ABOUT ONE MATHEMATICAL AND COMPUTER MODEL FOR RESOLVING POLITICAL CONFLICTS WITH THE PARTICIPATION OF INTERNATIONAL INVESTMENT INSTITUTIONS

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Abstract. The article proposes intricate nonlinear mathematical models that address the realms of economic cooperation amid two politically adversarial sides, aiming to foster unity among the populace and achieve a harmonious conflict resolution. This model considers both economic and alternative types of collaboration among different groups and each part of the population. This collaborative effort is engineered to bridge the gap between the sides and facilitate peaceful conflict resolution.

Within the mathematical framework, the model inherently encompasses the governing bodies of both sides, as well as the involvement of a third external entity such as international institutions (investment funds), carry out economic interest (one of the methods of political pressure), that actively supports and promotes the process of economic cooperation. The core objective revolves around the formulation of mathematical problems, wherever the notion of conflict resolution is predicated upon certain conditions.

The conflict is considered to be resolved if the number of people willing to cooperate economically exceeds the threshold. Specifically, this threshold is met when over half of the respective side's population exhibits a desire for economic collaboration, constituting a "weak condition" of conflict resolution. Alternatively, conflict can be considered to be resolved under a "strong condition" when a significant majority of the population, often more qualified or influential individuals, express a commitment to engage in economic cooperation.

The article considers computer modeling of conflict resolution processes through economic cooperation between two politically opposed sides, MATLAB software environment, in case of variable coefficients.

In mathematical models, the variables of population and management are taken by exponential, power, and trigonometric functions, the calculations also show the number of people on both sides who want to cooperate from the very beginning and until the period of conflict resolution, according to the data, there were found the cases of coefficients where the conflict is resolved.

Several options for different demographic factors and conflict resolution periods are considered. It shows how the change of conflict resolution time and population at the time of conflict resolution. Accordingly, as the coefficients change, the relationships between coefficients change as well.

A graphical visualization of the obtained results is given below.

Keywords: *Computer modeling, mathematical models of resolution of conflict, variable coefficients of model.*

Introduction. Synergetics gave a powerful push for using mathematical models in social sciences: sociology, history, demography, political science, conflicting science, etc. The creation of mathematical models is original in social sphere, because, they are difficult to substantiate [1-15].

In 2005, the Nobel Prize in Economics was bestowed upon mathematicians Robert Aumann and Thomas Schelling, marking their exceptional contributions to the scientific realm with their pioneering work in the cycle „Understanding of the problems of the conflict and cooperation through the game theory“.

Delving into the intricacies of conflict, the principle of the „repeated game“ emerges as a significant facet within the domain of mathematical modeling, particularly within the framework of game theory. This principle underscores a crucial methodology: sustained interactions between competing entities possess the capacity to foster cooperation - a phenomenon often elusive within isolated, singular interactions. In essence, extended relationships kindle shared interests and establish the very foundations for collaboration.

Lee Kuan Yew, the visionary behind Singapore's remarkable „Economic Miracle“, once wisely advised, „If you want economic growth, do not break out the war with neighbors, establish trade relations with them, instead“.

In 2018, Professor Temur Chilachava proposed mathematical models for resolving political conflicts. Depending on the specifics and history of these political conflicts, four different mathematical models described by different nonlinear dynamic systems have been revealed [16].

Surveying the global landscape riddled with conflict zones, it becomes evident that mathematical models of this nature hold immense promise and novelty. These models incorporate not only innovative theories but also intricate computer simulations capable of delineating the conditions (and interdependencies of model parameters) conducive to conflict resolution.

In the wake of this understanding, new approach has been forged. New nonlinear mathematical models have been meticulously crafted, unveiling the contours of economic cooperation between two politically divergent yet non-warring factions. These models ingeniously encompass the prospect of economic and other forms of cooperation among distinct segments of the population, steering their trajectory toward mutual understanding and the harmonious resolution of disputes [17-35].

