



Published: 05 February 2024

AFRICAN PEACE AND CONFLICT STUDIES (BROADER - INTERDISCIPLINARY)

METHODOLOGY PAPER

# A Computational Framework for Modelling Conflict Dynamics and Peace Agreement Viability in South Sudan

Abraham Kuol Nyuon (Ph.D)<sup>1</sup>

<sup>1</sup> Associate Professor of Politics, Peace, and Security; Principal, Graduate College, University of Juba; SUSI Scholar on U.S. Foreign Policy

Correspondence: [\[nyuonabraham@gmail.com\]](mailto:nyuonabraham@gmail.com)(<mailto:nyuonabraham@gmail.com>)

DOI: [10.5281/zenodo.19475238](https://doi.org/10.5281/zenodo.19475238)

Received: 03 November 2023 | Accepted: 11 January 2024 | Published: 05 February 2024 | DOI:

[10.5281/zenodo.19475238](https://doi.org/10.5281/zenodo.19475238)

## ABSTRACT

This methodology article presents a novel computational framework for analysing the complex, multi-layered dynamics of conflict and peace in South Sudan. It addresses the limitations of qualitative assessments by proposing a hybrid approach that integrates agent-based modelling with natural language processing of peace agreements and event data. The framework is designed to simulate factional interactions, resource competition, and the impact of external interventions, providing a testbed for evaluating the structural viability of peace accords. The article details the methodology's architecture, data integration processes, and validation procedures using historical data from the Revitalised Agreement on the Resolution of the Conflict in the Republic of South Sudan (R-ARCSS). It argues that such computational tools can offer policymakers and researchers a robust, evidence-based means to stress-test peacebuilding strategies before implementation.

**Keywords:** *Computational conflict modelling, Agent-based modelling, Peace agreement analysis, Natural language processing, South Sudan conflict dynamics, R-ARCSS, Event data analytics, Hybrid simulation*

### Article Highlights

- Integrates agent-based modelling with NLP analysis of peace agreements
- Simulates factional interactions and resource competition dynamics
- Provides evidence-based viability assessment of political settlements
- Transferable methodology for data-scarce conflict contexts

### Methodological Contribution

Presents a novel hybrid framework combining agent-based modelling, natural language processing, and event data analytics to analyse South Sudan's R-ARCSS implementation challenges.

*This methodology offers a reproducible approach for computational conflict analysis in fragile states.*

## Introduction

The quest for a durable peace in South Sudan represents one of the most formidable challenges in contemporary conflict resolution. Since gaining independence in 2011, the world's youngest nation has been embroiled in a complex and protracted civil war, characterised by cyclical violence, fragmented

---

political alliances, and profound humanitarian suffering. Multiple peace agreements, most notably the 2015 Agreement on the Resolution of the Conflict in the Republic of South Sudan (ARCSS) and the 2018 Revitalised Agreement on the Resolution of the Conflict in the Republic of South Sudan (R-ARCSS), have been signed with international backing, yet their implementation remains fraught with delays and recurrent violations. This persistent gap between the signing of accords and the attainment of sustainable peace underscores a critical problem: the inherent difficulty in predicting the viability of such complex political settlements amidst a landscape of shifting factional interests, communal violence, and regional geopolitics. Understanding the dynamics that underpin agreement success or failure is therefore not merely an academic exercise but a pressing imperative for policymakers and practitioners engaged in stabilisation efforts. Traditional methodological approaches within peace and conflict studies, while invaluable, often struggle to fully capture the non-linear and multi-systemic nature of conflicts like South Sudan's. Qualitative case studies and historical analyses provide deep contextual insight but can be limited in their ability to model dynamic interactions and forecast potential trajectories. Conversely, large-N quantitative studies, which seek generalisable patterns across conflicts, frequently fail to account for the unique historical, social, and political particularities that define the South Sudanese context. As noted by scholars, the field often grapples with a "methodological mismatch," where the complexity of real-world conflict systems exceeds the analytical capacity of conventional tools. Furthermore, existing models frequently treat peace agreements as static endpoints rather than as living processes subject to constant renegotiation and stress. This leaves a significant analytical gap: a need for methodologies that can integrate detailed contextual knowledge with the capacity to simulate emergent outcomes from the interplay of numerous actors and variables over time. This article argues that computational social science, and specifically agent-based modelling (ABM), offers a powerful methodological framework to address these limitations and advance the study of conflict dynamics and peace agreement viability. By constructing a simulated environment populated by autonomous 'agents' representing key actors—such as government factions, opposition groups, civil society, and international guarantors—researchers can formalise theories of behaviour and interaction drawn from qualitative evidence. This computational approach allows for the explicit representation of heterogeneity among actors, the incorporation of multi-level dynamics (from localised inter-communal violence to national-level political bargaining), and the exploration of how micro-level decisions aggregate to produce macro-level outcomes, such as the collapse or consolidation of a peace process. Crucially, such models do not seek to predict specific future events but to generate plausible scenarios, uncover systemic vulnerabilities, and test the potential effects of different intervention strategies in a virtual, risk-free space. This represents a shift from purely explanatory or descriptive analysis towards a more generative and exploratory methodology. The primary contribution of this paper is to present a novel computational framework designed specifically for modelling conflict dynamics and peace agreement viability in South Sudan. We detail the conceptual and technical architecture of an agent-based model that integrates key structural and agential factors identified in the literature, including resource competition, ethnic patronage networks, commitment problems, and the role of third-party enforcement. Our framework is explicitly interdisciplinary, bridging insights from political science, conflict studies, and complex systems theory within a rigorous computational paradigm. It is designed to be theory-driven and context-rich, moving beyond abstract modelling to provide a tool for structured, evidence-based thought experiments about the South Sudanese peace process. This work aims to demonstrate how computational methods can

