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PREDICTION MODEL OF THE PANDEMIC SPREADING BASED ON WEIBULL DISTRIBUTION

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Abstract:
Pandemics have the potential to cause immense disruption of our everyday activities and has impact on the communities and societies mainly through the restrictions applied to the business activities, services, manufacturing, but also education, transportation etc. Therefore, it is important to create suitable prediction models to establish convenient methods for the planning of the operations and processes to cope with the difficulty. In this paper, the prediction model for the spread of the viral disease in term of the estimated maximal weekly confirmed cases and weekly deaths using the Weibull distribution as a theoretical model for statistical data processing is presented. The theoretical prediction model was applied and confirmed on the data available for the whole world and compared to the situation in Europe and Slovakia for the pandemic waves and can be used for the more precise prediction of the pandemic situation and to enhance planning of the activities and processes regarding to the restrictions applied during the worsening pandemic situation.

Key words: *Pandemics, Prediction model, Weibull distribution*

INTRODUCTION

A pandemic can be defined as an epidemic of an infectious disease that has spread across a large region and affecting a substantial number of individuals. A widespread endemic disease with a stable number of infected individuals such as recurrences of seasonal influenza is not a pandemic, as they occur simultaneously in large regions of the globe rather than being spread worldwide. Therefore, in comparison to the endemic disease, it is much more complicated to predict behavior and spread of the pandemic and to estimate for example the number of confirmed cases. And considering the current situation related to the COVID-19 pandemic accompanied with high number of deaths, under the circumstances until for example vaccination is not available, as the most effective way how to eliminate spread of the virus is the temporary or permanent isolation from other people. However, the insolation itself has a immense disruption of our everyday life, activities and due to the restrictions and governmental regulations that are applied to slow the spread of the disease. And these can have significant impact on the business activities, services, manufacturing process, but also on the education, transportation etc.

Therefore, many studies deal with the mathematical models, related spread and consequences of the pandemic situation on the health, society, industry, economics and technology [1]. These models can be based for example on the stochastic model of the transmission dynamics of the pandemic [2], on the forecasting using the different types of linear regression models [3, 4] or even on the prediction models based on the artificial intelligence [5], deep learning models [6, 7] or fuzzy logic mathematics [8, 9]. For the prediction of the spread of the pandemic also for example logistic model [10] or arenas model [11]. In some studies, the prediction models are only short-term [12], in other the waves of the pandemic are considered [13]. And in addition to the analyses dealing with the COVID-19 analyses, in several cases also the parallel for example with the Spanish flue are analyzed [14].

As it was mentioned, the spread of the pandemic can be eliminated or at least slow down by different kind of restrictions, their impact was analyzed in many case studies,

such for example in the study dealing with the GAM functions and Markov-Switching models in the evaluation framework to assess countries' performance in controlling of the pandemic [15]. A comparative study of five countries dealing with the optimal control model of the pandemic is presented in [16]. These restrictions are applied with the goal to protect the most vulnerable part of the population and to eliminate the mortality [17, 18] at least until the time when vaccination is effective [19]. However, the problem with the insolation can be also in the social acceptability and feasibility of a focused protection strategy against the pandemic situation [20].
Prediction models have been developed and created also according to the specific needs or requirements, such for example due to the impact on the economics [21], public transportation and passenger flow [22, 23], cross-border mergers [24] or for example on the electricity consumption [25]. And we cannot forget to the other factors that influence spread of the pandemic, such for example population density, age of the population, geographical location and other factors [26], which can cause that the developed prediction models do not have to be generally applicable for any country or region.
The main goal of the article is to propose a methodology based on the Weibull distribution, which can be applied for the prediction of the weekly confirmed cases and deaths, because these data are most important for the planning of the governmental restrictions that usually have direct impact not only on the medical care, but also on the economics, transportation, services, manufacturing, production planning etc. And according to the created models it can be predicted if there is a necessity to isolate ill, infected, or potentially infected people individually or as a whole group. Furthermore, according to the characteristics of the disease, the restrictions can be applied not only on the most vulnerable part of the population, but also on the whole regions or even countries and in this case the movement of individuals, involving also the travelling to work can be restricted or even prohibited.

