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Gap Analysis of Novel Financial, Technological, and Governance Tools for natural disaster Risk Management in Iran

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ABSTRACT

BACKGROUND AND OBJECTIVES: In recent decades, the global community has witnessed a significant 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 risks, faces unique challenges in disaster risk management. Conventional disaster management frameworks predominantly emphasize post-disaster recovery, often neglecting proactive risk reduction strategies. Therefore, the integration of modern financial and insurance mechanisms with advanced technological solutions is a strategic necessity. This study aims to perform 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 toward a resilience-oriented, proactive framework.

METHODS: This descriptive-analytical study utilized both qualitative and quantitative approaches. The research framework was operationalized through a self-administered questionnaire consisting of six dimensions and initially 38 indicators. The statistical population comprised 30 experts and specialists from the Natural Disaster Insurance Fund (NDIF), the Climate Research Center, and the International Institute of Earthquake Engineering and Seismology. Participants were selected using purposive sampling based on their expertise in insurance, disaster risk management, and modern financial instruments. In the first stage, the content validity of the questionnaire was rigorously assessed by field experts, leading to refinement and reduction of the indicators to 35 final items. Internal consistency and reliability were confirmed through 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 employed to verify 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. FUCOM was chosen for its superior ability to manage expert judgments with a lower deviation rate compared to traditional methods such as AHP.

FINDINGS: The Binomial Test empirically confirmed all research hypotheses, demonstrating that technological, financial, and governance dimensions are essential and appropriate platforms for advancing natural disaster risk management in Iran. The gap analysis highlighted a dual reality: while conventional reactive approaches and structural/physical infrastructures 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 utilization 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 emphasizes 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 (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 policy-making. Based on these results, a comprehensive conceptual model for natural disaster risk management was developed, structured according to the priorities extracted 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 Natural Disaster Insurance Fund and other stakeholders, transforming them from mere loss compensators into proactive leaders in risk governance. Institutionalization of technological innovations, such as blockchain to ensure transparency in payments, and the use of Big Data for real-time risk assessment, are 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.

1.Introduction

Natural disasters refer to events originating from natural phenomena such as earthquakes, floods, storms, droughts, forest fires, landslides, or volcanic eruptions, which cause widespread damage by creating severe disruptions in human, economic, and environmental structures. The main characteristics of these events are their suddenness, high destructive power, and inability to be completely prevented. In academic literature, natural disasters are generally classified into two main categories: "rapid-onset hazards" like earthquakes and storms, and "slow-onset hazards" like drought and subsidence (Alexander, 2000). From the United Nations' perspective, natural disasters turn into a humanitarian crisis when the vulnerability of communities to them is high and the capacity for effective response is limited (UNDRR, 2022).

In recent decades, the intensity, frequency, and scope of natural disasters globally have increased alarmingly, leaving multifaceted effects across economic, social, and environmental dimensions. Climate change, uncontrolled urbanization, and population concentration in high-risk areas are among the factors that have weakened community resilience to these events (CRED, 2023). According to World Bank reports, the average losses from natural disasters in the last decade exceeded 300 billion per year, predominantly occurring in developing or low-resilience countries, yet only a fraction of these costs were covered by insurance. This underscores the necessity of investing in disaster risk management, especially through financial and insurance tools. Natural disasters are no longer just an environmental or humanitarian issue but are viewed as a major economic challenge requiring cross-sectoral and technological policies (World Bank, 2012).

In response to these developments, many countries, especially those that have experienced severe natural disasters in recent decades, have moved towards designing and implementing innovative disaster risk management models. These models generally combine innovative financial tools, such as Catastrophe Bonds (Cat Bonds), Compulsory Insurance, Risk Swaps, and technology-driven mechanisms, like Smart early warning Systems. With the participation of governmental bodies, the private sector, and local communities, they aim to increase economic resilience and accelerate post-crisis recovery (World Bank, 2014).

In developing countries, the lack of resilient insurance and financial infrastructure leads to a double 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; structures built upon multilayered coverage, capital market instruments like Cat Bonds, technological innovation, Catastrophe Risk Modeling, and multi-stakeholder participation (OECD, 2016; Swiss Re, 2020).

