Diagnostic Model for the Society Safety under Covid-19 Pandemic Conditions

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ABSTRACT

The aim of this paper is to develop an information-modeling method for assessing and predicting the consequences of the COVID-19 pandemic. To this end, a detailed analysis of official statistical information provided by global and national organizations is carried out. The developed method is based on the algorithm of multi-channel big data processing considering the demographic and socio-economic information. COVID-19 data are analyzed using an instability indicator and a system of differential equations that describe the dynamics of four groups of people: susceptible, infected, recovered and dead. Indicators of the global sustainable development in various sectors are considered to analyze COVID-19 data. Stochastic processes induced by COVID-19 are assessed with the instability indicator showing the level of stability of official data and the reduction of the level of uncertainty. It turns out that the number of deaths is rising with the Human Development Index. It is revealed that COVID-19 divides the global population into three groups according to the relationship between Gross Domestic Product and the number of infected people. The prognosis for the number of infected people in December 2020 and January-February 2021 shows negative events which will decrease slowly.

Keywords: COVID-19, Pandemic, Indicator, Model, algorithm, prognosis, population safety

1. Introduction

Despite the unprecedented discussions on sustainable development, the current negative interactions between society and nature are paradoxical. (Cracknell and Varotsos, 2007, 2011; Varotsos et al., 2019a,b). Various discussions on the survivability of the Nature/Society System (NSS) based on advanced global models are gaining new content and interest (Forrester, 1971; Kondratyev et al., 2004; Krapivin and Varotsos, 2007, 2008; Krapivin et al., 2012, 2017). Many substantial features of the current state of NSS complicate the assessment of trends in sustainable development as an indicator of population safety. The global COVID-19 pandemic processes introduce uncertainties into the economic strategies of almost all countries, which reduces the living standards of the population. COVID-19 can be seen as a new global threat to humanity that is rapidly spreading to all countries and marking the end of conventional life (HDP, 2020). Unfortunately, the second COVID-19 wave showed that almost all countries did not acquire reliable experience in both protecting against new stages of the virus and reducing health and standard of living risks. It is clear that COVID-19 is a significant and urgent threat to the health of the global population. Since December 2019, when COVID-19 infection began to spread from Hubei Province, more than 54 million cases of infection have been confirmed in more than 200 countries. The perspective of human development is determined by the human capacity for a long-term response to the effects of COVID-19 and by a resource allocation strategy that is indeed declining during 2020. Certainly, human capabilities play a significant role in responding to the COVID-19 crisis, including non-pharmaceutical interventions in social life, including social distancing, peoples' ability to interact with others at work, school, shopping, and leisure (WBG, 2020).

An issue of NSS survivability previously discussed by the Club of Rome and other authors concerns global models where the problems of limited energy resources and overpopulation must be addressed in different scenarios for predicting global climate change (Forrester 1971; Kondratyev et al., 2004; Krapivin and Varotsos, 2007, 2008; Krapivin et al., 2017; Meadows et al., 1972). Environmental and anthropogenic hazards and their mitigation have been the focus of much scientific research, as many governments could control air and water quality by making catalytic decisions to manage pollution processes. In the current circumstances, making such decisions has many limitations due to COVID-19.

Practically, unexpected and immediate global dispersion of COVID-19 in 2019 revises the traditional representation of interactions between nature and society by changing the priorities and indicators of sustainable development of the NSS (SDG, 2020). Ethical aspects of appropriate human-government interactions as well as approaches to the operation of natural life support systems must be considered. Numerous mathematical models have been developed to predict the spread and effects of COVID-19 disease and to understand how it rapidly affected the daily lives of the global population, business, and the disruption of the world trade and the movement of population groups and individuals (Nave et al., 2020; Varotsos and Krapivin, 2020). According to official statistics COVID-19 spreads very quickly from person to person, essentially not according to the various restrictions associated with human migration. The significant effects on the daily lives of citizens are limited, causing the social crisis in many countries.

