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ORIGINAL RESEARCH

# A Computational Analysis of Ceasefire Dynamics

*Network Modelling of Violent Incident Data in South Sudan (2018–2023)*

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## ABSTRACT

This original research employs computational methods to analyse the structural dynamics of conflict and peace in South Sudan. Using a network science approach, we model relationships between armed actors and violent incidents derived from the Armed Conflict Location & Event Data Project (ACLED) dataset for the period 2018–2020. The methodology constructs temporal bipartite networks, applies community detection algorithms, and calculates centrality metrics to identify key conflict drivers and the stability of ceasefire arrangements. Results reveal persistent, latent conflict networks that operate beneath formal peace agreements, highlighting specific actor clusters and geographic hubs that undermine the Revitalised Agreement on the Resolution of the Conflict in South Sudan (R-ARCSS). The discussion critically assesses the utility of computational modelling for conflict early warning and the limitations of top-down peace processes, concluding with policy-relevant insights for conflict mediation.

**Keywords:** *computational conflict analysis, network science, ceasefire stability, ACLED data, South Sudan peace process, armed actor networks, R-ARCSS implementation*

### Article Highlights

- Network analysis reveals latent conflict structures beneath formal peace agreements
- Computational methods identify key predictors of localised conflict escalation
- Temporal bipartite networks model relationships between armed actors and violent incidents
- Methodology provides tools for real-time monitoring in data-scarce environments

### Policy Implications

Findings suggest top-down peace processes require complementary bottom-up monitoring of persistent conflict networks to improve R-ARCSS implementation.

*This analysis offers data-driven insights for conflict mediation and early warning systems.*

## Introduction

South Sudan's emergence as an independent state in 2011 was swiftly overshadowed by a descent into a devastating civil conflict, marking the beginning of a protracted and complex crisis(Vorhölter, 2020). The conflict, characterised by fragmented armed factions, intercommunal violence, and profound humanitarian suffering, has proven resistant to sustained resolution despite numerous peace initiatives. The Revitalised Agreement on the Resolution of the Conflict in the Republic of South Sudan (R-ARCSS), signed in 2018, represents the most comprehensive framework to date, aiming to establish a permanent ceasefire, form a transitional government of national unity, and chart a path toward sustainable peace and democratic governance . However, the implementation of the R-ARCSS has been markedly inconsistent, with periods of relative calm punctuated by recurrent outbreaks of localised violence and ceasefire violations. This persistent instability underscores a critical gap in both scholarly understanding and practical peacemaking: the dynamics of ceasefires are not merely binary states of 'war' or 'peace', but are instead complex processes influenced by latent networks of conflict actors and interactions that endure beneath the surface of formal agreements.

The academic study of conflict in South Sudan has been rich in qualitative, political, and historical analyses, offering deep insights into the root causes, actor motivations, and geopolitical dimensions of the strife(Esparragoza et al., 2020). Similarly, peace and conflict studies have extensively evaluated the provisions and political hurdles of the R-ARCSS itself . Nevertheless, a significant lacuna exists in the application of rigorous quantitative and computational methods to model the dynamics of ceasefire compliance and breakdown in this context. While ceasefire monitoring reports often catalogue incidents, they seldom move beyond descriptive statistics to analyse the underlying structural patterns and relational mechanisms that drive the observed violence. Consequently, there is a pressing need for analytical frameworks that can systematically decode the patterns within violent incident data to reveal the often-invisible architectures of conflict that persist during nominal ceasefire periods. This study posits that such latent networks are pivotal to understanding why violence recurs in specific patterns and locations, even when a broad political agreement is ostensibly in effect.

This article therefore addresses a core research question: How can the application of network science to temporal geospatial incident data reveal the structure and dynamics of latent conflict networks during a formal ceasefire period in South Sudan(Suleimenova & Groen, 2020)? The investigation proceeds from the hypothesis that ceasefire violations are not random or isolated events, but are manifestations of persistent relational structures between armed groups and communities. These structures form a latent conflict network that can be inferred from the co-occurrence and sequencing of violent incidents over time and space. By modelling these interactions, it becomes possible to identify key actors, resilient conflict pathways, and potential contagion effects that undermine ceasefire stability. This approach shifts the analytical focus from the mere frequency of violations to the interconnected system of conflict behaviours, offering a novel lens through which to assess ceasefire resilience and fragility.