Given its broad climate diversity and specific geographical location, over 80% of Iran's area is exposed to one or more types of natural disasters (JICA & IIEES, 2000). Statistics show that in the past 20 years alone, tens of billions of dollars in losses from natural disasters have been imposed on the country, The major burden of this has fallen on public resources and uninsured citizens.

The Iranian government has spent around 29 billion USD on disasters during the last 100 years. Droughts, earthquake and flood have costs the government more than other disasters, accounting for more than 14, 6.9, and 6.1 billion USD, respectively, in the allocated budget (like Tabas,1978 , Bam 2003, Kermanshah, 2017, and the 2019 floods). Most of the Iranian government expenditure during the last 100 years on various disasters such as drought, flood, earthquake, and COVID-19 has been spent on involuntary costs including Response and Recovery. Mitigation and Preparedness are the two critical disaster management phases with very small shares of national budgeting (seddighi & seddighi,2020). Economically, throughout this century, the compensation system has remained based on public government budgets, and a sustainable, pre-funded financial cover for disasters has never been established. In the 2019 Golestan and Lorestan floods and the 2023 Khoy earthquake, governments were forced to allocate emergency credits without having sustainable resources for reconstruction or loss coverage (Safari et al.,2019).

Numerous regulations and laws 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 (1991), the Comprehensive Relief and Rescue Plan (2003), the Law on the Structure of the Comprehensive Welfare and Social Security System (2004), and the Law on the Formation of the National Disaster Management Organization (2008). Furthermore, in recent years, the Law on the Establishment of the Natural Disaster Insurance Fund (2015) and, ultimately, the New Disaster Management Law (2019) were approved. Despite the emphasis of these laws on the necessity of prevention and risk reduction, serious challenges remain regarding financial resource mobilization, insurance executive mechanisms, and the allocation of funds for responding to unforeseen disasters, which have hindered the full realization of these legal objectives.(Tabrizi, 2022).

The country's crisis management systems are mostly focused on post-disaster response, and tools for forecasting, early warning, and risk reduction do not have an adequate place in executive and policy-making structures. The lack of a comprehensive database, poor coordination among responsible institutions (such as the National Crisis Management Organization, Red Crescent, Central Insurance, and Ministries), and the absence of a comprehensive financial coverage system are considered fundamental challenges (Moradi far et al., 2020).
With the ratification of the 'Natural Disaster Insurance Fund for Buildings Act in 2020, the financial risk management system in Iran entered a new phase. This fund commenced its operations at the beginning of 2021 with the objective of providing basic coverage to all residential units equipped with legal electricity connections. According to the mechanisms envisioned in this law 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 (IPRC ,2023).
The present study is categorized as applied and developmental research in terms of its objective. In terms of nature and methodology, it is conducted using a descriptive-analytical and comparative approach, utilizing field data (expert questionnaires). The main focus of the study is to analyze the economic and insurance models of natural disaster risk management in leading countries and 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).
For this purpose, the documentary analysis method was used to gather theoretical, empirical, and governance studies. The 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, UN Office for Disaster risk reduction (UNDRR), and the International Disaster Database (EM-DAT). Additionally, credible articles published in scientific databases were used to examine innovations, novel financial tools, and applicable technologies in the field of disaster insurance. At the second level, a comparison and comparative analysis of the experiences of selected countries, including Japan, the United States, New Zealand, Turkey, France, Switzerland, Mexico, and India, were performed. These countries were chosen due to their history of frequent disasters and the development of diverse financial and insurance systems against catastrophic risks, including natural disaster insurance funds. The analytical approach of the study is focused on the comparative evaluation of the financial and insurance coverage layers of these countries, determining Iran's position, and extracting governance gaps and opportunities (Safari et al.,2019).
An examination of international experiences 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. Therefore, the main research question of this study 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 in order to reduce disaster-related losses, strengthen national resilience, and enhance the effectiveness of the Natural Disaster Insurance Fund?

2.Literature Review

Regarding natural disaster-related insurance, resilience policies include a range of measures such as designing multilayered insurance coverage models, developing early warning systems, strengthening infrastructure, offering tax incentives for risk reduction, public education, and improving risk governance. According to many researchers, the most important characteristics of successful resilience policies are "predictability" and "adaptive learning," which are manifested in data-driven policy-making (Bahadur et al., 2015).

