Analysis of Museum Digital Transformation and Development Path

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Abstract. In the industry, museums' digital transformation is becoming a prominent topic. Many museums have taken note of and are dedicated to utilizing digital technology for the preservation and exhibition of cultural artifacts in order to investigate new avenues for museums' future growth. This study uses the digitization of museums as the backdrop for its research, employs scientific research techniques—such as a multivariate ordered logistic model and fuzzy comprehensive evaluation—and conducts a thorough analysis of the research data to investigate the effects of digital development on the popularity of museums and their trajectory.

Keywords: museum, digital transformation, development path, logistic model, fuzzy comprehensive evaluation

1 Introduction

With the rapid development of a new generation of digital technology and cluster breakthroughs, digital technology is gradually integrated into the cultural field[1], injecting new vitality into the construction of a strong cultural country. The use of digital technology not only helps to continue the cultural roots[2] and enhance cultural self-awareness, but also promotes the upgrading of the cultural industry[3], improves the level of public cultural services, promotes advanced socialist culture, and further strengthens cultural self-confidence. Through the application of cloud computing, digital twin, blockchain, artificial intelligence, big data, AR/VR/MR, 3D scanning and other advanced technologies in museum exhibitions, we are able to realize a variety of display modes, such as simulation, virtual, no display boards, etc., which bring the audience dynamic, interactive, immersive, experiential and brand new feelings. These technical means combine invisible history with cultural relics and monuments, vividly displaying history, revitalizing the display of cultural relics, and providing new innovative means for museum exhibitions[4]. The term "digital transformation" has different applications and connotations in different fields[5],this paper aims to explore the preferences of the audience groups attracted by the digital transformation of museums, and to explore the public's attitude towards the digital development of museums and its development trend.

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2 Data processing

In order to deeply explore the impact of museums in the era of digitization, this paper takes Nanchang Bayi Memorial Museum as a specific research object. In order to comprehensively collect and analyze the potential factors affecting the development of digitization in this museum, a questionnaire was designed and distributed. In order to ensure the credibility and validity of the questionnaire results, this paper carries out strict quality control. Specifically, the KMO values of each part of the questionnaire reached more than 0.8 and passed the Bartlett's test of sphericity, indicating that the questionnaire data were statistically significant[6]. After data collection and pre-processing these influencing factors were systematically grouped into three categories and organized into Table 1 for further analysis.

Table 1 Outline of questionnaire design.

Outline of questionnaire design	Related content
Basic Information	Demographic information such as gender, age, literacy, etc.
The State of Museum Digitization	Advantages of museum services, current situation and difficulties encountered
Experience and Feedback on Digital Displays	Sensory Experience, Operational Experience
Reflections on development paths	Direction of digitization, enhancement of interaction

3 Model, 1: Logistic modeling to construct digital museum audience demographics

3.1 Problem analysis

Logistic regression, as a generalized linear regression analysis model, has a wide range of applications in many fields such as data mining, automatic disease diagnosis, and economic forecasting. This model is based on a given data set of independent variables and aims to estimate the probability of occurrence of a particular event. Since the output is a probability value, the range of values for the dependent variable is limited to between 0 and 1[7].

In examining the audience groups that visit digitized museums, we hypothesized that people who prefer digitized museums may possess some common characteristics. In order to identify these influencing factors, this paper constructs a logistic regression model for in-depth analysis.

Through in-depth analysis, this chapter will use the logistic model to accurately depict the core audience groups after the digital transformation of museums. Its functional expression is:

$$\ln\left[\frac{p(y \le n)}{1 - p(y \le n)}\right] = \alpha_n + \sum_{m=1}^{k} \beta_m x_m \tag{1.}$$

In this paper, we will comprehensively assess the fit between the potential audience and the target group based on a number of indicators such as age, gender, and literacy. Through the use of this model, the categorization characteristics of mainstream audiences can be more accurately grasped, providing a scientific basis for the subsequent path analysis.

