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Research Article

Analysis of Challenges and Strategies to Develop More Effective Early Warning System of Bank Bankruptcy

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Abstract:
Banks play an important role in the country's macroeconomics, they have a special importance in the economic pillars of the country, instability in macroeconomic policies, both in the supervision sector and in the real and financial sectors, makes banks as the last buffer against these shocks. Therefore, it is necessary to have an efficient warning system by benefiting from special economic forecasting tools in order to prevent their bankruptcy; This research tries to analyze the challenges and strategies of more effective development of the rapid warning system of banks' bankruptcy so that it can identify the existing obstacles and adopt appropriate approaches. The current research follows the post-positivist paradigm and in terms of its purpose, it is applied research, the results of which have been analyzed based on grounded theory. In the category of Early Warning System (EWS) development for bankruptcy, 11 main criteria and their various considerations were extracted; 10 key challenges and current problems and limitations were introduced and about 80 approaches and strategies were introduced for these 10 challenges, finally 13 main approaches were proposed to make the development of the banking bankruptcy warning system more effective.
Keywords: Early Warning System, Bank Bankruptcy, Data Quality and Availability, Machine Learning Models.

Introduction:

In the past decades, a large number of financial crises have occurred in various economic sectors of countries, which often had devastating economic, social and political consequences. These crises are not limited to the economy of one country, but also spread to the economy of other countries. As a result, international organizations and private sector institutions began to research and develop and provide Early Warning System (EWS), which are designed with the aim of predicting the occurrence of financial crises in different countries. This model was presented for the first time by Kaminsky et al. (1998) for the currency crisis, and after that, academicians and various institutions of the private sector in recent years presented early warning system models in other economic sectors as well (Kelman and Glantz, 2014).

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Empirical evidence shows that the banking crisis is one of the main causes of economic crises. Banks, like any economic enterprise, can face the problem of bankruptcy individually or as a group; But it should be kept in mind that the effect of bank bankruptcy goes far beyond the bankruptcy of commercial enterprises (Iturriaga and Sanz, 2015). On the one hand, shareholders will lose their capital, and on the other hand, depositors will lose their savings. Usually, such crises in the banking sector, similar to what happened in 2007-2008 in America, begin with the appearance of a problem in one or more banks, and with its rapid spread to other banks and affecting the financial markets, the entire economy is quickly affected. It affects Banking crises are accompanied by a decrease in trust in the performance of domestic financial institutions and cause a decrease in domestic savings and a large increase in capital outflows. Innovations and deregulation in the banking sector have made banking operations more complicated and riskier than in the past. This issue has created challenges for the bank performance monitoring department (Keshavarz Haddadha et al., 2023).
In response to this issue, banking supervisors have also developed new methods and tools for monitoring and evaluating banks. More attention in this field is to improve the quality of tests and develop systems that can help observers and identify major changes (Altman & Vosk, 2015).
The recent crises of the 2011s in the financial and banking system and the instabilities in the macroeconomic conditions have made it important to develop a comprehensive document for the banking early warning system (BEWS) for monetary and banking policymakers. The bankruptcy of some financial institutions and the merger of other institutions that have been exposed to bankruptcy have made the policy makers of the central bank and its non-attendance monitoring department focus more on the financial health of monetary and credit institutions. Iran's economy is bank-oriented, so that the share of banks in financing was equal to 91.3% in 2011, which reached 89.2% in 2013. While the share of the capital market in the total financing of projects in 2011 was equal to 6.2%, in 2012 it was about 9.5% and in 2013 it was equal to 7.6%. On the other hand, the country's banking network has faced the growth and expansion of private banks, authorized and unauthorized credit institutions in the last two decades. Also, in the last decade, the competition of banks has increased with each other to maintain market share, and due to the central role of the country's banking network in financing the production sector, any disruption in its performance will have an effect on the production sector and, consequently, on other macroeconomic variables. Because based on international experience, the cost of bank bankruptcy is very high if it occurs; It is important to identify important factors that have the power to distinguish between bankrupt and healthy banks in the country's banking network, as well as to design a model that has the power to predict bankruptcy in the country's banking network (Salehi-Isfahani, 2011; Kokabisaghi, 2018).
Although in recent years, the supervisory body and the monetary and banking research institute have designed some statistical and analytical models to predict the financial health of banks, but from the legal point of view, the institutional requirements of this research for implementation in the country's financial institutions have not yet been clarified. The lack of a proper system for monitoring the financial health of the country's banks in recent years has caused severe fluctuations in the financial health rating of the country's banks and ultimately reduced the well-being of all their beneficiaries, including borrowers, shareholders and depositors.

The existence of a supervisory and financial monitoring system that has the ability to be influenced by external shocks and to quantify them, is necessary to monitor the situation and improve the country's economy. In this system, in addition to examining the bank's financial health status with retrospective information, attention should also be paid to predicting the future situation and the possibility of deterioration of the bank's financial health status (Khoshnoud & Bultez, 2014).

Basically, whenever the depositors of a commercial bank lose their trust in that bank and a significant part of them turn to withdraw their deposits, because a large percentage of these deposits are allocated to giving credits and loans, and the bank is not able to respond to the requests; Such a situation is called "bank attacks" that may lead to the bankruptcy of banks (Claessens and Kose, 2013).

If bank raids happen widely, it is called "banking crisis" or "banking chaos". Whenever such a situation spreads from one bank to other banks, it is called "systematic banking crisis" or "systematic banking disorder" (Claessens & Kose, 2013).

In addition to this, the conditions in which the crowd of banks is not widespread, but the access of banks to funds is not convenient and there is basically no desire to give credit, is called "credit drought."

In this research, an attempt has been made to discuss and exchange opinions on the quick warning system of banks' bankruptcy from the perspective of experts with approaches to problems and challenges, solutions to make these systems more effective, examination of obstacles and possible implementation problems, and presentation of implementation strategies.

Literature Review

In examining the theoretical foundations, attention has been paid to the concepts that show the indicators of bank crisis prediction and the threshold of bankruptcy. Therefore, at the beginning, it is necessary to explain some terms; Terms such as "bankruptcy", "bank stoppage", "bank failure". The term "bankruptcy" refers to a legal process that occurs when an individual, business, or organization is unable to meet its financial obligations and seeks formal relief from its debts through a legal proceeding (Laitinen et al., 2000; Sami, 2014). Bankruptcy involves the distribution of assets, the discharge of certain debts, and the resolution of financial difficulties in a structured and regulated manner. It is an important concept in both law and finance, with significant implications for debtors, creditors, and the broader economy. White (2007) discusses the economic consequences of bankruptcy in the United States and provides insights into how bankruptcy affects debtors, creditors, and the overall economy. Agarwal et al. (2011) in research entitled “Consumer Bankruptcy and Default: The Role of Individual Social Capital" explores the relationship between consumer bankruptcy and individual social capital, shedding light on the decision-making process of individuals facing financial distress.

