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Study on The Measurement of Banks' Digital Transformation Level Based on Topsis Comprehensive Evaluation Method - Taking The Middle and Lower Yangtze River Region as An Example

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Abstract. Investigating the digital transformation of banks is essential to fostering regional economic expansion. This serves as the foundation for the bank digital transformation indicators article creates, which includes 15 tertiary indicators and 4 secondary indicators. The bank digital transformation indicators are given indicator weights using the AHP hierarchical analysis method. Finally, utilizing the Topsis complete assessment approach, a comparative study was carried out on the score measurement of banks' digital transformation development level in the middle and lower portions of the Yangtze River. The indicators of asset size, deposit, and loan ratios, and ROE were found to have bigger weights. The digital transformation scores of banks in Jiangxi Province were determined to be the lowest, while those in Shanghai were the highest. This results in suggestions for bolstering bank data governance, expediting digitization, and developing a forward-looking strategy plan.

Keywords: Bank Digital Transformation; Influential Factors; Hierarchical Analysis; Topsis Comprehensive Evaluation Method; Middle and Lower Yangtze River Region.

1. Introduction

As a result of the ongoing advancements in Internet technology, a growing number of banking institutions are now dependent on critical technologies like big data, blockchain, cloud computing, artificial intelligence, and biometrics. The rate at which commercial banks are undergoing this digital transformation has also increased due to the epidemic's pushback on their banking systems. The Party Central Committee has made several new declarations, deployments, and requirements since the 18th Party Congress, as noted by Xi Jinping, who presided over the 34th collective study of the Political Bureau of the Communist Party of China Central Committee. He emphasized the promotion of the industrialization and digitization of industry to better serve and integrate the digital economy into the new development pattern [1]. With an average annual growth rate above 27%, the commercial banks' digital transformation index climbed more than six times between 2010 and 2018, rising from 12.29 to 82.3. The digital transformation of banks has emerged as a significant trend in the growth of domestic commercial banks as a result of the enactment of several national digital transformation policies and the steady maturation of the application of cutting-edge technologies in the financial services industry [2]. The total amount of all bank loans and deposits in local and foreign currencies held by financial institutions in the Yangtze River Economic Zone represented 41.57% of the nation's GDP in 2019, up 0.42 percentage points from 41.15% in 2015. The finance industry has a bigger share in the country [3]. The banks and other financial institutions in the middle and lower sections of the Yangtze River are even more essential to the region's economic development because they are an important part of the Yangtze River Economic Belt. Regional banks do, however, typically face issues including unclear strategy objectives, inadequate investment in talent reserves and science and technology, inadequately rich scene links, and sluggish product iteration. Thus, it is especially crucial to investigate the growth of digital bank transformation and the assessment of development levels in the middle and lower parts of the Yangtze River.

Based on this, this paper first constructs an evaluation model and then uses the hierarchical analysis method to construct the three-level indicators of banks' digital transformation. The hierarchical

analysis method assigns different weights to the indicators of banks' digital transformation, with the ROE, the ratio of deposits and loans, and the factor of asset size being the important influencing factors. The evaluation model comprises 15 indicators, including return on net assets, net capital, and the year-over-year growth rate of operating income. To fulfill the job of advising the government, the entire score of banks' digital transformation in the middle and lower reaches of the Yangtze River is then measured and compared using the Topsis complete evaluation technique.

2. Literature Review

2.1. A Study of Factors Influencing Digital Transformation in Banks

The data of Chinese a-share listed banks from 2011 to 2021 was empirically studied by Yongjie Zhu and Shanyue Jin [4] using fixed-effects regression. They discovered that executives' technological background and innovative spirit play a positive regulatory role in the digital transformation of banks, which is particularly important for investors who have financial stakes in banks. Fuzzy set qualitative comparative analysis (fsQCA) was used by Jos´e Ant´onio Porfírio a, Jos´e Augusto Felício b, and Tiago Carrilho [5] to analyze the perceived impact of digital transformation on the banking industry. They found that managerial competence and flexibility are significant influencing factors, which led to recommendations like enhancing employee skills and stakeholders' digital experience. In addition to examining the possible effects of blockchain technology on the banking sector, Dr. (CA) Subrahmanya Bhat [6] explores the advantages and disadvantages of the digital transformation of the banking business from several angles and offers forecasts and trends for the sector's future in the digital era. Oliver Werth, Christoph Schwarzbach, Davinia Rodríguez Cardona, et al. [7] used the pest model and Porter's five forces to investigate the factors influencing digital transformation in the financial services industry. They discovered that the threat posed by large tech companies entering new markets is the primary driver of digital transformation, indicating that the banking industry is thought to have a greater impact than the insurance industry in terms of social factors and buyer bargaining power.