LITERATURE REVIEW

The prediction models presented in the article is based on the Weibull distribution, which is a is a continuous probability distribution originally proposed as a model for materials' breaking strength but recognized the further potential of the distribution already in his paper written in 1951 [27]. Nowadays Weibull distribution has been used for the different types of reliability and survival analyses [28, 29] in many different areas, involving economics [30], medicine [31], recycling and related environmental engineering [32]. For the creation of prediction models, the Weibull distribution is many times used to solve transportation and logistics issues for different kinds of transportation [33, 34, 35]. However, thanks to its versatility, the Weibull distribution also so many years from its definition and description, remains one of the most widely used distribution for the creation of the reliability and prediction models in material engineering [36-37] for different kinds of materials, involving metal [38], ceramic [39], hyperelastic [40], but also composite materials [41].
In general, Weibull distribution is commonly used for the predictive purposes and planning of many types of operations and activities. It can be also advantageously used for the production or maintenance planning. Our research is focused on the Weibull distribution utilization originally applied for the prediction of the pandemic situation development regarding the number of confirmed cases and deaths as a consequence of the pandemic situation. Furthermore, the research results can be consequently used for the improvement of the OneSAF simulation software, which is used for the constructive simulations of different types, involving a module determined for the simulation of the pandemic spread.

METHODOLOGY

Weibull distribution since its description has been studied, modified, extended or varied [42, 43, 44, 45].
In our case, the two-parameter Weibull distribution was used. The relationship for the probability assuming the Weibull distribution is:

$$P(t) = e^{-\left(\frac{x}{\alpha}\right)^{\beta}}, \quad (1)$$

where:
x represents the confirmed cases or deaths related to the COVID-19 pandemic;
α a measure of scale or dispersion in a data distribution;
β shape parameter that indicates whether the rate (total number of confirmed cases/deaths) is increasing.
Applying a linear regression, the Weibull parameter β can be determined directly from the slope of the line. The α parameter (2) has to be estimated as follows:

$$\alpha = e^{-\left(\frac{b}{\beta}\right)}, \quad (2)$$

The Weibull distribution was chosen for the statistical analysis due to its versatility. Thanks to the world-wide spread of the pandemic many data can be analyzed and compared. However, one of the most important advantages of this methodology is that it can be used for the analyses with a very small number of samples. Thanks to this analysis, it is possible to forecast how the pandemic situation will be developing based on the actually available data.
Other advantage is that the created graphs are very good readable and offer a clear interpretation of the output data. This is convenient for a wide range of personnel or people, who can, thanks to the analysis results, create and implement plans and to perform possible corrective actions or changes in the plans according to the development of the situation.

RESULTS

The Weibull analysis was used to determine the probability of the confirmed cases and deaths in one-week time intervals in three waves of the COVID-19 pandemic in the global world-wide scale, in Europe and for a comparison also in Slovakia.

Confirmed cases

As the input the data related to the confirmed cases summarized by the World Health Organization (WHO) were used. In Figure 1 the visualization in the form of the column bar graph for the global situation in the whole world can be seen.

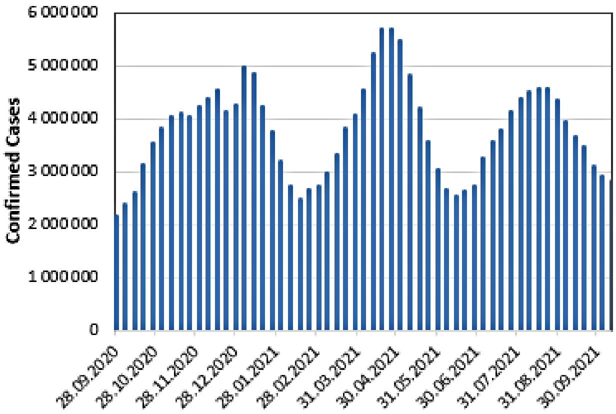

Fig. 1 Development of confirmed cases in the world

For the comparison also the situation separately at the European level – see Figure 2, was analyzed. The regional measure is represented by the situation in Slovakia, as can be seen in Figure 3.