1. The conflict resolution mathematical model, in case of the government of both sides encourages the process of economic cooperation. The article considers a mathematical model describing of settlement of the political conflict between two opposing sides by means of economic cooperation (conflict resolution model in case of the government of both sides encourages the process of economic cooperation), which is described with the following nonlinear dynamic system

$$\begin{cases} \frac{dN_1(t)}{dt} = -\alpha_1(t)[a(t) - N_1(t)][b(t) - N_2(t)] + \beta_1(t)N_1(t)N_2(t) + \gamma_1(t)[a(t) - N_1(t)] \\ \frac{dN_2(t)}{dt} = -\alpha_2(t)[a(t) - N_1(t)][b(t) - N_2(t)] + \beta_2(t)N_1(t)N_2(t) + \gamma_2(t)[b(t) - N_2(t)] \end{cases} \tag{1.1}$$

with the initial conditions

$$N_1(0) = N_{10}, N_2(0) = N_{20}, \tag{1.2}$$

where in (1.1) - (1.2):

$N_1(t)$ - Number of the citizens of the first side in time-point$t$, willing or already being in economic cooperation;

$N_2(t)$ - Number of the citizens of the second side in time-point t, willing or already being in economic cooperation;

$a(t)$ - number of the citizens of the first side in the time-point t;

$b(t)$ - number of the citizens of the second side in the time-point t;

$\alpha_1(t)$- coefficients of aggression (alienation) of the first side;

$\alpha_2(t)$- coefficients of aggression (alienation) of the second side;

$\beta_1(t)$ - coefficient of cooperation of the first side;

$\beta_2(t)$ - coefficient of cooperation of the second side;

$\gamma_1(t)$ - coefficient of coercion to the cooperation of the first side;

$\gamma_2(t)$ - coefficient of coercion to the cooperation of the second side;

$N_1, N_1 \in C^1[0,T]$;

N_{10} - number of the citizens of the first side in the initial moment, wish being in economic cooperation;

N_{20} - number of the citizens of the second side in the initial moment, wish being in economic cooperation;

$[0,T]$ - time interval for model consideration.

In mathematical models, we consider the following conditions of conflict resolution:

Weak condition of conflict resolution (when more than half of the population of both sides support the process of economic cooperation):

$$\begin{cases} \frac{a(t)}{2} < N_1(t) \le a(t) \\ \frac{b(t)}{2} < N_2(t) \le b(t) \end{cases}, \quad t \ge t_1. \tag{1.3}$$

Strong condition of conflict resolution (when more than two-thirds of the population of both sides support the process of economic cooperation):

$$\begin{cases} \frac{2a(t)}{3} < N_1(t) \le a(t) \\ \frac{2b(t)}{3} < N_2(t) \le b(t) \end{cases}, \quad t \ge t_2. \tag{1.4}$$

2. Computer modeling of a mathematical model with variable coefficients of political conflict resolution. We consider computer modeling of tasks (1.1) - (1.2) when the variable coefficients are given as

$$\begin{gathered} a(t) = a_0 e^{n_1 \frac{t}{T}} \left(1 + n_1 \sin\left(\frac{5t}{T}\right)\right),\ b(t) = b_0 e^{n_2 \frac{t}{T}} \left(1 + n_2 \sin\left(\frac{5.5t}{T}\right)\right), \\ \alpha_1(t) = \alpha_{10} e^{n_3 \frac{t}{T}} \sqrt{2} \sin\left(\frac{1.5t}{T} + \frac{\pi}{4}\right),\ \alpha_2(t) = \alpha_{20} e^{n_4 \frac{t}{T}} \sqrt{2} \sin\left(\frac{2.1t}{T} + \frac{\pi}{4}\right), \\ \beta_1(t) = \beta_{10} e^{n_5 \frac{t}{T}} \sqrt{2} \sin\left(\frac{1.1t}{T} + \frac{\pi}{4}\right),\ \beta_2(t) = \beta_{20} e^{n_6 \frac{t}{T}} \sqrt{2} \sin\left(\frac{2.2t}{T} + \frac{\pi}{4}\right), \\ \gamma_1(t) = \gamma_{10} e^{n_7 \frac{t}{T}} \sqrt{2} \sin\left(\frac{1.25t}{T} + \frac{\pi}{4}\right),\ \gamma_2(t) = \gamma_{20} e^{n_8 \frac{t}{T}} \sqrt{2} \sin\left(\frac{1.2t}{T} + \frac{\pi}{4}\right), \end{gathered} \tag{2.1}$$

