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Original Article

Strengths and challenges of tabletop exercises for climate resilience

Pontos fortes e desafios dos exercícios simulados de mesa para a resiliência climática

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ABSTRACT

Background: Extreme weather events driven by climate change increasingly threaten society. Tabletop Exercises (TTX) emerge as vital participatory tools for response coordination and climate adaptation.
Purpose: A lack of structured analysis persists regarding their application to climate risks. This study maps participant profiles, methodologies, take-aways and technological innovations to provide a systematic panorama of TTX effectiveness.
Design/Methodology: Drawing on Resilience Engineering, which studies success under variability, this study views TTX as a means to elicit strengths and brittleness, thereby boosting adaptive capacity. A systematic review was conducted using the PRISMA protocol across Scopus and Web of Science. Ten peer-reviewed papers met the eligibility criteria for final analysis.
Results & Discussion: TTX proved versatile across multiple sectors, fostering situational awareness, collaborative decision-making, and social learning. While digital platforms and simulation models represent significant technological innovations, governance gaps remain, particularly in unified command activation and the inclusion of lay populations.
Conclusion: TTX are cost-effective instruments to develop critical capacities and integrate actors in the management of extreme weather events. In addition to improving immediate performance, they provide insights applicable to long-term climate resilience strategies. However, challenges persist regarding social inclusion and response coordination, indicating the need for more inclusive and robust practices.
Originality/value: This review advances the literature by reframing TTX as mechanisms for revealing systemic brittleness and supporting social learning, rather than solely training tools, while identifying persistent governance and social gaps relevant to policy and practice.

Keywords: Climate resilience; Tabletop exercises; Extreme weather events

RESUMO

Contextualização: Eventos climáticos extremos impulsionados pelas mudanças climáticas ameaçam cada vez mais a sociedade. Os exercícios simulados de mesa (Tabletop Exercises – TTX) surgem como ferramentas participativas vitais para a coordenação de resposta e adaptação climática.
Objetivo: Há uma lacuna persistente de análises estruturadas quanto à sua aplicação aos riscos climáticos. Este estudo mapeia perfis de participantes, metodologias e inovações tecnológicas para fornecer um panorama sistemático da eficácia dos TTX.
Abordagem metodológica: Com apoio da Engenharia de Resiliência, que estuda o sucesso sob condições de variabilidade, este trabalho vê os TTX como um meio de identificar pontos fortes e vulnerabilidades, impulsionando assim a capacidade adaptativa. Neste contexto, foi realizada uma revisão sistemática utilizando o protocolo PRISMA nas bases Scopus e Web of Science. Dez artigos revisados por pares atenderam aos critérios de elegibilidade para a análise final.
Resultados e Discussão: Os TTX provaram ser versáteis em múltiplos setores, promovendo a consciência situacional, a tomada de decisão colaborativa e a aprendizagem social. Embora as plataformas digitais e os modelos de simulação representem inovações tecnológicas significativas, permanecem lacunas de governança, particularmente na ativação do comando unificado e na inclusão de populações leigas.
Conclusão: Os TTX são instrumentos custo-efetivos para desenvolver capacidades críticas e integrar atores na gestão de eventos climáticos extremos. Além de melhorar o desempenho imediato, geram insights aplicáveis a estratégias de longo prazo em resiliência climática. Contudo, persistem desafios quanto à inclusão social e à coordenação de resposta, indicando a necessidade de práticas mais inclusivas e robustas.
Originalidade/valor: Esta revisão contribui para o avanço da literatura ao reformular o TTX como mecanismos para revelar fragilidades sistêmicas e apoiar a aprendizagem social, em vez de meras ferramentas de treinamento, ao mesmo tempo que identifica lacunas de governança e sociais persistentes relevantes para políticas e práticas.

Palavras-chave: Resiliência climática; Exercícios simulados de mesa; Eventos climáticos extremos

1 INTRODUCTION

Extreme weather events (EWE) such as floods, droughts, and heatwaves have become more frequent and intense due to global climate change (Bastos et al., 2025). These events pose a constant threat to society and the environment, with impacts that extend beyond the environmental scope to deeply affect social, economic, and institutional dimensions (IPCC, 2023; Bichueti et al., 2025). Vulnerable populations are disproportionately affected, and essential services are at risk of collapse (Carvalho et al., 2024).