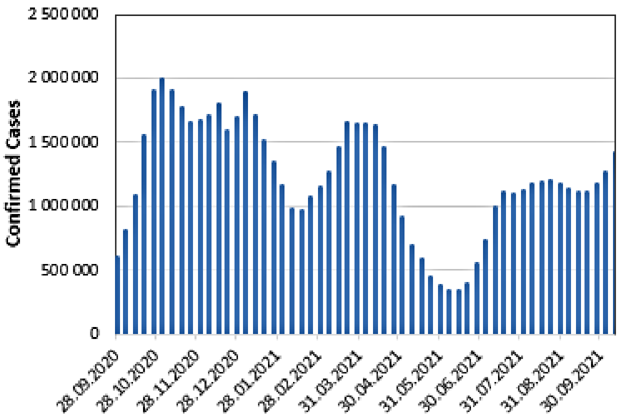

Fig. 2 Development of confirmed cases in Europe

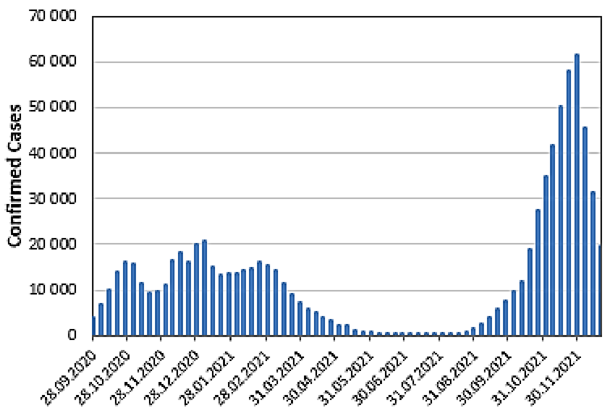

Fig. 3 Development of confirmed cases in Slovakia

These input data were processed using the Weibull analysis and the probability of the confirmed cases in three waves in the global (Figure 4), European (Figure 5) and regional (Slovakia) (Figure 6) measure were determined.

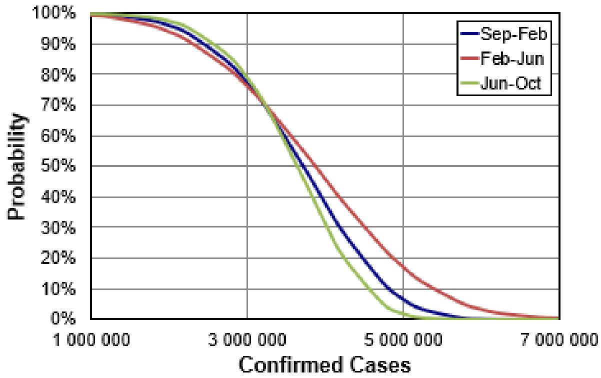

Fig. 4 Probability of confirmed cases in the world

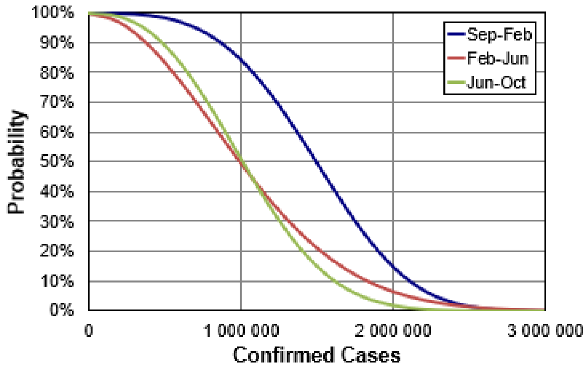

Fig. 5 Probability of confirmed cases in Europe

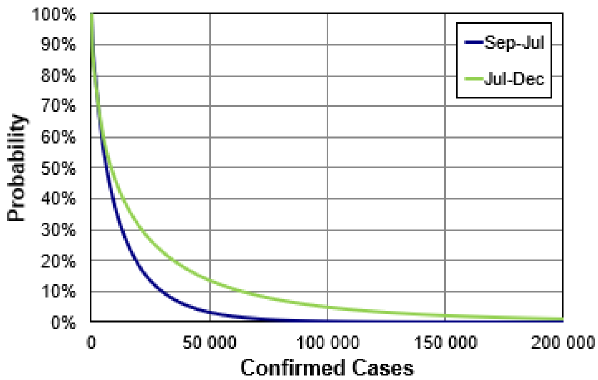

Fig. 6 Probability of confirmed cases in Slovakia

Number of deaths

Accordingly, to the previous part, as the input the data served the data about the deaths related to the COVID-19 pandemic confirmed and summarized by the World Health Organization (WHO). For this case, in Figure 7 the visualization of deaths related to the COVID-19 in global representation can be seen.