A closer examination of the concept of bankruptcy shows that bankruptcy is actually a special situation of the "stop" event. Comparing the definitions of the term "bankruptcy" with "bankruptcy" shows that these two words have similar meanings in the mind of the users. This is while different sources have deeply emphasized their distinction. In fact, the differences between the two phenomena of suspension and bankruptcy are summarized as follows: (1) Suspension can be temporary, (2) Bankruptcy is a legal solution for a deadlock situation, but such a situation may also be possible if the deadlock situation can be overcome through a precise economic and financial plan or through the provision of external resources, (3) Bankruptcy can be the last step in the process of resolving the issue of suspension and it is related to the conditions that there is no other option for the issue of suspension.

The reasons for the importance of bank bankruptcy compared to other commercial institutions

Banks, because of the special role they play in the macro economy, and also because they provide a unique set of financial and credit services, for example, they make long-term loans while

guaranteeing that they will repay their debts. pay in cash, they pay attention to strict regulations. But despite this special regulation, banks still face problems. The reasons for this importance are as follows:

1- As mentioned, the bankruptcy of a bank can lead to people's trust in other banks or even the entire banking system of the country being distorted or taken away, and this in turn will lead to people going to the bank to receive their deposits. Banks should refer. This phenomenon, which is referred to as an invasion of banks, causes banks to face an unexpected volume of requests to receive deposits, and it is very likely that banks will not be able to respond to these requests. Therefore, the bankruptcy of one bank will lead to the bankruptcy of other banks and finally, create systemic risk.

2- Considering the extent of banks' activities and the important contribution they have in the economy, the bankruptcy of a number of banks and sometimes even the bankruptcy of one bank can lead to the loss of financial stability in the country.

3- Banks are the main actors of the payment system in the country. In such a situation, their bankruptcy can lead to disruption of the payment system in the country.

4- Bankruptcy can lead to unforeseen social and political consequences in the country. Considering all these factors, in most legal systems, special rules and regulations have been considered for bank bankruptcy, which are different from the rules and regulations governing the activities of commercial companies. This distinction is manifested in relation to the definition of bank bankruptcy, the bankruptcy authority and the restructuring methods of bankrupt banks.

The importance of EWS

In the last 25 years, many countries with advanced economies have experienced serious crises in their banking sector. In 2004, the Basel Committee, in examining bank failures in eight countries (Germany, Japan, Norway, Spain, Sweden, Switzerland, Great Britain and the United States of America), observed the following common trends:

Credit risk, especially in real estate loans, led to broader banking problems in the banking sector in Switzerland, Spain, Great Britain, Norway, Sweden, Japan, and the United States of America. Also, market risk led to the first phase of the United States savings and loan crisis. Economic liberalization (deregulation) has been one of the common features of major banking crises, which have often been associated with regulatory systems lacking sufficient preparation for changes; Credit concentration risk, usually the real estate sector, has been observed in 9 out of 13 banking crises. The level of the crisis had wide differences. In Switzerland, the United Kingdom, and more recently in the United States, only small banks were affected by the crises. In Spain, Norway, Sweden, Japan and the United States of America in the 1980s, the entire banking system was affected by this crisis. In most of the cases where large-scale crises were created, there was a need for some kind of government support, sometimes, this government support involved large sums of money. In all the cases where there was a need for large amounts of government support, the crisis was caused by credit risk problems. Most countries initiated regulatory and regulatory changes after the crises, with the exception of the UK, which did so after the crisis of small banks.

Instability in macroeconomic policies, both in the supervision sector and in the real and financial sectors, makes banks act as the last shock absorbers. In this regard, it can be argued that a change in the asset portfolio of the country's banking network is considered a positive event in terms of financial health if it is to achieve a better position in increasing profitability, but this type of transfer in assets or liabilities if it is not a positive phenomenon if it is forced or imposed by existing

economic conditions. Therefore, banking supervisors need forward-looking tools to improve banking supervision to respond to the challenges that arise in macroeconomic conditions. The need to pay attention to the recent state of the banking network and the instabilities in the macroeconomic conditions, it seems necessary to compile a quick warning system document to estimate the probability of downgrading and estimate the time of bankruptcy for the country's banking network. According to the type of methodology used in this document and the results obtained, policy recommendations are made by taking into account the change in the state of financial health of banks, such as the optimal time to increase capital, reserve banks, contrary to the conditions of recession and economic prosperity, and how to smooth the income of banks.

Early warning systems operated in developed countries, considering the importance of the subject, the theoretical framework of rapid warning systems can be different with the influence of the structural and economic conditions of the countries. This framework mainly consists of two steps, using a suitable statistical model and finally predicting the bank's rating or reducing the bank's rating. Countries with advanced economies have also used these systems to design their rating system and have used well-known statistical models in this connection. Supervisory rating helps to identify banks that need special supervision. In this type of evaluation, the performance of the bank is evaluated on a comparative basis and the problematic bank is identified. In this type of system, the audited financial statement is used and this type of assessment considers the change in the financial situation and is more focused on the assessment of banks at risk. This system requires reliable information and is suitable for evaluating the existing situation. Mostly, the model used to rate banks is the Camels rating, and countries such as America, France, and Italy use this method as a first step to identify banks at risk (Ben Lahouel et al., 2022; Sahajwala & Van den Bergh, 2000).

The financial crisis of 2008 has created a potential and numerous capacities to design a rapid warning system of warning signs and the remarkable stability of these warning signs among sample countries including developed, emerging, and developing countries from 1950 to 2011 for 60 years and various banking, currency, debt, stock and inflation crises have been published in 83 studies (Frankel & Saravelos, 2012). There are many evidences that foreign exchange reserves and exchange rates have been surprising in predicting crises (Christofides et al., 2016). The approach of the early warning system mainly monitors the daily financial markets against abnormal movements and the hypothesis of the development of crises that the financial crisis is often caused by the mass behavior of investors (Ahn et al., 2011).

The history of early warning systems (EWS)

The history of the early warning system of bank bankruptcy can be traced back to the 1970s, when researchers started to apply statistical and econometric techniques to analyze the financial performance and condition of banks, and to identify the factors that influence their solvency and viability.

One of the earliest and most influential studies on bank failure prediction was done by Altman et al. (2017), who developed a multivariate discriminant analysis model based on five financial ratios to distinguish between failed and non-failed banks in the United States. Their model achieved an accuracy rate of over 90% in predicting bank failures one year before they occurred. Their study also introduced the concept of Z-score, which measures the distance of a bank from insolvency, and is widely used as an indicator of bank soundness (Liu et al., 2021).

