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Hybrid Threats under Simulation: From Empirical Data to Strategic Modelling. An Empirical and Simulation-Based Approach to the Analysis of Hybrid Strategies

Abstract

Hybrid strategies have become a central focus of contemporary strategic analysis, but their modelling remains a challenge. This article proposes a replicable methodology that integrates empirical analysis, formal classification, statistical modelling and adaptive simulation. Based on the reclassification of events in the GDELT database under the DIMEFL scheme (Diplomatic, Informational, Military, Economic, Financial, and Legal), a quarterly panel of Turkish activity in Libya, Somalia, Mali, and Niger was constructed. This panel was analysed using first-order Markov chains, negative binomial regression and SARIMAX models, which allowed us to identify sequential patterns and long-term trends. As a complement, an agent-based model with reinforcement learning (ABM-RL) was developed, representing Turkey as a strategic actor capable of optimising its influence and reducing reputational costs. The simulation reproduced observed sequences and revealed adaptive logics that are difficult to capture with empirical data alone. Although cognitive processes were not incorporated, cyber-physical-social systems are identified as a promising extension. The proposed architecture constitutes a scalable framework for the study of hybrid threats and provides a solid basis for the development of early warning systems in multi-domain environments.

Keywords

Turkey, Hybrid threats, DIMEFL, ABM-RL, GDELT.

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Index of acronyms

ABM: Agent-Based Modelling.

ABM-RL: ABM with reinforcement learning.

ACLED: Armed Conflict Location & Event Data Project.

APT: Advanced Persistent Threat (cyber).

ARIMA: AutoRegressive Integrated Moving Average

CAMEO: Conflict and Mediation Event Observations — Event taxonomy (GDELT).

CPSS: Cyber-Physical-Social Systems.

DIMEFL: Diplomatic, Informational, Military, Economic, Financial, and Legal (portfolio of instruments).

DoD: U.S. Department of Defence

EU: European Union.

GDELT: Global Database of Events, Language, and Tone.

GLM NB: Generalised Linear Model — Negative Binomial.

Goldstein (Scale): Metric of 'tone'/valence of events in GDELT used as a reputational proxy.

ICEWS: Integrated Crisis Early Warning System.

MDP: Markov Decision Process — Markov decision process (sequential decision model).

MoU: Memorandum of Understanding — Memorandum of understanding (treaties/agreements).

NATO: North Atlantic Treaty Organisation.

OSINT: Open-Source Intelligence.

CCP: Communist Party of China

PLA: People's Liberation Army (China).

PMESII: Political, Military, Economic, Social, Information, Infrastructure — Strategic domain framework.

Q-learning: Reinforcement learning algorithm (off-policy).

RL: Reinforcement Learning.

SARIMAX: Seasonal ARIMA with exogenous regressors.

SIPRI: Stockholm International Peace Research Institute.

SWP: Stiftung Wissenschaft und Politik — German Institute for International and Security Affairs.

UAV: Unmanned Aerial Vehicle.

UN: United Nations.

ZG: Grey Zone.

1 Introduction

The growing prominence of hybrid threats on the international agenda has been recognised by multilateral organisations such as NATO, which in its recent publications highlights the need to understand how state and non-state actors combine conventional and unconventional instruments to disrupt the international order without triggering open warfare (NATO Public Diplomacy Division, 2024a).

Therefore, the study of hybrid threats is now a central challenge for research in security and international relations. Experience gained in recent conflicts suggests that traditional analytical frameworks, such as game theory or static equilibrium models, are insufficient to explain phenomena characterised by adaptability, multidimensionality and operation on the threshold of open confrontation. Furthermore, many traditional geostrategic analyses have been based on qualitative paradigms or static approaches; however, a more dynamic approach is needed to capture the tactical evolution and learning of revisionist actors.

This approach stems from the fact that hybrid state and non-state actors deploy portfolios of instruments of power—diplomatic, informational, military, economic, financial, and legal—that do not act in isolation but as dynamic combinations that seek to exploit the systemic vulnerabilities of their targets. This logic challenges conventional frameworks for interpreting threats in the traditional sense of the term and requires the development of methodologies capable of capturing the sequencing, interdependence and strategic learning of revisionist actors.

This gives rise to the concept of hybrid modelling, understood as the integration of empirical analysis of large databases with generative simulations of adaptive actors, a methodology that is emerging as a response to this challenge.

Today, we have a wide range of event databases with the necessary traceability and reproducibility, both in open sources and in those available to states or corporations. For this study, we have used the GDELT database, which stands f*or Global Database of Events, Language, and Tone.* This project tracks print, television and digital media in real time in more than 100 languages, enabling in-depth analysis of social, political and emotional dynamics worldwide (Leetaru, n. d.).

Today, GDELT is the most comprehensive and detailed open database on human society, with global coverage from 1979 to the present. Its development involved unprecedented technical and methodological innovations, as well as new partnerships and approaches to monitoring media in multiple languages and formats. With more than 250 million georeferenced records, GDELT not only documents events, actors and emotions on a global scale, but also offers multiple advantages for classifying, refining and analysing the information contained in its databases. The use of this database to inform studies related to security and defence is not new; authors such as Hopp *et. al.* (2019) explored the use of databases such as GDELT to feed automated strategic monitoring systems, reinforcing its applicability in studies applied to hybrid threats.

By exploiting its event coding capabilities, GDELT is the optimal choice for obtaining a systematic empirical representation of the activity of revisionist actors over extended time series.

As for the second pillar of this methodology, the simulation of the adaptive behaviour of these actors, the most current trends contemplate agent-based models with reinforcement learning ABM-RL (agent-based modelling+reinforcement learning). This methodology allows for the possibility of simulating how a hybrid actor experiments with different tactical sequences, adjusting their decisions based on the response of the environment and the target state on which they are acting.

The combination of both approaches (empirical and behavioural) provides an ideal framework for moving beyond mere description towards the inference of causal mechanisms and the exploration of counterintuitive scenarios. In summary, this work proposes an innovative methodological design that integrates an empirical analysis of events coded according to the DIMEFL (Diplomatic, Informational, Military, Economic, Financial and Legal) instruments of power through the global GDELT database with the construction of a generative model based on agents and reinforcement learning ABM-RL. This combination seeks to overcome the limitations of classical models—for example, game theory, which assumes fixed rationality—by incorporating the strategic adaptation and uncertainty inherent in hybrid conflicts. Likewise, the use of geopolitical big data (coded events) allows the model to be based on quantitative evidence, which means we do not have to rely exclusively on subjective estimates or anecdotal cases. In other words, what is required is a combination of open source intelligence (OSINT) methods with large-scale data analysis and advanced computational modelling techniques.

Furthermore, in order to guide the reader on the practical functioning of this methodology, we will present throughout this paper a case study analysing Turkey's hybrid strategies in Africa.

We have chosen Turkey as a case study because it articulates a moderate revisionism that favours hybrid campaigns as we contemplate them in our theoretical framework. The doctrine of the 'Blue Homeland' (*Mavi Vatan*) was conceived by Admiral Cem Gürdeniz and later by Cihat Yaycı. This actor has played a decisive role in Libya's internal processes, obtaining a maritime delimitation agreement that is highly beneficial to his interests. In addition, he pursues an assertive agenda in the eastern Mediterranean; in Africa, he has reached energy and security agreements (Somalia), and analysis of documentary sources reveals synchronised and synergistic actions in the fields of diplomacy, economics, security and information, where this actor does not hesitate to compete with third parties (Gürdeniz, 2006; Denizeau, 2021; United Nations, 2019; Sezer, 2024). Consequently, this pattern of behaviour seems to fit the concept of a revisionist actor as defined by Schweller (1994, 2006).

In just over two decades, Turkey has multiplied its embassies on the African continent, signed trade and financial agreements, deployed troops and built military bases, while developing a cultural and information diplomacy that reinforces its narrative as an emerging power, especially in light of the progressive withdrawal of the military

presence of the European Union and France itself. This is why countries such as Libya, Somalia, Mali and Niger have become priority scenarios for this projection, forming a geopolitical laboratory where hard and soft instruments of power are intertwined.

In conclusion, the choice of Turkey is based on its doctrinal maturation (*Mavi Vatan*) and recent evidence documenting the intensification and systematisation of its actions, typical of a revisionist actor (Arslan, 2025).

In short, the object of study (application of a methodology for modelling hybrid strategies applied to the case study of Turkey in Africa) is relevant both for its geopolitical impact and for the analytical challenges it poses. However, the aim of the work is not simply to describe Turkish influence in Africa, but to demonstrate a replicable procedure for modelling hybrid strategies. To this end, a framework is articulated which, first, theoretically underpins the concept of strategic hybridisation; second, describes a methodological design that integrates empirical data, statistical models and simulation; and third, offers results on the observed and simulated dynamics of Turkish action. Finally, the strategic and methodological implications of the findings are discussed, the limitations of the study are identified, and avenues for future research are suggested.