Many publications attempt to develop algorithms and models using that they can provide constructive prognostic mechanisms for evaluating the effects of COVID-19 and the effectiveness of limited risk mitigation measures. Lagadinou et al. (2020) analyzed the possible effects of COVID-19 using biomarkers as predictive factors of the disease taking into account the demographic characteristics of patients. Nave et al. (2020) attempted to evaluate the stability of COVID-19 disease by looking for the equilibrium points in the system of differential equations that describe the interactions between disease characteristics. Yanev et al. (2020) proposed a suitable model for the development of COVID-19 infection in the population and calculated the infection rate of individuals based on daily statistics and predicted this parameter for the unobserved population. He et al. (2020) used a discrete-time stochastic model to study patients' epidemiological status and assess the risk of returning to work at different times. Ivorra et al. (2020) proposed a new model that allows the estimation of the number of infected cases, deaths and hospital bed needs. This model uses epidemiological features of the COVID-19 pandemic, placing each individual in one of the following groups: exposed, infected, hospitalized, recovered and dead. These and similar publications make progress in the understanding the role of various pandemic scenarios, such as isolation, quarantine, tracing, increase of health resources and classification of patients by age.

This paper analyzes COVID-19 global epidemiological data by correlating them with demographic statistics to understand and predict future global and regional dynamics of pandemic features. To this end, a previously proposed COVID-19 decision-making system (CDMS) is being upgraded, based on demographic data and existing pandemic statistics from December 2019 to November 2020.

2. Materials and Method

The material of this study was obtained from official statistics and literature sources. Official statistics provides real-time information on the number of susceptible (S (t)), infected ($P(t)$), recovered ($R(t)$), and dead ($D(t)$) as well as data on various World Development Indicators (WDI) covering a range of countries by poverty, health, and demographics, trade, and

environment. To describe the role of a given country in the world sustainable development, the Sustainable Development Goals (SDG) indicator is used. The official indicator list includes the Human Development Index (HDI), the Food Production Index (FPI), the Human Capital Index (HCI) etc. (Jahan and Palanivel, 2018; Poudel et al., 2020; WBG, 2020). Reliable evaluation of global COVID-19 results in a given country with forecast is feasible taking into account the maximum number of information sources and the use of algorithms for big data processing (Krapivin et al., 2015; Varotsos and Krapivin, 2017). The main problem that arises here is the timely heterogeneity of information flows, the overcoming of which is suggested by a decision-making procedure illustrated in Figure 1. This procedure is supported by the Social System Simulation Model (SSSM) developed by Varotsos and Krapivin (2017). SSSM generates and synchronizes data feeds as X vector components (x_1, x_2, …, x_k) that reflect NSS features such as $S(t)$, $P(t)$, $R(t)$, $D(t)$, HDI, FPI, population density, GDP, age structure, different indicators of restrictions (masks, medical service, restriction of social contacts, quarantine, closure of schools and organizations). The components of this vector are processed by SSSM.
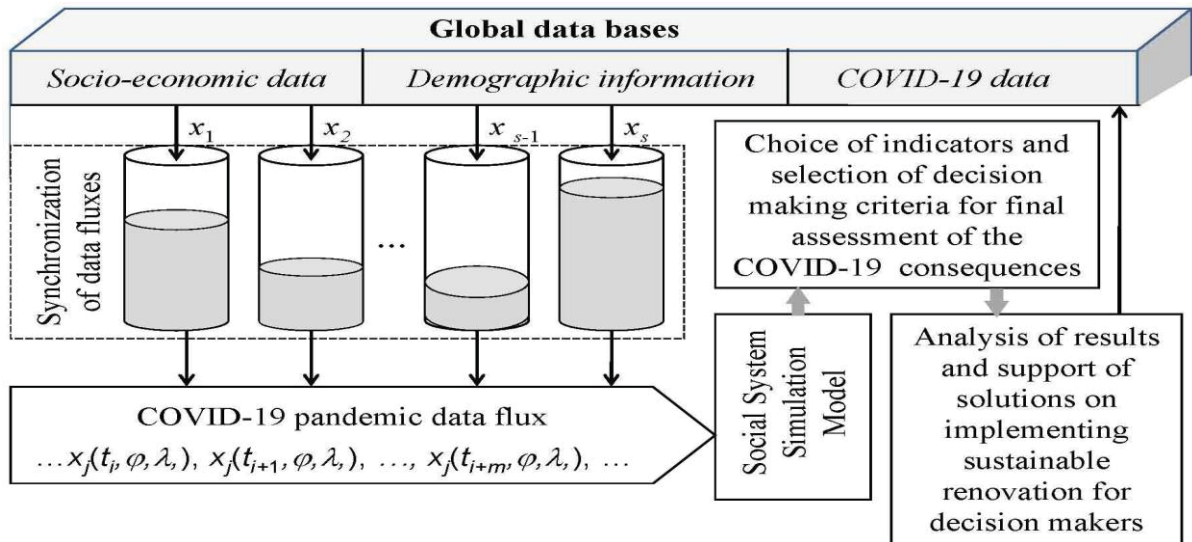

