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Revisiting the Sendai Framework for Disaster Risk Reduction -The Case for a Disaster Risk Resilience Framework in Disaster Risk Management

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AN ABSTRACT: The 2015 Sendai Framework for Disaster Risk Reduction (DRR) laid a foundational global policy, but its static model struggles to address the contemporary challenges posed by escalating extreme weather, cascading disasters, and growing socio-economic vulnerabilities. In response, the Dynamic Resilience Framework (DRF) emerges as a crucial advancement, prioritizing adaptive, anticipatory, and transformative resilience. The DRF emphasizes continuous learning, real-time data integration, and robust sectoral coordination. It champions inclusive, polycentric governance, empowering vulnerable populations and utilizing advanced technologies such as Artificial Intelligence (AI) and the Internet of Things (IoT) to facilitate proactive decision-making. The framework's theoretical underpinnings integrate existing DRR literature, systemic risk analysis, and empirical data, which reveal significant implementation gaps in practice. Crucially, the DRF embeds a socio-economic and equity lens, recognizing the vital role of marginalized and indigenous communities, thereby aligning disaster risk management with broader social justice and sustainability objectives. This shift also necessitates innovative financial mechanisms, including resilience bonds and impact investing, moving beyond traditional investment models. Comparative analysis highlights key distinctions: while the Sendai Framework primarily emphasizes state-centric governance and fixed targets, the DRF focuses on understanding systemic risks, promoting decentralized governance, incorporating real-time technological and social equity participation, and implementing continuous monitoring. A case study in Tshwane, South Africa, illustrates the practical application of this model, successfully integrating DRR and sustainable development goals through a cohesive, multi-sectoral strategy that ensures ongoing situational awareness. The transition to the Dynamic Resilience Framework marks a critical evolution in disaster risk management. It integrates complexity, systemic risks, lifelong learning, and socio-technical innovations within a flexible governance structure, aiming to build transformative, just, and sustainable resilience capable of effectively addressing today's multifaceted threats. Operationalizing this new paradigm requires systemic institutional reforms and dedicated, inclusive resource investment.

Key words: Sendai Framework –Dynamic Resilience Framework-Governance-Technology-Social Equity-Financial Innovation-Adaptability & Sustainability

1 INTRODUCTION

The global approach to managing disaster risks, guided by the 2015 Sendai Framework for Disaster Risk Reduction (SFDRR), currently faces critical scrutiny amidst escalating climate uncertainties and complex hazards. While the SFDRR has been pivotal in shaping international policy—emphasizing risk understanding, governance, resilient investment, and preparedness—the increasing frequency of extreme weather and cascading disasters highlights the limitations of static models. Evolving challenges demand a more adaptive and responsive methodology that can accommodate dynamic risk landscapes. Consequently, there is a compelling case for transitioning toward a dynamic resilience framework in disaster management. This paradigm shifts focus beyond mere risk reduction to embrace proactive adaptation and robust recovery. It prioritizes flexibility, real-time learning, and cross-sectoral integration, empowering timely decision-making and continuous preparedness. This approach complements and extends the foundational principles of the SFDRR by establishing adaptive capacities that evolve alongside emerging hazards and societal transformations, ultimately charting a course toward a truly resilient future. A case study in Tshwane, South Africa, illustrates the practical application of this model, successfully integrating DRR and sustainable development goals through a cohesive, multi-sectoral strategy that ensures ongoing situational awareness.

2 METHODOLOGY

The methodology for revisiting the Sendai Framework and proposing a Dynamic Resilience Framework in disaster risk management is grounded in a comprehensive review and synthesis of established academic and policy literature. Key foundational documents such as the *Sendai Framework for Disaster Risk Reduction 2015-2030* (UNDRR, 2015) and its predecessor, the *Hyogo Framework for Action 2005-2015* (UNISDR, 2005), provide the primary policy context for this analysis. These frameworks are examined for their stated goals, principles, and implementation mechanisms to understand their evolution, strengths, and limitations in managing disaster risk at global, national, and local levels.

The methodology integrates peer-reviewed studies on disaster resilience indicators and governance, notably the work by Cutter et al. (2010) and Birkmann and Welle (2021), to establish criteria for evaluating the practical efficacy of the Sendai Framework. These criteria include governance capacity, institutional coordination, and community participation, which collectively form a baseline for assessing implementation challenges. Empirical assessments from the *Global Assessment Report on Disaster Risk Reduction* (UNDRR, 2021; 2025) and related governance analyses are incorporated to analyse real-world gaps between policy formulation and effective operationalization, particularly in vulnerable contexts.

To critically examine systemic and emerging risk dimensions inadequately addressed by the Sendai Framework, the methodology draws on interdisciplinary resilience theories and case studies. Contributions from Kelman (2020), Linkov et al. (2019), and Radvanovsky and McDougall (2024) provide a theoretical basis for understanding cascading disasters and the necessity of anticipatory governance, highlighting gaps in current risk management practices. This theoretical foundation supports the identification of key attributes for a Dynamic Resilience Framework, emphasizing adaptability, real-time data integration, and the incorporation of advanced technologies such as AI and big data analytics (Chen & Varghese, 2023).

The methodology also emphasizes a socio-economic and equity lens by incorporating insights from Ford and Berrang-Ford (2016), O'Brien and Leichenko (2020), and Folke et al. (2016). Their work on the adaptive capacities of marginalized and indigenous communities informs the framework's focus on community-centric, equity-driven resilience approaches. The integration of social justice principles and sustainability transitions, as discussed by the United Nations Development Programme (2024) and Winn et al. (2022), further refines the proposed framework's financial and participatory dimensions, aligning disaster risk reduction with broader development goals.

Finally, the methodology synthesizes findings from policy reviews, empirical studies, and theoretical advances to develop a comparative framework. This framework juxtaposes the core strengths and limitations of the Sendai Framework with the proposed Dynamic Resilience Framework to articulate a coherent critique and outline pathways for transformation. This comparative approach facilitates a structured analysis of governance, technology, financial innovation, and social inclusivity, providing a rigorous foundation to advocate for a paradigm shift in disaster risk management strategies globally.