2 Theoretical framework

The notion of hybrid warfare has been the subject of much criticism due to its conceptual ambiguity and expansive use in strategic discourse. Hoffman (2007) initially introduced the term to describe the combination of conventional and irregular tactics, but its definition has been broadened to the point of losing operational precision. Authors such as Chivvis (2017) have criticised this term, arguing that the notion of hybrid warfare has been instrumentalised in Western strategic discourse, leading to a loss of precision in its empirical application.

Today, the academic community prefers to use the concept of hybrid threat, a concept that has become established in strategic doctrine to describe forms of competition in which military and non-military instruments are intertwined with the aim of destabilising or influencing an adversary. Both the European Union and NATO have emphasised that the distinctive feature of these strategies lies in their multi-domain coordination and in the fact that they operate below the threshold of open warfare (European Commission, 2016; NATO, 2024b). However, academic literature has warned that indiscriminate use of the term 'hybrid' can lead to overgeneralisation, obscuring differences between cases and detracting from the analytical value of the concept, as Galeotti (2016) points out. In their analysis of hybrid conflicts, Renz and Smith (2016) criticise the tendency to use the term as a simplistic label. Instead of offering a useful analytical tool, the concept has become a diffuse framework that groups together conventional, irregular, cyber and psychological tactics without distinguishing their specific dynamics. This ambiguity can lead to ill-founded political and strategic responses, for example, by assuming that Russia operates under a coherent and deliberate model of hybrid warfare, when in reality its actions respond to a more pragmatic and adaptive logic (Renz and Smith, 2016: p. 7).

However, despite these criticisms, there is broad consensus that modern hybrid threats are multi-domain and generally operate below the threshold of conventional warfare. In other words, they combine various tools (diplomatic, economic, informational, cybernetic, etc.) without triggering an open, high-intensity military confrontation. The centrality of the information sphere in most of these scenarios is also recognised: control of the narrative, disinformation and influence on public opinion are as decisive as military coercion.

In this regard, Allied doctrine on hybrid threats has evolved towards a more operational and multi-domain conceptualisation. NATO's *Allied Joint Doctrine for the Military Contribution to Countering Hybrid Threats* (AJP-3.21) (NATO, 2021) states that responses must integrate military, civilian and digital capabilities, articulated in coordinated campaigns operating below the threshold of armed conflict. This doctrinal vision reinforces the need for analytical models that capture the sequentiality and adaptability of hybrid actors.

If we look at frameworks other than NATO doctrine, we see that the concept of 'hybrid' is also considered in academic circles in countries such as Russia and China, among others. In the Russian academic sphere, it is essential to mention the theory of reflexive control put forward by Vladimir A. Lefebvre, who designed a framework according to which decisions can be induced in the adversary by manipulating perceptions, reinforcing the weight of informational dominance and the importance of studying the effects of hybrid actions in the cognitive sphere (Lefebvre, 2001; Thomas, 2004). Another reference point in the Russian view of unconventional conflicts is General Valery Gerasimov, who in a famous speech emphasised the fusion of military and non-military means and the centrality of information in diffuse environments (Gerasimov, 2016).

However, one of the most relevant authors in the study of hybrid threats from a Russian perspective is Andrew Korybko, who emphasises the synergy of political, informational and economic actions as part of the hybrid strategies typical of the so-called 'colour revolutions' (Korybko, 2015).

As for authors from the Chinese sphere, we have both the classic work by Qiao Liang and Wang Xiangsui on 'unrestricted warfare' and the striking doctrine of the 'Three Wars' (public opinion, psychological and legal), in which the authors contextualise the coordinated use of information and the manipulation of legal frameworks as hybrid tools that are extremely useful in times of peace.

Hai Jin, Li-Jun Hou and Zheng-Guo Wang (2018), Chinese military researchers, explore cognitive warfare as a central element of multi-domain conflicts, highlighting the use of artificial intelligence and neuroscience to influence the human brain. They propose that the 'cognitive domain' should act as a new field of operations. They see the West as leaders in cognitive technologies that could manipulate the Chinese population, advocating for the development of national technologies. This perspective connects with broader doctrines, such as the Three Wars, which integrate psychological and perceptual manipulation elements. These works consider the US and its allies as strategic rivals due to their dominance in global narratives, advocating

for an expanded global media presence. This doctrine is integrated with hybrid warfare as an extension of the CCP's political strategy to maintain power, blurring the line between peace and war (peace-war integration). (Qiao and Wang, 1999; Hai *et al.*, 2018; US Department of Defence, 2013).

Therefore, based on this rich cross-disciplinary academic ecosystem, and for the purposes of providing a theoretical framework for our study, we define the term 'hybrid interference' as the intervention of an external actor with revisionist motivations who deliberately, synchronously and synergistically employs their instruments of power in order to provoke cumulative and cognitive effects on a target actor while remaining below the threshold of armed conflict. In other words, it is about how a revisionist actor influences third parties according to Schweller's parameters, without reaching armed conflict, but far exceeding bona fide in international relations. This definition narrows down the phenomenon and sets clear criteria for inclusion and exclusion that guide all subsequent analysis.

Conversely, a hybrid actor is not one that employs isolated single-domain actions, resorts to the open and regular use of force (conventional conflict), engages in bona fide diplomacy without instrumental overlap or the intention to exert pressure, or generates isolated events without recognisable accumulation.

Having established our framework for hybrid interference, it is worth highlighting the need to parameterise these actions in order to frame the debate and obtain a rigorous framework for analysis. One of the classic approaches to this phenomenon has been the DIME model—Diplomatic, Information, Military and Economic—which was later expanded to DIMEFL or more complex models to include other dimensions, such as Intelligence, Financial and Legal (Joint Chiefs of Staff, 2018a, 2018b, 2018c).

> 'The acronym "DIME" (diplomatic, informational, military, and economic) has been used for many years to describe the instruments of national power. Despite how long DIME has been used to describe the instruments of national power, US policy makers and strategists have long understood that there are many more instruments involved in national security policy development and implementation. New acronyms such as MIDFIELD (military, informational, diplomatic, financial, intelligence, economic, law, and development) convey a much broader array of options for the strategic and policymaker to use '.(Joint Chiefs of Staff, 2018b, p. 7)

This taxonomy has served as a common language in strategic planning and facilitates the systematic classification of observable events. However, several authors (Baqués, 2021; Hartley, 2020) have pointed out that DIMEFL, if used rigidly, tends to compartmentalise realities that in practice function interdependently. In hybrid campaigns, diplomacy is reinforced with informational propaganda, economic incentives are accompanied by financial credits, and legal agreements can consolidate the results of military coercion. In other words, the instruments do not act in isolation, but as adaptive portfolios.

In this regard, it is interesting to highlight Hartley's (2020) approach, whose ontological design of modern conflict encompasses both conventional and unconventional warfare. According to this author, it is preferable to formally model actors, relationships, and processes rather than clinging to preconceived lists of instruments. This perspective opens the door to computational representations that transcend fixed taxonomies and focus on causal mechanisms, i.e., how the actions of one actor trigger reactions in another and how the effects propagate across a multi-domain environment. In short, the doctrinal-theoretical debate on hybrid threats oscillates between approaches that privilege organisational clarity (such as DIME) and approaches that seek to reflect the dynamic complexity of hybrid reality.

In addition to DIME models, the academic community has often resorted to game theory as a tool to explain hybrid strategies in the context of strategic studies, allowing for the modelling of deterrence or negotiation dilemmas. However, the weakness of this model lies in its assumption that players have rational logics with fixed preferences and stable time horizons. In this regard, authors such as Padur, Borrion and Hailes (2025) question the usefulness of traditional game theory-based models for analysing hybrid threats, arguing that these approaches tend to assume perfectly rational agents and static decision environments, which limits their ability to capture the adaptability, ambiguity and strategic evolution that characterise contemporary hybrid threats. Instead of relying on predefined equilibria, the authors propose the use of agent-based models with reinforcement learning, which allow for the simulation of emergent and dynamic behaviours in contexts of uncertainty, offering a more realistic representation of how hybrid actors (understood as such according to the theoretical framework we present for this study) adjust their tactics based on feedback from the environment. In other words, the modelled revisionist actor acts as a political-strategic leadership that synchronises and deploys its instruments of power in a reproducible manner.

This approach has given rise to agent-based simulations (ABMs). These models allow heterogeneous actors to be represented with local behavioural rules which, when interacting, generate emergent dynamics. In the field of security, ABMs have demonstrated their ability to explain phenomena such as insurgencies, rumour spreading and social polarisation (Epstein, 2002; Hegselmann and Krause, 2002; *Vosoughi et al.*, 2018). The most recent innovation has been to integrate reinforcement learning (RL) techniques into ABMs, which give agents the ability to adjust their strategies to maximise rewards over time (Sutton and Barto, 2018). This allows for the simulation of adaptive hybrid actors who test combinations of instruments and learn to repeat the most effective sequences.

