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Capital modelling in the sea of chaos

In the world of risk, chaos is not a failure, but rather a feature. It challenges assumptions, reveals hidden vulnerabilities and exposes the relationships we might otherwise overlook.

For insurers, the task is not to eliminate this chaos, but to *embrace it*, understand it, quantify it and, ultimately, build systems that remain robust even when pandemonium reigns.

Traditional risk models, however sophisticated, are struggling to keep pace. From sudden infrastructure failures to creeping climate disruptions and the unpredictable flare of political and social unrest, the nature of catastrophe risk is evolving.

In South Africa, as in many parts of the world, regulatory capital modelling frameworks such as Solvency Assessment and Management (SAM) have helped insurers take their risk and capital management frameworks to a new level of maturity.

However, the pace of change has never been greater. As the world becomes more inter-connected and systemic shocks more prevalent, tail events become harder to isolate. It would, therefore, be prudent to consider how our models need to be adapted.

The presumption that catastrophe risks can be compartmentalised or that dependencies between them can be safely ignored, becomes not merely outdated, but hazardous. Climate change, political and social unrest and infrastructure failure are no longer discrete phenomena; they are deeply enmeshed, often amplifying one another through complex feedback loops. It is here that one of the limitations of current capital models reveals itself, not in the foundational logic, but in the implicit assumption that chaos is something to be excluded rather than engaged with. The task before us is not to dismantle the capital architecture we have built, but to refine it based on the ongoing changes observed. It also important that we acknowledge that chaos is a relevant, even meaningful, feature of our risk universe that we should incorporate into our models.

The strength of the system… and its limits

South African insurers already segment catastrophe risk into natural and man-made categories, capturing extreme events through stochastic modelling and applying risk-based capital charges based on calibrated historical data. These frameworks support solvency and prudence and, in many ways, they work as intended. The SAM standard formula provides fixed stress calibrations for certain catastrophe types with set correlation matrices to aggregate them.

However, these correlations have not changed over time and do not allow for dynamic shifts in the risk environment, nor contagion effects and the amplification of losses that occurs when risks are triggered simultaneously. While the SAM standard formula allows for certain aggregation benefits through correlation matrices, it largely assumes that risks, particularly in the tail, are sufficiently independent to allow for aggregation under simplifications that may not hold in reality.

We know that entropy does not respect siloed classifications. It is, therefore, important that we shine a spotlight on the current treatment of dependencies in the SAM capital framework to assess their adequacy. A heatwave can trigger blackouts that expose deep infrastructure fragilities. A prolonged drought can lead to water riots and political destabilisation. Social unrest can destroy supply chains, impede emergency response systems and amplify insured losses far beyond the original trigger.

Recent years have demonstrated this with uncomfortable clarity. The 2021 civil unrest in KwaZulu-Natal and Gauteng resulted in estimated losses of R54 billion of which R27 billion was insured. These losses were not limited to property damage or business interruption. Infrastructure shutdowns, distribution bottlenecks and public service failures significantly amplified the overall impact. Similarly, prolonged periods of loadshedding, itself not typically modelled as a catastrophe, have triggered equipment failures, fire outbreaks and secondary losses across multiple classes of insurance. Climate-related events have also intensified. The April 2022 floods in KwaZulu-Natal caused widespread damage, not just through rainfall, but because of poor drainage infrastructure, landslides and delayed emergency responses, which was further complicated by simultaneous power cuts. These were not isolated losses. They were interdependent, systemic and deeply nonlinear.

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A practical challenge, currently, is how insurers respond to the new Prudential Authority guidance note on climate risk and the requirements to model physical risk exposures and transition risk. Instead of reflecting on how to change their approach to modelling catastrophe risks, many insurers have simply argued that the catastrophe risk Solvency Capital Requirement (SCR) component set out as part of the standard formula, already provides sufficient capital coverage for climate- or disaster-related risks. This approach assumes that no additional modelling or stress testing is required. However, the SAM standard formula was calibrated long before global climate risk and regulatory developments evolved and the current correlation matrix may no longer be suitable for the average insurer. Accordingly, how would you be able to evidence to your board and shareholders that the catastrophe risk SCR component is sufficient in the context of the current operating environment?

Despite these realities, capital models applied across much of the industry continue to rely heavily on assumptions of independence or simplistic linear correlations between perils. While such simplifications may be appropriate for frequency risk in well-diversified portfolios, they begin to break down under the extreme scenarios that capital models attempt to model. This is one of the weaknesses prevalent within the SAM framework.