The competitive relationship between commercial banks and fintech companies is the main market competition factor that determines the digital transformation of China's commercial banks, according to Hui Ailing's [8] empirical analysis of the factors influencing the digital transformation of China's commercial banks. She also made the argument that the organizational change of the digital transformation of commercial banks should be promoted. To examine the influence of digital finance on the digital transformation practices of commercial banks, Dou Xianglong [9] built an empirical model. He discovered that digital finance has a major positive influence and recommended differentiating digital transformation strategies for large and small banks alike. The impact of innovation ecological elements group effect on the quality of digital transformation of commercial banks is investigated by Hao Zheng, Lv Jia, Yang Lei, et al. [10] using fuzzy set qualitative comparative analysis (fsQCA) and necessary condition analysis (NCA). They found that innovative ecological elements synergistically linked to improving the quality of the transformation, and they proposed that small and medium-sized banks can make up for the software facilities through the development of market deficiencies and other reference paths. Wang Ting [11] examines the influence of fintech on the digital transformation of commercial banks using a role mechanism model and benchmark model. She concludes that the influence is significant in advancing the modernization and transformation of commercial banks and offers recommendations for how to improve the quality and efficiency of digital transformation as well as speed up the building of network infrastructure.

2.2. Trends in Digital Transformation of Banks

Based on theoretical research in this area and empirical experience of digital transformation, Lihua Zuo, Jack Strauss, and Lijuan Zuo [12] studied the digital transformation of the Chinese banking industry using the DEA-Malmquist index method and subsequently proposed a path for the digital transformation of banks. To extrapolate to the financial services industry, Timo Cziesla [13]

synthesized previous studies on specific units or industries. He discovered that digital technologies have led to the emergence of new business models, modifications in user-technology interactions, and an increase in the digitization of information. To achieve a strategic positioning in the digital environment, Carmen Cuesta, Macarena Ruesta, and David Tuesta [14] identified three successive phases of the digitalization process in banks: the creation of new channels and products, the adaptation of technological infrastructures, and extensive organizational changes. After researching the digital transformation of commercial banks and the banking sector in Vietnam, Minh Son Ha and Thuy Linh Nguyen [15] concluded that digital banking should be viewed as an essential component of smart cities and that digital transformation is how the banking industry will be able to provide value to its clients and stay up to date with the rapid pace of innovation in these areas.

Through online and offline research on a few domestic commercial banks, Zhao Dandan [16] analyzes the key components of the digital transformation of commercial banks' financial inclusion under the data drive. She then presents policy recommendations for the advancement of China's commercial banks' financial inclusion through digital transformation, with an emphasis on fostering the transformation of digital processes, accelerating the transformation of data applications, and developing digital transformation professionals. In their investigation of the idea of digitization in small and medium-sized banks, Du Erle, Ji Meng, and Yuan Bei [17] offer recommendations for advancing more intelligent financial personalization innovation, creating a contactless financial service model, bolstering the growth of online channels and new customer segments, and creating more efficient and synergistic online and offline services. The index system for bank digital transformation is built by Xie Xuanli and Wang Shihui [18] using the three aspects of strategy, business, and management. They discover that digital transformation may enhance bank performance, fend against the effects of emerging technologies, and encourage channel change. In light of the current financial technology wave, Lu Minfeng and Zhou Junyu [19] explain how digital technology encourages innovation and change in commercial banks. They also offer strategic recommendations for how commercial banks can use digital technology to achieve strategic transformation from the perspectives of talent development, technological reserves, structural reorganization, and scenario innovation.