Another seminal study on bank failure prediction was done by Reinhart, who proposed a composite index of leading indicators of banking crises, based on macroeconomic, financial, and external variables. Their index was able to signal banking crises in advance in 76% of the cases, with an average lead time of 19 months. Their study also showed that banking crises are often preceded by currency crises, and that both types of crises are associated with deteriorating economic conditions (Reinhart, 2022).

Since then, many studies have followed and improved upon these pioneering works, using different methods, data, variables, and criteria to develop early warning systems for bank failures. Some of the common methods include financial ratios analysis, logit or probit models, neural networks, support vector machines, system dynamics simulation, and machine learning algorithms. Some of the common variables include capital adequacy, asset quality, profitability, liquidity, efficiency, solvency, macroeconomic factors, market conditions, and regulatory variables. Some of the common criteria include bankruptcy declaration, regulatory intervention, merger or acquisition, negative net worth, or low Z-score.

The history of early warning systems for predicting bank bankruptcy dates back several decades, and it has evolved significantly over time. Early warning systems are designed to identify signs of financial distress in banks so that corrective actions can be taken to prevent bankruptcy or mitigate its effects. Below is a brief overview of the history of EWS for bank bankruptcy, along with some academic references:

1st-1980s: Early Model

The earliest EWS focused on simple financial ratios and indicators, such as capital adequacy, asset quality, and profitability. These models aimed to identify banks with deteriorating financial health (Altman, 1968).

2nd-1990s: Emergence of Statistical Models

The 1990s saw the development of statistical models, including logistic regression and neural networks, to enhance the accuracy of predicting bank failures (Merton, 1977).

3rd-2000s: Incorporating Macroeconomic Factors

Researchers began to incorporate macroeconomic variables, such as interest rates and GDP growth, into EWS models to account for the broader economic context (Demirgüç-Kunt & Huizinga, 2004).

4th-Post-2008 Financial Crisis: Enhanced Risk Assessment

The global financial crisis of 2008 highlighted the need for more sophisticated EWS that could capture systemic risks and interdependencies among financial institutions (Acharya, 2009).

5th- Current Trends: Machine Learning and Big Data

In recent years, machine learning techniques and big data analytics have gained prominence in EWS for bank bankruptcy. These models can process vast amounts of data and detect early warning signals more effectively (Guerra & Castelli, 2021).

It's important to note that regulatory authorities, such as the Basel Committee on Banking Supervision, have also played a role in shaping EWS by issuing guidelines on stress testing and risk assessment for banks (Basel Committee, 2013; Durango-Gutiérrez et al., 2023).

In 1980, the American regulatory department introduced the first rating system to the face-to-face regulatory body through the use of the complete rating system. This led to the introduction of a similar bank rating method in the United States. This rating method is used by three regulatory bodies, the Federal Reserve, the Office of the Comptroller of the Currency and the Federal Deposit Insurance Corporation. Under this system, each bank is evaluated by 5 criteria. These elements include capital adequacy, management quality, asset quality, profitability and liquidity, and evaluate the financial performance of banks and their health. The design of the early warning system in

different countries is as much as the internal and external monitoring department, the control mechanism, and the reporting method. and audit, information sources and financial statement data of banks depend (Sahajwala & Van den Bergh, 2000).

In general, the supervisory systems that are currently used in most developed countries use four methods to monitor the performance of banks, which are: the supervisory rating system of banks, the financial ratios analysis system, the comprehensive risk assessment system and statistical modeling. France, external banking supervision rating system, early warning-expected loss models have been experienced in 1997. Also in Germany, similar group analysis system and financial ratio have been implemented in 1997. In Italy, these two systems have also been experienced. External banking supervision rating system in 1993 and early warning models - bankruptcy and bankruptcy time prediction that are currently being implemented. In the Netherlands, the comprehensive banking risk assessment system in 1999 and the system of analysis of the matched group and financial ratio that are currently being implemented have been experienced (See Table 1).
Based on the studies of Ahmadian and Heydari from Central Bank Monetary and Banking Research Institute (Ahmadian & Heydari, 2016), the monitoring systems currently used in most developed countries are described in Table 1.

Samitas et al. (2020) studied early warning systems by investigating potential risks of contagion, based on structured financial networks, and improving the performance of early warning indicators of standard crisis forecasting models using network analysis and algorithms. Machine learning was tested. The research results show that this model provides significant information to policy makers and investors regarding the use of the financial network as a useful tool to improve portfolio selection by targeting assets based on centrality.

Casabianca et al. (2019) proposed an early warning system with the aim of paying attention again to currency and credit fluctuations, financial crises and policy responses. This system is based on identifying the macroeconomic drivers of banking crises, and going beyond the use of traditional discrete choice models by using supervised machine learning, and finally evaluating the exposure of countries to systemic risks by means of predicted probabilities. They warn against the possible creation of macroeconomic imbalance before the crisis.

Filippopoulou et al. (2020) investigates a multivariate logit early warning model (EWM) for systemic banking crises with the aim of assessing the predictive validity of the risk indicators available in the MPDB, as well as other variables not used in previous relevant studies. The main finding of this research shows that the mentioned model is also significant for important indicators of financial stress such as CLIFS and SovCISS and economic expectations. The model is robust to different specifications and performs better when post-crisis observations are not included.

Padhan & Prabheesh (2019) proposed a new agenda for building early warning models in order to increase their effectiveness in predicting financial crises. The main objective of the new agenda is to eradicate the weaknesses of existing EWMs, as their failure to predict the 2007-2008 global financial crisis shows the need to improve their efficiency. The new agenda includes three main functional areas: 1) accurate measurement of a financial crisis, 2) implementation of a fourth-generation crisis model to understand the dynamic nature of financial crisis, and 3) inclusion of contagion/contagion variables as explanatory variables for the financial crisis.

Wang et al. (2020) establishes an integrated early warning system that detects and predicts stock market turbulence. Based on switching ARCH (SWARCH) high volatility regime filter probabilities, the proposed EWS has first classified stock market crises according to an indicator function with thresholds dynamically selected by the double peak method. The results of the research have shown that the stability and practical value of the model in real-time decision-making is also proven by cross-validation, back-testing and reality check.

