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Mathematical methods in the study of political conflicts: parametric estimation model

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This study aims to develop a comprehensive parametric model for quantifying and predicting political conflicts through mathematical analysis. It addresses the need for objective tools to assess the intensity, dynamics, and potential development trajectories of conflicts across different scales of political confrontation. The research employs an integrated analytical framework that combines discrete dynamical systems, parametric modeling, and stability analysis to construct a robust mathematical apparatus. The model is based on a system of difference equations describing the interactions among key conflict parameters-confrontation intensity, resource potential of parties, external influences, and socio-political context. An integral indicator of conflict intensity is introduced, using weighted coefficients of parameter significance to account for both explicit and latent factors. Stability analysis of the system identifies conditions under which political conflicts tend toward resolution or escalation. The study finds that sustainable conflict resolution occurs when cross-response parameters (mutual reactions between parties) exceed self-response parameters (reactions to one's own conflict situation). Behavioral strategies are expressed through linear relationships that capture how parties adapt their approaches in response to their own and their opponents' actions. These findings highlight that empathy, strategic consideration of opponents, and interdependent behavioral dynamics are essential factors in achieving conflict resolution. Validation through case studies - such as wage disputes and social movements - demonstrates the model's effectiveness in analyzing complex socio-political processes. The study concludes with practical recommendations for implementing the model in analytical centers and government agencies to support evidence-based conflict management strategies.

KEYWORDS

parametric indicators, mathematical modeling, conflict, inconsistency, climax of conflict, parametric inequalities, social conflicts, individual demand

1 Introduction

Political conflicts represent complex multidimensional phenomena requiring comprehensive analysis and forecasting through rigorous scientific methods. Mathematical modeling has emerged as an indispensable tool for studying political processes, enabling identification of hidden patterns and relationships between various factors in conflict situations. The growing global instability necessitates improved objectivity in analysis and quality of management decisions, making parametric assessment models a promising approach for conflict studies through quantification and analysis of key confrontation characteristics (Kahne, 2018).

Contemporary political conflicts are characterized by high uncertainty levels, demanding advanced mathematical methods for analysis and prediction of possible development scenarios. Parametric modeling enables systematic structuring of conflict data, identification of significant influencing factors, and construction of predictive scenarios based on key parameter variations. This approach offers new opportunities for understanding conflict occurrence, development, and resolution mechanisms, particularly important for preventing tension escalation and identifying effective resolution pathways.

The mathematical modeling of political conflicts opens new possibilities for understanding the mechanisms of their emergence, development and resolution, which is especially important in the context of preventing escalation of tension and finding effective ways to resolve contradictions. This research presents an analysis of the possibilities of using a parametric model to assess political conflicts, considering current trends in the development of mathematical methods for studying socio-political processes. The proposed approach is based on a synthesis of quantitative and qualitative methods of analysis, which allows for a more complete and objective understanding of the nature and dynamics of political conflicts.

2 Literature review

The mathematical modeling of political conflicts has evolved significantly since the foundational work of Richardson (1960), who developed differential equations for modeling arms races in the 1960s. This pioneering approach established the theoretical groundwork for subsequent quantitative conflict analysis and demonstrated the potential for applying mathematical methods to complex political phenomena.

The 2000s marked a significant advancement with Fearon and Laitin (2003) developing quantitative methods for analyzing civil wars and ethnic conflicts, demonstrating regression analysis effectiveness in identifying factors influencing conflict occurrence and escalation probability. Their research showed that quantitative approaches could provide valuable insights into previously subjective areas of political analysis. Building upon this foundation, Collier and Sambanis (2005) proposed quantitative methods for analyzing economic conflict factors, expanding the scope of mathematical modeling to include economic dimensions of political confrontation.

Barbara Walter's research on civil war problems made a significant contribution to understanding the role of institutional factors in conflict development, while Gates and Strand (2004) enhanced methodology for assessing geographical factors' impact on conflict dynamics. These studies collectively demonstrated that multiple factors could be mathematically modeled and their interactions analyzed systematically. Carment (1997) proposed an integrated approach to political instability risk assessment, while Schlichte (2009) demonstrated textual analysis effectiveness in studying political discourse within conflict situations.

The late 2000s witnessed methodological integration advances, with Cederman and Gleditsch (2009) utilizing geospatial data in conflict analysis, opening new possibilities for political instability prediction through spatial analysis techniques. This work showed how geographic information systems could be integrated with mathematical models to enhance predictive capabilities. More recently, Hegre (2019) developed machine learning models for predicting armed conflicts, significantly impacting methodological development by introducing artificial intelligence approaches to conflict analysis.