This reality highlights the behaviour of complex systems, comprising interacting actors, technologies, and organisational processes, in which outcomes emerge from nonlinear interactions, feedback loops, and interdependencies (Perrow, 1984). In such

systems, governance operates through the coordination of multiple interdependent actors under conditions of uncertainty and partial information (Renn, 2008). To cope with this, it is crucial to strengthen climate resilience, which refers to a system's capacity to adapt, recover, and thrive despite climate impacts (Lv et al., 2024). Although widely discussed, a single, operational definition of climate resilience remains elusive, underscoring the need for clearer frameworks (Peri et al., 2024).

Resilience Engineering offers a complementary perspective, shifting the focus from simply recovering from failures to enhancing a system's ability to succeed under variable conditions. This approach provides a promising basis for operationalizing resilience in systems affected by climate change (Hollnagel et al., 2021).

In this context, tabletop exercises (TTX) have emerged as a widely used tool for integrated preparedness. As a form of scenario-based training (SBT), TTX are participatory simulations that promote collective learning, plan reviews, and the identification of vulnerabilities before real crises occur (Elvegård & Andreassen, 2024). Their effectiveness in strengthening coordination and building systemic climate resilience is well-documented (Elvegård & Andreassen, 2024).

Despite their growing use, the literature lacks structured analyses on how TTX are applied to address extreme climate risks. There is a notable gap in understanding participant profiles, methodological approaches, outcomes, and the use of technologies or innovations (Nazli et al., 2015). This absence of a comprehensive overview hinders organizational learning and the development of evidence-based guidelines (Wieszczeczynska et al., 2024).

Hence, this study addresses the following research question: How have tabletop exercises been used with different populations to address extreme climate risks, what methodologies are employed, what are the main observed outcomes, and what technologies or innovations have been incorporated? Our objective is to map and analyze these approaches to provide a clearer understanding of TTX application in the context of EWEs.

2 SCENARIO-BASED TRAINING

Scenario-based training (SBT) is not attributable to a single inventor but emerged through the convergence of military scenario planning, aviation human factors, educational psychology, and professional simulation (Helmreich & Foushee, 2019). While its early roots can be traced to post-war military war-gaming and strategic scenario planning (Kahn & Wiener, 1969), the concept was consolidated during the 1990s and 2000s as a formal instructional and training approach focused on the use of realistic, context-rich scenarios to support decision-making, coordination, and reflective learning. During this period, advances in cognitive psychology and constructivist learning theory shifted training paradigms away from rote procedural rehearsal toward experiential learning, in which learners actively engage with complex, ill-defined problems and explore the consequences of their actions (Schank et al., 1999; Salas & Cannon-Bowers, 2001).

This consolidation was marked by the systematic integration of scenarios into training design frameworks, in which scenarios function not merely as illustrative examples, but as the central structure around which learning objectives, task complexity, and feedback are organized. Instructional models such as the Four-Component Instructional Design (4C/ID) explicitly positioned scenario-based learning as a core mechanism for developing complex professional competencies, including judgment, situational awareness, and adaptive expertise (van Merriënboer et al., 2025). In parallel, high-risk domains such as aviation and healthcare adopted scenario-based simulation to train non-technical skills, such as teamwork, communication, and leadership, recognizing that safe and effective performance depends on cognitive and social processes as much as technical proficiency (Gaba, 2004; Helmreich & Foushee, 2019).

Table 1 – SBT subcategories

	Format	Primary Objective	Degree of Realism	EWE Example: Severe Urban Flood
Tabletop Exercise (TTX) (Perry, 2004)	Scenario-based discussion	Decision-making, interagency coordination	Low to Moderate	Simulation of flood response involving health managers, civil defense, and transportation agencies in a physical or virtual meeting room.
Drill (Hsu et al., 2004)	Practical and localized action	Training a specific task under pressure	Moderate	Evacuation training for patients from an Emergency Care Unit during a sudden flood event.
Functional Exercise (Alexander, 2003)	Operational simulation of organizational functions	Testing systems, protocols, and communication flows	Moderate	Activation of the municipal emergency operations center in response to extreme rainfall forecasts.
Full-Scale Exercise (Berlin & Carlström, 2015)	Large-scale simulation with real teams and resources	Assessing integrated and field-level operational response	High	Deployment of firefighters, ambulances, and shelters during a live flood simulation in a high-risk neighborhood.
Computer-Based Simulation (Persson et al., 2014)	Interactive digital simulation	Training individual or group decision-making in a virtual environment	Moderate	A platform simulating the progression of a flood, allowing decision-makers to test alternative strategic responses.
VR / AR Simulation (Kinateder & Warren, 2016)	Virtual or augmented reality simulation	Immersive sensory and behavioral engagement in an extreme scenario	High	VR simulation placing an emergency shelter operator in charge of displaced populations following a major flood event.
Serious Game (Mayer, 2014)	Interactive scenario-based game	Engaging participants in problem-solving and critical learning	Moderate	A game where players act as crisis managers tasked with allocating resources during a multi-neighborhood flood event.