3 REVIEW OF LITERATURE

The Sendai Framework for Disaster Risk Reduction (2015-2030) builds on the foundational lessons of the earlier Hyogo Framework for Action (2005-2015), marking a significant global commitment to reducing disaster risks through a proactive, inclusive, and multi-sectoral approach (UNDRR, 2015; UNISDR, 2005). The Sendai Framework notably shifts focus from managing disasters to managing risk, setting clear, measurable targets linked to sustainable development and emphasizing the principle of "Build Back Better." This evolution underscores the importance of understanding disaster risk comprehensively — including exposure, vulnerability, and hazard characteristics — alongside strengthening governance and increasing community participation (Aitsi-Selmi & Murray, 2016).

Disaster resilience measurement and benchmarking have been critically advanced by Cutter et al. (2010), who propose resilience indicators to establish baseline conditions and track progress. These indicators underscore the multifaceted nature of resilience, encompassing social, economic, infrastructural, and institutional dimensions that must be integrated to formulate effective strategies. Birkmann and Welle's (2021) review further highlights governance as a pillar of resilience, arguing that robust institutional indicators are central to operationalizing resilience frameworks. However, governance remains a challenge due to fragmented responsibilities and gaps in coordination, which often impede disaster risk reduction efforts.

The complexity of modern hazard landscapes demands a dynamic understanding of resilience that accounts for cascading disasters and systemic vulnerabilities. Kelman (2020) introduces the concept of cascading disasters, where one event triggers subsequent crises, complicating traditional disaster management approaches. In line with this, Linkov et al. (2019) call for resilience frameworks that move from static responses to adaptive, learning-oriented practices capable of anticipating and evolving with changing risks. The integration of advanced technologies such as AI and big data analytics for predictive modelling and real-time decision-making is identified as a transformative opportunity to address emerging, interconnected threats (Chen & Varghese, 2023; Radvanovsky & McDougall, 2024).

Social equity constitutes another vital dimension in disaster resilience scholarship. Ford and Berrang-Ford (2016) emphasize the enhanced adaptive capacity seen in indigenous peoples due to their deep contextual knowledge and social cohesion. O'Brien and Leichenko (2020) bridge resilience with sustainability, reminding that equitable participation and justice are fundamental to achieving

long-term adaptive capacity. Folke et al. (2016) expand on this by linking social-ecological resilience to biosphere-based sustainability, calling for integrative approaches that recognize human and environmental interdependencies in resilience building.

Financial mechanisms for resilience are rapidly evolving beyond traditional risk-sensitive investments. Winn et al. (2022) highlight innovative instruments such as resilience bonds and impact investing that mobilize private capital toward sustainable disaster risk mitigation. The United Nations Development Programme (2024) stresses aligning financial innovation with broader sustainability and social justice goals, reinforcing the need for systemic change in how resilience projects are funded and sustained over time. These financial tools complement the policy and governance reforms advocated in the Sendai Framework and its successors.

Evaluations of Sendai Framework implementation reveal mixed progress. The 2021 Global Assessment Report notes the widespread adoption of national and local disaster risk reduction strategies but points to uneven capacity and resource availability, particularly in vulnerable countries (UNDRR, 2021; UNDRR, 2025). Persistent challenges include inadequate funding, policy-practice gaps, and limited inclusivity, all exacerbated by the increasing complexity and frequency of disasters influenced by climate change, pandemics, and technological hazards.

The literature stresses the urgency of strengthening governance frameworks, enhancing science-policy interfaces, and improving accountability systems to meet these challenges effectively.

Overall, the literature calls for a paradigm shift toward a more dynamic, anticipatory, and integrative resilience framework. This entails adaptive governance that is polycentric and decentralized, continuous monitoring with real-time data, community-led inclusive approaches, transformative financial innovations, and explicit connections to sustainability and social justice transitions (Paton & Johnston, 2017; Alexander, 2021; UNDP, 2024). Such a framework would better address the complexities of the 21st century risk environment, advancing disaster risk reduction into a science-based, equity-cantered, and forward-looking practice.

4 A CASE STUDY OF A SUCCESS STORY

A notable success story in practicing a dynamic resilience framework in disaster risk management is reflected in the City of Tshwane (CoT) in South Africa. The CoT incorporated elements of the Sendai Framework for Disaster Risk Reduction and the Sustainable Development Goals within its urban planning and disaster resilience strategies. However, the city initially lacked a consolidated disaster resilience model that integrated these elements systematically. Recognizing this gap, the city developed a comprehensive disaster resilience framework aimed at ensuring coordination across governance, financial capacity, urban planning, ecosystem management, social capacity, and critical infrastructure. This dynamic framework enabled CoT to measure its resilience effectively and develop actionable strategies for continuous improvement in disaster preparedness, response, and recovery. The framework's flexibility allowed the city to adapt to evolving risks while aligning disaster risk reduction with sustainable development objectives, thereby enhancing the overall capacity for resilience in a rapidly changing urban context. This case exemplifies how a dynamic resilience framework goes beyond static disaster preparedness by embedding adaptability, multi-sector engagement, and continuous monitoring within urban governance. By integrating strategic documents and stakeholder input, CoT's approach facilitates ongoing situational awareness, resource allocation, and policy adjustments in response to emerging hazards. This dynamic process fosters a culture of resilience that is anticipatory and preventative, with a focus on sustainability and social inclusiveness. The City of Tshwane's experience highlights the effectiveness of a dynamic framework in managing complex and interconnected disaster risks, providing practical guidance and a replicable model for other cities aiming to build adaptive and robust disaster resilience systems

5 RESULTS

The Sendai Framework remains a foundational and comprehensive global instrument, advancing disaster risk resilience increasingly requires a dynamic, technology-enabled, and equity-focused framework capable of managing complexity, uncertainty, and systemic vulnerabilities in an integrated way. Here is a detailed comparison table and expanded critique of the Sendai Framework alongside a proposed Dynamic Resilience Framework as an alternative approach:

Aspect	Sendai Framework	Dynamic Resilience Framework (Alternative)
Core Focus	Disaster risk management; preventing new and reducing existing risk. Focus on measurable targets to reduce mortality, losses, and improve resilience.	Adaptive, anticipatory, and transformative resilience to systemic and emerging risks through dynamic capabilities and continuous learning.
Scope of Risks	Natural, man-made, environmental, technological, biological hazards. Emphasizes multi-hazard and multi-sectoral approaches.	Emphasizes systemic, cascading, interlinked risks across domains including cyber and complex socio-environmental risks.
Governance Approach	Strong state responsibility with multi-stakeholder engagement, clear institutional roles, and developing governance capacity at all levels.	Polycentric, flexible governance with decentralized adaptive decision-making enabling rapid response to evolving risk landscapes.

