Iranian Journal of Insurance Research, 15(S1), 87-102, Special Issue, 2026, Serial #59

Iranian Journal of Insurance Research
(IJIR)

Homepage: https://ijir.irc.ac.ir/?lang=en

Insurance Research Center (IRC)

ORIGINAL RESEARCH PAPER

Gap Analysis of Novel Financial, Technological, and Governance Tools for Natural Disaster Risk Management in Iran

Somaieh Babaei[1,*], Shamsallah Salami[2], Najmeh Molaei[3]

[1] *PhD Graduate, Economic, Management and Economics, Science and Research Branch, Islamic Azad, Tehran, Iran.*

[2] *PhD Graduate, Management, Ghaemshahr Branch, Islamic Azad, Tehran, Iran.*

[3] *PhD Student, ECO Institute of Higher Education, Allameh Tabataba'i University, Tehran, Iran.*

ARTICLE INFO

Article History:
Received: 21 December 2025
Final revision: 18 February 2026
Accepted: 17 May 2026
Early online access: 17 May 2026
Published: 23 September 2026

Keywords:
Disaster risk management
Full consistency method (Fucom)
Gap analysis
Natural disasters
Resilience

*Corresponding Author:
Email: S.babei@srbiai.ac.ir
Phone: +98 9126786233
ORCID: 0000-0003-3250-6666

DOI: 10.22056/ijir.2026.S1.08

ABSTRACT

BACKGROUND AND OBJECTIVES: In recent decades, the global community has witnessed a marked increase in both the intensity and frequency of natural disasters, resulting in catastrophic human and economic losses. Iran, located in a region characterized by high seismic and climatic risk, faces unique challenges in disaster risk management. Conventional disaster management frameworks predominantly emphasize post-disaster recovery, often neglecting proactive risk-reduction strategies. Therefore, integrating modern financial and insurance mechanisms with advanced technological solutions is a strategic necessity. This study aims to conduct a comprehensive gap analysis and prioritize disaster risk management strategies in Iran, with a particular focus on incorporating innovations in financial instruments, technology, and governance to address existing operational deficiencies. By evaluating the current infrastructure and operational effectiveness of the Natural Disaster Insurance Fund (NDIF), this research seeks to provide a roadmap for transforming Iran's disaster management system from a reactive model into a resilience-oriented, proactive framework.

METHODS: This descriptive-analytical study employed both qualitative and quantitative approaches. The research framework was operationalized through a self-administered questionnaire comprising six dimensions and 38 initial indicators. The statistical population included 30 experts and specialists from the NDIF, the Climate Research Center, and the International Institute of Earthquake Engineering and Seismology. Participants were selected through purposive sampling on the basis of their expertise in insurance, disaster risk management, and modern financial instruments. In the first stage, field experts rigorously assessed the content validity of the questionnaire, resulting in refinement and reduction of the indicators to 35 final items. Internal consistency and reliability were confirmed using Cronbach's alpha, yielding a total coefficient of 0.85. Data normality was examined using the Kolmogorov-Smirnov test, which indicated a non-normal distribution; consequently, the non-parametric binomial test was used to verify the research hypotheses and assess the suitability of the proposed dimensions. In the subsequent stage, the Full Consistency Method (FUCOM), a modern multi-criteria decision-making tool, was implemented in a Python programming environment to calculate weight values. FUCOM was selected for its superior ability to handle expert judgments with a lower deviation rate than traditional methods such as AHP.

FINDINGS: The binomial test confirmed that the technological, financial, and governance dimensions are essential for natural disaster risk management in Iran. The gap analysis revealed a dual reality: while conventional reactive approaches and structural/physical infrastructure have reached relative maturity, significant gaps persist in modern risk management domains. Critical deficiencies were identified in the integration of advanced technologies, including Early Warning Systems (EWS) and big data analytics, as well as in the financial sector's use of contemporary risk-transfer instruments such as Catastrophe Bonds (Cat Bonds) and blockchain-based smart insurance contracts. FUCOM analysis provided precise prioritization of strategic phases, indicating that the "pre-occurrence" or "prevention and preparedness" phase holds absolute priority with a dominant weight of 0.648. This finding underscores the urgent need to transition from a reaction-oriented (ex post) system to a proactive, risk-oriented (ex ante) framework. Among the specific indicators, "Blue Resilience and Emergency Water Supply" (C1312) emerged as the highest-priority item (weight 0.096), followed by "Land Use Planning and Hazard Zoning" (C1311) with a weight of 0.083. The FUCOM model demonstrated exceptional mathematical precision, with a consistency rate (deviation factor) of 0.0018, reinforcing the reliability of these prioritizations for policymaking. Based on these results, a comprehensive conceptual model for natural disaster risk management was developed according to the priorities derived from FUCOM, highlighting the central role of technological, financial, and governance innovations.

CONCLUSION: This study concludes that the traditional passive role of insurance and financial institutions in Iran is no longer sufficient to cope with the growing risks posed by natural hazards. There is a strategic imperative to redefine the functional role of the NDIF and other stakeholders, transforming them from mere compensators of losses into proactive leaders in risk governance. Institutionalizing technological innovations, such as blockchain to ensure transparency in payments and big data for real-time risk assessment, is essential for this transition. Prioritizing the pre-disaster phase, as highlighted by the FUCOM analysis, will reduce future economic liabilities and significantly enhance national resilience and sustainable development. The findings provide a scientifically validated roadmap for policymakers, emphasizing that proactive, technology-driven, and financially innovative approaches are critical for effective disaster risk reduction in Iran, while also offering a scalable framework transferable to other developing economies facing similar climate risks.

This is an open access article under the CC BY license (http://creativecommons.org/licenses/by/4.0/).

INTRODUCTION

Natural disasters (e.g., earthquakes, floods, droughts, wildfires) severely disrupt human, economic, and environmental systems, causing widespread damage. The defining characteristics of these events are their suddenness, high destructive power, and the impossibility of complete prevention. In academic literature, natural disasters are classified into two primary categories: (1) "rapid-onset hazards," such as earthquakes and storms, and (2) "slow-onset hazards," such as drought and subsidence (Alexander, 2000). According to the United Nations Office for Disaster Risk Reduction (UNDRR), natural disasters escalate into humanitarian crises when community vulnerability is high and the capacity for effective response is limited (UNDRR, 2022).

In recent decades, the intensity, frequency, and global scope of natural disasters have increased notably, exerting multifaceted effects on economic, social, and environmental dimensions. Climate change, uncontrolled urbanization, and population concentration in high-risk areas are primary factors that have weakened community resilience to these events (CRED, 2023). Reports from the World Bank indicate that average annual losses from natural disasters have exceeded USD 300 billion in the last decade, predominantly in developing or low-resilience countries; however, only a fraction of these costs were covered by insurance. This underscores the necessity of investing in disaster risk management, particularly through financial and insurance instruments. Natural disasters are no longer solely an environmental or humanitarian issue but are viewed as a major economic challenge requiring cross-sectoral and technological policies (Government of Mexico & World Bank, 2012).

In response, many nations—particularly those that have experienced severe natural disasters—have moved toward designing and implementing innovative disaster risk management models. These models generally combine innovative financial tools, such as Catastrophe Bonds (Cat Bonds), compulsory insurance, and risk swaps, with technology-driven mechanisms, including smart Early Warning Systems (EWS). Through the participation of governmental bodies, the private sector, and local communities, these frameworks aim to increase economic resilience and accelerate post-crisis recovery (World Bank, 2014).

In developing countries, the lack of resilient insurance and financial infrastructure imposes a dual financial burden on governments and citizens. Furthermore, the escalation of climate change impacts and the increased severity and frequency of natural events have compelled countries to design new financial structures for disaster risk management. These structures are built upon multilayered coverage, capital market instruments like Cat Bonds, technological innovation, catastrophe risk modeling, and multi-stakeholder participation (OECD, 2016; Swiss Re Institute, 2020).

Given its broad climate diversity and specific geographical location, more than 80% of Iran's territory is exposed to one or more types of natural disasters (JICA & CEST, 2000). Statistics indicate that in the past 20 years alone, tens of billions of dollars in losses from natural disasters have been imposed on the country, with the major burden falling on public resources and uninsured citizens. Over the last century, the Iranian government has spent approximately USD 29 billion on disaster-related costs. Droughts, earthquakes, and floods have imposed the highest expenditures—exceeding USD 14 billion, 6.9 billion, and 6.1 billion, respectively—including costs from the Tabas (1978), Bam (2003), and Kermanshah (2017) earthquakes, as well as the 2019 floods.