Russian-language contributions include Bushuev (2005), who presented an innovative conflict modeling approach in technical creativity contexts, developing mathematical frameworks for describing contradictions in inventive problem-solving. His work was particularly valuable for demonstrating how differential equations could be used to describe the dynamics of conflict situations and predict the development of contradictions. Antipova (2024) offered a modern perspective on mathematical conflict modeling, emphasizing game theory and optimization methods application while highlighting the importance of considering multifactorial aspects when building mathematical models.

Semenov (2021) contributed significantly to time series analysis methodology in political science, examining dynamic aspects of political conflicts. His work is particularly important for understanding the temporal dimensions of political conflicts and the possibilities and limitations of using time series analysis for studying political processes, which is crucial for building predictive models.

Kazakhstani scholarship is represented by several significant researchers who have adapted international methodological approaches to regional contexts. Ashimbayev (2002) and Kadyrzhanov (2014) adapted international conflict analysis methods to Central Asian regional specifics, revealing the features of using mathematical methods in analyzing interethnic and territorial conflicts in the post-Soviet space. Yskak and Tolen (2024) contributed to international experience studies in mathematical conflict modeling, focusing on US practices and conducting comparative analysis of various modeling approaches while assessing possibilities for their adaptation to post-Soviet conditions.

Nassimova (2006) provided fundamental analysis of social conflict factors in Kazakhstan, identifying key determinants of social tension and suggesting a systematic approach to their classification. The value of this work lies in the researcher's consideration of conflicts within the context of Kazakhstani society's specifics, considering its multinational character and socio-economic development peculiarities. Bakirlanova (2023) investigated international conflicts' influence on contemporary society's value orientations, focusing on the analysis of social value transformation under global conflict influence and emphasizing the importance of considering value aspects when analyzing and predicting conflict situations.

The analysis of Kazakhstani scientists' works demonstrates an integrated approach to conflict studies, combining mathematical modeling, sociological analysis, and examination of value aspects of conflict situations, which provides a comprehensive foundation for developing context-specific analytical frameworks.

3 Methodology

Our methodology employs a systematic approach to analyzing conflict situations, incorporating both quantitative and qualitative assessment methods. The fundamental basis lies in game theory, which enables modeling of strategic interactions between conflict parties while considering their interests and possible behavioral strategies. The parametric conflict assessment model incorporates multifactorial analysis with several key components that work together to provide comprehensive conflict analysis.

The first component involves assessment of conflict intensity through quantitative metrics that can be measured and tracked over time. This includes developing scales for measuring confrontation levels and establishing baseline measurements for comparison purposes. The second component focuses on the determination of spatial and temporal characteristics using statistical analysis, which allows for understanding how conflicts develop across different geographic areas and time periods. The third component involves analysis of resource potential of conflicting parties, examining both material and non-material resources that may influence conflict outcomes. The fourth component centers on identification of cause-effect relationships between various conflict parameters, establishing how different factors interact and influence each other within the conflict system.

Regression analysis serves as the primary mathematical tool for establishing relationships between conflict factors and dynamics, allowing researchers to identify which variables most significantly impact conflict development. Correlation analysis methods identify relationships between individual conflict situation parameters, providing insight into how different aspects of conflicts are interconnected. Probability theory and mathematical statistics assess conflict escalation likelihood through probabilistic model construction, enabling estimation of various outcome scenarios and their associated probabilities.

For predicting conflict situation development, we employ time series extrapolation methods, including trend analysis and cyclical components identification. These methods help identify patterns in conflict evolution and project future developments based on historical data. Simulation modeling methods reproduce various conflict development scenarios while considering multiple variable factors, allowing for testing of different intervention strategies and their potential outcomes. The Monte Carlo method evaluates probabilistic characteristics of various conflict scenarios, providing statistical confidence intervals for predictions.

The hierarchy analysis method structures problems and prioritizes various factors influencing conflict development, helping researchers focus on the most critical elements of conflict situations. Methods of fuzzy set theory work with uncertain and poorly formalized parameters of conflict situations, acknowledging that many aspects of political conflicts cannot be precisely quantified but still require systematic analysis. Expert assessment methods obtain qualitative characteristics of conflicts and enable their subsequent quantification, bridging the gap between subjective expert knowledge and objective mathematical analysis.

For dynamic conflict analysis, we utilize differential equations describing main parameter changes over time, capturing the continuous nature of conflict evolution. Optimization methods identify effective conflict resolution strategies by evaluating different intervention options mathematically. Decision theory methods evaluate action options under uncertainty conditions, providing frameworks for decision-making when complete information is not available.

3.1 Parametric model definition

We define conflict as inconsistency between subject desire and capabilities, representing a fundamental mismatch between what an actor wants to achieve and what they can realistically accomplish given their current resources and constraints. This definition provides a mathematical foundation for conflict analysis by establishing measurable parameters that can be tracked and analyzed over time.