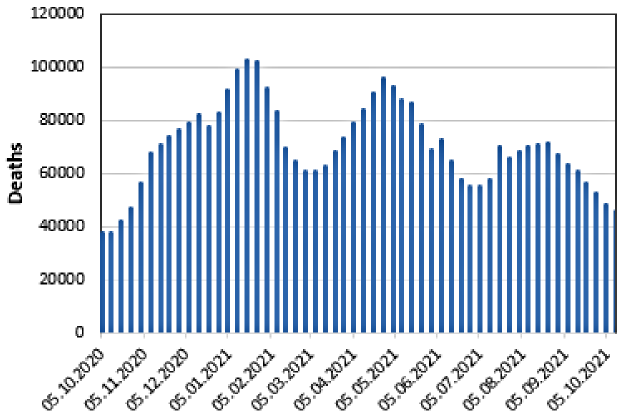

Fig. 7 Number of deaths in the world

For the comparison also the situation separately at the European level – see Figure 8, was analyzed. The regional measure is also in this case represented by the situation in Slovakia, as it can be seen in Figure 9.

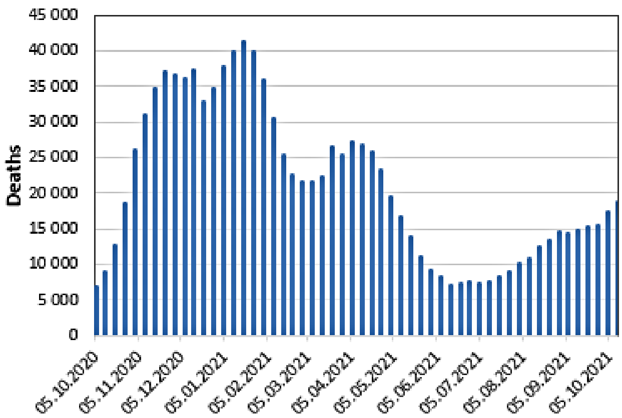

Fig. 8 Number of deaths in Europe

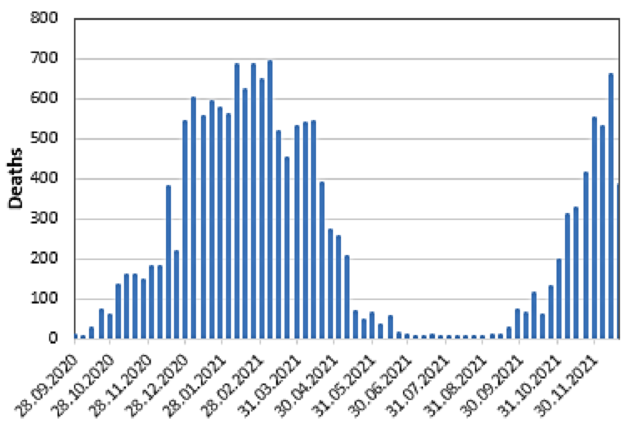

Fig. 9 Number of deaths in Slovakia

The input data from the WHO were processed using the Weibull analysis and the probability of the deaths in three waves in the world (Figure 10) and in the European (Figure 11) and regional level in Slovakia (Figure 12) were determined.