Source: Authors

By the early 2000s, SBT had thus evolved into a mature approach emphasizing learning through realistic decision contexts, structured debriefing, and reflection on both actions and underlying system constraints, providing a foundation for its later adoption in disaster preparedness, emergency management, and resilience-oriented training (Perry, 2004; Rudolph et al., 2006).

In recent theoretical and applied literature, SBT serves as a methodological umbrella that includes various formats of progressively realistic scenario-based training. The main SBT subcategories, organized according to their level of complexity, realism, resources involved, and with one example of an EWE, are described in the table 1.

3 METHODOLOGY

This study used a systematic literature review to collect, select, and analyze empirical studies relevant to our objective, following a replicable protocol. This approach helps us identify recurring themes, inconsistencies, and gaps, which provides a solid foundation for future research and practical applications (Tranfield et al., 2003).

We selected Scopus and Web of Science databases to find documents relevant to our study, limiting our search to papers published from 2021 onward. These criteria were established to capture the most recent five years of TTX practices, and because the chosen databases yield broad coverage of high-impact journals. We used a two-part search string (Table 2), with both parts, terms for climate hazards and the term "Tabletop", applied to the title, abstract, and keywords.

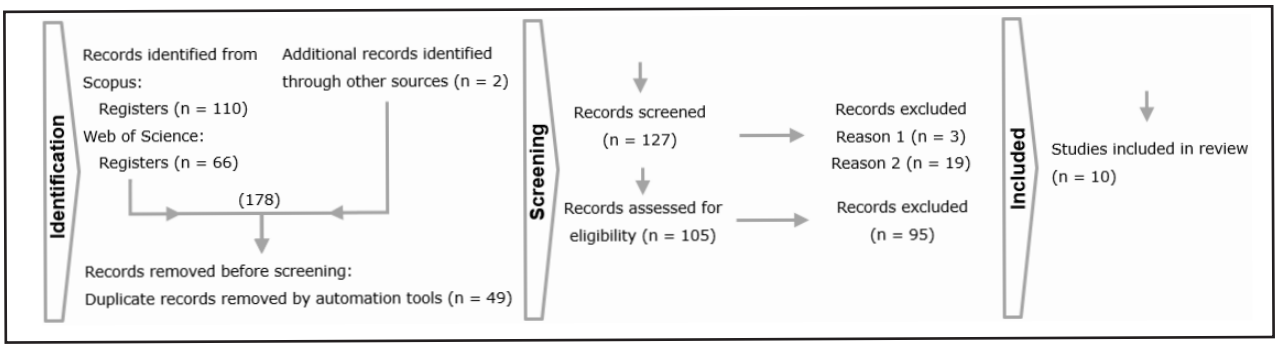
Table 2 – String strategy

climate* OR weather OR flood* OR drought OR hurricane* OR cyclone* OR typhoon* OR storm* OR "heat wave*" OR "cold wave*" OR "extreme temperature*" OR "natural disaster*" OR "heavy rainfall" OR "torrential rain" OR wildfire* OR "forest fire*" OR windstorm* OR hailstorm* OR "extreme precipitation"	AND	tabletop

Source: Authors

This study followed the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) for data collection (Page et al., 2021). Figure 1 illustrates the sequential stages of identification, screening, and inclusion of relevant studies.

Figure 1 – PRISMA flow diagram for this study



Source: Authors

In the identification phase, the initial search yielded 178 records: 110 from Scopus and 66 from Web of Science. An additional two records were identified through manual search on Google Scholar. After the initial identification, screening procedures were applied. First, 49 duplicate records were removed prior to screening, resulting in 127 unique records for further assessment. These records underwent automated screening, which resulted in the exclusion of 22 papers based on two criteria: (i) they were not written in English and (ii) they were publication types such as book chapters, books, editorials, notes, and reports. During the final eligibility phase, 105 full-text articles were assessed. Of these, 95 were excluded either because they were off-topic or for not providing sufficient information to address the research question, including five articles because we could not access full-text due to paywalls. The inclusion criteria considered were: *(i)* indication of population involved, *(ii)* description of methodology used, and *(iii)* presentation of technologies or innovation adopted in the TTX. By applying these inclusion criteria, ten studies were eventually selected for the systematic review.