Formally, this relationship is expressed as: $u = [W - H]$, where $W > H$.

In this formulation, $[x]$ represents a function defined as: $[x] = \{x, \text{ if } x > 0; 0, \text{ if } x \leq 0\}$.

Here, u represents conflict intensity, indicating the magnitude of inconsistency between desires and capabilities. W denotes subject desires or goals, encompassing what the actor seeks to achieve through their actions. H represents current possessions or capabilities, including all resources, power, and opportunities currently available to the actor. Conflict occurs when $u > 0$, indicating a positive difference between goals and capabilities, which creates tension and motivation for action.

This mathematical representation allows for quantitative analysis of conflict situations by establishing clear parameters that can be measured, compared, and tracked over time. The model recognizes that conflicts arise from discrepancies between aspirations and reality, and that the magnitude of this discrepancy directly relates to conflict intensity.

4 Results

4.1 Mathematical model development

Our analysis distinguishes between different types of conflicts based on the relationship between parameters W and H, and particularly on which actor has control over these parameters. This distinction is crucial for understanding conflict dynamics and developing appropriate resolution strategies, as established in the foundational work of Mueller (2017), who emphasized that conflict arises from discrepancy between subject desire and capabilities.

Internal Conflict occurs when parameter H belongs to the same subject as parameter W, meaning the actor has direct control over their capabilities and can independently change parameter H through their own actions. As Mueller (2017) notes, in such situations, the subject has two primary paths for conflict resolution: either modify their goals (parameter W) to match their capabilities, or enhance their capabilities (parameter H) to meet their goals. This type of conflict often involves personal or organizational decision-making where actors have significant control over both their objectives and their resources.

External Conflict arises when a subject cannot directly change parameter H because it belongs to or is controlled by another entity, as described by Petukhov (2015). In such cases, the actor must influence other parties to modify parameter H in the desired direction, often requiring negotiation, persuasion, or other forms of indirect influence. This type of conflict is more complex because resolution requires coordination between multiple actors with potentially conflicting interests.

A special case of external conflict occurs when parameter H is determined by external circumstances or natural laws that cannot be influenced by any actor. As Mueller (2017) observes, in such situations, the only path to conflict resolution involves adaptation, requiring the subject to modify their goals (parameter W) to align with unchangeable external constraints.

4.2 Dynamic system analysis

For conflicts involving multiple subjects with common conflict objects, we establish a system describing interaction dynamics over time. Following the approach developed by Konca and Capin (2023), we define conflict as a discrepancy between subject desire and capabilities, which can be mathematically expressed and analyzed through systematic equations.

The evolution of capabilities for two conflicting parties can be expressed through the following dynamic equations (algebraic system based on differential equations):

$$H_1^{(n)} = [H_1^{(n-1)} + \Delta H1]H_2^{(n)} = [H_2^{(n-1)} + \Delta H_2]$$

where n represents the interaction number or time step, and $\Delta H1$ and ΔH_2 represent changes in capabilities for each party during each interaction period, as formulated in our earlier mathematical framework.

Correspondingly, the evolution of conflict intensity for each party follows:

$$u_1^{(n)} = [u_1^{(n-1)} - \Delta H_2]u_2^{(n)} = [u_2^{(n-1)} - \Delta H_1]$$

This system captures the interdependent nature of conflict dynamics, where actions by one party (changes in their capabilities) directly affect the conflict intensity experienced by the other party. As Antipova (2024) emphasizes, the cross-coupling in these equations reflects the reality that in most political conflicts, one party's gain often corresponds to another party's loss, creating zero-sum or negative-sum dynamics.

4.3 Behavioral strategy modeling

We model entity behavior through linear relationships that describe how parties adjust their strategies based on their own conflict intensity and their perception of their opponent's situation. Building on the theoretical framework established by Dushkin et al. (2018), we express these relationships as:

$$\Delta H_1(u_1, u_2) = k_{11}u_1 + k_{12}u_2$$
$$\Delta H_2(u_1, u_2) = k_{21}u_1 + k_{22}u_2$$

As noted by Dushkin et al. (2018), the parameters k_{ij} describe different psychological characteristics and behavioral strategies that actors employ in conflict situations. Parameter k11 characterizes how intensely the first party responds to their own conflict situation, representing their self-focused reaction intensity. Parameter $k1_2$ indicates how the first party responds to the second party's conflict situation, reflecting their level of empathy, strategic consideration, or competitive response to opponent distress.

Following the analysis presented by Lewis (2016), parameters k_{21} and k_{22} represent the second party's behavioral patterns. These parameters can take positive or negative values, representing different behavioral patterns. Positive values indicate that increased conflict intensity leads to increased efforts to change capabilities, while negative values suggest that higher conflict intensity may lead to reduced efforts, possibly due to discouragement or resource depletion.

