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International Journal of Finance and Managerial Accounting, Vol.7, No.26, Summer 2022 IJFMA

Effective Dimensions on Digital Banking Risk Management

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Submit: 08/03/2021 Accept: 24/04/2021

ABSTRACT

In today's world, information technology (IT) has an undeniable influence on life and businesses, and activities in the digital environment are ever-rising. Digital transformations in modern time will dramatically change banking systems and financial service provider companies. The widespread of banking operations and digital transformations in this field indicates that other risks are also of paramount importance in addition to the current risks of banks. In today's environment full of evolution, the success of firms relies on their mastery of risks. In this study, we intend to examine the risk of banks after today's developments in the digital domain. In this survey, interviews were carried out with banking industry experts in the city of Tehran. The focus of interviews was on experts' views and specialized opinions on the factors affecting digital banking risk management. The FUZZY DEMATEL (Decision Making Trial and Evaluation Laboratory) method deals with the examination of the relationships between criteria and sub-criteria.

Keywords:

Risk Management, Banking Industry, Digital Transformation (DT).

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1. Introduction

Nowadays, financial institutions play a key role in the economic development and progress of any country and banks are regarded as the main financiers of the most important elements of the country's economic system. The dominant feature of the modern financial system is the high speed of innovation. The pace adopted by today's modern banking is unprecedented. Digital transformations in modern time will dramatically change banking systems and financial service provider companies. Digital financial ecosystems, financial technology (FinTech) and other third-party based interfaces will have the opportunity to try their chance at overtaking banks, thanks to the emergence and development of open banking and the ever-rising growth of digital channels. The realities of digital developments in the new age are much closer than they appear. In today's high-speed world, it is the clarity of vision and speed of action that defines their success; that everyone, in any area of the works, while understanding and overcoming the developments and dilemmas of their industry, also identify external opportunities and developments and employ all their thoughts and power to benefit from these opportunities.

Environmental complexities, the intensity of competition, widespread of novel and advanced technologies, development of information and communication technology, modern methods of offering goods and services, environmental issues, etc. are among the major factors, which has caused organizations and businesses to face many and even unforeseen risks during their lifetime. In today's volatile environment, the success of firms depends on their mastery of risks. Digital banking enhances banks' dependence on information technology (IT); hence, a great deal of technical complexity in operational and security problems occur. The importance of security controls, customer authentication methods, data protection, audit approaches and privacy standards are among the requirements of modern technology.

Research Literature

In the information age, which is the main axis of power, knowledge, and insight, information technology, as a tool to create value in business activities, has undertaken new roles. New technologies and the high speed of innovation in this area have changed the banking business models and have led to the dynamism of the financial and banking services ecosystem. The advancement of technology has today had a great impact on the way we operate in the financial and banking fields, and these areas have always been leading in the application of technology. As experience has indicated, banking has always had the greatest attraction and tendency to technology. Digital Transformation (DT) means the application, development, and dominance of digital technologies to improve the performance of the organization and fundamental and gradual changes in the principles and logic of business. "Digital Banking" is the offering of tailored, personalized, and customized products and services at the right time and in real-time through appropriate and integrated tools or channels to deliver service to customers based on advanced analysis and real-time customer data. In recent years, a new generation of banking called digital banking has been operationalized in renowned European and American banks. Banks will be successful in the challenge of digital transformation if they can have a framework for comprehensive measurement and assessment in this regard and properly explore the process from all perspectives.

Definition of Risk

In today's society, almost everyone is familiar with this notion and argues that life is risky. Risk in the common language is the hazard that arises due to uncertainty about the occurrence of an accident in the future. The higher the level of this uncertainty, the higher the risk (Fathian & Mir Shafieian, 2008). Any managerial decision and even an innovation or adoption of a new method can be associated with risks. Management thinkers have enumerated the following four strategies for risk management: risk transfer, risk avoidance, risk mitigation, and risk acceptance. In addition to the financial aspect, changes created in today's world influence other parts.

Risk Management

Today's life continues, while uncertainty has overshadowed all matters and changed the decision-making process. Changes in commodity prices, exchange rate fluctuations, interest rate changes, as well as stock price fluctuations, are items that today's organizations are continually grappling with. These changes, along with other environmental changes,

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have led to the rise of new scientific theories in the field of management, to the extent that Chaos Theory has emerged and depicted organizations in an environment with high complexity, yet manageable. Financial engineering and integrated risk management are responsible for the task of risk control. By providing new solutions and innovative strategies, it has been able to create systematic methods for commercial, manufacturing and service companies, mainly banks. Risk management is the process in which various risks and threats are detected, measured and controlled. The main objective of risk management is the measurement and forecasting of the types of risks in order to control them.

Major Risks of Financial Markets

There are eight main factors of risk in financial markets that banks, financial institutions and other financial institutions are most likely to face. Credit risk, regional risk, exchange rate risk, market risk, liquidity risk, operational risk, regulatory risk and reputation risk. Adaptation risk, modern e-banking risk, and cybersecurity risk have also been recently highlighted. The banking industry is considered as one of the most crucial sectors of the country's economy, which can provide the grounds for economic growth and prosperity by properly organizing and managing its resources and expenditures. As the essential economic, monetary, and financial institution of the country, the banking industry encounters numerous challenges. Many factors, both at micro and macro levels, create banking risk and disrupt financial and banking stability. Identification and management of these factors can not only reduce banking risk but also bring financial stability. The development of novel technologies and the expansion of their acceptance and application in the realm of digitalization has led to a significant impact on the financial and banking industry. Digital banking is a new paradigm that has remarkable benefits for banks in terms of increasing productivity. This pattern is implemented using advanced technology infrastructure in order to make changes in internal processes and external user interfaces. In the current situation, the banking industry is continuously changing. Indeed, banks will continue their survival in the future to fulfil this goal with proper planning and a reliable roadmap.