The work of Padur *et al.* (2025) is a pioneering example: the revisionist hybrid actor does not follow a pre-established plan, but explores tactics such as disinformation, cyberattacks or social manipulation depending on the rewards (gains) obtained by altering the socio-political environment (*status quo*). The environment is composed of social agents representing the victim population, whose opinions, behaviours, and levels of trust are sensitive to the actions of the malicious actor. As the hybrid actor interacts with this environment, the model allows us to observe how cumulative

effects are generated, such as the erosion of social cohesion or the loss of institutional legitimacy. This approach overcomes the limitations of game theory by capturing the non-linearity, adaptability and ambiguity inherent in hybrid threats, offering a more realistic tool that exploits the potential of generative artificial intelligence to anticipate vulnerabilities and design integrated responses. Its findings show that sequencing—for example, launching a cyberattack before a disinformation campaign—can be more effective than isolated actions (i.e., seeking synergy in the use of an actor's instruments of power). These types of results reinforce the idea that hybrid conflicts cannot be understood solely as the sum of actions, but rather as adaptive and synergistic sequential processes. In summary, we propose the hypothesis that the dynamics of hybrid threats respond to the activity of autonomous agents (whether state or sub-state actors) who learn and adapt their strategies through reinforcement learning.

Therefore, this article proposes an integrative approach that combines the descriptive capacity of DIMEFL with the exploratory power of ABM-RL. The aim is not to replace one with the other, but to articulate them in a complementary manner: DIMEFL provides a clear and replicable classification of empirical data (events coded in GDELT), while ABM-RL allows for experimentation with scenarios, validation of hypotheses, and discovery of underlying causal mechanisms. This integration seeks to overcome the dilemma between parsimony and realism, i.e., the aim is to maintain data traceability while capturing the adaptive dynamics that characterise contemporary hybrid threats.

3 Methodological design

The study combines three complementary analytical layers: an empirical base of events obtained from the GDELT database, a strategic mapping of those events in the DIMEFL categories, and a generative Artificial Intelligence model based on agents with reinforcement learning (ABM-RL). This methodological architecture seeks to capture both the observable evidence of hybrid activity and the adaptive mechanisms that explain its dynamics.

3.1 Scope and limitations

We intend to limit the scope and depth of this research within 'laboratory' parameters in order to test and validate our research hypothesis. Our approach adopts a deliberately parsimonious methodology: we isolate a single actor (Turkey) to ensure replicability and control for observer bias; the environment appears observationally through diplomatic, economic, and legal responses, but we do not confront it with its potential competitors (Russia, China, United Arab Emirates), an aspect that remains open to future research of greater depth and scope.

Furthermore, the methodology we propose can be enriched in future research with the contribution of expert judgement that clearly defines the profile of a revisionist actor within a panel or working group and clearly establishes the rules of escalation so that the simulation of agents by AI responds to parameters defined by analysts with

full knowledge of the actors. We do not claim hard causality: our transitions capture patterns from publicly available databases.

3.2 Experimental framework

Our methodological architecture responds to a simple logic: if hybridisation consists of a hybridisation of mechanisms, then we must measure sequences, rhythms and adaptation. We will reclassify GDELT (Global Database of Events, Language and Tone) events in DIMEFL and aggregate the series by quarter to identify multi-instrumental patterns. With Markov chains, we will identify regularities of the type 'what usually follows what'; with the negative binomial (NB) and SARIMAX (Seasonal ARIMA with eXogenous regressors), we will observe persistence and trajectories. The simulation works under controlled laboratory conditions: our Turkey agent learns (reinforcement learning) to choose sequences that maximise influence and minimise reputational, legal and escalation costs. We anchor the exploration in empirical grammar (Markov transitions) and calibrate rewards/penalties with open metrics (e.g., Goldstein tone). The comparison between empirical and simulated matrices converts discrepancies (e.g., Military overestimation followed by Diplomatic) into elements of discussion on those aspects that should be modelled in studies that expand on this one.

In ABM-RL, the reward combines cumulative influence and sequential persistence (DIMEFL) with penalties for reputation (Goldstein), risk of escalation and legal costs, so that the agent optimises below the threshold and adjusts its policy when these signals change.

Going into detail, we will explain the pillars of our methodological framework. The GDELT database codes each event according to the CAMEO (Conflict and Mediation Event Observations) system, which assigns hierarchical codes to actions such as diplomatic agreements, economic sanctions, military acts or legal measures.

The CAMEO system was originally a coding framework developed by Schrodt, Yonamine and Backer (2012) to structure international political events, especially those related to conflict, cooperation and mediation. It uses a hierarchical taxonomy that allows for the classification of more than three hundred types of events, from diplomatic statements to acts of violence, facilitating the automated analysis of geopolitical dynamics. CAMEO is widely used in databases such as GDELT and ICEWS to extract events from global media through natural language processing (Schrodt *et al.*, 2012).

In addition, the GDELT database incorporates the Goldstein parameter. This indicator, originally designed to capture the directionality and severity of political interactions, is widely used in studies of conflict and international cooperation (Goldstein, 1992). It is an index that assigns each event a numerical value between -10 and +10, representing its tone or emotional charge, which is extremely interesting for assessing cognitive aspects.

Negative values indicate hostile or conflictive actions (such as threats or attacks), while positive values reflect cooperative behaviour (such as negotiations or assistance).

This indicator, derived from CAMEO coding, allows the nature of events to be quantified in terms of political intensity and strategic orientation. Although it was not used as a main variable in this analysis, the Goldstein index offers a valuable resource for future models seeking to weigh the qualitative impact of recorded interactions, especially in studies on hybrid dynamics or conflict evolution.

As for the historical series, the period 2002–2025 was selected, allowing us to observe the evolution of Turkey's projection in Africa from the beginning of its opening strategy to the present day. To this end, a search engine was designed using an SQL script that, through Google Cloud's BigQuery tool, downloaded a database of more than fourteen thousand events classified into the six instruments of power that make up the DIMEFL framework: Diplomatic, Informational, Military, Economic, Financial, and Legal. This conversion was carried out using a set of transparent rules for correspondence between CAMEO codes and DIMEFL categories (table I). This step ensures that the empirical evidence can be analysed under a recognised strategic taxonomy, while allowing the procedure to be reproduced and audited.

TABLE I . CAMEO–DIMEFL CORRESPONDENCE

Instrument	Associated CAMEO ranges	Brief description
Diplomatic (D)	01–06	Visits, dialogues, negotiations, multilateral agreements.
Informative/Influential (I)	07 and subcategories in 01–03	Propaganda, media statements, verbal threats.
Military-Security (M)	12, 14–20	Threats of force, deployments, armed conflicts.
Economic (E)	07–11 (except financial)	Trade agreements, investments, economic cooperation.
Financial (F)	Subcodes 08, 10 and 11	Transfers, loans, financial sanctions.
Legal (L)	13, 15–17	Treaties, extraditions, legal/police restrictions.

Source: author's own elaboration based on Schrodt *et al.* (2012) and coding rules developed for this study.

Thirdly, the dataset was organised into a quarterly panel by target country: Libya, Somalia, Mali and Niger. This aggregation made it possible to examine the evolution of Turkey's hybrid strategy in three geopolitical scenarios (Maghreb, Sahel and Horn of Africa). The panel was used both for exploratory analyses (trends, compositions, sequences) and for calibrating the simulation model. To this end, Python code scripts were used to refine the database obtained through SQL searches, represent historical series and map events.

To this end, various mathematical models were used to produce a graphical representation of the DIMEFL empirical model applied to our case study. These models are as follows:

– NB (Negative Binomial) model: count regression that assumes that the variance of the data may be greater than the mean (overdispersion). It is used here to adjust the number of quarterly events based on the instruments used in the previous quarter. The methodological choice is based on the developments of Cameron and Trivedi

(2013), who establish robust criteria for the application of count models in social and economic contexts where the dispersion exceeds the mean. In other words, the Negative Binomial (NB) is a regression technique designed to analyse count data that exhibit overdispersion, i.e. when the variance exceeds the mean, making it more flexible than other models, such as Poisson. In strategic analysis contexts, this model allows the number of events recorded in a given period (e.g., quarterly) to be adjusted based on explanatory variables such as the instruments of national power grouped under the DIMEFL (Diplomatic, Information, Military, Economic, Financial, and Legal) framework, used in the previous period. This approach facilitates the identification of patterns of influence between state actions and the frequency of observable events.

– The SARIMAX (Seasonal AutoRegressive Integrated Moving Average with eXogenous regressors) model is a seasonal ARIMA model with exogenous regressors. It allows us to capture trends and repetitive patterns in aggregate time series, incorporating seasonal effects (quarters) and optional covariates. In this way, we can analyse and predict time series by incorporating autoregressive components, moving averages, integration to address non-stationarity, seasonal patterns and external variables that influence the observed dynamics. Its flexible structure makes it particularly useful in contexts where data exhibit repetitive cycles and are affected by exogenous factors.