Table 1. Early warning and assessment systems in developed countries

Country	Supervisory authority	System	Year	Type of System
France	Banking Committee	ORAP (Organization and Reinforcement of Preventive Action)	1997	Banking external supervision rating system
		SAABA (Support System for Banking Analysis)	1997	Early warning models - expected loss
Germany	Federal regulatory office	BAKIS (BAKred Information System)	1997	Similar group analysis system and financial ratio
Italy	Bank of Italy	PATROL	1993	Banking external supervision rating system
		Early Warning System	In progress	Bankruptcy early warning models and bankruptcy time prediction
Netherlands	Bank of Netherlands	RAST (Risk Analysis Support Tool)	1999	Comprehensive banking risk assessment system
		Observation system	In progress	Similar group analysis system and financial ratio
England	Financial services authority	RATE (Risk Assessment, Tools of Supervision and Evaluation)	1998	Comprehensive banking risk assessment system
	Bank of England	TRAM (Trigger Ratio Adjustment Mechanism)	1995	Warning models
America	Federal Reserve System	SEER Rating (System for Estimating Exam Ratings)	1993	Rapid warning models - rank estimation
		SEER Risk Rank	1993	Early warning models - bankruptcy estimation
	FDIC (Office of the Comptroller of the Currency)	GMS – Growth Monitoring System	1990	Early warning model - tracking high growth banks
		SCOR (Statistical CAMELS Off-site Rating)	1995	Quick Alert Model - Downgrade System
	OCC (Federal Deposit Insurance Corporation)	Bank Calculator	In progress	Early warning model - Bankruptcy prediction

Barrell et al. (2010) point out that early warning systems for banking crises typically exclude bank capital, bank liquidity, and property prices. Most of the work on EWS concerns global samples dominated by emerging market crises, where time series data on bank capital adequacy and property prices are usually lacking. Berle et al. have estimated logit crisis models for OECD countries, finding strong effects of capital adequacy and liquidity ratios as well as real estate prices, and can exclude traditional variables.

Materials and Methods

The present research follows the paradigm of post-affirmation. In this paradigm, by focusing on the dynamic, multiple and real reality and accepting the principle of falsifiability and the impossibility of obtaining evidence, it is emphasized on the explanation of the phenomenon or event in a probable and non-deterministic way. The current research is applied research in terms of its purpose. In terms of its nature, it is of a qualitative type and it decides to analyze and analyze qualitative data. Qualitative research is any type of research that produces findings that were not obtained by resorting to statistical operations or other counting methods (Green, 2001). The main part of analysis in qualitative research is interpretive (Cooper et al., 2012) qualitative analysis is a completely different way of thinking about information data. Qualitative methods mainly refer to matters such as collection, analysis, interpretation and presentation of verbal, verbal and qualitative information and data. The current research was carried out based on a multi-stage design including the following:

a) In the first stage, all primary data, concepts, hypotheses, and descriptive theories related to the research topic regarding bank bankruptcy warning systems were examined, the most important of which were summarized in the introduction and theoretical literature of the research.

b) In the second stage, all the important texts (related to the topic of research regarding bank bankruptcy warning systems, existing common systems, background of related researches) were examined, and the most important issues were summarized in the research background section.

c) Then, three people who had several years of experience in the management of banks, were members of the board of directors and senior managers were selected to conduct exploratory interviews and exploratory interviews were conducted with these people. The interview was done in a semi-structured way.

d) At this stage, the interviews with banking experts were conducted in a semi-structured way until the researchers were convinced that opinions with importance for confirming or rejecting the bankruptcy predictor indicators from a new person will not be presented.

e) In this stage, the implementation of interviews was carried out and measures were taken to extract the desired indicators such as criteria, sub-criteria, problems and classification of problems related to the bank bankruptcy warning system.

It is necessary to mention that the main method of data collection in the current research is "semi-structured interview" (McIntosh & Morse, 2015). The use of semi-open interview creates enough flexibility for talking to different respondents who can cover similar areas of data collection. The methodology of the research methodologist is presented in Fig. 1.

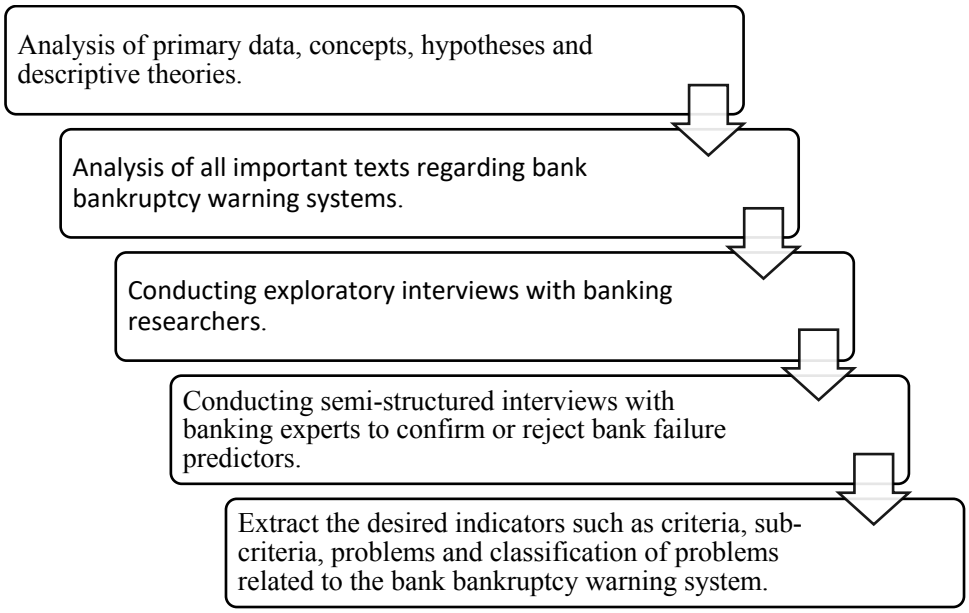

Figure 1. Research methodology framework

Research strategy

The qualitative research method is based on grounded theory; Through grounded theory, theorizing is formed based on the main concepts obtained from the data in the field. This kind of theorizing is based on the collage metaphor and is like a decision-making trash can model, which is created from the random intersection of components and, of course, with the artistry of the theoretician. In other words, the ground-based theorist walks in a land consisting of numerous and diverse scattered data and combines them in order to achieve new theories with artistic performance. Creativity is one of the important components of grounded theory (Khan, 2014).

The procedures of this method force the researcher to break the assumptions and create a new order from the old elements. Since grounded theory identifies the main concerns and worries of the participants and states how this concern can be solved by them, instead of using data to test the theory, the data is used to create the theory. This method includes coherent actions that lead to the emergence of conceptual categories. Because in this research, multiple and scattered data of different qualitative types and structures, including criteria, sub-criteria, major problems and minor problems related to them and finally a guide to solve them regarding the banking bankruptcy warning system, are examined and analyzed. was placed, grounded theory was used to achieve accurate and new analysis with applied strategies (Backman & Kyngäs, 1999).