Digital Banking

The financial services sector has experienced significant structural changes over a period of time. The term "digital banking", similar to many emerging concepts in banking, has different meanings and is interpreted by stakeholders with different meanings and applications. Digital banking for customers can mean the experience of buying and paying for new services and products, and it means setting up an advanced information technology and communications (ICT) infrastructure for bank managers. In the field of business, digitalization means analyses to provide knowledge and develop insight for correct decision making. A review of scientific sources and specialized articles on digital banking suggests that digital banking will be the future model of the world banking industry in accordance with the prediction of many international institutions. On the basis of the forecasting of these institutions, digital banking is no longer just an option that banks can simply ignore, but according to forecasts, digital banking is a necessity in the daily agenda of banks, and banks around the world are actively implementing digitalization issues in their internal processes and services. After identifying the dimensions of the research, the following factors are provided to complete the theoretical literature.

1) Business management dimension
2) Economic, financial and market dimensions
3) Political, legal and legislative dimension
4) Technology dimension
5) Social responsibility dimension

Subsequently, a brief description of the dimensions criteria will be discussed:

1) Business management dimension: The widespread influence of digital technologies in daily life has caused extensive changes in people's lifestyles and today's business models. Banks are no exception. Between 2015 and 2016, a new generation of competitors has emerged in the financial and banking industry, which are attempting to establish new and modern banks by focusing on the mobile platform. In this way, while reducing costs and growth and profitability, they want to challenge traditional banks and physical branches. Continuous technological innovation has played an important role in ensuring the

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survival and development of the enterprise in today's economy.

2) Economic, financial and market dimension: Businesses and enterprises always face a set of risks. However, the issue of risk in financial and banking activities is of special importance because of its rapid spread and the consequences for the entire economy. In financial and banking systems, the term risk comes to mind more than any other subject, credit, liquidity, financial and market risks. The risks of the economic dimension are enormous. It is worth noting that we are not able to handle all risks, but we can reduce them to a tolerable level with the knowledge and experience gained from risk management.
3) Political, legal and legislative dimension: The importance of proper supervision and legislation in the banking system and its positive impact on creating a safe space away from all kinds of crises, tensions and extreme volatility is no secret. Establishing such an atmosphere is a prerequisite for economic stability and greatly contributes to preventing violations by the banking system.
4) Technology dimension: Nowadays, the utilization of information technology in the banking industry has caused the facilitation of the banking activities of customers and has made competitive advantage a necessity and prevents many risks in this industry. If technology risks are not properly identified and managed, it can negatively affect the performance of banks in the long-term. The purpose of risk management is to identify, consider, and eliminate risk factors before they are taken into account as a threat to the successful implementation of the project.
5) Social responsibility dimension: Today, the banking industry is facing a dynamic and changing environment. Due to the changing and competitive market conditions and numerous opportunities for customers to receive better services, banks should be customer-oriented and customer attraction should be deemed as their top priority. Customer orientation and moving on to the demands of customers are among the most important factors for success in the banking industry that digital transformation technologies have created a new paradigm for leading banks to achieve this concept by providing the possibility of personalized presentation.

2. Background

Table 2- Research associated with the factors affecting risk management

Researcher name	Year	Title	Effective components
Francisco Zabala and Beta Slosarkes	2020	Risks of digitalization of banking services: diversification and sustainable development goals	It turned out that the main external risk of Santander Bank in 2018 was fraud in the use of online payments. Investing in cyber risk management and taking action to cover cyber-attacks can be effective. Insurance payments for operational risks were identified.
Khanboubi and Azdin	2018	Risk management roadmap in the digital space	This study, with a review of the history of risk management in banks, points to cybercrime and data security as new dimensions in digital risk.
Romain Gimblet et al	2018	Operational risk management in the digital space in the Switzerland banking industry	If processes are somewhat digitalized and banks are integrated across the Switzerland industry, we may see an increase in the impact of risk factors.
Temnus	2017	Experience-oriented banking	Based on this report, 10 vital necessities for digital banks include: Banking at any time and any place and with any device, analysis of personal experience of customers, customer orientation, swift realization of needs, acceptance of open banking power, efficient cost, lower operational risk, ongoing updating, market leadership to change and offer new product, scalability and implementation of cloud infrastructure
Tabavar, Dehghani and Marashi	2019	Identifying solutions to improve the customer experience through digital banking	Opportunities achieved from improving the customer experience in using digital banking services including all categories of employees, structure, cultural and social factors, customers, organization and infrastructure, respectively.

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Researcher name	Year	Title	Effective components
Fadaei and Rahimi	2019	Analysis of the nature of risk in electronic banking	Identified risks include liquidity risk, credit risk, operational risk, legal risk, security risk, privacy risk and reputation risk, which are examined using qualitative, systematic and non-systematic analysis. It also turns out that some of these risks can cause problems for the entire e-banking system
Mohammad Hussein Deymkar and Peyman Akhavan	2018	The Impact of Perceived Risk on Electronic Banking Services Case Study: Mobile Banking of Bank Shahr Branch in Kashan	Efficiency, financial, security, social and privacy risks have a negative and significant impact on the acceptance of mobile banking in Bank Shahr, and time risk does not have a significant influence on the adoption of mobile banking

3. Methodology

Process of FUZZY DEMATEL Technique Analysis

A fuzzy approach is exploited to deal with the uncertainty and ambiguity in respondents' verbal expressions. A variety of ranges have been proposed based on the conventional DEMATEL scoring scale. Among these, two fuzzy spectra have been welcomed, both of which are listed in the table below.