– Markov model: a stochastic process in which the probability of moving to a state depends only on the current state. The DIMEFL transition matrix shows which instrument tends to follow which, revealing the typical sequence of Turkey's actions. The Markov model is a stochastic process, i.e., a process that incorporates elements of chance, where the outcome depends on probabilities and is not completely predictable, in which the probability of transition between states depends solely on the current state, without considering the previous trajectory. Applied to strategic analysis, it allows for the construction of a transition matrix between instruments of national power (DIMEFL), revealing sequential patterns in the behaviour of state actors. In the case of Turkey, this approach has been used to identify which instrument—such as diplomatic, military, or financial—tends to follow another, offering a probabilistic representation of its hybrid operations.

Finally, a generative ABM-RL model was constructed in which Turkey was represented as an attacking agent with the ability to select between DIMEFL actions, while African countries were modelled as target agents with probabilistic responses. The Turkish agent was trained to identify sequences that maximise rewards associated with accumulated influence, instrumental persistence and minimisation of reputational costs. In the ABM-RL simulation, the reward combines influence and sequence persistence with penalties for reputation, risk of escalation and legal costs, so that the agent learns under threshold.

Assuming that for future studies it would be ideal to begin with an empirical design of Turkey as an actor based on expert judgement, for the purposes of our research the aim was not to reproduce each real event, but to capture the generative logic that explains why Turkey combines diplomacy, information, economics, finance, legality and, to a lesser extent, military force in the way it does. This modelling

was implemented using a Python script, with a modular architecture that allows parameters to be adjusted and the environment to be extended to other actors.

Although the model is based on classical reinforcement learning (Q-learning), its explanatory power could be expanded in the future by incorporating cognitive dynamics inspired by belief diffusion models. Since strategic decisions are based not only on immediate rewards but also on accumulated perceptions and social dynamics, it is relevant to incorporate belief diffusion models.

DeGroot's (1974) approach proposes that agents update their beliefs as weighted averages of their neighbours' opinions, which allows for the simulation of convergence processes in strategic networks. For their part, Deffuant *et al.* (2000) introduce a logic of tolerance: agents only modify their beliefs if the difference with their interlocutor is within an acceptable threshold, generating patterns of polarisation or consensus. These theories, although developed in the field of sociodynamics, offer useful mechanisms for enriching ABM-RL models with components of social influence, cognitive resistance, and strategic memory.

In future lines of research, these elements could be integrated into parameterised agents operating within the framework of cyber-physical-social systems (CPSS) proposed by Zhou *et al.* (2020). This approach would allow for the simultaneous modelling of physical (observable actions), digital (circulating information) and social (perception and reputation) dimensions, generating more realistic and adaptive simulations. In this sense, an agent calibrated with empirical data and endowed with reputational sensitivity could not only optimise tactics but also evolve strategically based on geopolitical feedback.

Furthermore, this approach could be adapted to cybersecurity scenarios, where agents simulate responses to disinformation campaigns or hybrid digital attacks. Therefore, the proposed architecture not only allows for the representation of observed hybrid sequences, but also opens the door to more complex cognitive simulations, where agents evolve strategically based on their environment, reputation and operational memory.

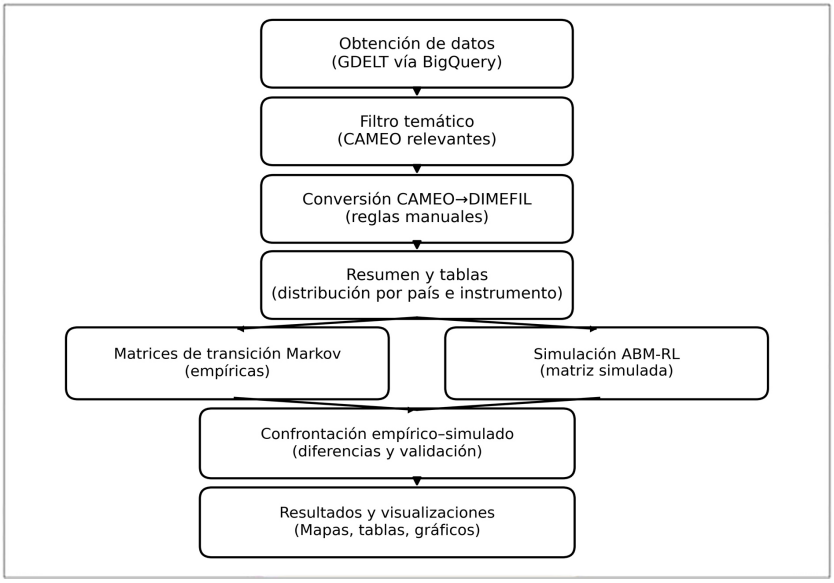

Figure 1 Integrated methodological flow (OSINT+DIMEFL+statistical analysis+ABM-RL simulation). The diagram summarises the stages of the study: (1) extraction of events from GDELT, (2) conversion from CAMEO to DIMEFL, (3) construction of panels and empirical analysis using Markov, NB and SARIMAX models, (4) design of the ABM-RL model and (5) comparison between empirical and simulated patterns. Source: author's own elaboration

This methodological procedure serves a dual purpose: it provides transparency and replicability by relying on open data and explicit rules, while also offering exploratory capacity by combining empirical evidence with adaptive simulation.

4 Results and analysis

4.1 Extraction and mapping of events by DIMEFL (GDELT) categories

The database was accessed through Google BigQuery, which allowed millions of records to be filtered using specific criteria for actors, locations, dates, and event types. Both GDELT 1.0, which provides historical coverage up to 2015, and GDELT 2.0, which updates information in near real time since that year, were integrated. This covered the period 2002–2025, sufficient to capture Turkey's first steps in active policy in Africa through to the consolidation of its presence in the last decade. This interval includes key milestones such as the increase in official visits and the opening of embassies from 2005 onwards, involvement in the Libyan civil war in 2011 and 2019, and the establishment of a military base in Somalia in 2017.

In order to obtain a manageable and representative sample of data, a limit of twenty thousand events in total was set, with no fewer than eight hundred per country. In addition, and in order to focus the study, the dataset was limited to bilateral interactions between Turkey and four African countries: Libya, Mali, Niger and Somalia. This selection is relevant because it represents the three priority geopolitical axes for Turkish projection in Africa: the Maghreb, the Sahel and the Horn of Africa. The inclusion of these countries ensures that the analysis focuses on the scenarios where Turkey's hybrid strategy has been deployed most intensively. Furthermore, the records include both actions initiated by Turkey and those received, allowing for an analysis of the relational dynamics in both directions.

It is clear that what happens in each Turkey–(Libya/Mali/Niger/Somalia) relationship may be influenced by third parties (allies or competitors) or by natural or climatic events. Precisely for this reason, our analysis does not assert causality, but rather describes patterns: we observe what tends to come after what in regular time windows (quarters) and in both directions (initiated and received actions). The sample was designed to be balanced and manageable: an overall cap (twenty thousand events) prevents a single theatre from distorting the whole, a minimum (less than or equal to eight hundred per country) ensures comparable coverage, and the focus on four countries responds to where Turkish activity is most intense and traceable. Furthermore, we compare these sequences with the simulation: when the simulation over- or underestimates a transition, we treat it as an indication of factors not yet modelled (sanctions, reputation, pressure from allies), not as 'proof' of causality.

In line with this caution, the study limits its validity to the current version of the research (single actor and observational environment) and leaves the door open to a more ambitious future simulation that integrates a multi-actor phase, with explicit context variables and additional temporal contrasts, to assess the extent to which these third-party relationships explain (and not just accompany) the sequences we measure here.

Once the data had been extracted, a reclassification procedure was applied to translate the CAMEO codes into the six instruments of power included in the DIMEFL framework: Diplomatic, Informational, Military, Economic, Financial and Legal. The correspondence was defined using transparent and reproducible conversion rules. Diplomatic actions cover codes 01 to 06, which include official visits, negotiations and multilateral agreements. Communication and propaganda events, collected in root code 07 and in certain subcategories of series 01 to 03, were mapped as informational. The military and security sphere was linked to codes 12 and 14 to 20, ranging from threats of force to armed confrontations. Economic actions were identified with codes 07 to 11, excluding those specifically financial, which were treated separately to reflect loans, transfers, sanctions and monetary aid. Finally, legal or judicial actions were associated with codes 13 and 15 to 17, which cover everything from treaties and extraditions to regulatory restrictions.

