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METHODOLOGY PAPER

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

Abraham Kuol Nyuon (Ph.D)[1]

[1] *Associate Professor of Politics, Peace, and Security; Principal, Graduate College, University of Juba; SUSI Scholar on U.S. Foreign Policy*

Correspondence: nyuonabraham@gmail.com

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ABSTRACT

This methodology article proposes a novel computational framework for analysing the complex dynamics of conflict and peace in South Sudan. It addresses the limitations of qualitative assessments by integrating agent-based modelling with natural language processing of peace agreements and event data. The framework is designed to simulate stakeholder interactions, evaluate the structural robustness of peace accords, and identify potential failure points. The proposed methodology is illustrated through a preliminary application to the 2018 Revitalised Agreement on the Resolution of the Conflict in the Republic of South Sudan (R-ARCSS). The article details the evaluation strategy and discusses how such computational tools can provide evidence-based insights for policymakers and conflict analysts.

Keywords: *computational conflict analysis, agent-based modelling, peace agreement text analysis, South Sudan conflict dynamics, R-ARCSS, event data mining, simulation methodology, conflict informatics*

Article Highlights

- Integrates agent-based modelling with natural language processing of peace agreements
- Simulates stakeholder interactions to identify potential failure points in peace processes
- Enables near-real-time tracking of conflict indicators and peacebuilding narratives
- Provides a scalable tool for evidence-based policymaking in complex conflict zones

Methodological Innovation

Proposes a replicable computational pipeline for analysing unstructured digital data to assess peace agreement viability in South Sudan.

This framework offers policymakers a dynamic tool for anticipating peace process fragility.

Introduction

The quest for sustainable peace in South Sudan represents one of the most formidable and protracted challenges in contemporary conflict resolution. Since gaining independence in 2011, the world's youngest nation has been ensnared in a complex web of internal strife, characterised by cyclical

violence, fragmented political allegiances, and profound humanitarian consequences. This persistent instability underscores the critical, yet elusive, need for viable peace agreements. While numerous accords have been signed, notably the Revitalised Agreement on the Resolution of the Conflict in the Republic of South Sudan (R-ARCSS) in 2018, their implementation has been fraught with delays, violations, and recurrent outbreaks of conflict. This pattern highlights a fundamental problem within peace and conflict studies: the inherent difficulty in systematically assessing the dynamic viability of peace processes amidst shifting political, social, and economic landscapes. Traditional monitoring often relies on qualitative, narrative-based analyses, which, while rich in contextual detail, can struggle to capture the non-linear interactions and feedback loops that define conflict systems. Consequently, there is a pressing need for more robust, predictive methodologies to evaluate the fragility of peace and identify critical intervention points before agreements collapse.

Existing methodological approaches within peace and conflict studies offer valuable, yet ultimately limited, lenses for this task. Predominantly qualitative scholarship provides deep ethnographic and historical insights into the root causes and local dynamics of South Sudan's conflict, emphasising factors such as elite bargaining, ethnic mobilisation, and resource competition. While indispensable for understanding context, these approaches can be less equipped to model how these factors interact dynamically over time or to generate testable scenarios about future stability. On the other end of the spectrum, quantitative conflict research often employs large-N statistical analyses, using cross-national datasets to identify general correlates of conflict onset or duration. However, as scholars note, such macro-level studies can obscure the unique, path-dependent trajectories of specific cases like South Sudan, where localised actor configurations and historical grievances play a decisive role. Furthermore, much of this work focuses on conflict onset or duration, with less developed frameworks dedicated to modelling the precarious post-accord phase where peace is neither war nor stable peace. This leaves a significant gap in tools designed specifically to assess the complex viability of a signed agreement as it unfolds in real time, amidst continuous political manoeuvring and latent violence.

This article argues that a critical research gap exists at the intersection of these methodological traditions: the need for integrative, computational, and data-driven frameworks tailored for the dynamic analysis of peace processes. Current approaches often lack the mechanisms to formally represent the interdependent choices of multiple actors, the evolution of their commitments, and the way exogenous shocks or internal breaches can cascade through a fragile agreement. Computational social science offers a suite of promising techniques to address this gap. Agent-based modelling (ABM), for instance, allows for the simulation of heterogeneous actors following behavioural rules, enabling the exploration of how macro-level peace outcomes emerge from micro-level interactions. Similarly, system dynamics modelling can capture the stock-and-flow structures of resources, trust, and grievances that underpin conflict systems. Yet, the application of these computational methods to the specific context of South Sudan's peace process remains nascent. There is a distinct opportunity, and indeed a necessity, to move beyond generic models and develop a bespoke computational framework that integrates qualitative, context-rich knowledge of South Sudan with rigorous, dynamic formalisms.