2.3. Literature Review Commentary

In conclusion, Chinese scholars primarily concentrate on the effects of financial technology and digital finance on the digital transformation of banks, and they provide specific development recommendations for the digital transformation of banks based on research and the concept of digitalization. Foreign scholars, on the other hand, primarily focus on the impact of management ability, science, and technology on the digital transformation of banks, and they predict the trend of in-depth digital development of banks based on the research of local banks. However, research on local areas is lacking, and the data is not timely enough, with most Chinese and foreign scholars concentrating on the overall development of banks' digital transformation. To investigate the digital transformation of banks in the middle and lower parts of the Yangtze River, this research creatively chooses to use data from 2022. To make up for the shortcomings in the previous articles, this paper uses the cascade analysis method to assign weights to the indicators. It then divides the middle and lower reaches of the Yangtze River according to provinces and cities using the Topsis comprehensive evaluation method. Finally, it performs a comparison and measurement analysis of the digital transformation of banks between provinces and cities.

3. Construction of Indicator Weights

3.1. Preliminary Screening of Indicators and Data Sources

As indicated in Table 1, a total of one primary indicator, four secondary indicators, and fifteen tertiary indicators were created for this study by thorough reading of the literature and screening.

Table 1 Indicator Weights Construction Table

Primary Indicators	Secondary Indicators	Tertiary Indicators
Digital transformation of bank	Assets	ROE (%)
		Assets under management (Billion)
		Net risk-weighted assets (Billion)
		Asset-liability ratio (%)
		ROA (%)
	Capitals	Net capital (Billion)
		CAR (%)
		Debt to capital ratio (%)
	Deposits and loans	Loan-deposit ratio (%)
		Total deposits (Billion)
		Total loans (Billion)
	Income	Operating revenue (Billion)
		Year-on-year growth rate of main business revenue (%)
		Interest revenue (Billion)
		Other income (Billion)

All of the above data are from: www.chinamoney.com.cn, www.gzccb.com, bbs.pinggu.org, www.hunan-bank.com, www.z-bank.com, www.crcbbank.com.

3.2. Analytic Hierarchy Process Constructions

A methodical, hierarchical approach to analysis that blends qualitative and quantitative elements is called the Analytic Hierarchy Process (AHP). This method's unique selling point is that it offers a straightforward approach to solving complex problems involving multiple objectives, multiple criteria, or unstructured features. It achieves this by thoroughly examining the characteristics of the complex problems, the factors that influence them, and the inherent relationships between them. The decision-making process is then mathematically solved with a minimal amount of quantitative data.

3.2.1. Construct a Hierarchical Analysis Model

The primary indicator in this paper is the Digital transformation of bank; 15 tertiary indicators, namely ROE, Assets under management, Net risk-weighted asserts, Asset-liability ratio, ROA, Net capital, CAR, Debt to capital ratio, Loan-deposit ratio, Total deposits, Total loans, Operating revenue, Year-on-year growth rate of main business revenue, Interest revenue, other income. The hierarchical model Figure 1 is shown below.

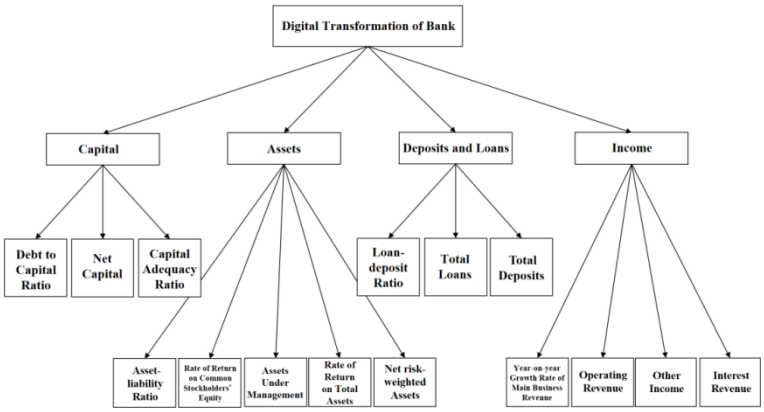

Fig. 1 Hierarchical analysis model diagram

3.2.2. Construct the Judgment Matrix

In AHP, the judgment matrix plays a key computational role. The values of its elements represent the perceived relative importance of different factors, which directly shape the outcome of the decision. Typically, the elements of the judgment matrix are scaled from 1 to 9 and its reciprocal, as shown in Table 2.