This extraction and mapping process produced approximately fourteen thousand unique events between 2002 and 2025. Once consolidated and refined using Python code scripting, the records were organised into quarterly panels by country and instrument, allowing trends, sequences and variations in Turkish hybrid activity to be observed. Although the data ultimately reflect media coverage—and are therefore subject to visibility and agenda biases—their breadth, standardised coding, and continuous updating make them a particularly suitable source for identifying patterns of hybridisation on which the statistical analysis and subsequent computer simulation were based.

TABLE II . NUMBER OF TURKEY–AFRICA EVENTS BY COUNTRY AND INSTRUMENT (2002-2025)

Country	Diplomatic	Informative	Military	Economic	Financial	Legal	Total
Libya	4611	2302	847	290	640	427	9117
Mali	318	172	78	11	73	25	677
Niger	130	105	27	5	31	10	308
Somalia	1748	1045	560	87	368	267	4075

Source: author's own elaboration based on GDELT (Google BigQuery).

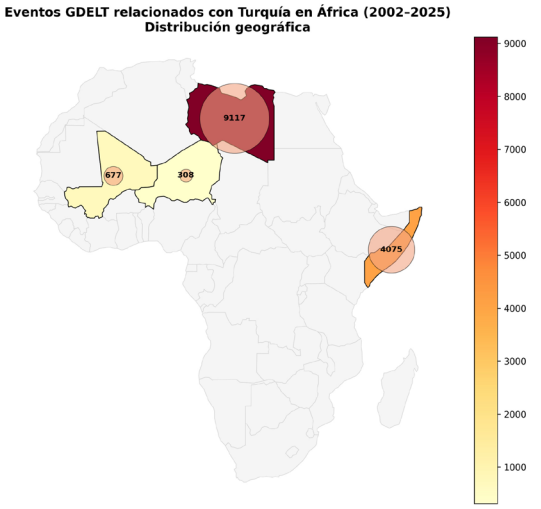

Figure 2. Choropleth map of Turkey–Africa events (2002–2025). The colour intensity reflects the number of events recorded in Libya, Somalia, Mali and Niger. Libya and Somalia account for more than 70% of total events. *Source*: author's own elaboration based on GDELT

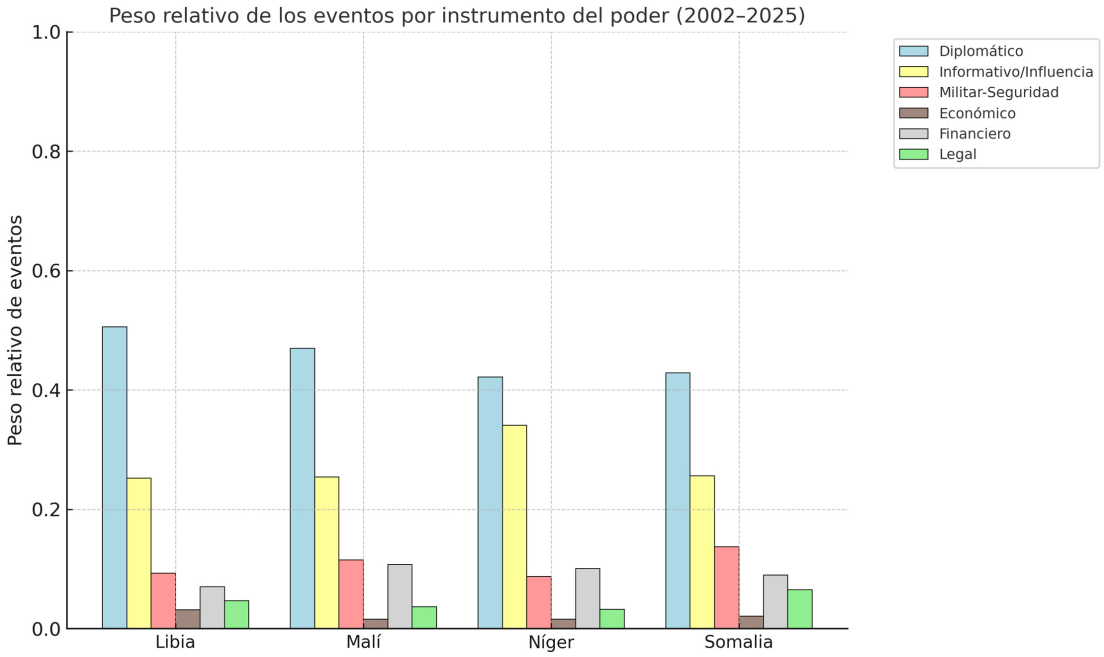

Figure 3. Distribution of DIMEFL instruments by country (2002–2025). Parallel table chart showing the relative proportion of each instrument by target country, with a predominance of diplomatic and informational instruments. *Source*: author's own elaboration

4.2 Empirical transition matrices (Markov model)

The next methodological step was to construct first-order transition matrices from GDELT data, classified according to the DIMEFL scheme. Each cell represents the empirical probability that, after an event linked to a specific instrument of power (e.g., diplomatic), the next observed event will belong to the same instrument or to a different one. This approach is based on Markov processes, which assume that the probability of transition depends solely on the immediately preceding state, allowing strategic sequences to be modelled without the need to reconstruct complete trajectories.

Sequential analysis using Markov chains made it possible to identify the operational grammar of Turkey's hybrid strategy in Africa (Somalia, Libya, Niger and Mali). The matrices reveal high internal persistence, especially in diplomatic and informational instruments, where Turkey repeats consecutive actions (74% and 57% respectively), suggesting prolonged positioning and narrative campaigns. In addition, significant bridge transitions emerge, such as those connecting diplomacy with information (13%) and military with diplomacy (36%), indicating that coercive actions are often followed by institutional or media legitimisation efforts. This pattern can be seen, for example, in Turkey's military intervention in Libya (2020), followed by intense diplomatic efforts and media coverage.

Diplomacy appears to be the dominant structural instrument, while information acts as a narrative reinforcement. Military action, on the other hand, is used in a surgical and contextual manner, almost always followed by a diplomatic-informational offensive that seeks to minimise reputational costs and consolidate influence. As for African responses, the data show a concentration on the diplomatic and legal

levels, probably due to material limitations that prevent a symmetrical military or economic response. This dynamic reveals a structural asymmetry: Turkey deploys complex hybrid sequences, while its counterparts channel the confrontation towards institutional frameworks, such as international law or multilateral diplomacy.

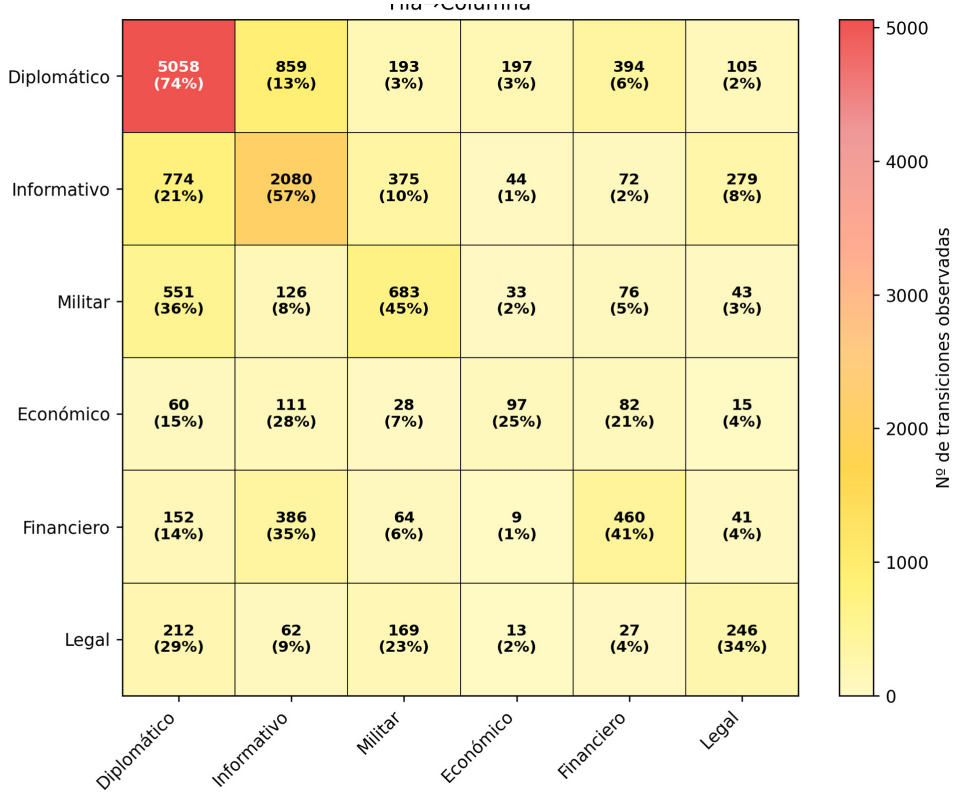

Figure 4. Heatmap of DIMEFL transitions (empirical Markov). Matrix representation of instrument sequences. The diagonal shows persistence (e.g., diplomatic→diplomatic), while the cells outside the diagonal reveal key transitions such as military→informational. *Source*: author's own elaboration

The suitability of this approach to the case study actor and its comparison with the ABM-RL simulation model are explained in the section.