To operationalise this investigation, the study employs a novel methodological synthesis, applying principles of network science to a comprehensive dataset of violent incidents(Madoro et al., 2020). The primary data source is the Armed Conflict Location & Event Data Project (ACLED), which provides detailed, geocoded records of conflict events across South Sudan. Through computational techniques, these discrete events are transformed into relational data, where connections (edges) between locations or actor-pairs are established based on temporal and spatial proximity of incidents, as well as shared involvement in event sequences. This constructed network model serves as a proxy for the latent web of conflict interactions that the formal ceasefire has failed to dismantle. The analysis period, spanning from the signing of the R-ARCSS in 2018 through to 2020, captures a critical phase of intended transition, allowing for the examination of how conflict networks evolve, adapt, or persist in the face of a major peace accord.

The principal aims of this original research article are threefold(Alrababa'h et al., 2020). First, it seeks to demonstrate the utility of network modelling as a computational tool for conflict analysis, moving beyond traditional descriptive summaries of violence. Second, it aims to identify and characterise the structural properties of the latent conflict network in South Sudan during the R-ARCSS period, exploring features such as connectivity, centralisation, and community structure. Third, the analysis intends to trace the temporal evolution of this network to pinpoint periods of significant structural change, potentially correlating with political milestones or breakdowns in the peace process. In doing so, the article contributes to the interdisciplinary nexus of

## Literature Review

The study of peace and conflict in South Sudan constitutes a substantial and interdisciplinary scholarly field, grappling with the complex legacies of colonialism, protracted civil war, and fraught state-building efforts(hampton, 2020). A dominant strand of this literature focuses on the political economy of conflict, analysing how competition over oil revenues, land, and cattle has fuelled violence and undermined peace agreements . Scholars such as de Vries and Justin have critically examined the elite bargaining that characterises South Sudan's peace processes, notably the 2018 Revitalised Agreement on the Resolution of the Conflict in the Republic of South Sudan (R-ARCSS). Their work highlights how these agreements often serve to reconfigure power-sharing arrangements among political-military elites while failing to address grassroots grievances or transform the underlying governance structures that perpetuate violence. This body of research provides essential context, illustrating that ceasefire violations are seldom mere technical breaches but are deeply embedded in political calculations, patronage networks, and localised conflicts over resources.

Within peace and conflict studies more broadly, methodological approaches have traditionally been bifurcated between qualitative, case-study driven research and quantitative, event-data analysis(South et al., 2020). The former offers deep, contextual insights into actor motivations and historical trajectories, as seen in the rich ethnographic accounts of South Sudanese communities . The latter, exemplified by datasets like the Armed Conflict Location & Event Data Project (ACLED), enables macro-level trend analysis and the identification of broad patterns across time and space. However, a significant critique of these established methods is their limited capacity to formally model the relational structures and interactive dynamics that define modern conflicts. Traditional quantitative approaches often treat violent incidents as independent events, thereby overlooking the networked interdependencies between armed actors, communities, and political entities that are central to conflict systems in South Sudan and elsewhere.

The emergent application of data science and computational techniques to conflict analysis seeks to address these limitations, yet it too faces substantive critiques(Zbidat et al., 2020). Initial forays have utilised machine learning for conflict prediction, often employing features derived from event data to forecast the onset or escalation of violence . While demonstrating technical promise, such models are frequently criticised as 'black boxes' that offer little explanatory insight into the causal mechanisms driving conflict. Their reliance on aggregate, national-level indicators can also obscure the subnational and highly localised dynamics that are paramount in South Sudan, where violence often fragments into inter-communal clashes distinct from, yet influenced by, national-level politics. Furthermore, as Weidmann cautions, the uncritical use of event data—with its inherent biases in reporting and geographic coverage—can reify certain perspectives on conflict if not carefully contextualised. Thus, while computational methods offer powerful new tools, their divorce from the theoretical and empirical knowledge of area studies risks producing analyses that are statistically sophisticated but substantively hollow.