Table 2 Judgment Matrix Element Table

Scales	Mseanings
1	Indicates that the two factors are of equal importance compared to each other
3	Indicates that one factor is slightly more important than the other when compared to two factors
5	Indicates that one is significantly more important than the other when comparing two factors
7	Indicates that one factor is more strongly important than the other when compared to two factors
9	Indicates the extreme importance of two factors compared to one over the other
2, 4, 6, 8	Denotes the median of the above two neighboring judgments
Reciprocal	If factor i is compared with factor j to get the judgment Bij, then factor j is compared with factor i to get the judgment Bji=1/Bij.

3.2.3. Hierarchical Single Ordering and Consistency Tests

In AHP, single sorting refers to the order in which the factors at this level are ranked in terms of their importance to a factor at the previous level. This ranking is represented by the eigenvectors of the judgment matrix. For example, for judgment matrix A, the solution vector W of its eigenproblem $AW=\lambda_{max}W$ represents the relative importance ranking weights of the corresponding factors of the same level to a factor of the previous level after normalization, and this process is called hierarchical single sorting.

To ensure the reliability of hierarchical single sorting, the consistency of the judgment matrix needs to be tested, i.e., the random consistency ratio needs to be calculated.

Consistency Indicator:

$$CI=\frac{\lambda_{max}-n}{n-1} \tag{1}$$

λ_{max} is the largest eigenvalue of A. The stochastic consistency indicators are shown in Table 3.

Table 3 Stochastic Consistency Indicators

Order of the judgment matrix n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

Consistency ratio:

$$CR = \frac{CI}{RI} = \frac{\lambda_{max} - n}{RI(n-1)} \tag{2}$$

The results of hierarchical single sorting are considered satisfactory only if CR < 0.1, otherwise the values of the judgment matrix elements need to be adjusted.

3.2.4. Hierarchical Total Ordering and Consistency Tests

Determining the relative importance ranking weights of factors at the same level with respect to the topmost factor is called hierarchical general ranking. This process is performed layer by layer from the top down.

The combined consistency ratio of layer p to the first layer is shown below.

$$CR^{(p)} = CR^{(p)} + \frac{CI^{(p)}}{RI^{(p)}}, p = 3,4, \ldots \tag{3}$$

The results of the hierarchical total ordering are considered to have satisfactory consistency only when CR < 0.1; otherwise, the values of the elements of the judgment matrix need to be readjusted.

For this example, by calculating CR=0.0879<0.1, the hierarchical analysis construction passed the test and the AHP construction was completed.

3.3. Table of Indicator Weights

In this paper, the hierarchical weight table is obtained as shown in Table 4 below.

Table 4 Hierarchical Weight Table

Primary Indicators	Secondary Indicators	Tertiary Indicators	Weight of indicators at three levels
Digital transformation of bank	Assets	ROE	0.2711
		Assets under management	0.1577
		Net risk-weighted asserts	0.0775
		Asset-liability ratio	0.0380
		ROA	0.0221
	Capitals	Net capital	0.0693
		CAR	0.0114
		Debt to capital ratio	0.0281
	Deposits and loans	Loan-deposit ratio	0.1686
		Total deposits	0.0683
		Total loans	0.0277
	Income	Operating revenue	0.0376
		Year-on-year growth rate of main business revenue	0.0037
		Interest revenue	0.0069
		Other income	0.0120

The hierarchy weighting diagram is shown in Figure 2 below.