Fuzzy equivalent (B)	Fuzzy equivalent (A)	Definitive equivalent	Time variable
(0.0, 0.0,0.25)	(0.0, 0.1,0.3)	0	Effectless
(0.0, 0.25,0. 5)	(0.1, 0.3,0.5)	1	Low impact
(0.25, 0. 5,0. 5)	(0.3, 0.5,0.7)	2	Medium impact
(0. 5, 0. 75,1.0)	(0.5, 0.7,0.9)	3	high impact
(0. 75, 1.0,1.0)	(0.7, 0.9,1.0)	4	Impact very much

The triangular fuzzy representation of fuzzy spectrum A is as follows:

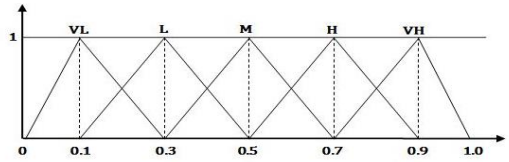

Figure: Triangular fuzzy numbers equivalent to the DEMATEL spectrum

Fuzzy DEMATEL Technique Algorithm

- Calculate the direct relation matrix
- Direct relation matrix normalization
- Calculate the total relation matrix

The fuzzy DEMATEL method examines the relationships between criteria and sub-criteria and specifies cause and effect relationships by the total relation matrix, which is one of the multi-attribute decision-making methods.

Steps of Fuzzy DEMATEL Method

Lin and Wu (2008) presented the following steps to perform the fuzzy DEMATEL technique.

Step 1: The formation of a group of experts to gather their group knowledge to solve the problem

Step 2: Determining the evaluation criteria as well as designing language scales: Using the opinions of experts, research factors and indicators are identified. The fuzzy numbers used in this study are of the triangular fuzzy type.

Linguistic expressions	Definitive equivalent	Triangular fuzzy numbers
Effectless(NO)	(0.0, 0.0,0.25)	(0.0, 0.1,0.3)
Low impact(VL)	(0.0, 0.25,0. 5)	(0.1, 0.3,0.5)
Medium impact(L)	(0.25, 0. 5,0. 5)	(0.3, 0.5,0.7)
high impact(H)	(0. 5, 0. 75,1.0)	(0.5, 0.7,0.9)
Impact very much(VH)	(0. 75, 1.0,1.0)	(0.7, 0.9,1.0)

Step 3: Creating a of initial direct relation fuzzy matrix with the collection of expert opinions. To measure the relationships between criteria, we need to put them in a square matrix and ask experts to compare them in pairs based on how much they affect each other. Assuming we have n criteria and p experts, we will have p fuzzy matrix, each of which corresponds to the opinions of an expert with triangular fuzzy numbers as its elements.

Step 4: Fuzzy direct relation matrix normalization. To this end, linear scale conversion is employed as a normalization formula to convert scales of criteria to comparable criteria.

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$$\tilde{a}_{ij}=\sum_{j=1}^{n}\tilde{Z}_{ij}=\left(\sum_{j=1}^{n}l_{ij},\sum_{j=1}^{n}m_{ij},\sum_{j=1}^{n}r_{ij}\right)\text{ and }r=\max_{1\le i\le n}\left(\sum_{j=1}^{n}r_{ij}\right)$$

$$\tilde{X}=\begin{bmatrix}\tilde{X}_{11} & \tilde{X}_{12} & \cdots & \tilde{X}_{1n}\\ \tilde{X}_{21} & \tilde{X}_{22} & \cdots & \tilde{X}_{2n}\\ \vdots & \vdots & \ddots & \vdots\\ \tilde{X}_{m1} & \tilde{X}_{m2} & \cdots & \tilde{X}_{mn}\end{bmatrix}\text{ and }\tilde{X}_{ij}=\frac{\tilde{Z}_{ij}}{r}=\left(\frac{l_{ij}}{r},\frac{m_{ij}}{r},\frac{r_{ij}}{r}\right)$$

Step 5: Calculating the fuzzy total relation matrix. In this step, we first calculate the normal inverse matrix and then subtract it from matrix I, and finally multiply the normal matrix by the multiplication matrix.

$$\left[l''_{ij}\right] = X_l \times (I - X_l)^{-1}$$

$$\left[m''_{ij}\right] = X_m \times (I - X_m)^{-1}$$

$$\left[r''_{ij}\right] = X_r \times (I - X_r)^{-1}$$

Step 6: Creating and analyzing causal diagrams. For this purpose, we first calculate the sum of the elements of each row (Di) and the sum of the elements of each column (Ri) of the fuzzy matrix. Then, we easily obtain the values D + R and D-R. To draw a causal diagram, we must de-fuzzy these two values, like the definitive DEMATEL method. Here we use the CFCS method for the defuzzification of these two values. After defuzzification of numbers, a Cartesian coordinate system is drawn. In this system, the longitudinal axis represents the value D + R and dD-R is the transverse axis. Thus, the horizontal vector in the coordinate system shows the cause and effect factors and the vertical vector of the coordinate system shows the power of each factor.

Reasons for Selecting Fuzzy DEMATEL for Research Method

The DEMATEL technique is employed to identify and evaluate the relationship between criteria and to construct a network relationship mapping. To better illustrate the relationships of the elements of a system, the principles of graph theory is exploited, and the causal and effect factors of the elements can be extracted, and the relationship between the factors can be represented as a systematic structural model. By studying and reviewing articles and theses and interviews with experts, a list of factors in the research literature was identified. The main dimensions identified as influential dimensions on risk management in the digital banking sector include business management dimensions (C1), economic, financial and market dimensions (C2), political, legal, and legislative dimensions (C3), technology dimensions (C4), social responsibility dimensions (C5).

Entering the Field of Research

In this study, interviews were conducted with banking industry experts in Tehran. After identifying and selecting the panel members, first, two experts and then a list of experts and using their opinions were identified through the snowball sampling method and considered as a statistical population. The following tables are on the basis of the interviews.