For inequality $k_{11} < 0$, as demonstrated in our mathematical framework, consumer representatives of the population receive lower wages or face challenges when costs rise sharply. The more u1 increases, the population may begin to perform poorly at work. In this case, as Lewis (2016) suggests, there are streams of government actions that, only by increasing wages, motivate the population to work better and avoid conflict situations.

At the same time, with the $k_{22} < 0$ inequality, as shown by Malte et al. (2023), the lower employees work, the lower the wages paid by the government. Conversely, government representatives can communicate to employees that wages will increase if they work better. We can build a system based on these two inequalities.

As Malte et al. (2023) observe, when $_{11} > 0$, the lower the salary that employees receive, the better they start working. However, this situation may seem counterintuitive but can be caused by the employee's inner desire and belief that better performance will lead to employer recognition and salary increases.

Even when $k_{22} > 0$, as noted by Malte et al. (2023), while the employee works worse, the employer pays higher salary. This situation also seems illogical but stems from the employer's hope that the employee will perform better if paid more. These different patterns follow in all four inequality scenarios, each differing from the others in their behavioral implications.

Through parameters $_{11}$ and k_{22}, we can observe how and to what extent entities can influence each other. These parametric indicators can be mathematically modeled within our research framework, and the results obtained in the modeling process can help prevent conflicts and maintain continuous monitoring of conflict situations.

4.4 Stability analysis

The system reaches a stationary conflict-free state when $u1 = 0$ and $u_2 = 0$, meaning both parties have achieved consistency between their goals and capabilities. As established by Kochedykov et al. (2017), to determine when such a stable state can be reached, we analyze the eigenvalues of the linearized system around the equilibrium point.

Through eigenvalue analysis, following the methodology developed by Kochedykov et al. (2017), we determine that the characteristic equation takes the form of a quadratic equation. The eigenvalues are:

$$\lambda_{1,2} = 1 - ½(k_{12} + k_{21}) \pm ½\sqrt{[(k_{12} - k_{21}) + 4k_{11}k_{22}]}$$

Specifically, the system can be represented as a two-dimensional discrete dynamical system of the form x_{n+1} = Ax_n, where A is the coefficient matrix containing the parameters k_{11}, k_{12}, k_{21}, and k_{22}. The eigenvalues λ are obtained by solving the characteristic equation det (A - λI) = 0, where I am the identity matrix. For a 2 × 2 system, this yields a quadratic equation whose solutions are given by the standard quadratic formula, resulting in the expression $\lambda 1,_2 = 1 - ½(k_{12} + k_{21}) \pm ½\sqrt{[(k_{12} - k_{21}) + 4k_{11}k_{22}]}$. The trace and determinant of matrix A directly determine the coefficients of this characteristic polynomial, with the trace equal to $(k_{11} + k_{22})$ and the determinant equal to $(k_{11}k_{22} - k_{12}k_{21})$. The eigenvalue analysis provides the necessary conditions for asymptotic stability of the equilibrium point, requiring $|\lambda 1| < 1$ for all eigenvalues to ensure convergence rather than divergence of system trajectories. This mathematical framework is well-established in the literature on discrete dynamical systems and has been appropriately applied to analyze the stability properties of our conflict resolution model.

As demonstrated by Kochedykov et al. (2017), for system stability, requiring that conflicts eventually resolve rather than escalate, all eigenvalues must have absolute values less than 1. This condition ensures that disturbances to the system decay over time rather than grow.

From the fulfillment of these conditions, we obtain the following inequalities:

1. $\sqrt{[(k_{12} - k_{21}) + 4k_{11}k_{22}]} < (k_{12} + k_{21})$
2. $\sqrt{(k_{12} - k_{21}) + 4k_{11}k_{22}]} < (k_{12} + k_{21})$
3. $-\sqrt{[(k_{12} - k_{21}) + 4k_{11}k_{22}]} < (k_{12} + k_{21})$

If $k_{12} + k_{21} > 0$, then the condition will be executed automatically and the primary stability condition can be expressed as:

$$k_{11}k_{22} < k_{12}k_{21}$$

This inequality defines the relationship between behavioral parameters that ensures conflict resolution rather than escalation. When this condition is satisfied, the mathematical model predicts that conflicts will tend toward resolution over time, even if they experience temporary intensification.

As noted by Pokornaya (2009), if the opposite condition $k_{12} + k_{21} < 0$ holds, then the stability condition is not met. It turns out that if one of the inconsistencies tends to zero, since the equations are nonlinear, the system stops at zero. In this case, only one of the two equations can be implemented.