One of the main challenges in natural disaster risk management in Iran is the lack of effective connection between new technologies and risk reduction policies. While many countries use technologies such as AI-based warning systems, Big Data, satellite imagery, and risk modeling, in Iran, these technologies have largely remained at the research project stage and have not reached operational use (safari et al., 2019). These shortcomings have kept the country's economic and social resilience to natural disasters at a low level.

According to Research Report No. 151 of the Insurance Research Center (2021), this study examined the challenges of 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 was proposed that the Fund's structure should be upgraded to a multi-layered 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 nascent system faces challenges such as the lack of precise risk assessment models, weak connection with the capital market, the absence of a strategy for supplementary insurance, and the lack of 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 a proper 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 its financial sustainability (Insurance Research Center, 2022). 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.

2-1- Natural Disaster Risk Management from an Economic and Financial Perspective

Multilayered financial coverage systems include basic insurance, supplementary insurance, emergency reserve funds, and risk transfer instruments to the capital market (Cummins & Mahul, 2009). Theoretical studies have shown that combining traditional insurance tools with innovative instruments like Catastrophe Bonds and Catastrophe Swaps can create important advantages in increasing financial response capacity (Ghesquiere & Mahul, 2010). The World Bank, in a comprehensive report (2017), emphasized the importance of designing multi-tiered insurance systems and suggested that countries use a combination of compulsory insurance, the reinsurance market, risk securitization, and government budgetary support. An OECD study (2020) also showed that countries that combined incentive policies for retrofitting and broad insurance coverage with advanced financial instruments enjoyed faster reconstruction and a greater reduction in financial pressure. Designing pre-emptive financial structures like Catastrophe Bonds allows countries to secure necessary resources before an event occurs and access them immediately when it happens. The parametric model of these bonds, used in Mexico and the Caribbean, is recognized as a successful international model due to its speed of payment and the elimination of complex loss assessment processes (World Bank, 2014). Insurance swaps can be a suitable solution for managing large natural risks, especially for countries that lack the capacity to issue Catastrophe Bonds (World Bank, ۲۰۲۱).

2-2- Natural Disaster Risk Management from a Technological and Data-Driven Perspective

Alongside financial tools, the role of new technologies in natural disaster risk management has been highlighted. Technologies such as catastrophe loss modeling, AI-based predictive analytics, and the Internet of Things (IoT) for real-time risk monitoring have become a cornerstone of risk management in developed countries (Swiss Re Institute, 2020). This dimension includes the application of technologies like loss modeling, remote sensing and satellite data, Artificial Intelligence, Blockchain, and spatial data infrastructure in the assessment, forecasting, and settlement of natural disaster claims (Swiss Re, 2021). Furthermore, the theory of data-driven governance emphasizes that the use of spatial data, forecasting algorithms, and early warning systems is essential for the effectiveness of disaster response policies (World Bank, 2014). In the area of technology use, a Swiss Re report (2022) indicates that insurance companies in Europe and East Asia are increasingly using data-driven platforms, AI, and Blockchain in the process of risk assessment, pricing, and claim payment.

In the technology domain, studies conducted by the OECD (2017) highlight the role of new technologies like Blockchain in policy issuance, AI in loss assessment, and Big Data in risk modeling in increasing the transparency and effectiveness of insurance structures. At the regional level, research by Swiss Re (2021) emphasizes the importance of global reinsurance in managing catastrophic risks. This report stresses that the use of catastrophe risk models in developing countries is vital for designing risk-proportionate premiums, and the lack of access to accurate data is one of the main obstacles to developing these systems in the Middle East, including Iran.

In the realm of natural disasters, InsurTech plays a vital role in prediction, rapid response, and resource allocation. For example, combining satellite data with weather forecasting models and real-time analysis of losses from earthquakes or floods enables insurance companies to make automated and rapid insurance payments (OECD, 2017). In this context, natural disaster insurance funds can increase their risk absorption capacity and have a more effective performance against catastrophic events by relying on new technologies.