Historically, the majority of Iranian government expenditure on disasters has been directed toward involuntary costs, including response and recovery. Mitigation and preparedness remain two critical phases of disaster management that receive minimal shares of national budgeting (Seddighi & Seddighi, 2020). Economically, the compensation system has remained dependent on public government budgets, and a sustainable, pre-funded financial cover for disasters has yet to be established. During the 2019 Golestan and Lorestan floods and the 2023 Khoy earthquake, the government was compelled to allocate emergency credits without having sustainable resources for reconstruction or loss coverage (Safari et al., 2019).

Numerous laws and regulations have been enacted in the field of disaster management in Iran, including the Law on the Formation of the National Committee for Natural Disaster Reduction (Islamic Consultative Assembly Research Center [ICARC], 1991), the Comprehensive Relief and Rescue Plan (ICARC, 2003), the Law on the Structure of the Comprehensive Welfare and Social Security System (ICARC, 2004), and the Law on the Formation of the National Disaster Management Organization (ICARC, 2008). Furthermore, the Law on the Establishment of the Natural Disaster Insurance Fund (NDIF) (ICARC, 2015) and the New Disaster Management Law (ICARC, 2019) were approved. Despite the emphasis of these statutes on the necessity of prevention and risk reduction, serious challenges persist regarding financial resource mobilization, insurance executive mechanisms, and the allocation of funds for responding to unforeseen disasters, all of which have hindered the full realization of these legal objectives (Tabrizi, 2021).

The country's crisis management systems are predominantly focused on post-disaster response; consequently, tools for forecasting, early warning, and risk reduction are inadequately integrated into executive and policy-making structures. The lack of a comprehensive database, poor coordination among responsible institutions (such as the National Crisis Management Organization, the Red Crescent, the Central Insurance of Iran, and relevant ministries), and the absence of a comprehensive financial coverage system constitute fundamental challenges (Moradifar et al., 2021).

With the ratification of the Natural Disaster Insurance Fund for Buildings Act ([ICARC], 2020), the financial risk management system in Iran entered a new phase. This fund commenced operations in early 2021 with the objective of providing basic coverage to all residential units equipped with legal electricity connections. Under the mechanisms envisioned in this legislation and higher-level documents, the owners' share of the insurance premium is collected through monthly electricity bills and deposited into the Fund's account. Although the ceiling for basic disaster insurance coverage for each residential unit has been set at 200 million Tomans in recent years, the evaluation of credit allocation trends indicates that the full realization of these objectives depends on the timely provision of the government's share (pursuant to Article 10 of the Law on Regulating a Part of the Government's Financial Regulations) and the optimal management of resources derived from subscribers' premiums (Payab, 2023).

The present study is categorized as applied and developmental research. It is conducted using a descriptive-analytical and comparative approach, utilizing field data gathered through expert questionnaires. The primary focus of this study is to analyze the economic and insurance models of natural disaster risk management in leading countries and to evaluate Iran's capacities and challenges in this area. To achieve this goal, the research conceptually examines successful international experiences in natural disaster risk management across three levels: technological, financial, and policy-making (Creswell, 2014).

Documentary analysis was used to gather theoretical, empirical, and governance studies. Reviewed sources include official reports from international bodies, such as the World Bank, International Monetary Fund (IMF), Organization for Economic Co-operation and Development (OECD), Swiss Re Institute, the UNDRR, and the International Disaster Database (EM-DAT). Additionally, peer-reviewed articles were utilized to examine innovations, novel financial tools, and applicable technologies in the field of disaster insurance. A comparative analysis of the experiences of selected countries—Japan, the United States, New Zealand, Turkey, France, Switzerland, Mexico, and India—was performed. These countries were selected due to their history of frequent disasters and the development of diverse financial and insurance systems against catastrophic risks, including NDIF-type funds. The analytical approach focuses on the comparative evaluation of financial and insurance coverage layers, determining Iran's position, and extracting governance gaps and opportunities (Safari et al., 2019).

International experience demonstrates that shifting from traditional compensation-oriented approaches toward modern disaster risk management frameworks—grounded in innovative financial instruments, advanced technologies, and integrated governance structures—plays a critical role in reducing economic vulnerability and strengthening national resilience. In this context, Iran's current disaster risk management system faces fundamental challenges related to limited insurance penetration, insufficient application of risk transfer mechanisms, and inadequate integration of technology-driven solutions.

Accordingly, the central problem addressed in this study concerns the structural transformation of Iran's natural disaster risk management framework through the effective utilization of modern insurance models, innovative financial instruments, and emerging technological capacities. The main research question is formulated as follows: How can Iran's natural disaster risk management system be restructured through the integration of modern insurance models, innovative financial instruments, and advanced technologies to reduce disaster-related losses, strengthen national resilience, and enhance the effectiveness of the NDIF?

LITERATURE REVIEW

Regarding natural-disaster-related insurance, resilience policies encompass a range of measures, including the design of multilayered insurance coverage models, the development of EWS, infrastructure strengthening, tax incentives for risk reduction, public education, and improved risk governance. According to many researchers, the most important characteristics of successful resilience policies are "predictability" and "adaptive learning," which are reflected in data-driven policymaking (Bahadur et al., 2013).

One of the main challenges in natural disaster risk management in Iran is the weak linkage between emerging technologies and risk-reduction policies. Although many countries use technologies such as AI-based warning systems, big data, satellite imagery, and risk modeling, these technologies in Iran have largely

remained at the research-project stage and have not reached operational deployment (Safari et al., 2019). These shortcomings have kept the country's economic and social resilience to natural disasters at a low level.

Hamzeh & Banimostafa Arab (2022), in Research Report No. 151, examined the challenges facing the Natural Disaster Insurance Fund for Buildings in terms of financing, the lack of supplementary insurance, weak insurance penetration in high-risk areas, and the absence of a reinsurance mechanism. Furthermore, it proposed that the Fund's structure should be upgraded to a multilayered financial institution—with the capacity to attract international capital and transfer risks to financial markets—as a necessity for enhancing the country's economic resilience.

A review of national studies indicates that this emerging system faces challenges such as the lack of precise risk-assessment models, weak linkage with the capital market, the absence of a supplementary insurance strategy, and limited digital infrastructure. Furthermore, recent disaster experiences, including the 2019 floods and the Kermanshah earthquake, revealed the absence of a rapid warning system, the lack of an appropriate loss-assessment framework, and delays in payments. In the absence of multilayered financial models, the government is forced to finance emergency budgets from public resources, which weakens financial sustainability (Hamzeh & Banimostafa Arab, 2021). Following the review of international models, an innovative model for enhancing the country's economic resilience to natural disasters is presented across three axes: financial, technological, and policy-making.

Natural Disaster Risk Management from an Economic and Financial Perspective

Multilayered financial coverage systems encompass basic insurance, supplementary insurance, emergency reserve funds, and capital market-based risk transfer instruments (Cummins & Mahul, 2009). Theoretical studies demonstrate that combining traditional insurance tools with innovative instruments—such as Cat Bonds and catastrophe swaps—offers significant advantages in enhancing financial response capacity (Ghesquiere & Mahul, 2010). In a comprehensive report, the World Bank (2017) emphasized the importance of designing multi-tiered insurance systems, suggesting that nations utilize a combination of compulsory insurance, reinsurance, risk securitization, and government budgetary support. Furthermore, an OECD (2020) study indicated that countries that combined incentive policies for retrofitting and broad insurance coverage with advanced financial instruments achieved faster reconstruction and greater reductions in financial pressure. Designing preemptive financial structures, such as Cat Bonds, enables nations to secure necessary resources before a disaster occurs and access them immediately upon its onset. The parametric model of these bonds, implemented in Mexico and the Caribbean, is recognized as a successful international framework due to its rapid payment speed and the elimination of complex loss-assessment processes (World Bank, 2014). Catastrophe swaps serve as a viable solution for managing large-scale natural risks, particularly for countries that lack the capacity to issue Cat Bonds (World Bank, 2021).

Natural Disaster Risk Management from a Technological and Data-Driven Perspective

Concurrent with the development of financial tools, the integration of emerging technologies into natural disaster risk management has gained prominence. Technologies—including catastrophe loss modeling, Artificial Intelligence (AI)-based predictive analytics, and the Internet of Things (IoT) for real-time risk monitoring—have become fundamental to risk management frameworks in developed nations (Swiss Re Institute, 2020). This dimension encompasses the application of loss modeling, remote sensing, satellite data, AI, blockchain, and spatial data infrastructure in assessing, forecasting, and settling natural disaster claims (Lot & Haegeli, 2021). Furthermore, the theory of data-driven governance emphasizes that the utilization of spatial data, forecasting algorithms, and EWS is critical for effective disaster response policies (World Bank, 2014). In terms of technological adoption, a report by the Swiss Re Institute (Lot & Haegeli, 2022) indicates that insurance providers in Europe and East Asia are increasingly leveraging data-driven platforms, AI, and blockchain to enhance risk assessment, pricing, and claims settlement processes.

