museums based on determined efficiency boundary using the deterministic non-parametric non-convex technique (Free Disposal Hull) [3]. Guccio adopted a generalized conditional efficiency model to evaluate the actual efficiency of Italian museums [4], and analyzes the influence of information and communication technology (ICT) on the efficiency of attracting visitors to Italian museums [5].

Based on a lot of case studies, the study of assessing museum efficiency has developed greatly and adopted different methods. Data Envelopment analysis (DEA), as a tool widely used in the efficiency evaluation of public management, has been used more and more in the efficiency analysis of museums. Basso [6], Barrio [7], Taheri [8], Bo Chen [9] analyzed the operational efficiency of museums in Italy, Spain, China and Iran by using DEA. Basso and Funari proposed a museum performance evaluation model that combines data envelopment analysis (DEA), balanced scorecard (BSC) methods and analytic Hierarchy Process (AHP) [10].

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According to the definition of ICOM, museums are non-profit permanent institutions serving the community that study, collect, preserve, interpret and display the material and intangible heritage. Social education or public education is an important function of museums. However, from the perspective of relevant studies, most of them focus on the management efficiency of the organization itself, ignoring the efficiency of the museum in social education and social influence. Especially in DEA analysis, it can handle production processes involving multiple inputs and outputs, but because of the different definitions of inputs and outputs, the results on museum efficiency will be different. Therefore, the analysis of museum efficiency must focus on its function, since all activities revolve around the realization of the function.

2 Research Objectives

Hechi, a small city in southwest China, is rich in historical and cultural resources and has eight museums of various types. However, due to the influence of geographical location and economic conditions, their social education function has not been fully realized. The main purpose of this paper is to quantitatively analyze the social education efficiency of eight museums in Hechi area by measuring their inputs and outputs.

The samples of this paper are all eight museums in Hechi area. The data comes from the National Museum Annual Report Information System, released by the National Cultural Heritage Administration of China. This data is the latest and most authoritative statistics in the field of museums, covering the type, rating, number of collections, number of precious cultural relics, number of exhibitions, number of educational activities and visitor flow of more than 6,000 museums in China. The fund data comes from the annual fund accounts of each museum. The above data sources are accurate with strong credibility and authenticity.

3 Methodology

3.1 DEA Model

This paper selects Data-envelopment-analysis (DEA) as the measure of performance evaluation of museums in HeChi. DEA, proposed by Charnes, Cooper and Rhodes in 1978, is dedicated to studying the effectiveness of input and output of each DMU (decision-making-unit). By studying the inputs and outputs data of DMU, it evaluates the technical and scale effectiveness of the same type of multi-input and multi-output DMU with the same type within a certain range from the perspective of relative effectiveness. The main advantage is that it can evaluate each input, especially for multiple outputs, and it is proved to be an effective method to evaluate the efficiency of an organization with multi-input and multi-output structures.

In view of the difference of input efficiency in different regions, this paper will adopt the BCC model of return to scale to measure the efficiency of museum investment. The specific expressions are Formula (1) and Formula (2):

$$\min \left[\theta - \varepsilon \left(\sum_{i=1}^m s_j^- + \sum_{r=1}^n s_r^+ \right) \right] \quad (1)$$

$$\text{s.t.} \begin{cases} \sum_{j=1}^J \lambda_j x_{ij} + s_i^- = \theta x_{i0} (i = 1, 2, \dots, m) \\ \sum_{j=1}^J \lambda_j y_{rj} - s_r^+ = y_{r0} (r = 1, 2, \dots, n) \\ \sum_{j=1}^J \lambda_j = 1 \\ \lambda \geq 0, s_i^- \geq 0, s_r^+ \geq 0 \end{cases} \quad (2)$$

In Formula (2), where, x_{ij} is the i -th input of the j -th decision unit of the input variable, y_{rj} is the r -th output value of the j -th decision unit of the output variable, θ is the value of efficiency evaluation, λ_j is the value of the decision variable, s_i^- and s_r^+ are the relaxed variables, ε is non-archimedean infinitesimal. When $\theta = 1$ and $s_i^- = s_r^+ = 0$, it shows that DEA of DMU is effective. When $\theta = 1$ and $s_i^- \neq 0$ or $s_r^+ \neq 0$, this shows that it is a weak DEA efficient DMU. When $\theta < 1$, it means that the DEA is invalid.

3.2 Malmquist Index

Malmquist index is a non-parametric efficiency evaluation method for measuring the production efficiency of multi-input and multi-output DMU. Contrast the DEA model for measuring static efficiency, Malmquist index can dynamically reflect the changes of museum operation efficiency over a number of periods, and can be used to explain the dynamic changes in the efficiency of museum operations.