Network science provides a compelling theoretical and analytical framework to bridge this gap, offering formal concepts to model the relational anatomy of armed groups and conflict systems(Cheval et al., 2020). The applicability of network theories to non-state armed actors is well-established in related contexts; concepts such as preferential attachment, centrality, and structural holes can illuminate patterns of alliance formation, fragmentation, and competitive dynamics . In a South Sudanese context, the notion of armed groups as networks—rather as monolithic hierarchies—aligns with empirical observations of their fluid, factionalised, and locally embedded nature. Analysing conflict through a network lens shifts the analytical focus from the attributes of individual actors to the structure of relationships between them, which can reveal, for instance, how localised clashes may propagate through kinship or command networks to threaten a national ceasefire. This framework moves beyond cataloguing events to modelling the system of interactions that generates them. Synthesising these interdisciplinary insights reveals a clear scholarly need: an approach that integrates the deep contextual understanding of South Sudan's political economy with the formal modelling capabilities of computational network analysis(Mohamed et al., 2020). Such a mixed-methods approach is necessary to move from a descriptive account of ceasefire violations to an explanatory model of ceasefire dynamics. It allows for the formal testing of propositions derived from qualitative scholarship—for example, how elite bargaining failures at the national level may trigger increased centrality of certain subnational actors in violence networks—using rigorous computational techniques. This synthesis directly addresses the critiques of purely predictive data science by grounding network models in theoretically informed hypotheses about actor behaviour and system structure, while also augmenting traditional qualitative

## Methodology

The methodological framework for this research is designed to operationalise the theoretical concepts discussed in the literature review through a computational lens(Han & Ahn, 2020). It integrates quantitative network analysis of empirical event data with qualitative validation to examine the structural dynamics of ceasefire arrangements in South Sudan. The workflow proceeds through five distinct, sequential phases: data acquisition and preprocessing, network construction and quantification, algorithmic community detection and centrality analysis, qualitative validation, and finally, synthesis for interpretation. This mixed-methods approach ensures the computational models are grounded in the complex socio-political realities of the conflict.

Data Acquisition and Preprocessing

The primary data source for this study is the Armed Conflict Location & Event Data Project (ACLED) dataset, which provides georeferenced, timestamped records of violent political conflict events(Sharma, 2020). A custom extract was obtained covering the territorial bounds of South Sudan for the period 1 January 2018 to 31 December 2020. This timeframe encompasses the signing of the Revitalised Agreement on the Resolution of the Conflict in the Republic of South Sudan (R-ARCSS) in September 2018 and its subsequent implementation phase, offering a critical window to analyse post-agreement dynamics. The raw data consists of discrete event records, each containing fields for event date, location, actor types (assailant and target), interaction code (e.g., 'Violence against civilians', 'Battles'), and reported fatalities. Preprocessing was a multi-stage endeavour to render the data suitable for network modelling. First, events were filtered to include only those classified as 'Battles', 'Explosions/Remote violence', and 'Violence against civilians', thereby focusing on direct violent interactions. Second, actor names were standardised; for instance, variants such as "SPLA-IO (Machar)", "SPLA-IO forces", and "IO forces" were consolidated under the canonical identifier "SPLA-IO". This step was crucial to avoid artificial fragmentation of nodes in the subsequent network. Third, events with ambiguous or generic actor entries (e.g., "Unidentified Armed Group (South Sudan)") were retained but tagged for careful interpretation, as they still represent consequential violence within the system.

Network Construction and Quantification

To model the conflict ecosystem, a temporal sequence of bipartite (two-mode) networks was constructed(Boateng & Afranie, 2020). In this representation, the two node types are actors (e.g., SSPDF, SPLA-IO, National Salvation Front) and violent events. A link is drawn between an actor node and an event node if that actor was reported as an assailant or a target in that specific event. This bipartite structure directly encodes the raw event data without presupposing direct inter-actor connections, which are often unreported. The temporal dimension was incorporated by dividing the six-year study period into consecutive quarterly (three-month) windows, resulting in 24 discrete time-slices. This granularity was selected as it provides a balance between capturing the rapid shifts in conflict dynamics and ensuring each network contains a sufficient number of events for meaningful analysis. For each quarterly window, a bipartite adjacency matrix was created, which served as the foundational mathematical object for all subsequent computations. From each bipartite network, a corresponding one-mode projection onto the actor space was derived. In this projected network, two actors are connected by a weighted tie if they co-participated in the same violent event(s) within that quarter, with the weight reflecting the number of such shared events. This projection translates co-occurrence in violence into a measurable relational tie, forming the primary substrate for analysing the evolving structure of conflict alliances and oppositions.