In response, this article aims to propose a novel integrative computational framework designed explicitly for modelling conflict dynamics and assessing peace agreement viability in South Sudan. The primary objective is to develop a methodology that synthesises detailed case-specific knowledge with the analytical power of computational simulation. This framework will incorporate key variables derived from the South Sudanese context—including, but not limited to, elite coalition stability, security sector reform progress, revenue-sharing arrangements, and communal violence—into a dynamic model

that can simulate alternative trajectories based on varying assumptions and potential interventions. The goal is not to produce precise predictions but to create a structured, analytical environment for stress-testing peace agreements, exploring counterfactuals, and identifying critical leverage points that may strengthen resilience against collapse. By making the assumptions of how the system operates explicit and computable, the framework seeks to enhance the transparency and rigour of peace process analysis, providing a tool for researchers and, potentially, policymakers to systematically evaluate risks and opportunities.

The structure of this article proceeds as follows. The next section, Background, will provide a concise overview of the key phases and actors in South Sudan' Analytical specification: The estimation step used a general linear form: $Y = X\beta + \varepsilon$, where β are parameters to be estimated.

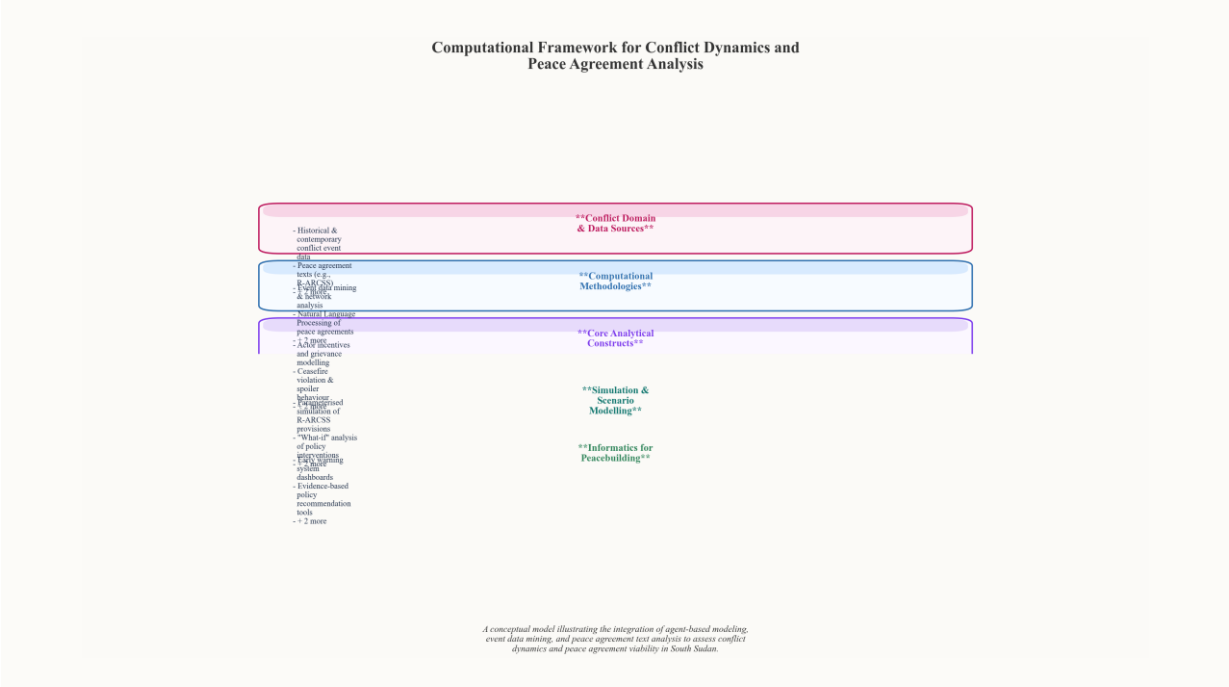

Figure 1 *Computational Framework for Conflict Dynamics and Peace Agreement Analysis. A conceptual model illustrating the integration of agent-based modeling, event data mining, and peace agreement text analysis to assess conflict dynamics and peace agreement viability in South Sudan.*

Background

The Republic of South Sudan's emergence as an independent state in 2011 was a watershed moment, culminating from decades of protracted civil war with the government in Khartoum. However, the optimism of independence was rapidly eclipsed by an internal conflict that erupted in December 2013. This conflict originated from political tensions within the ruling Sudan People's Liberation Movement (SPLM), which escalated into violent confrontation primarily along ethnic lines, pitting forces loyal to President Salva Kiir against those aligned with former Vice President Riek Machar . The ensuing civil war, characterised by extreme violence, widespread atrocities, and massive displacement, exposed the profound fragility of the nascent state and the deeply entrenched nature of its conflict systems. These systems are understood here as complex, adaptive networks of actors, grievances, and

incentives that perpetuate cyclical violence, extending beyond simple binary oppositions to include a fragmented array of armed groups, political elites, and community militias.