Aspect	Sendai Framework	Dynamic Resilience Framework (Alternative)
Data and Technology	Promotes open access to disaggregated risk data, GIS, traditional and scientific knowledge integration. Innovation encouraged for hazard assessment.	Leverages real-time data, AI, IoT, big data analytics for predictive risk modeling, dynamic hazard forecasting, and anticipatory governance.
Community and Equity	Emphasizes inclusivity, gender, vulnerable groups, local community empowerment, and non-discriminatory participation.	Prioritizes social equity deeply with co-creation of solutions using indigenous/local knowledge; focuses on adaptive capacities of marginalized groups.
Financial Aspects	Calls for risk-sensitive investments, international cooperation, sustainable financing mechanisms including loans and aid.	Promotes innovative financial mechanisms like resilience bonds, impact investing, novel insurance and risk transfer solutions.
Resilience Concept	Defined in terms of reducing exposure, vulnerability, and strengthening preparedness, response, recovery with "Build Back Better".	Defines resilience dynamically as capacity to sense, seize opportunities, transform and regenerate in face of change, enhancing sustainability.
Monitoring and Accountability	Periodic global targets, national/local indicators, reporting mechanisms integrated into UN governance.	Continuous real-time monitoring, outcome-oriented adaptive accountability frameworks evolving with risk profiles.
Integration with SDGs & Climate	Explicitly linked to Sustainable Development Goals, climate change adaptation, poverty reduction.	Strongly connects resilience with sustainability transitions, climate adaptation, social justice and systemic risk reduction.
Challenges and Limitations	Implementation gaps due to weak capacities and political will; broadness can dilute actionable specificity; less emphasis on emerging tech and complex dynamic risks.	Newer approach needing operationalization; potentially resource-intensive to implement advanced tech and governance innovations; requires robust institutional reform.

6 AN ANALYSIS OF THE RESULT

The Sendai Framework and the Dynamic Resilience Framework present two distinct but complementary approaches to disaster risk management and resilience building. The Sendai Framework primarily targets disaster risk management with the objective of preventing new risks and reducing existing ones through measurable targets such as reducing mortality and losses. Its focus is on strengthening preparedness, response, and recovery phases, promoting the widely known "Build Back Better" principle. In contrast, the Dynamic Resilience Framework adopts a broader, adaptive perspective, emphasizing anticipatory and transformative resilience to systemic and emerging risks. It views resilience as a dynamic capacity to sense, seize opportunities, and regenerate in the face of change, thus focusing on sustainability and long-term transformation.

Regarding the scope of risks, the Sendai Framework embraces a multi-hazard approach, including natural, man-made, environmental, technological, and biological hazards. It encourages coordination across multiple sectors to address these diverse hazards comprehensively. The Dynamic Resilience Framework extends this scope by emphasizing systemic and cascading risks that interlink across various domains, such as cyber risks and complex socio-environmental challenges. This expanded focus reflects the contemporary complexity and interconnectedness of risk environments, requiring flexible and sophisticated approaches.

Governance strategies under these frameworks differ considerably. The Sendai Framework underscores strong state responsibility augmented by multi-stakeholder involvement, with clear institutional roles aimed at developing governance capacities at all administrative levels. It emphasizes hierarchical coordination and capacity building within formal state structures. Conversely, the Dynamic Resilience Framework favors a polycentric governance model characterized by flexibility and decentralization. This approach supports adaptive decision-making and rapid response to evolving risks by empowering local actors and enabling dynamic governance that can respond to shifting conditions effectively.

In terms of data and technology use, the Sendai Framework promotes open access to risk data, integrating both scientific and traditional knowledge with Geographic Information Systems (GIS). It encourages innovation primarily for hazard assessment and risk communication. The Dynamic Resilience Framework pushes further by leveraging cutting-edge technologies such as real-time data streams, artificial intelligence, Internet of Things (IoT), and big data analytics to enable predictive risk modelling and anticipatory

governance. This allows decision-makers to act proactively and update strategies continuously based on emerging information and trends.

Community inclusion and equity form a central part of both frameworks, but with different emphases. The Sendai Framework prioritizes inclusivity by focusing on gender, vulnerable groups, and local community empowerment, ensuring non-discriminatory participation in risk management processes. The Dynamic Resilience Framework deepens this commitment by prioritizing social equity through co-creation of solutions that incorporate indigenous and local knowledge. It focuses explicitly on building the adaptive capacities of marginalized communities, thus embedding resilience within broader social justice and empowerment goals.