2-3- Natural Disaster Risk Management from a Governance and Policy-making Perspective

This dimension includes designing multi-level governance mechanisms, public-private partnership (PPP), a retrofitting incentive system, data-driven governance, and enhancing institutional resilience (OECD, 2020). This Fund, by utilizing a multilayered approach to risk coverage, plays a key role in increasing the economic resilience of households and reducing the government's financial burden during disasters. In developed countries, resilience policies are primarily pursued through medium- and long-term programs with the active participation of the private sector, local communities, and international organizations. For instance, the European Union has a framework called the EU Strategy on Adaptation to Climate Change, which regulates resilience policies in areas such as finance, energy, infrastructure, and insurance (European Commission, 2021). Implementing such policies is considered a vital necessity, especially in countries like Iran that face various types of natural disasters.

According to international experiences, the success of such funds depends on the simultaneous implementation of complementary policies such as retrofitting, tax incentives, private sector participation, and innovative financial tools like Cat Bonds and accurate risk modeling (Swiss Re Institute, 2022). The World Bank Group's Climate Action Plan (2021c) is built on three main pillars: Emission Reduction, Adaptation and Enhanced Resilience, and Accelerating a Just Transition. Installing new renewable energy capacity (e.g., solar or wind electricity megawatts); increasing energy efficiency in industries and buildings; and reducing greenhouse gas emissions through improved public transport fall under Emission Reduction. Protecting coastal areas from flooding and erosion; increasing access to potable water in drought-prone areas; and creating climate-resilient infrastructure are among the strategies for Adaptation and Enhanced Resilience. Creating training and skills-building programs for workers in carbon-dependent industries; and designing social protection systems for communities vulnerable to economic changes are planned for Accelerating a Just Transition.

2-4- Successful International Experiences in Natural Disaster Risk Management with a Focus on Natural Disaster Insurance Funds

A look at Iran's history shows that in the early decades of the 20th century, the lack of formal structures to cope with disasters meant that responses were mostly local, scattered, and based on traditions and public aid. Only in rare cases, such as the Buyin Zahra earthquake (1962) or Tabas (1978), did the government intervene centrally, which was still without pre-planning (Ambraseys & Melville, 1982; Berberian, 1976).

Despite the launch of the "natural disaster Insurance Fund for Buildings," according to Central Insurance data, the majority of losses from earthquakes, floods, and other natural disasters in Iran remain uninsured, and the burden of financing these losses falls on the government. Furthermore, mechanisms such as risk securitization, parametric insurance, or hybrid instruments have yet to enter Iran's executive structure (Insurance Research Center ,2022).

A review of the structures of leading countries in natural disaster risk management shows that the effectiveness of their insurance and financial systems is due to a combined and multilayered approach. Successful country experiences are also used as a comparative reference point for analyzing structural gaps in Iran. Among these, countries like Japan, the United States, Turkey, New Zealand, Switzerland, Mexico, and France have succeeded in developing market-based risk financing structures while reducing direct government dependence on public budget resources by adopting multilayered composite strategies. For example, Japan, by utilizing advanced warning systems, compulsory earthquake insurance, and government reinsurance support, has one of the most advanced financial systems in disaster management (OECD, 2018).

Japan, due to its high seismicity, has an advanced earthquake risk management system, providing a high level of preparedness through a combination of compulsory earthquake insurance, government participation in reinsurance, investment in risk modeling, advanced technology in early warning infrastructure, and resilient infrastructure (World Bank, 2014). By utilizing its earthquake insurance system, the country allows property owners to be covered by paying a small premium. Furthermore, retrofitted infrastructure and earthquake warning systems have played a key role in reducing human and material losses. Additionally, the Japanese government, as part of its Disaster risk reduction Strategy, emphasizes investment in remote sensing technologies, real-time seismic analysis, and public education (Shaw and Izumi, 2018). In these studies, Japan is presented as an advanced model that benefits from early warning technologies, a collaborative government-private sector insurance structure, and stringent construction requirements. The country also uses AI-based systems and Big Data analysis for real-time loss assessment and resource allocation. Studies by Gurenko (2019) and Clarke et al.(2018) examined the successful experiences of Turkey, Japan, and Mexico in implementing compulsory earthquake and natural disaster insurance programs, emphasizing that the link between insurance, public investment in retrofitting, and capital market instruments has been key to the success of these programs.

