

# DISPLAY RATES OF CHINESE MUSEUMS AND STATISTICAL ANALYSES OF FACTORS INFLUENCING EXHIBITION QUANTITY

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## 1. Introduction

"Museum displays are extremely important because they often represent the only controlled contact between a collection and the audience" Bertscher once said, adding that, "Exhibitions are the core use of museum collections and play a critical role in the work of museums. They are the embodiment of the preservation and research results of collections and the basic way to realize the cultural value and core functions of museums" [1]. At present, other methods of using museum collections, such as providing access through digital technology and promoting cultural and creative products, are based on the collections in the exhibition line-up [2-3]. This paper adopts a method of quantitative evaluation to examine the display rates of museum collections in China.

The low display rate in museums in China is an indisputable fact. According to data released by the Palace Museum in Beijing, most of the artifacts on display are exhibited in ancient buildings in which space and conditions are limited. The Palace Museum exhibits approximately 30,000 artifacts from its own collection, which accounts for only about 2% of its total holdings of 1.86 million items [4]. More than 420,000 artifacts in the Nanjing Museum, including 40,000 artifacts used in permanent exhibitions, temporary exhibitions, and exchange exhibitions, have reached a utilization rate of 9.5%, making the museum an outstanding player among major museums in the utilization of collections [5], especially since most of the collections stored in museum warehouses have not been displayed. Some international museums have accelerated the turnover rate and renewal rate of collections by changing artifacts and holding special exhibitions, achieving good results [6-8]. For example, the Metropolitan Museum of Art in the United States has more than three million pieces in its collection, and as many as one million pieces are open to the public all the year round, with a display rate of 30% [9-10]. It also holds "special exhibitions" to improve the utilization rate of the collection [11-12]. The Louvre Museum in France revitalizes its vast collections through strategies such as regular rotations and temporary exhibitions, enhancing public access and engagement [13].

Lasso (Least Absolute Shrinkage and Selection Operator) regression and logistics regression (LR) statistical methods have been widely used in the medical field [14], and have helped doctors find the rules of disease occurrence, and development and clinical medication [15]. In this study, 670 randomly collected exhibitions were taken as examples to discuss the basic situation of museum exhibitions in China, and to analyze and predict the factors influencing museum exhibition by using statistical methods and

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deeply analyze their correlation. Only by profoundly understanding and analyzing the real and specific exhibition data and correlation coefficient of museums in China can we provide data support and scientific guidance to improve the exhibition and utilization efficiency of museum collections.

## 2. Materials and methods

### 2.1. Source of data

The basic information for the 670 randomly chosen exhibitions from 31 provinces and cities in China was collected through official museum websites, website news, the "Museum Exhibition Overview (2016)," and the "Annual Record of Important Exhibitions in Museums of China," among which, 272 were permanent exhibitions and 398 were temporary exhibitions. The collected information included the name of the exhibition, the organizer, the administrative level of the museum (national, provincial, and city level), the type of museum (for example, history, arts, natural science and technology, and a comprehensive category), the area of the museum, exhibition time, and subject matter (such as ancient history, construction of modern revolution, general history, natural history, arts, science and technology, and a comprehensive category), the type of exhibition (e.g., permanent exhibition or temporary exhibition), artifact quantity, and other factors.

### 2.2. Establishing a mathematical model to estimate the display rate of national museum collections

Given the density function of the log-normal distribution, we can calculate the expression of the reliability function and the unreliability function of the distribution according to the definition of the reliability function and the unreliability function [16].

#### Definition

$\chi$ : A continuous random variable representing the number of artifacts in a single exhibition.  $\ln\chi$ : The natural logarithm of the artifact count, assumed to follow a normal distribution.  $\mu$ : The mean of the log-normal distribution, reflecting the average value of the log-transformed artifact count.  $\sigma^2$ : The variance of the log-normal distribution, describing the dispersion of the log-transformed artifact count.

Let  $\chi$  be a continuous random variable with a positive number, if

$$\ln\chi \sim N(\mu, \sigma^2),$$

the probability density of  $\chi$  is

$$f(x, \mu, \sigma) = \begin{cases} \frac{1}{\sqrt{2\pi}\sigma} \exp\left[-\frac{1}{2\sigma^2}(\ln x - \mu)^2\right], & x > 0 \\ 0, & x \leq 0 \end{cases}$$

The random variable  $\chi$  is said to obey the log-normal distribution, recorded as

$$\ln\chi \sim N(\mu, \sigma^2).$$

### Calculation

Let  $\chi$  obey the log-normal distribution, and its density function is as follows:

$$p(x) = \frac{1}{x\sigma\sqrt{2\pi}} e^{-\frac{(\ln x - \mu)^2}{2\sigma^2}}$$

The mathematical expectation is as follows:

$$E(\chi) = e^{\mu}$$

### Symbol Definitions

$E(\chi)$ : The mathematical expectation (expected value) of the artifact count, representing the average number of artifacts per exhibition.  $\mu$ : The mean parameter of the log-normal distribution.

If the number of permanent exhibitions, temporary exhibitions, and collections in China in 2017 is  $\alpha$ ,  $\beta$ , and  $m$ , then the display rate  $f(\chi)$  of the collections in museums of China in 2017 is as follows:

$$f(\chi) = \sum (E(\chi_1) \cdot \alpha + E(\chi_2) \cdot \beta) / \varphi$$

### Symbol Definitions

$\chi_1, \chi_2$ : Represent the artifact counts for permanent exhibitions and temporary exhibitions, respectively, both following log-normal distribution.  $E(\chi_1), E(\chi_2)$ : The average artifact counts for permanent and temporary exhibitions.  $\alpha, \beta$ : The number of times a museum hosts permanent and temporary exhibitions in a year.  $\varphi$ : The total number of artifacts in the museum's collection.  $f(\chi)$ : The display rate, expressed as a percentage, indicating the proportion of artifacts on display.