Within the technological domain, OECD (2017) research highlights how innovations—such as blockchain for policy issuance, AI for loss assessment, and big data for risk modeling—enhance the transparency and efficacy of insurance structures. At the regional level, research by the Swiss Re Institute (Lot & Haegeli, 2021) emphasizes the strategic importance of global reinsurance in managing catastrophic risks. The authors underscore that the implementation of catastrophe risk models in developing nations is essential for designing risk-proportionate premiums, noting that limited access to accurate data remains a primary barrier to system development across the Middle East, including Iran.

In the context of natural disasters, InsurTech plays a pivotal role in prediction, rapid response, and resource allocation. For instance, integrating satellite data with weather forecasting models and real-time loss

analysis—such as for earthquakes or floods—allows insurers to facilitate automated, rapid claims payments (OECD, 2017). Consequently, natural disaster insurance funds can augment their risk-absorption capacity and improve performance during catastrophic events by adopting these advanced technologies.

Natural Disaster Risk Management from a Governance and Policy-making Perspective

This dimension entails the design of multi-level governance mechanisms, Public-Private Partnerships (PPP), retrofitting incentive systems, data-driven governance, and the enhancement of institutional resilience (OECD, 2020). Natural Disaster Insurance Funds (NDIF), by utilizing a multilayered approach to risk coverage, play a pivotal role in increasing the economic resilience of households and mitigating the government's financial burden during disasters. In developed nations, resilience policies are primarily pursued through medium- and long-term programs that necessitate the active participation of the private sector, local communities, and international organizations. For instance, the European Union (EU) operates under the EU Strategy on Adaptation to Climate Change, which regulates resilience policies across finance, energy, infrastructure, and insurance sectors (European Commission, 2021). The implementation of such policies is a vital necessity, particularly in countries like Iran that are exposed to diverse natural disasters.

International experiences indicate that the success of such funds depends on the simultaneous implementation of complementary policies, including retrofitting, tax incentives, private sector participation, and innovative financial tools such as Cat Bonds and accurate risk modeling (Lot & Haegeli, 2022). The World Bank Group's Climate Action Plan (World Bank, 2021) rests on three primary pillars: emission reduction, adaptation and enhanced resilience, and accelerating a just transition. Strategies under emission reduction include installing new renewable energy capacity (e.g., wind and solar), increasing energy efficiency in industries and buildings, and reducing greenhouse gas emissions through improved public transport. Adaptation and enhanced resilience strategies include protecting coastal areas from flooding and erosion, increasing access to potable water in drought-prone regions, and constructing climate-resilient infrastructure. Finally, the "just transition" pillar encompasses the development of training and skill-building programs for workers in carbon-dependent industries, as well as the design of social protection systems for communities vulnerable to economic shifts.

Successful International Experiences in Natural Disaster Risk Management with a Focus on Natural Disaster Insurance Funds

Historical analyses of Iran's disaster management landscape reveal that in the early 20th century, the absence of formal structures resulted in responses that were mostlylocalized, fragmented, and reliant on traditional public aid. Government intervention was infrequent and reactive—seen only in instances such as the 1962 Buyin Zahra or 1978 Tabas earthquakes—and lacked centralized planning (Berberian, 1976; Vita-Finzi, 1982). Despite the subsequent launch of the "Natural Disaster Insurance Fund for Buildings," data from Central Insurance of I.R. Iran (CII – Insurance Supervisory and Regulatory Authority) indicate that the majority of losses from earthquakes, floods, and other natural disasters remain uninsured, leaving the financial burden of reconstruction primarily to the government. Furthermore, advanced mechanisms such as risk securitization, parametric insurance, or hybrid instruments have yet to be integrated into Iran's executive framework (Hamzeh & Banimostafa Arab, 2021).

A review of leading nations in natural disaster risk management demonstrates that the efficacy of their insurance and financial systems stems from a combined, multilayered approach. These international experiences serve as a comparative reference point for analyzing structural gaps in Iran. Nations such as Japan, the United States, Türkiye, New Zealand, Switzerland, Mexico, and France have successfully developed market-based risk financing structures while reducing direct reliance on public budget resources by adopting multilayered, composite strategies.

Japan, due to its high seismicity, maintains an advanced risk management system that ensures high preparedness through a combination of compulsory earthquake insurance, government participation in reinsurance, investment in risk modeling, early warning infrastructure, and resilient construction (OECD, 2018-a; World Bank, 2014). By utilizing this earthquake insurance system, property owners secure coverage through modest premiums. Furthermore, retrofitted infrastructure and earthquake warning systems have played a key role in mitigating human and material losses. Japan's government also emphasizes investment in remote sensing, real-time seismic analysis, and public education (Shaw et al., 2025). The country is frequently cited as an advanced model that leverages AI-based systems and big data for real-time loss assessment and resource allocation (OECD, 2018a). Studies by Gurenko (2019) and Clarke et al. (2015) examined successful experiences in Türkiye, Japan, and Mexico, emphasizing that the nexus between insurance, public investment in

retrofitting, and capital market instruments is critical to program success.

The New Zealand Earthquake Commission (EQC), one of the oldest and most sustainable mechanisms globally, has been recognized for its legal continuity, professional resource management, and support for resilient infrastructure (Wood & Ambler, 2016). This model consists of three coverage layers: basic government insurance, supplementary private insurance, and international reinsurance. By collecting earthquake premiums via fire insurance and utilizing these funds for post-disaster reconstruction—with the government acting as the reinsurer—New Zealand ensures rapid claims processing and effective reconstruction (GFDRR, 2014).

In 1996, the government of Mexico established the Natural Disaster Fund (*Fondo de Desastres Naturales*; FONDEN), financed by public budgets and innovative instruments such as Cat Bonds. Upon the occurrence of a disaster and the fulfillment of parametric triggers, international investors are obligated to cover losses. This innovative tool increases the speed of financing while reducing pressure on the public budget, serving as a template for other Latin American nations (World Bank, 2014).

Türkiye, with the launch of the Turkish Catastrophe Insurance Pool (TCIP) in 2000, developed an integrated system based on compulsory insurance, seismic engineering data, and collaboration with international reinsurers (OECD, 2018a). Following the devastating earthquakes of the 1990s, Türkiye mandated earthquake insurance for all residential properties, with premiums collected at variable rates based on regional risk. The government acts as the ultimate reinsurer, and the TCIP benefits from international reinsurance capacity (World Bank, 2017). This entity is recognized as a successful catastrophe insurance model for developing nations due to its independent structure and use of remote sensing (Swiss Re Institute, 2020).

France's Catastrophe Naturelle (CATNAT) model mandates that all property insurance policies include natural disaster coverage, with the government serving as the ultimate guarantor (Arnold-Dwyer, 2025). Premium rates are uniform, and losses are compensated rapidly within the legal framework (Faure & Hartlief, 2003). This structure is widely considered a successful European model for automatic, comprehensive coverage. Similarly, India has expanded coverage in rural areas by developing index-based insurance for drought and utilizing satellite technology for loss assessment (ADB & OECD, 2020).

The United States utilizes a multi-sectoral structure, including the National Flood Insurance Program (NFIP), investment in Cat Bonds, and collaboration with private entities (FEMA, 2023). Some states, such as California, leverage Cat Bonds to finance earthquake insurance, demonstrating the importance of PPPs and capital market instruments in ensuring financial flexibility (Kunreuther et al., 2009). Switzerland integrates natural disaster coverage into property insurance through a participatory system involving cantons, private firms, and citizens, achieving high payout rates. The Swiss Re Institute, acting as a global reinsurer, supports widespread disaster coverage through rigorous catastrophe risk modeling (ADB & OECD, 2020).

In Iran, challenges—including a lack of supplementary coverage, limited resources, and insufficient integration of advanced technologies like EWS —persist (Hamzeh & Banimostafa Arab, 2021; Surminski, 2022). The operational model of the "Natural Disaster Insurance Fund for Buildings" is conceptually aligned with successful international experiences such as Türkiye's TCIP and New Zealand's EQC, as it relies on compulsory premiums, government support, and domestic investment (OECD, 2018b). However, as international evidence suggests, the long-term success of such a fund depends on the simultaneous implementation of complementary policies, including retrofitting, tax incentives, private sector participation, and the use of innovative financial tools like Cat Bonds and accurate risk modeling (Lot & Haegeli, 2021, 2022).