The selected papers were analysed using a simplified thematic approach based on the principles proposed by Braun and Clarke (2016), involving three main stages: *(i)* initial coding of relevant data (e.g., identifying references to participants, methods, and innovation), *(ii)* grouping codes into broader categories (e.g., clustering similar methodological approaches or types of outcomes), and *(iii)* synthesis into overarching findings. Although a formal quality appraisal was not

conducted, attention was given to the clarity of study objectives, methodological transparency, and consistency of reported outcomes, which supported a cautious interpretation of TTX effectiveness. The identification of themes was deductive and guided by the research question, thus there were four themes: population, methodology, key results, and innovation and technology.

4 RESULTS AND DISCUSSION

Table 3 presents a summary of the ten articles included in the review.

Table 3 – Tabletop exercises on extreme weather events over the last five years based on the PRISMA data collection

(Continue)

Authors	Population	Methodology	Key Outcomes	Technology / Innovation
Maslanka & Hurwitz (2022)	Medical Monitoring Station (MMS) leadership and over 70 professionals from health, cleaning, food services, security, communication and pharmaceuticals in New Orleans (USA).	Following the development of a MMS Shelter-in-Place Plan, a virtual TTX simulated the organization's preparations for a major hurricane during the COVID-19 pandemic.	Patient care without evacuation, ensured food, supplies, and shelter for staff, and coordinated with other health centers; Enabled emergency inventory, predicted evacuation routes, reviewed admission criteria, and designated areas for critical care.	Combining hospital and shelter practices, the scalable care plan incorporated an emergency critical care zone, 14-day supply kits, redundant power and communication systems, zoning for physical distancing, a reverse triage system, and detailed logistical planning.
Wijaya et al. (2022)	100 residents of the Musi Rawas region, Indonesia.	Quasi-experiment: 2 TTX sessions vs leaflets for floodings.	Increased community readiness and intentional behaviour.	Styrofoam-shaped simulation board; Pre- and post-assessment.

Table 3 – Tabletop exercises on extreme weather events over the last five years based on the PRISMA data collection

(Continue)

Authors	Population	Methodology	Key Outcomes	Technology / Innovation
Allred et al. (2023)	First responders and caregivers in senior housing facilities in California (USA).	Situation Awareness Global Assessment Technique through a smart-space platform with planned stops for group decision data collection for wildfires.	Adoption of the smart-space platform improved situational awareness, safer decisions, and maintained resident data privacy.	L-shaped conference room with two projectors; regional information based on previous real data; stored and exchanged real-time and pre-event information with response agencies.
Granström et al. (2023)	20 Swedish incident commanders (IC)	Questionnaires, analysis of decisions and tactical strategies taken for data-driven fire scenarios.	Reasonable consensus on risk perception, but deficiencies for large-scale incidents due to limited formal training.	Exercise focused on perception and tactics with ICs; recommendations to improve national training.
Kimura et al. (2023)	17 nursing home staff from Japan	Web-based Disaster Imagination Game (DIG) simulating flood evacuation.	Ease of participation, objective assessment, and performance recording.	Remote training ICT(Information and Communication Technology)-based DIGs; reduction in operation efforts with easy adjustment of training load.
Elvegård & Andreassen (2024)	125 master's degree students from diverse backgrounds enrolled in the Norwegian Preparedness and Emergency Management Programme.	Remote 4h-exercise of radiological-nuclear search and rescue maritime event.	Improved collaboration; Recommendations for capturing crucial competencies.	Mixed-group discussions in digital breakout rooms; The traffic of nuclear-propelled vessels in the Arctic Sea areas is noticeably increasing.

Table 3 – Tabletop exercises on extreme weather events over the last five years based on the PRISMA data collection

(Continue)