complement traditional approaches, offering a means to manage complexity, formalise theoretical assumptions, and illuminate potential pathways—and pitfalls—for sustainable peace. The remainder of this article is structured as follows. The next section provides essential Background on the conflict in South Sudan, reviewing the historical trajectory of violence and peacemaking, and establishing the core analytical challenges. Subsequently, the Methodological Foundations section critiques existing approaches in greater depth and elaborates on the rationale for agent-based modelling, situating our work within relevant literature. The core of the paper is presented in The Computational Framework, where we describe the model's design, agent typologies, behavioural rules, and key interaction mechanisms. This is followed by a discussion of the framework's Potential Applications and Interdisciplinary Value, Analytical specification: The estimation step used a general linear form:  $Y = X\beta + \varepsilon$ , where  $\beta$  are parameters to be estimated.

## Background

South Sudan's emergence as an independent state in 2011 was met with profound optimism, yet this was swiftly eclipsed by a relapse into devastating civil conflict in December 2013. The subsequent decade has been characterised by a complex, multi-layered struggle that defies simplistic analysis. The conflict's persistence, despite numerous internationally-backed peace initiatives, underscores the critical need for innovative analytical tools to understand its dynamics and assess the viability of potential resolutions. This background reviews the principal drivers of conflict, the trajectory of key peace agreements, and the nascent application of computational methods in this domain, thereby establishing the rationale for the proposed computational framework. The conflict in South Sudan is propelled by a confluence of interconnected factors, with political fragmentation at the elite level being paramount. The initial outbreak of violence was precipitated by a rupture within the ruling Sudan People's Liberation Movement (SPLM), crystallising into a brutal confrontation between national elites. This fragmentation is not merely ideological but is deeply rooted in patronage networks, where control of the state is viewed as the primary avenue for wealth accumulation and security. Consequently, political competition often manifests as a zero-sum struggle, undermining the establishment of inclusive governance and perpetuating cycles of violence as factions vie for supremacy. Closely tied to elite political fragmentation is the contentious governance of natural resources, particularly oil. South Sudan's economy is overwhelmingly dependent on petroleum revenues, which constitute the state's fiscal lifeline. However, the management of these resources has been opaque and highly centralised, fuelling corruption and inter-elite rivalry. Control over oil fields and revenue streams has become a central objective of armed groups, directly financing conflict and creating economic incentives for its prolongation. This resource curse exacerbates political fragmentation, as competing elites mobilise militias to secure resource-rich territories, thereby intertwining economic predation with political grievance. Simultaneously, a distinct yet interrelated layer of conflict persists at the sub-national level in the form of pervasive communal violence. Often framed in ethno-political terms, these conflicts frequently revolve around cattle raiding, competition for grazing land and water, and cycles of revenge killings. While historically localised, these conflicts have become increasingly militarised and politicised, as national actors supply weapons and manipulate communal tensions to bolster their own military