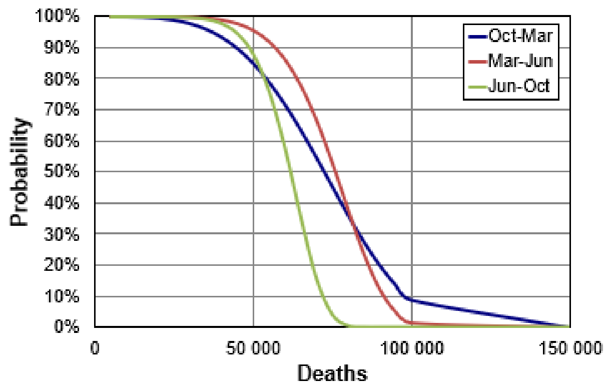

Fig. 10 Probability of number of deaths in the world

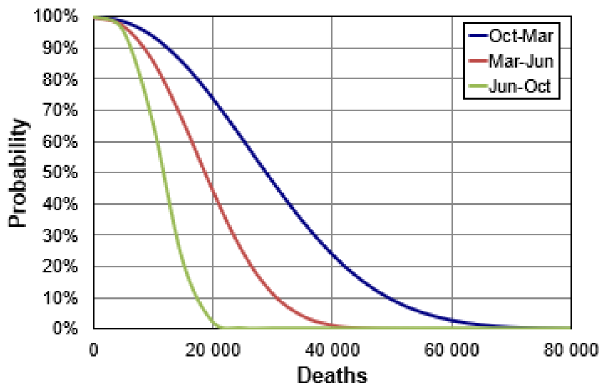

Fig. 11 Probability of number of deaths in Europe

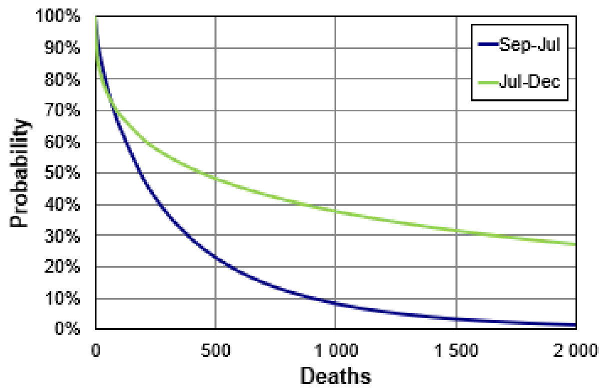

Fig. 12 Probability of number of deaths in Slovakia

DISCUSSION

From the obtained data it can be seen that if we consider COVID-19 pandemics, the number of cases confirmed worldwide has a very similar development as in the Europe. It can be also stated that number of deaths is directly related to the number of the confirmed cases, but with a delay of approx. one month. From the global point of view, we are talking about three waves of the pandemic situation – the first wave ended approx. in February 2021, the second wave in June 2021 and the third wave lasting until now. Currently, due to the "omicron" variant, we can expect the fourth wave development.

However, the situation at the regional level – in our case in Slovakia – can be completely different. Due to the governmental restrictions and the necessity of testing for example due to the opened schools, possibility to travel etc., the development of the first and second wave had not so significant maximum values. But if we look at the number of deaths, it seems like we passed only through one wave of the pandemics lasting until the summer 2021 and the wave corresponding to the third wave was shifted to the end of the year 2021. Therefore, also the prediction analysis needed to be evaluated differently for this regional level.

These input data create can create a basis for the different kinds of prediction models. In our case, for the prediction of the pandemic situation development, the Weibull analysis was applied. From the obtained prediction data, it can be seen the probability of the confirmed cases or deaths for the one-week time intervals. It means that for example from Figure 4 it can be stated that there is a 96% probability that number of confirmed cases in the world during the first wave (marked with blue line) will be 2 millions. For the second wave (marked with the red line), the probability will be 94%. This lower number is due to the effect of vaccination. But due to the new variants with higher spread, during the third wave (marked with the green line) the probability again raised and in this case, it was up to the 98 %. Interesting is also the fact that for all waves there is a 70% probability that the number of confirmed cases will be 3.25 millions. The peak values of the confirmed cases can occur only with a small probability. It means that for example 5 million of confirmed cases can be expected only with the probability 7%, 17% or 2% for the first, second and third wave, respectively. From these data it can be predicted the peak values for the waves of pandemics, which will correspond to the level of approx. 9%.

From the number of deaths (Figure 10) we can clearly see the effect of the vaccination during the second and especially during the third wave, where number of deaths decreased significantly. During the first wave there was 90% probability that number of deaths will be more than 45000, during the second wave the same probability corresponds to the approx. 57000 deaths and during the third wave of the pandemic we could expect approx. 48000 deaths during one week of the pandemic situation. The situation in Europe had a very similar development during the second and third wave of the pandemic. The first wave was of course delayed. Only in the mortality we can see more significant decrease of number of confirmed cases ended by the death of people.

These data obtained either from the global, or from the European point of view are satisfactory for the prediction of the pandemic situation development, however as we can see, they are not satisfactory for the national level.

Because the governmental restrictions for leading for example to the home office or to the transition to the distance learning of students during the first and second wave of the pandemics, the testing of people at the national level and similar regulations can lead to the situation that the statistical data at the national or regional level do not correspond to the global situation. From the national level point of view, it can be stated that the best situation can be observed during the summer months during the summer holidays when there was only small necessity to testing and therefore number of confirmed cases was small. With the beginning of the academic year the number of confirmed cases started to rise significantly. It seems that the pandemic situation in our country is strongly dependent on the academic year with no significant transition among first and second wave. It can be predicted that similar situation will occur also between the third and upcoming fourth wave of the pandemics with the in our country still only rarely confirmed omicron variant.

During the first and second wave of the pandemics – in case of Slovakia represented only by one trend line due to the small differences among the confirmed cases – the probability to achieve for example number of 50000 confirmed cases was only 3%. From the second (green) line it is clear that this probability is much more higher – 14%. It is caused by the much more significant weekly growths.