## 2.3. Data set processing of input R language

The data come from the "Statistical Yearbook of Chinese Culture" and are released by the National Bureau of Statistics. The "Statistical Yearbook of Chinese Culture" systematically collects data on all aspects of Chinese cultural development. The selection of Area, Professional staff, Employee count, GDP ranking, Collection number, Income, and Per capita GDP, ranking as independent variables, is driven by two primary considerations. First, the yearbook systematically documents institutional metrics, while detailed data on ticket prices or collection themes lack national standardization. Second, museum operations in China are heavily dependent on government funding and regional economic capacity. Professional staff directly influence the planning and execution capabilities of exhibitions. Its processing for the Lasso regression analysis is as follows: the respective variable names are Exhibition\_quantity, GDP\_ranking, Per capita\_GDP\_ranking, collection\_number, area (refers to the exhibition area of museums in various provinces and cities), employee, professional\_employee, and income (refers to the funds allocated by the central government to regional museums). The file is named 'input3.txt'.

Logistics regression applies to variables whose dependent variable is a dichotomy. In dataset X, the Exhibition\_quantity of 31 provinces is ranked from high to low, ranking

1-15 as 'high =0', and 16-31 as 'low =1'. The GDP\_ranking and Per capita\_GDP\_ranking are ranked from small to large, wherein 1-10 is 'high =0', 11-20 is 'medium =1', and 21-31 is 'low =2'. Other independent variables, such as collection\_number, area, employee, professional\_employee, and income were ranked from high to low, ranking 1-10 as 'high =0', 11-20 as 'middle =1', and 21-31 as 'low =2'. The dataset is named 'input4.txt'.

## **2.4. Statistical analysis**

Statistical analyses included normality testing (Shapiro-Wilk test), Pearson/Spearman correlation analyses, and Least-Significant Difference (LSD) tests for multi-group mean comparisons, following established methodologies[17]. R (version 3.6.2, <http://www.r-project.org/>) is used for Lasso or logistics regression analysis, and for drawing the nomogram, ROC curve, and calibration curve. The C-index (consistency index) is used to evaluate the accuracy of the nomogram. The dataset of basic information of museums in various regions of China in 2017 is shown in the supplementary material (Table 1).

## **3. Basic information on the 670 exhibitions**

### **3.1. Basic information on the artifact quantity and subject matter of the 670 exhibitions**

A simple statistical analysis on artifact quantity in 670 exhibitions was conducted, as shown in Fig. 1A. Among the 670 randomly chosen exhibitions, there were 120 exhibitions with less than 100 artifacts, accounting for 17.91%; 386 exhibitions with 100–500 objects, accounting for 57.61%; 95 exhibitions with 501-1000 objects, accounting for 14.18%; and 69 exhibitions with more than 1000 artifacts, accounting for 10.3%.

In addition, based on the contents of each exhibition, they were categorized into the following subject areas: ancient history, construction of modern revolution, general history, natural history, arts, science and technology, and comprehensive [18]. The collected 670 exhibition typologies were categorized by subject, as shown in Fig. 1B. Among them, the number of permanent exhibitions for ancient history is 111, and for arts it is 50. The number of temporary exhibitions for ancient history is 139, and for arts it is 172. Permanent exhibitions thus account for 37.31% and 33.13% of the total exhibitions within the ancient history and arts categories, respectively. For other subjects, the counts are as follows: in the category of construction of modern revolution, there are 66 permanent and 57 temporary exhibitions, accounting for 18.36%; in general history, 19 permanent and 1 temporary, accounting for 2.99%; in natural history, 12 permanent and 12 temporary, accounting for 3.58%; in science and technology, 7 permanent and 15 temporary, accounting for 3.28%; and in the comprehensive category, 7 permanent and 2 temporary, accounting for 1.34%. These data are consistent with the great majority of historical and artistic exhibitions in China with regards to the traditional classification of exhibition subjects.

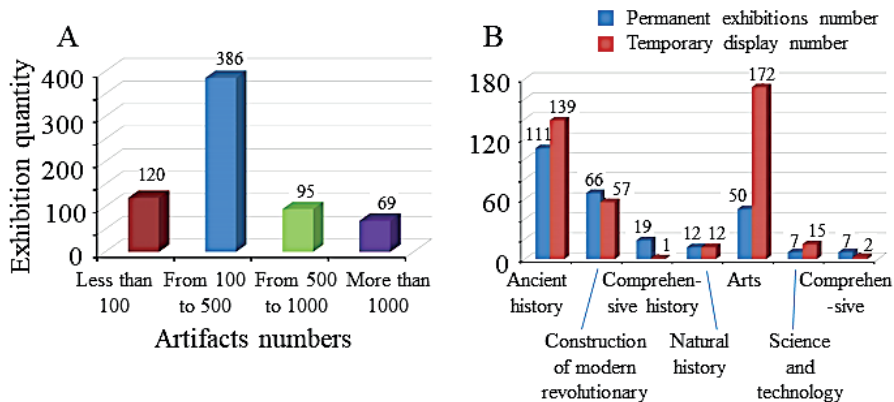


Figure 1. Basic information on the artifact quantity and subject matter of 670 exhibitions. A) shows the distribution of artifact quantity collected; B) shows the statistics of the classification of the subject matter in the exhibitions.