Society and statistical sample

The statistical population is the working managers of the country's banks, the members of the board of directors and the senior managers of the bank, the members of the scientific faculty of the universities and the bank auditors. The statistical sample includes the interviewees who are subject to semi-structured exploratory interviews according to the researchers' identification based on their specialty, and according to them, the people who are introduced to the researchers by the interviewees based on the snowball method. It should be mentioned that the sampling used in the qualitative part of this research is purposive (non-probability) sampling, which was proposed in

the classification of sampling methods for behavioral and social sciences (Onwuegbuzie & Collins, 2007).

Results and Discussions

Although this article did not intend to introduce the most models or systems used or designed in early warning systems for bankruptcy, but according to the dominant results of the interviews, these models have been mentioned by experts, of which 5 models have been introduced. Below are the most used models in early warning systems for bankruptcy:

1- **Altman Z-Score Model**: The Altman Z-Score is a well-known bankruptcy prediction model that has been applied to banks. The prediction of banks having financial problems is a topic that has been thoroughly investigated in the field of finance (Altman et al, 2017; Ghosh & Kapil, 2022). The first studies date back to the 1930s, when predicting future bank failure was done using univariate analysis. This prediction was based largely on the comparison of individual ratios between bankrupt and intact firms. The most common univariate study was proposed by Beaver (1996) and shortly after, in 1968, Altman presented the first multivariate study. Altman's work paved the way for the development of bankruptcy prediction models, and since then, more than 400 studies have been published (Lohmann et al., 2022).
2- **Logistic Regression Models**: Logistic regression models are commonly used in bankruptcy prediction (Sahiq et al., 2022).
3- **Machine Learning Models:** Various machine learning techniques have been applied to predict bank bankruptcies. These include decision trees, random forests, support vector machines, and neural networks (Chen et al., 2023).
4- **Market-Based Models**: Some academic research focuses on market indicators and their relevance to bankruptcy prediction for listed banks. These studies may explore the use of credit default swap (CDS) spreads, stock prices, and bond prices (Li & Faff, 2019).
5- **Merton's Structural Model**: Merton's model for credit risk, also known as the structural model, has been applied to assess the risk of default in banks (Thanh et al., 2021).

In the process of analyzing the theory of textual data in the interviews, based on the research questions, the following findings were obtained.

Category of developing EWS for bank bankruptcy:

In the category of developing an EWS for bankruptcy, 11 main criteria and their various considerations were extracted, which are presented in Table 2.

Category main challenges and problems of developing EWS for bank bankruptcy:

The phenomenon of bank failure in the monetary systems of the world is highly sensitive, because the consequences of systemic risk associated with this phenomenon can have very destructive effects on the monetary and financial systems of countries and lead to severe political and security crises. Similarly, one of the main questions of the research that was raised with the experts was to examine the challenges and problems that can be considered in the more effective development of the rapid warning system of bank bankruptcy.

In the review of the main challenges and problems of the development of EWS of bank bankruptcy, 10 main sections were introduced as key challenges and current problems and limitations, which are presented in Table 3.

Table 2. Category of developing EWS for bank bankruptcy.

Row	Main Factor/Criteria	Sub-factors/Sub-criteria
1	Data Quality and Availability	Ensure access to accurate and timely financial data, including balance sheets, income statements, and market data
2	Early Warning Indicators	Identify key early warning indicators (EWIs) that can predict financial distress in banks, such as declining capital adequacy ratios or increasing non-performing loans.
3	Model Development	Develop predictive models that incorporate quantitative and qualitative factors, utilizing statistical or machine learning techniques.
4	Thresholds and Triggers	Set thresholds and trigger points for EWIs to generate alerts when these indicators breach predefined levels.
5	Timely Monitoring	Implement real-time or near-real-time monitoring to detect emerging risks promptly and generate automated alerts.
6	Scenario Analysis and Stress Testing	Include scenario analysis and stress testing to evaluate the bank's resilience under various adverse conditions.
7	Interdisciplinary Collaboration	Collaborate with experts from multiple disciplines, including finance, economics, risk management, and data science.
8	Regulatory Compliance	Ensure the system complies with relevant banking and financial regulations, including those from regulatory bodies like central banks and financial authorities.
9	Human Expertise	Combine automated systems with human expertise to provide context and judgment to risk assessments.
10	Transparency and Accountability	Maintain transparency in methodologies and assumptions, documenting and reporting findings to stakeholders and regulatory authorities.
11	Continuous Improvement	Continuously update and refine the warning system based on changing risk profiles and industry dynamics.

Based on what was announced in Table 4 under the title of problems and challenges of more effective development of the rapid warning system of bank bankruptcy, for each of the challenges raised, discussions were held with experts and practical solutions were presented, in Figures 2 to 11. The solutions provided for each challenge are presented in the form of main headings.

Addressing the challenge of “Data Quality and Availability” to obtaining accurate and timely financial data for international banks involves a combination of technology, data management practices, and regulatory compliance. These solutions aim to enhance data accuracy, comparability, and accessibility, ultimately supporting the development of effective early warning systems for bank bankruptcies (Fig. 2).

Solving the challenge of “Model Complexity” to developing predictive models that accurately capture the complexity of banking operations and market dynamics requires a thoughtful approach that leverages advanced modeling techniques and comprehensive data. Fig. 3 shows strategies to address this challenge.

Table 3. Category main challenges and problems of developing EWS for bank bankruptcy.

Row	Main Challenges	Description of Challenges	References
1	Data Quality and Availability	Obtaining accurate and timely financial data can be challenging, especially for international banks with complex operations.	Penman, 2010
2	Model Complexity	Developing predictive models that accurately capture the complexity of banking operations and market dynamics can be difficult.	Saadatmand & Daim, 2021
3	Parameter Estimation	Estimating model parameters and variables, especially in machine learning models, can be sensitive to sample size and data quality.	Fan & Yao, 2017
4	Overfitting	Overfitting occurs when a model fits the training data too closely, leading to poor generalization to new data.	Hastie et al., 2009
5	Imbalanced Data	Imbalanced datasets, where instances of bankruptcies are rare compared to non-bankruptcies, can lead to biased models.	Nyitrai & Virág, 2009
6	Data Privacy and Security	Protecting sensitive financial data while allowing for analysis and model development can pose data privacy and security challenges.	Borisov & Diaz, 2021
7	Model Interpretability	Complex machine learning models may lack interpretability, making it difficult to explain model predictions to stakeholders and regulators.	Nori et al., 2019
8	Regulatory Compliance	Ensuring that warning systems comply with evolving financial regulations and standards can be demanding.	Schwarcz, 2019
9	Dynamic Market Conditions	Rapid changes in market conditions and economic factors can affect the accuracy of models trained on historical data.	Hull, 2012
10	Human Expertise and Judgment	Balancing automated systems with human expertise and judgment can be challenging, particularly in interpreting model outputs.	Hull, 2012