Table: First interview

Dimension	Criteria	Component
Business management	Business risk	Welcoming of customers and newcomers from the valid offer for digital banking
		Lack of attention to futures studies
	Operational risk	Lack of using new tools in digital banking
		Inadequate and incomplete deployment of digital banking
	Risk of organizational culture and personnel	Lack of specialized and professional training for staff preparation in the face of environmental changes
		Lack of team skills and user experiences
Economic, financial and market	Financial risk	Liquidity risk
		Empowerment of the competitors, reduction in profit margins and an increase in certain operating risks
	Market risk	Unrealistic expectations of customers
		Changes in demand
		Aggressive technologies
Political, legal, and legislative	Risk of rules and regulations	The Basel Committee on Banking Supervision
Technology	Information technology risk	Technology changes in the field of customer data analysis

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Dimension	Criteria	Component
		and artificial intelligence
	Project management risk	Lack of executive support
	Organizational architecture risk	Bank fraud
Social responsibility	Branding risk	Emergence of new non-banking players in the banking system in the form of financial technology (FinTech) or startups

Table: Second interview

Dimension	Criteria	Component
Business management	Business risk	Lack of future risk management plan
	Operational risk	Lack of adequate infrastructure (computer hardware and software)
	Risk of organizational culture and personnel	Lack of attention to the principles of Islamic banking in digital banking
		Unwillingness of bank officials for the transition from traditional banking to digital banking
Economic, financial and market	Market risk	Conducting automated processes
Political, legal, and legislative	Political risk	Emergence of accidents at home and abroad
Technology	Information technology risk	Inefficient management of data and operational models
	Risk of mechanization and automation	Moving from manual processing to computer processing
	Risk of observing citizenship rights	Privacy and security of customer information

Table: Third interview

Dimension	Criteria	Component
Business management	Business risk	Delays of banks in timely identification of customer needs
		Lack of future risk management plan
	Operational risk	Lack of using new tools in digital banking
	Risk of organizational culture and personnel	Lack of assessing the Technology Readiness Level (TRL) in the country's banking network
Economic, financial and market	Financial risk	Lack of data analysis and credit records of customers for lending
	Market risk	Changes in demand
Political, legal, and legislative	Risk of rules and regulations	Lack of ability and micro-attitude and lack of professional knowledge of the board of directors and managers in the field of information technology
Technology	Project management risk	Lack of technical knowledge, lack of expertise of the project team, insufficient support of project users
	Risk of mechanization and automation	Communications and technical equipment
Social responsibilities	Accountability risk and social responsibility	The principle of localization

Table: Fourth interview

Dimension	Criteria	Component
Business management	Business risk	Digital innovations in the banking industry
		Lack of attention to new banking technologies such as FinTech, online payment companies and ...
	Operational risk	Digitization and the use of digital innovations
	Risk of organizational culture and personnel	Disproportion of the speed of adaptation of knowledge, skills and performance of bank personnel to the growth rate of technology
		Lack of team skills and user experiences
		High degree of uncertainty in technology projects
Economic, financial and market	Financial risk	Liquidity risk
		Marketing risk
	Market risk	Lack of alignment with digital transformation

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Dimension	Criteria	Component
Political, legal, and legislative	Political risk	Changes in government policies
Technology	Project management risk	Leadership, control and monitoring of projects
	Organizational architecture risk	Ambiguity in the definition of objectives and scope of the project
		Lack of virtual activity insurance
Social responsibilities	Risk of observing citizenship rights	Differentiation of customers based on their needs and demands in digital banking

Table: Fifth interview

Dimension	Criteria	Component
Business management	Business risk	Lack of attention to futures studies
	Operational risk	Inability of risk analysis by staff
	Risk of organizational culture and personnel	Unwillingness of bank officials for the transition from traditional banking to digital banking
Economic, financial and market	Market risk	More competitive pressure in the market
Political, legal, and legislative	Risk of rules and regulations	Delays in the implementation of rules and regulations
Technology	Project management risk	Lack of executive support
Social responsibilities	Branding risk	Instability and short-term durability in delivery of service to customers

Table: Sixth interview

Dimension	Criteria	Component
Business management	Business risk	Lack of attention to new banking technologies such as FinTech, online payment companies and ...
		High cost of traditional banking compared to digital banking
		Lack of future risk management plan
	Risk of organizational culture and personnel	Disproportion of the speed of adaptation of knowledge, skills and performance of bank personnel to the growth rate of technology
		Lack of attention to the principles of Islamic banking in digital banking
		The unwillingness of bank officials for the transition from traditional banking to digital banking
Economic, financial and market	Financial risk	Marketing risk
Political, legal, and legislative	Risk of rules and regulations	Lack of evaluation and selection processes, establishment, operation and risk management of banking systems
Technology	Organizational architecture risk	Cyberattacks
		Data security threats
		Bank fraud
Social responsibilities	Accountability risk and social responsibility	Lack of accurate understanding of customer needs compared to digital banking

Table: Seventh interview

Dimension	Criteria	Component
Business management	Business risk	Digital innovations in the banking industry
		Welcoming of customers and newcomers from the valid offer for digital banking
	Operational risk	Inability of risk analysis by staff
		Inadequate and incomplete deployment of digital banking
	Risk of organizational culture and personnel	Lack of team skills and user experiences
		High degree of uncertainty in technology projects
Economic, financial and market	Financial risk	Liquidity risk
	Market risk	Lack of alignment with digital transformation
		Aggressive technologies
Political, legal, and legislative	Risk of rules and regulations	The Basel Committee on Banking Supervision

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Dimension	Criteria	Component
Technology	Information technology risk	Technology changes in the field of customer data analysis and artificial intelligence
	Organizational architecture risk	Bank fraud
Social responsibilities	Branding risk	Emergence of new non-banking players in the banking system in the form of financial technology (FinTech) or startups

Table: Eighth interview

Dimension	Criteria	Component
Business management	Operational risk	Lack of up-to-date banking system
		Inability of risk analysis by staff
	Risk of organizational culture and personnel	Lack of assessing the Technology Readiness Level (TRL) in the country's banking network
		Unwillingness of bank officials for the transition from traditional banking to digital banking
Economic, financial and market	Financial risk	Credit risk
	Market risk	More competitive pressure in the market
Political, legal, and legislative	Risk of rules and regulations	Lack of evaluation and selection processes, establishment, operation and risk management of banking systems
Technology	Project management risk	Lack of executive support
	Risk of mechanization and automation	Moving from manual processing to computer processing
Social responsibilities	Accountability risk and social responsibility	Lack of accurate understanding of customer needs compared to digital banking