The New Zealand Earthquake Commission (EQC), as one of the oldest and most sustainable earthquake insurance mechanisms globally, has been examined in studies by Wood and Ambler (2016), which determined that the model's success lies in legal continuity, professional resource management, and supporting resilient infrastructure. The Commission has provided one of the most successful insurance models by using a multilayered financial mechanism for earthquake loss coverage. This model consists of three coverage layers: basic government insurance, supplementary private insurance, and international reinsurance. Claim payment in a short timeframe and the participation of the insurance industry in risk assessment have resulted in high effectiveness in reconstruction. New Zealand, through the EQC mechanism, collects earthquake premiums as part of fire insurance and uses the funds for post-disaster reconstruction. The government also acts as the reinsurer (GFDRR, 2014).

In 1996, the Government of Mexico established the "natural disaster Fund" (FONDEN), financed by public budgets and innovative instruments such as Catastrophe Bonds from international markets. In this structure, upon the occurrence of a disaster and the fulfillment of parametric triggers, international investors are obliged to pay for losses. This innovative tool not only increases the speed of financing but also reduces the financial pressure on the public budget, and this model has become a template for Latin American countries (World Bank, 2014).

Turkey, with the launch of TCIP in 2000, built an integrated system based on compulsory insurance, the use of seismic engineering data, and collaboration with international reinsurers (OECD, 2018). Following the devastating earthquakes of the 1990s, Turkey mandated earthquake insurance for all residential property owners. Premiums are collected through the TCIP entity at a variable rate based on regional risk. The government acts as the ultimate reinsurer, and TCIP benefits from international reinsurance (World Bank, ۲۰۱۷). This Fund, with its independent structure and use of remote sensing technology, is recognized as a successful example of a catastrophe insurance model in developing countries (Swiss Re, 2020).

France, with its Catastrophe Naturelle (CATNAT) model, mandates all property insurance policies to cover natural disasters, and the government acts as the ultimate guarantor (ARNOLD-DWYER, 2025). The premium rate is uniform for all, and following disasters, losses are quickly compensated within the legal framework (Faure & Hartliep, 2003). The CATNAT structure in France is one of the successful European models for automatic coverage of natural disasters for all properties. This system, with a fixed premium rate, comprehensive coverage, and the participation of reinsurers, has managed to fairly distribute the financial burden of disasters among the insured.

India has succeeded in expanding coverage in rural areas by developing index-based insurance for drought and using satellite technologies for loss assessment (Panda and Singh , 2021). The United States has developed a multi-sectoral structure using federal programs like the NFIP (National Flood Insurance Program), investment in Catastrophe Bonds, and collaboration with private companies (FEMA, 2022). The NFIP provides flood coverage. Furthermore, some states, like California, use Catastrophe Bonds to finance earthquake insurance resources. The PPP structure and capital market instruments play an important role in financial flexibility (Kunreuther & Michel-Kerjan, 2009).

In Switzerland, natural disaster coverage is an integral part of property insurance policies. Through a participatory system involving cantons, private companies, and citizens, it has developed an insurance system with a high minimum repayment rate. Swiss Re, as a global reinsurer, guarantees the necessary financial resources for widespread disaster coverage through accurate risk analysis and catastrophe risk modeling (ADB & OECD, 2020).

In Iran, challenges such as the lack of suitable supplementary coverage, limited resources, and weak use of advanced technologies like an integrated early warning system persist (Surminski , 2022; Insurance Research

Center, 2022). The operational model of the natural disaster Insurance Fund for Buildings is designed to be similar to successful international experiences such as Turkey's TCIP Fund and New Zealand's EQC Commission, in that its financing is secured from compulsory premiums, government aid, and domestic resource investment, as well as the use of reinsurance (; OECD, 2018b). According to international experiences, the success of such funds depends on the simultaneous implementation of complementary policies such as retrofitting, tax incentives, private sector participation, and innovative financial tools like Cat Bonds and accurate risk modeling (Swiss Re Institute, 2021). (Swiss Re, 2022b).

3- Research Methodology

3-1- Statistical Population and Sampling Method

Due to the specialized nature of the subject and the complexity of modern tools in natural disaster risk management, Purposive Sampling was employed. The research experts were selected based on three key criteria: "holding advanced degrees in related fields," "having at least 10 years of executive experience in the insurance industry or related sectors," and "specialization in the fields of Fintech and disaster monitoring."