RESEARCH METHODOLOGY

Statistical Population and Sampling Method

Given the specialized nature of the subject and the complexity of modern tools in natural disaster risk management, purposive sampling was employed. The experts were selected based on three criteria: possession of an advanced degree in a related field, at least 10 years of executive experience in the insurance industry or related sectors, and specialization in Fintech and disaster monitoring.

In the first stage, 12 senior managers and experts were selected to localize the indicators. In the final stage, the questionnaire was distributed among 30 key elites from the Natural Disaster Insurance Fund (NDIF), the insurance industry, the International Institute of Earthquake Engineering and Seismology (IIEES), and the Atmospheric Science and Meteorological Research Center (ASMERC). The demographic characteristics of the sample are presented in Table 1.

The primary instrument of this study was a self-administered questionnaire derived from the literature

Table 1. Demographic Characteristics of the Statistical Sample

No.	Indicator	Category	Frequency (N)	Percentage (%)
1	Education	Higher Education	30	100%
2	Executive Experience	10 to 15 years	12	40%
		15 to 20 years	10	33%
		More than 20 years	8	27%
3	Main Specialization	Insurance	15	50%
		Disaster Risk Management	8	27%
		Modern Financial Tools (Fintech)	7	23%

Table 2. Overall Reliability of Research Components based on Cronbach's Alpha

No.	Dimension (Component)	Number of Items	Cronbach's Alpha Value
1	Technological (Pre-occurrence)	6	0.82
2	Financial (Pre-occurrence)	6	0.84
3	Policy-making (Pre-occurrence)	11	0.89
4	Technological (Post-occurrence)	3	0.81
5	Financial (Post-occurrence)	4	0.83
6	Policy-making (Post-occurrence)	5	0.8
Total	Risk Management Questionnaire	35	0.85

review. In the first stage, the initial questionnaire was presented to the experts to assess content validity. Following their feedback, structural revisions were made. By merging overlapping indicators—such as those in the areas of blockchain and parametric insurance—the number of indicators was refined from 35 to 38 final items.

Reliability of the Measurement Instrument

To assess the reliability of the research instrument, Cronbach's alpha was used. The analysis was conducted using SPSS version 22, and the detailed results for each of the six dimensions are presented in Table 2. As shown in the table, the overall reliability coefficient of the questionnaire was 0.85. Because the alpha values for all dimensions, as well as for the entire questionnaire, exceed the 0.7 threshold, the measurement instrument demonstrates high reliability, and the items exhibit satisfactory internal consistency in explaining the research variables.

In order to explain the conceptual model and determine the causal relationships among the identified dimensions, the research hypotheses were formulated as follows:

- **Hypothesis1 (H1):** Pre-occurrence technological tools, such as EWS and big data, have a positive and significant impact on natural disaster risk management.
- **Hypothesis2 (H2):** Pre-occurrence financial tools, such as Cat Bonds and reinsurance, have a positive and significant impact on natural disaster risk management.
- **Hypothesis3 (H3):** Pre-occurrence governance and sovereign policies, such as land-use planning and construction regulations, have a positive and significant impact on natural disaster risk management.
- **Hypothesis4 (H4):** Post-occurrence technological tools, such as drones and geographic information systems (GIS) for damage assessment, have a positive and significant impact on natural disaster risk management.
- **Hypothesis5 (H5):** Post-occurrence financial tools, such as reconstruction loans and insurance payouts, have a positive and significant impact on natural disaster risk management.
- **Hypothesis6 (H6):** Post-occurrence operational and sovereign policies, such as crisis management headquarters and response protocols, have a positive and significant impact on natural disaster risk management.

Data Analysis

Statistical Tests

The one-sample t-test was utilized to test the hypotheses when data followed a normal distribution; otherwise, the binomial test was employed. The Kolmogorov-Smirnov (K-S) test was initially conducted to examine the assumption of normality in the data distribution. Given that expert opinion data typically exhibit non-normal distributions, the results of this test determined whether non-parametric methods were appropriate for supplementary analyses. When examining data normality, the null hypothesis (H_0), stating that the data distribution for each variable is

normal, was tested at a 5% error level. Consequently, if the test statistic yielded a significance value exceeding 0.05, the null hypothesis of normality was not rejected. The statistical hypotheses were formulated as follows:

- H0: The data distribution for each variable is normal.
- H1: The data distribution for each variable is not normal.

Subsequently, the binomial test was utilized for quantitative content validity assessment and indicator screening. This test ensured that each of the 35 indicators was identified as a suitable factor from the experts' perspective at a significance level (Sig < 0.05) (Sarmad et al., 2022) and was qualified to enter the final weighting stage using the Full Consistency Method (FUCOM).

Determining Final Weights with the Full Consistency Method (FUCOM)

To facilitate the mathematical modeling process and track indicators during the weighting and ranking stages, unique identification codes were assigned to each dimension and indicator, as presented in Table 3. Weighting was performed at three levels: phases, dimensions, and indicators. After finalizing and coding the research indicators, FUCOM was utilized to derive precise weights with a minimal deviation rate. This method is a subset of Multi-Criteria Decision-Making (MCDM) models, operating based on pairwise comparisons and the optimization of mathematical models (Pamucar et al., 2018).

Implementation of the Full Consistency Method (FUCOM)

The implementation of FUCOM in this study is anchored in mathematical optimization, selected specifically to mitigate the challenge of inconsistency in pairwise comparisons. This process commences with the qualitative prioritization of the six dimensions; specifically, each of the 30 experts ranks the dimensions from most to least significant based on their perceived impact on natural disaster resilience:

$$C_{j(1)} > C_{j(2)} > \cdots > C_{j(k)}$$

The output of this stage forms the basis for constructing the experts' subjective priority vector. In the subsequent step, the analysis transitions from the qualitative to the quantitative phase, where comparative priorities (Ø) are calculated. In this stage, the relative superiority of each ranked criterion over the one immediately following it is determined. This index represents the coefficient by which one criterion is preferred over the next-ranked one:

$$\Phi = (\varphi_{1/2}, \varphi_{2/3}, \dots, \varphi_{k-1/k})$$

The primary advantage of FUCOM lies in its requirement for only $n-1$ comparisons, thereby avoiding the unnecessary and laborious redundant comparisons common in methods such as the Analytic Hierarchy Process (AHP). This approach enhances respondent concentration and the precision of the results. Finally, to extract the final weights, a mathematical optimization model is formulated. The primary goal is to maximize the consistency between the determined priorities such that the final weights (w_j) are calculated while satisfying the following mathematical conditions:

$$1.\ \frac{w_{j(i)}}{w_{j(i+1)}} = \varphi_{i/i+1}$$

$$2.1.\ \frac{w_{j(i)}}{w_{j(i+2)}} = \varphi_{i/i+1} \cdot \varphi_{i+1/i+2}$$

The final weights are computed under a minimum deviation rate (χ). The resulting optimization model is defined as:

$$\min \chi$$

$$s.t. \quad \left|\frac{w_{j(i)}}{w_{j(i+1)}} - \varphi_{i/i+1}\right| \le \chi \quad , \quad \left|\frac{w_{j(i)}}{w_{j(i+2)}} - (\varphi_{i/i+1} \cdot \varphi_{i+1/i+2})\right| \le \chi$$

$$\sum w_j = 1 \ , w_j \ge 0$$

This optimization model ensures that the extracted weights provide the most accurate representation of expert consensus and exhibit minimal systematic deviation in the final analysis of natural disaster risk management.

RESEARCH FINDINGS

Normality Test

If the data distribution is normal, the one-sample t-test is utilized to test the research hypotheses; however, if the distribution is not normal, the binomial test is employed.

Given the obtained significance levels (Sig.) presented in Table 4, the data distribution was found to be non-normal, necessitating the use of non-parametric tests. Consequently, the binomial test was employed to evaluate the research hypotheses.

Analysis of Disaster Risk Management Strategies using the Binomial Test

To evaluate the proposed hypotheses, the results of the binomial test are compiled and analyzed in Table 5.