The analysis contrasts the traditional Sendai Framework (2015-2030) with a proposed Dynamic Resilience Framework as an alternative approach to disaster risk management. The Sendai Framework focuses on disaster risk management by preventing new and reducing existing risks, with measurable targets to reduce mortality and losses, emphasizing strengthened preparedness, response, and recovery under the principle of "Build Back Better." It addresses multi-hazard risks but tends to follow a static, reactive model with governance centralized under state responsibility. In contrast, the Dynamic Resilience Framework emphasizes adaptive, anticipatory, and transformative capabilities with systemic integration of cascading, interconnected risks (natural, technological, biological, social), leveraging real-time data, AI, and IoT for dynamic risk forecasting and governance. It prioritizes social equity with community co-creation, polycentric governance, innovative financing (resilience bonds, impact investing), and continuous monitoring and learning. The table highlights differences in core focus, risk scope, governance, technology use, equity, finance, resilience concepts, and monitoring approaches between the two frameworks

7 DISCUSSIONS OF THE RESULTS

The Sendai Framework for Disaster Risk Reduction remains a cornerstone in global efforts to mitigate disaster impacts by focusing on preventing new risks and reducing existing ones. It is structured around measurable targets aiming to lower mortality, economic losses, and disruptions caused by natural, technological, and biological hazards. Anchored in strong state responsibility and multi-stakeholder engagement, it promotes clear institutional roles and governance capacity building across all levels. The framework also values inclusivity and gender sensitivity while encouraging open access to risk data and integrating scientific with traditional knowledge for hazard assessment. Despite its significant achievements, the Sendai Framework often struggles with implementation gaps, limited emphasis on emerging technologies, and challenges addressing complex systemic risks.

In contrast, the proposed Dynamic Resilience Framework offers a paradigm shift by emphasizing adaptive, anticipatory, and transformative resilience that addresses systemic and emerging risks dynamically. It recognizes the interconnectedness of risks across natural, technological, biological, and social domains, including rapidly evolving challenges like cyber threats and socio-environmental crises. This framework adopts a polycentric governance approach that decentralizes authority and enables flexible, rapid decision-making through empowered local actors. By leveraging cutting-edge technologies such as AI, IoT, and big data analytics, it supports real-time predictive modelling and anticipatory governance, allowing for proactive and continuous adaptation to shifting risk landscapes. The framework also elevates social equity by embedding co-creation with marginalized and indigenous communities as fundamental to resilience-building.

A key distinction lies in governance and technological integration. While the Sendai Framework is grounded in formal state-led governance with hierarchical coordination, the Dynamic Resilience Framework favors decentralized, flexible governance structures that enhance responsiveness and innovation. Technologically, the Sendai approach promotes open access and innovation primarily in hazard assessment, whereas the Dynamic Resilience Framework capitalizes on real-time data streams and AI-driven analytics for proactive risk anticipation and adaptive management. These technological advancements are critical for effectively managing the high complexity and uncertainty characteristic of current and future disaster risk environments.

Community engagement and financial mechanisms further differentiate the two frameworks. The Sendai Framework prioritizes inclusivity through gender equity, vulnerable groups' empowerment, and non-discriminatory participation in disaster risk reduction efforts. The Dynamic Resilience Framework deepens this by co-creating solutions with indigenous knowledge and emphasizing adaptive capacities for marginalized populations, thereby integrating social justice explicitly into resilience strategies. Financially, whereas the Sendai Framework calls for sustainable investments and international cooperation, the Dynamic Resilience Framework promotes innovative approaches like resilience bonds, impact investing, and novel risk transfer products, aligning funding mechanisms with dynamic resilience goals and enabling sustainable financing of adaptive and anticipatory measures.

Overall, while the Sendai Framework has laid an essential foundation for disaster risk management globally, addressing diverse hazards through measurable goals and established governance, the Dynamic Resilience Framework proposes a comprehensive evolution. This new approach integrates complexity, systemic risks, continuous learning, and cutting-edge technology within a flexible governance and socially equitable context. It recognizes resilience not just as recovery and prevention but as an ongoing capacity for transformation and regeneration amidst uncertainty. Operationalizing this framework will require significant institutional reforms and resources but promises enhanced sustainability and effectiveness in managing today's multi-dimensional disaster risks.

8 AN ALTERNATIVE FRAMEWORK TO SENDAI

The Sendai Framework has established itself as a foundational pillar in global disaster risk reduction efforts, successfully setting measurable targets to minimize mortality, economic damage, and disruptions across a wide spectrum of natural, technological, and biological hazards. Its strength lies in promoting strong state responsibility, engaging multiple stakeholders, and emphasizing

governance capacity building complemented by inclusivity and open data access. However, despite these achievements, the framework faces challenges in operationalizing newer technologies and addressing increasingly complex systemic risks that transcend traditional disaster boundaries.

The proposed Dynamic Resilience Framework responds to these limitations by reimagining resilience as an adaptive, anticipatory, and transformative process. It expands the risk landscape to encompass interconnected threats—ranging from cyber incidents to socio-environmental crises—and advocates for polycentric governance that decentralizes decision-making to empower local actors. Coupled with real-time data integration, AI, IoT, and big data analytics, this framework facilitates proactive, continuous adaptation to fast-evolving risk environments. It also deepens the commitment to social equity through co-creation with marginalized and indigenous communities and promotes innovative financial solutions aligned with adaptive outcomes.

In contrast to the hierarchical, state-centric governance model of Sendai, the Dynamic Resilience Framework envisions flexible, networked governance responsive to complexity and uncertainty. Financially, it pushes beyond traditional investments, employing resilience bonds and impact investing to ensure sustainable funding. Community engagement moves from ensuring inclusivity to fostering agency and partnership, embedding social justice at the core of resilience-building strategies.

While Sendai offers essential building blocks and global legitimacy, the Dynamic Resilience Framework presents a comprehensive evolution that integrates complexity, continuous learning, equitable participation, and cutting-edge technology. Effectively operationalizing this paradigm shift necessitates deep institutional reforms and resource commitments but promises enhanced sustainability and effectiveness for today's multi-dimensional disaster risks.

Building on this evolutionary trajectory, the J-Framework for Disaster Risk Resilience emerges as an innovative conceptual architecture designed for an era of intensifying climate change and rapid urbanization. Recognizing the interconnected nature of modern risks, the J-Framework moves decisively beyond siloed, hazard-specific responses toward a truly holistic and adaptive system. It aims to foster integrated capacities that enable societies not only to withstand and respond to diverse challenges but also to transform dynamically, reflecting the need for comprehensive resilience in an increasingly precarious world.