Fig. 1. Block-scheme of the decision-making system for assessing human development trends during the COVID-19 pandemic. Notation: φ and λ are latitude and longitude, respectively.

The prediction of the distribution of the population groups affected by COVID-19 is done through the following mathematical model as a function of the SSSM block:

$$\begin{cases} S_\Xi(t+\Delta t) = S_\Xi(t) - [ab(t)S_\Xi(t)P_\Xi(t)/n]\Delta t \\ P_\Xi(t+\Delta t) = P_\Xi(t)\{1 + b(t)S_\Xi(t)/n - c(t)\}J_\Xi(t)\Delta t \\ R_\Xi(t+\Delta t) = R_\Xi(t) + c(t)q(t)P_\Xi(t)\Delta t \\ D_\Xi(t+\Delta t) = D_\Xi(t) + d(t)[1 - q(t)]P_\Xi(t)\Delta t \end{cases} \tag{1}$$

where t is the running time, Δt is the operation time interval, $b(t)$ is the probability of transition at time t, a is the immune indicator, $c(t)$ is the recovery rate at time t, $d(t)$ is the disease-related death rate, $q(t)$ is the medical support indicator, $J(t)$ is the instability indicator of stochastic component, Ξ is the country indicator, n is the number of countries.

The parameters in (1) are evaluated by statistical analysis of official COVID-19 data (Chen et al., 2020; Varotsos and Krapivin, 2020):

$$b(t) = \left[\Delta P_\Xi(t) + \Delta R_\Xi(t)\right] / P_\Xi(t) \, , \quad c(t) = \Delta R_\Xi(t) / P_\Xi(t) \tag{2}$$

The analysis of official statistical data reflects the evolution of the COVID-19 impact indicators and the strategic components aimed at reducing the number of infected people and deaths, allowing the evaluation of the management parameters in (1). The evaluation of these parameters for selected countries is given in Table 1.

Table 1

Management parameters of COVID-19 spread in different countries.

Country	b	c	a	d	q
Countries with GDP>2×10^{12} current &USD					
USA	0.095	0.019	0.31	0.056	0.68
China	0.076	0.021	0.63	0.055	0.75
Japan	0.081	0.014	0.45	0.053	0.79
Germany	0.089	0.021	0.42	0.047	0.81
India	0.079	0.023	0.52	0.054	0.72
United Kingdom	0.087	0.033	0.38	0.057	0.78
France	0.091	0.026	0.39	0.092	0.79
Italy	0.093	0.036	0.44	0.043	0.72
Countries with GDP<2×10^{12} current &USD					
Brazil	0.088	0.022	0.44	0.058	0.67
Greece	0.089	0.111	0.54	0.052	0.76
Canada	0.082	0.017	0.68	0.047	0.81
Russia	0.077	0.018	0.71	0.013	0.77
Indonesia	0.079	0.032	0.55	0.055	0.67
Finland	0.073	0.034	0.66	0.049	0.8.2
Kazakhstan	0.075	0.029	0.72	0.048	0.83
Bulgaria	0.092	0.027	0.47	0.035	0.78
Tunisia	0.080	0.013	0.61	0.062	0.79