4.3 Dynamic adjustments and temporal trends

The application of statistical models such as Negative Binomial (NB) and SARIMAX complemented the sequential analysis with a more structured reading of temporal dependencies and aggregate trends in historical series. The NB model, designed for count data with overdispersion, showed a robust ability to capture the carry-over effect in diplomatic and informational instruments: quarters with high activity in these domains tend to be followed by new similar episodes, confirming the cumulative nature of hybrid campaigns. This dynamic is particularly evident in Libya and Somalia, where Turkey's projection maintains operational continuity, while in Mali and Niger the behaviour is more erratic and associated with critical junctures such as coups d'état or external interventions. In the Sahel, these disruptions are intertwined with insurgency and local violence, which conditions both Turkey's projection and the predictive capacity of the model (Tollefsen and Buhaug, 2015).

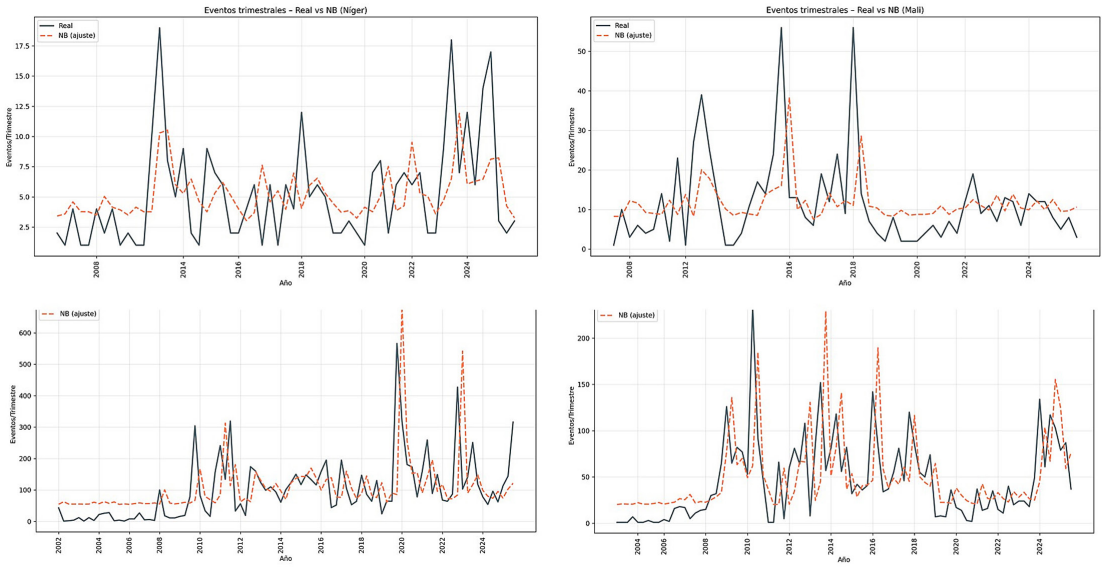

Figure 5. NB adjustment vs. actual data by country. Each graph shows the actual quarterly series (solid line) against the NB model adjustment (dashed line). Libya and Somalia show good predictive capacity; Mali and Niger show greater volatility. *Source*: author's own elaboration

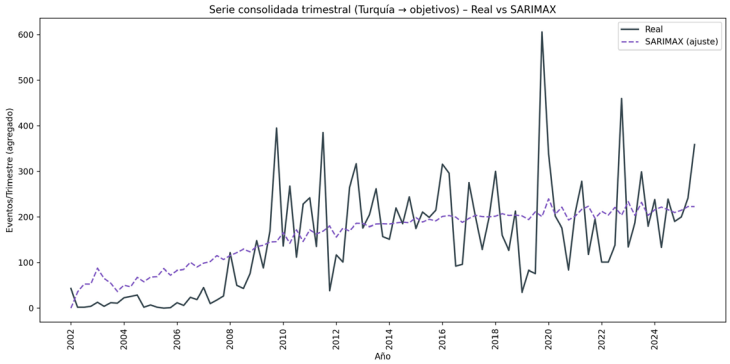

Figure 6. Consolidated series with SARIMAX adjustment (2002-2025). The continuous line reflects observed events and the broken line reflects the SARIMAX adjustment. The upward trend and peaks linked to strategic milestones can be seen. *Source*: author's own elaboration

The adjustment of time series using SARIMAX identified a sustained upward trend in Turkish hybrid activity between 2002 and 2025, with acceleration from 2015 onwards. The most notable peaks coincide with strategic milestones such as the intensification of the conflict in Libya, the opening of the Mogadishu base, and the Turkey-Africa summits. Although no regular seasonality was detected, the model captured structural oscillations linked to these events, reinforcing the idea that Turkey's strategy combines institutional continuity with tactical adaptability in the face of geopolitical opportunities.

The graphs included (figures 5 and 6) illustrate these findings: NB shows greater predictive accuracy in continuity scenarios (Libya and Somalia), while SARIMAX reflects an upward curve with peaks synchronised with moments of high strategic visibility.

The articulation between these dynamic results and the ABM-RL simulation is developed in section 4.4, in order to concentrate the methodological discussion there and avoid redundancies.

4.4 Integration with ABM-RL simulation

The third phase of the analysis consisted of comparing the empirical DIMEFL transition matrix, obtained using first-order Markov chains, with a simulated matrix generated from an agent-based model with reinforcement learning (ABM-RL). The comparison was made for reasons of methodological parsimony: implementing a multi-agent environment, in which African countries would also develop adaptive learning, would have exceeded the scope of this study. Instead, we opted to demonstrate a replicable procedure that contrasts empirical observation and adaptive generation. The ABM-RL matrix does not constitute an 'alternative reality', but rather a virtual laboratory, calibrated with real data, which allows plausible causal mechanisms to be inferred.

In other words, the model is already dynamic in the strict sense: the agent learns over time and adjusts its policy according to signals from the environment observed in the data (e.g., diplomatic-legal responses, variations in reputational tone/Goldstein and context shocks), incorporated as costs and thresholds in the reward function. These signals operate as an adversarial 'proxy' reflex: when the target reacts, the expected cost of certain sequences changes and the agent re-optimises its behaviour. Our objective is to contrast patterns (what tends to follow what) rather than assert hard causality. However, we do not rule out third-party mediations: that is why we treat discrepancies between empirical and simulated matrices as indications of unmodelled constraints. In line with this caution, the work limits its validity to the current version (single actor and observational environment) and opens up a natural extension to a future multi-actor study, with an explicit reaction function and additional context variables.

Turkey was modelled as an attacking agent with the ability to choose between diplomatic, informational, military, economic, financial and legal actions, while African countries were represented as passive targets with probabilistic responses. The Turkish agent was trained to maximise influence, consolidate effective sequences and minimise reputational costs, thus reproducing adaptive strategic decisions. Although the model does not incorporate a complex internal doctrine, the reward function acts as a proxy for Ankara's strategic objectives: the pursuit of influence and the consolidation of presence, balanced with the need to keep reputational costs and escalation risks below a threshold that would trigger open confrontation. This approach, based on the Q-learning method (Watkins and Dayan, 1992), is one of the pillars of adaptive agent modelling.

The comparison between empirical and simulated matrices reveals significant structural consistency. Both confirm diplomatic-informational persistence (D→D, I→I) and the recurrence of bridge transitions (M→D, M→I), reflecting Turkey's tactic of accompanying military interventions with diplomatic offensives or narratives to legitimise its actions. Likewise, the model reproduced economic-financial couplings, indicating that the agent learned to combine these resources to consolidate its presence without directly resorting to force.

The consistency found (D→D, I→I and M→D/M→I bridges) is interpreted within the case of Turkey and not as a universal rule. Future, more extensive studies

could determine whether this is a specific *modus operandi* (e.g., of NATO countries) or a more general grammar of the current international system. In the meantime, our conclusions are limited to the case analysed and are offered as a replicable basis for that comparison.