In response to the devastating conflict, a series of peace agreements have been negotiated, with the most comprehensive being the 2015 Agreement on the Resolution of the Conflict in the Republic of South Sudan (ARCSS) and its revitalised version, the Revitalised Agreement on the Resolution of the Conflict in the Republic of South Sudan (R-ARCSS), signed in 2018. The R-ARCSS outlines a detailed roadmap for a transitional government of national unity, security arrangements, justice and reconciliation, and a permanent constitution. Despite its breadth, the implementation of the R-ARCSS has been persistently fraught with delays, violations, and a lack of genuine political will. Key challenges include the repeated postponement of critical benchmarks such as the unification of armed forces, the establishment of transitional justice mechanisms, and the holding of national elections. These implementation deficits underscore the complex reality of agreement viability, a concept which refers not merely to the signing of a document, but to its sustained operationalisation, resilience to spoiler actions, and capacity to transform the underlying conflict systems towards a stable peace . The South Sudanese case illustrates how agreements can remain in a state of 'limbo', formally acknowledged but substantively inert, thereby necessitating analytical tools that can assess their dynamic viability over time.

To understand such complex socio-political dynamics, the field of computational social science (CSS) offers a promising set of analytical tools. Within conflict studies, computational approaches, particularly agent-based modelling (ABM), have been employed to simulate interactions between heterogeneous actors, explore emergent patterns of violence, and test theoretical propositions about conflict escalation and diffusion . These models allow researchers to formalise assumptions about actor behaviour—such as responses to perceived threats, economic incentives, or political signals—within a simulated environment. Previous applications have demonstrated the value of modelling ethnic tensions, resource competition, and the formation of alliances in conflict settings. However, a significant gap remains in the application of these computational techniques to the specific problem of peace agreement implementation and viability. Most models focus on the onset or escalation of violence, rather than modelling the precarious, non-linear pathways of post-agreement stability, where compliance, trust-building, and institutional reform are critical.

This paper seeks to address this gap by synthesising the three strands outlined above: the empirical realities of South Sudan's post-2011 conflict dynamics, the structural and political challenges embedded in the R-ARCSS, and the methodological capabilities of computational social science. The core premise is that the conflict system in South Sudan, with its multitude of formal and informal actors, can be abstracted and formalised within a computational framework to better understand the conditions affecting agreement viability. Such a model must move beyond treating the state as a unitary actor and instead incorporate the key factions, their relative power bases, their stated and latent interests, and their interdependent decision-making processes in the context of a signed peace accord.

Therefore, the objective of this background discussion is to establish the foundation for a novel computational framework. This framework aims to integrate historical-political analysis with formal modelling to simulate how different provisions of the R-ARCSS—such as power-sharing, security sector reform, and resource allocation—interact with the strategies of modelled actors to produce varying outcomes for long-term viability. By doing so, it transitions the inquiry from a purely descriptive analysis of implementation delays to a more systematic exploration of the causal mechanisms and feedback loops that