The official data on the components of vector X are characterized by certain levels of overcoming uncertainty from which it is possible by calculating the instability indicator that helps to reduce the level of uncertainty in the observed data which helps to forecast the COVID-19 consequences. All processes caused by COVID-19 have a stochastic component, a stability of which characterizes the level of uncertainty in the observed data and helps to forecast epidemic characteristics more accurately. The indicator instability ($J(t)$) is calculated by the following equation (Krapivin et al., 2015; Krapivin and Soldatov, 2009; Krapivin and Mkrtchyan, 2009, 2019; Sukov et al., 2008):

$$J(t) = \frac{1}{Nk} \sum_{j=M}^{M+N} \sum_{i=1}^{s} \xi_i U_i(t_j) \tag{3}$$

where N is the mean time interval, M is the time in data entry, k is the number of vector X components, $\xi_i \in [0.1]$ is the significance level of the *i-th* characteristic,

$$U_i(t_j) = \begin{cases} 1 \text{ when } \Delta x_i(t_j) \cdot \Delta x_i(t_{j-1}) \leq 0; \\ 0 \text{ when } \Delta x_i(t_j) \cdot \Delta x_i(t_{j-1}) > 0 \end{cases} \tag{4}$$

$$\Delta x_i = \bar{x}_i - x_i; \quad \bar{x}_i(N) = \frac{1}{N}\sum_{j=1}^{N} x_i(t_j); \; t_i - t_{j-1} = \Delta t \qquad (5)$$

3. Results and discussion

A comparison of the numbers of the daily death rates due to COVID-19 in April-August and September-November worldwide shows the dynamic deterioration of the condition with negative medical and social results and the human losses of COVID-19 exceed the human losses due to malaria, suicide, road traffic accidents, HIV/AIDS, self-harm etc. (UNDP, 2020), It is obvious that COVID-19 has created a social, economic and political crisis around the world, an overcoming of which is the main problem in almost more countries. The real situation shows that there is some confusion in the management structures under the choice of a constructive strategy to deal with pandemic consequences and minimize future losses. The main ways to overcome the negative effects of the pandemic are to assess the marketability of sustainable development goals (Srivastava et al., 2020). In practice, the search for human strategy comes to a solution of mini-max equation where the payoff function is the number of deaths due to COVID-19 (Krapivin and Varotsos, 2007, 2008). Strategic human components practically in all countries include identical internal and external restrictions on the spread of virus. The decision-making system illustrated in Figure 1 helps to assess the effectiveness of these restrictions and to understand a possible trend in the future development of human society.

Figure 2 shows the correlation between the Human Development Index (HDI) and the number of deaths due to COVID-19. The result demonstrates that strategic solutions in countries with low HDI are more effective than in countries with high HDI. Unfortunately, the strategic losses of COVID-19 have no reliable pharmaceutical explanation and occur only in the number of infected individuals. An analysis of official statistics on the impact of the COVID-19 pandemic shows a significant delimitation of countries by GDP that does not lead to the development of an international strategy to protect the world's population from the COVID-19 virus.

In practice, most countries use an obvious set of strategic tools to reduce the impact of the COVID-19 pandemic, including different restrictions on the contacts of people who expect to reduce the spread of the pandemic. Very likely only China and Vietnam distinguish from the management strategy that provides the minimum number of deaths both at the beginning of the pandemic period and in October-November 2020 when there was the second wave of pandemic. It is clear that a strategic set of measures needs to be modernized to protect the standard of living of the majority. Indeed, the world population can be divided into three groups living in different zones per level of GDP (Figure 3):