or

$$a(t) = a_0 \left(\frac{t}{T}\right)^{n_1} \left(1 + n_1 \sin\left(\frac{5t}{T}\right)\right),\ b(t) = b_0 \left(\frac{t}{T}\right)^{n_2} \left(1 + n_2 \sin\left(\frac{5.5t}{T}\right)\right),$$

$$\alpha_1(t) = \alpha_{10} \left(\frac{t}{T}\right)^{n_3} \sqrt{2} \sin\left(\frac{1.5t}{T} + \frac{\pi}{4}\right),\ \alpha_2(t) = \alpha_{20} \left(\frac{t}{T}\right)^{n_4} \sqrt{2} \sin\left(\frac{2.1t}{T} + \frac{\pi}{4}\right), \quad (2.2)$$

$$\beta_1(t) = \beta_{10} \left(\frac{t}{T}\right)^{n_5} \sqrt{2} \sin\left(\frac{1.1t}{T} + \frac{\pi}{4}\right),\ \beta_2(t) = \beta_{20} \left(\frac{t}{T}\right)^{n_6} \sqrt{2} \sin\left(\frac{2.2t}{T} + \frac{\pi}{4}\right),$$

$$\gamma_1(t) = \gamma_{10} \left(\frac{t}{T}\right)^{n_7} \sqrt{2} \sin\left(\frac{1.25t}{T} + \frac{\pi}{4}\right),\ \gamma_2(t) = \gamma_{20} \left(\frac{t}{T}\right)^{n_8} \sqrt{2} \sin\left(\frac{1.2t}{T} + \frac{\pi}{4}\right),$$

Functions, where

- n_1 – first side demographic factor coefficient;
- n_2 – second side demographic factor coefficient;
- n_3 – first side aggression factor coefficient;
- n_4 – second side aggression factor coefficient;
- n_5 – first side cooperation factor coefficient;
- n_6 – second side cooperation factor coefficient.
- n_7 – coefficient of first-side cooperation (alienation);
- n_8 – coefficient of second side cooperation (alienation);

For computer modeling, we have selected the following initial data of population quantity:

- $a_0 = 7.5 \cdot 10^6$ – the population of the first side at the initial moment of time;
- $b_0 = 3.95 \cdot 10^7$ – the population of the second side at the initial moment of time;

Taking into account (2.1), and (2.2) we determined the following orders of the coefficients:

- α_{10}, α_{20}: -12;
- β_{10}, β_{20}: -10;
- δ_{10}: -4;
- γ_{10}: -5;

The subsequent initial data were meticulously curated to serve as the foundation for computational modeling.

Case 1:

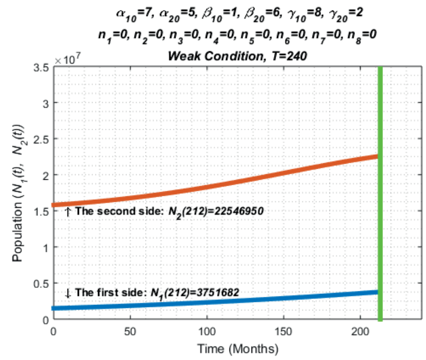
Consider the case with the following initial conditions:

$N_{10} = 1.5 \cdot 10^6$ – 20% of the population of the first side, willing cooperation from the beginning;

$N_{20} = 1.58 \cdot 10^7$ – 40% of the population of the second side, willing cooperation from the beginning;