Table: Ninth interview

Dimension	Criteria	Component
Business management	Business risk	Delay of banks in timely identification of customer needs
	Operational risk	Inadequate and incomplete deployment of digital banking
		Lack of adequate infrastructure (computer hardware and software)
	Risk of organizational culture and personnel	Lack of attention to the principles of Islamic banking in digital banking
Economic, financial and market	Financial risk	Lack of data analysis and credit records of customers for lending
Political, legal, and legislative	Risk of rules and regulations	Lack of ability and micro-attitude and lack of professional knowledge of the board of directors and managers in the field of information technology
Technology	Organizational architecture risk	Improper planning and scheduling of project implementation
	Risk of mechanization and automation	Communications and technical equipment
Social responsibilities	Accountability risk and social responsibility	The principle of localization

Table: Tenth interview

Dimension	Criteria	Component
Business management	Business risk	Welcoming of customers and newcomers from the valid offer for digital banking
	Operational risk	Inadequate and incomplete deployment of digital banking
	Risk of organizational culture and personnel	High degree of uncertainty in technology projects
		Unwillingness of bank officials for the transition from traditional banking to digital banking
Economic, financial and market	Financial risk	Credit risk
	Market risk	Lack of alignment with digital transformation
		Conducting automated processes
Political, legal, and legislative	Risk of rules and regulations	Lack of evaluation and selection processes, establishment, operation and risk management of banking systems
Technology	Organizational architecture risk	Lack of virtual activity insurance
Social responsibilities	Risk of observing citizenship rights	Differentiation of customers based on their needs and demands in digital banking

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Table: Eleventh interview

Dimension	Criteria	Component
Business management	Business risk	Lack of attention to new banking technologies such as FinTech, online payment companies and ...
		High cost of traditional banking compared to digital banking
		Lack of future risk management plan
	Operational risk	Lack of adequate infrastructure (computer hardware and software)
	Risk of organizational culture and personnel	Lack of specialized and professional training for staff preparation in the face of environmental changes
Economic, financial and market	Financial risk	Empowerment of the competitors, reduction in profit margins and an increase in certain operating risks
	Market risk	Unrealistic expectations of customers
Political, legal, and legislative	Risk of rules and regulations	Strong legal frameworks and codified processes for key stakeholders (government, legislators and banks)
Technology	Project management risk	Lack of technical knowledge, lack of expertise of the project team, insufficient support of project users
Social responsibilities	Risk of observing citizenship rights	Providing the highest level of customer service in digital banking

Table: Twelfth interview

Dimension	Criteria	Component
Business management	Business risk	Digital innovations in the banking industry
		Lack of future risk management plan
	Risk of organizational culture and personnel	Disproportion of the speed of adaptation of knowledge, skills and performance of bank personnel to the growth rate of technology
		Lack of team skills and user experiences
Economic, financial and market	Financial risk	Liquidity risk
	Market risk	Unrealistic expectations of customers
	Political risk	Emergence of accidents at home and abroad
Technology	Information technology risk	Technology changes in the field of customer data analysis and artificial intelligence
	Organizational architecture risk	Bank fraud
Social responsibilities	Risk of observing citizenship rights	Privacy and security of customer information

Table: Thirteenth interview

Dimension	Criteria	Component
Business management	Business risk	Welcoming of customers and newcomers from the valid offer for digital banking
		Delays of banks in timely identification of customer needs
		Lack of future risk management plan
	Risk of organizational culture and personnel	Lack of specialized and professional training for staff preparation in the face of environmental changes
		The unwillingness of bank officials for the transition from traditional banking to digital banking
Economic, financial and market	Financial risk	Credit risk
		Empowerment of the competitors, reduction in profit margins and an increase in certain operating risks
Political, legal, and legislative	Risk of rules and regulations	Strong legal frameworks and codified processes for key stakeholders (government, legislators and banks)
Technology	Information technology risk	Inefficient data management and operational models
	Organizational architecture risk	Cyberattacks
Social responsibilities	Branding risk	Instability and short-term durability in delivery of service to customers

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Formation of main categories and classes

In this section, we express the relationship between the concepts extracted from the interviews. Also, we try to create a comprehensive, complete, and integrated connection between the listed categories. Table 14 illustrates the formation of general classes of categories.

Dimensions	Criteria
Business management	Business risk
	Operational risk
	Risk of organizational culture and personnel
Economic, financial and market	Financial risk
	Market risk
Political, legal, and legislative	Risk of rules and regulations
	Political risk
Technology	Information technology risk
	Project management risk
	Organizational architecture risk
	Mechanization and automation risk
Social responsibilities	Branding risk
	Accountability and social responsibility risk
	Observance of citizenship rights risk

The Main Dimensions of FUZZY DEMATEL Technique

Using the fuzzy expert method, the opinions of experts on the importance of risk management components and expert consensus, and prioritization of research components were examined in three stages. Ultimately, according to the optimal Pareto Principle, 80/20 Rule, the factors that had the highest score were identified as effective factors, and the causal and effect relationships of research variables were investigated using the FUZZY DEMATEL technique. The main dimensions identified as effective dimensions on risk management are as follows.

Main dimensions
Business management (C1)
Economic, financial and market (C2)
Political, legal, and legislative (C3)
Technology (C4)
Social responsibility (C5)

Step 1: Initially, pairwise comparison test is done for all factors by experts and they are compared based on the degree of priority of factors in the five-point Likert scale. The verbal comments of each respondent on the dimensions affecting risk management in digital banking are collected and then verbal phrases become fuzzy numbers using the Chang's Fuzzy Analytic Hierarchy Process (Fuzzy AHP) Method .