From the prediction model it can be seen that according to the number of confirmed cases and deaths in one-week intervals we can determine the probability of the future development of the pandemic situation. We can for example predict that in Slovakia the probability of deaths also due to the lower number of vaccinated people will be similar to the previous waves with the 70% probability.

From the previous development of the governmental restriction regarding to the pandemic situation it can be predicted that the "higher" the prediction curve for the Slovakia is, the sooner we can predict the governmental restrictions because it means that the pandemics will have growing number of confirmed cases and due to the planning of the manufacturing processes, services or business activities, the early prediction can be determining. And with the arising amount of statistical data, the prediction can be easily supplemented by the new data to obtain more precise prediction model. Because as we can see from the Figure 6 and Figure 12, the prediction for the actual wave is not final, and therefore there is still a long-term, but small probability of high numbers of confirmed cases or deaths.

The prediction model based on the Weibull analyses was verified on the number of confirmed cases and also on the number of deaths. However, we propose that the methodology can be applied in the OneSAF software to enhance the module for the pandemics or epidemics spread, which can be used to simulate number of healthy, immune, positive and ill people in the chosen area and thanks to the enhancement of the prediction model used for the constructive simulation it will be possible also to improve planning and related decision-making processes in the management of the different kind of companies or organizations.

CONCLUSION

The pandemic situation has had a dramatic impact on our everyday life, particularly due to the high numbers of mortality caused by the COVID-19. Until the vaccination had been developed, one of the most effective ways how to eliminate the spread of the disease was to isolate people – not only people with the confirm virus, but also possibly positive people and most vulnerable people in hospitals or in retirements houses. However, in many regions and countries the whole societies regulatory restrictions were or have been applied. These restrictions have had an influence on many types of business activities, services, manufacturing process, but also on the education, transportation etc.

Therefore, the goal of this article was to create a prediction model based on the Weibull distribution, which can be applied to predict the pandemic situation particularly in term of the number of confirmed cases or deaths, which have the most significant influence on the implementation of the regulatory restrictions. And thanks to the versatility of the Weibull distributions, the proposed methodology can be used for the analyses with a very small number of samples and to predict how the pandemic situation will be developing based on the actually available data. Consequently, it will be easier to create and implement business, manufacturing, transportation, logistic, economic etc. plans and to perform possible corrective actions or changes in these plans according to the actual development of the pandemic situation.

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REFERENCES

[1] A. Micheletti, N. Araújo, A. Budko, Carpio and M. Ehrhardt. “Mathematical models of the spread and consequences of the SARS-CoV-2 pandemics: Effects on health, society, industry, economics and technology”. *Journal of Mathematics in Industry*, vol. 11(1),15, 2021. doi: 10.1186/s13362-021-00111-w

[2] A.W. Tesfaye and T.S. Satana. “Stochastic model of the transmission dynamics of COVID-19 pandemic”. *Advances in Difference Equations*, vol. 2021(1), 457, 2021. doi: 10.1186/s13662-021-03597-1

[3] H.M. Sabri, A.M. Gamal El-Din and L. Aladel. “Forecasting COVID-19 Pandemic Using Linear Regression Model”. *Lecture Notes in Networks and Systems*, vol. 224, pp. 507-520, 2022. doi: 10.1007/978-981-16-2275-5_32

[4] A.K. Gupta, V. Singh, P. Mathur and C.M. Travieso-Gonzalez. “Prediction of COVID-19 pandemic measuring criteria using support vector machine, prophet and linear regression models in Indian scenario”. *Journal of Interdisciplinary Mathematics*, vol. 24(1), pp. 89-108, 2021. doi: 10.1080/09720502.2020.1833458

[5] P. Guha. “Spatiotemporal Analysis of COVID-19 Pandemic and Predictive Models based on Artificial Intelligence for different States of India”. *Journal of The Institution of Engineers (India): Series B*, vol. 102(6), pp. 1265-1274, 2021. doi: 10.1007/s40031-021-00617-2

[6] A.I. Shahin and S. Almotairi. “A deep learning BiLSTM encoding-decoding model for COVID-19 pandemic spread forecasting”. *Fractal and Fractional*, vol. 5(4),175, 2021. doi: 10.3390/fractalfract5040175

[7] M. Humayun and A. Alsayat. “Prediction Model for Coronavirus Pandemic Using Deep Learning”. *Computer Systems Science and Engineering*, vol. 40(3), pp. 947-961, 2021. doi: 10.32604/CSSE.2022.019288