Authors	Population	Methodology	Key Outcomes	Technology / Innovation
Filippidis et al. (2024)	First responders, civil protection organisations, fire service, and emergency and medical response services from Greece.	Simulation using urbanEXODUS modelling before and during the TTX of evacuation of a fortified medieval city.	Enhanced understanding of evacuation complexities challenging assumptions; providing quantitative metrics on evacuation times and routes.	A variant of the EXODUS Agent Based Model, which is agentic computational model simulating realistic urban evacuations; with dynamic analyses to test and visualize decisions in crisis scenarios.
Hogg et al. (2024)	51 individuals: municipal and emergency services employees, National Weather Service (NWS) staff (USA).	First module with 3 phases: pre-storm, active severe weather operations, immediate response; second module using NWSChat for real-time information updates.	Improved communication, identified gaps in plans, and use of impact-based decision support service charts.	Firsthand implementation of a communication platform dedicated to connecting weather forecasters and emergency responders in real time during disasters.
Wang et al., 2024	68 nurses and 29 physicians from the emergency department of a university hospital in Taiwan.	15-min pre-test followed by 30-min introduction of contingency evacuation plan, 90-min TTX, 30-min discussion, 15-min post-test questionnaire	Participants significantly improved their approach to mass casualty incidents, their patient evacuation methods, and their triage skills. The pre- and post-test accuracy rate increased from 68.75% to 94.33%.	Time□controlled mechanism to cause stress for the participants, challenging their responses; integration of game design elements such as challenge, collaboration and feedback.

Table 3 – Tabletop exercises on extreme weather events over the last five years based on the PRISMA data collection

(Conclusion)

Authors	Population	Methodology	Key Outcomes	Technology / Innovation
Levett-Jones et al. (2025)	(24-36) Nursing students in Australia	Six groups of 4 to 6 students were given different scenarios. New developments for each scenario were revealed by drawing a card from a deck every 5 to 10 minutes.	Improved decision-making, collaboration, and prioritization under pressure; Enhanced understanding of resource management, decision ramifications, and contingency planning.	Encouraged the development of higher order thinking skills along with the application of theoretical concepts; Pre-debriefing about social/emotional/ and mental health impacts.

Source: Authors

4.1 Population analysis

The analysis of the populations involved in ten TTXs highlights the notable adaptability of this methodology as a tool for training, integration, and evaluation across diverse contexts. The exercises ranged from highly technical populations, such as incident commanders, to community residents, demonstrating flexibility in both target audience and purpose. Applications were observed on a small scale, involving nursing home staff, as well as in large-scale mobilisations with dozens of participants from multi-agency teams, hospital emergency department, and academic settings including undergraduate and postgraduate students. It is worth noting that Fillipidis et al. (2024) and Allred et al. (2023), although describing the population, did not report the number of participants. Among the ten studies, only one included laypeople, namely, community residents, and one focused on the vulnerable elderly population.

Beyond demonstrating adaptability across populations and sectors, the findings suggest that TTXs function as boundary-spanning mechanisms that connect actors operating at different organizational and institutional levels. This characteristic is

particularly relevant in the context of extreme weather events, where coordination failures often emerge not from technical limitations, but from misaligned responsibilities, fragmented authority, and weak interorganizational interfaces (Comfort, 2007; Boin and van Eeten, 2013). By enabling shared sensemaking and collective interpretation of evolving scenarios, TTXs support what has been described as adaptive governance capacity, allowing organizations to anticipate cascading effects and negotiate priorities under uncertainty (Folke et al., 2005; Duit et al., 2010). However, the limited participation of lay populations observed in this review indicates that such boundary-spanning effects remain largely confined to formal institutional domains.

From a complex systems and governance perspective, polycentric governance systems are also shaped by power and capacity asymmetries, which influence who participates, who leads, and who benefits from decision-making processes (Duit et al., 2010). Actors with limited resources or institutional capacity may struggle to engage meaningfully in coordination mechanisms, potentially reinforcing existing inequalities (Morrison, 2017; Van der Plank, 2022). In the context of TTX, this raises concerns about whose perspectives are represented and whose vulnerabilities remain underexplored.

Research distinguishes individual acts (e.g., self-care, compliance) from collective activities (e.g., community groups), which have different drivers and need different policy tools (Bovaird, 2016; Loeffler, 2020). Low lay participation in collective forms may reflect weak political self-efficacy and the greater complexity of group-based engagement (Bovaird, 2016).

These dynamics are consistent with polycentric governance systems, which are characterised by multiple, relatively autonomous centres of decision-making operating at different scales, with overlapping jurisdictions and mutual adjustment rather than top-down control (Ostrom, 2010). In such systems, coordination emerges through interaction, negotiation, and feedback across actors, rather than through centralized command structures (Renn, 2008). Key mechanisms include self-organization,

sensitivity to site-specific conditions, experimentation, iterative learning, and the gradual building of trust among stakeholders (Ostrom, 2010).

To translate polycentric principles into public policy, it is crucial to design general rules that create genuine space for local self-organisation, establish multi-level coordination forums, encourage experimentation and learning, and actively monitor power, equity, and coordination (Carlisle and Gruby, 2019). Polycentric systems are not a panacea; their performance depends on detailed institutional choices, sustained political support, and continuous adjustment mechanisms over time (Ostrom, 2010).