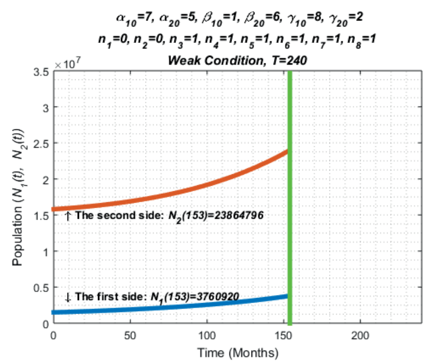
Case 1.1:

In case of functions (coefficients are given on the graph), the conflict resolution time is determined as 212 months:



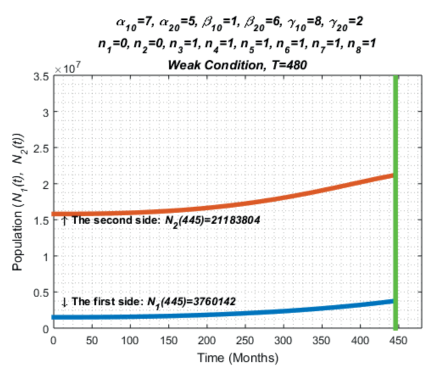
Case 1.2:

If we take 1 instead of 0 as the control parameters in case of (1.2), then the conflict resolution time will decrease from 212 months to 153 months:



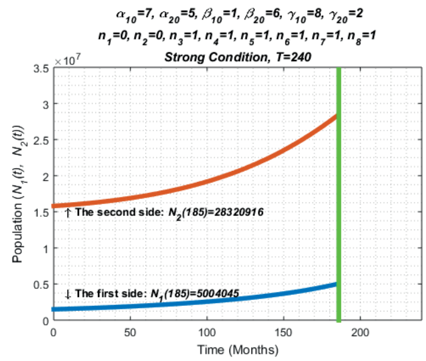
Case 1.3:

If we consider the case (1.2) for functions (2.2), then we will have to increase the conflict resolution period to 480 months in order to regulate the conflict:



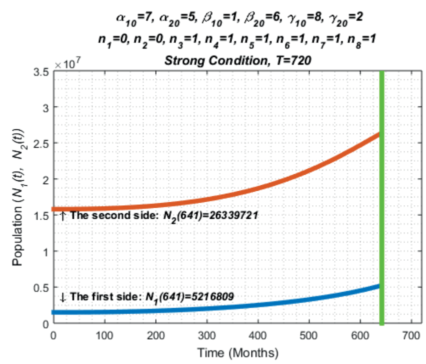
Case 1.4:

If we consider the case (1.2) for a strong condition, then the conflict resolution time will increase from 153 months to 185 months:



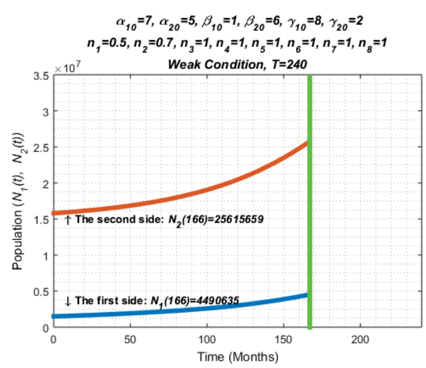
Case 1.5:

If we consider the case (1.3) for a strong condition, then the conflict resolution period should be increased from 480 months to 720 months:



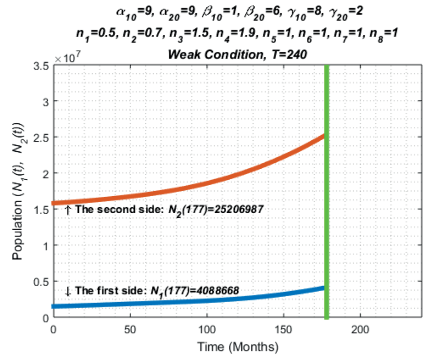
Case 1.6:

If we increase the coefficients of the demographic factor in the case (1.2), then the conflict resolution time will increase from 153 months to 166 months:



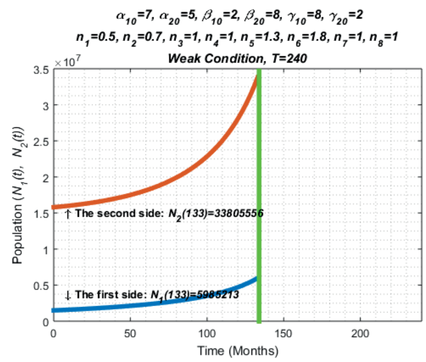
Case 1.7:

If in the case (1.6) we increase the coefficients of aggressiveness and aggressiveness factor of the both sides, then the time to resolve the conflict will increase from 166 months to 177 months:



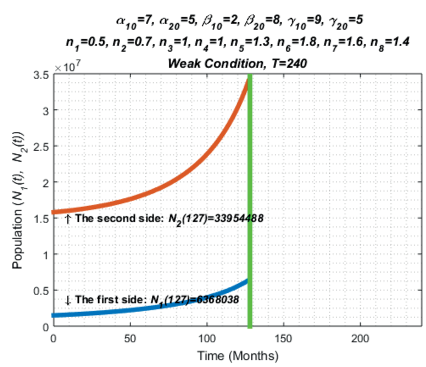
<u>Case 1.8:</u>

If in the case (1.6) we increase the coefficients of cooperation and cooperation factor of both sides, then the time of conflict resolution will decrease from 166 months to 133 months:



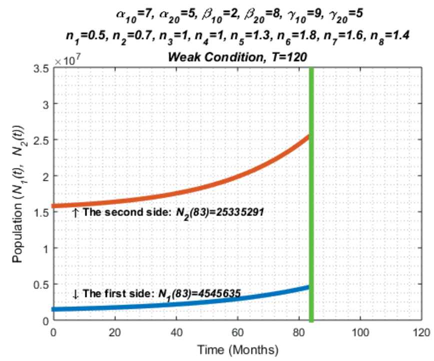
<u>Case 1.9:</u>

If in the case (1.8) we increase the coefficients of the coercion of both sides and the coercion factor, then the time for conflict resolution will decrease from 133 months to 127 months:



<u>Case 1.10:</u>

If in the case (1.9) we reduce the conflict resolution period from 240 months to 120 months, then the conflict resolution time will decrease from 127 months to 83 months:



<u>Case 2:</u>

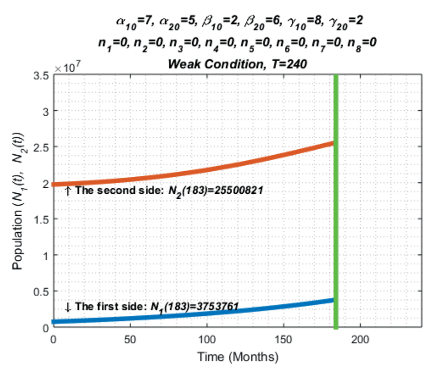
Consider the case with the following initial conditions:

$N_{10} = 7.5 \cdot 10^5$ – 10% of the population of the first side, willing cooperation from the beginning;

$N_{20} = 1.975 \cdot 10^7$ – 50% of the population of the second side, willing cooperation from the beginning;

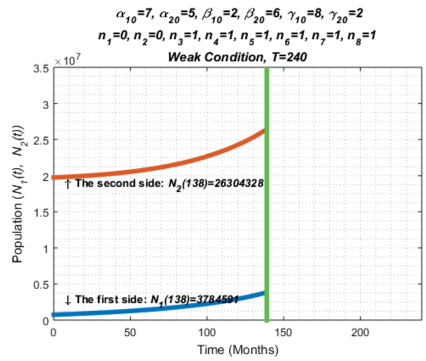
<u>Case 2.1:</u>

In the case (1.1), the conflict could not be resolved with the coefficients, because at the initial moment of time, a smaller number of the population of the first party wants to cooperate, so we need to increase the cooperation coefficient of the first party:



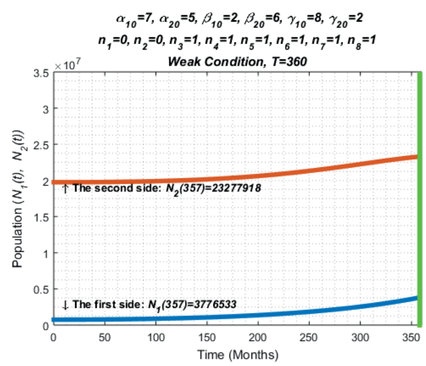
<u>Case 2.2:</u>

If we take 1 instead of 0 as the control parameters in the case (2.1), then the conflict resolution time will decrease from 183 months to 138 months:



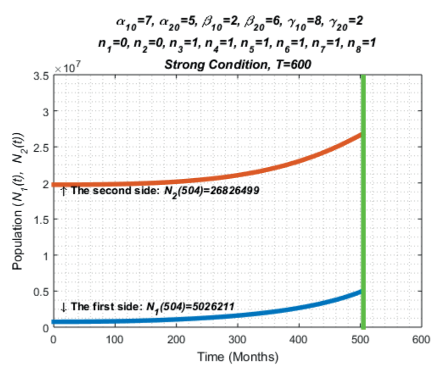
Case 2.3:

If we choose functions (2.2) in the case (2.2), then we need to increase the conflict resolution period from 240 months to 360 months to resolve it:



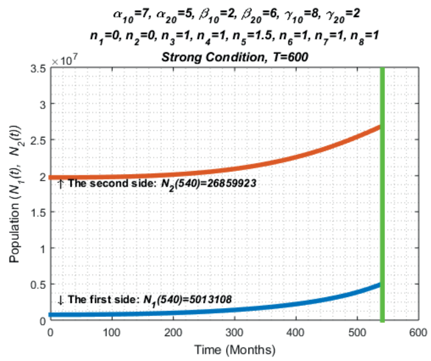
Case 2.4:

If the strong conflict resolution condition must be fulfilled in the case (2.3), then we must increase the conflict resolution period from 360 months to 600 months to resolve the conflict:



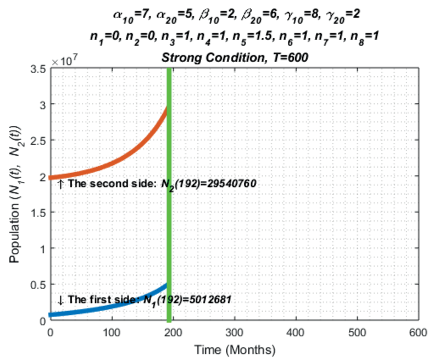
Case 2.5:

If in the case (2.4) we consider the functions (2.2) and increase the coercion coefficient of the first party to cooperate, then the conflict resolution period will increase from 504 months to 540 months:



Case 2.6:

If in the case (2.4) instead of functions (2.2) we consider functions (2.1) and increase the coefficient of coercion of the first party, then the period of conflict resolution will decrease from 504 months to 192 months:



Case 3:

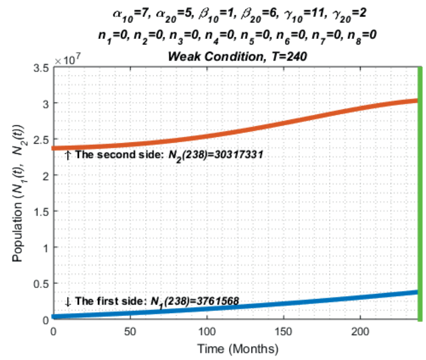
Consider the case with the following initial conditions:

$N_{10} = 3.75 \cdot 10^5$ – 5% of the population of the first side, willing cooperation from the beginning;

$N_{20} = 2.37 \cdot 10^7$ – 60% of the population of the second side, willing cooperation from the beginning;