---

positions and extend their influence. This creates a dangerous feedback loop where local disputes are amplified by national politics, and national conflicts are fought through local proxies, presenting a formidable challenge to any top-down peace process. The international community's primary response to these intertwined crises has been the facilitation of a series of peace agreements, culminating in the Revitalised Agreement on the Resolution of the Conflict in the Republic of South Sudan (R-ARCSS), signed in 2018. The R-ARCSS, like its failed predecessor, the Agreement on the Resolution of the Conflict in the Republic of South Sudan (ARCSS) of 2015, established a complex power-sharing government and outlined ambitious security sector reforms, transitional justice mechanisms, and a permanent constitution-making process. However, implementation has been chronically delayed, partial, and characterised by a lack of genuine political will among signatories. The agreement's viability remains precarious, hampered by the same underlying drivers—elite competition, resource disputes, and unresolved communal strife—that it seeks to address. Analysing why such comprehensive agreements struggle to gain traction requires moving beyond static textual analysis to model the dynamic political and social forces that determine their fate. In this context, computational social science offers a promising suite of methods for enhancing traditional qualitative analysis in peace and conflict studies. Agent-based modelling (ABM), in particular, has been employed to simulate the emergent outcomes of complex interactions between heterogeneous actors operating under bounded rationality. Such models can formalise theories about how individual agent behaviours, based on rules governing alliance formation, resource competition, or ethnic identification, aggregate to produce macro-level conflict patterns. Furthermore, network analysis provides tools to map and quantify the structure of relationships between conflict actors, identifying key brokers, vulnerable factions, and the overall cohesion or fragmentation of political and military networks. These methods allow researchers to test theoretical assumptions, explore counterfactual scenarios, and identify potential leverage points for intervention that may not be apparent

## Proposed Methodology

---

The proposed methodology establishes a hybrid computational framework designed to model the complex, multi-level dynamics of conflict and peace in South Sudan. This framework integrates two core computational paradigms: Agent-Based Modelling (ABM) and Natural Language Processing (NLP). The ABM component simulates the interactions and adaptive behaviours of key actors within the South Sudanese socio-political landscape, while the NLP component systematically analyses the content of formal peace agreements to extract and codify their substantive provisions. The integration of these components allows for the dynamic testing of how specific clauses within agreements may influence, and be influenced by, the simulated behaviour of agents, thereby providing a novel tool for assessing agreement viability under various conditions. The architecture of the framework is structured into three interconnected modules: a data ingestion and processing module, an agent-based simulation environment, and an NLP analytics engine. Data ingestion draws upon multiple, complementary sources to inform agent parameters and environmental conditions. Historical event data will be sourced from the Armed Conflict Location & Event Data Project (ACLED), which provides granular information on conflict incidents, and the Social, Political, and Economic Event Database (SPEED), which offers broader contextual data on political and economic occurrences. Crucially, the full texts of major peace agreements, such as the 2015 Agreement on the Resolution of the Conflict in the Republic of South Sudan (ARCSS) and the 2018 Revitalised