For the equation that must be fulfilled, following Pokornaya (2009), we obtain the following conditions:

$$k_{21} > 0, k_{22} > 0, k_{12} > 0$$

Thus, for specific values of λ parameters, as demonstrated by Beal et al. (2022), the condition λ < 1 can be fulfilled, which makes the conflict-free state of the system stable (in the case of u1 = 0 and $u_2 = 0$). This indicates the conflict potential can be managed through appropriate parameter selection.

We can represent the stability requirements in the form of the following system of inequalities:

$$\{k_{12} - k_{21} > 0\{k_{11}k_{22} < k_{12}k_{21}$$

The stability analysis reveals several important insights about conflict dynamics. First, the relationship between self-response parameters (k_{11}, k_{22}) and cross-response parameters ($k12$, $k21$) is crucial for determining whether conflicts escalate or resolve. Second, stable conflict resolution requires that parties' responses to each other's situations (cross-terms) be stronger than their individual responses to their own conflicts (self-terms). This suggests that empathy, strategic consideration of opponents, or competitive dynamics that connect parties' behaviors are essential for conflict resolution.

4.5 Case study application: social conflict analysis

To demonstrate the model's practical application, we examine conflict situations similar to those analyzed by Lewis (2016) in the context of social movements and government responses. Consider a scenario involving wage disputes between government and social groups, where social groups desire higher wages (W1) while the government offers lower wages (H_2), creating conflict intensity u1 = W1 - H_2 for social groups.

Simultaneously, the government desires higher work quality/productivity (W_2) while observing current work performance levels (H1), creating conflict intensity $u_2 = W_2$ - H1 for government representatives. This bi-directional conflict structure reflects the complex interdependencies characteristic of many political conflicts.

As Lewis (2016) observed in analyzing social conflicts, the behavioral parameters in this context can be interpreted as follows: $k_{11} > 0$ represents social groups increasing their demands or protest activities as their wage dissatisfaction grows. Parameter $k_{22} > 0$ might represent government reducing wage offers as they become more dissatisfied with work quality. The cross-terms k_{12} and k_{21} capture how each party responds to the other's dissatisfaction.

The equations describing this dynamic can be expressed as:

$$u_1^{(n)} = W_1 - H_2^{(n)} u_2^{(n)} = W_2 - H1^{(n)}$$

The presented system of equations $u_1^{(n)} = W1 - H_2^{(n)}$ and $u_2^{(n)} = W_2 - H_1^{(n)}$ does not constitute a system of differential equations but rather represents a system of difference equations or a discrete dynamical system. The independent variable (argument) is n, denoting the iteration number or discrete time step. The dependent variables include $u_1^{(n)}$ and $u_2^{(n)}$, which represent utility or response functions of the first and second entities at iteration n, respectively, as well as $H_1^{(n)}$, representing the quality and volume of work performed by social group representatives, and $H_2^{(n)}$, representing the salary level offered by the government at iteration n. The discrete nature of this system is evidenced by the superscript notation (n) indicating discrete time steps, the absence of derivatives of the form du/dt, and the contextual framework suggesting iterative negotiations between social groups and the government. To complete the system, additional equations are typically required to specify how $H_1^{(n1)}$ and $H_2^{(n)}$ evolve based on the current values of $u_1^{(n)}$ and $u_2^{(n)}$, thereby establishing a feedback mechanism between the parties' responses and their subsequent actions. This mathematical framework models an iterative bargaining or negotiation process between social groups and governmental entities, characterized by sequential decision-making and mutual interdependence of strategic choices.

The stability condition $k11k_{22} < k_{12}k_{21}$ suggests that resolution requires that each party's response to the other's concerns be stronger than their response to their own concerns. In practical terms, this means that sustainable wage agreements require both parties to prioritize addressing each other's needs rather than simply pushing their own positions more strongly.

This analysis framework can be applied to various social conflict situations, including those examined by Lewis (2016) in the context of the "Zhanaozen events" and other social movements. The mathematical model provides a systematic approach to understanding why some conflicts escalate while others find resolution, offering insights for conflict prevention and management strategies.

4.6 Advanced mathematical analysis

We can derive more sophisticated solutions for specific parameter configurations. When $k1_2 = k_21 = 0$, representing situations where subjects do not consider opponents' interests when making decisions, the system of equations can be solved analytically:

$$\begin{aligned}
u_1^{(n)} &= u_1^{(0)} \sum^{m=0n-1} 1/(2m)!_2 k_1 1^m k_{22}^m \\
-k_{22} u_2^{(0)} &\sum^{m=0n-1} 1/(2m+1)!_2^{m+1} k11^m k_{22}^m \\
u_2^{(n)} &= u_1^{(0)} \sum^{m=0n-1} 1/(2m)!_2 k_1 1^m k_{22}^m \\
-k_{11} u_2^{(0)} &\sum^{m=0n-1} 1/(2m+1)!_2^{m+1} k11^m k_{22}^m
\end{aligned}$$

where $(n)_2m$ = n(n-1)(n-2)...(n-2m+1) and $(n)_{2m+1}$ = n(n-1)(n-2)...(n-2m) represent falling factorials.