If the output function for Period t is D^t , the output function for Period $t + 1$ is D^{t+1} , and the input and output vectors are respectively (X^t, Y^t) and (X^{t+1}, Y^{t+1}) , then the expression for the Malmquist exponent for Period t to Period $t + 1$ is Formula (3):

$$M(X^{t+1}, Y^{t+1}, X^t, Y^t) = \left[\frac{D^t(X^{t+1}, Y^{t+1})}{D^t(X^t, Y^t)} \times \frac{D^{t+1}(X^{t+1}, Y^{t+1})}{D^{t+1}(X^t, Y^t)} \right]^{\frac{1}{2}} \quad (3)$$

In Formula (3), when $M < 1$, it means the total factor productivity drops from Period t to Period $t + 1$. At when $M = 1$, it shows that total factor productivity is constant from Period t and Period $t + 1$. At when $M > 1$, it shows that total factor productivity adds from Period t to Period $t + 1$.

Moreover, Malmquist index can be disassembled into EFC and TEC index. Its expressions are Formula (4) and Formula (5), and the relationship is Formula (6). The details are as follows:

$$\text{EFC} = \frac{D^t(X^{t+1}, Y^{t+1})}{D^t(X^t, Y^t)} \quad (4)$$

$$\text{TEC} = \left[\frac{D^t(X^{t+1}, Y^{t+1})}{D^{t+1}(X^{t+1}, Y^{t+1})} \times \frac{D^t(X^t, Y^t)}{D^{t+1}(X^t, Y^t)} \right]^{\frac{1}{2}} \quad (5)$$

$$M(X^{t+1}, Y^{t+1}, X^t, Y^t) = \text{EFC} \times \text{TEC} \quad (6)$$

In Formula (4), EFC stands for technical efficiency index. If EFC is less than 1, the technical efficiency reduces. Conversely, if EFC is greater than 1, the technical efficiency

is improved. And if EFC equals 1, the technical efficiency remains the same. In Formula (5), TEC represents an index of technological progress. If TEC is less than 1, technical decline is indicated. If TEC is equal to 1, the technology is the same. If TEC is greater than 1, it indicates that the technology has made progress.

4 Model Operation and Data Analysis

This paper mainly measures and evaluates the efficiency of the social education function of museums. When selecting input indicators, the three aspects mainly considered were financial input, human input, and material input. In the selection of output indicators, we mainly consider the data that can reflect the social education function of museums (See Table 1).

4.1 Static Analysis Based on DEA Model

Based on the available data, this paper analyzes the social education operation efficiency of 8 museums in Hechi area. In this paper, the number of collections, the number of investment funds and the number of exhibitions are taken as input variables, the number of social education activities and the number of tourists are taken as output variables. Detailed figures are shown in Table 2:

DEA model can produce three main result indexes, namely scale efficiency, pure technical efficiency and comprehensive technical efficiency. Scale efficiency represents the operational efficiency affected by the size factor of DMU, that is, the impact of the operational scale of a museum on its operational efficiency. Pure technical efficiency represents the operational efficiency of DMU influenced by factors such as management ability, which is mainly reflected in the effective utilization of collection resources and the digitalization degree of museums in the field of museums. Comprehensive technical efficiency refers to the consideration and evaluation of the comprehensive operation ability of the DMU, namely the overall operation efficiency of museums. In the analysis, CRSTE, also known as comprehensive efficiency is used on behalf of technical efficiency, VRSTE stands for pure technical efficiency, Scale stands for scale efficiency, RTE stands for returns to scale, IRS stands for increasing incremental returns, - stands for constant returns to scale, and DRS stands for diminishing returns to scale.

Table 1. Input-Output Indicators of Museum

Indicator	Content
Input Indicators	financial allocation
	employment of museum
	Area of museum
	number of cultural relics
Output Indicators	exhibitions
	visitors

Table 2. Input-Output Efficiency of Museums in 2021

Firm	Crste	Vrste	Scale	Rte	Ranking
Donglan Memorial Hall	1.000	1.000	1.000	-	1
Hechi Military Parade Memorial Hall	0.890	1.000	0.890	irs	5
Guhe Memorial Hall	0.933	1.000	0.933	irs	3
Yizhou Museum	0.762	0.952	0.800	irs	6
Nandan Baikuyao Ecological Museum	0.924	1.000	0.924	irs	4
Hechi Memorial Hall	1.000	1.000	1.000	-	1
Huanjiang Maonan Museum	1.000	1.000	1.000	-	1
Luocheng Mulam Museum	0.960	1.000	0.960	irs	2
value	0.933	0.994	0.938		

In terms of scale efficiency, the mean value of scale efficiency is smaller than that of technical efficiency, and most museums are at the level of increasing scale efficiency. In general, the scale efficiency of museums is insufficient, and the small scale has become the main factor restricting the improvement of the comprehensive efficiency of museums. Museums need to organize and excavate higher-grade collections, carry out high-quality exhibitions and educational activities to improve the utilization rate of collections and attract more tourists.