Conversion of verbal phrases to fuzzy numbers using Chang's fuzzy method

Step 2: Extraction of the matrix of aggregation of expert opinions: Using the geometric mean of each of the three components (I, M.U) of the matrices obtained in the previous step, we calculate the aggregation matrix of comments using the average of the experts' opinions by the triangular fuzzy numbers of the three components, which are listed in the following table.

Step 3: Normalization of the matrix: First, we calculate the sum of all the lower bounds of expert opinion and select its maximum from the sum of the lower bound numbers and divide all the numbers by the maximum number.

Step 4: Calculation of the lower bound (HL) of the normalized matrix of expert opinions: To do this, we only enter the lower bound of the normalized matrix.

Step 5: Calculation of the lower bound (I-HL): The identity matrix (I) is a matrix in which all the elements on the original diameter are equal to one and the rest of the elements are zero. To do this, we subtract all the elements of the identity matrix minus all the lower bound (HL) matrices whose results are provided in the table.

Step 6: Calculation of the lower bound (I-HL) ^-1: We bring all the elements of the lower bound to the power of negative one, the results of which are presented in the table.

Step 7: Calculation of the lower bound (HL* (I-HL) ^-1): We bring all the elements of the lower bound to the power of negative one whose results are given in the table.

Step 8: Calculation of the middle bound (HM) of the normalized matrix of expert opinions: To do this, we only enter the middle bound of the normalized matrix.

Step 9: Calculation of the middle bound (I-HM): Calculating the middle bound (I-HM) of an identity matrix (I) is a matrix in which all the elements on the original diameter are equal to one and the other elements are zero. To do this, we subtract all the matrix elements minus all the middle bound (HM) matrices. The results are presented in the table.

Step 10: Calculation of the middle bound ((I-HM) ^-1): Calculating the middle bound ((I-HM) ^-1): We bring all the lower middle elements to the power of negative one whose results are provided.

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Step 11: Calculation of the upper bound (HU): Calculating the upper bound (HU) of the normalized matrix of expert opinions: To this this, we only insert the middle bound of the normalized matrix.

Step 12: Calculation of the upper bound (I-HU): Calculating the upper bound (I-HU) of identity matrix (I) is a matrix in which all the elements on the original diameter are equal to one and the other elements are zero. To do this, we subtract all the elements of the identity matrix minus all the upper bound (HU) matrices, the results of which are given in the table.

Step 13: Calculation of the upper bound ((I-HLU) ^-1): Calculating the upper bound ((I-HLU) ^-1): We bring all the upper elements to the power of negative one, the results of which are provided in the table.

Step 14: Calculation of the upper bound (HU * (I-HU) ^-1): Calculating the upper bound (HU * (I-HU) ^-1): We bring all elements of the upper bound to the power of negative one, the results of which are presented in the table.

Step 15: Construction of a fuzzy total-relation matrix (T): To construct this matrix, we enter all elements of the lower bound calculation (HU * (I-Hl) ^-1), the middle bound calculation (Hl * (I-Hl) ^-1) and the upper bound calculation (HU * (I-HU) ^-1) in the total relation matrix, the results of which are presented in the table below.

Step 16: Defuzzification matrix: To calculate the defuzzification, lower bound plus upper bound plus 2 times the middle bound divided by four of the total relation matrix is obtained, the results of which are provided in detail in the table.

Then, we calculate the sum of rows (D) and the sum of columns (J). Next, the threshold value (average of the total relation matrix which is equal to 0.7292) is calculated using the average of the total elements of the defuzzification matrix.

Step 17: Construction of a Cause and Effect Matrix: To construct this matrix, we compare all the elements one by one with the threshold value. If the value of each element is greater than or equal to the threshold value, we put the number one in the cause and effect matrix, otherwise we put the number zero, the results of which are expressed in the table.

Step 18: Drawing cause and effect relations and the relationship of variables in the form of charts

Step 19: Calculation of the importance of the components and the relations between the criteria: To achieve the importance of these components, we initially calculate the sum of the rows plus the column and the rows minus the column of the defuzzification matrix, the value of which is calculated in Table 28.

Table14: Geometric mean of expert opinions

	C1			C2			C3			C4			C5			جمع
C1	0	0	0	0.29	0.50	0.71	0.25	0.46	0.67	0.38	0.63	0.88	0.21	0.38	0.58	1.38
C2	0.29	0.54	0.79	0	0	0	0.50	0.75	0.88	0.38	0.58	0.75	0.33	0.54	0.75	1.79
C3	0.21	0.46	0.71	0.33	0.50	0.67	0	0	0	0.33	0.54	0.79	0.29	0.54	0.79	1.67
C4	0.25	0.50	0.75	0.25	0.50	0.75	0.25	0.46	0.71	0	0	0	0.08	0.13	0.38	1.04
C5	0	0	0.25	0.08	0.17	0.42	0.08	0.33	0.58	0.04	0.08	0.33	0	0	0	0.29

Table15: Normalized matrix of geometric mean of expert opinions

	C1			C2			C3			C4			C5		
C1	0	0	0	0.16	0.28	0.40	0.14	0.26	0.37	0.21	0.35	0.49	0.12	0.21	0.33
C2	0.16	0.30	0.44	0	0	0	0.28	0.42	0.49	0.21	0.33	0.42	0.19	0.30	0.42
C3	0.12	0.26	0.40	0.19	0.28	0.37	0	0	0	0.19	0.30	0.44	0.16	0.30	0.44
C4	0.14	0.28	0.42	0.14	0.28	0.42	0.14	0.26	0.40	0	0	0	0.05	0.07	0.21
C5	0	0	0.14	0.05	0.09	0.23	0.05	0.19	0.33	0.02	0.05	0.19	0	0	0

Table16: Calculation of the lower bound (HL) of the normalized matrix of expert opinions