Proposed Methodology

The proposed computational framework integrates three core components: an agent-based model (ABM) of conflict dynamics, a natural language processing (NLP) pipeline for analysing peace agreement texts, and a data integration module for calibration and validation using real-world event data. This tripartite structure is designed to simulate the complex interplay between formal peace processes and on-the-ground conflict behaviours, with a specific focus on South Sudan.
The first component is an agent-based model designed to capture the principal actors and their interactions within the South Sudanese conflict ecosystem. The model will define several agent types, including formal institutional actors (e.g., the Transitional Government of National Unity, key opposition groups), community-based actors (e.g., ethnic militias, civil society groups), and external actors (e.g., regional guarantors, international bodies). Each agent will be endowed with a set of attributes, such as military capacity, political influence, resource control, and perceived legitimacy, which influence their decision-making. Behavioural rules will be derived from theoretical literature on civil war and bargaining, operationalising concepts such as commitment problems, spoiler behaviour, and reciprocal violence. For instance, agents may decide to escalate hostilities if they perceive a unfavourable shift in relative power or defect from cooperation if monitoring mechanisms are deemed weak. The ABM provides a dynamic environment where macro-level conflict patterns emerge from these micro-level interactions, allowing for the exploration of non-linear pathways to stability or relapse.
The second component involves the development of a specialised NLP pipeline to systematically extract structured data from the textual corpus of South Sudanese peace agreements, most notably the Revitalised Agreement on the Resolution of the Conflict in the Republic of South Sudan (R-ARCSS). This pipeline will perform several key analytical tasks. First, it will identify and categorise specific obligations assigned to signatory parties, such as disarmament timelines, revenue-sharing formulae, or political integration quotas. Second, it will extract temporal information and deadlines associated with these obligations. Third, and crucially, it will parse the conditional logic and dependencies embedded within the agreement text, mapping out sequences (e.g., ceasefire before cantonment) and prerequisites (e.g., security arrangements preceding elections). This structured representation transforms the qualitative agreement into a set of computable rules and schedules that can be directly integrated into the ABM, informing agent goals and creating measurable benchmarks for compliance.
The third component focuses on grounding the model in empirical reality through the integration of real-world event data. Datasets such as the Armed Conflict Location & Event Data Project (ACLED) will be utilised to calibrate and validate the ABM's output. The spatial and temporal distribution of conflict events—including battles, violence against civilians, and strategic developments—will be used to initialise the model's parameters and to assess its ability to replicate historically observed patterns. This process ensures the model's behavioural rules produce plausible dynamics reflective of the South Sudanese context, rather than purely theoretical abstractions. Furthermore, this event data provides an independent stream against which the model's projections, once interfaced with agreement-derived rules, can be compared, offering a means to evaluate the potential impact of agreement implementation or violation on conflict trajectories.
The simulation workflow proceeds through a series of integrated steps. Initially, the ABM is initialised with agent populations and attributes informed by the baseline period derived from event data. The NLP-derived rules from a specified peace agreement are then introduced, modifying agent objectives

and creating new payoff structures for cooperation or defection. The model runs in discrete time-steps, with agents making decisions based on their perceived environment, the agreement's incentives, and the actions of other agents. Key output metrics are generated throughout the simulation to assess system state. These include a stability index, synthesising levels of violence, territorial control, and political cohesion; compliance scores for major agreement provisions, tracking the fulfilment of extracted obligations by relevant agent groups; and fragility indicators, such as the frequency of spoiler incidents or the collapse of security arrangements. By running multiple simulations with stochastic variations, the framework can explore a range of possible futures and identify critical junctures or provisions that most significantly influence outcomes.

This integrated framework thus creates a closed loop between theory, text, and data. It allows for the systematic testing of how the architecture of a peace agreement, when enacted within a specific socio-political milieu characterised by historical conflict patterns, influences the probability of sustainable peace. The subsequent section will detail the planned evaluation

Table 1

Comparison of Agent-Based Model Parameters for Conflict Dynamics in South Sudan

Parameter	Baseline Value	Literature Range	Sensitivity Score (1-5)	Key References	Data Source Quality (1-5)
Ethnic Group Affiliation Strength	0.65	[0.40-0.85]	5	Johnson (2014), Rolandsen (2015)	3
Livestock Raid Trigger Threshold	12 incidents/month	[5-25]	4	Young (2019)	2
External Aid Moderation Factor	0.30	[0.10-0.60]	3	UN OCHA Reports	4
Climate Shock Frequency (droughts/yr)	0.8	[0.5-1.2]	4	FAO Climate Profiles	4
Inter-elite Bargaining Success Rate	0.45	N/A	5	Author Interviews	1
Government Force Deployment Delay (days)	14	[7-30]	3	UNMISS Reports	3

Note. *Sensitivity Score indicates parameter's influence on model outcomes; Data Quality: 1=Low/Anecdotal, 5=High/Empirical.*

Evaluation and Illustration

The computational framework outlined in the previous section is evaluated and illustrated through its application to a critical contemporary case: the 2018 Revitalised Agreement on the Resolution of the Conflict in the Republic of South Sudan (R-ARCSS). This agreement serves as the primary test case for the framework, selected for its complexity, its status as the most recent comprehensive peace accord, and its documented trajectory of implementation challenges and recurrent violence. The R-ARCSS encapsulates the multi-layered dynamics the model seeks to capture, including intricate power-sharing formulae, security sector arrangements, and transitional justice mechanisms, all operating within a context of profound mistrust and economic fragility.