[8] M.K. Sharma, N. Dhiman, Vandana and V.N. Mishra. “Mediative fuzzy logic mathematical model: A contradictory management prediction in COVID-19 pandemic”. *Applied Soft Computing*, vol. 105,107285, 2021. doi: 10.1016/j.asoc.2021.107285

[9] A. Safari, R. Hosseini and M. Mazinani. “A novel deep interval type-2 fuzzy LSTM (DIT2FLSTM) model applied to COVID-19 pandemic time-series prediction”. *Journal of Biomedical Informatics*, vol. 123,103920, 2021. doi: 10.1016/j.jbi.2021.103920

[10] B. Cheng and Y.-M. Wang. “A logistic model and predictions for the spread of the COVID-19 pandemic”. *Chaos*, vol. 30(12),123135, 2020. doi: 10.1063/5.0028236

[11] S.L. Smith, J. Shiffman, Y.R. Shawar and Z.C. Shroff. “The rise and fall of global health issues: an arenas model applied to the COVID-19 pandemic shock”. *Globalization and Health*, vol. 17(1),33, 2021. doi: 10.1186/s12992-021-00691-7

[12] R. Wang, C. Ji, Z. Jiang, Z., Y. Wu, L. Yin and Y. Li. “A Short-Term Prediction Model at the Early Stage of the COVID-19 Pandemic Based on Multisource Urban Data”. *IEEE Transactions on Computational Social Systems*, vol. 8(4),9371309, pp. 1021-1028, 2021. doi: 10.1109/TCSS.2021.3060952

[13] S. Cabaro, V., D’Esposito, T. Di Matola, T.S. Sale, M. Cennamo, D. Terracciano, V. Parisi, F. Oriente, G. Portella, F. Beguinot, L. Atripaldi, M. Sansone, and P. Formisano. “Cytokine signature and COVID-19 prediction models in the two waves of pandemics”. *Scientific Reports*, vol. 11(1),20793, 2021. doi: 10.1038/s41598-021-00190-0

[14] E. Berbenni and S. Colombo. “The impact of pandemics: revising the Spanish Flu in Italy in light of models’ predictions, and some lessons for the COVID-19 pandemic”. *Journal of Industrial and Business Economics*, vol. 48(2), pp. 219-243, 2021. doi: 10.1007/s40812-021-00182-1

[15] A.M.B. de Oliveira, J.M. Binner, A. Mandal, L. Kelly and G.J. Power. “Using GAM functions and Markov-Switching models in an evaluation framework to assess countries’ performance in controlling the COVID-19 pandemic”. *BMC Public Health*, vol. 21(1),2173, 2021. doi: 10.1186/s12889-021-11891-6

[16] A.K. Dhaiban and B.K. Jabbar. "An optimal control model of COVID-19 pandemic: a comparative study of five countries". *OPSEARCH*, vol. 58(4), pp. 790-809, 2021. doi: 10.1007/s12597-020-00491-4

[17] C. Donadee and K.E. Rudd. "Mortality prediction models: Another barrier to racial equity in a pandemic". *American Journal of Respiratory and Critical Care Medicine*, vol. 204(2), pp. 120-121, 2021. doi: 10.1164/rccm.202103-0809ED

[18] M. Saban, V. Myers, O. Luxenburg and R. Wilf-Miron. "Tipping the scales: a theoretical model to describe the differential effects of the COVID-19 pandemic on mortality". *International Journal for Equity in Health*, vol. 20(1),140, 2021. doi: 10.1186/s12939-021-01470-x

[19] J. Jankhonkhan and W. Sawangtong. "Model predictive control of COVID-19 pandemic with social isolation and vaccination policies in Thailand". *Axioms*, vol. 10(4),274, 2021. doi: 10.3390/axioms10040274

[20] T. Akamatsu, T. Nagae, M., Osawa, K. Satsukawa, T. Sakai and D. Mizutani. „Model-based analysis on social acceptability and feasibility of a focused protection strategy against the COVID-19 pandemic". *Scientific Reports*, vol. 11(1),2003, 2021. doi: 10.1038/s41598-021-81630-9

[21] X. Tang, Z. Li, X. Hu, Z. Xu and L. Peng. "Self-correcting error-based prediction model for the COVID-19 pandemic and analysis of economic impacts". *Sustainable Cities and Society*, vol. 74,103219, 2021. doi: 10.1016/j.scs.2021.103219