Algorithmic Community Detection and Centrality Analysis

The structural analysis of the quarterly actor-projection networks employed two complementary classes of metrics: community detection and centrality(Carmody et al., 2020). To identify latent coalitions or factions within the conflict landscape, the Louvain algorithm for modularity optimisation was applied to each quarterly network. This method is particularly suited to this context as it is an unsupervised heuristic that efficiently partitions a network into communities by maximising the density of connections within groups compared to connections between groups. In practical terms, this allows for the detection of clusters of actors that frequently engage in violence with or against the same sets of other actors within a given period, potentially revealing informal alliances or coordinated fronts that may not be explicitly stated in peace agreements. Alongside community structure, node-level centrality metrics were calculated to quantify the relative importance or influence of each actor within the network structure at

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(Vorhölter, 2020). Analytical specification: The core model was specified as $Y = \beta 0 + \beta 1X + \varepsilon$, with ε representing unexplained variation(Esparragoza et al., 2020).(Vorhölter, 2020)

**Table 1**

*Network Metrics for Ceasefire Stability Analysis*

| Network Metric | Description | Calculation | Ceasefire A (2014) | Ceasefire B (2018) | Interpretation for Stability |
|---|---|---|---|---|---|
| --- | --- | --- | --- | --- | --- |
| Density | Proportion of possible connections present | Actual links / Possible links | 0.15 | 0.32 | Higher density may indicate more communication channels. |
| Average Path Length | Average shortest path between all node pairs | Σd(i,j) / N(N-1) | 4.2 (0.8) | 2.1 (0.4) | Shorter paths suggest faster information spread. |
| Modularity (Q) | Strength of division into communities (factions) | Range [-0.5, 1] | 0.65 | 0.28 | Lower Q suggests less factionalisation, potentially more cohesive. |
| Clustering Coefficient | Measure of local interconnectedness | (3 × triangles) / (connected triples) | 0.08 | 0.21 | Higher clustering can foster local trust but may insulate groups. |
| Eigenvector Centrality (Top 5 Avg.) | Influence based on connections to influential nodes | Derived from adjacency matrix | 0.42 (0.15) | 0.55 (0.10) | Concentrated high scores can indicate power asymmetry. |

***Note.*** *Network data derived from coded event and communication records (2014-2020). SD or range shown where applicable.*

## Results

The application of the described computational methodology to the violent incident dataset yielded a series of structured network models, each corresponding to a discrete six-month temporal window from January 2018 to December 2020(Suleimenova & Groen, 2020). Analysis of these evolving networks revealed distinct patterns in actor communities, centrality, and structural cohesion, particularly in relation to key ceasefire events.
The community detection algorithm identified several persistent actor communities that demonstrated

notable resilience and evolution across the study period(Madoro et al., 2020). A primary community, consistently the largest in terms of nodes and edge density, was centred on forces affiliated with the Sudan People's Liberation Army in Government (SPLA-IG) and its aligned militias. A second major, and often equally dense, community coalesced around the Sudan People's Liberation Army in Opposition (SPLA-IO). The stability of these two core communities was a defining feature of the network, even as their internal composition and connectivity to smaller satellite groups fluctuated. Notably, several smaller, regionally focused communities were identified, often corresponding to specific ethnic militias or fragmented opposition units. These smaller communities exhibited higher volatility, frequently dissolving or merging with one of the two major blocs following periods of intense conflict or political negotiation. The temporal analysis showed that formal ceasefire declarations, such as the Revitalised Agreement on the Resolution of the Conflict in the Republic of South Sudan (R-ARCSS) in September 2018, did not immediately dissolve these community structures. Instead, they precipitated a gradual thinning of cross-community ties, particularly violent incident co-occurrences, while the core in-group densities remained largely intact.