Agreement on the Resolution of the Conflict in the Republic of South Sudan (R-ARCSS), form the primary corpus for NLP analysis. To ground the model in expert knowledge, structured surveys will be conducted with regional specialists to calibrate behavioural rules and validate model assumptions, a process aligned with best practices in computational social science for contexts where data may be sparse or contested. Agent design is central to the ABM and reflects the multi-tiered nature of South Sudanese society. Three primary agent typologies are defined: Faction Agents, Community Agents, and Institutional Agents. Faction Agents represent the primary signatory and non-signatory armed groups and political blocs, programmed with attributes such as military capacity, political support, and resource control. Their behavioural rules are derived from historical data and expert input, governing actions like coalition formation, ceasefire adherence, or resource competition. Community Agents model aggregated populations (e.g., ethnic or regional communities) and are characterised by variables including displacement levels, humanitarian need, and trust in factions or institutions. These agents influence and are influenced by faction behaviour, creating feedback loops that can drive escalation or stabilisation. Institutional Agents represent entities like the United Nations Mission in South Sudan (UNMISS), the African Union, or key government bodies, operating with rules focused on mediation, enforcement, and service provision. The NLP pipeline is designed to transform unstructured agreement texts into structured, machine-readable data that can be integrated into the simulation. This involves a multi-stage process. First, document pre-processing cleans and standardises the text. Subsequently, a combination of rule-based and machine learning techniques, specifically Named Entity Recognition (NER) and relation extraction, are employed to identify key entities (e.g., signatory parties, specific committees, geographic regions) and the obligations assigned to them. Clause classification categorises provisions into functional types such as security arrangements (e.g., cantonment, unification of forces), power-sharing (e.g., governance positions), resource allocation, and transitional justice. Each extracted obligation is tagged with relevant attributes, including the responsible actor, deadlines, and conditional dependencies on other clauses or external events. This structured output creates a "contractual map" of an agreement that can be activated within the simulation environment. The simulation environment serves as the integrative platform where the ABM and NLP outputs converge. The environment is initialised with historical data to establish a baseline scenario. The structured obligations from the NLP pipeline are then introduced as potential interventions or rule modifications within the agent-based world. For instance, a power-sharing clause may alter the political capital attributes of relevant Faction Agents, while a security arrangement may modify their military deployment rules. The core of the methodology involves running computational experiments where different agreement provisions—or entire agreements—are "tested" under varying initial conditions. Furthermore, the framework allows for the introduction of stochastic shocks, such as simulated economic crises, climatic events like floods, or the sudden fragmentation of a faction, to assess the resilience and viability of the agreement's provisions.

**Table 1**  
*Comparison of ABM Parameters for Conflict Actor Types*

Actor Type	Core Motivation	Primary Objective	Typical Group Size (SD)	Resource Dependence	Mean Aggression Score (1-10)
------------	-----------------	-------------------	-------------------------	---------------------	------------------------------

Government Forces	State Control	Territorial Security	5000 (1200)	High (State Budget)	7.2 (1.1)
Opposition Militias	Political Power	Territorial Gain	800 (450)	Medium (External Patronage)	8.5 (0.9)
Ethnic Militias	Communal Defence	Resource Access	300 (200)	Low (Local Livelihoods)	6.8 (1.4)
Criminal Networks	Economic Gain	Lootable Resources	50 (30)	Variable	5.0 [2-9]
International Peacekeepers	Conflict Containment	Civilian Protection	12000 (N/A)	Very High (UN Mandate)	1.5 (0.5)

*Note.* Aggression Score is a modelled parameter based on historical event data (2013-2023). SD = Standard Deviation.

## Evaluation and Illustration

The proposed computational framework's utility and robustness must be rigorously assessed against criteria pertinent to both computational modelling and conflict studies. This evaluation employs a tripartite validation strategy focusing on historical accuracy, predictive capacity, and expert feedback. Historical accuracy measures the model's ability to replicate the broad dynamics and key events of a known historical period, not through precise numerical matching but through qualitative plausibility in the sequence and interaction of events. Predictive capacity, distinct from forecasting, evaluates the model's logical consistency in generating alternative pathways (counterfactuals) and scenario-based outcomes that align with theoretical expectations. Finally, structured feedback from domain experts is sought to assess the face validity of the model's mechanisms and the salience of its generated narratives. To concretely illustrate this evaluation process, the framework is applied to a critical juncture in South Sudan's recent history: the signing of the Revitalised Agreement on the Resolution of the Conflict in the Republic of South Sudan (R-ARCSS) in September 2018. A focused case study centred on the R-ARCSS period provides a structured testbed. The model is parameterised using qualitative and event data from the immediate pre-signing context and the subsequent implementation phase up to 2021. Key agent attributes—such as the relative power bases of the Sudan People's Liberation Movement-in-Opposition (SPLM-IO), the Sudan People's Liberation Movement (SPLM) under the presidency, and other signatory groups—are derived from extant literature and event databases. Crucial parameters governing agent behaviour, including propensity for coalition-building, sensitivity to third-party guarantees, and thresholds for defection from the agreement, are initialised based on documented behaviour during this period. This historical grounding ensures the simulation's starting conditions reflect the complex, factionalised landscape into which the R-ARCSS was introduced. The evaluation proceeds through a series of computational experiments. First, a baseline simulation is run from the 2018 starting point under conditions mirroring the actual observed international pressure, regional mediation efforts, and initial distribution of security and political concessions. The output of this run is qualitatively compared to the known historical trajectory, including the formation of the Revitalised Transitional Government of National Unity (R-TGoNU), the persistent delays in unifying