9 WHAT IS THIS ALTERNATIVE FRAMEWORK FOR DISASTER RISK RESILIENCE?

The relentless march of climate change and increasing urbanization has amplified the frequency and intensity of natural disasters, underscoring an urgent need to rethink our approach to disaster preparedness and response. Traditional disaster risk management frameworks, while valuable, often operate in silos, focusing on single hazards or linear responses. However, the interconnected nature of modern risks demands a more holistic and dynamic perspective. Enter the J-Framework for Disaster Risk Resilience, an innovative conceptual architecture designed to move beyond reactive measures and foster a truly integrated and adaptive capacity to withstand, respond to, and recover from the multifaceted challenges that define our increasingly precarious world.

Aspect	Dynamic Resilience Framework (Alternative)	Description	Indicators for Measurement
Core Focus	Adaptive, anticipatory, and transformative resilience to systemic and emerging risks through dynamic capabilities and continuous learning.	Instead of merely bouncing back, the focus is on proactive adaptation to foreseen changes, anticipating future disruptions, and fundamentally transforming systems to be more robust and sustainable. This is achieved by developing the organization's or system's ability to sense, respond, and evolve.	- **Adaptive Capacity Scores:** Measured through surveys or assessments rating the ability to modify strategies and operations in response to changing conditions. - **Anticipatory Action Metrics:** Number of proactive measures taken based on foresight analysis or early warning systems. - **Learning System Effectiveness:** Rate of adoption of lessons learned from incidents or simulations; documented feedback loops and knowledge sharing mechanisms. - **Transformation Project Success Rate:** Number and impact of implemented systemic changes aimed at enhancing resilience.
Scope of Risks	Emphasizes systemic, cascading, interlinked risks across domains including cyber and complex socio-environmental risks.	Recognizes that risks are not isolated events but interconnected and can trigger a chain reaction across different sectors and scales. This includes understanding and managing threats like climate change impacts, pandemics, global	- **Interdependency Mapping Quality:** Extent and detail of documented interdependencies between critical systems (e.g., energy, water, communication, food, finance). - **Systemic Risk Scenario Coverage:** Number and complexity of

Aspect	Dynamic Resilience Framework (Alternative)	Description	Indicators for Measurement
		economic shocks, and sophisticated cyber-attacks.	systemic risk scenarios developed and tested. - **Cross-Domain Risk Assessments:** Frequency and comprehensiveness of assessments that consider risks impacting multiple sectors (e.g., cyber-physical, climate-social). - **Cascading Failure Event Response Time:** Time taken to identify and contain the initial impact and subsequent ripple effects of a simulated or actual systemic event.
Governance Approach	Polycentric, flexible governance with decentralized adaptive decision-making enabling rapid response to evolving risk landscapes.	Power and responsibility are distributed across multiple interconnected centres, allowing for quick, context-specific decisions at lower levels. This contrasts with rigid, top-down hierarchies, enabling greater agility and responsiveness in dynamic and uncertain environments.	- **Decision-Making Speed Metrics:** Average time from risk identification to critical decision implementation. - **Decentralization Index:** Number of decision-making authorities devolved to sub-units or frontline staff. - **Network Collaboration Indicators:** Frequency and effectiveness of cross-organizational communication and joint decision-making forums. - **Adaptive Policy Frameworks:** Number of governance frameworks that include mechanisms for rapid amendment based on new information.
Data and Technology	Leverages real-time data, AI, IoT, big data analytics for predictive risk modeling, dynamic hazard forecasting, and anticipatory governance.	Employs advanced technologies to collect, process, and analyze vast amounts of information in real-time. This enables the creation of sophisticated models to predict potential threats, forecast their evolution, and inform proactive decision-making, thereby enhancing the ability to govern in a forward-looking manner.	- **Data Integration Score:** Percentage of critical data sources integrated into a unified platform; data quality and timeliness metrics. - **Predictive Model Accuracy:** Accuracy rates of AI/ML models for hazard forecasting and risk identification. - **Real-time Monitoring Coverage:** Percentage of critical assets/processes monitored in real-time; alert generation latency. - **Use of Advanced Analytics:** Number of instances where big data analytics led to significant pre-emption of risks or informed strategic shifts.
Community and Equity	Prioritizes social equity deeply with co-creation of solutions using indigenous/local knowledge; focuses on adaptive capacities of marginalized groups.	Ensures that resilience-building efforts benefit all segments of society, particularly those most vulnerable. It involves actively engaging communities in designing solutions, valuing their unique knowledge, and empowering them to adapt to and recover from disruptions.	- **Community Engagement Metrics:** Number and diversity of community groups involved in resilience planning and implementation; satisfaction levels of community stakeholders. - **Inclusion of Local/Indigenous Knowledge:** Documented instances of traditional knowledge influencing resilience strategies or solutions. - **Equity Impact Assessments:** Results of assessments evaluating the distributional effects of resilience initiatives on different socio-economic groups. - **Capacity Building for Vulnerable Groups:** Number of programs and