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

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%

The primary instrument of this research is a self-administered questionnaire derived from the literature review. In the first stage, to assess Content Validity, the initial questionnaire was provided to the experts. Following the receipt of their feedback, structural modifications were implemented; by merging overlapping indicators (such as merging indicators in the fields of Blockchain and Parametric Insurance), the number of indicators was refined from 35 to 38 final items.

3-2- Reliability of the Measurement Instrument

To evaluate the reliability of the research instrument, Cronbach's Alpha coefficient was utilized. This analysis was conducted using SPSS software version 22, and the detailed results for each of the six dimensions are presented in Table 2. According to the findings in this table, the overall reliability coefficient of the questionnaire was calculated to be 0.85. Since the alpha values for all dimensions, as well as for the entire questionnaire, are above the threshold of 0.7, it can be concluded that the measurement tool possesses high reliability and validity, and the items exhibit desirable internal consistency in explaining the research variables.

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

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

- **Hypothesis1(H1):** Pre-occurrence technological tools (such as early warning systems and Big Data) have a positive and significant impact on natural disaster risk management.
- **Hypothesis2(H2):** Pre-occurrence financial tools (such as catastrophe 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 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.

3-3- Data Analysis

3-3-1- Statistical Tests

If the data distribution is normal, the one-sample t-test is used to test the hypotheses; otherwise, the Binomial Test is employed. Initially, the Kolmogorov-Smirnov (K-S) test was used to examine the assumption of normality in the data distribution. Given the nature of expert opinions, which usually follow a non-normal distribution, the results of this test determine whether non-parametric methods should be used in supplementary analyses. When examining the normality of the data, the null hypothesis (H0), stating that the data distribution is normal, was tested at a 5% error level. Therefore, if the test statistic is greater than or equal to 0.05, there is no reason to reject the null hypothesis of normality. The statistical hypotheses for the normality test were formulated as follows:

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

Subsequently, the Binomial Test was used for quantitative content validity and the screening of extracted indicators. In fact, this test ensures that each of the 35 indicators is recognized as a "suitable factor" from the experts' perspective at a significance level ($Sig < 0.05$) (Sarmad et al., 2022) and is qualified to enter the final weighting stage (FUCOM).

3-3-2- Determining Final Weights with the Full Consistency Method (FUCOM)

To facilitate the mathematical modeling process and track indicators during the weighting and ranking stages, an identification code has been assigned to each dimension and indicator, as shown in Table 3. The weighting was performed at three levels: phases, dimensions, and indicators. After finalizing the research indicators and their coding (according to Table 3), the Full Consistency Method (FUCOM) was used to achieve precise weights with the minimum 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).

Table 3. Indicators Extracted from Literature Review and Respective Codes

Natural Disaster Risk Management Strategies	Operational Definition & Strategic Objective	Code
Pre-occurrence Strategies (C1)		

Technological (C11)		
Development of Early Warning Systems	Prediction and notification of hazards before occurrence	C111
Disaster Risk Modeling using Big Data, Machine Learning, and 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 (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

3-3-2- Implementation of the Full Consistency Method (FUCOM)

The implementation of the Full Consistency Method (FUCOM) in this research is a process built upon mathematical optimization, selected with the objective of overcoming the challenge of inconsistency in pairwise comparisons. This process begins with the qualitative prioritization of the six dimensions; specifically, each of the 30 research experts ranks the set of dimensions from most significant to least significant based on their level of impact on the 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 next step, the analysis transitions from the qualitative phase to the quantitative phase, where comparative priorities ($\emptyset$) are calculated. In this stage, the relative superiority of each ranked indicator over the indicator immediately following it is determined. This index signifies the coefficient by which one criterion is preferred over the next-ranked criterion.