### 3.2. Basic information about the host museum for the randomly selected exhibitions

The administrative levels of the collection of 670 exhibitions were analyzed, as shown in Table 1. The number of permanent and temporary exhibitions sponsored by national and provincial museums is 14 and 75, and 89 and 169, respectively, accounting for 13.28% and 42.09%, respectively. The number of permanent exhibitions sponsored by city-level museums is 169, while the number of temporary exhibitions is 130, accounting for 44.63%. Due to the lack of exhibition information in museums with lower administrative levels, data are difficult to collect, and few data are published online. Generally speaking, the exhibitions found on the Internet are high-quality exhibitions. Therefore, the artifact quantity in the sample may exceed the national average. The proportional distribution of museum administrative levels and types in our sample of 670 exhibitions is consistent with the national profile reported in the “2018 Statistical Yearbook of Chinese Culture”. Although city-level museums do not constitute the absolute majority in our sample, their proportion in relation to national and provincial museums is consistent with the national pattern; this consistency supports the representativeness of our sample.

The type of host museums of the 670 exhibitions were classified as shown in Table 1. Among them, the permanent exhibition quantity sponsored by comprehensive, historical, art, and natural science and technology museums is 128, 111, 24, and 9 respectively, while the temporary exhibition quantity is 304, 62, 24, and 8, respectively, accounting for 64.48%, 25.82%, 7.16%, and 2.54%, respectively, in total. Compared with the information on exhibitions held by various types of museums in China in 2017, published in the “2018 Statistical Yearbook of Chinese Culture,” exhibitions held by comprehensive and historical museums also accounted for an absolute number, consistent with national data, indicating that the collected exhibitions were representative to some extent.

Table 1. Statistics on the administrative level and type of the host museums of the 670 exhibitions

		Permanent exhibition quantity	Temporary exhibition quantity	Total percentage
Administrative level of the museum <sup>1</sup>	National level	14	75	13.28%
	Provincial level	89	193	42.09%
	City level	169	130	44.63%
	Total	272	398	100%
Type of Museum <sup>2</sup>	Comprehensive	128	304	64.48%
	History	111	62	25.82%
	Arts	24	24	7.16%
	Natural science and technology	9	8	2.54%
	Total	272	398	100%

## 4. Result

### 4.1. Normality test of dataset

In this study, a mathematical mean model was established using the artifact quantity in 670 exhibitions. Then, the exhibition quantity and collections of museums of various types and administrative levels in China from 2009 to 2017 (published in the "Statistical Yearbook of Chinese Culture"), was used to estimate the display rate of museums in China.

In order to confirm that the artifact quantity collected in the exhibition conforms to the normal test, first, the non-parametric normal test on the artifact quantity was conducted, as shown in Fig. 2A and B. Normal Probability Plot and Quantile-Quantile Plot (Q-Q Plot) showed that exhibitions with less than 2000 artifacts accounted for more than 95%, and the artifact quantity did not conform to the normal distribution.

When the data set  $X$  does not conform to the normal distribution, the logarithm ( $\log x$ ) of the data set  $X$  of the random variable may conform to the normal distribution, which is mathematically called lognormal distribution. The results are shown in Fig. 2C and D. The Normal Probability Plot shows that after taking the logarithm of the artifact quantity, the mean value ( $\mu$ ) is equal to 2.3753, the variance ( $\sigma$ ) is equal to 0.44974, and the Normal Probability Plot shows the distribution of "high in the middle, low on both sides." In addition, the Q-Q Plot also indicates that  $\log x$  is basically distributed on  $y=x$ . These results indicate that  $\log X$ , a logarithmic set on the artifact quantity, is normally distributed.

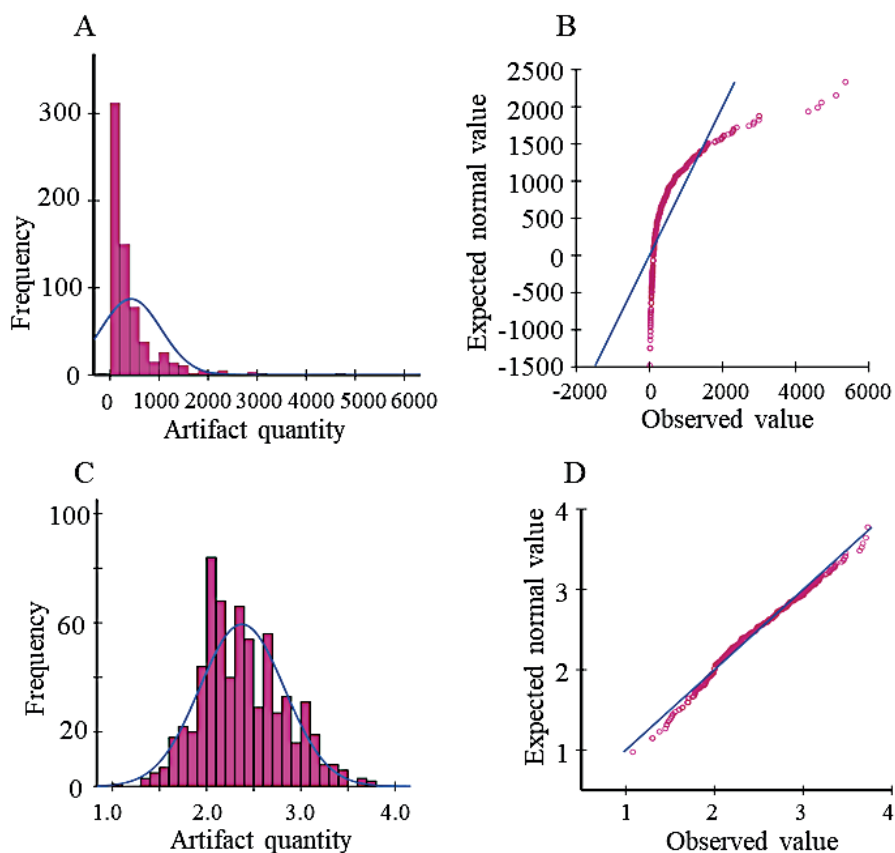


Figure 2. Normality test of artifact quantity for 670 exhibitions. A) is the Normal Probability Plot of the artifact quantity; B) is the Q-Q plot of the artifact quantity; C) is the Normal Probability Plot of artifact quantity after log transformation; D) is the Q-Q plot of the artifact quantity after log transformation.