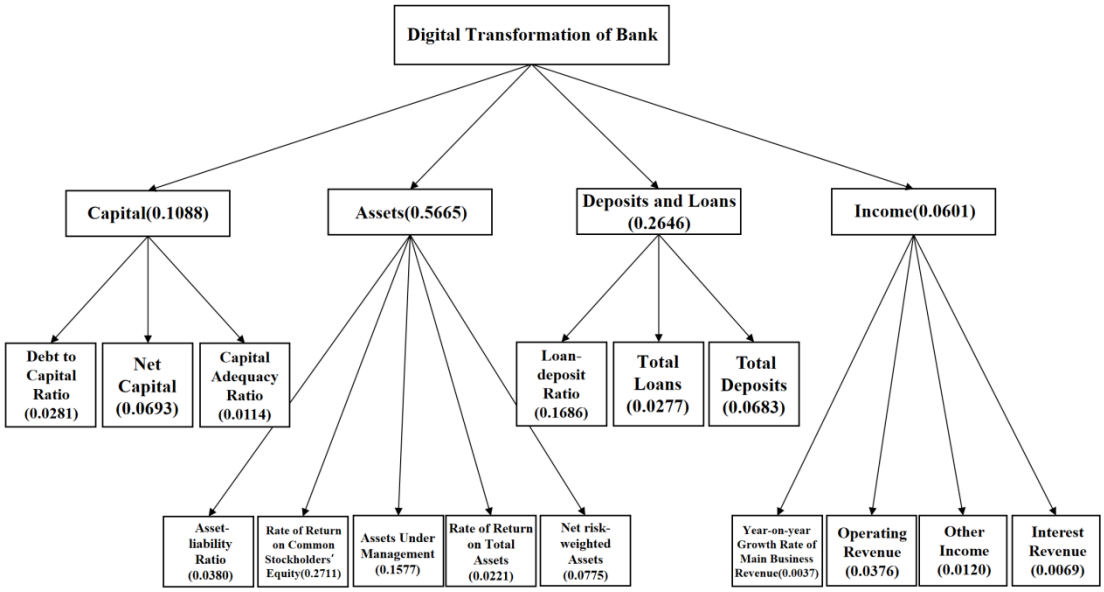

Fig. 2 Diagram of AHP weighting indicators

4. Topsis Comprehensive Evaluation Method

The Topsis method is a popular comprehensive evaluation technique that efficiently makes use of the raw data, can accurately display the differences between the evaluated schemes, and, by ranking the various schemes, can create the best and worst possible solutions for a system made up of all the schemes. Any scheme in the scheme system can have its combined distance from the worst and ideal optimal solutions calculated precisely; the scheme that is closer to the ideal optimal solution and further away from the worst solution is considered to be superior.

4.1. Construct the Decision Matrix

Construct the decision matrix $A=(a_{ij})_{m\times n}$ each column is an evaluation index, and each row is a program to be evaluated; in order to remove the effect of the scale and facilitate comparison, the data need to be decision-making and normalization.

When the data is an extremely large attribute:

$$x^* = \frac{x - \min}{\max - \min} \tag{4}$$

When the data is a very small attribute:

$$x^* = \frac{\max - x}{\max - \min} \tag{5}$$

The normalized data is $B = (b_{ij})_{m\times n}$.

4.2. Weight Allocation of Indicators

Assign different weights to each evaluation indicator depending on the degree of its contribution to the evaluation results.

$$w = [w_1, ..., w_n] \tag{6}$$

Multiplying the jth column of B by its weight w_j yields the canonical matrix with weights $C = (c_{ij})_{m\times n}$.

4.3. Determine Positive and Negative Ideal Solutions

Determine the positive ideal solution C^+ and the negative ideal solution C^-:

$$C^+ = \left[c_1^+, c_2^+, ..., c_n^+\right] \tag{7}$$

$$C^- = \left[c_1^-, c_2^-, ..., c_n^-\right] \tag{8}$$

For positive ideal solutions, the following equation is used for the treatment.

$$c_j^+ = \begin{cases} \max\limits_i c_{ij}, & j \text{ is an extremely large property,} \\ \min\limits_i c_{ij}, j & j \text{ is a very small property,} \end{cases} \qquad j = 1, 2..., n \tag{9}$$

For negative ideal solutions, the following equation is used for the treatment.