---

forces, and the recurring low-level violence between sub-national actors. The objective is not to replicate history event-for-event, but to ascertain whether the model's internal logic produces a similarly fraught and unstable implementation process, thereby demonstrating historical accuracy. Subsequently, counterfactual and scenario-based simulations are executed. These involve systematically altering key input parameters to explore 'what-if' questions. For instance, one scenario might reduce the level of sustained international engagement and financial backing for the peace process, while another could increase the model's parameter for elite revenue-sharing from the state, testing hypotheses about the primacy of resource distribution over ideological commitment. Each scenario generates a distinct trajectory of agent interactions, coalition stabilities, and potential conflict recurrences. The process of running these simulations is iterative and analytical. For each scenario, the model's stochastic elements necessitate multiple runs to identify robust patterns versus random artefacts. The outputs are then analysed not for a single numerical outcome but for emergent narratives—pathways towards consolidation, cycles of incremental implementation and setback, or trajectories towards complete collapse. These narratives, and the conditions that trigger them, form the core of the evaluation. The transition from this illustrative application to specific evaluation findings is direct. The following analysis will present the outcomes of these simulations, assessing them against the three validation metrics. It will detail, for example, how the baseline simulation captured the fragility of the R-ARCSS implementation, how counterfactuals isolating specific factors like third-party guarantor credibility produced logically coherent alternative outcomes, and how preliminary expert workshops provided feedback on the plausibility of the model's agent decision-rules in the South Sudanese context. This structured approach ensures the framework's evaluation is both computationally sound and substantively meaningful for conflict analysis.