#### 4.2. Estimating the display rate of museums in China in past years using a mathematical model

The display rate of the collections in national museums in 2017 was taken as an example. According to the formula  $f(\chi) = \sum(E(\chi_1) \cdot \alpha + E(\chi_2) \cdot \beta) / \varphi$  the specific calculation process is as follows. First, the artifact quantity of 14 permanent exhibitions at the national level was screened out, with a base of 10. After log transformation, the average value of the logarithm was equal to 2.96 ( $\mu=2.96$ ). The mathematical mean of the artifacts count for this group was then calculated as  $E(\chi_1)=10^\mu=912.01$ . Similarly,  $E(\chi_2)=10^\mu=213.80$  for the mathematical average of artifacts of 75 temporary exhibitions at the national level. It was concluded that the display rate  $f(\chi)$  of national museums in 2017 was 1.58%.

In order to further understand the state of exhibitions of museum collections in past years, the above method was used to obtain statistics on the display rate of museums in China from 2009 to 2017, and a graph was drawn of their estimated value, as shown in Fig. 3A. From 2009 to 2017, the display rates of national museums were 3.06%, 2.46%, 2.04%, 2.50%, 1.89%, 2.19%, 2.14%, 1.45%, and 1.58%. The display rates of provincial museums from 2009 to 2017 were 5.69%, 5.28%, 5.66%, 5.36%, 4.82%, 4.88%, 4.90%, 4.84%, and 4.41%. It can be seen that the display rate of museums above the provincial level fluctuated very little from 2009 to 2017 and showed a downward trend. From 2009 to 2017, the display rate of city-level museums was 34.11%, 41.82%, 36.76%, 32.91%, 22.39%, 24.47%, 25.38%, 24.65%, and 24.27%. It can be seen that the collection display rate of small city-level museums fluctuated greatly from 2009 to 2017 and also showed a downward trend. To a certain extent, with the increase in the number of museums and collections in China from 2009 to 2017, the display rate has not improved or even declined, indicating that improving the utilization efficiency of museum collections is an urgent problem faced by museums in China.

The display rates of various types of museums from 2009 to 2017 were counted, and the curves of their estimated values were drawn, as shown in Fig. 3B. It can be seen that the estimated curve of the collection display rate of all types of museums shows a downward trend, which, to some extent, indicates that the overall display rate of all types of museums is declining, and it is necessary to improve the utilization efficiency of collections.

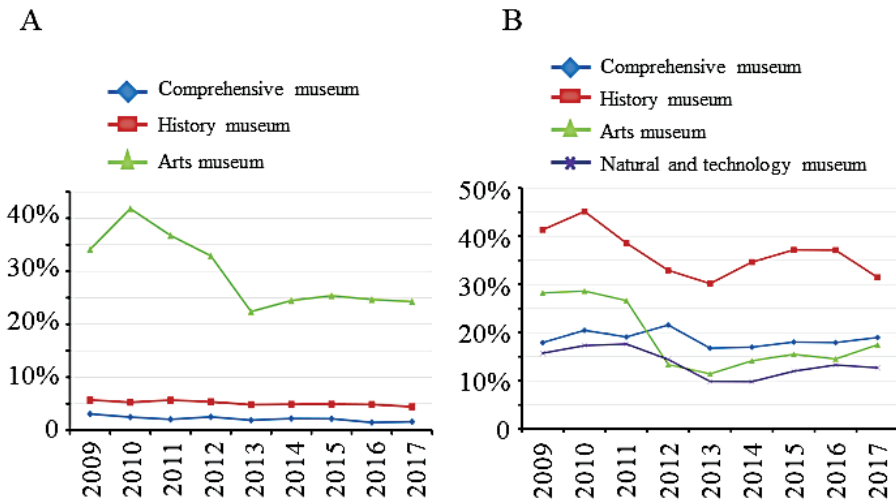


Figure 3. Estimated value curve of display rate of Chinese museums from 2009 to 2017. A) is the display rate for museums at three administrative levels: national, provincial, and city-level; B) is the display rate for four museum types: comprehensive, history, arts, and natural science & technology.

#### 4.3. Using Lasso regression to screen characteristic factors influencing exhibition quantity

The prediction of relevant factors affecting the exhibition quantity of the museum has a guiding role in discussing the correlation between single factors (independent

variables) and exhibition quantity (dependent variables) and has a certain directivity in exploring the reasons for the low display rate of museum collections. As shown in Fig. 4A, there are seven factors in the selection range. The vertical coordinate of Fig. 4A is the regression coefficient and the horizontal coordinate is  $\text{Log}\lambda$ . From left to right, when  $\lambda$  is sufficiently large the coefficient of the seven factors can be precisely reduced to zero to obtain the  $\lambda$  value:  $\log_e\lambda=29.45846$ ,  $\lambda=3.38$ . The first imaginary line to the left of Fig. 4B shows that when  $\lambda=3.38$ , there is a corresponding 3. From this, it can be seen that of the seven factors included in the selection, three are the most relevant: GDP\_ranking, area, and professional\_employee.