$$c_j^- = \begin{cases} \min\limits_i c_{ij} & j \text{ is an extremely large property,} \\ \max\limits_i c_{ij} & j \text{ is a very small property,} \end{cases} \qquad j = 1, 2..., n \tag{10}$$

4.4. Calculate the Distance to the Positive and Negative Ideal Solutions for Each Program to be Evaluated

The distance from alternative a_i to the positive ideal solution:

$$d_i^* = \sqrt{\sum_{j=1}^{n} (c_{ij} - c_j^+)^2}, i = 1, 2, ..., m \tag{11}$$

The distance from alternative a_i to the negative ideal solution:

$$d_i^0 = \sqrt{\sum_{j=1}^{n} (c_{ij} - c_j^-)^2}, i = 1, 2, ..., m \tag{12}$$

4.5. Calculate the Relative Progress of Each Program to be Evaluated

Calculate the relative posting schedule (evaluation reference value) for each program to be evaluated.

$$f_i = \frac{d_i^0}{d_i^0 + d_i^*}, \quad i = 1, ..., m \tag{13}$$

Then f_i is ranked from largest to smallest to get the priority order of the alternatives.

(14)

4.6. Weight Analysis of the Topsis Integrated Evaluation Method

The software Python 3.7.3 and the previously mentioned formulae are utilized in this paper to build a model that determines the comprehensive assessment scores of banks' digital transformation in every province and city in the middle and lower reaches of the Yangtze River. Table 5 below displays the banks' digital transformation evaluation scores.

Table 5 Bank Digital Transformation Evaluation Scores Table

Province (city)	Scores
Zhejiang Province	0.6408
Jiangsu Province	0.6146
Shanghai	0.8062
Hunan Province	0.4948
Hubei Province	0.3172
Jiangxi Province	0.0842
Anhui Province	0.4971

5. Conclusions

(1) The bank with the highest digital transformation score score is Shanghai, with a score of 0.8062. Shanghai Municipal Bank topped the list in nine key indicators, including asset size, weighted net risk assets, and net capital, demonstrating its strong overall strength. At the same time, the excellent performance of the deposit and loan category indicators and the income category indicators strongly contributed to the rapid development of Shanghai Bank's digital transformation.

The fact that Shanghai banks have achieved such remarkable results in digital transformation is attributed to their comprehensive and in-depth application and flexible use of digital technology [20]. By comprehensively deepening the application of digital innovation, strengthening data-driven and intelligent upgrading, and continuously improving service quality and efficiency, Shanghai banks have injected a strong impetus into developing their digital transformation.

(2) The digital transformation scores of banks in Zhejiang and Jiangsu provinces ranked better, at 0.6146 and 0.6146 respectively.

Zhejiang Province performs well in ROE, ROA, CAR, and other asset and capital indicators; Jiangsu Province ranks first in ROE and ROA, and also performs well in asset and capital indicators. It is found that the asset and capital indicators drive the digital transformation of banks in Zhejiang and Jiangsu provinces to achieve better development.

In addition, the forward-looking strategic layout of banks in the two provinces has helped the development of digital transformation. The “14th Five-Year” financial development plan released by Jiangsu Province, is put forward to strengthen the policy support and guarantee for the science and technology financial system [21]. Banks in both provinces have made “intelligence” one of the core elements of their development strategies, which helps to promote the digital transformation of the banking business.

(3) The digital transformation scores of banks in Hubei, Hunan and Anhui provinces are poorer, at 0.3172, 0.4948 and 0.4971, respectively.

The asset-liability ratio and debt-to-capital ratio indicators of Hubei banks are at the top of the list, reflecting that the enterprises are facing greater debt-servicing pressure and financial risk; Hunan banks are in a disadvantageous position in the indicators of deposits and loans and income; and Anhui banks are in a disadvantageous position in the indicators of asset-liability ratio and debt to capital ratio, although they are both ranked last. liability ratio and debt to capital ratio indicators, although both ranked last, but deposits loans, and income indicators are in a disadvantageous position. The poor performance of all three provinces in the deposit loans and income indicators reflects the important role of deposit loans and income in the digital transformation of banks.