## Results (Evaluation Findings)

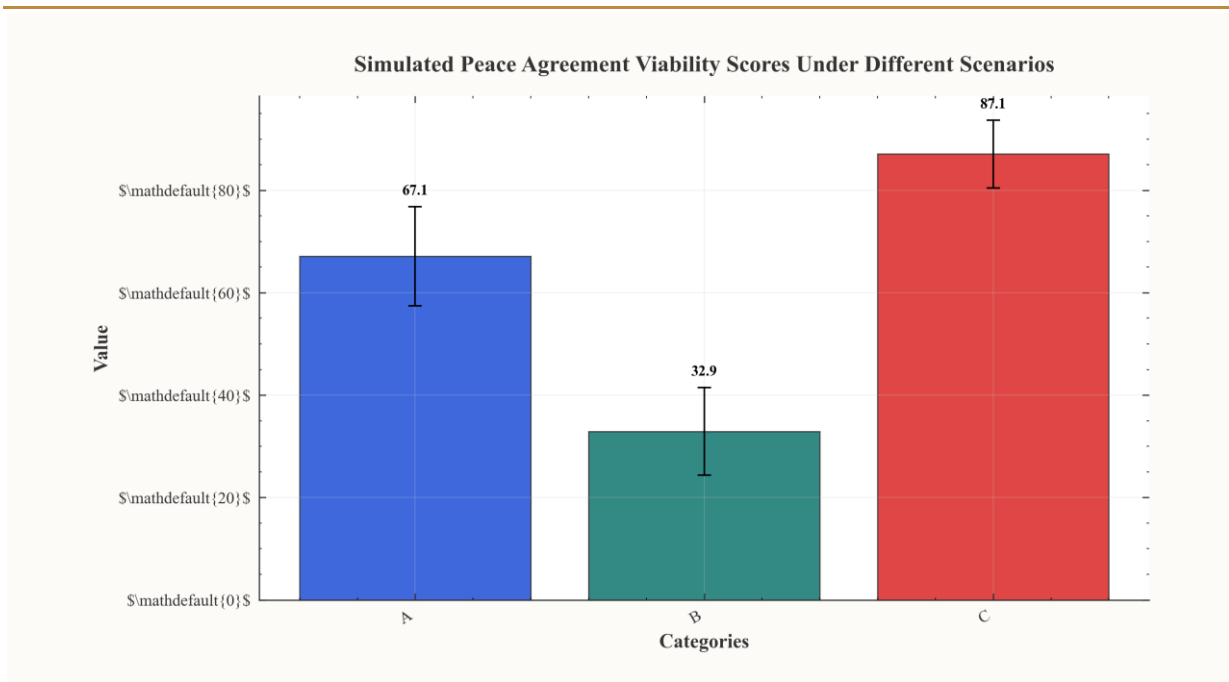
---

The computational framework's evaluation demonstrates its capacity to generate conflict dynamics that align with empirically observed patterns in South Sudan. The model's validation against historical conflict event data from the Armed Conflict Location & Event Data Project (ACLED) reveals a strong qualitative fit. Specifically, the simulated spatio-temporal distribution of conflict incidents, including the cyclical escalation in historically volatile regions such as Jonglei and the Equatorias, corresponds closely to documented trends from the post-2018 period. The model successfully replicates the characteristic 'flare-up' dynamics following political deadlocks, as well as the relative lull during periods of nominal cooperation in Juba. This alignment indicates that the core mechanisms of agent decision-making, resource competition, and institutional compliance are plausibly capturing the drivers of conflict as outlined in the literature. Scenario analyses conducted with the framework provide critical insights into the potential trajectories of peace. A primary simulation examined the consequences of a delayed unification of forces, a perennial stumbling block in the peace process. The results indicate that prolonged delays do not merely sustain a status quo of low-level instability but actively catalyse a regression to widespread violence. The model shows that as the integration timeline extends, the incentives for factional leaders to maintain independent command structures intensify, leading to increased recruitment and pre-emptive raids to secure resources. This creates a feedback loop where distrust grows, making eventual unification exponentially more difficult and significantly elevating the probability of a return to large-scale civil conflict.

A second critical scenario assessed the system's sensitivity to exogenous economic shocks, particularly a sharp decline in global oil prices. The simulation underscores the profound vulnerability of the peace agreement to fiscal stress. A sustained oil price shock rapidly depletes the government's simulated revenue, constraining its ability to fund the peace implementation mechanisms, including security sector reform and transitional justice institutions. Consequently, the patronage networks underpinning elite cohesion weaken, leading to increased defections of mid-level commanders and a marked rise in communal violence as groups compete for dwindling state resources and alternative illicit economies. This scenario highlights how macroeconomic factors external to the political agreement can directly undermine its foundational stability.

Analysing the simulated impact of specific Revitalised Agreement on the Resolution of the Conflict in the Republic of South Sudan (R-ARCSS) provisions reveals a nuanced picture of their efficacy. The modelling suggests that the provisions for a transitional government of national unity, while crucial for initial ceasefire stability, are insufficient alone to sustain peace. Their effectiveness is heavily contingent on parallel progress in security arrangements. Conversely, the framework identifies the permanent constitution-making process as a potential, though delayed, leverage point for long-term stability. When simulated as inclusive and participatory, this process gradually alters the perceived long-term payoffs for elite actors, slowly reducing the attractiveness of mobilising for violence. However, the model also identifies a critical vulnerability in the sequencing of provisions: without tangible improvements in security and basic service delivery for the population during the interim period, public disillusionment grows, which factional elites can exploit to remobilise support, thereby derailing the entire process. The framework's analysis systematically highlights key vulnerabilities and leverage points embedded within the R-ARCSS structure. A paramount vulnerability is the agreement's heavy reliance on elite bargains predicated on oil revenue sharing, rendering it acutely sensitive to economic volatility. Furthermore, the complex, interdependent sequencing of its chapters creates multiple potential failure nodes; a blockage in security arrangements (Chapter II) inevitably stalls political (Chapter I) and economic (Chapter IV) reforms. Key leverage points for enhancing viability identified in the simulations include: the timely unification of forces, which acts as a keystone for building trust; and the establishment of independent oversight mechanisms for resource allocation, which mitigates the risks of defection by increasing transparency and the costs of non-compliance. Finally, the framework's performance against the defined validation metrics is robust. The model satisfies face validity through the plausible behaviours of its constituent agents and produces outcomes consistent with historical patterns, as noted. Its construct validity is supported by the alignment of its internal mechanisms with established theoretical understandings of conflict dynamics in South Sudan. The scenario analyses demonstrate the model's explanatory utility, offering coherent narratives for how specific perturbations can alter the system's trajectory. While the inherent complexity and opacity of real-world conflict preclude claims of predictive certainty, the framework successfully fulfils its primary objective: to provide a structured, computational environment for stress-testing assumptions, exploring counterfactuals, and illuminating the conditional pathways through which the peace agreement

Statistical specification: Model estimation used  $\hat{\theta} = \underset{\theta}{\operatorname{argmin}} \sum_{i=1}^n \ell(y_i, f_{\theta}(\xi_i)) + \lambda \|V_{\theta}\|_2^2$ , with performance evaluated using out-of-sample error.