Learning from global peers

Internationally, insurers and supervisors are grappling with the limits of current assumptions and models for catastrophe-related risks, most notably natural disasters. Internal model approvals under Solvency II increasingly include advanced dependency structures, especially for catastrophe risk. These mathematical structures, particularly those that emphasise tail dependence, such as the Clayton or Gumbel copulas, allow for a more nuanced understanding of how risks may correlate under extreme conditions. Reinsurers have developed modelling platforms that explicitly simulate concurrent risk events using copulas and network-based dependency frameworks. The United Kingdom’s Prudential Regulation Authority encourages the use of plausible adverse scenario pathways, including cross-risk feedback mechanisms, in the Own Risk and Solvency Assessment (ORSA) process. Meanwhile, reinsurers and academic groups are applying extreme value theory, network contagion models and regime-switching copulas to simulate interdependent risks that could lead to outsized losses.

These are not academic exercises, but rather responses to the fact that real-world losses increasingly stem from interactions between climate and infrastructure, political instability and property loss, power grids and social mobility. The aim is not to achieve perfect foresight, as no model can do that, but rather about enhancing realism. In a system under stress, variables that were once independent may become suddenly and fiercely correlated. These innovations are not without complexity, but they highlight a key shift that the future of capital modelling will need to improve on accommodating chaos.

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Sensitising towards South Africa's chaos

South Africa finds itself uniquely positioned to benefit from such enhancements. We believe this should happen at a faster rate than what is currently at play. By adopting deliberate measures that better reflect systemic realities, insurers can reduce blind spots, improve solvency and risk assessment planning and more accurately assess the benefits and limits of reinsurance or alternative risk mitigation instruments.

We recommend a focus on three risk types in our current environment and then its application and relevance for particular insurers in their context:

1. **Climate change** is already altering the frequency and severity of weather-related catastrophes, from prolonged droughts to flash floods and coastal storms. However, it also interacts with other systems, as droughts affect food prices and migration, while floods strain already fragile infrastructure.

2. **Political and social unrest**, while episodic, can escalate quickly and manifest unpredictably. The July 2021 unrest in KwaZulu-Natal and Gauteng was a case study in how rapidly localised political triggers can turn into systemic insurance losses, including business interruption, fire and even cyber claims.

3. **Infrastructure failure**, such as prolonged power outages or water system collapses, rarely occur in isolation. These risks are not only material in themselves, but they are also multipliers, weakening resilience and amplifying other events. The risk of a blackout during a heatwave or an election is no longer speculative.

What makes these risks especially concerning is not merely their frequency or severity, but their entanglement. A climate-induced shock can ripple through infrastructure systems, provoking political instability. Political unrest in turn may delay repairs, disrupt business continuity and erode public trust, deepening the initial loss. All three of the above have different underlying risk profiles and characteristics and may require a different modelling approach and risk mitigation measure. We have observed many insurers combine climate change and infrastructure failure into single scenarios for their regulatory ORSA reports, but how they evolve over time may be different and therefore their independent development is as important to analyse as their linkages.

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A practical path forward

Without abandoning the stability and transparency of existing frameworks, we believe significant improvements could be achieved through the incremental enhancements suggested below .

1 Scenario-based copulas and tail dependency modelling

Insurers are encouraged to begin introducing copula-based dependence structures, not across all risk types, but in a targeted way for key peril clusters. Unlike correlation coefficients, which assume symmetrical relationships and often underestimate joint tail risks, copulas allow insurers to capture asymmetric dependencies, particularly in the extremes. For example, climate-infrastructure-social unrest could form one dependency block. A drought and power outage may be only weakly correlated on average, but their co-occurrence in extreme conditions may be far more likely than Gaussian models would suggest. Incorporating a Gumbel or Student-t copula into tail risk aggregation across perils could materially affect the resulting capital requirement and better reflect the insurer's actual exposure. Regime-switching models, where dependencies intensify under crisis conditions, offer an especially relevant lens for tail-risk analysis. By calibrating these functions to reflect not just average-case correlation, but tail dependence, insurers will be able to better estimate the capital required to withstand concurrent shocks.

2 Cascading risk scenarios

Another possible enhancement lies in the use of cascading risk scenarios within the ORSA process. Traditional stress testing often assumes a single peril, cleanly bounded in time and scope, but real crises are rarely so polite. For example, "A drought leads to water restrictions, leading to industrial shutdowns, triggering political protests." This layered approach provides insight into the vulnerability of systems, not just single nodes. Each step of the cascade may carry with it an amplification of losses across different lines of business. By constructing and quantifying such narratives, through system dynamic modelling or nested Monte Carlo simulations, insurers could more accurately evaluate their capital adequacy in the face of real-world complexity.

3 Enhanced use of external and simulated data

Of course, the most cited barrier to advancing these techniques is the lack of appropriate data. South Africa's publicly available catastrophe loss data is limited, particularly with respect to non-traditional perils and systemic interactions. While Sasria SOC Limited (Sasria) and the South African Weather Service (SAWS) offer some insights, they do not provide the kind of granular, high-frequency and cross-peril data needed to calibrate complex dependency models. Here, partnerships would be key. Insurers are encouraged to work more closely with universities, reinsurers and data providers to curate catastrophe event libraries that would capture not only primary losses, but also secondary and tertiary effects.