- *Survivability zone* (A). This group of people is most affected by coronavirus infection, such as job losses, deteriorating medical care and social restrictions.
- *Moderate zone* (B). People living in this zone are experiencing socio-economic restriction to a minority degree due to financial support from governments and other funds.
- *Restoring zone* (C). COVID-19 spread statistics has shown the existence of countries where socio-economic restrictions are minimized or absent. This is achieved at the expense of a weighted strategy for controlling the spread of the virus and managing social processes, with the exception of personal restrictions.
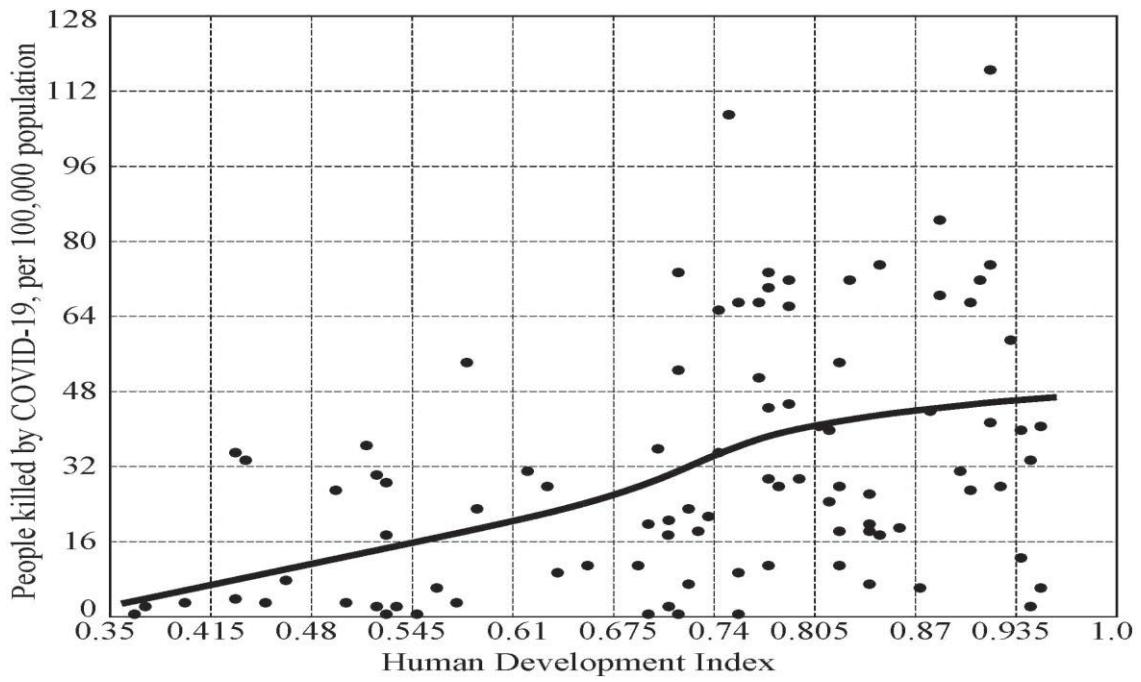
Fig. 2. Dependence of the number of deaths on the Human Development Index during the COVID-19 period (November 2020).
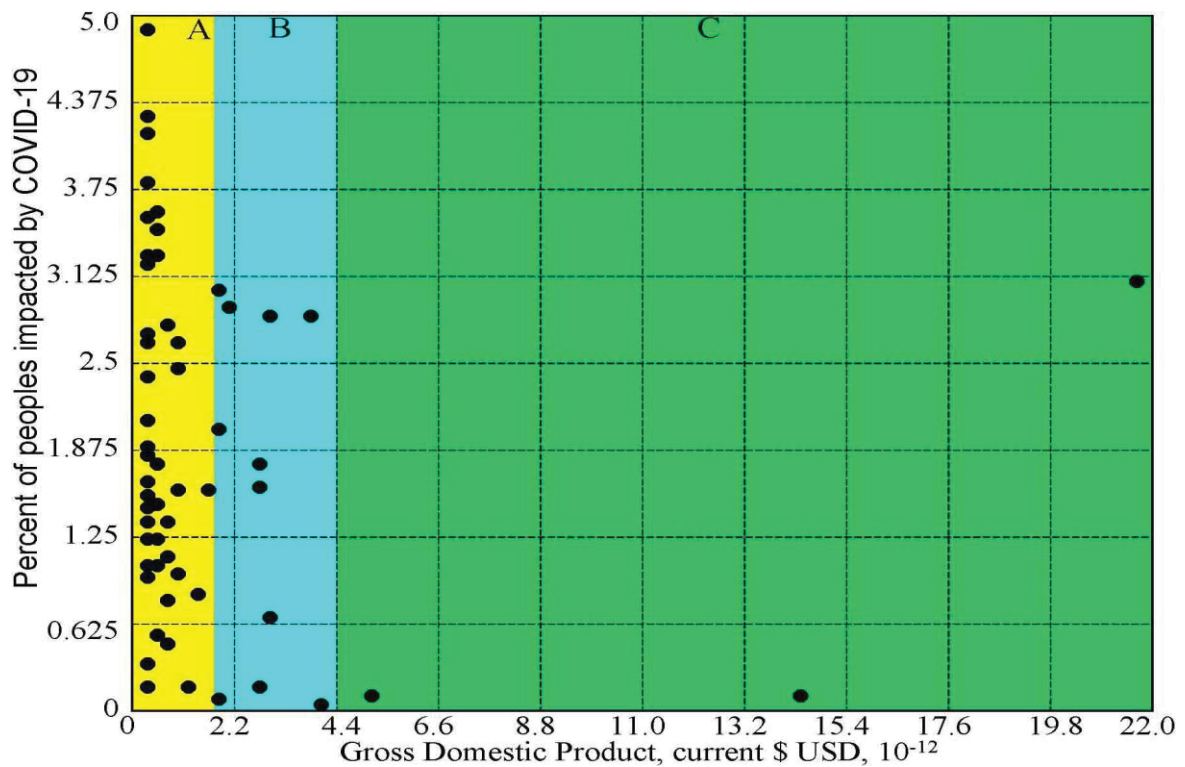