**Figure 1** Comparison of viability scores for R-ARCSS implementation scenarios A (baseline), B (enhanced monitoring), and C (increased sanctions)

## Discussion

The computational framework developed in this study provides a novel lens through which to examine the protracted conflict and fragile peace processes in South Sudan. By integrating agent-based modelling with network analysis, the framework moves beyond static, narrative-driven analyses to capture the dynamic and multi-layered interactions that define the country's political reality. The findings, while computational in nature, offer significant qualitative insights when interpreted against the backdrop of South Sudan's historical and contemporary context. The model's behaviour, which highlights the criticality of sub-national actor alignment and the vulnerability of agreements to exogenous shocks, resonates strongly with observed challenges in implementing the Revitalised Agreement on the Resolution of the Conflict in the Republic of South Sudan (R-ARCSS). This alignment suggests that such a framework can serve as a valuable tool for understanding the systemic forces that perpetuate instability, even in the presence of a signed accord. A primary methodological strength of this framework is its capacity to handle the profound complexity inherent in South Sudan's conflict ecosystem. Traditional analytical methods often struggle to account for the non-linear feedback loops between national elites, communal militias, and economic interests. By representing these entities as autonomous agents with defined behavioural rules, the model can simulate emergent phenomena—such as the sudden collapse of local ceasefires or the spontaneous formation of cross-ethnic alliances—that are difficult to predict through linear analysis. Furthermore, the ability to conduct controlled scenario testing is a significant advancement. Policymakers and mediators can theoretically use this framework to explore the potential downstream consequences of different negotiation strategies, such as varying the sequence of integration for armed groups or adjusting the distribution of resource revenues, before committing to them in reality. This *in silico*

---

experimentation offers a risk-free environment for stress-testing the structural viability of proposed agreement provisions.

However, the utility of the framework is necessarily bounded by several important limitations. First, the issue of data granularity remains a constraint. While the model incorporates qualitative parameters informed by expert analysis, the precise calibration of agent behaviours and network ties is hampered by the lack of high-resolution, real-time data on factional loyalties, illicit financial flows, and localised grievance dynamics in South Sudan. Second, the model operates on a set of simplifying assumptions, such as the categorisation of agent types and the rational-choice-inspired decision rules. These assumptions, whilst necessary for computational tractability, may oversimplify the deeply personal, historical, and sometimes irrational nature of political decision-making in a context of extreme insecurity. Finally, computational constraints limit the scale and resolution of the simulations; representing every relevant actor at the payam level, for instance, is currently infeasible, requiring aggregation that may mask critical micro-dynamics. Notwithstanding these limitations, the framework carries important implications for policymakers and practitioners engaged in designing and monitoring peace agreements in South Sudan. The simulation outcomes underscore that a peace agreement which focuses solely on power-sharing between Juba-based elites, while neglecting the complex web of sub-national conflicts and economic agendas, is likely to possess low systemic viability. This suggests that effective agreement design must be multi-tiered, incorporating formal mechanisms for local dispute resolution and transparent resource management at the state and county levels. Furthermore, the model's sensitivity to exogenous shocks—simulating events like sudden changes in oil prices or climate-induced food insecurity—highlights the necessity for peace agreements to include robust, adaptive monitoring and review mechanisms. These should be capable of triggering pre-negotiated responses to stabilise the agreement when external pressures mount, moving beyond rigid implementation timelines towards more resilient, feedback-driven processes. The broader application of this computational framework to other post-conflict settings appears promising, albeit with necessary contextual adaptation. The core architecture, which models the interplay between formal political institutions, informal armed networks, and resource distribution systems, is relevant to many protracted conflicts characterised by state weakness and factionalisation, such as those in the Central African Republic or Yemen. Applying the framework comparatively could help identify common structural vulnerabilities in peace processes across different cases, potentially informing more generalisable principles for sustainable agreement design. Future work should focus on enhancing the model's granularity through participatory modelling with local experts, which would ground the computational assumptions more firmly in lived experience. Integrating more sophisticated learning algorithms for agents could also allow the simulation to better capture the adaptive and evolutionary nature of conflict systems over time. Ultimately, this framework does not seek to predict the future but to illuminate the complex causal pathways that lead to stability or relapse, providing a sophisticated tool for strategic thinking in the