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

The superiority of the FUCOM method lies in the fact that by utilizing only n-1 comparisons, it avoids unnecessary and tedious redundant comparisons common in methods such as AHP, thereby increasing the concentration and accuracy of the experts. Finally, to extract the final weights, a mathematical optimization model is formulated. The primary goal in this section is to maximize the consistency between the determined priorities such that the final weights (w_j) are calculated while satisfying the mathematical conditions:

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

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

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

$$\min \chi$$

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

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

This optimization model ensures that the extracted weights provide the most accurate representation of the experts' consensus and possess the minimum systematic deviation in the final analysis of natural disaster risk management.

4- Research Findings

4-1- 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 distribution (Binomial Test) is employed.

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

Given the obtained significance levels (Sig.) presented in Table 4, the data distribution is non-normal, necessitating the use of non-parametric tests. Consequently, the Binomial Distribution (Binomial Test) has been employed to evaluate the research hypotheses.

4-2- Analysis of Disaster Risk Management Strategies using the Binomial Test

In accordance with the defined hypotheses, the results of the Binomial Test are presented and analyzed in Table 5.

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	≤۳	24	0.8	0.5	0.001
	Group 2	>۳	6	0.2		
	Total		30	1		
Dimension 2	Group 1	≤۳	28	0.93	0.5	0
	Group 2	>۳	2	0.07		
	Total		30	1		
Dimension 3	Group 1	≤۳	26	0.87	0.5	0
	Group 2	>۳	4	0.13		
	Total		30	1		
Dimension 4	Group 1	≤۳	25	0.83	0.5	0
	Group 2	>۳	5	0.17		
	Total		30	1		
Dimension 5	Group 1	≤۳	28	0.93	0.5	0
	Group 2	>۳	2	0.07		
	Total		30	1		
Dimension 6	Group 1	≤۳	27	0.9	0.5	0
	Group 2	>۳	3	0.1		
	Total		30	1		

Based on the results in Table 5, the significance level for all questions 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. All six research sub-hypotheses (H1 to H6) were supported by the experts. This result indicates that modern financial, technological, and governance tools—both in the risk reduction and preparedness phase (Ex-ante) and in the response and reconstruction phase (Ex-post)—are appropriate 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.

4-3- 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.

4-3-1- Response-Oriented and Physical Strategies (Relatively Desirable Status)

A number of strategies, particularly in technical-infrastructural fields and post-occurrence compensation layers, 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 and Geographic Information Systems (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 (C232, C233, and C221).

4-3-2- 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 Public-Private Partnership (PPP) models (C131).
- Lack of success in reducing greenhouse gas emissions through public transport improvements (C136).

4-3-3- Modern Technological and Financial Strategies (Undesirable Status & Strategic Gap)

The absence of advanced technological tools in the preparedness 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 Natural Disaster Insurance Fund (NDIF) to transition from traditional management toward "Smart Risk Management." These gaps include:

- Smart Prediction: Development of Early Warning Systems (C111) and modeling with Big Data and Machine Learning (C112).
- Modern Finance and Data: Index-based insurance (C113), leveraging Blockchain technology for payment transparency (C125), and integrated data platforms.
- Environmental Resilience: Protection of coastal areas against erosion (C137) and enhancing energy efficiency (C135).

4-4- 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 "Crisis Management" to "Risk Management."

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

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

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%.

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

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.

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

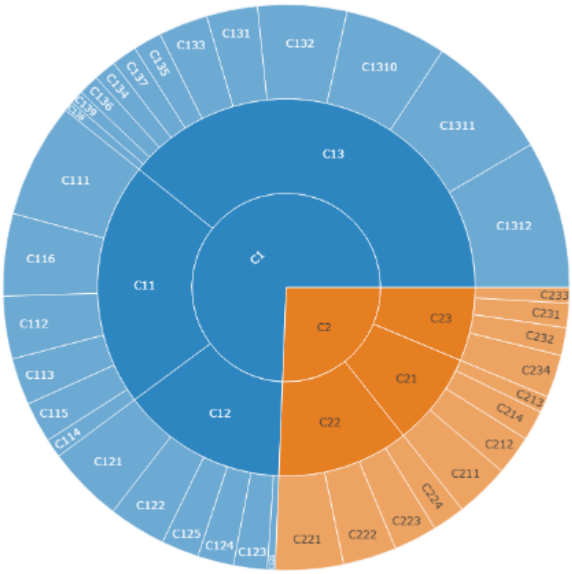

Figure 1. Sunburst Chart of Weights (Phases, Dimensions, and Indicators)

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 Figure 1, the visual span of phase C1 demonstrates the strategic focus of the experts on preventive and proactive measures.