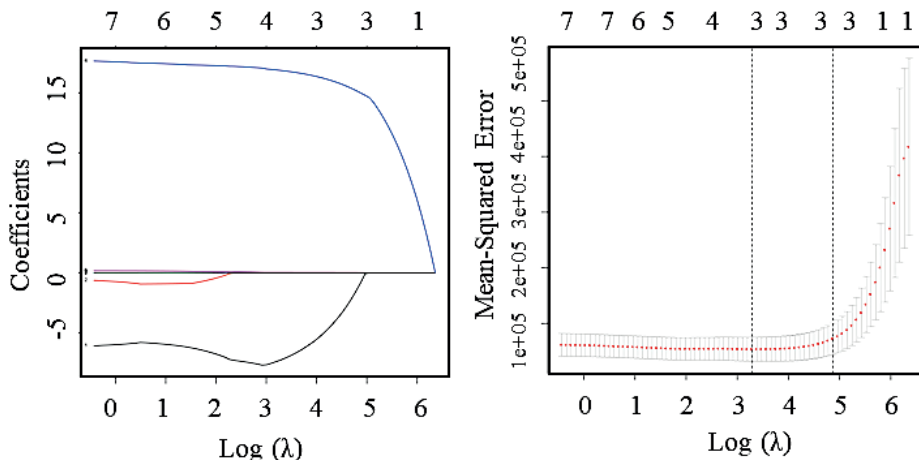


Figure 4. Lasso regression screened the characteristic factors that influence the exhibition quantity. A) The seven-fold cross-validation via minimum criteria is used to select the optimal parameter ( $\lambda$ ) in the Lasso model; B) Lasso coefficient profiles of the seven factors. A vertical line was drawn at the value selected using seven-fold cross-validation, where optimal  $\lambda$  resulted in the features with nonzero coefficients, when the  $\lambda$  value is 3.38.

#### 4.4. Nomogram of the characteristic factors affecting exhibition quantity

Nomograms are used to predict the probability of dependent variables occurring when other independent variables are known. We further constructed the mathematical model of the nomogram to predict the probability of more or less in the exhibition quantity; the results are shown in Fig. 5. To demonstrate the application of this nomogram, we used the 2017 museum data of Shaanxi Province as an example, its GDP\_ranking is 15 (Middle), the Area is 623,500 square meters, ranked fifth (High), and the professional\_employee is 2205, ranking third (High). Compared with the results shown in Fig. 5, which has a score of 34, 0, and 0, respectively, the Probability of Non\_Exhibition\_quantity corresponding to the total score of 34 was much lower than 0.1. Therefore, it can be predicted that the number of exhibitions in Shanxi province is among the highest in China. The nomogram is of guiding significance in predicting the exhibition quantity of the museum in different regions of China; other provinces can also make predictions according to the nomogram.

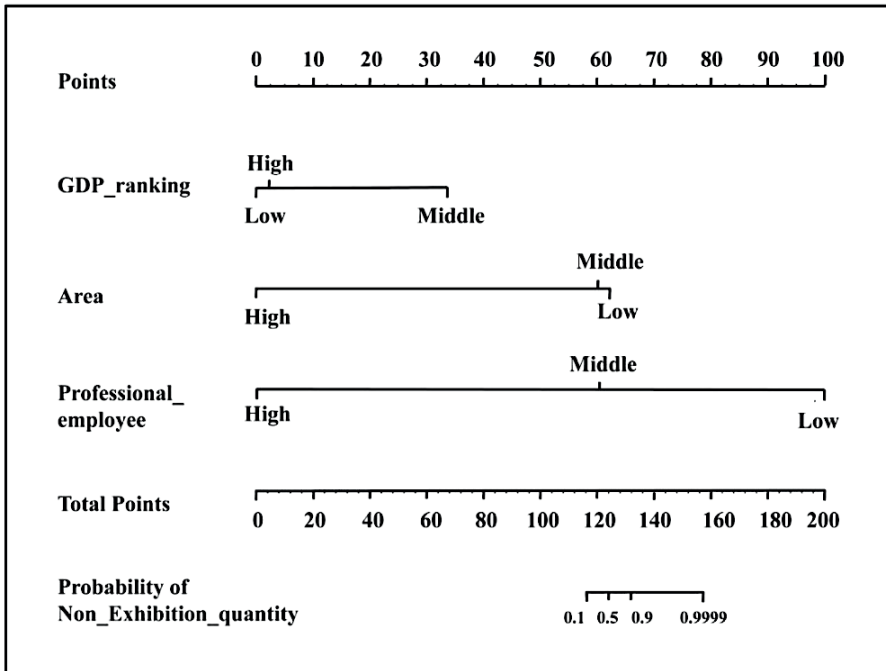


Figure 5. Nomogram of the characteristic factors affecting the exhibition quantity. This is a general predictive model. The method of use of the nomogram, the value of each province (high, middle, low of the GDP ranking, area, and professional employee), draws a line upward to determine the score of the variable, summarizes the total score of all the variables, and compares the probability of axis to predict the probability of more or less in exhibition quantity.

#### 4.5. Calculation of C-index and AUC

The C-index is the index of concordance, which evaluates the predictive power of a model by estimating the probability that the predicted results are in agreement with the observed results [19]. In addition, the Area Under Curve (AUC) is derived from the area under the receiver operating characteristic (ROC) curve. The value of the AUC is between 0.1 and 1, which can directly evaluate the quality of the model. The closer the value is to 1, the better the accuracy of the model [20-22]. After constructing the nomogram of the GDP\_ranking, area, and professional\_employee, in order to further judge the accuracy of the forecast of the nomogram, the C-index was calculated, the ROC curve was drawn and the AUC value was calculated, to analyze them. Running on the R language, the C-index is 0.99, the standard deviation is 0.023, and the C-index is close to 1. The ROC curve is shown in Fig. 6A. It can be seen from the figure that the AUC is 0.923, which is close to 1. Both the C-index and AUC indicate that the nomogram model used to predict the exhibition quantity of the museum is highly accurate.

#### 4.6. Drawing the calibration curve of the nomogram

The calibration curve is a curve fitted by a scatter plot of the actual probability of occurrence and the predicted probability of occurrence [23]. The closer the predicted curve is to the actual curve ( $y=x$ ), and the closer the predicted curve is to the measured incidence, the better the model. The calibration curve of the nomogram is drawn by R language. The result is as shown in Fig. 6B. It can be seen from the graph that the curve is close to  $y=x$ , which shows that the results of the screening and prediction in the nomogram are more accurate, conforming to the actual state of museum operation. GDP ranking, area, and professional employees, are important factors that affect the exhibition quantity of provincial museums. Indirectly, these factors are also the key factors affecting the exhibition quantity and the efficiency of the use of collections in individual museums.