In terms of comprehensive efficiency, the value of ethnic museum is higher than that of history museum and comprehensive museum. Exhibitions and collections with specific or ethnic themes are obviously more attractive to the public.

4.2 Dynamic Analysis Based on Malmquist Index

Malmquist index was applied in this paper to decompose the efficiency of eight museums in Hechi area from 2019 to 2021 for purpose of more clearly depict the dynamic change process of museum input efficiency. And the following results can be obtained (See Tables 3 and 4).

From the perspective of the average Malmquist index of museums in the past few years, as shown in Table 3, the value of the total factor productivity index (TFPCH) is greater than 1 in every year, reflecting that the operational efficiency of museums is in a stage of steady increase. The value of the change index of technological progress

Table 3. Average Malmquist Index and Decomposition of Museums from 2019 to 2021

Time	Effch	Tech	Pech	Sech	Tfpch
2019–2020	1.019	1.141	0.986	1.034	1.162
2020–2021	0.786	2.991	1.039	0.757	2.350
value	0.895	1.847	1.012	0.884	1.653

Table 4. Malmquist Index and Decomposition of Museum Efficiency

Firm	Effch	Tech	Pech	Sech	Tfpch	Ranking
Donglan Memorial Hall	1.000	2.101	1.000	1.000	2.101	4
Hechi Military Parade Memorial Hall	1.301	1.617	1.114	1.168	2.104	3
Guhe Memorial Hall	0.821	1.589	1.000	0.821	1.305	6
Yizhou Museum	0.513	1.953	0.985	0.520	1.002	7
Nandan Baikuyao Ecological Museum	1.000	2.120	1.000	1.000	2.120	2
Hechi Memorial Hall	1.072	2.632	1.000	1.072	2.823	1
Huanjiang Maonan Museum	0.991	1.632	1.000	0.991	1.617	5
Luocheng Mulam Museum	0.704	1.412	1.000	0.704	0.995	8
value	0.895	1.847	1.012	0.884	1.653	

(TECH) is higher than 1 in every year, and shows a development trend. The values of the technical efficiency change index (EFFCH) and the scale efficiency change index (SECH) are both less than 1 and show a decreasing trend. It reflects that the operation technology of museums is constantly improving, but the efficiency of technology into income is not high, which hinders the improvement of comprehensive efficiency to a certain extent.

From the data shown in table 4, the value of TFPCH of most museums is higher than 1, indicating that their operational efficiency is constantly improving. The index of pure technical efficiency change (PECH) of most museums is 1, indicating that their technological progress is no longer able to improve the comprehensive efficiency. The average value of EFFCH is greater than that of SECH, and the value of SECH of most museums is less than 1. It can be seen that the main factor restricting the improvement of comprehensive efficiency is scale efficiency.

5 Conclusions and Recommendations

This paper analyzes the social education operation efficiency and the dynamic change process from 2019 to 2021 of museums in Hechi area by DEA method and Malmquist index method. The data show that the overall scale efficiency of museums is insufficient, the comprehensive efficiency of type museums is higher than that of comprehensive museum, and the technical efficiency is difficult to be fully realized due to the impact of scale efficiency.

Local museums should make more efforts in scale, differentiation and digital development. First of all, museums should pay attention to the excavation and research of collections, collect and organize more collections, improve the quantity and quality of museum collections, and lay a foundation for the play of museum functions. Museums can also expand their exhibitions by borrowing from other museums. At the same time, relevant departments should pay attention to integrating similar resources, merging smaller museums of the same type, expanding the scale of museums, improving economies of scale and reducing repetitive investment. Secondly, it is necessary to

adhere to differentiated development, determine the development direction according to the type, positioning and content of museum collections, form characteristic themes, improve the quality of exhibition, highlight the characteristics of museums, and enhance the attraction and influence of museums. Thirdly, museums should improve the digital level, develop online exhibitions or digital museums, provide digital products, strengthen the use of network platforms, adapt to the needs of the information age, and expand the coverage of social education.

In research, the statistics of data is a very big difficulty. The normative construction of local museum data needs to be strengthened. DEA model is highly dependent on the setting of input value and output value, but there is still room for improvement in the statistics of output variables in this paper, such as the public's subjective experience of museum exhibitions, the influence of museums and other statistics are missing. In addition, comparative studies on the operational efficiency of museums in different regions should also be strengthened.

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