Fig. 3. Zone structure of the world population in the context of survivability during the COVID-19 pandemic.

Figure 4 demonstrates the trends in the number of infected individuals while maintaining existing social restrictions. The precision of the official data approach for October-November is 97.2 percent. The simulation results show that the number of infected people will increase substantially in the next two months. The comparative analysis of the results depicted in Figs 2-4 shows that the role of governments is important in responding quickly to the pandemic challenge and in supporting the effective balance between financial resources and the health of the population.

A comparative analysis of COVID-19 data in many countries shows that high level of GDP does not help reduce the number of infections and, conversely, countries with low levels of GDP show a small percentage of infected people. Certainly, there is a factor of undetected or undocumented cases, as it is necessary to consider large and small areas that are important factors for the spread of the disease. Ivorra et al. (2020) noted that the spread between countries has a documented effect on the results of the distribution of infections. The results in Table 2 demonstrate how COVID-19 infections change when the following scenario occurs within the restricted area:

- passengers who arrived in the territory (country) are directed to quarantine not depending on the positive test;
- socio-economic and industrial organizations work without restrictions; and
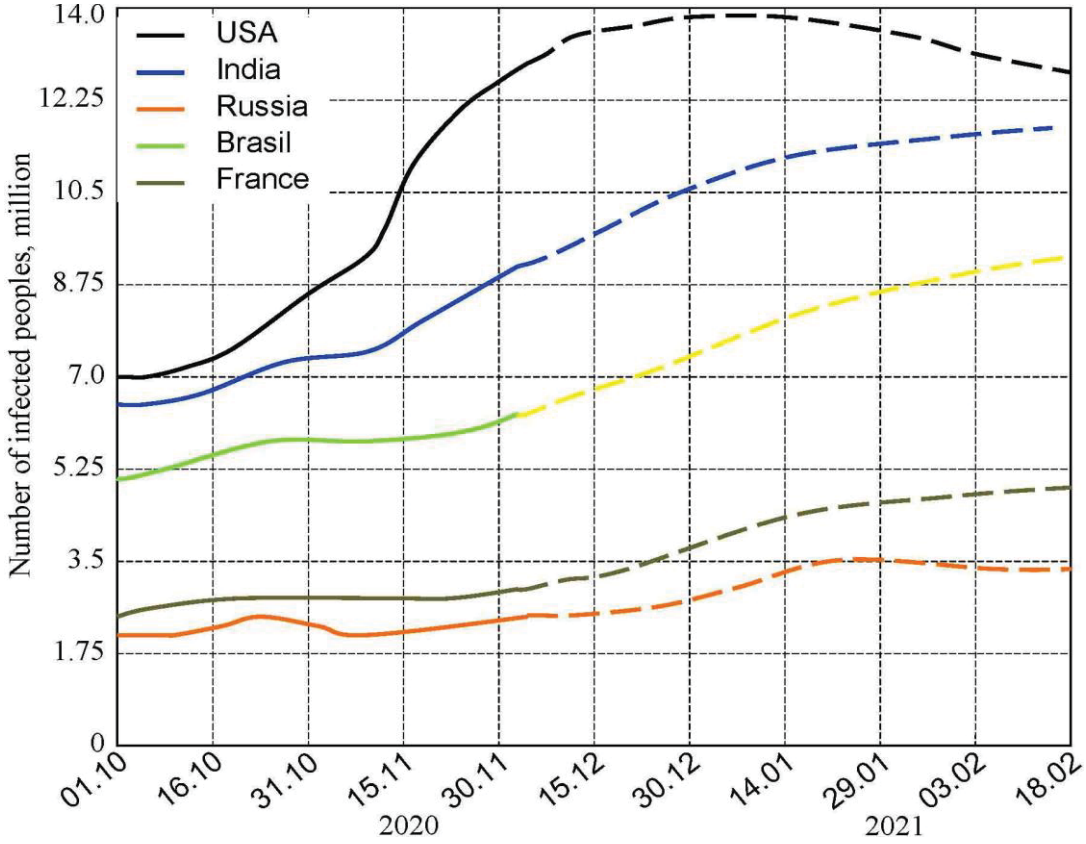- public health inspectors regularly monitor the population for COVID-19 symptoms.