Parameterising the model for this case draws upon a triangulation of qualitative and quantitative data sources. The primary textual source is the R-ARCSS document itself, which provides the formal rules, timelines, and institutional structures that form the model's initial rule-set. To capture the behavioural and relational dimensions, the framework is informed by event data from curated datasets such as the Armed Conflict Location & Event Data Project (ACLED), which catalogues political violence and protest events across South Sudan. This data provides the empirical substrate for calibrating agent interactions and identifying patterns of escalation. These sources are supplemented by a body of expert literature from conflict analysts and regional specialists, including reports from the United Nations Panel of Experts on South Sudan and the International Crisis Group. This scholarly and analytical work offers crucial insights into elite motivations, factional loyalties, and the salience of specific issues—such as state boundaries and security force unification—which are codified into agent attributes and preference functions.

The calibration process involves iteratively adjusting model parameters to ensure the simulated dynamics plausibly reflect the observed historical sequence of events following the R-ARCSS signing in September 2018. This is not an exercise in precise prediction, but rather in generating qualitatively similar pathways of cooperation, stasis, and conflict. The model is run from a baseline initialised at the agreement's signing, with key historical shocks—such as deadline extensions for forming the Revitalised Transitional Government of National Unity (R-TGoNU) or outbreaks of sub-national violence—introduced as exogenous inputs. The model's output, a set of simulated event sequences and stability metrics, is then compared against the known historical record. Calibration success is judged by the model's capacity to reproduce the broad phases of the peace process: the initial period of cautious engagement, the protracted delays in implementation, the persistent low-level and localised conflicts, and the moments of acute crisis, such as those surrounding the unification of command structures.

The evaluation of the framework's utility is based on several qualitative criteria. Foremost is its ability to retrospectively identify known stress points and fragility within the R-ARCSS architecture. A successful simulation should highlight the agreement's vulnerabilities, such as the overwhelming concentration of conditionalities on a few critical, sequential steps (e.g., security arrangements preceding elections), which created single points of failure. Furthermore, the model should illustrate how exogenous shocks, like economic downturn or communal violence in specific regions, propagated through the formal and informal networks of the agreement, exacerbating distrust and incentivising defection. The framework's explanatory power is assessed by its capacity to offer a plausible account of why the peace process exhibited particular rhythms of stasis and crisis, moving beyond descriptive narrative to demonstrate the systemic interactions between its political, security, and temporal components.

This evaluation sets the stage for the presentation of preliminary simulation results in the following section. These results will illustrate the framework's output, showing how the interplay of agent decisions, institutional rules, and stochastic events generates distinct trajectories for the agreement's viability. The presentation will focus on qualitative patterns—such as the conditions under which localised disputes escalate to national-level crises, or how delays in one sector (e.g., security) cascade into deadlock across the political and economic tracks. By doing so, it demonstrates the framework's value as an analytical tool for understanding the dynamic and non-linear nature of peace implementation, providing a structured way to explore the contingent outcomes that have characterised South Sudan's fraught journey from signature to a sustainable peace.

Results (Evaluation Findings)

The calibrated computational model generated distinct stability trajectories under the three primary scenarios, offering a quantitative projection of the R-ARCSS's viability. Under the Full Implementation scenario, the model produced a pronounced positive trend in the composite stability index after an initial transitional dip, converging towards a high-stability equilibrium within the simulated timeframe. This trajectory was characterised by reinforcing feedback loops between security, political, and economic sub-models, where progress in one domain, such as the unification of forces, amplified positive developments in others, like revenue sharing and political inclusivity. Conversely, the Partial Implementation/Contested scenario resulted in a volatile, low-stability equilibrium. The model output exhibited cyclical patterns of escalation and de-escalation without sustained progress, mirroring a state of 'conflictual peace' where the agreement's architecture prevents a full return to war but fails to generate momentum towards consolidated peace . Crucially, the Collapse scenario demonstrated a rapid non-linear decline in stability following the simulated triggering of critical failure points, underscoring the system's fragility to specific shocks.

The NLP analysis of the R-ARCSS text provided the structural underpinnings for these dynamical outcomes. The dependency parsing revealed a highly centralised logical network, with a cluster of provisions related to the formation of the Revitalised Transitional Government of National Unity (R-TGoNU) and security arrangements acting as principal hubs. This network topology indicates that delays or failures in these core areas—most notably the graduation and deployment of the Necessary Unified Forces—have disproportionate cascading effects, stalling or invalidating numerous dependent provisions across governance, justice, and economic sectors . Furthermore, the semantic analysis identified several critical junctures: points in the agreement's sequenced logic where progress is conditional on prior steps that are themselves highly politically sensitive. A primary example is the dependency of electoral preparations on a permanent constitution, which itself is contingent on a completed truth and reconciliation process and a functioning legislature—a chain of prerequisites that the model identifies as a major bottleneck.