3.2 Variable Assignment

Logistic regression analysis has no specific restrictions on the type of independent variables and can flexibly handle a wide range of data types such as dichotomous, unordered, ordered, and quantitative variables[8]. However, in order to ensure the validity of the analysis, the independent variables must be properly assigned. In practice, different assignment methods for the same data can lead to changes in the estimated values of the parameters, their signs and their interpretations. Therefore, the rationality of the assignment of the independent variables has a crucial impact on the accuracy of the Logistic regression model, and the reference variable assignments are derived from Table 2.

Table 2 Variable Assignment Reference Table.

letter	hidden meaning	quantitative value
y	Implicit variable	y=1 indicates interest in visiting the digitized pavilion; y=0 indicates no interest
x1	Gender	x1=1 for male; x1=0 for female
x2	Age Group	for quantitative variables (years)
x3	Educational Level	X3=1 indicates a university degree or higher, x3=0 indicates less than
X4	Swareness Channel	as a quantitative variable
X5	Visited	X5=1 means visited, x5=0 means not visited

3.3 Parameter Estimation

The estimation of the partial regression coefficients is often done using great likelihood estimation with a sample likelihood function of:

$$L = \prod_{i=1}^{n} p_i^{y_i}(1-p)^{1-y_i} \quad (i = 1,2,\ldots,n) \tag{2}$$

Based on the above rationale, the parameter estimates and hypothesis tests for the final results are shown in Table . The table shows the correlation with y after adjusting for gender, age, literacy and so on. Its logistic regression model can be written as:

$$\text{logit}(P) = 1.56 * \text{Gender} - 0.68*\text{Age Group} + 2.94*\text{Educational Level} - 0.41*\text{Swareness Channel} + 4.54*\text{Visited} \tag{3}$$

The resulting detailed data are shown in table 3 below:

Table 3 Regression results table.

Varible	Partial regression coefficient	Standard error of the partial regression coefficient	P	OR	95%LCI	95%UCL
Gender	1.5671	0.207	0.001***	4.79	3.19	7.19
Age Group	-0.6865	0.102	0.001***	0.50	0.41	0.61
Educational	2.9417	0.237	0.001***	18.95	11.90	30.17
Swareness	-0.4126	0.097	0.001***	0.66	0.55	0.80
Visited	4.5464	0.331	0.001***	94.29	49.28	180.42

3.4 Visualization of data

After in-depth data analysis, a forest plot of the logistic model was used to clearly present the degree of influence of each variable. In the figure 1, the red dashed line serves as a reference to identify the reference point where OR is equal to 1, i.e., the no-effect state. The dots, in turn, represent the estimated values of the OR of each variable, while the horizontal lines connected to them visualize the range of 95% confidence intervals.

This way of presenting the data allows us to visualize the specific effects and statistical significance of the variables on the target variable "Interested in". The influence of "Visited" is particularly prominent, followed by "Education Level". The results of this analysis provide a valuable reference for further understanding and grasping the relationship between the variables and the target variables.

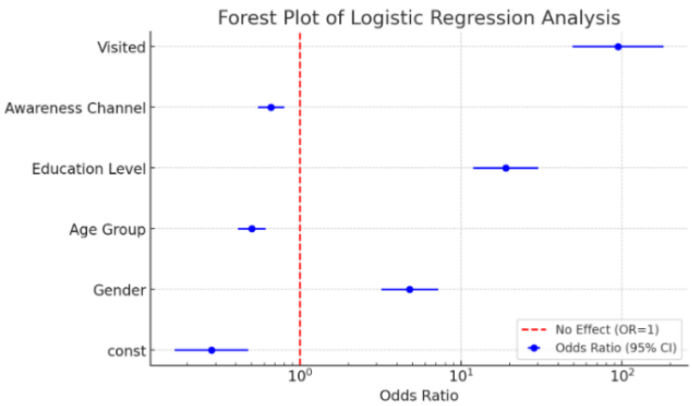

Figure 1 Forest plots for logistic models.