These solutions, as analyzed by Beal et al. (2022), reveal that the dynamics depend critically on the signs and magnitudes of the behavioral parameters. The series expansions show how initial conditions propagate through the system and either converge to stable equilibria or diverge toward escalation.

For the general case with non-zero cross-coupling terms, the system exhibits richer dynamics that can include oscillatory behaviors, conditional stability, and multiple equilibria. As demonstrated throughout our analysis, these mathematical properties have direct implications for conflict management strategies and policy interventions.

The comprehensive mathematical framework presented here, building on the contributions of Mueller (2017), Konca and Capin (2023), Antipova (2024), Lewis (2016), Malte et al. (2023), Kochedykov et al. (2017), Pokornaya (2009), Beal et al. (2022), and Dushkin et al. (2018), provides a robust foundation for quantitative analysis of political conflicts and offers practical tools for conflict prevention and resolution.

5 Discussion

Let's consider the algorithmic aspects of constructing new logical equations based on the samples considered earlier. "To begin with, it is of interest to find out by what parameters k_{ij} (that is, by what strategies of the parties involved) the system comes to a stationary conflict-free state from the point of view of the stated problems of modeling conflict situations. If $u_1 = 0$ and $u_2 = 0$ (i.e., all conflicts arising in the system are resolved), it will go to the normal state" (Kochedykov et al., 2017).

"At the same time, the legitimate question arises as to what conditions it is impossible to resolve all conflicts in the system when they are met, and how they can develop at this time. When $k_{12} = k_{21} = 0$, the solutions of the system of equations can be transformed when subjects do not consider the interests of opponents when making decisions. To do this, let's consider compiling the following system of equations" (Kochedykov et al., 2017):

$$\begin{cases}
u_1^{(n)} = u_1^{(0)} \sum_{m=0}^{n-1} \frac{1}{(2m)!} (n)_{2m}\, k_{11}^m k_{22}^m \\
-k_{22} u_2^{(0)} \sum_{m=0}^{n-1} \frac{1}{(2m+1)!} (n)_{2m+1}\, k_{11}^m k_{22}^m \\
u_2^{(n)} = u_2^{(0)} \sum_{m=0}^{n-1} \frac{1}{(2m)!} (n)_{2m}\, k_{11}^m k_{22}^m \\
-k_{11} u_1^{(0)} \sum_{m=0}^{n-1} \frac{1}{(2m+1)!} (n)_{2m+1}\, k_{11}^m k_{22}^m
\end{cases}$$

The presented system constitutes a linear system of first-order differential equations, whose solution describes the interaction dynamics between system components under given parametric condition. Our mathematical equivalent, which we will consider here, is as follows:

$$\begin{aligned}
(n)_{2m} &= n\,(n-1)\,(n-2)\ldots(n-2m+1)\,,\ (n)_{2m+1} \\
&= n\,(n-1)\,(n-2)\ldots(n-2m)\,,\ n,\ m \in N
\end{aligned}$$

For the linear system to admit a non-trivial solution, a compatibility condition must be satisfied. This yields the characteristic equation determining the admissible values of λλ, under which the system has solutions other than the trivial zero solution. Obviously, we can find the type of equation that can give new solutions by looking for the equation in the state:

$$\begin{cases}
(\lambda - 1 + k_{21})\, a + k_{22} b = 0 \\
k_{11} a + (\lambda - 1 + k_{12})\, b = 0
\end{cases}$$

By parameterizing the values derived from this, we obtain the following equation:

$$(\lambda - 1)^2 + (k_{12} + k_{21})(\lambda - 1) - k_{11}k_{22} + k_{12}k_{21} = 0$$

We put the available conflict parameters into the new equation to find the true solutions of the last equation:

$$\lambda_{1,2} = 1 - \frac{1}{2}(k_{12} + k_{21}) \pm \frac{1}{2}\sqrt{(k_{12} - k_{21})^2 + 4k_{11}k_{22}}$$

As a result of our analysis, we observe that the quantity representing the discrepancy—interpreted here as the underlying cause of conflict—can assume only negative values. This implies that a stationary (conflict-free) state exists only when the parameter λ < 1λ < 1. Under this condition, the asymptotic constants satisfy a = 0a = 0 and b = 0b = 0, indicating that both variables a(t)a(t) and b(t)b(t), as well as the relevant system parameters, decay monotonically over time. Therefore, the stability condition is satisfied only if either λ < 0λ < 0 or another related inequality (e.g., μ < 0μ < 0) holds.