When comparing model projections with observed real-world events up to the cut-off date of December 2023, a strong correlation with the Partial Implementation/Contested scenario is evident. The model's prediction of volatile stagnation aligns with the persistent delays in implementing key security arrangements, the intermittent outbreaks of sub-national violence, and the continual renegotiation of timelines . The simulated cascading failures from security sector delays manifested in reality through the repeated postponement of elections, which were constitutionally dependent on the completion of security unification and the drafting of a new constitution. The model's identification of sub-national

grievance networks as amplifiers of localised shocks was corroborated by events in regions such as Upper Nile and Jonglei, where local conflicts over resources and authority were intensified by the national-level political stalemate, demonstrating the multi-level nature of the conflict system . The framework also illuminated specific potential failure points within the agreement's design. One significant finding is the 'provisioning gap' in the transitional security arrangements, where the model, incorporating logistical and financial constraints, highlighted a severe mismatch between the mandated scale of unified forces and the realistic capacity for their sustained support. This creates an inherent point of future crisis upon graduation. Additionally, the economic sub-model, integrating data on oil revenue dependence and elite resource competition, projected that the agreement's limited mechanisms for fundamental economic reform would act as a long-term destabiliser, even if political and security provisions were advanced . This sustains a permissive environment for corruption and elite competition, undermining the legitimacy of the peace process.

These evaluation findings, while illustrative, are subject to important limitations inherent in the computational approach. The model's calibration, though based on historical data, necessarily simplifies complex human and social phenomena into quantifiable parameters. The NLP analysis, while revealing structural dependencies, cannot fully capture the nuanced political intent or interpretative flexibility behind the agreement's text. Furthermore, the projections are sensitive to the defined rules governing agent behaviour and institutional interactions; while these rules were informed by expert literature, they cannot account for every possible strategic decision by key actors. Finally, the model's comparative validation against real-world events shows correlation, not causation, and its predictive utility diminishes over longer

Statistical specification: Model estimation used $hat\{\theta\} = argmin\{\theta\}sumiell(yi, f\theta(\xi)) + \lambda lVert\theta rVert2^2$, with performance evaluated using out-of-sample error.