Hubei province banks perform better in retail business customer acquisition channels, risk control decisions, and customer service [22]. Still, data quality issues and organizational restructuring are difficult to affect the effectiveness and efficiency of the digital transformation of Hubei province banks, restricting the development of Hubei province banks [23]. Banks in Hunan Province perform better in optimizing IT architecture [24], but insufficient awareness of risk prevention restricts the pace of innovation in the digital transformation of banks in Hunan Province. Anhui province has a better risk control mechanism for assets and capital. Still, insufficient reference to developed provinces leads to gaps in transformation strategies and technology selection in the process of digital transformation in Anhui province.

(4) The lowest ranked bank digital transformation score is in Jiangxi Province with only 0.0842 points.

LDK banks ranked at the bottom of the core evaluation indicators in the categories of bank assets, deposits and loans, and income, which is a key factor contributing to LDK banks' poor performance in the digital transformation score.

The main source of profitability for banks in Jiangxi Province still relies heavily on the spreads generated by attracting deposits and granting loans. However, under the wave of the Internet era, online financial business platforms have become more convenient and efficient to conduct business, and the traditional business model of banks in Jiangxi Province is facing unprecedented challenges and threats [25].

6. Suggestions

6.1. Enhance Data Governance in Banks

Based on the study's findings and the data quality issues facing Hubei banks, it is advised that the banks enhance their data systems even more, create a thorough data structure that includes customer, business, and risk data, and achieve comprehensive coverage of a variety of data types. In addition, make full use of data analysis technology, expand your understanding of the deposit and loan industry, conduct a thorough investigation of the company to identify potential growth areas and risk areas, and establish a solid foundation for business decision-making. Furthermore, it guarantees the completeness and accuracy of the data and reinforces the management and oversight of the data quality to give the bank's loan and deposit operations more dependable data protection, which in turn improves the bank's overall competitiveness and risk management capacity.

6.2. Create a Forward-looking Strategic Layout

According to this paper, banks in Zhejiang and Jiangsu provinces have successfully embraced the digital transformation of their operations, whereas banks in Anhui province have not developed such strategies. As a result, it is advised that banks in the province of Anhui should make clear the strategic goals of digital transformation, create detailed plans for this process based on the government's "14th Five-Year Plan" and other policy documents, and prioritize collaborative efforts with a variety of partners. These plans should cover technology selection, system building, and talent development. Additionally, by cooperating with fintech startups and Internet industries, banks can get more technological resources and market channels to speed the process of digital transformation. Banks can simultaneously build strong cooperative ties with businesses farther up and downstream in the supply chain to work together to advance innovation and improve financial services.

6.3. Enhance Fintech Enablement

It is advised that enhancing technological empowerment serves as the driving force behind the digital transformation of banks, given the deficiencies in Anhui Province's technology offerings. First, by introducing cutting-edge digital technologies that are deeply integrated into the bank's deposit and loan business system, like big data, blockchain, artificial intelligence, and cloud computing, to improve business operation efficiency and fortify risk management capabilities. Second, to

effectively overcome the time and space constraints of traditional banking business, we have launched a variety of digital financial products, including but not limited to cutting-edge services like online loans and online deposits. This has allowed the bank to increase its customer base and greatly enhance customer satisfaction. To further improve our service efficiency and successfully lower our operating costs, we have also improved our digital service experience by consistently streamlining our online service channels to offer more practical and effective deposit and loan services, such as real-time loan application approval and prompt fund disbursement.

6.4. Build a Digital Integrated Scene

It is suggested to use cutting-edge network thinking and technological innovation to improve the operation model of traditional commercial banks, strengthen cooperation and communication with various platforms, and build an innovative and open network platform in response to the issue of banks in Jiangxi Province relying on traditional business models [25]. This platform is available to a broad spectrum of client groups and will feature an extensive display of our full-platform goods and services. A natural fusion of goods, clients, and enterprises to create a comprehensive financial services ecosystem. We will achieve the successful integration of scenario resources and establish a new comprehensive account system by collaborating with big online platforms, life insurance, and other service-oriented businesses that have extensive experience in scenarios. This will improve efficiency and simplify and expedite business processes.

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