4 Model, 2 Fuzzy Comprehensive Evaluation to Explore the Development Path of Digital Museums

4.1 Principles of Fuzzy Comprehensive Evaluation Method

Fuzzy comprehensive evaluation method is a comprehensive evaluation tool based on fuzzy set theory. The method utilizes the principle of fuzzy relationship synthesis to comprehensively and systematically evaluate the affiliation grade of the evaluated object. It can not only sort and judge according to the synthesized scores, but also carry out precise rating according to the principle of maximum affiliation degree based on the values on the fuzzy evaluation set. The method has clear and systematic results and is suitable for dealing with fuzzy and difficult-to-quantify problems, as well as a variety of non-deterministic problems[9].

During the research process, seven core evaluation indicators were selected, and in order to systematically assess these indicators, they were categorized into three major modules and a second-level comprehensive evaluation model was constructed. Details are shown in the table 4 below:

Table 4 Integrated Assessment Model (IAM) table.

Level 1 indicators	Secondary indicators
Trends in digitization	Enrichment of exhibition digital resources Enhanced maintenance of digital equipment Improve the experience feedback mechanism
Digital Experience	AR Show, Light & Shadow 3D Virtual Reality Applications
Digital Characteristics	Easy and fast access Highly interactive

4.2 Fuzzy Comprehensive Evaluation Model and Steps

4.2.1 Divide the set of factors

First level factor set:

$$U = \{U_1, U_2 U_3\}, \text{and} U = \bigcup_{i=1}^{3} U_i \text{and} U_i \cap U_j = \varphi(i \neq j) \tag{4}$$

Second level factor set:

$$U_1 = \{a_{1,}a_{2,}a_3\} \tag{5}$$

4.2.2 Divide the evaluation set

This paper utilizes questionnaire survey as the main data collection means. In order to ensure the scientificity and accuracy of the scoring criteria, a five-level scale was chosen, including "very satisfied, satisfied, average, dissatisfied, and very dissatisfied". For the seven indicator sets, according to the discussion, the evaluation scores are divided into. For the three indicators at the first level, the evaluation scores are calculated based on the scores at the second level and the corresponding weights.

4.2.3 Creating weight sets

For the three factors at the first level, different weights were assigned to each factor:

$$V = \{V_1, V_2, V_3\}, \text{and} \sum_{i=1}^{3} V_i = 1, V_1 \geq 0, i = 1,2,3 \tag{6}$$

For the seven factors at the second level, different weights were assigned to each factor:

$$X = \{x_1, x_2, x_3\}, \text{and} \sum_{i=1}^{3} x_i = 1, x_i \geq 0, i = 1,2,3 \tag{7}$$

$$Y = \{Y_1, Y_2\}, \text{and} \sum_{i=1}^{2} y_i = 1, y_i \geq 0, i = 1,2 \tag{8}$$

$$Z = \{Z_1, Z_2\}, \text{and} \sum_{i=1}^{2} z_i = 1, z_i \geq 0, i = 1,2 \tag{9}$$

Construct an evaluation matrix for the development pathway from one factor in the factor set alone. GettingS_1, S_2,S_3：

$$S_1 = \{X_1, X_2, X_3\}_{1\times 3} * P_{3\times 5} * Q^T_{1\times 5} \quad (10)$$

$$S_2 = \{y_1, y_2\}_{1\times 2} * P_{2\times 5} * Q^T_{1\times 5} \quad (11)$$

$$S_3 = \{z_1, z_2\}_{1\times 2} * P_{2\times 5} * Q^T_{1\times 5} \quad (12)$$

The propensity score was calculated based on the three scores calculated at the second level:$P = \{V_1, V_2, V_3\}_{1\times 3} * \{S_1, S_2, S_3\}^T_{1\times 3}$,where the P-matrix contains frequency percentage data for the seven indicators on a five-level scale.