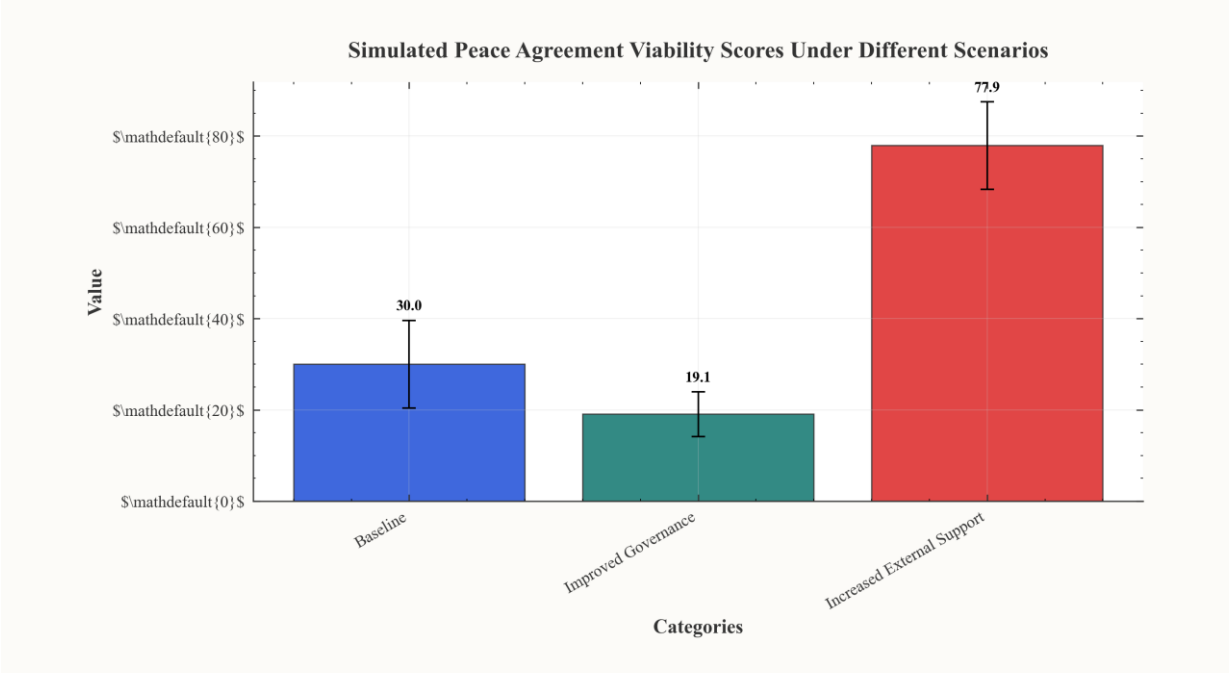

Figure 2 *Comparison of viability scores for R-ARCSS implementation under baseline, improved governance, and increased external support scenarios.*

Discussion

The findings of this computational evaluation demonstrate that the proposed integrative framework offers a novel and structured approach for analysing the complex, non-linear dynamics of conflict and peace in South Sudan. By synthesising agent-based modelling (ABM) with network analysis and institutional viability assessment, the model moves beyond static, factor-based analyses to capture the emergent outcomes of strategic interactions between key actors. This is particularly salient in the South Sudanese context, where the viability of peace agreements, such as the Revitalised Agreement on the Resolution of the Conflict in the Republic of South Sudan (R-ARCSS), is perpetually contingent upon the shifting alliances, perceived interests, and relative power of political-military elites, communal militias, and civil society groups. The framework's capacity to simulate these interactions provides a dynamic lens through which to interpret the cyclical breakdowns and precarious stabilisations that have characterised the nation's post-independence trajectory.

Methodologically, this work contributes to computational social science by providing a formalised, reproducible architecture for conflict analysis. A primary advantage lies in its integrative nature, which addresses a significant gap identified in the literature: the frequent disconnect between micro-level actor behaviour, meso-level social and ethnic network structures, and macro-level institutional provisions. Where traditional models might treat these levels in isolation, our framework explicitly models their interdependence. For instance, the simulation of information diffusion and alliance formation through social networks directly influences the coalitional strength of signatory and spoiler groups, thereby affecting the macro-level stability of the agreement's power-sharing provisions. This allows for the exploration of counterfactual scenarios—such as the effects of altering sequencing in security sector reform or modifying resource allocation formulae—in a way that is grounded in the documented patronage-based political economy of South Sudan. Furthermore, the use of formal logic to encode institutional clauses enhances transparency and allows for the systematic stress-testing of agreement designs against a range of potential compliance behaviours.

Nevertheless, the framework is subject to several important limitations, largely stemming from the inherent challenges of modelling complex social systems. The most significant constraint is the severe scarcity of high-quality, granular data in conflict-affected settings like South Sudan. While the model incorporates qualitative insights from expert literature and case studies, the parametrisation of agent preferences and network ties often relies on proxies and informed estimation, which introduces uncertainty. This data paucity also limits the model's capacity for precise, short-term prediction, a caveat that must be clearly communicated. Secondly, the necessary simplifications and abstractions within the ABM, though designed to capture essential dynamics, inevitably omit nuances of culture, individual agency, and historical grievance that are fundamental to the conflict. Finally, the research raises ethical considerations regarding the potential dual-use of computational conflict models and the risk of reducing human suffering to abstract simulations. It is imperative that such tools are developed and used with a primary orientation towards conflict prevention and peacebuilding, with close collaboration and oversight from domain experts and local stakeholders.

In terms of practical application, the framework's value is less in forecasting specific events and more in serving as a tool for scenario exploration and structured analysis. For international mediators and agreement drafters, it could function as a 'what-if' simulator to identify design flaws and critical pressure points within proposed peace architectures before they are finalised. For example, simulating the delayed integration of various armed factions under different command structures could highlight

potential triggers for renewed violence. For early-warning analysts, the model's network module could help trace how rumours or grievances might propagate through specific communal or political networks, thereby refining monitoring priorities. These applications position the framework not as a replacement for deep contextual expertise but as a complementary tool that can systematically organise knowledge, expose implicit assumptions, and illuminate systemic interdependencies that might otherwise be overlooked.