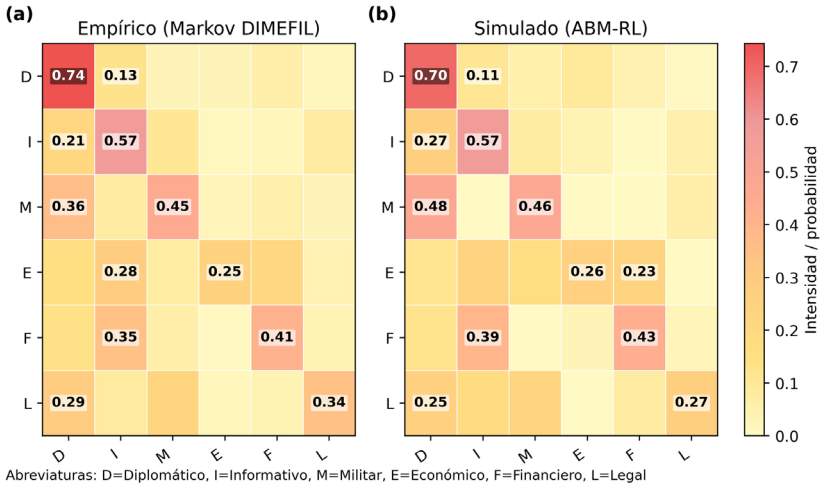

Figure 7 . Transition matrix: empirical (Markov) vs. simulated (ABM-RL). Side-by-side comparison of transition probabilities. The ABM-RL model reproduces the main patterns observed, although it overestimates some military sequences. *Source*: author's own elaboration

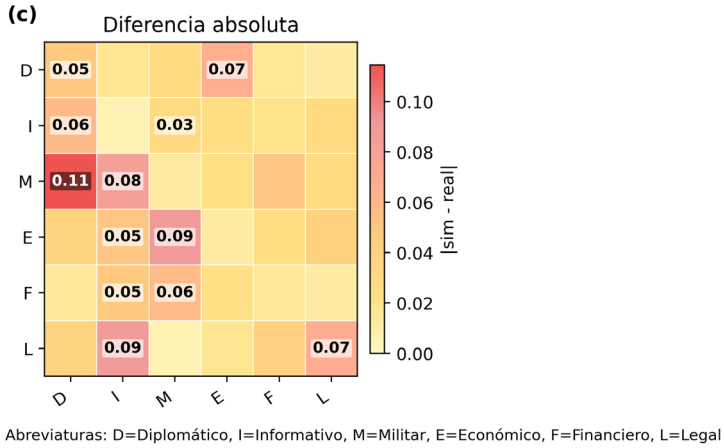

Figure 8. Absolute difference between empirical and simulated matrices. Heatmap of |sim–real|. Low values (yellow) indicate a good fit; high values (orange/red) indicate divergences that point to unmodelled factors, such as reputational costs or interventions by third parties. *Source*: author's own elaboration

However, the absolute difference matrix (figure 8) allows us to identify relevant divergences between the empirical and simulated models, which is key to assessing the limits of the generative approach. The most notable discrepancies are concentrated in transitions involving the military instrument, particularly M→D (military to diplomatic), with an absolute difference of 0.11, indicating that the ABM-RL model predicts this transition with a significantly higher frequency than that observed in the actual data (diplomatic agreements are reached after deploying defence diplomacy or coercive actions, as the case may be). Similarly, the M→I (military to informational) cell shows a difference of 0.08, suggesting that the simulated agent tends to link military actions to media narratives more intensely than empirical patterns reflect.

In addition, other relevant discrepancies emerge in less expected transitions: E→M (economic to military) and L→I (legal to informational), both with differences of 0.09. These values indicate that the simulated model attributes a higher frequency to the conversion of economic or legal instruments towards military coercion dynamics or a rebound in narratives to give visibility to possible agreements, which could reflect a logic of strategic escalation.

These overestimations can be attributed to factors not modelled in the simulated environment. Empirically, transitions from military to diplomatic or informational approaches are conditioned by international reputational costs, such as the risk of sanctions, multilateral condemnation or loss of regional legitimacy. Likewise, the conversion of legal or economic instruments to military or informational ones may be limited by institutional norms, multilateral pressures, or the presence of external actors such as France, the US, or Russia, which introduce operational restrictions that the simulated agent does not face.

In other words, the simulated agent optimises its decisions based on an internal logic of instrumental efficiency, maximising transitions that in theory produce greater strategic impact. However, by not incorporating geopolitical, regulatory or diplomatic constraints, the model tends to overemphasise certain sequences that, in practice, are subject to external costs and structural constraints. This difference between the simulated and the observed does not invalidate the model, but rather reveals its explanatory limitations and points to areas where future simulations could incorporate adaptive penalties or geopolitical counterweights to improve their realism.

4.5 Theoretical discussion and implications

The empirical-simulated comparison allows us to draw several lessons about Turkey's hybrid operations in Africa. First, it confirms that these strategies do not respond to rigid sets of actions, but rather to a sequential and multisectoral design: Turkey combines diplomacy, information, economics and force in a chain, adjusting their deployment to the context. Markov matrices show the structural persistence of diplomacy and information, as well as bridging transitions—especially military→diplomacy and military→information—and economic-financial couplings that illustrate a flexible architecture geared towards consolidating influence.

Secondly, NB models applied to quarterly series confirm that diplomatic and information activity exhibits a carry-over effect, reflecting sustained campaigns in scenarios such as Libya and Somalia. In contrast, volatility in Mali and Niger suggests a more tactical and opportunistic logic, where interventions respond to critical situations rather than prolonged strategies. The SARIMAX model complements this finding by identifying a sustained upward trend since 2015, marked by milestones such as the Libyan civil war, the opening of the Mogadishu base and the Turkey-Africa summits.

Thirdly, the ABM-RL simulation reproduces many of these patterns—persistence in diplomacy and information, military→diplomacy/information sequences,

economic-financial linkages—but also reveals discrepancies. The overestimation of transitions such as M→D or E→M suggests that, in an unrestricted virtual environment, post-coercion legitimisation and economic leaps towards the military would be more frequent. In practice, factors such as international reputational costs, the presence of third parties, or material constraints mitigate these sequences.

Methodologically, the comparison between empirical and simulated matrices demonstrates the complementarity of the approaches: Markov provides descriptive transparency, NB allows for the quantification of persistence, SARIMAX reveals structural trends, and ABM-RL introduces explanatory and exploratory capacity. The decision to limit the simulated model to an attacking agent responds to a criterion of methodological parsimony, which prioritises replicability over complexity.

Taken together, this design not only describes Turkey's hybrid operations, but also offers explanatory hypotheses that enrich the literature on hybrid threats and lay the groundwork for comparative studies in other geopolitical contexts.

4.6 Composite sketch of the hybrid strategy in Africa

The combined analysis of transition matrices, statistical models and adaptive simulation allows us to clearly outline the operational architecture of Turkey's hybrid strategy in Africa. Turkey does not act through isolated interventions, but rather articulates a strategic sequence in which diplomacy constitutes the structural core, reinforced by the information narrative, while military coercion and economic-financial penetration are activated tactically depending on the context. This logic responds less to rigid planning than to tactical adaptability, confirmed by both empirical data and simulated patterns.

Markov chains show high persistence in diplomatic (74%) and informational (57%) instruments, indicating prolonged positioning and legitimisation campaigns. Specific examples include Somalia, where Turkey consolidated its presence with the Mogadishu base in 2017 and the 2024 naval agreement, and Libya, where the 2020 intervention was accompanied by a maritime memorandum and the deployment of advisers and drones. These cases illustrate how the military→diplomacy/information sequence functions as a post-coercion legitimisation mechanism.

For their part, NB models confirm a spillover effect in the diplomatic and information domains, while ABM-RL simulations reproduce these sequences, although they tend to overestimate M→D and M→I transitions. This divergence reflects the absence in the model of factors such as international reputational costs or the intervention of third parties, which in practice limit escalation. In the Sahel, on the other hand, Turkey adopts a more tactical and opportunistic profile: military agreements and the sale of drones to Mali and Niger show a logic of technological penetration, but with greater volatility and dependence on critical situations, such as coups d'état or power vacuums.

Overall, the resulting picture describes a sequential and adaptive hybrid strategy: diplomacy as a structural pillar, information as narrative reinforcement, occasional

military coercion followed by institutional legitimisation, and economic and financial resources as instruments of consolidation. African countries, limited in their symmetrical capabilities, respond mainly at the diplomatic and legal levels, which consolidates a structural asymmetry favourable to Turkey.

This section summarises the findings regarding the 'what' (empirical diagnosis), the 'how' (observed sequences) and the 'why' (logics inferred in the simulation). It thus offers a clear and replicable characterisation of Turkey's hybrid strategy, paving the way for the strategic and methodological implications developed in the conclusions.

4.7 Validation of the hypothesis

The results of the empirical-simulated contrast are consistent with the hypothesis that the dynamics of hybrid threats can be reproduced with autonomous agents that learn and adapt their behaviour. The ABM-RL agent, initialised with the empirical transition grammar, converged towards a stable policy that increases the average return and reduces reputational and escalation penalties throughout the episodes, a sign of learning and not simple random reproduction. The learned policy prioritises the use of instruments of power in the diplomatic and informational spheres and activates connections with security policies and the use of military instruments when the expected cost is low, replicating the patterns observed in the empirical matrices; it also reproduces economic-financial couplings by seeking consolidation without directly resorting to force. Where imbalances appeared (e.g., occasional overestimation of M→D/M→I), the introduction/adjustment of reputational penalties and escalation risk led the agent to re-optimise its sequencing in subsequent iterations, behaviour consistent with strategic adaptation based on feedback.