As an illustration, two practical approaches can be highlighted: hybrid policy mixes and adaptive multi-level governance. For example, combining regulation, economic incentives, and public–private co-creation arrangements can foster self-governance and co-production, as observed in cases such as Oslo and policies addressing wildfires and multifunctional forests (Velded et al., 2021; Nagendra and Ostrom, 2012; Kelly et al., 2019). Similarly, co-management arrangements between central and local levels can help maintain desirable network properties, such as collaboration and information flow, but are not inherently superior to more centralised models; trade-offs must be carefully assessed in each context (Mathias et al., 2017).

4.2 Methodology analysis

Compared to full-scale or live drills, TTXs are cost-effective, easier to organise, and allow for broader participation, but may lack the realism and stress of live simulations. However, this limitation was mitigated in some cases by incorporating the prior knowledge of individuals with real-world experience in EWE, both to advise and manage the simulation and to develop scenarios closer to reality, as well as by using time-control mechanisms that applied time pressure as a stressor. The analysis of the methodologies applied in the ten TTXs reveals a diversity of approaches, ranging from simple activities with limited resources, such as the use of a Styrofoam-shaped simulation board, to highly sophisticated simulations with

detailed data-driven guidance, simultaneous dual-projection displays with different information, modern algorithms (*e.g.*, urbanEXODUS), and the introduction and implementation of information and communication technologies (*e.g.*, NWSChat). Different degrees of formalization were observed, from highly scripted exercises to those mediated by facilitators. In terms of scope, the exercises addressed a variety of scenarios, including evacuation and route planning, radio-nuclear maritime rescue, compound disasters (*e.g.*, pandemic combined with hurricane), and frontline mental health. Evaluation strategies predominantly included debriefing sessions, post-action reports, and structured questionnaires. However, the impact on long-term preparedness and real-world disaster response varied, indicating the need for more rigorous evaluation methods.

From a Resilience Engineering perspective, the reduced physical realism of TTXs should not be interpreted as a methodological weakness, but rather as a trade-off that privileges cognitive, organizational, and relational realism (Hollnagel et al., 2015). While drills and full-scale exercises are more effective in exposing physiological stress and task-level breakdowns, TTXs excel at revealing systemic brittleness, such as unclear command structures, fragile communication channels, and overreliance on informal coordination (Baumann et al., 2025). Several studies in this review demonstrated that time-pressure mechanisms and scenario escalation were sufficient to induce decision stress, suggesting that realism in TTXs operates primarily through temporal compression and informational ambiguity rather than physical enactment (Kick, 2014; Gernhardt et al., 2025). This reinforces their suitability for testing governance arrangements and interagency coordination under climate-induced uncertainty.

Within this perspective, TTXs can be interpreted as safe experimental environments for governance. Polycentric and adaptive governance literature emphasises that effective adaptation depends on balancing levels (local to global), modes of coordination (regulatory versus collaborative), and policy instruments,

while recognising that decentralised experimentation may fail to scale without some degree of overarching coordination (Ostrom, 2010; Renn, 2008). In this sense, TTX function as controlled 'experiments' that allow stakeholders to explore coordination strategies, test decision rules, and anticipate trade-offs without the consequences of real-world failure.

From a crisis governance perspective, this experimental character of TTX is particularly relevant, as it allows organizations to iteratively test and refine the core functions of cognition, communication, and coordination described by Comfort (2007). Rather than evaluating isolated competencies, TTX enable the observation of how these functions interact under simulated stress, providing insights into systemic performance and governance capacity.

4.3 Key outcomes analysis

As for key outcomes, TTX strengthened operational readiness, decision-making, and inter-agency coordination in complex emergencies. Common outcomes included enhanced healthcare preparedness, such as ensuring patient care without evacuation, safeguarding staff welfare through guaranteed shelter, food, and supplies, optimizing admission criteria, and designating critical care areas, alongside improved community readiness and promoted more intentional protective behaviours. Technological solutions, including a smart-space platform, boosted situational awareness, supported safer decisions, and preserved data privacy. Exercises generally improved collaboration, communication, and competency capture. Communication protocols were strengthened, with clearer identification of plan deficiencies and better use of impact-based decision support tools, while quantitative evacuation modelling provided measurable performance metrics and challenged existing assumptions. Skill gains were reported in mass casualty management, evacuation strategies, and triage, with one study noting an accuracy increase from 68.75% to 94.33% (Wang et al., 2024). Overall, participants demonstrated better prioritization,

resource management, and adaptability under time pressure and uncertainty, even though some limitations in large-scale incident preparedness persisted due to gaps in formal training, as reported by Granström et al. (2023).