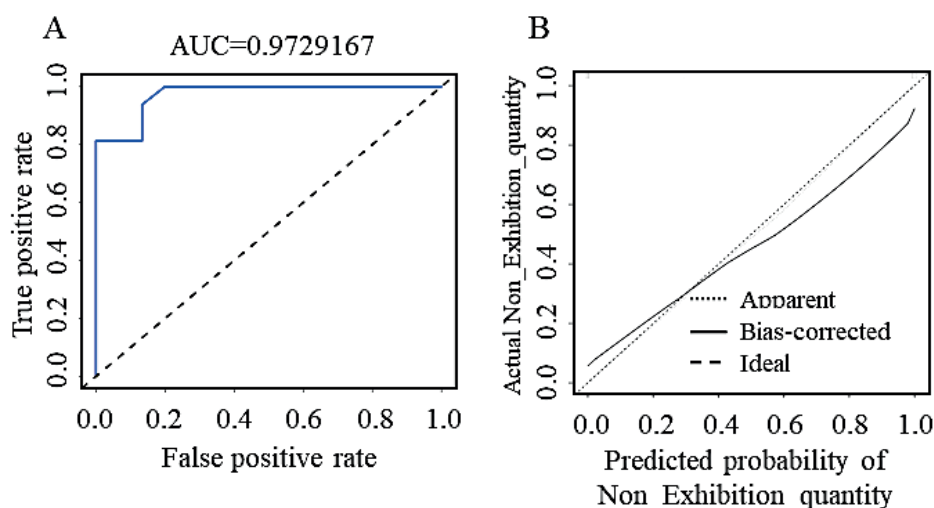


Figure 6. ROC curve and calibration curve influencing characteristic factors of the exhibition quantity. A) is the ROC curve; B) is the calibration curve.

#### 4.7. Correlation analysis between the administrative level of the museum, museum type and display rate

Least significant difference (LSD) statistical tests on the average number of different samples were conducted with the display rates of museum collections from 2009 to 2017; the results are shown in Table 2. Compared with the display rate of high-level museums during these years (national level,  $0.02 \pm 0.00$ ; provincial level,  $0.05 \pm 0.00$ ), the display rate of city-level museums is  $0.30 \pm 0.07$ . Through the LSD statistical test, LSD-t values were -13.50 and -12.50, respectively (A vs. C,  $P = 0.00$ ; B vs. C,  $P = 0.00$ ). According to the test level of  $\alpha = 0.05$ ,  $P < 0.05$  has statistical significance. Therefore, there is a statistically significant difference between the high display rate of city-level museums and the low display rate of national and provincial museums.

Similarly, the LSD statistical test was conducted on the average number of different

samples in the display rates of various types of museums from 2009 to 2017; the results are shown in Table 2. Compared with other types of museums ( $0.19 \pm 0.02$  for comprehensive,  $0.19 \pm 0.07$  for art, and  $0.14 \pm 0.03$  for natural science and technology), the display rate of history museums in this period is higher at  $0.37 \pm 0.05$ . The LSD-t values were -9.00, 9.00, and 11.50, respectively (A vs. B,  $P=0.00$ ; B vs. C,  $P=0.00$ ; B vs. D,  $P=0.00$ ). Therefore, there is a statistically significant difference between the high display rate of historical museums and the low display rate of other categories.

We used Spearman's rank correlation to analyze the relationship between the administrative level of museums and display rates from 2009 to 2017; the result is shown in Table 3. The correlation coefficient is 0.943456, which shows that the administrative grade of museums is highly correlated with the display rate; the P value is 0.000001, which is statistically significant. It can be concluded that the display rate of high-level museums is low, while that of low-level museums is higher, which further proves the relevance between museum level and exhibitions.

In addition, the relationship between museum type and display rate was statistically analyzed by Spearman's correlation; the correlation coefficient was -0.55486 as shown in Table 3. The absolute value of the correlation coefficient indicated that the relationship between museum type and display rate was moderate. The P value is 0.00044, which is statistically significant. It can be considered that the display rate of history museums is high, while that of other types of museums is low, which further proves the correlation between museum types and exhibitions.

*Table 2. Results of LSD tests on the display rate in museums of different administrative levels and types from 2009 to 2017*

Groups	Count	Mean <sup>3</sup>	Std. Deviation		LSD-t	P value
National level museum (A)	9	0.02	0.00	A vs B	-1.50	0.13
Provincial level museum (B)	9	0.05	0.00	A vs C	-13.50	0.00
City-level museum (C)	9	0.30	0.07	B vs C	-12.50	0.00
Comprehensive museum (A)	9	0.19	0.02	A vs B	-9.00	0.00
History museum (B)	9	0.37	0.05	A vs C	0.00	0.91
Arts museum (C)	9	0.19	0.07	A vs D	2.50	0.03
Natural science and technology museum (D)	9	0.14	0.03	B vs C	9.00	0.00
				B vs D	11.50	0.00
				C vs D	2.50	0.02

Table 3. Results of Spearman's correlation coefficient between display rates and various administrative levels and types of museums over the past decade

		N <sup>4</sup>	Correlation Coefficient	P value
Display rate vs.	Administrative level of the museum	27	0.94	0.000001
	Type of Museum	36	-0.55	0.00044

#### 4.8. Correlation analysis between exhibition quantity and objective factors

We screened GDP ranking, area, and professional employees, as the most relevant factors affecting the exhibition quantity of the museum. Moreover, a nomogram was constructed to verify the accuracy of the prediction, but the specific correlation coefficients between these factors and the exhibition quantity were not clear. Therefore, the Pearson test was used to calculate the correlation coefficients between these three objective factors and other possible factors and the exhibition quantity, to accurately reflect the relationship between these objective factors and the exhibition quantity.