Based on the results in Table 5, the significance level for all dimensions was below 0.05; thus, the null hypothesis (H0) was rejected, and the alternative hypothesis (H1), confirming the significance of the respective dimensions, was accepted. Consequently, all

Table 3. Indicators Extracted from Literature Review and Respective Codes

Natural Disaster Risk Management Strategies	Operational Definition and Strategic Objective	Code
Pre-occurrence Strategies (C1)		
Technological (C11)		
Development of Early Warning Systems (EWS)	Prediction and notification of hazards before occurrence	C111
Disaster Risk Modeling using Big Data, Machine Learning (ML), and Geographic Information Systems (GIS)	Identification of critical points using big data and ML	C112
Index-Based Premium Calculation	Compensation based on specific indices (e.g., earthquake intensity)	C113
Design of Specialized Natural Disaster Apps	Two-way communication between citizens and emergency centers	C114
Development of a National Disaster Risk Dashboard	Data integration for macro-level decision-making	C115
Continuous Monitoring via Sensors (Internet of Things [IoT]), Satellites, and Climate Indices	Real-time observation of environmental and atmospheric changes	C116
Financial (C12)		
Issuance of Catastrophe Bonds (Cat Bonds)	Risk transfer to international capital markets	C121
Expansion of Supplementary Natural Disaster Insurance	Reducing financial pressure on the government via the private sector	C122
Utilization of International Reinsurance	Global risk distribution and protection of national capital	C123
Designing a Multi-layered Financial Structure	Optimal resource allocation at different crisis levels	C124
Leveraging Blockchain for Payment Transparency and Speed	Transparency in resource distribution and contract management	C125
Incentive Tax Policies for Retrofitting	Encouraging the private sector to retrofit buildings	C126
Policy-making / Governance (C13)		
Public-Private Partnerships (PPP) in Disaster Management	Utilizing private sector capital for reconstruction	C131
Formulation of a Risk Data Governance System	Standardization and security of information exchange	C132
Promotion of Insurance Culture and Public Education	Increasing public participation in financial risk management	C133
Installation of New Renewable Energy Capacities	Reducing physical vulnerability through nature-based methods	C134
Increasing Energy Efficiency in Industries and Buildings	Reducing pressure on the grid during emergency conditions	C135
GHG Emission Reduction via Public Transport Improvement	Reducing emissions and facilitating emergency evacuation	C136
Protection of Coastal Areas against Flooding and Erosion	Combating coastal floods and land erosion	C137
Education and Skill-building Programs for Carbon-Dependent Workers	Enhancing the preparedness of the community and operational forces	C138
Social Protection Systems for Vulnerable Communities	Protective standards for the workforce during crisis conditions	C139
Dam Construction and Flood Diversion Channels	Flood diversion control and reduction of destructive power	C1310
Land-Use Planning	Preventing construction in high-risk zones	C1311
Enhancing Access to Drinking Water in Drought-Prone Areas	Measuring infrastructure resilience against climate change	C1312
Post-occurrence Strategies (C2)		
Technological (C21)		
Satellite Imagery for Damage Estimation	Accelerating the expert assessment process and reducing human error	C211
Utilizing Drones for Damage Assessment	Rapid estimation of destruction levels and reconstruction prioritizing	C212
Geographic Information Systems (GIS)	Analyzing damage patterns for principled reconstruction	C213
Financial (C22)		
Reconstruction Loans	Banking facilities for the renovation of damaged units	C221
Government Emergency Aid	Direct financial support for uninsured victims	C222
International Financial Assistance	Creating cash reserves to cope with financial shocks	C223
Insurance Company Payouts	Providing rapid liquidity to return to business/activity	C224
Policy-making / Governance (C23)		
Emergency Communication Networks	Maintaining communication stability at the moment of disaster	C231
Formation of Crisis Management Headquarters	Unified command and inter-agency coordination	C232
Emergency Response Protocols	Provision of immediate shelter, psychological support, and livelihood aid	C233
Evacuation Systems	Safely guiding the population away from high-risk points	C234

Table 4. Results of the Kolmogorov-Smirnov (K-S) Test

		Dimension 1	Dimension 2	Dimension 3	Dimension 4	Dimension 5	Dimension 6
N (Sample Size)		30	30	30	30	30	30
Normal Parameters	Mean	2.47	2.13	2.47	2.67	2.3	2.43
	Std. Deviation	1.167	0.819	0.973	0.758	0.877	0.774
Most Extreme Differences	Absolute	0.455	0.298	0.351	0.310	0.401	0.312
	Positive	0.455	0.298	0.351	0.310	0.401	0.312
	Negative	-0.278	-0.235	-0.249	-0.190	-0.299	-0.221
Test Statistic		0.455	0.389	0.401	0.298	0.310	0.351
Asymp. Sig. (2-tailed)		0.000c	0.000c	0.000c	0.000c	0.000c	0.000c

Table 5. Binomial Test Results for Research Dimensions

Questions	Group	N (Sample Size)	Observed Proportion	Test Proportion	Exact Sig. (2-tailed)	Result
Dimension 1	Group 1	≤3	24	0.8	0.5	0.001
	Group 2	>3	6	0.2		
	Total		30	1		
Dimension 2	Group 1	≤3	28	0.93	0.5	0
	Group 2	>3	2	0.07		
	Total		30	1		
Dimension 3	Group 1	≤3	26	0.87	0.5	0
	Group 2	>3	4	0.13		
	Total		30	1		
Dimension 4	Group 1	≤3	25	0.83	0.5	0
	Group 2	>3	5	0.17		
	Total		30	1		
Dimension 5	Group 1	≤3	28	0.93	0.5	0
	Group 2	>3	2	0.07		
	Total		30	1		
Dimension 6	Group 1	≤3	27	0.9	0.5	0
	Group 2	>3	3	0.1		
	Total		30	1		

six research sub-hypotheses (H1 to H6) were supported. These findings indicate that modern financial, technological, and governance tools—both in the pre-occurrence (ex ante) phase and in the post-occurrence (ex post) phase—are statistically significant dimensions for natural disaster risk management in Iran from the experts' perspective. Following the confirmation of the significance and suitability of all 35 indicators through the binomial test, the process of determining the relative weights of these indicators was executed using the FUCOM model.

Gap Analysis and Categorization of Existing Strategies

By analyzing the experts' opinions, the status of disaster risk management strategies in Iran can be categorized into three operational levels. This analysis explains the gap between the "current state" and the "desired state" from the perspective of the elites. Identifying these gaps serves as a precursor to the FUCOM mathematical model, which determines the importance and weight of each indicator in achieving the strategic goals of disaster risk management.

Response-Oriented and Physical Strategies (Relatively Desirable Status)

A number of strategies, particularly in technical-infrastructural fields and post-occurrence funding mechanisms, are evaluated as being in a "medium to good" state. This suggests that the Iranian management system possesses well-established traditional approaches in the response and recovery sector. The strategies in this category include:

- Continuous monitoring using sensors IoT and GIS (C116 and C213).
- Structural measures such as dam construction, canalization, and land-use planning (C1310 and C1311).
- Emergency response mechanisms, including crisis management headquarters, response protocols, and reconstruction loans (C221, C232, and C233).

Intersectoral Partnerships and Risk Distribution (Weak Status)

Strategies focusing on structural changes and intersectoral partnerships are evaluated as "weak". This deficiency indicates an underutilization of capital market capacities and the private sector to reduce government reliance on public budgets. Key examples include:

- Weakness in expanding supplementary natural disaster insurance (C122).
- Incomplete implementation of PPP models (C131).
- Lack of success in reducing greenhouse gas emissions through public transport improvements (C136).

Modern Technological and Financial Strategies (Undesirable Status and Strategic Gap)

The absence of advanced technological tools in the pre-occurrence phase and modern financial instruments in the risk transfer phase constitutes the most serious gap in Iran's risk management system. Activating these strategies is a vital priority for the future of the NDIF to transition from traditional management toward "smart risk management." These gaps include:

- Smart Prediction: Development of EWS (C111) and modeling with big data and machine learning (C112).
- Modern Finance and Data: Index-based insurance (C113), leveraging blockchain for payment transparency (C125), and integrated data platforms.
- Environmental Resilience: Protection of coastal areas against erosion (C137) and enhancing energy efficiency (C135).

Weighting of Strategies using the FUCOM Method

Following the final confirmation of indicators via the binomial test, FUCOM coding in a Python environment using mathematical optimization libraries was utilized to prioritize the strategies. First, all confirmed strategies were categorized into macro-dimensions and assigned specific codes (as detailed in Table 3).

A) Macro Phase Level: According to Table 6, pre-occurrence strategies (C1) obtained the primary priority with a weight of 64.8%. This result signifies the necessity of a paradigm shift from "reactive crisis management" to "proactive risk management."

B) Level of the Six Dimensions: Table 7 shows that "pre-occurrence policy-making (C13)" holds the first rank with an overall (global) weight of 24.1%.

C) Level of Indicators: In the final stage, the ultimate weights of all 35 indicators were calculated, and the results are presented in Table 8. The indicator C1312 (Enhancing Water Resilience), with a weight of 9.6%, was identified as the central strategic focal point and the most sensitive indicator.

The consistency rate (χ) in solving this numerical model was calculated as 0.0018. Given that this value is exceptionally close to zero, the stability of expert consensus and the computational precision of the model in extracting weights are confirmed. As illustrated in Fig. 1, the visual span of phase C1 demonstrates the strategic focus of the experts on preventive and proactive measures.