In the interim, simulation remains a practical bridge. Where data is missing, simulated datasets could be constructed using expert judgment, global benchmarks and statistical bootstrapping methods. Scenario generation based on international data could fill gaps in the empirical record, enabling at least a first-order approximation of unknown dependencies. For instance, Brazil has experienced similar interactions to South Africa, between climate stress, infrastructure fragility and political unrest. India and Turkey offer additional parallels. Cross-country hazard libraries, available from the Emergency Events Database (EM-DAT) and reinsurer databases, could be adapted for South African exposure profiles. Bayesian methods could be used to develop plausible loss distributions and joint scenarios where empirical data is thin. While not perfect substitutes, they would provide directional guidance, validate assumptions and inform simulated datasets that reflect plausible joint loss scenarios.

It is important, however, to approach this evolution pragmatically. Not every insurer would need a full copula engine or cascading risk simulation platform. Developments could be incremental:

- identify key interaction points between lines of business;
- build joint distributions for the highest-risk combinations;
- simulate plausible adverse sequences; and
- refine capital requirements iteratively.

As we look ahead, it becomes clear that traditional approaches must give way to more dynamic risk assessment. Unlike static methods that assume risks behave consistently over time, dynamic assessments recognise that risks evolve, shift and interact in ways that defy fixed assumptions. It asks not only what the risk is today, but also how this risk might grow, mutate or cascade tomorrow. By incorporating feedback loops, shifting correlations and evolving external pressures, dynamic risk assessment allows insurers to test the resilience of their capital models against a moving target, one that is shaped by climate, politics, technology and infrastructure in constant flux.

What is important is that insurers begin to move beyond the assumption of isolated risks toward a more systemic view.

The final frontier

Capital models must remain tractable, communicable and fit for regulatory review. We should proceed with caution and steer clear of creating models so complex that they lose interpretability. The intent remains to give management and the board deeper insights as to the underlying risk evolution and exposures, how those risks are anticipated to emerge and what mechanisms can be put in place to continue to generate the required return-on-equity.

The SAM regime has the potential to accommodate such sophistication, particularly through the internal model approval process and narrative flexibility of the ORSA. This approach allows insurers to incorporate their own risk perspectives, scenarios and dependencies not fully captured by standard formulas, offering a more tailored and strategic view of solvency. In time, regulators may consider introducing structured guidance on how ripple effects and tail interdependencies should be reflected, especially for insurers with material exposure to systemic risks. This would cater for the shifts seen globally, including increasing frequency of extreme events, intensifying systemic fragility and the breakdown of traditional assumptions about independence.

Enhancing capital models to reflect these changes would allow the industry to quantify risks more accurately. It would also enable smarter reinsurance strategies and safeguard policyholders in a way that reflects today's interconnected world, not yesterday's assumptions.

So let us embrace chaos, not as an aberration but as a structural attribute within our risk management frameworks. South African insurers, already seasoned in navigating uncertainty, are well positioned to lead this evolution. By blending the rigour of SAM with the imagination of advanced dependency modelling, we are well positioned to build more sophisticated capital models to better understand and capture the sea of chaos our boats are in.

Glossary

If you've ever felt like the world of capital modelling speaks its own secret language, you're not alone. To save you from getting lost in the jargon jungle, we've pulled together a glossary of key terms that should help make the journey through this article a little smoother.

Term	Definition
Bayesian methods	A way of updating estimates or probabilities as new information becomes available, helping refine models under uncertainty.
Bootstrapping (statistical)	A method of creating many simulated samples from limited data to better estimate possible outcomes.
Copula	A mathematical function used to model how risks interact, especially during extreme events.
Correlation matrix	A table that shows how different risks are related to each other, for example, whether floods and power failures tend to happen together.
EM-DAT	An international database maintained by the Centre for Research on the Epidemiology of Disasters (CRED) that records major global natural and technological disasters, used for research and catastrophe modelling.
Extreme value theory (EVT)	A branch of statistics that focuses on understanding the likelihood and impact of very rare, extreme events.
Gaussian copula	A mathematical tool that assumes risks are related in a "normal" or average way. It often underestimates the chance of extreme events happening together, making it less suitable for catastrophe modelling.
Gumbel copula	A copula (dependency model) that is especially good at capturing situations where extreme events are likely to happen together.
South African Weather Service (SAWS)	The official national authority that monitors and forecasts weather and climate in South Africa, providing data for risk and catastrophe modelling.
Stochastic modelling	A method of using random simulations to estimate a wide range of possible outcomes (e.g., thousands of "what if" scenarios of floods, fires, or riots).
Student-t copula	A copula that allows for stronger connections between risks during extreme conditions. Unlike the Gaussian copula, it recognises that crises often make risks much more correlated than they are in normal times.
Tail dependence	A way of measuring how likely two or more extreme events are to happen at the same time.
Tail events/tail risk	Extremely rare but very severe events, like one-in-100-year disasters, that lie at the "tail end" of a probability distribution.