The Pearson test was used to calculate the correlation between the number of museum exhibitions in each region and seven objective factors, such as exhibition area in 2017. The results are shown in Table 4. Pearson's correlation coefficient ranges from high to low, including area, professional employees, employees, GDP ranking, collection number, income, and per capita GDP ranking. The correlation coefficient is 0.94, 0.89, 0.79, -0.77, 0.62, 0.54, and -0.4, respectively, with  $P < 0.05$ . The results show that these objective factors are related to the exhibition quantity of the museum, and they are all important factors influencing the exhibition quantity. In addition, it can also be seen from the correlation coefficient that the prediction models used to construct the nomograms using the three most relevant factors that were selected, mutually confirm that, area, professional employees, and GDP ranking, are indeed the important factors influencing the exhibition quantity of the museum in a region.

Table 4. Pearson's correlation statistical analysis of the factors influencing the exhibition quantity of museums

		No. of Provinces	Correlation Coefficient	P value
Exhibition quantity vs.	Area	31	0.94	0
	Professional employees	31	0.89	0
	Employees	31	0.79	0
	GDP ranking	31	-0.77	0
	Collection number	31	0.62	0.000201
	Income	31	0.54	0.001868
	Per capita GDP ranking	31	-0.4	0.025101

## 5. Discussion

### 5.1. Correlation factors

We used Lasso regression and logistics regression to analyze the basic data of the Chinese museum type, the subordinate relations, district and collection, exhibition area, employees, and income. The study analyzed the correlation between these factors and exhibition quantity in order to comprehensively examine the factors that affect the exhibition quantity of museums in China.

First, Lasso regression analysis was used to screen three (GDP ranking, area, and professional employees) of the seven factors that are important in influencing the exhibition quantity of museums. Then, a nomogram model for predicting the exhibition quantity was constructed using these three factors, and the accuracy of the model was verified by using the C-index, ROC curve, and calibration curve, which proved that GDP ranking, area, and professional employee, provided good accuracy in predicting exhibition quantity.

We calculated the Pearson's correlation coefficient between the GDP ranking and the exhibition quantity and found that the correlation coefficient of the two was -0.77, indicating that the higher the GDP ranking (better economic performance), the greater the number of exhibitions held in the specific region. Therefore, the degree of economic development is one of the factors affecting local museum exhibitions, thus, the financial strength of a museum inevitably affects the exhibition quantity and the use efficiency of the collection.

The Pearson's correlation coefficient between exhibition area and exhibition quantity is 0.94, which is the highest of all factors. It can be considered that areas with more exhibition space have more exhibitions, while areas with less exhibition space have fewer exhibitions. Exhibition area is undoubtedly one of the important factors affecting the utilization of collections [24]. Increasing exhibition area is, therefore, one of the effective ways for a museum to improve the utilization efficiency of collections [25-26].

The Pearson correlation coefficient between the number of professional employees and exhibition quantity is 0.89, indicating that the two are also highly correlated. It can be explained by the fact that the number of employees plays an important role in the development of museum exhibitions. If a museum lacks necessary professional employee allocation, it will seriously restrict the development of the museum and the utilization efficiency of its collections [27].

However, other factors are also important. For example, there is a strong correlation between the total number of staff and exhibition quantity. This suggests that sufficient overall staffing capacity is a fundamental constraint on a museum's ability to produce exhibitions. Similarly, regions with fewer collections tend to have fewer exhibitions, while those with more collections have comparatively more. More exhibitions, to some extent, mean that more collections are being used, consequently, more cultural and historical values are being passed on. Furthermore, as both staffing and collection utilization are resource-dependent, the income of a museum is another important factor that affects the exhibition of museum collections. Increasing funds is therefore one of the effective ways for a museum to improve the utilization efficiency of collections.

Although factors such as ticket prices, collection value, or exhibition themes may influence visitor engagement, these variables were not individually analyzed. First, most Chinese museums adopt free or low-cost admission policies, with ticket revenue constituting an extremely small proportion of total income (less than 10%). Therefore, it was not listed separately but incorporated into the broader "revenue" factor, which primarily includes government fiscal funding and ticket revenue. In China, only a small number of national-level museums charge admission fees, while the majority are free to the

public. In this study, the author focused on analyzing how internal museum resources (e.g., floor area, staff) and external economic conditions (e.g., GDP) drive exhibition output, rather than visitor behavior or market mechanisms, due to unavailable data.

## **5.2. Low display rate in China**

Collections are the foundation of a museum and play an important role in the museum's development. According to the "Statistical Yearbook of Chinese Culture," the number of museum collections in China reached 14,554 million pieces or sets in 2008, and up to 151.6% to 36,623 million pieces or sets by the end of 2017. With social and economic development, the spiritual and cultural needs of the public are constantly increasing [28]. However, the low display rate of museums in China is an objective problem. The phenomenon of a "dead collection" is common, and a large number of collections are silently stored in warehouses. According to the statistics of the National Cultural Heritage Administration of China on the collections in eight museums jointly built by the central and local governments in 2013, the display rate is between 1.2% and 5% across these museums, and the calculated mean is less than 2.8%.

Whether a collection can be fully displayed is the expression of a museum's survival ability and the motivating force in a museum's smooth development. In this study, we used the mathematical model to estimate the display rate of museums of different administrative levels and types from 2009 to 2017. It was found that the display rate of museums was relatively low in terms of both the administrative level and the type of museum. In addition, although there are two points when the display rate during this period increases, overall, it declines.

This study mainly uses mathematical modeling and statistical methods to analyze the display rate of the museums in China by relative quantitative analysis. However, for museums, it is not only the quantity, but also the quality of the exhibitions that is important [29], such as the depth of the research and interpretation of the collection's value [30], whether the frequency of the artifact's use in exhibitions is appropriate, and the absence of factual inaccuracies or misleading interpretations in the exhibition [31].