4.3 Determination of weights based on hierarchical analysis

4.3.1 Overview of Hierarchical Analysis

Hierarchical analysis is a method used for multi-indicator evaluation and subjective assignment evaluation. It first disassembles the problem into relevant factors and constructs a multilevel structural model. Then, through expert experience or professional judgment, it assesses the relative importance of the lower-level elements relative to the higher-level elements and determines the weight ranking. The method divides the elements into multiple levels, such as objectives, guidelines, and programs, and combines qualitative and quantitative analysis, which is characterized by simplicity and practicality[10]. The following table 5 is the definition of the judgment scale:

Table 5 Definition table for the scale.

scale	hidden meaning
1	Equal importance of the two elements compared to each other
3	Comparison of the two elements, with the former being slightly more important or advantageous than the latter
5	Comparison of the two elements, with the former being more important or advantageous than the latter
7	Comparison of the two elements, with the former being very important or having an advantage over the latter
9	Comparison of the two elements, with the former having absolute importance or advantage over the latter
2, 4, 6, 8	is the intermediate value between the above scales
from the bottom	When two elements are compared, the inverse is used as a scale to describe the importance of the latter in relation to the former.

4.3.2 Define the scale matrix for each factor

According to the weight scaling method in the above table, based on the survey and literature judgment, the corresponding two-by-two relative importance judgment matrix of factors is as follows:

$$A:\begin{bmatrix} 1 & 3 & 5 \\ 1/3 & 1 & 1/3 \\ 1/5 & 1/3 & 1 \end{bmatrix},B:\begin{bmatrix} 1 & 3 \\ 1/3 & 1 \end{bmatrix},C:\begin{bmatrix} 1 & 5 \\ 1/5 & 1 \end{bmatrix},V:\begin{bmatrix} 1 & 5 & 3 \\ 1/5 & 1 & 1/3 \\ 1/3 & 1/3 & 1 \end{bmatrix} \quad (13)$$

4.3.3 Calculate the weights of each factor set

Calculating the product of the elements of each row of the scalar matrix yields the following result.

$$M_i = \prod_{j=1}^{n} V_{ij} (i = 1,2,\dots,n) \tag{14}$$

The nth root of the calculation is computed as follows.

$$w_i = \sqrt[i]{M_i} (i = 1,2,\dots,n) \tag{15}$$

Normalize the vector to get:

$$W_i = \frac{w_i}{\sum_{i=1}^{n} w_i} (i = 1,2,\dots,n) \tag{16}$$

The weight matrix is obtained by rooting the above matrix by rows and normalizing it to get the weights of A, B, C and U. The weight of A X=(0.74,0.14,0.12),the weight of B Y=(0.68,0.32),the weight of C Z=(0.75,0.25),the weight of V U=(0.74,0.12,0.14).

4.4 Calculation of Consumption Propensity Based on Fuzzy Comprehensive Evaluation Method

The A, B and C scores were calculated from the weighting matrix and the evaluation model:$S_1 = X \cdot P \cdot Q^T = 83.03, S_2 = Y \cdot P \cdot Q^T = 80.91, S_3 = Z \cdot P \cdot Q^T = 83.00$,According to the evaluation model, the total score of final consumption tendency is $R = V \cdot (S_1, S_2, S_3) = 82.77$.See table 6 for details:

Table 6 Scoresheet.

	Trends in digitization	Digital Experience	Digital Characteristics	totals
score	83.03	80.91	83.00	82.77

It can be seen that the public has shown a higher degree of concern for the future development trend of digital exhibition halls, especially for the more urgent need to enhance the specific digital functions possessed by digital exhibition halls.

5 Conclusion

By constructing a logistics model, this paper successfully portrays the personality traits of the audience population after the transformation of digital museums. This model can be applied when faced with the need to determine whether a certain group of people is likely to be interested in digital museums, providing a basis for predicting new consumer groups. The analysis shows that the age factor is less influential on audience interest in digital museums, while prior knowledge and experience with digital museums becomes a key influence. This suggests that public interest in digital museums can be effectively enhanced by increasing their publicity.