	C1	C2	C3	C4	C5
C1	0	0.16	0.14	0.21	0.12
C2	0.16	0	0.28	0.21	0.19
C3	0.12	0.19	0	0.19	0.16
C4	0.14	0.14	0.14	0	0.05
C5	0	0.05	0.05	0.02	0

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Table17: Calculation of lower bound (I-HL)

HL-I	C1	C2	C3	C4	C5
C1	-1	0.16	0.14	0.21	0.12
C2	0.16	-1	0.28	0.21	0.19
C3	0.12	0.19	-1	0.19	0.16
C4	0.14	0.14	0.14	-1	0.05
C5	0	0.05	0.05	0.02	-1

Table18: Calculation of the lower bound (I-HL) ^-1

(I-HL)^ -1	C1	C2	C3	C4	C5
C1	-0.47	-1.64	1.14	-0.59	-2.27
C2	2.87	-2.04	-0.07	2.88	-6.27
C3	-0.98	4.65	-2.24	3.38	-3.60
C4	3.83	-2.72	-0.09	-4.38	16.30
C5	-0.07	0.90	4.80	-4.72	-47.76

Table19: Calculation of the lower bound (HL* (I-HL) ^-1)

HL* (I-HL) ^-1	C1	C2	C3	C4	C5
C1	-0.93	-0.75	1.29	0.82	-4.38
C2	5.91	-3.97	-1.09	4.93	-9.61
C3	0.29	2.01	-3	1.75	5.73
C4	3.15	-1	0.84	-6.80	6.04
C5	3.64	1.99	-0.78	7.18	-31.13

Table20: Calculation of the middle bound (HM) of the normalized matrix of expert opinions

HM	C1	C2	C3	C4	C5
C1	0	0.28	0.26	0.35	0.21
C2	0.30	0	0.42	0.33	0.30
C3	0.26	0.28	0	0.30	0.30
C4	0.28	0.28	0.26	0	0.07
C5	0	0.09	0.19	0.05	0

Table21: Calculation of the middle bound (I-HM)

	C1	C2	C3	C4	C5
C1	0.73	1.19	1.76	1.38	1.18
C2	1.79	0.64	1.98	1.67	1.33
C3	1.64	1.30	1.08	1.53	1.21
C4	1.33	1.04	1.55	0.46	1.13
C5	0.61	0.43	0.56	0.55	-0.52

Table22: Calculation of middle bound ((I-HM) ^-1)

	C1	C2	C3	C4	C5
C1	0	0.33	0.45	0.48	0.25
C2	0.54	0	0.83	0.54	0.40
C3	0.42	0.36	0	0.46	0.37
C4	0.37	0.29	0.40	0	0.08
C5	0	0.04	0.10	0.03	0

Table23: Calculation of the upper bound (HU) of the normalized matrix of expert opinions

	C1	C2	C3	C4	C5
C1	0	0.40	0.37	0.49	0.33
C2	0.44	0	0.49	0.42	0.42
C3	0.40	0.37	0	0.44	0.44
C4	0.42	0.42	0.40	0	0.21
C5	0.14	0.23	0.33	0.19	0

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Table24: Calculation of lower bound (I-HU)

	C1	C2	C3	C4	C5
C1	-1	0.40	0.37	0.49	0.33
C2	0.44	-1	0.49	0.42	0.42
C3	0.40	0.37	-1	0.44	0.44
C4	0.42	0.42	0.40	-1	0.21
C5	0.14	0.23	0.33	0.19	-1

Table 25: Calculation of the upper bound ((I-HLU) ^-1)

(I-HU) ^-۱	C1	C2	C3	C4	C5
C1	-0.34	0.30	0.44	0.31	0.34
C2	0.41	-0.37	0.43	0.40	0.33
C3	0.42	0.36	-0.25	0.39	0.32
C4	0.33	0.25	0.39	-0.40	0.37
C5	0.30	0.20	0.21	0.26	-0.63

Table 26: Calculation of the upper bound (HU * (I-HU) ^-1)

	C1	C2	C3	C4	C5
C1	0	0.12	0.16	0.15	0.11
C2	0.18	0	0.21	0.17	0.14
C3	0.17	0.13	0	0.17	0.14
C4	0.14	0.11	0.15	0	0.08
C5	0.04	0.05	0.07	0.05	0

Table 27: Construction of a fuzzy total-relation matrix (T)

	C1			C2			C3			C4			C5		
C1	0	0	0	-0.12	0.33	0.12	0.18	0.45	0.16	0.17	0.48	0.15	-0.51	0.25	0.11
C2	0.96	0.54	0.18	0	0	0	-0.30	0.83	0.21	1.03	0.54	0.17	-1.79	0.40	0.14
C3	0.03	0.42	0.17	0.37	0.36	0.13	0	0	0	0.33	0.46	0.17	0.93	0.37	0.14
C4	0.44	0.37	0.14	-0.14	0.29	0.11	0.12	0.40	0.15	0	0	0	0.28	0.08	0.08
C5	0	0	0.04	0.09	0.04	0.05	-0.04	0.10	0.07	0.17	0.03	0.05	0	0	0

Table 28: Defuzzification calculations

ماتریس دی‌فازی	C1	C2	C3	C4	C5	D
C1	0	0.66	1.24	1.29	0.10	3.29
C2	2.23	0	1.56	2.29	-0.85	5.23
C3	1.04	1.23	0	1.42	1.80	5.49
C4	1.32	0.54	1.07	0	0.52	3.45
C5	0.04	0.22	0.24	0.27	0	0.77
J	4.63	2.65	4.11	5.27	1.57	0.7292

Table 29: Cause and effect matrix

ماتریس علت معلولی	C1	C2	C3	C4	C5
C1	0	0	1	1	0
C2	1	0	0	1	1
C3	1	0	0	1	0
C4	1	0	1	0	0
C5	0	0	0	0	0