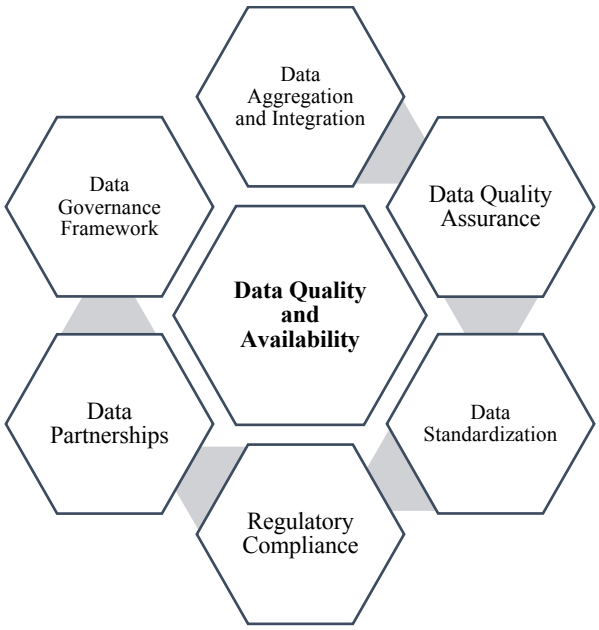

Figure 2. Title of proposed solutions and strategies for "Data quality and availability" challenge.

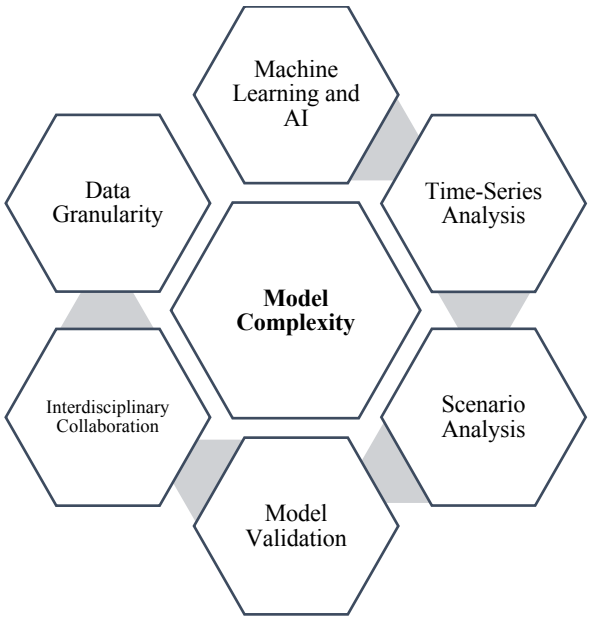

Figure 3. Title of proposed solutions and strategies for "Model Complexity" challenge.

Solving the challenges of "Parameter Estimation" to estimating model parameters and variables, which can be sensitive to sample size and data quality, in the development of early warning systems for bank bankruptcies requires careful consideration and application of statistical techniques. Fig. 4. show strategies to address this challenge.

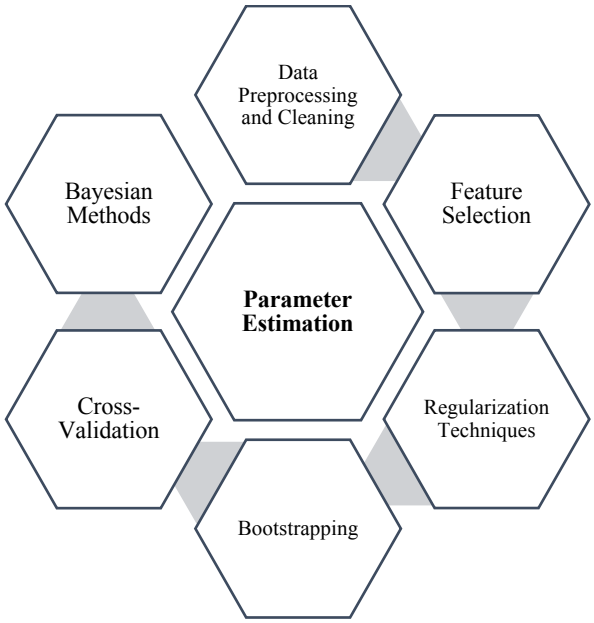

Figure 4. Title of proposed solutions and strategies for "Parameter Estimation" challenge.

Addressing overfitting is essential to ensure the reliability and generalizability of early warning systems for bank bankruptcies. By applying these strategies, researchers and practitioners can build models that provide accurate predictions while avoiding the pitfalls of overfitting (Fig 5.).

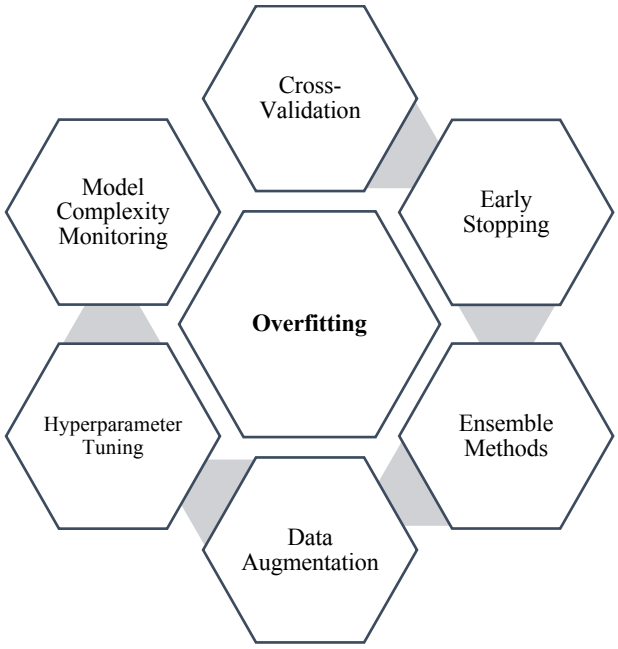

Figure. 5. Title of proposed solutions and strategies for "Overfitting" challenge.

Addressing class imbalance is crucial to building reliable early warning systems for bank bankruptcies. These strategies can help ensure that models do not favor the majority class and can effectively identify minority class instances of interest. Fig. 6. show strategies to address this challenge.