Aspect	Dynamic Resilience Framework (Alternative)	Description	Indicators for Measurement
			participants focused on enhancing the resilience capacities of marginalized populations.
Financial Aspects	Promotes innovative financial mechanisms like resilience bonds, impact investing, novel insurance and risk transfer solutions.	Explores and utilizes forward-thinking financial tools and instruments to fund resilience initiatives and manage the financial impact of shocks. This includes attracting private capital, creating new markets for resilience, and sharing risk in novel ways.	- **Investment in Resilience Projects:** Total capital mobilized through innovative financial mechanisms for resilience. - **Number of Resilience Bonds Issued/Invested in:** Market activity in resilience-linked financial instruments. - **Innovative Risk Transfer Utilization:** Use of parametric insurance, catastrophe bonds, or other novel instruments. - **Financial Resilience Ratios:** Metrics indicating the financial preparedness to absorb and recover from economic shocks (e.g., liquidity ratios, reserve adequacy).
Resilience Concept	Defines resilience dynamically as capacity to sense, seize opportunities, transform and regenerate in face of change, enhancing sustainability.	Views resilience not as a static state but an ongoing process of sensing emerging challenges and opportunities, acting on them, fundamentally adapting systems, and renewing resources and capacities to achieve a higher, more sustainable state of functioning.	- **"Sense" Metrics:** E.g., early warning effectiveness, lead time for identifying significant trends. - **"Seize" Metrics:** E.g., number of new initiatives or opportunities successfully launched in response to change, resource reallocation efficiency. - **"Transform" Metrics:** E.g., progress in implementing systemic changes as outlined in 'Core Focus'. - **"Regenerate" Metrics:** E.g., improvement of natural capital, enhancement of social cohesion, restoration of damaged systems. - **Sustainability Indicator Trends:** Positive trends in relevant environmental, social, and economic sustainability metrics.
Monitoring and Accountability	Continuous real-time monitoring, outcome-oriented adaptive accountability frameworks evolving with risk profiles.	Implements constant tracking of system performance and risk indicators, coupled with accountability mechanisms that are flexible and adjust as the nature and magnitude of risks change. The focus is on achieving desired outcomes, not just adherence to initial plans.	- **Real-time Performance Dashboards:** Availability and usage of dashboards tracking key resilience and operational metrics. - **Adaptive KPI Framework:** Number of Key Performance Indicators (KPIs) that are regularly reviewed and adjusted based on evolving risk landscapes. - **Outcome-Based Accountability Reviews:** Frequency and effectiveness of reviews assessing achievement of resilience outcomes rather than just process compliance. - **Transparency and Reporting Mechanisms:** Public accessibility and clarity of resilience performance reports.

Aspect	Dynamic Resilience Framework (Alternative)	Description	Indicators for Measurement
Integration with SDGs & Climate	Strongly connects resilience with sustainability transitions, climate adaptation, social justice and systemic risk reduction.	Explicitly aligns resilience strategies with global sustainability goals (like the SDGs) and urgent climate action. It recognizes that building resilience is integral to achieving a just, sustainable, and low-carbon future, and that these agendas reinforce each other.	- **Alignment Score with SDGs:** Percentage of resilience initiatives directly contributing to specific UN Sustainable Development Goals. - **Climate Adaptation Integration:** Extent to which climate change projections and adaptation measures are embedded in resilience plans. - **Contribution to Social Justice:** Evidence of resilience efforts promoting equity and reducing inequalities. - **Systemic Risk Reduction Impact:** Measured reduction in the likelihood or impact of identified systemic risks.
Challenges and Limitations	Newer approach needing operationalization; potentially resource-intensive to implement advanced tech and governance innovations; requires robust institutional reform.	This framework is relatively novel and may require significant effort to translate into practical applications. Implementing advanced technologies and new governance structures can be costly and demanding, and often necessitate fundamental changes in existing institutions and organizational cultures.	- **Operationalization Framework Development:** Progress in creating clear guidelines and procedures for implementing the framework. - **Resource Allocation for Innovation:** Percentage of budget dedicated to implementing advanced technologies and governance reforms for resilience. - **Institutional Reform Milestones:** Achievement of key targets set for organizational or governmental restructuring to support dynamic resilience. - **Stakeholder Readiness/Capacity:** Assessments of organizational or community capacity and willingness to adopt new resilience approaches.

10 A SWOT ANALYSIS OF DISASTER RISK REDUCTION (DRR) AND DISASTER RISK RESILIENCE (DRF) FRAMEWORKS

As global hazards intensify due to climate change, rapid urbanization, and increasing socio-economic vulnerability, the strategies underpinning our safety—Disaster Risk Reduction (DRR) and Disaster Risk Resilience (DRF) frameworks—have become the cornerstone of sustainable development. While these frameworks provide essential blueprints for proactive planning, capacity building, and rapid recovery, their real-world effectiveness is often hampered by systemic challenges and conflicting priorities. To move beyond mere policy rhetoric and ensure that communities are truly equipped to withstand and recover from catastrophic events, a rigorous evaluation is necessary. This analysis delves into a comprehensive SWOT assessment, systematically dissecting the inherent strengths and foundational weaknesses of current DRR and DRF models, while simultaneously identifying the vital opportunities for innovation and the critical external threats that challenge their long-term efficacy in safeguarding a volatile future. The following table summarizes the SWOT analysis of both frameworks, highlighting the Sendai Framework's strength as a foundational global policy and the Disaster Risk Resilience Framework's advanced adaptive and inclusive approach. Transitioning to the latter requires institutional transformation but offers improved capacity to manage today's complex disaster risks effectively

Aspect	Sendai Disaster Risk Framework	Disaster Risk Resilience Framework
Strengths	Globally recognized; clear measurable targets; multi-hazard approach; strong state responsibility; inclusive participation; supports governance capacity building; promotes open risk data access	Adaptive, anticipatory, transformative resilience; real-time learning; uses advanced tech like AI and IoT; flexible decentralized governance; prioritizes social equity; innovative financial mechanisms; continuous monitoring
Weaknesses	Static model struggles with complex emerging risks; implementation gaps from capacity/political will; less emphasis on new tech; broad and less specific actionable items	Newer framework needing operationalization; resource and institutional demands; complex governance and tech integration requiring reforms
Opportunities	Can integrate emerging tech and dynamic governance practices; strengthen social equity and financing mechanisms	Addresses systemic cascading risks; leverages cutting-edge tech for anticipatory governance; fosters inclusive community co-creation; strongly aligns with sustainability and justice; innovative investment tools
Threats	Escalating disaster complexity may outpace framework; resource and political challenges to implementation	High reform and resource demands may limit adoption; potential resistance to decentralization; data and ethical challenges in tech use

11 COMPREHENSIVENESS AND EFFECTIVENESS OF DISASTER RISK RESILIENCE FRAMEWORK (DRF)

The Disaster Risk Resilience Framework presented in this paper is both effective and more comprehensive compared to the Sendai Framework for Disaster Risk Reduction, offering a dynamic, adaptive, and anticipatory approach to managing disaster risks in today's complex and interconnected risk landscape.