It is thus essential to continuously verify the solution space in order to determine whether the constructed equation yields valid (i.e., truthful and consistent) results. This verification depends on whether the formulated model reflects a correct or incorrect structure, as emphasized by Kochedykov et al. (2017).

From the fulfillment of the stability conditions derived earlier, we obtain the following inequalities. Specifically, our analysis shows that the discrepancy term—interpreted as the root cause of system conflict—can assume only negative values under these conditions. As a result, we conclude that a stationary (conflict-free) state is possible only when λ < 1λ < 1. In such a regime, the asymptotic constants are u1 = 0u1 = 0 and u2 = 0u2 = 0, meaning that both variables monotonically decrease over time until they converge to zero.

Consequently, in this context, the system satisfies a stability criterion only when at least one of the inequalities λ1 < 0λ1 < 0 or λ2 < 0λ2 < 0 holds. Therefore, it is necessary to continuously evaluate the solution space, in order to determine whether the constructed equation leads to a valid (i.e., physically or logically consistent) model—depending on whether the equation is correctly or incorrectly formulated, as discussed in Kochedykov et al. (2017).

From the fulfillment of these conditions, we obtain the following inequalities:

1. $\sqrt{(k_{12} - k_{21})^2 + 4k_{11}k_{22}} < (k_{12} + k_{21})$
2. $\sqrt{(k_{12} - k_{21})^2 + 4k_{11}k_{22}} < (k_{12} + k_{21})$
3. $-\sqrt{(k_{12} - k_{21})^2 + 4k_{11}k_{22}} < (k_{12} + k_{21})$

If $k_{12} + k_{21} > 0$, then the condition will be executed automatically and will look like this:

$$k_{11}k_{22} < k_{12}k_{21}$$

"If the opposite is $k_{12} + k_{21} < 0$ then the stability condition is not met. It turns out that if one of the inconsistencies tends to zero since the equations that drew attention are non-linear, the one that stops at zero. In this case, only one of the two equations can be implemented. Let $u_2 = 0$ for the statement to be clear. Even at this point, the equation can take the form" (Kochedykov et al., 2017):

$$u_1^{(n)} = \left[1 - k_{21}\right] u_1^{(n-1)}$$

And at the same time the following action is also performed:

$$k_{21} > 0$$

In the same way, for the equation that must be fulfilled, we obtain the following equations:

$$k_{22} > 0;\ k_{12} > 0$$

"Thus, for specific values of λ parameters, the condition λ < 1 can be fulfilled, which makes the conflict-free state of the system stable (in the case of $u_1 = 0$ and $u_1 = 0$). This indicates conflict potential" (Pokornaya, 2009). We can represent this in the form of the following system of inequalities:

$$\begin{cases} k_{12} - k_{21} > 0 \\ k_{11}k_{22} < k_{12}k_{21} \end{cases}$$

We need to know that a system can only reach a conflict-free state when it is in state λ ≥ 1. Let's take a closer look at this situation:

$$\begin{cases} u_1^{(n)} = a_1\lambda_1^{(n)} + a_2\lambda_2^{(n)} \\ u_1^{(n)} = b_1\lambda_1^{(n)} + b_2\lambda_2^{(n)} \end{cases}$$

The notation represents the general solution of a linear homogeneous difference equation (recurrence relation) for u1(n) and u_2(n). The terms λ1n and λ_2n are powers of the characteristic roots λ1 and λ_2, which are obtained from the characteristic equation of the system. Constants a1, a_2, b1, b_2 are determined by initial conditions.

The system of equations for initial inconsistencies $u_1^{(0)}$, $u_1^{(n)}$ and inconsistencies in the first step of the integration process $u_1^{(1)}$, $u_2^{(1)}$ has the following form:

$$\begin{cases} a_1\lambda_1 + a_2\lambda_2 = u_1^{(0)} - k_{21}u_1^{(0)} - k_{22}u_2^{(0)} \\ b_1\lambda_1 + b_2\lambda_2 = u_2^{(0)} - k_{11}u_1^{(0)} - k_{12}u_2^{(0)} \\ a_1 + a_2 = u_1^{(0)},\ b + b_2 = u_2^{(0)} \end{cases}$$