RESULTS AND RECOMMENDATIONS

This study concludes that the traditional, passive role of insurance and financial institutions in Iran is no longer sufficient to mitigate the growing risks posed by natural hazards. There is a strategic imperative to redefine the functional role of the NDIF and other stakeholders, transforming them from mere loss compensators into proactive leaders in risk governance. This fundamental shift from a reactive to a proactive paradigm aligns closely with the foundational assessments of Safari et al. (2019) and Moradifar et al. (2021), who argued that Iran's current legal and crisis frameworks remain heavily response-oriented. Furthermore, our findings

Table 6. Weights of Disaster Risk Management Phases using the FUCOM Method

Code	Strategic Title	Local Weight	Strategic Analysis
C1	Pre-occurrence Strategies (Prevention and Preparedness)	0.648	Primary focus on risk reduction and prediction
C2	Post-occurrence Strategies (Response and Reconstruction)	0.352	Focus on loss compensation and recovery

Table 7. Weights of Disaster Risk Management Dimensions using the FUCOM Method

Code	Dimension Title (Phase)	Local Weight	Global Weight	Level 2 Priority
C13	Policy-making (Pre)	0.372	0.241	1
C11	Technological (Pre)	0.358	0.232	2
C12	Financial (Pre)	0.27	0.175	3
C22	Financial (Post)	0.451	0.159	4
C21	Technological (Post)	0.31	0.109	5
C23	Policy-making (Post)	0.239	0.084	6

Table 8. Final Weights of Disaster Risk Management Indicators (FUCOM)

Code	Final Weight	Code	Final Weight	Code	Final Weight	Code	Final Weight
C1312	0.0962	C116	0.0538	C131	0.0332	C137	0.0166
C1311	0.0831	C121	0.0498	C133	0.032	C231	0.0159
C111	0.0748	C221	0.0443	C113	0.0306	C134	0.0146
C1310	0.0666	C112	0.0409	C223	0.0284	C136	0.0134
C132	0.0579	C122	0.0374	C234	0.0279	C114	0.0123
C116*	0.0538	C211	0.0355	C115	0.0272	C213	0.0108
C121*	0.0498	C222	0.0349	C212	0.0258	C233	0.0101
C221*	0.0443	C125	0.0245	C124	0.0234	C139	0.0087
C112*	0.0409	C214	0.0197	C135	0.0185	C138	0.0066
C122*	0.0374	C232	0.0181	C123	0.0219	C126	0.005

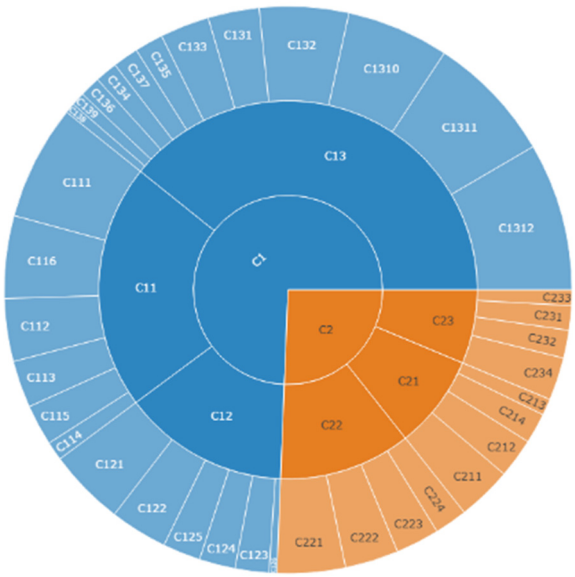


Fig. 1. Sunburst Chart of Weights (Phases, Dimensions, and Indicators)

regarding the vulnerabilities and structural gaps of the NDIF empirically support the evaluation by Hamzeh and Banimostafa Arab (2021), reinforcing the conclusion that weak insurance penetration and the absence of supplementary mechanisms severely hinder national economic resilience.

The institutionalization of technological innovations, such as blockchain to ensure transparency in payments and the use of big data for real-time risk assessment, is essential for this transition. The high prioritization of these data-driven tools in our FUCOM analysis corroborates international evidence from the Swiss Re Institute (Loh & Haegeli, 2021, 2022) and the OECD (2017), which highlights that advanced catastrophe loss modeling and InsurTech platforms are vital cornerstones for effective premium pricing and rapid claim settlements in developing economies. Prioritizing the pre-occurrence phase, as highlighted by the FUCOM analysis (with a dominant weight of 0.648), will reduce future economic liabilities and significantly enhance national resilience and sustainable development. This absolute priority given to the ex ante phase mathematically echoes the successful institutional experiences of Turkey's TCIP and New Zealand's EQC, where multi-layered, pre-funded frameworks successfully lessened direct financial pressure on public budgets (Clarke et al., 2015; World Bank, 2014).

The results of the literature review indicate that countries successful in disaster risk financing consistently utilize multi-layered, hybrid, and data-driven models. In contrast, despite the establishment of the NDIF, Iran's current natural disaster insurance system is still in the early stages of development. Some of the most critical challenges in the efficient implementation of the fund include: inadequacy of resources against catastrophic losses (especially in high-density urban areas), the absence of supplementary insurance or mechanisms for optional coverage expansion, lack of operational connectivity to international reinsurers, the absence

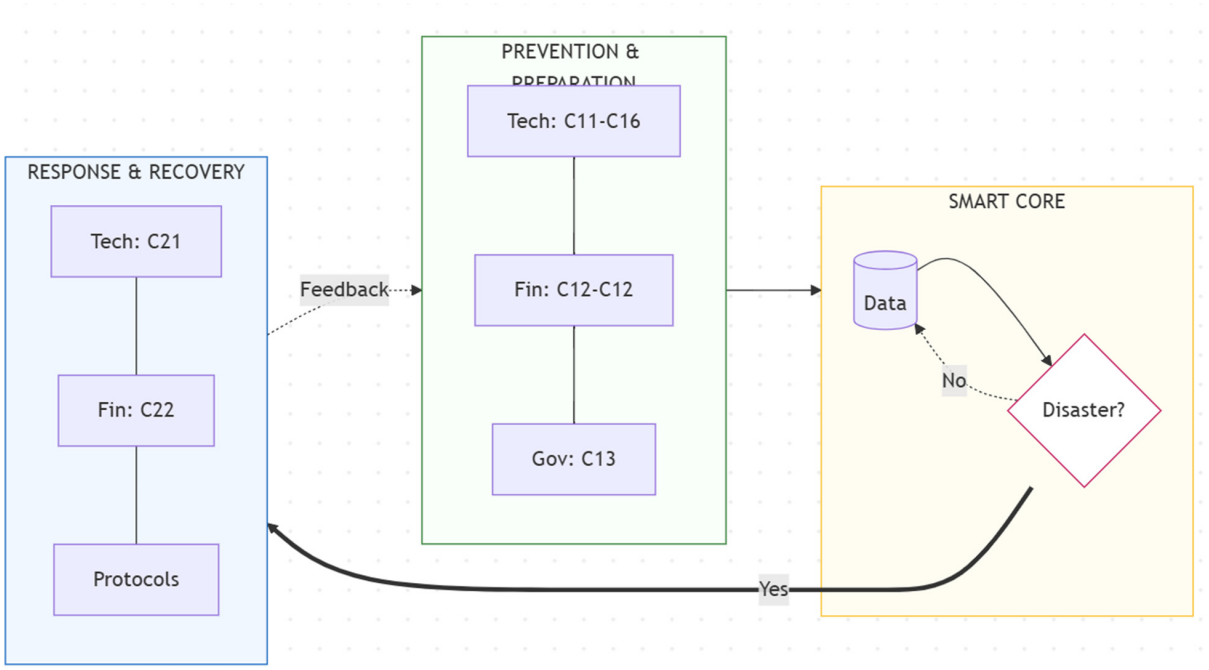


Fig. 2. Conceptual Model of Natural Disaster Risk Management

of modern instruments such as Cat Bonds, weakness in retrofitting policies, lack of tax incentives for risk reduction, absence of rapid assessment systems and data-driven modeling, and limitations in the fund's governance and institutional autonomy.

To organize the 35 indicators and better understand their interrelationships, they have been categorized into three layers (technological, policy, and financial). The integrated conceptual model for disaster risk management (derived from the FUCOM weight analysis) categorizes these indicators into four layers based on chronological sequence and functional nature, which interact within a continuous cycle:

1. Intelligent Observation and Monitoring Layer (Technological Layer): Providing precise data for the decision-making layer.
2. Prevention and Structural Retrofitting Layer (Policy-Executive Layer): Physically reducing the impacts of disasters before occurrence.
3. Financing and Risk Transfer Layer (Financial Layer): Ensuring rapid liquidity for reconstruction.
4. Operational Response and Resilience Layer (Crisis Management Layer): Saving lives and ensuring a swift return to normalcy.