To move beyond a descriptive account of training benefits, these findings can be interpreted through the lens of crisis governance capacity. According to Comfort (2007), effective crisis management depends on the interaction of four core functions: cognition, communication, coordination, and control. First, TTX contribute to collective cognition by enabling shared sensemaking of risks, priorities, and cascading effects across organizations. Second, they provide a controlled environment to test communication infrastructures, revealing fragmentation, delays, and redundancies in information flows. Third, they expose coordination challenges, such as role ambiguity, missing interdependencies, and weak interorganizational interfaces, which are critical in polycentric governance systems. Finally, although less emphasized, TTX also inform control mechanisms by clarifying decision authority and escalation pathways under conditions of uncertainty.

In this sense, TTX function as "near-crisis" environments that allow organizations to rehearse coordination, identify structural weaknesses, and reconfigure governance arrangements before real disruptions occur (Boin and van Eeten, 2013). Therefore, their primary contribution lies in building governance capacity rather than solely improving short-term training outcomes.

Despite consistent short-term gains in preparedness and coordination, the findings raise concerns regarding the sustainability of learning outcomes generated through TTXs. Some studies reported improved performance without clear evidence of institutionalization, such as formal plan revisions, policy updates, or integration into routine preparedness cycles. This gap reflects what the literature describes as the risk of symbolic or performative resilience, in which organizations demonstrate adaptive capacity during exercises without addressing underlying structural constraints (Cilliers, 2001; Power, 2007). In the context of climate resilience, such dynamics may

inadvertently shift adaptive burdens toward frontline professionals, who compensate for organizational gaps through intensified individual effort (Terra et al., 2023). Without explicit mechanisms for translating insights into organizational change, TTXs risk reinforcing fragile forms of resilience sustained by human adaptability rather than systemic robustness.

4.3 Technology and innovation analysis

The ten selected studies demonstrated a diverse range of innovations and technologies applied to TTXs, reflecting efforts to enhance realism, interactivity, and decision-making under extreme weather scenarios. On one hand, some interventions integrated advanced simulation tools, such as a variant of the EXODUS Agent-Based Model used to replicate urban evacuations with dynamic crisis visualizations. This provides immediate feedback on decisions and helps participants understand the impact of their actions on community outcomes. On the other hand, countries in developing economies like Indonesia applied a more rudimentary technology, Styrofoam-shaped boards, developed to support tangible scenario mapping and resulting in one of the largest participant groups, highlighting that methodological simplicity does not necessarily undermine the scope of implementation. Digital solutions were prominent, including: ICT (Information and Communication Technology)-based remote training platforms (Disaster Imagination Game - DIGs) that reduce operational effort, communication platforms linking environmental experts and climate science experts with emergency responders in real time, and mixed-group discussions conducted in virtual breakout rooms to facilitate geographically distributed participation. Physical and logistical innovations were also observed, such as scalable care plans combining hospital and shelter protocols, equipped with critical care zones, redundant systems, and reverse triage strategies. Scenario realism was reinforced through the use of real data from past events, time-controlled stress-inducing mechanisms, and game design elements intended

to promote collaboration and feedback. Some exercises emphasised experiential learning through pre- and post-assessment activities, others incorporated pre-debriefing on psychosocial impacts or fostered higher-order thinking skills, as well as embedding sector-specific challenges, such as navigating Arctic Sea vessel traffic or applying incident command system tactics to improve national training capacity. Among the challenges faced by technological innovations are the associated costs, as with any investment in infrastructure solutions, the need for user-friendly interfaces that are accessible to lay and vulnerable populations, and the reliance on prior knowledge to adequately define the desired level of complexity of simulated scenarios.

The diversity of technological solutions observed across the reviewed studies further indicates that effectiveness is not primarily determined by technological sophistication, but by contextual fit and facilitation quality. Simple, low-cost tools proved capable of engaging large populations, while advanced digital platforms offered analytical depth and decision traceability. This finding aligns with research on sociotechnical systems, which emphasizes that technologies only enhance resilience when embedded within supportive organizational practices and learning processes (Orton & Weick, 1990; Leveson, 2012). Consequently, investments in TTX technologies should be accompanied by deliberate attention to inclusivity, usability, and follow-up mechanisms that ensure learning translates into adaptive capacity at multiple system levels.