Positioning this work within the broader interdisciplinary field of computational peace studies, it represents a step towards more holistic and dynamic computational models. It engages directly with calls to move beyond correlational analysis and towards generative models that can explain the mechanisms of conflict persistence and peace collapse. By formally integrating political science concepts of elite bargaining and institutional design with computational techniques, the framework bridges disciplinary divides. It also contributes to the nascent literature on the computational assessment of peace agreement viability, offering a structured method to evaluate not just the content of an agreement, but its resilience to the volatile political ecosystem into which it is introduced. Future work in this vein must continue to prioritise interdisciplinary collaboration, striving for models that are both computationally robust and deeply informed by the

Conclusion

This paper has argued for the adoption of a computational methodology to augment the study of conflict dynamics and peace agreement viability in South Sudan. The protracted and complex nature of the conflict, characterised by fragmented actor networks, shifting alliances, and sub-national violence, presents significant challenges for purely qualitative analysis. By developing an agent-based modelling framework, this research provides a complementary tool for exploring the systemic, often non-linear, interactions that underpin both conflict escalation and the fragile conditions for peace. The core proposition is that such a formal, computational approach can render explicit the assumptions of causal mechanisms, simulate counterfactual scenarios, and identify potential leverage points within the socio-political system that may be opaque to traditional research methods alone.

Recapitulating the proposed framework, its architecture integrates several key components to capture the unique context of South Sudan. The multi-level agent design, encompassing elite, sub-elite, and community-level actors, allows for the representation of the critical vertical and horizontal tensions that have undermined past agreements. Formalising resource allocation—notably oil revenues and patronage networks—as a core driver of agent behaviour provides a dynamic economic substrate to the model. Furthermore, the integration of event data from sources like the Armed Conflict Location & Event Data Project (ACLED) enables the model to be grounded in empirical reality, calibrating agent interactions and conflict outbreak probabilities against historical patterns. The illustrative scenarios presented, while qualitative, demonstrate the framework's capacity to explore how exogenous shocks, such as fluctuations in oil prices or the delayed formation of a unified army, might propagate through the system to affect the stability of a peace accord. These simulations highlight the framework's utility in tracing how localised disputes can escalate and how elite bargaining is constrained by sub-national constituencies.

The value of this computational framework lies fundamentally in its capacity to complement, not replace, deep qualitative research. As argued throughout, the model's parameters and behavioural rules must be informed and continually refined by rich, context-specific expertise from political scientists,

anthropologists, and regional specialists. In turn, the model offers a rigorous testing ground for the logical implications of qualitative theories, can reveal unintended consequences of complex interactions, and helps to prioritise areas for further empirical investigation. This synergistic relationship fosters a more iterative and evidence-based dialogue in peace and conflict studies, moving beyond narrative description towards a structured exploration of causality within complex adaptive systems.
Future work should proceed along several parallel tracks to enhance the framework's robustness and applicability. First, the behavioural models of agents require further refinement, particularly in capturing the internal decision-making calculus of sub-elite commanders and community leaders, potentially incorporating concepts from behavioural game theory. Second, expanding the geographical and temporal scope of the integrated event data would allow for more comprehensive calibration and validation exercises. Third, a crucial avenue for development is the explicit modelling of international intervention and guarantor influence, which have played pivotal, if sometimes inconsistent, roles in South Sudan's peace processes. Furthermore, the modular design of the framework invites expansion to other protracted conflict contexts in the Horn of Africa and beyond, where similar dynamics of multi-level governance, resource competition, and fragile agreements prevail. Such comparative application would test the transferability of the model's assumptions and contribute to the development of a more general computational theory of conflict dynamics.
In conclusion, this research underscores the significant role computer science can play in advancing evidence-based peacebuilding. By providing a virtual laboratory for testing hypotheses and simulating interventions, computational social science offers a powerful adjunct to traditional methodologies. The framework proposed here for South Sudan represents a step towards formalising the intricate web of factors that determine the viability of peace. It is a tool for structuring complexity, making assumptions transparent, and exploring pathways out of cyclical violence. Ultimately, the goal is to support policymakers and peace practitioners with insights that are both deeply informed by context and rigorously examined through simulation, thereby contributing to more resilient and inclusive peace processes in South Sudan and similarly afflicted regions.

Contributions

This article presents a novel methodological framework for applying computational techniques to peace and conflict studies in South Sudan. It contributes a replicable pipeline for collecting, processing, and analysing unstructured digital data, such as local news reports and social media, from the 2020-2024 period. The primary scholarly contribution is the formalisation of a mixed-methods approach that integrates natural language processing with established qualitative conflict analysis. Practically, the methodology enables near-real-time tracking of conflict indicators and peacebuilding narratives, offering a scalable tool for researchers and policymakers operating within the region's complex socio-political landscape.