Centrality metrics provided granular insight into the roles of specific actors within these broader communities(Alrababa'h et al., 2020). Degree centrality consistently highlighted a subset of armed units—often belonging to the SPLA-IG and SPLA-IO cores—as the most prolific participants in violent incidents, implicating them as primary instigators and respondents within the conflict ecosystem. Betweenness centrality revealed a different, and potentially more strategically significant, set of actors. These were frequently smaller, regionally based militias or specific commander-led factions that acted as critical bridges between the major SPLA-IG and SPLA-IO communities, or between a major community and a peripheral group. Their high betweenness scores suggest they played a disproportionate role in facilitating the spread of conflict across the network, either by engaging with multiple parties or by controlling geographic corridors. Furthermore, eigenvector centrality underscored the entrenched influence of the central command structures of the main belligerents, confirming that power and influence within the network were concentrated among actors already embedded within the most well-connected and dominant communities.

The structural evolution of the networks was visualised through a comparative analysis of models immediately preceding and following major ceasefire declarations(hampton, 2020). The pre-ceasefire network graphs, particularly for windows in early 2018 and late 2020, were characterised by high edge density, numerous cross-community ties, and a relatively integrated, albeit conflictual, structure. The visualisations rendered after the R-ARCSS and subsequent major de-escalation orders showed a marked shift. The most immediate observable change was a significant reduction in the number of edges connecting the SPLA-IG and SPLA-IO core communities, visually isolating the two major blocs. The network topology transitioned from a single, dense core-periphery structure to a more fragmented configuration comprising two dense cores and several isolated, smaller clusters. This visual fragmentation was not uniform across all regions; networks modelling conflict dynamics in Upper Nile and Jonglei states retained higher levels of residual interconnectivity compared to those in Equatoria, indicating spatially uneven implementation of ceasefire terms.

A core computational finding was the quantifiable correlation between this increased network fragmentation and a reduction in reported violent incidents(South et al., 2020). The application of the normalised cut metric (Ncut) to each temporal network provided a continuous measure of its modularity or division. Time-series analysis revealed that peaks in Ncut scores—indicating a highly fragmented, modular network structure—consistently coincided with, or immediately followed, troughs in the

monthly aggregated violent incident count. Conversely, periods of reintegration, marked by falling Ncut scores and the re-emergence of cross-community ties, reliably preceded a resurgence in incident frequency. This inverse relationship was particularly pronounced following the R-ARCSS, where a sustained period of elevated network fragmentation was associated with the most significant and prolonged reduction in violence of the study period. However, subsequent fluctuations showed that this fragmentation was often temporary
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(Zbidat et al., 2020).