Although the collection resources of museums in China are very rich, museums have not done enough to display, study, interpret, and activate their value comprehensively, to obtain lasting cultural attraction. For example, although some collections have been preserved digitally, they have not been used effectively [32]. In some museums, the exhibitions are just simple exhibitions, which merely show the objects. By ignoring the perspective of the visitors, the value connotation of the artifacts cannot be understood by the patrons. For most museums, research is a weakness. The content of the published exhibition books is mostly pictures and a brief introduction. The content in the book does not delve deeply enough into the value of the collection and shows a lack of ability to translate professional knowledge of the collection into a popular language that is easy to understand and so be accepted by the public. Abstruse, abstract, and tedious content is not rendered in a vivid form, making it difficult for readers to feel the subtlety of the collection [33]. Exhibitions are an important way to display Chinese culture, but intellectual errors in the exhibition can seriously impact the effect of the exhibition. In exhibitions, the overuse of 'national treasures' (those artifacts designated as having the highest historical or artistic value) is a noticeable problem. Unlike collections that are considered national treasures, most of the collections in museums are ordinary collections (the majority of holdings with significant but relatively lower-tier cultural value), though they are an important part of supporting exhibitions. The over-utilization of national treasures and the lack of utilization of ordinary collections highlight the polarization of the utilization frequency of museum collections. Insufficient interpretation of the

value of a collection will inevitably affect the depth of the exhibition, but also affect the function of the museum [34].

### **5.3. Deficiency**

First, the collection of 670 exhibitions has limited representation. Due to the lack of published data and difficulty in data collection, the exhibition data that were finally collected are representative of high-quality exhibitions in China. This factor has a certain impact on the estimation of the display rate of museums; in fact, the actual display rate will be lower than the estimated display rate. Even so, it is undeniable that the low display rate is an objective problem.

Second, the seven factors of the data set that were used, are all from the "Statistical Yearbook of Chinese Culture" published in past years. Only data related to the topic of the article from the yearbook can be selected. However, the factors that affect the exhibition quantity of the museum are not limited to these seven factors since the impact of other factors on museum exhibitions must also be considered, such as grade/value hierarchy of the artifacts, the museum's philosophy and policies regarding collection management and utilization, relevant governmental regulations, the depth of collection research and so on.

## **6. Conclusion**

The basic information of 670 randomly chosen exhibitions was collected from 31 provinces and cities in China from the official website of museums and the "Annual Records of Important Exhibitions of Museums in China," and the display rate at different levels and types of collections from 2009 to 2017 was estimated by means of mathematical modeling. It was found that the display rate of the collections in both city-level museums and museums above the provincial level was on a declining trend over this period, and that the estimated display rate curves of the collections of all types of museums showed a downward trend. These results demonstrate that the display rate neither increased nor decreased, in the period from 2009 to 2017, even though the number of museums and collections increased significantly over the same period.

The statistical analysis method of Lasso regression and logistics regression allowed the screening of three factors related to the exhibition quantity from a number of seven factors to be carried out. The three factors were used to construct a nomogram model that could then be used to predict the exhibition quantity in museums. The C-index, ROC curve, and calibration curve all confirmed the good consistency of the nomogram model.

Using Spearman's and Pearson's statistical methods, we analyzed the correlation between the administration level and type of museum and the display rate, and the exhibition quantity and the objective factors, respectively. It was found that the relationship between administrative level and display rate is "high level–low display rate, low level–high display rate." In addition, it was confirmed that when the level of economic development is high, there are more professional employees, and larger exhibition areas consistently host a greater number of exhibitions.

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## Notes

- <sup>1</sup> *The administrative level of museums in China refers to the subordination of museums, which are listed as national, provincial, and city museums, from high to low.*
- <sup>2</sup> *With reference to the classification system commonly used worldwide, in China, museums are divided into four types according to actual representation, namely, history, art, natural science and technology, and comprehensive.*
- <sup>3</sup> *Mean is the average display rate from 2009 to 2017.*
- <sup>4</sup> *N denotes the sample size. For administrative level analysis, N = 27 (9 years × 3 levels); for museum type analysis, N = 36 (9 years × 4 types).*

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### Biographical notes

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### Summary

The actual display rate of exhibitions in Chinese museums is unknown. A mathematical model was developed to estimate the display rate, and Lasso and logistics regression were used to analyze factors affecting exhibition quantity. From 2009 to 2017, display rates across different museum levels and types were low and declining. Among seven factors, area, GDP ranking, and professional employee count, were identified as most relevant to exhibition quantity. A nomogram was constructed using these factors to predict exhibition quantity probability, achieving results with a level of high accuracy (C-index: 0.99, AUC: 0.923). These factors showed a strong correlation (>0.7) with exhibition quantity.

## Riassunto

Il tasso effettivo di esposizione delle mostre nei musei cinesi non è stato ancora oggetto di studi approfonditi. È stato sviluppato un modello matematico per stimare tale tasso, utilizzando il metodo Lasso e la regressione logistica per analizzare i fattori che influenzano il numero di mostre. Nel periodo compreso tra il 2009 e il 2017, i tassi di esposizione nei diversi livelli e tipologie di musei sono risultati bassi e in calo. Tra i sette fattori considerati, la superficie, la posizione nella classifica del PIL e il numero di dipendenti qualificati sono risultati i più rilevanti per il numero di mostre. È stato sviluppato un nomogramma utilizzando questi fattori per prevedere la probabilità del numero di mostre, ottenendo risultati con un elevato livello di accuratezza (indice C: 0,99, AUC: 0,923). Tali fattori hanno evidenziato una significativa correlazione ( $>0,7$ ) con il numero di mostre.