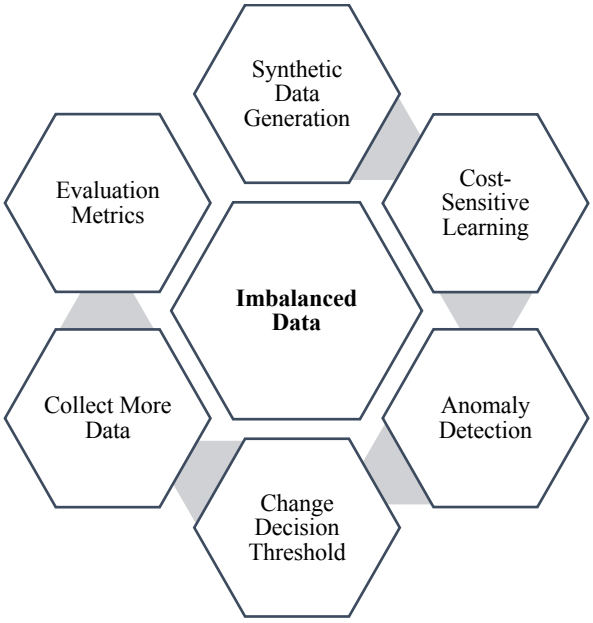

Figure 6. Title of proposed solutions and strategies for "Imbalanced Data" challenge.

Addressing the challenge of "Data Privacy and Security" to protecting sensitive financial data while allowing for analysis and model development in the context of developing early warning systems for bank bankruptcies involves a combination of data privacy and security measures. Fig. 7 shows the strategies to mitigate this challenge.

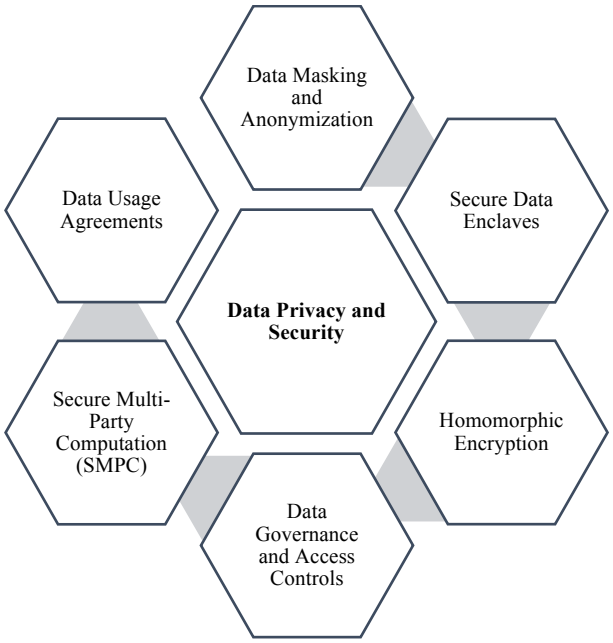

Figure 7. Title of proposed solutions and strategies for "Data Privacy and Security" challenge.

Addressing the challenge of “Model Interpretability” for complex machine learning models lacking interpretability in the development of early warning systems for bank bankruptcies is crucial for gaining trust from stakeholders and regulators. Fig. 8 presents the strategies to mitigate this challenge.

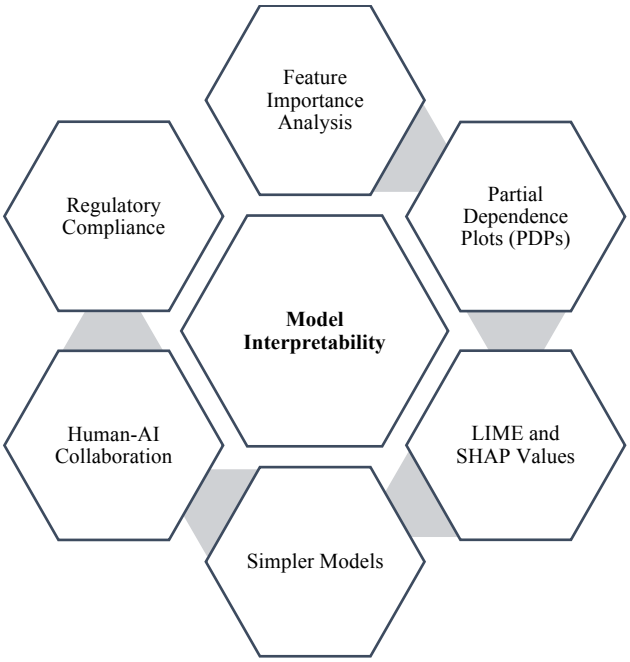

Figure 8. Title of proposed solutions and strategies for "Model Interpretability" challenge

Ensuring that warning systems comply with evolving financial regulations and standards is essential when developing early warning systems for bank bankruptcies. Fig. 9 presents the strategies for regulatory compliance challenge.

By implementing these strategies, organizations can navigate the demanding landscape of evolving financial regulations and standards more effectively while developing rapid warning systems for bank bankruptcies. Staying compliant not only mitigates regulatory risks but also contributes to the system's credibility and trustworthiness.

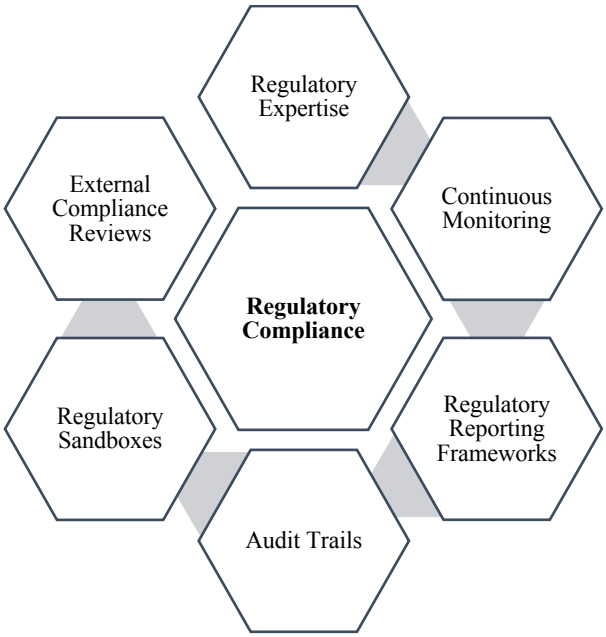

Figure 9. Title of proposed solutions and strategies for "Regulatory Compliance" challenge.

Addressing the challenge of "Dynamic Market Conditions" for rapid changes in market conditions and economic factors affecting the accuracy of models in the development of rapid warning systems for bank bankruptcies requires a proactive and adaptive approach. Fig. 10 presents the strategies for dynamic market conditions challenge.