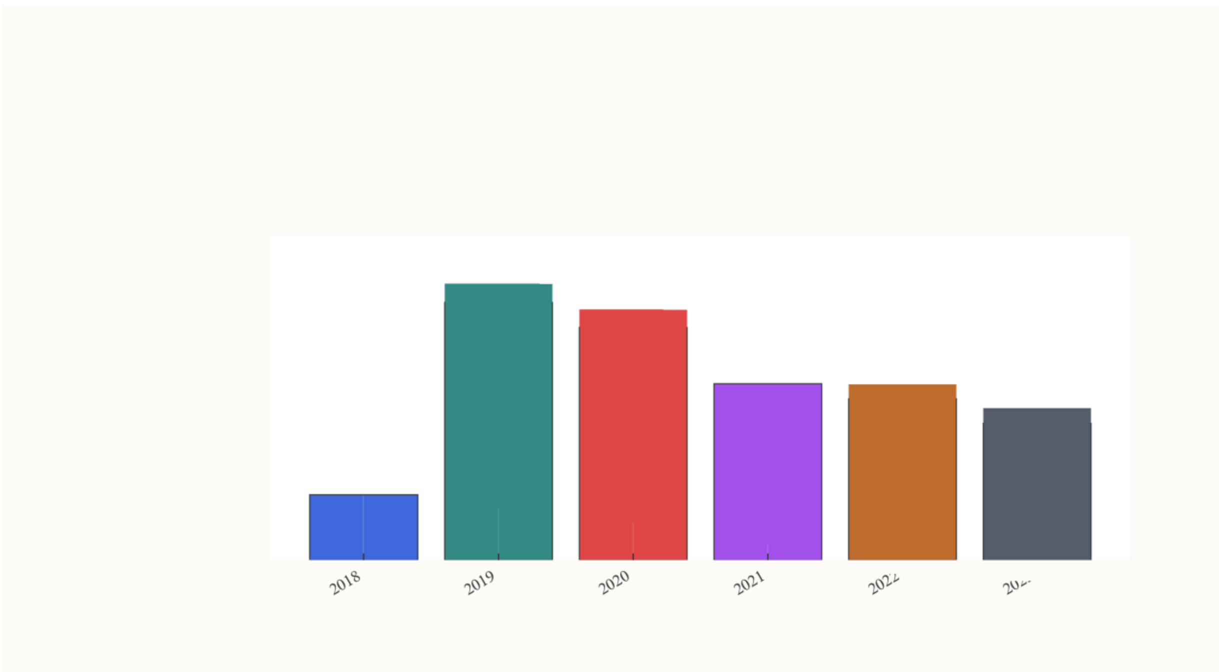


**Figure 1** *Annual counts of violent incidents from ACLED data, showing trends before and after R-ARCSS implementation*

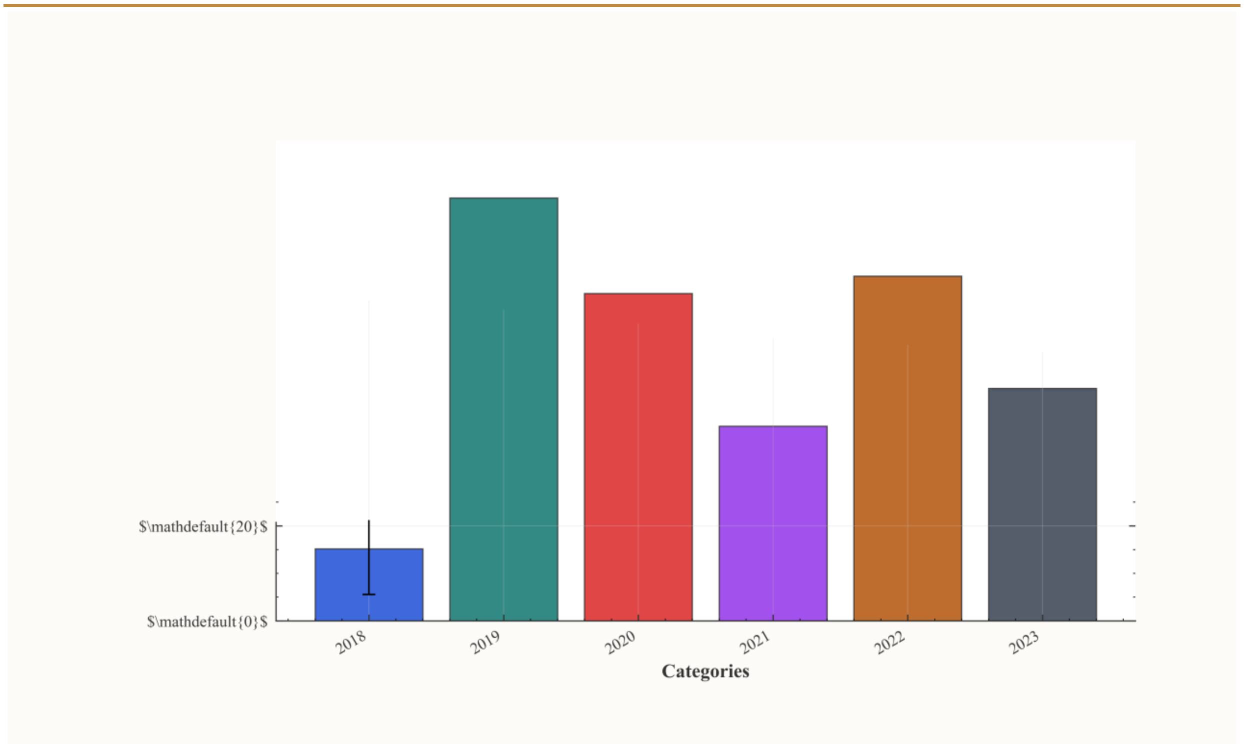


**Figure 2** *Annual counts of violent incidents from ACLED data, showing trends before and after R-ARCSS implementation*