The first layer represents the system's inputs, covering modern risk identification tools including codes C111 (EWS), C112 (big data modeling), C116 (sensors and Internet of Things [IoT]), and C211/ C212 (damage assessment via drones and satellites). The second layer is where the highest weight in Iran's disaster risk management was observed according to the analysis (C13), covering codes C1312 (drought resilience), C1311 (land-use planning), C1310 (flood management), and C134 to C136 (energy efficiency and carbon reduction).

The third layer serves as the model's economic pillar to alleviate the financial burden on the government during a disaster. Covered codes include C121 (Cat Bonds), C122 (supplementary insurance), C125 (blockchain in payments), and C221 to C224 (loans and emergency aid). The final layer pertains to human and systemic protocols immediately following an event, including codes C231 (communication networks), C232 (crisis HQ), C234 (evacuation systems), and C138–C139 (training and social protection).

Fig. 2 illustrates the sequence of these layers. While the presented conceptual model displays the research's operational framework, the weights extracted from the FUCOM model form the basis for prioritizing activities within each step of this model (from monitoring to response).

The binomial test results demonstrated that the selected dimensions are appropriate and critical for the natural disaster risk management model in Iran from the experts' perspective. Meanwhile, the implementation status of these strategies currently falls into three levels based on weighted averages: desirable, weak, and very weak.

The results of the FUCOM model implementation revealed a significant shift in the mindset of risk management experts in Iran, moving from "post-occurrence financing" toward "prevention and structural resilience." The allocation of 64.8% of the total weight to ex ante strategies confirms that spending during the pre-occurrence phase is a strategic investment to mitigate the astronomical costs of future damage compensation. Furthermore, the exceptionally low consistency rate (0.0018) indicates that despite the diverse expertise of the participants (insurance, FinTech, and crisis management), a powerful consensus exists regarding the priority of infrastructural policy-making.

Based on the FUCOM prioritization results—particularly the dominance of ex ante strategies (weight = 0.648) and the highest-ranked indicators (C1312, C1311, and C111)—the following policy recommendations are proposed to enhance national resilience against natural disasters:

1. Institutional Repositioning of the Natural Disaster Insurance Fund (NDIF)

- Redefine the NDIF from a passive compensation-paying entity into an active national risk governance institution.
- Assign the NDIF a formal mandate in prevention-oriented financing, disaster data governance, and risk-based policy coordination.

2. Development of a National Water Resilience Strategy (C1312 – Highest Priority)

- Prioritize public investment in emergency drinking water infrastructure for both urban and rural settlements exposed to drought and climate-related risks.
- Integrate water resilience indicators into insurance premium calculations and national disaster preparedness frameworks.

3. Risk-Based Land Use Regulation and Insurance Pricing (C1311)

- Establish a mandatory linkage between insurance policy issuance and compliance with land-use planning regulations, seismic zoning, and floodplain boundaries.
- Implement progressive insurance premium surcharges for buildings located in high-risk zones identified through Geographic Information System (GIS)-based hazard mapping.

4. Deployment of Integrated Smart Early Warning Systems (EWS)

- Develop a national, data-driven disaster risk dashboard integrating climatic, structural, financial, and insurance datasets.
- Invest in IoT-based EWS to reduce casualties and insured losses through timely and location-specific alerts.

5. Legal and Technical Framework for Blockchain-Based Smart Insurance (C125)

- Design regulatory and technical mechanisms to enable the use of blockchain-based smart contracts in damage assessment and claims settlement.
- Utilize smart contracts to enhance transparency, accelerate compensation payments, and increase public trust in disaster insurance systems.

6. Mandatory Integration of Insurance Coverage with Structural Retrofitting Policies (C13 Group)

- Require insurance coverage as a prerequisite for construction permits and retrofitting approvals in hazard-prone areas.
- Introduce tax incentives and insurance premium discounts for compliance with seismic retrofitting, energy efficiency, and resilience standards.

Given the deterministic nature of the current model, it is suggested that future studies utilize the fuzzy FUCOM model to account for ambiguity in expert opinions. Additionally, it is recommended that the indicators validated in this study be ranked in a specific case study (e.g., the Tehran metropolis) using the MARCOS method to evaluate the field effectiveness of each strategy.

REFERENCES

ADB, & OECD. (2020). *Leveraging Technology and Innovation for Disaster Risk Management and Financing*. ADB; OECD. http://dx.doi.org/10.22617/TCS200393-2

Alexander, D. (2000). *Confronting Catastrophe: New Perspectives on Natural Disasters*. *Oxford University Press.* https://cir.nii.ac.jp/crid/1970586434845026435

Arnold-Dwyer, F. (2025). Insurance public private partnerships for natural catastrophe risk. In M. Sonnentag, J. Gal, & P. Reusch (Eds.), *Versicherungsrecht, Haftungs- und Schadensrecht: Festschrift für Manfred Wandt zum 70*. Geburtstag. https://doi.org/10.33283/978-3-86298-913-3_2

Bahadur, A. V., Ibrahim, M., & Tanner, T. (2013). Characterising Resilience: Unpacking the Concept for Tackling Climate Change and Development. *Climate and Development, 5*(1), 55-65. https://doi.org/10.1080/17565529.2012.762334

Berberian, M. (1976). *Contribution to the Seismotectonics of Iran* (Part II: Geological Survey of Iran, Report No. 39). Geological Survey of Iran. https://www.academia.edu/14144988.

Clarke, D., de Janvry, A., Sadoulet, E., & Skoufias, E. (2015*). Disaster Risk Financing and Insurance: Issues and Results*. HAL Open Science. https://hal.science/hal-03347321/document

CRED. (2023). *2022 Disasters in Numbers* [Report]. *Université catholique de Louvain*. https://reliefweb.int/report/world/2022-disasters-numbers

Creswell, J. W. (2014). *Research Design: Qualitative,*

Quantitative, and Mixed Methods Approaches (4th ed.). *SAGE Publications*. http://books.google.com/books?id=4uB76IC_pOQC

Cummins, J. D., & Mahul, O. (2009). *Catastrophe Risk Financing in Developing Countries: Principles for Public Intervention*. World Bank. https://hdl.handle.net/10986/6289

European Commission. (2021). *Forging a Climate-Resilient Europe: The New EU Strategy on Adaptation to Climate Change*. European Union. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52021DC0082&from=EN

Faure, M. G., & Hartlief, T. (2003). *Insurance and Expanding Systemic Risks* (Policy Issues in Insurance, No. 5,). OECD. https://doi.org/10.1787/9789264102910-en

FEMA. (2023). *National Flood Insurance Program: Program Overview*. U.S. Department of Homeland Security. https://www.fema.gov/sites/default/files/documents/fema_nfip-summary-of-coverage-brochure.pdf

GFDRR. (2014). *Financial Protection against Natural Disasters: From Products to Comprehensive Strategies, An Operational Framework for Disaster Risk Financing and Insurance*. World Bank Group. https://www.gfdrr.org/sites/default/files/documents/Financial%20Protection.pdf

Ghesquiere, F., & Mahul, O. (2010). *Financial Protection of the State against Natural Disasters: A Primer*. World Bank. https://openknowledge.worldbank.org/handle/10986/3912

Government of Mexico, & World Bank. (2012). *Improving the Assessment of Disaster Risks to Strengthen Financial Resilience: A Special Joint G20 Publication by the Government of Mexico and the World Bank. World Bank*. https://openknowledge.worldbank.org/entities/publication/ec1e6935-4c56-5ffe-8d03-702b1e9b0df4

Gurenko, E. (2019). *Climate Change and Insurance Disaster Risk Financing in Developing Countries*. Routledge. https://www.routledge.com/p/book/9781138384101

Hamzeh, A., Banimostafa Arab, F. (2021). *The Role of the Insurance Industry in Preventive Measures for Natural Disaster Losses* [Research Report, No. 151]. Tehran: Insurance Research Center. https://www.irc.ac.ir/fa-IR/Irc/4946/Articles/view/14643/1552 **[In Persian].**

Hamzeh, A., Banimostafa Arab, F. (2022). *Examining natural Disaster Risk Transfer Tools in the Insurance Industry* [Research Report, No. 168]. Tehran: Insurance Research Center. https://www.irc.ac.ir/fa-IR/Irc/4946/Articles/view/14643/1578 **[In Persian].**

Islamic Consultative Assembly Research Center. (1991). *Law on the Formation of the National Committee for Natural Disaster Reduction*. Tehran: Islamic Consultative Assembly Research Center. https://rc.majlis.ir/fa/law/show/114614 **[In Persian]**.