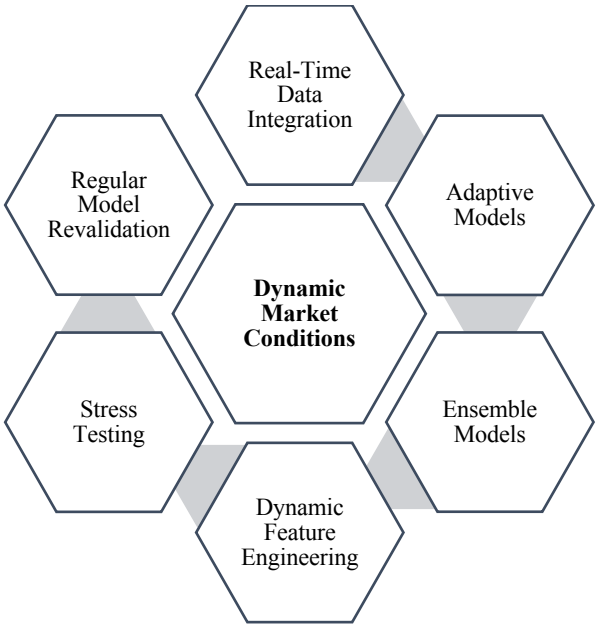

Figure 10. Title of proposed solutions and strategies for "Dynamic Market Conditions" challenge.

Balancing automated systems with human expertise is essential for the effective and responsible operation of rapid warning systems for bank bankruptcies. These strategies ensure that the strengths of both automated models and human judgment are leveraged to make informed decisions. Fig. 11 presents the strategies for human expertise and judgment challenge.

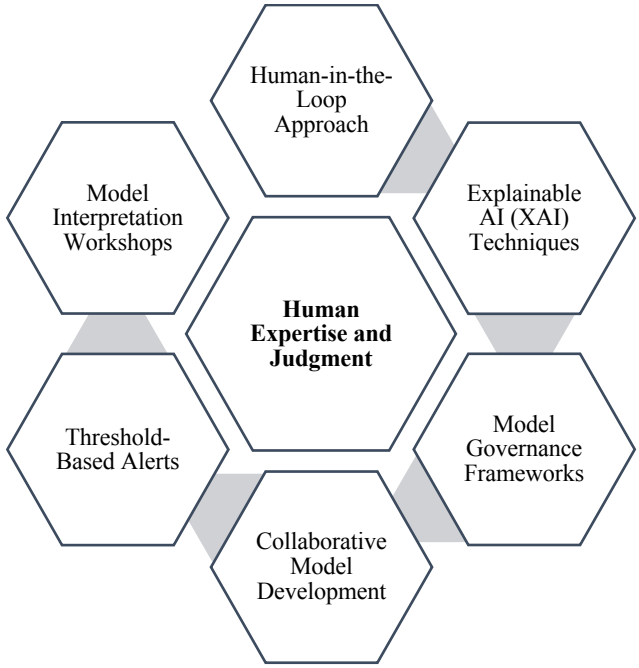

Figure 11. Title of proposed solutions and strategies for "Human Expertise and Judgment" challenge.

Based on the analyzes performed and the points of opinion obtained from the experts, the following approaches can be presented for the better and more effective development of effective early warning systems for predicting bank bankruptcy (Table 4).

As presented in Table 4, 13 key approaches and strategies have been extracted for better and more effective effectiveness of early warning systems of bank bankruptcy, which include all the strategies and approaches suggested by experts.

Conclusion

In the realm of early warning systems for predicting bank bankruptcy, these interconnected factors hold immense significance and should guide both strategy and implementation. Data Quality and Availability underscore the need for a robust data infrastructure, especially in international banks with complex operations, to ensure that EWS can rely on accurate, timely, and comprehensive financial data. Model Complexity reminds us that predictive models should be sophisticated enough to capture the multifaceted nature of banking operations and market dynamics. Parameter Estimation highlights the critical role of robust modeling techniques, emphasizing the importance of careful parameter tuning influenced by data quality and sample size. Overfitting cautions against overly complex models that can hinder generalization to new data. Imbalanced Data stresses the importance of addressing data biases when bankruptcies are rare, while Data Privacy and Security call for a delicate balance between safeguarding sensitive information and enabling meaningful analysis.

Table 4. List of key approaches and strategies affecting banks' bankruptcy EWS.

Row	Key approaches	Descriptions of approaches
1	Data Gathering and Integration	- Ensure that the system has access to high-quality financial data from listed banks. This data should include balance sheets, income statements, cash flow statements, and other relevant financial metrics. - Timeliness of data is crucial. Real-time or near-real-time data feeds are essential for detecting early warning signs promptly.
2	Advanced Analytics	- Utilize advanced analytics and modeling techniques to analyze the data. This may include machine learning algorithms, logistic regression, time-series analysis, and more. - Develop models that can identify both quantitative and qualitative indicators of financial distress. This includes financial ratios, market data, and macroeconomic factors.
3	Early Warning Indicators	- Identify specific early warning indicators that are relevant to the banking sector. These could include deteriorating capital adequacy ratios, increasing non-performing loans, declining profitability, or adverse changes in market sentiment. - Consider qualitative factors such as changes in management, regulatory issues, or legal problems that could signal financial distress.
4	Scenario Analysis	- Conduct scenario analysis to assess how different economic or market scenarios could impact a bank's financial health. Stress testing models can help evaluate a bank's resilience to adverse conditions.
5	Machine Learning and AI	- Leverage machine learning and artificial intelligence to continuously learn from new data and adapt the warning system over time. These techniques can uncover complex patterns that might not be evident with traditional methods.
6	Regular Monitoring	- Establish a continuous monitoring process to track the health of listed banks. This involves setting up alerts and triggers that notify relevant stakeholders when predefined warning thresholds are breached.
7	Interdisciplinary Collaboration	- Collaborate with experts from various fields, including finance, economics, risk management, and data science, to ensure a holistic approach to bankruptcy prediction.
8	Backtesting and Validation	- Regularly backtest and validate the warning system's effectiveness using historical data. Ensure that the system's predictions align with past financial crises or bank failures.
9	Regulatory Compliance	- Ensure that the warning system complies with relevant financial regulations and reporting requirements.
10	Transparency and Accountability	- Maintain transparency in the methodology and assumptions used in the warning system. - Document and report findings to stakeholders and regulatory authorities.
11	Human Expertise	- Combine automated warning systems with human expertise. Experienced financial analysts can provide valuable insights and context that automated systems may miss.
12	Feedback Loop	- Implement a feedback loop that allows for adjustments and improvements in the warning system based on the performance of previous alerts and predictions.
13	Continual Improvement	- Continually update and refine the warning system to adapt to changes in the banking industry, market conditions, and regulatory requirements.

Model Interpretability signals the need for transparent models to satisfy stakeholders and regulatory bodies. Regulatory Compliance underscores the continuous adaptation of EWS to ever-evolving financial regulations. Dynamic Market Conditions remind us that EWS must remain vigilant and flexible in the face of rapid changes. Finally, Human Expertise and Judgment emphasize that while automation is crucial, human insights remain indispensable, particularly in interpreting model outputs and making crucial decisions. In conclusion, a holistic approach that incorporates these factors is imperative for the development of robust EWS in the banking sector, ensuring both effective risk management and regulatory compliance.

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