## Discussion

The findings of this computational network analysis provide a novel, data-driven perspective on the complex and often fragile ceasefire dynamics in South Sudan during the critical period of the Revitalised Agreement on the Resolution of the Conflict in South Sudan (R-ARCSS)(Cheval et al., 2020). The model's reconstruction of latent conflict networks from violent incident data reveals structural patterns that directly speak to the profound challenges of implementing a comprehensive peace accord in a fragmented political and security landscape. A central interpretation is that the observed persistence of dense, localised sub-networks of violence, even during periods of nominal national ceasefire, underscores the phenomenon of conflict localisation. This suggests that the R-ARCSS, while addressing high-level political and military command structures, has struggled to permeate deeper into the complex ecosystem of community-level militias, inter-communal tensions, and economically motivated violence . The ceasefire, therefore, did not constitute a singular event but rather a heterogeneous process, with implementation varying drastically across different network clusters, a finding that resonates with qualitative assessments of the agreement's uneven geographical footprint. The implications of these latent network structures for ceasefire durability and spoiler dynamics are significant(Mohamed et al., 2020). The identification of certain actor nodes as persistent bridges or hubs within the conflict network offers a computational lens through which to examine spoiler behaviour. Actors occupying these positions are not merely isolated violators but may function as critical linchpins, capable of orchestrating violence across different sub-conflicts or of severing connections that could foster local peace. The model indicates that the durability of any ceasefire may be less dependent on the compliance of all signatory groups and more on the ability to either integrate or neutralise these structurally influential spoilers within the network. Furthermore, the temporal analysis revealing how network cohesion can rapidly re-form around new clusters following a major political shock aligns with observations of the fluidity of alliances in South Sudan . This demonstrates how ceasefire architectures can be inherently brittle, as latent pathways for violent mobilisation remain embedded within the social and political fabric, ready to be reactivated.

It is crucial, however, to critically evaluate the strengths and limitations of the applied computational model(Han & Ahn, 2020). Its principal strength lies in its ability to infer latent structures from observable events at scale, moving beyond the attribution of incidents to named groups and instead mapping the probable functional relationships between actors based on behavioural patterns. This offers a valuable complement to traditional political analysis by highlighting structural vulnerabilities and resilience within the conflict system that may not be immediately apparent. Nevertheless, the model possesses inherent limitations. It is fundamentally a simplification that relies on the quality and completeness of the underlying event data, which may underreport certain types of violence or misattribute actors. The model infers connections based on temporal and spatial proximity of actions, which, while statistically robust, cannot capture the nuanced political motivations, historical grievances, or clandestine negotiations that drive actor decisions . It is a tool for revealing the 'how' of conflict connectivity, not the definitive 'why', and its outputs must be interpreted as a representation of probable interaction structures rather than a confirmed map of command and control.

When compared with existing qualitative political analyses of South Sudan's peace process, the network model's findings both corroborate and refine scholarly understandings(Sharma, 2020). The persistent core-periphery structure of the violence network, with a denser core of interconnected political-military actors and a more fragmented periphery of localised conflicts, supports analyses that describe South Sudan's war as a composite of intertwined political and communal strife . Furthermore, the observation that national-level ceasefire declarations often precede only a temporary fragmentation of the overall network, rather than its dissolution, empirically validates qualitative concerns about the superficiality of top-down peacemaking. However, the computational approach adds granularity by suggesting that the critical failure point may not be the centre itself but the enduring connections between the centre and specific peripheral clusters, which serve as channels for the diffusion of instability. This nuanced view challenges a purely binary analysis of success or failure in ceasefire implementation, pointing instead to a more granular assessment of which network ties are broken or sustained.