5. Results and Recommendations

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 Natural Disaster Insurance Fund (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 or issuance of modern instruments such as Catastrophe Bonds, weakness in retrofitting policies and lack of tax incentives for risk reduction, absence of rapid assessment systems and data-driven/technological 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 3 layers (Technological, Policy, and Financial). The Integrated Conceptual Model for Disaster Risk Management (derived from the FUCOM weight analysis) categorizes these indicators into 4 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 (Early Warning), C112 (Big Data Modeling), C116 (Sensors and 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), 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 (Catastrophe 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).

Conceptual Diagram (figure No. 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).

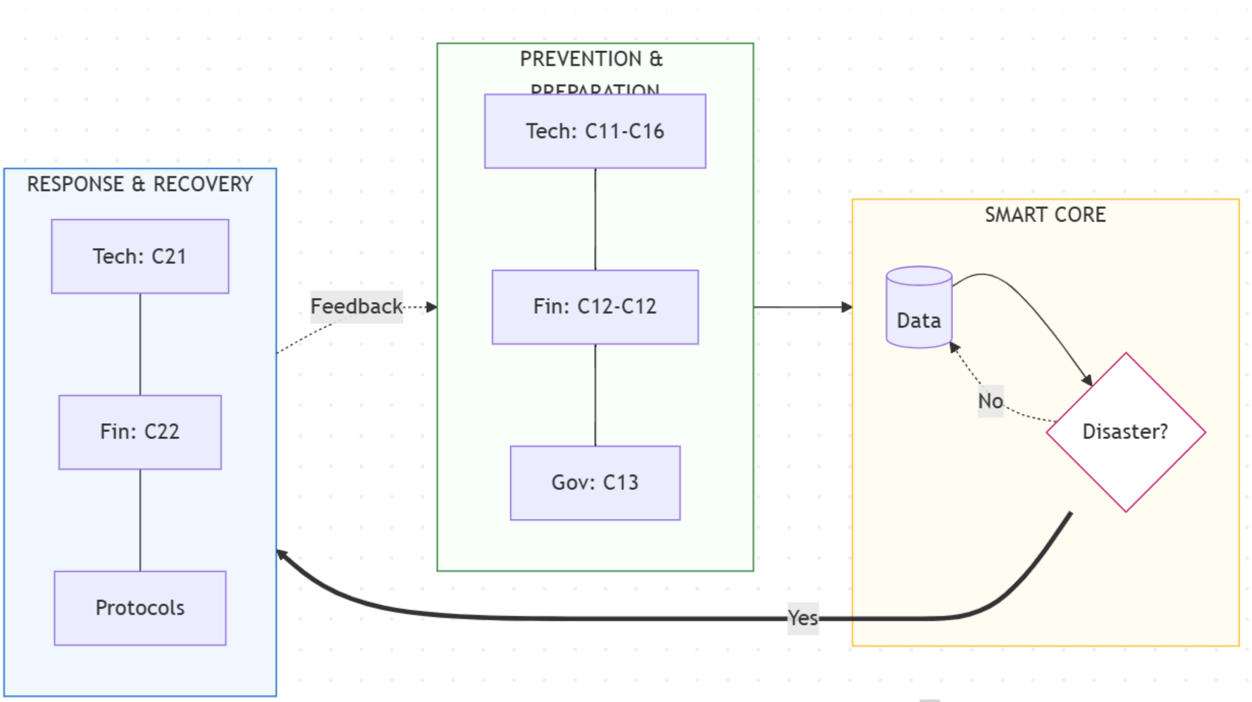

Figure 2. Conceptual Model of Natural Disaster Risk Management

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-disaster financing" toward "prevention and structural resilience." The allocation of 64.8% of the total weight to ex-ante strategies confirms that spending during the preparedness 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 GIS-based hazard mapping.

4. Deployment of Integrated Smart Early Warning Systems (C111)

- Develop a national, data-driven disaster risk dashboard integrating climatic, structural, financial, and insurance datasets.

- Invest in IoT-based Early Warning Systems (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.

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