Fig. 4. Prediction of the number of infected individuals under conditions when defense strategies do not change.

The hypothetical implementation of this scenario could give any country in Table 2 a 12-18 percent reduction in deaths over two months. Certainly, this can be done with little probability due to unacceptable for trans-commercial organizations. In other words, there is management that maintains the structure and subject matter of which can be evaluated through the method developed here.

Table 2

Prediction of the death rate in some selected countries when the above scenario is used from 01.12.2020.

Country	December 2020		January 2021		February 2021	
	01.12.2020	20.12.2020	15.01.2021	30.01.2021	10.02.2021	28.02.2021
USA	2.34	2.33	2.27	1,89	1.84	1,78
Brazil	2.91	2.89	2.83	2.65	2.59	2.54
United Kingdom	3.96	3.93	3.73	3.58	3.37	3.26
Italy	4.27	4.14	3.93	3.77	3.71	3.59
France	2.32	2.21	2.16	2.05	1.97	1.89
Russia	1.72	1.67	1.64	1.59	1.52	1.47
Germany	1.69	1.64	1.57	1.51	1.46	1.41
India	1.52	1.46	1.41	1.35	1.29	1.24
Indonesia	3.29	3.19	3.06	2.94	2.85	2.73
South Africa	2.69	2.58	2.49	2.38	2.31	2.23
Philippines	1.92	1.84	1.77	1.69	1.63	1.58

4. Conclusions

The World Health Organization is concerned about the current epidemiological situation of the second pandemic wave and sets the main objective of establishing and maintaining a set of indicators to more effectively support governments decisions to minimize COVID-19 pandemic losses (WHO, 2020). Varotsos and Krapivin (2020) proposed an instability indicator to assess trends in data characterizing the number of infected and dead. This paper, which uses this indicator, analyzes official data on the effects of the COVID-19 pandemic and identifies the phenomenon of global population distribution into three groups characterized by GDP levels in pandemic management. The results obtained help to evaluate the measures to limit the effectiveness of potential ways of COVID-19 spread. In the light of a global pandemic, the role of restrictions imposed by governments can be assessed using a decision-making system presented in Figure 1.

Indeed, coronavirus disease that spreads across a country can be modelled on the occasional walk of an object on a plane when studying both mathematics and the epidemiology of the probability of its transition between different positions. The difference between the traditional stochastic problem and the COVID-19 case is the association of the virus spread with many socio-economic and demographic indicators. The use of different restrictions on the spread of the virus leads to the deterioration of the living conditions of the population and poses obstacles to the way of development of the country as a whole. The results from Table 2 show that there is a simple management scenario, the implementation of which by country can help reduce the negative impact on the population due to the small number of restrictions on international tourists and aviation passengers.

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