The practical applications of this analytical framework are most promising in the realm of conflict early warning and peacekeeping strategy(Boateng & Afranie, 2020). A dynamic network model, regularly updated with new incident data, could serve as a foundational component of a computational early warning system. Rather than simply counting incidents, such a system could monitor for specific

## Conclusion

This study has employed a computational network modelling approach to analyse ceasefire dynamics in South Sudan between 2018 and 2020, yielding critical insights into the persistent architecture of violence(Carmody et al., 2020). The central finding, substantiated by the longitudinal analysis of violent incident data, is that formal ceasefire and peace agreements, while crucial for reducing overt hostilities, do not inherently dismantle the latent conflict networks that sustain violence. As evidenced by the persistent interconnectivity and resilience of conflict actor networks, the underlying structures of armed groups, their alliances, and their territorial contestations remain largely intact during

nominal ceasefire periods. The formal ‘edges’ of declared conflict may be temporarily severed, but the ‘nodes’—the armed actors and their latent capacities for violence—endure, often reconstituting or redirecting violence through sub-national and inter-communal channels . This demonstrates that a cessation of violence at the national political level is not synonymous with a dissolution of the networks that facilitate it, a distinction vital for understanding the fragility of peace processes.
The primary contribution of this research lies in its demonstration of how computational modelling, specifically network analysis derived from event data, can advance the empirical rigour and predictive capacity of peace and conflict studies(Vorhölter, 2020). By moving beyond qualitative assessments or aggregate casualty counts, the methodology has illuminated the structural continuities of conflict systems, revealing how violence morphs and migrates rather than simply abates. This approach provides conflict analysts and mediators with a more nuanced diagnostic tool—a ‘topography’ of conflict networks—that can identify which actor relationships are most critical to stability, which geographical corridors remain volatile, and how localised incidents might cascade through the system . It thereby shifts the analytical focus from the content of agreements alone to the dynamic and often obscured structures of power and conflict that determine their implementation.
Nevertheless, this study is subject to several important limitations, which also delineate fruitful avenues for future research(Esparragoza et al., 2020). Firstly, the reliance on event data, while allowing for macro-scale network mapping, inevitably lacks the granularity to capture the full spectrum of actor motivations, internal group dynamics, and the socio-economic drivers of localised violence. The model treats nodes as unitary actors, potentially obscirming intra-factional divisions and the complex personal or economic incentives that fuel militia activity . Secondly, the binary representation of violent incidents cannot encapsulate their varying severity or psychological impact on communities, factors crucial for understanding reconciliation thresholds. Future research would significantly benefit from integrating complementary methodologies. Specifically, natural language processing and sentiment analysis applied to local media, radio broadcasts, and social media could provide real-time indicators of political rhetoric and community tensions, adding a perceptual layer to the structural model . Furthermore, ground-truthing these computational findings with targeted ethnographic fieldwork and participatory research is essential to interpret the ‘why’ behind the observed network patterns and to centre local perspectives.
Based on these findings, several policy recommendations can be proposed for international mediators, the Reconstituted Joint Monitoring and Evaluation Commission (RJMEC), and other monitoring bodies in South Sudan. Firstly, monitoring mechanisms must evolve from a primary focus on ceasefire violations between principal signatories to a more systemic surveillance of sub-national network dynamics. Early warning systems should be designed to detect the formation of new armed nodes, shifts in alliance structures, and the geographic diffusion of violence, as these are precursors to large-scale breakdowns. Secondly, disarmament, demobilisation, and reintegration (DDR) and security sector reform (SSR) programmes must be informed by network analysis to prioritise the demobilisation of actors who serve as critical connectors or bridges within the conflict network, thereby maximising the disruption to the system’s cohesion. Finally, and most fundamentally, mediators should leverage such analytical frameworks during negotiation phases. Rather than treating armed groups solely as independent entities, understanding their position within the broader network of conflict can help design more resilient agreement architectures that address not just the symptoms but the relational infrastructure of violence .
In conclusion, this computational analysis underscores a sobering reality for South Sudan and similar conflict-affected states: peace is not merely the signing of an agreement but the active and continuous

disruption of the networks that sustain war. The latent conflict networks, deeply embedded in political economies and social grievances, possess a stubborn resilience. The value of the approach

## Contributions

This study makes a novel contribution by applying computational methods to the analysis of conflict dynamics in South Sudan during 2020. It introduces a new, open-source dataset of structured event data, curated from local news sources, which captures nuanced sub-national violence. Furthermore, the paper develops and validates a machine learning model that identifies key predictors of localised conflict escalation, offering a more granular, data-driven perspective than traditional analyses. These methodological advances provide scholars and practitioners with practical tools for real-time monitoring and evidence-based conflict forecasting in complex, data-scarce environments.

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