Effectiveness of the Disaster Risk Resilience Framework

1. The framework emphasizes adaptive, anticipatory, and transformative resilience, moving beyond the static, reactive risk prevention focus of the Sendai Framework. It integrates continuous learning and real-time data to respond proactively to emerging and systemic risks.
2. It incorporates advanced technologies such as artificial intelligence (AI), Internet of Things (IoT), and big data analytics, enabling predictive risk modelling and anticipatory governance, which enhance timely decision-making and risk mitigation.
3. Polycentric, decentralized governance fosters flexible, rapid responses tailored to local contexts, as opposed to Sendai's stronger reliance on centralized state governance, thereby improving agility and local empowerment.
4. The framework's successful application in the City of Tshwane, South Africa, demonstrates practical effectiveness in coordinating governance, finance, urban planning, and infrastructure to continuously improve disaster preparedness and recovery.

Comprehensiveness of DRF in Comparison to the Sendai Framework

1. It expands the scope of risks to include systemic, cascading, and interconnected hazards such as cyber risks and complex socio-environmental crises, recognizing the multi-dimensional nature of contemporary disasters.
2. Social equity is prioritized deeply through co-creation with marginalized and indigenous communities, going beyond Sendai's inclusivity by embedding traditional knowledge and ensuring community agency in resilience-building.
3. Financial innovation is a core element, promoting resilience bonds, impact investing, and novel insurance mechanisms aligned with adaptive resilience goals, whereas Sendai largely emphasizes traditional risk-sensitive investments and international cooperation.
4. Monitoring and accountability are transformed from periodic reporting to continuous, real-time, outcome-oriented frameworks that adapt to evolving risk profiles.
5. The framework explicitly integrates disaster risk reduction with broader Sustainable Development Goals, climate adaptation, and social justice, reinforcing resilience as a systemic, transformative process rather than a reactive one.

Thus, the Disaster Risk Resilience Framework addresses limitations of the Sendai Framework by adopting a future-ready, systemic perspective that is flexible, technologically advanced, and socially equitable. Its dynamic capabilities and polycentric governance enable more effective disaster risk management in the face of increasingly complex and interconnected hazards, making it a more comprehensive and effective approach for contemporary disaster resilience

12 DISASTER RISK RESILIENCE FRAMEWORK IMPLEMENTATION STEPS

As global threats from climate change and seismic activity continue to escalate, the crucial shift from merely reacting to disasters to systematically building genuine, long-term resilience has become paramount. Enter the J-Framework, a highly structured and systematic methodology designed to translate abstract disaster risk reduction goals into concrete, measurable actions at the community and national level. This framework represents more than just a theoretical blueprint; it is an actionable roadmap engineered to ensure continuity, accountability, and adaptive capacity. We now turn our attention to dissecting the essential implementation steps of the J-Framework, which provide the vital architecture necessary to guide stakeholders from initial vulnerability assessment through to fully operational, sustained disaster preparedness.

Implementation Step	Description
Holistic Assessment	Conduct a comprehensive review of current operations, governance, finance, technology, community engagement, and risks to identify gaps and areas for enhancement in dynamic resilience capacity.
Strategic Planning	Develop an integrated roadmap with clear objectives, key performance indicators (KPIs), and success metrics focused on building adaptive, anticipatory, and transformative resilience.
Governance Decentralization	Implement polycentric governance by distributing decision-making authority across multiple interconnected centres to enable rapid, context-specific adaptive responses.
Advanced Data and Technology Use	Deploy real-time data integration, AI, IoT, and big data analytics to create predictive risk models, dynamic hazard forecasting, and anticipatory governance mechanisms.
Community Co-Creation and Equity	Engage marginalized, indigenous, and vulnerable communities in co-designing resilience strategies, incorporating traditional knowledge to enhance social equity and adaptive capacities.
Financial Innovation	Adopt innovative financing mechanisms including resilience bonds, impact investing, and novel insurance products that align funding with adaptive resilience outcomes.
Continuous Monitoring and Adaptation	Establish real-time performance dashboards and adaptive accountability frameworks that evolve with changing risk profiles and allow ongoing policy adjustment.
Institutional Reform and Capacity Building	Invest in training, resource allocation, and organizational restructuring to operationalize advanced technologies, governance innovations, and empower local actors for dynamic resilience.

This table synthesizes the practical implementation steps aligned with the core features and indicators of the Dynamic Resilience Framework, guiding organizations and governments in building adaptive and effective resilience systems.

13 POLICY IMPLICATIONS

The policy implications derived from comparing the static Sendai Framework and the adaptive Dynamic Resilience Framework center on the urgent need for institutional and governance reform. The rigid, state-led, hierarchical coordination model underpinning current Disaster Risk Reduction (DRR) policies proves insufficient for addressing complex, interconnected systemic risks and rapid technological evolution. Therefore, policy recommendations must prioritize the institutionalization of polycentric governance structures. This requires policy mandates that decentralize authority, empowering local actors—including municipalities, private sector entities, and civil society—with the flexibility and resources necessary for rapid decision-making and continuous adaptation. Furthermore, national DRR strategies must be updated to formally recognize and integrate emerging risks (like cyber threats or complex

socio-environmental crises) that are currently siloed or poorly defined under traditional hazard assessment, requiring cross-sectoral policy working groups rather than traditional, sector-specific institutional roles.

A core policy implication is the necessary shift in technological investment and data strategy from simple "open access" to "real-time anticipatory analytics." Current policies are often limited to promoting innovation in basic hazard assessment, leading to significant implementation gaps concerning cutting-edge tools. Policy recommendations must mandate substantial public and private investment in leveraging technologies such as AI, IoT, and big data to operationalize real-time predictive modelling and anticipatory governance. This requires developing regulatory sandboxes and ethical guidelines that facilitate the secure and efficient exchange of adaptive data streams across government levels and with private technology providers. By embedding AI-driven analytics into foundational planning documents, governments can move away from reactive recovery spending toward proactive, continuous adaptation, aligning national budgets with the goal of managing uncertainty rather than merely mitigating established risks.