Overall, polycentric and adaptive governance literature highlights that effective climate coordination depends on linking multiple semi-autonomous actors through mechanisms of trust-building, experimentation, and learning across scales (Ostrom, 2010; Renn, 2008). In this regard, tabletop exercises emerge as practical governance arenas that enable repeated interaction, co-creation, and the development of trans-local networks. When explicitly designed around these principles

and followed by systematic learning and institutional reform, TTX can play a critical role in strengthening coordination, aligning decision-making processes, and enhancing the adaptive capacity of complex systems through updated technologies and innovation processes.

5 LIMITATIONS

Several limitations of this study should be acknowledged. The review is based on a relatively small sample of studies, reflecting the still limited body of literature addressing tabletop exercises in the context of extreme climate-related risks. While this constrains the generalisability of the findings and calls for cautious interpretation of the conclusions, it also highlights the emerging nature of the field and the need for further empirical research. As with any systematic literature review, the adopted search string, focused specifically on extreme climate-related risks, as well as the inclusion and exclusion criteria, necessarily defined the scope of the analysis and may have excluded relevant studies addressing other types of hazards or broader risk contexts. In addition, the exclusion of articles due to the impossibility of paywall access should be explicitly recognised as a limitation, as it may introduce selection bias and restrict the comprehensiveness of the evidence base. The temporal restriction applied (2021–present) may have excluded earlier relevant studies, potentially limiting the historical depth of the analysis. Furthermore, the heterogeneity of the included studies in terms of design, context, and reported outcomes poses challenges for comparison and synthesis. No specific target population was predefined, as the risks analysed affect both individuals embedded in institutional settings and the wider community, which, in turn, may limit the depth of insights into particular groups. Nevertheless, this broader scope enhances the relevance of the findings for governance and social practices, as it reflects the multi-actor nature of climate risk management. Finally, the use of Resilience Engineering as an analytical lens emphasises the identification of strengths and systemic brittleness, which, while analytically valuable, may privilege

certain interpretations of system performance over others. Taken together, the evidence suggests that TTX can be conceptualized as mechanisms that operationalize crisis governance functions, transforming abstract principles of coordination and resilience into observable and testable practices.

6 CONCLUSION

This systematic review examined how tabletop exercises (TTX) have been applied over the last five years to address extreme weather events, highlighting their role in strengthening preparedness, coordination, and learning across diverse contexts. The findings demonstrate that TTX are versatile and cost-effective instruments capable of engaging actors operating at multiple organizational and institutional levels, from healthcare professionals and emergency responders to students and community representatives. Across sectors, TTX consistently supported the development of situational awareness, collaborative decision-making, and response coordination, capabilities that are central to climate resilience in complex systems.

Beyond their function as training tools, the findings indicate that TTX operate as governance instruments that strengthen crisis management capacity. By supporting collective cognition, testing communication systems, and exposing coordination structures, TTX contribute directly to the core functions of crisis governance (Comfort, 2007). In line with the Resilience Engineering, their value lies in enabling organizations to adapt structures, roles, and interactions under simulated stress, thereby enhancing systemic resilience rather than merely improving individual performance. Although they exhibit lower physical realism than drills or full-scale exercises, TTX offer high cognitive and organizational realism by exposing decision trade-offs, interdependencies, and coordination failures under time pressure and uncertainty. In this sense, TTX complement other exercise formats and are particularly well suited to examining governance arrangements and response coordination in climate-related emergencies.

However, the review also identified persistent limitations. Participation was

largely restricted to institutional actors, with limited involvement of lay populations and vulnerable groups, despite their central role in disaster risk outcomes. Moreover, some studies reported short-term performance improvements without clear evidence of institutionalization, such as formal plan revision or policy change. This raises concerns about symbolic or performative resilience, in which learning remains confined to the exercise context and fails to translate into durable organizational transformation. Without explicit mechanisms to embed insights into routine preparedness practices, adaptive capacity may be sustained primarily through intensified individual effort, potentially shifting risk and burden to frontline actors.

Overall, the findings suggest that TTX can play a critical role in bridging the knowledge–action gap by translating experiential learning into actionable insights for preparedness and governance. When thoughtfully designed, inclusively implemented, and linked to follow-up actions, TTX can support adaptive governance and long-term climate resilience, aligning practice with international policy frameworks such as the Hyogo Framework for Action, Sendai Framework for Disaster Risk Reduction, the Paris Agreement, and the 2030 Agenda.

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Data will be available upon request