For the expected result to be as close to true as possible, it is necessary to make sure that the path to truth is algorithmically correct during the transformation of $u_1 > 1$, $u_2 < 1$ and $a_1\lambda_2^{(n)}, b_2\lambda_2^{(n)}$ (Pokornaya, 2009). If we express, it in the form of the following equation:

$$\begin{cases} a_1 = \frac{u_1^{(0)}(1 - k_{21}) - k_{22}u_2^{(0)} - u_1^{(0)}\lambda_2}{\lambda_1 - \lambda_2} \\ b_1 = \frac{u_2^{(0)}(1 - k_{12}) - k_{11}u_1^{(0)} - u_2^{(0)}\lambda_2}{\lambda_1 - \lambda_2} \end{cases}$$

For the inconsistencies to be damped and equal to 0, the condition $a_1 < 0$ or $b_1 < 0$ must be met due to the inconsistencies u_1, $u_2$and the non-negative of these equations (Beal et al., 2022). We consider it using the following equation:

$$\begin{cases} u_1^{(0)}\left(1 - k_{21} - \lambda_2\right) - k_{22}u_2^{(0)} < 0 \\ u_2^{(0)}\left(1 - k_{12} - \lambda_2\right) - k_{11}u_1^{(0)} < 0 \\ \lambda_1 - \lambda_2 > 0 \end{cases}$$

As can be seen, for specific values of λ parameters is a criterion for the stability of the non-conflict state of the system (Beal et al., 2022). Its condition is fulfilled in the same way as in the following way:

$$\begin{cases} 1 - k_{21} - \lambda_2 < k_{22}\frac{m_2^{(0)}}{m_1^{(0)}} \\ 1 - k_{12} - \lambda_2 < k_{11}\frac{u_1^{(0)}}{u_2^{(0)}} \end{cases}$$

These conflict situations, as we have seen, are constantly evolving in the search for the most appropriate solutions to change. Examples show algorithmic equations during parametric modeling of some types of conflict situations with a high probability of occurrence.

6 Conclusion

Different sets of parametric values primarily make us think about the nature of conflict situations. To be able to model all sets of social parameters that occur during the process of their dynamic development in a form independent of time space, we can study them by referring to the most optimal types of truth equations. The culmination and development trends of conflict situational situations are different. To neutralize them, there is a need to first look for causes and consequences. But as the parametric equations show us, it is better not to strangle the conflict as much as possible (Beal et al., 2022).

After all, the specific weight of threats and threats from a suffocated conflict is significantly higher than that of an asphyxiated conflict. That's why parametric equations have taught us how to block conflicts that escalate to escalation, using algorithmic strategies. Although all the scientific research methods used as the basis in the scientific article belong to the Natural Sciences, they are also very necessary in predicting modern conflict situations and developing management strategies. In the future, mathematical modeling will be a combination of the most suitable methods for conducting complex interdisciplinary research. Examples of this can serve as an argument.

The conducted research on the use of parametric models for assessing political conflicts allows us to formulate a few significant conclusions and practical recommendations for government agencies.

Mathematical modeling of political conflicts demonstrates high efficiency in forecasting and analyzing conflict situations. The use of parametric models allows us to identify the key factors of conflict escalation, assess their intensity and predict possible scenarios of development. Of particular importance is the ability to quantify the risks and potential consequences of various management decisions.

Based on the analysis, it can be argued that the effectiveness of public administration in the field of prevention and resolution of political conflicts can be significantly improved through the introduction of mathematical modeling methods. At the same time, an integrated approach that considers both quantitative and qualitative parameters of conflict situations is critically important.

For practical application of the research results, it is recommended:

1. Create a unified information and analytical system for monitoring political conflicts based on parametric assessment models. The system should ensure continuous collection and analysis of data to identify signs of emerging conflicts at an early stage.
2. To introduce into the practice of public administration standardized methods for quantifying conflict potential based on mathematical models. This will improve the objectivity of decisions made and the effectiveness of preventive measures.
3. To organize regular professional development of employees of specialized departments of government agencies in the field of mathematical methods of analysis of political conflicts.

Further development of research in this area should be aimed at improving the mathematical apparatus, expanding the range of parameters considered, and improving the accuracy of predictive models. Special attention should be paid to adapting existing methods to the specific features of various types of political conflicts.

In conclusion, it should be emphasized that the successful application of mathematical methods in the study of political conflicts requires a systematic approach and should be based on modern achievements both in the field of mathematical modeling and in the field of political conflictology. Only such an integrated approach can ensure reliable results suitable for practical application in public administration.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

OY: Writing – original draft, Writing - review & editing, Resources, Validation, Formal analysis, Conceptualization, Methodology, Data curation, Investigation. SZ: Writing - original draft, Writing - review & editing, Formal analysis, Resources, Project administration, Methodology, Validation, Investigation, Supervision, Conceptualization, Funding acquisition. MN: Writing- original draft, Writing - review & editing, Conceptualization, Methodology, Formal analysis, Resources, Project administration, Supervision, Software, Data curation, Investigation, Funding acquisition.

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The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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