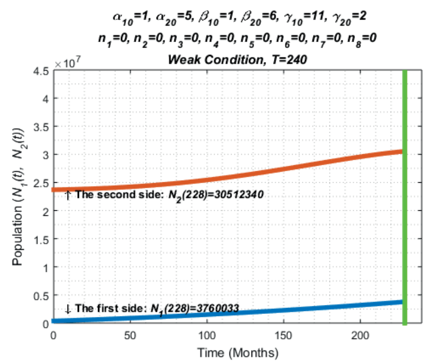
Case 3.1:

With the parameters of the case (1.1), the conflict cannot be resolved, because, at the initial moment of time, a smaller number of the population of the first party wants to cooperate, so we have to increase the coercion coefficient of the first party to cooperate:



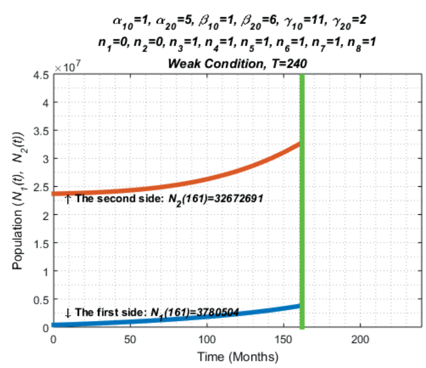
Case 3.2:

If in the case (3.1) we reduce the coefficient of aggressiveness of the first party, then the time to resolve the conflict will decrease from 238 months to 228 months:



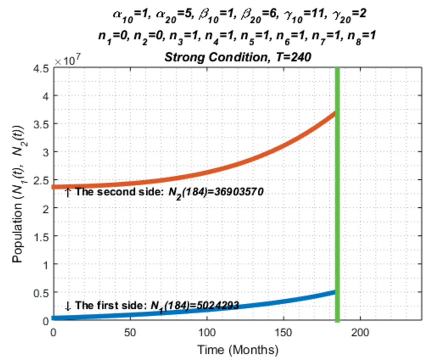
Case 3.3:

If in the case (3.2) we take the value of the management coefficient factor as 1, then the conflict resolution time will decrease from 228 months to 161 months:



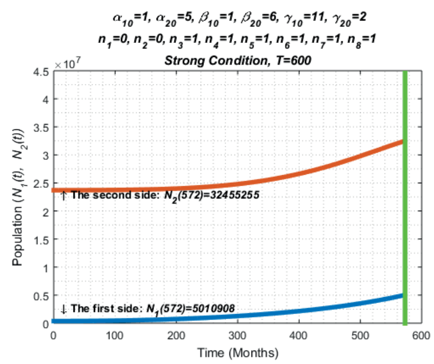
Case 3.4:

If we consider the case (3.3) for the strong condition, then the conflict resolution time will increase from 161 months to 184 months:



Case 3.5:

If we consider functions (2.2) in the case (3.4), then the conflict resolution period should be increased to 600 months:



Conclusion. In the article, the computer modeling of the processes of conflict resolution through economic cooperation between two politically opposed sides is carried out with variable coefficients using the MATLAB software environment. In mathematical models, population and governance variable coefficients are shown by exponential, power and trigonometric functions, the number of populations of both sides willing to cooperate is indicated during calculations. There is also shown the period of conflict review. According to the data, the coefficients show the cases when the political conflict is resolvable. Several different options for conflict resolution time and demographic factors are taken into consideration. When the coefficients change, it is shown how the conflict resolution time and the population at the moment of the conflict resolution change, as well as the interrelationship between the coefficients. A graphical representation of the obtained values is provided.

During variable coefficients, computer modeling is run. Based on the obtained results, we can emphasize that the range of conflict resolution depends on both the condition of conflict resolution and the time of conflict review, as well as the coefficients considered in the mathematical model. When the coefficients in the model are taken by exponential, power, and trigonometric functions, the relationships between the coefficients of population composition, negative attitude and cooperation factor, and the time interval of conflict resolution are confirmed by computer calculations and it is also constructed graphically.

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