Islamic Consultative Assembly Research Center. (2003). *Comprehensive Relief and Rescue Plan*. Tehran: Islamic Consultative Assembly Research Center. https://rc.majlis.ir/fa/law/show/123469 **[In Persian]**.

Islamic Consultative Assembly Research Center. (2004). *Law on the Structure of the Comprehensive Welfare and Social Security System*. Tehran: Islamic Consultative Assembly Research Center. https://rc.majlis.ir/fa/law/show/96961 **[In Persian]**.

Islamic Consultative Assembly Research Center. (2008). *Law on the Formation of the National Disaster Management Organization*. Tehran: Islamic Consultative Assembly Research Center. https://rc.majlis.ir/fa/law/show/134208 **[In Persian]**.

Islamic Consultative Assembly Research Center. (2015). *Law on the Establishment of the Natural Disaster Insurance Fund*. Tehran: Islamic Consultative Assembly Research Center. https://rc.majlis.ir/fa/law/show/1630899 **[In Persian]**.

Islamic Consultative Assembly Research Center. (2019). *New National Disaster Management Law*. Tehran: Islamic Consultative Assembly Research Center. https://rc.majlis.ir/fa/law/show/1262578 **[In Persian]**.

Islamic Consultative Assembly Research Center. (2020). *Act on the Establishment of the Natural Disaster Insurance Fund for Buildings*. Islamic Consultative Assembly Research Center. https://rc.majlis.ir/fa/law/show/1752871 **[In Persian]**.

JICA, & CEST. (2000). *The Study on Seismic Microzonation of the Greater Tehran Area in the Islamic Republic of Iran* [Executive Summary]. Japan International Cooperation Agency (JICA); Center for Earthquake Studies of Tehran (CEST) of Tehran Municipality. https://openjicareport.jica.go.jp/pdf/11611753_01.pdf

Kunreuther, H. C., & Michel-Kerjan, E. O., & Doherty, N. A. (2009). *At War with the Weather: Managing Large-Scale Risks in a New Era of Catastrophes*. MIT Press. https://www.google.com/books/edition/_/gKRwjgEACAAJ?hl=en&sa=X&ved=2ahUKEwj43_DUsrKVAxWlU6QEHcUCCJoQre8FegQIERAH

Lot, G., & Haegeli, J. (2021). *More risk: The Changing Nature of P&C Insurance Opportunities to 2040* [Sigma No. 4/2021]. Swiss Re Group. https://www.swissre.com/dam/jcr:5b5c9666-8faf-4ee2-9080-fba57c442702/virtual-rvs-%202021-pc-insurance%20opportunities.pdf

Lot, G., & Haegeli, J. (2022). *Maintaining Resilience: The Role of P&C Insurers in a New World Order* [Sigma No. 5/2022]. Swiss Re Group. https://www.swissre.com/dam/jcr:066012d3-b071-4802-8714-150bbda3208f/2022-09-sri-sigma-maintaining-resilience.pdf

Moradifar, B., Sheikh Almolook, H., & BagherAbadi, F. (2021). *Requirements* review the civil liability of natural disaster damages to citizens in Iran (An approach based on citizenship rights and good crisis governance). *Political Sociology of Iran*, *3*(4), 3433-3450. https://doi.org/10.30510/psi.2022.368799.4123 **[In Persian].**

OECD. (2016). *Financial Management of Flood Risk*. OECD Publishing. https://doi.org/10.1787/9789264257689-en

OECD. (2017). *Technology and Innovation in the Insurance Sector*. OECD Publishing. https://doi.org/10.1787/ddf9df41-en

OECD. (2018-a). *Assessing the Real Cost of Disasters: The Need for Better Evidence, OECD Reviews of Risk Management Policies*. OECD Publishing. https://doi.org/10.1787/9789264298798-en

OECD. (2018-b). *Financial Management of Earthquake Risk*. OECD Publishing. https://doi.org/10.1787/eebded10-en

OECD. (2020). *Development Co-Operation Report 2020: Learning from Crises, Building Resilience.* OECD Publishing. https://doi.org/10.1787/f6d42aa5-en

Pamucar, D., Stevic, Z., & Sremac, S. (2018). A New Model for Determining weight coefficients of criteria in MCDM models: Full consistency method (FUCOM). *Symmetry, 10*(9), 393. https://doi.org/10.3390/sym10090393

Payab, M. (2023). *Monitoring Report-Assessment of the Reconstruction and Renovation of Buildings and Areas*

Affected by Natural Disasters; Lessons Learned and Strategic Recommendations [Access No. 19397]. Tehran: Islamic Consultative Assembly Research Center. https://lib.majles.ir/parvan/resource/145553 **[In Persian].**

Safari, M., Seyedin, H., & Jahangiri, K. (2019). Disaster risk governance in Iran: Document analysis. *Journal of Education and Health Promotion, 8*(1), 142. https://doi.org/10.4103/jehp.jehp_30_19

Seddighi, H., & Seddighi, S. (2020). How much the Iranian Government spent on disasters in the last 100 years? A critical policy analysis. *Cost Effectiveness and Resource Allocation, 18*(1), 46. https://doi.org/10.1186/s12962-020-00242-8**.**

Shaw, R., Izumi, T., Djalante, R., & Imamura, F. (Eds.). (2025). *Two Decades from the Indian Ocean Tsunami: Key Challenges and Advancements*. Springer. https://doi.org/10.1007/978-981-96-2669-4

Surminski, S. (2022). The role of insurance in integrated disaster risk management with a focus on how insurance can support climate adaptation and disaster resilience. In M. Skidmore (Ed.), *Handbook on the Economics of Disasters* (pp. 294-318). Edward Elgar Publishing. https://doi.org/10.4337/9781839103735.00026.

Swiss Re Institute. (2020). *Natural Catastrophes in Times of Economic Accumulation and Climate Change* [Sigma No. 2/2020]. Swiss Re Group. https://www.swissre.com/dam/jcr:9b947084-929d-41b9-a051-114e883a1294/sigma2_2020_en.pdf

Tabrizi, A. G. (2021). Compensation system in the public insurance fund of natural disasters. *Journal of Private Law Research, 9*(35), 179-210. https://doi.org/10.22054/jplr.2022.64636.2626 **[In Persian].**

UNDRR. (2022). *Global Assessment Report on Disaster Risk Reduction 2022: Our World at Risk—Transforming Governance for a Resilient Future*. United Nations. https://www.undrr.org/media/79595/download?startDownload=20260214

Vita-Finzi, C. (1982). N. N. Ambraseys and C. P. Melville: A history of Persian earthquakes. *Bulletin of the School of Oriental and African Studies*, *46*(2), 360–360. https://doi.org/10.1017/S0041977X00079131

Wood, A., & Ambler, J. (2016). *Lessons from Treasury's Role in the Canterbury Earthquakes*. New Zealand Treasury. https://www.treasury.govt.nz/sites/default/files/2025-03/oia-20250119.pdf.

World Bank. (2014). *Financial Protection against Natural Disasters: An Operational Framework for Disaster Risk Financing and Insurance*. World Bank Group. https://hdl.handle.net/10986/21725

World Bank. (2017). *Sovereign Catastrophe Risk Pools: World Bank Technical Contribution to the G20. World Bank Group*. https://hdl.handle.net/10986/28311

World Bank. (2021). *World Bank Group Climate Change Action Plan 2021–2025: Supporting Green, Resilient, and Inclusive Development*. World Bank. https://hdl.handle.net/10986/35799

AUTHOR (S) BIOSKETCHES

AUTHOR (S) BIOSKETCHES

Somaieh Babaei, PhD Graduate, Economic, Management and Economics, Science and research Branch, Islamiv Azad, Tehran, Iran.
Email: S.babei@srbiai.ac.ir
ORCID: 0000-0003-3250-6666

AUTHOR (S) BIOSKETCHES

Shamsallah Salami, PhD Graduate, Management, Ghaemshahr Branch, Islamiv Azad, Tehran, Iran.
Email: Sh.salami@iraninsurance.ir
ORCID: 0009-0002-4334-886X

AUTHOR (S) BIOSKETCHES

Najmeh Molaei, PhD Student, ECO Institute of Higher Education, Allameh Tabataba'i University, Tehran, Iran.
Email: N-Molaei@Taavon-ins.ir
ORCID: 0009-0008-7527-0706

HOW TO CITE THIS ARTICLE

Babaei, S., Salami, S., & Molaei, N. (2026). Gap analysis of novel financial,technological, and governance tools for natural disaster risk management in Iran. *Iranian Journal of Insurance Research, 15*(S1), 87-102.

DOI: 10.22056/ijir.2026.S1.08

URL: https://ijir.irc.ac.ir/article_160386.html