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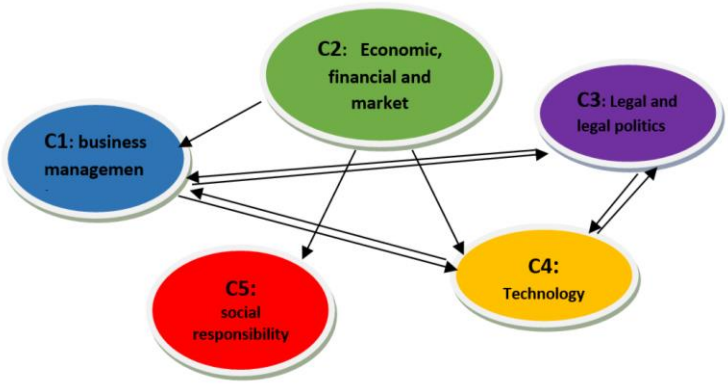

Table 28: Calculation of the importance of the components and the relations between the criteria

ماتریس روابط	C1	C2	C3	C4	C5
D+j	8.77	2.70	5.21	10.13	1.65
D-j	1.08	3.94	1.55	1.39	-1.03

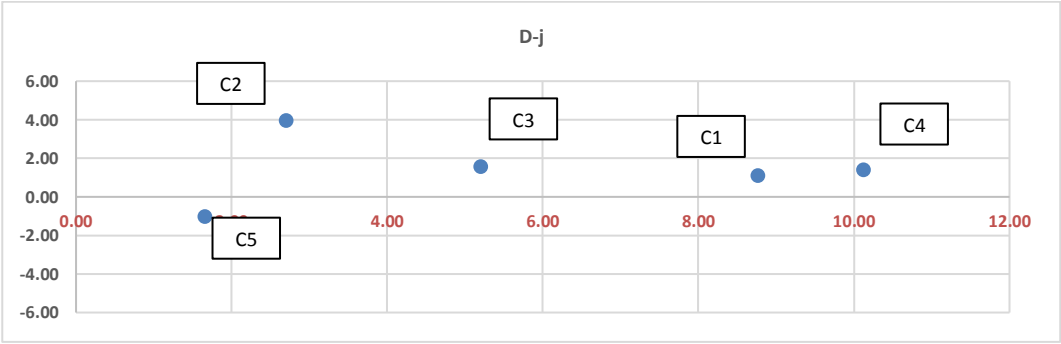

Figure: Chart of calculating the importance of the components and the relations between the criteria

As indicated in the results gained from the above tables, among the top 5 components from the expert opinion using fuzzy Delphi method and also the pairwise comparison of these 5 components by experts one by one, the results of this study demonstrate that the larger the vertical axis J + D, it will have the most interaction with others and the smaller the vertical axis J + D, it will have the least interaction with others. The results of classification for the factors influencing the digital banking risk management on the basis of the above figure represent that factors of C1, C2, C3, and C4 require a higher level of focus relative to factors C5.

Conclusions & Suggestions

In this study, after three stages, experts 'opinions on the importance of risk management components and experts' consensus and component prioritization were achieved. Using the optimal Pareto Principle, 80/20 Rule, the 20% effective risk management index in digital banking, which gained first to sixth ranks in terms of experts 'opinions, was explored. With regard to the obtained values as well as the values of (D-J), (D + J) and the number of output and input arrows of each criterion and considering the Fuzzy DEMATEL hypotheses, the conclusion was reached. Finally, the level of influence and impact, as well as the intensity of influence and impact (cause and effect relationship) of the criteria, are expressed as follows.

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1) Business management (C1): It is a criterion that affects the criteria (C3 and C4) and is affected by the criteria of C2, C3, and C4. In accordance with the formula of fuzzy DEMATEL technique, as (D + J) = 8.77 and (D-J) = 1.08, so one can argue that the criterion (C1) is in the second rank of cause factors and is also in the group of effect factors.
2) Economic, financial and market (C2): It is a criterion that affects the criteria (C1, C4, C5) and is not affected by any criteria. In accordance with the formula of fuzzy DEMATEL technique, as (D + J) = 2.7 and (D-J) = 3.94, so one can argue that the criterion (C2) is in the group of cause factors with the fourth degree of importance relative to other factors.
3) Political, legal and legislative (C3): It is a criterion that affects the criteria (C1 and C4) and is affected by the criteria (C1, C4). In accordance with the formula of fuzzy DEMATEL technique, as (D + J) = 5.21 and (D-J) = 1.55, so one can argue that criterion (C3) is in the group of cause and effects criteria.
4) Technology (C4): It is a criterion that affects the criteria (C3, C1) and is affected by the criteria (C2, C1 and C3). In accordance with the formula of fuzzy DEMATEL technique, as (D + J) = 10.13 and (D -J) = 1.39, so one can argue that criterion (C4) has the most interaction with other factors and is in the first rank of effectiveness in terms of cause and effect.
5) Social responsibility (C5): It is a criterion that is affected by criterion C2. In accordance with the formula of fuzzy DEMATEL technique, as (D + J) = 1.65 and (D-J) = - 1.03, so one can argue that the criterion (C5) is in the first rank of effects factor and the main effect of the research model and enjoys the utmost importance.

Regarding the results of analyzing the fuzzy DEMATEL technique, factors C1, C2, C3, C4 require a higher level of focus than factors C5. The factors of the first group have a lot of interaction with other factors and are of special importance. Besides, in this group, which is also called the cause group (credit risk, inability, and micro-attitude and lack of professional knowledge of the board and managers in the field of information technology and change in government policies) are taken into account as the most important factors, respectively. In the other group, which is called the effect group, it is the least important factor compared to other factors in the field of social responsibilities (the emergence of new non-banking players in the banking system in the form of financial technology (FinTech) or startups). It is evident that the identification and classification of these factors can be beneficial in decision-making and executive action for risk management in the digital banking sector via specifying the influence of one component on other components. Similar to any other research and thesis, this study has some limitations, the most important of which are problems associated with cross-sectional research, available resources, lack of similar investigations.

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