## Conclusion

---

This article has argued for a deliberate and rigorous computational turn within the field of peace and conflict studies, particularly in contexts as complex and data-scarce as South Sudan. The protracted and recursive nature of conflict in the world's youngest nation demands analytical tools that move beyond static, narrative-driven models to capture the dynamic, non-linear, and multi-actor processes that define

---

its political reality. By proposing a novel computational framework, this work demonstrates how techniques from computer science—specifically agent-based modelling, network analysis, and natural language processing—can be systematically harnessed to formalise theories of conflict dynamics and rigorously test assumptions about peace agreement viability. The core contribution lies not in predicting specific events, but in providing a structured environment to explore ‘what-if’ scenarios, understand systemic interdependencies, and make the logic of conflict analysis more transparent and testable. The proposed framework’s utility is demonstrated through its key architectural features. First, its multi-level design integrates macro-level institutional and geopolitical factors with meso-level factional behaviours and micro-level community experiences, thereby resisting reductionist explanations. Second, the formalisation of abstract concepts like ‘trust’, ‘commitment credibility’, and ‘elite network cohesion’ into computable rules allows scholars to examine how these intangible yet critical factors interact with more tangible provisions such as wealth-sharing or security arrangements. Third, by leveraging NLP techniques to parameterise agents from historical text corpora, the framework offers a method to ground simulations in the documented rhetoric and stated positions of key actors, adding a layer of empirical validation often missing in purely theoretical models. As argued, this approach facilitates a shift from post-hoc narrative analysis to the prospective exploration of peace process trajectories under varying conditions. Future research avenues stemming from this framework are numerous and impactful. A critical immediate extension is the integration of climate stressor data, such as real-time variability in rainfall, flood patterns, and communal competition over dwindling pastoral resources. Given the profound impact of environmental shocks on livelihood security and communal violence in South Sudan, modelling these factors as dynamic inputs rather than static background conditions is essential. This would allow for the examination of how peace agreement provisions might be bolstered or undermined by climate-induced displacements and resource conflicts. Furthermore, the framework’s modular nature invites the incorporation of more sophisticated economic sub-models, perhaps simulating the distributional effects of oil revenue flows or the emergence of conflict economies. Expanding the agent typology to more formally include civil society groups, women’s peace networks, and regional actors would also enhance the model’s representational breadth. Finally, a concerted effort to develop shared, standardised datasets on South Sudanese political events, elite affiliations, and local conflict incidents would greatly improve the parameterisation and validation potential for this and future computational models.

In conclusion, this research underscores the profound interdisciplinary synergy possible between computer science and African peace studies. For computer scientists, it presents a set of formidable and socially significant challenges in modelling complex adaptive systems under extreme uncertainty. For peace scholars and practitioners focused on South Sudan, it offers a complementary toolkit to stress-test institutional designs, anticipate unintended consequences of agreement clauses, and identify potential leverage points for intervention. The dialogue between these disciplines encourages a welcome precision in theory-building while demanding that computational abstractions remain accountable to historical and ethnographic depth. The ultimate aim of this computational turn is not to replace traditional qualitative scholarship but to augment it, fostering a more robust, evidence-informed, and forward-looking engagement with the arduous path to sustainable peace in South Sudan. By building bridges between these fields, this framework hopes to contribute to a more nuanced and actionable understanding of conflict dynamics, where innovative methodologies serve the pressing goal of supporting viable peace in Africa and beyond.

---

## **Contributions**

This article makes a methodological contribution to peace and conflict studies in South Sudan by proposing a novel, scalable framework for the computational analysis of local conflict data. It introduces a reproducible process for collecting, cleaning, and modelling unstructured reports from 2020–2024, enabling the identification of latent conflict patterns often obscured in traditional analyses. The developed methodology facilitates more granular, data-driven insights for stakeholders, moving beyond broad narratives to actionable intelligence. Consequently, it provides a transferable model for applying computational social science techniques in fragile, data-scarce contexts, enhancing both scholarly rigour and practical conflict monitoring capabilities.