Overall, the agent's convergent learning and adjustment capacity lend internal validity to the hypothesis and reinforce the value of the model as a virtual laboratory for exploring decision rules. The next logical step—already noted in the scope—is to extend this dynamic to a multi-actor scenario to capture adversarial reflection and third-party mediation, based on a design of our own actor based on expert judgement.

5 Conclusions

This study has addressed a central gap in the analysis of hybrid threats: operationalising the phenomenon with a working definition—hybrid interference as sequential coordination of DIMEFL instruments below the threshold of war, with plausible ambiguity/deniability and cumulative material and cognitive effects—and linking that definition to a replicable pipeline.

To this end, we have worked on three levels, using empirical reclassification (GDELT→DIMEFL) in quarterly panels, dynamic analysis with Markov chains, NB and SARIMAX to identify patterns, persistences and trajectories, and finally an adaptive ABM-RL simulation that transforms the evidence into decision rules under explicit costs and thresholds in 'laboratory' conditions. The result is a transparent

framework that describes observable patterns and, at the same time, explains how an actor can adapt to changing environments.

Applied to the Turkish case in Africa, the approach offers a coherent picture of a hybrid strategy: persistence of diplomatic to informational transitions, bridges from military to diplomatic/informational, so that military intervention is supported by diplomacy or a narrative of legitimisation, and economic-financial reinforcements that consolidate the actor's presence without resorting unnecessarily to force, without this meaning that its use is renounced, as we have seen in the case of Libya.

These findings coincide with and confirm previous research (Arslan, 2025), which already pointed out the following:

> '[…] this study has explained how hybrid warfare and grey zone strategies transformed Turkey's Middle East security policy through multi-level causal mechanisms. Findings have demonstrated with concrete indicators the reciprocal interaction among threat exposure, securitisation discourse, and policy output. The integration of neorealist power balance with Copenhagen School securitisation theory has provided an original theoretical framework explaining both material and discursive dimensions of hybrid strategies'.

The differences between theatres—prolonged campaigns with clear objectives in Libya and Somalia, versus more opportunistic interventions in Mali and Niger—reinforce the idea of sequences that react to the environment. For their part, the empirical response of African countries is concentrated on the diplomatic and legal levels, maintaining the sub-threshold framework and an asymmetry favourable to Ankara.

However, the objective of this work is not specifically the case study itself. What is relevant is that the empirical-simulated comparison validates the working hypothesis: we can model hybrid agents to study how they learn and adapt in order to carry out policies that maximise their influence and minimise reputational and escalation costs. The ABM-RL reproduces the central grammar detected in the data and adjusts its policy when penalties change, which lends internal validity to the approach. Where discrepancies appear (for example, in the occasional overestimation of the military over the diplomatic or informational), they are interpreted as indications of unmodelled constraints (alliances, sanctions, reputational pressure), i.e., they constitute approaches for subsequent multi-actor trials rather than 'failures' of the model.

These conclusions are supported by a deliberately parsimonious scope. Our study has presented one actor (Turkey) and one observational environment to ensure clarity, traceability and replicability; it describes temporal patterns but does not assert structural causality. The sampling of GDELT events (global cap and minimum per country) aims to balance coverage and manageability, reducing biases due to media overexposure and favouring comparability between theatres.

All in all, the main value of the framework we present lies in its portability and its ability to open up and propose future lines of research. The natural extension of

subsequent studies would consist of making an initial design of the actor based on a panel of experts who define and lead the simulations in a multi-actor environment that incorporates adversarial reflection (opponent learning) and explicit context variables and rules of engagement to assess the extent to which the dynamics of opportunistic or competitive actors explain—and not merely accompany—the measured sequences. At the same time, cross-replication of the pipeline in other actors (NATO, non-NATO, non-aligned) and other scenarios will make it possible to determine whether the patterns observed are idiosyncratic to Turkey or correspond to general trends in the ecosystem of international relations in today's world. It should be noted that the analytical framework applied here, based on the DIMEFL scheme and NATO's conceptualisation of hybrid threats, has a Western doctrinal origin. Its application to actors with radically different strategic frameworks (e.g., China or Russia) may require conceptual and methodological adaptations to capture their specific logics of interference (cognitive, legal instruments of power, etc.). Undoubtedly, the analysis of their theoretical frameworks is a starting point for future work in this regard.

In terms of utility, the proposed assembly provides a reproducible basis for early warning and scenario exploration: it integrates open data, transparent rules and a 'virtual laboratory' that converts divergences into research questions. With these pieces, the agenda remains open to richer multi-domain and multi-actor models—without losing sight of the common thread of measuring sequences and patterns and explaining learning below thresholds—moving towards comparative assessments that connect observable tactics with strategic trajectories, always under the guidance of expert judgement, but in an environment that goes beyond simple game theory to take a step further and exploit the potential offered by generative artificial intelligence and agent learning.

Technical Annex: Data extraction, processing and modelling procedure

This annex documents the technical flow followed in the study in order to ensure the reproducibility of the analysis. It details the SQL queries in BigQuery, the mapping of CAMEO codes to DIMEFL, the phases of the Python pipeline, and the statistical and simulation models used.

Data extraction (SQL BigQuery)

The empirical basis was constructed from the GDELT Event Database, combining GDELT 1.0 (2002–2013) and GDELT 2.0 (2015–2025). The SQL script applied the following criteria:

- Actors: Turkey as Actor1 or Actor2.
- Target countries: Libya (LY), Mali (ML), Niger (NG) and Somalia (SO).
- Time interval: 2002-2025.
- Key fields extracted: event identifier, date, actors, CAMEO codes (EventCode, EventBaseCode, EventRootCode), Goldstein, AvgTone, coverage metrics (mentions, sources, articles) and geolocation (ActionGeo_CountryCode, coordinates).

- Preliminary DIMEFL classification: already applied in the query, using explicit rules:
  - Diplomatic: root codes 04–06.
  - Informative/Influence: root 01–03 and any EventCode/EventBaseCode with prefix 07.
  - Legal: root 13, 15–17.
  - Military-Security: root 12, 14, 18–20.
  - Economic: root 08–11, except for financial subcodes.
  - Financial: subcodes 081–087, 101–108, 109–116 (aid, loans, sanctions, transfers).

In addition, to avoid record overload, a maximum of eight hundred events/year and an overall limit of twenty thousand records were established, selecting the most relevant events according to NumMentions, NumSources and NumArticles. The result was a consolidated file with approximately fourteen thousand unique events, exported in CSV for further analysis.

Processing and reclassification (Python pipeline)

The processing was implemented in the pipeline_turquia_hibrida.py script, designed to be reproducible in any environment. The main phases were:

1. Loading and validation: normalisation of dates, cleaning of duplicates, verification of the DIMEFL column and country codes (LY, ML, NG, SO).
2. Geographic visualisation: generation of a choropleth map of Africa with the distribution of events by country.
3. Quarterly panel: aggregation of events by country, quarter and DIMEFL instrument, exporting the quarterly_panel.csv table.
4. Markov transition matrices: calculation of transitions between instruments (empirical) by country and as a whole, with heatmap-type visualisation and export of matrices in CSV.
5. Statistical models:
   - Negative binomial regression (GLM-NB): to estimate the persistence of events based on lagged values[1] for each instrument.
   - SARIMAX: to identify trends and cyclical dynamics in the consolidated quarterly series.
6. Summary by country: table of absolute distribution of events by instrument and country (events_summary_by_country_type.csv).

1 Lagged value: in econometrics and time series analysis, the term *lagged value* is commonly used to refer to the value of a variable in a previous period. Although it is not included in the RAE dictionary, its use is widely standardised in technical manuals and specialised literature (e.g., Greene, 2018).

7. Empirical-simulated comparison: comparison between empirical and simulated Markov matrices (ABM-RL), with graphical outputs in PNG/PDF.

Statistical modelling and simulation

The models applied were:

- Markov chains (order 1): to capture the tactical sequence between instruments.
- Negative binomial GLM: to model overdispersion and temporal persistence.
- SARIMAX: to analyse long-term trends and cycles.
- ABM-RL (Q-learning): to represent Turkey as an adaptive agent that learns to choose between DIMEFL instruments by maximising rewards (accumulated influence, persistence of effective sequences, minimisation of reputational costs).

The comparison between the empirical Markov model and the ABM-RL simulation validated the learning model's ability to reproduce real patterns while exploring informational divergences.

Operational considerations

- Media bias control: limitation of events per country and selection of relevant records.
- Temporal homogeneity: use of quarters as the minimum unit.
- Transparency: all SQL and Python scripts are documented and available for review.
- Scalability: the pipeline can be applied to other actors, countries or periods with minimal modifications.

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