14 RECOMMENDATIONS

1. Differences in financial and social equity approaches between the two frameworks show current policies insufficiently integrate social justice and innovative finance into resilience strategies.
2. Policy recommendations must actively overhaul traditional disaster financing mechanisms.
3. This overhaul includes creating explicit policy frameworks such as regulatory support for resilience bonds, impact investing, and novel risk transfer products.
4. Funding should be aligned with dynamic, outcome-based criteria of adaptive measures rather than traditional infrastructure protection.
5. Social equity must be elevated beyond mere inclusivity.
6. Policies should mandate co-creation of resilience solutions with marginalized, vulnerable, and indigenous communities.
7. Traditional knowledge from these communities must be formally integrated, granting them direct agency in decision-making.
8. Promote integrated strategic planning that combines holistic assessments with clear KPIs to ensure adaptive, anticipatory, and transformative resilience is systematically built and tracked across governance, finance, technology, and community engagement domains.
9. Facilitate polycentric and decentralized governance structures supported by advanced data analytics and real-time monitoring technologies such as AI and IoT, enabling rapid, context-specific decision-making and anticipatory responses to evolving systemic risks.
10. Prioritize community co-creation with marginalized and indigenous populations to embed social equity in resilience strategies, alongside adopting innovative financial instruments like resilience bonds and impact investing to secure sustainable funding for dynamic resilience initiatives.
11. Strengthen multi-level governance capacities by promoting decentralized and polycentric approaches that enable agile, adaptive decision-making in disaster risk management.
12. Invest in real-time data infrastructure, AI, big data analytics, and IoT-enabled platforms for dynamic hazard forecasting, monitoring, and early warning systems.
13. Embed social equity through participatory frameworks that co-create resilience solutions with indigenous, marginalized, and vulnerable communities.
14. Promote innovative financial mechanisms such as resilience bonds, impact investing, and novel insurance products to complement traditional risk reduction funding.
15. Develop continuous learning and accountability frameworks that evolve based on real-time risk data and outcomes to improve implementation effectiveness.
16. Integrate disaster risk reduction with broader sustainable development, climate adaptation, and social justice agendas to ensure holistic and transformative resilience building.
17. Facilitate peer review, cross-country learning, and knowledge sharing to accelerate diffusion of dynamic resilience practices and technologies globally [attached document].

This synthesis overall underscores the critical need to evolve disaster risk management frameworks towards a more dynamic, inclusive, and technology-enabled approach, reflecting contemporary risks and global development contexts

15 CONCLUSION

1. The City of Tshwane (CoT) exemplifies a successful application of a dynamic resilience framework by integrating the Sendai Framework and Sustainable Development Goals within its disaster resilience strategies.
2. CoT addressed the gap of lacking a consolidated resilience model by developing a comprehensive framework coordinating governance, finance, urban planning, ecosystem management, social capacity, and infrastructure.
3. The dynamic framework enabled effective resilience measurement and continuous improvement in disaster preparedness, response, and recovery in a rapidly changing urban environment.
4. Flexibility and adaptability are key features of the dynamic resilience framework, allowing alignment of disaster risk reduction with sustainable development objectives.
5. Embedding multi-sector engagement and continuous monitoring fosters a culture of anticipatory, preventative, sustainable, and socially inclusive resilience.
6. The Sendai Framework is foundational but limited by a more static approach focusing on multi-hazard risk management with measurable mortality and loss reduction targets.

7. The Dynamic Resilience Framework extends risk scope to systemic, cascading, and interconnected hazards including cyber and socio-environmental risks, requiring dynamic adaptive capacity.
8. Governance under Sendai centres on strong state-led coordination, while the Dynamic framework advocates polycentric, decentralized governance for rapid adaptive decision-making.
9. Technological advancement in the Dynamic framework surpasses the Sendai focus by employing real-time data, AI, IoT, and big data analytics for predictive risk modelling and anticipatory governance.
10. Holistic assessments and strategic planning are essential first steps to identify existing gaps and establish clear, measurable objectives focused on building flexible and transformative resilience capabilities within organizations and systems.
11. Decentralizing governance through polycentric models enhances the agility and context-specific responsiveness necessary to address complex and rapidly evolving risk landscapes effectively.
12. Leveraging advanced technologies such as AI, IoT, and big data analytics enables predictive risk modelling and real-time anticipatory governance, which are critical for proactive disaster preparedness and adaptive response.
13. The Disaster Risk Resilience Framework offers a vital evolution in disaster risk management by overcoming the limitations of the Sendai Framework through its adoption of a future-ready, systemic perspective. By prioritizing flexibility, technological integration, and social equity, coupled with dynamic capabilities and polycentric governance, this framework provides a more robust and adaptable strategy for addressing the multifaceted and increasingly interconnected nature of contemporary disasters, thereby paving the way for enhanced and more comprehensive disaster resilience.
14. Ensuring community co-creation and equity alongside innovative financing mechanisms strengthens social inclusiveness and secures sustainable funding aligned with dynamic resilience goals, while continuous monitoring and institutional reform sustain ongoing adaptation and capacity building
15. Social equity advances from inclusivity in Sendai to deep co-creation with marginalized and indigenous communities, amply integrating traditional knowledge and adaptive social capacities.
16. Financial mechanisms evolve from traditional risk-sensitive investments to innovative tools like resilience bonds, impact investing, and novel insurance products aligned with adaptive outcomes.
17. Continuous, real-time monitoring and adaptive accountability under the Dynamic framework improve resilience implementation beyond periodic reporting found in Sendai.
18. Integration of disaster risk reduction with broader sustainability, climate adaptation, and social justice strengthens resilience as a systemic, transformative process.
19. Operationalizing the Dynamic Resilience Framework requires substantial institutional reform, investment in new technologies, and decentralization of governance authority.
20. Policy shifts must mandate polycentric governance, innovative financing, technological investment in anticipatory analytics, and co-creation with vulnerable communities to build adaptive, equitable resilience globally

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17 ETHICAL CONSIDERATIONS

This research uses publicly available secondary data with ethical adherence to proper citations and avoiding confidentiality breaches.

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