In addition, through fuzzy comprehensive evaluation, this paper finds that the public shows strong interest in the future development trend of museum digitization, especially in the areas of enriching exhibition digital resources, strengthening the maintenance of digital equipment, and improving the experience feedback mechanism. For those who are not aware of digital museums, they may prefer cooler forms of expression; while for those who have already had some understanding and knowledge, they are more likely to focus on the essential functions and responsibilities of "digitization". This reveals that the appeal of memorial museums still needs to be improved. Although they have expectations of digitization, the current standard of "digitization" is still insufficient to effectively demonstrate its advantages.

The wave of digitization has its roots in the current shift from the interactive Internet (Web 2.0) to the protocol Internet (Web 3.0). This shift is manifested in a number of ways, such as the shift from physical to virtual goods and from physical to virtual tools. Meanwhile, with the rise of emerging technologies such as meta-universe and bitcoin, as well as landmark events such as Apple's launch of Apple Vision Pro, digital transformation has become an inevitable trend in the industry. The irreversibility of the digital wave is further evidenced by the fact that many leading companies are actively seeking to capitalize on the emerging trend. In today's Internet era, although the traditional form of museums may appear to be relatively lagging behind, there is no doubt that through digital transformation, museums have been revitalized and energized to shine brightly once again. This transformation has not only injected new vitality into museums, but also enabled them to continue to carry the important mission of passing on history and culture and promoting the spirit of mankind in a more innovative and attractive way in the context of the new era.

Acknowledgments. The team started from the macro topics of current technological development and finally focused on the digital transformation of museums. In the process, a wealth of experience has been accumulated, and we expect that this study will provide you with valuable references, and at the same time, after that, we will embark on a new journey to continue to pursue the frontiers of science and technology, and strive to achieve higher goals.

References

[1] Russo Spena, T.; Bifulco, F. (Eds.) Digital Transformation in the Cultural Heritage Sector. Challenges to Marketing in the New Digital Era, 1st ed.; Springer: Cham, Switzerland, 2021.

[2] Giannini, T.; Bowen, J.P. (Eds.) Museums and Digital Culture. New Perspectives and Research, 1st ed.; Springer: Cham, Switzerland, 2019.

[3] NESTA & ACE 2019. Digital Culture. 2019. Available online: https://media.nesta.org.uk/documents/Digital-Culture-2019.pdf (accessed on 6 February 2024).

[4] Zuanni, C. Heritage in a digital world. Algorithms, data and future value generation.Limina 2020,3, 236–259.

[5] Vial, G. Understanding digital transformation: A review and a research agenda.J. Strateg. Inf. Syst.2019,28, 118–144.

[6] Field, A. (2000). Discovering Statistics using SPSS for Windows. London – Thousand Oaks – New Delhi: Sage publications.

[7] Dimitris Bertsimas.Angela King."Logistic Regression: From Art to Science."Statist. Sci. 32(3)367 - 384,August 2017.https://doi.org/10.1214/16-STS602.

[8] Hosmer, D. W., Lemeshow, S., & Sturdivant, R. X. (2013). Chapter 10 Binary Logistic Regression. In Companion to BER 642: Advanced Regression Methods. Retrieved from https://bookdown.org/ContentEcon/ber642_advanced_regression_methods/chapter-binary-logistic-regression.html.

[9] Liu, B., & Heath, T. (2022). Research on the Design of Community Museums Based on the Fuzzy Comprehensive Evaluation Method. Sustainability, 14(17), 10802. https://doi.org/10.3390/su141710802.
[10] Suleymanova, S., & Hasanov, F. (2020). Fuzzy Analytic Hierarchy Process-Based Multi-Criteria Decision Making for Universities Ranking. Symmetry, 12(8), 1351. https://doi.org/10.3390/sym12081351.