[22] K.C. Kiptum. "Logistic model for adherence to ministry of health protocols and guidelines by public transport vehicles in Kenya during COVID-19 pandemic". *Engineering and Applied Science Research*, vol. 49(1), pp. 88-95, 2022. doi: 10.14456/easr.2022.10

[23] F. Jiao, L. Huang, R. Song and H. Huang. "An improved stl-lstm model for daily bus passenger flow prediction during the COVID-19 pandemic". *Sensors*, vol. 21(17),5950, 2021. doi: 10.3390/s21175950

[24] H.-S. Lee, E.A. Degtereva and A.M. Zobov. "The impact of the COVID-19 pandemic on cross-border mergers and acquisitions' determinants: New empirical evidence from quasi-poisson and negative binomial regression models". *Economies*, vol. 9(4),184, 2021. doi: 10.3390/economies9040184

[25] A.K. Konyalıoğlu, T. Beldek, and T. Özcan. "An Optimized Nonlinear Grey Bernoulli Model for Forecasting the Electricity Consumption During COVID-19 Pandemic: A Case for Turkey". *Lecture Notes in Networks and Systems*, vol. 307, pp. 649-656, 2022. doi: 10.1007/978-3-030-85626-7_76

[26] A. Maštalský and E. Dolný. "Behavioral models of isolated individuals and entities". *Acta Avionica*, vol. 24 (2), pp. 25-30, 2021. doi: 10.35116/aa.2021.0013

[27] W. Weibull. "A Statistical Distribution Function of Wide Applicability". *Journal of Applied Mechanics*, pp. 293-297, 1951.

[28] T. Thanh Thach and R. Briš. "An additive Chen-Weibull distribution and its applications in reliability modeling". *Quality and Reliability Engineering International,* vol. 37(1), pp. 352-373. 2021. doi: 10.1002/qre.2740

[29] C.W. Zhang "Weibull parameter estimation and reliability analysis with zero-failure data from high-quality products". *Reliability Engineering and System Safety*, vol. 207, 107321, 2021. doi: 10.1016/j.ress.2020.107321

[30] B. Silahli, K.D. Dingec, A. Cifter, and N. Aydin. "Portfolio value-at-risk with two-sided Weibull distribution: Evidence from cryptocurrency markets". *Finance Research Letters*, vol. 38, 101425, 2021. doi: 10.1016/j.frl.2019.101425.

[31] R. Alshenawy, A. Al-Alwan, E.M. Almetwally, A.Z. Afify and H.M. Almongy. "Progressive type-ii censoring schemes of extended odd Weibull exponential distribution with applications in medicine and engineering". *Mathematics*, Vol. 8(10), 1679, pp. 1-19, 2020. doi: 10.3390/math8101679

[32] S.M.M. Rahman, J. Kim and B. Laratte. "Disruption in Circularity? Impact analysis of COVID-19 on ship recycling using Weibull tonnage estimation and scenario analysis method". *Resources, Conservation and Recycling*, vol. 164, 105139, 2021. doi: 10.1016/j.resconrec.2020.105139

[33] A. Abebaw Gessesse and R. Mishra. "Genetic Algorithm-Based Fuzzy Programming Method for Multi-objective Stochastic Transportation Problem Involving Three-Parameter Weibull Distribution". *Advances in Intelligent Systems and Computing*,, vol. 1170, pp. 155-167. 2021. doi: 10.1007/978-981-15-5411-7_11

[34] K. Draganová, K. Semrád, M. Blišťanová, T. Musil and R. Jurč. "Influence of disinfectants on airport conveyor belts". *Sustainability (Switzerland)*, vol. 13(19),10842, 2021. doi: 10.3390/su131910842

[35] P. Niu, Z. Wang, S. Liu and K. Jia. "Demand Forecast of Restoring Air Material of Helicopter Based on NHPP and Weibull Model". *Journal of Physics: Conference Series*, vol. 1676(1), 012089, 2020. doi: 10.1088/1742-6596/1676/1/012089

[36] P. Strzelecki. "Determination of fatigue life for low probability of failure for different stress levels using 3-parameter Weibull distribution". *International Journal of Fatigue*, vol. 145, 2021. doi: 10.1016/j.ijfatigue.2020.106080

[37] K. Semrád, J. Čerňan and K. Draganová. "Rolling Contact Fatigue Life Evaluation Using Weibull Distribution". Mechanics, Materials Science & Engineering Journal. vol. 2(3), p. 28-33, 2016. doi: 10.13140/RG.2.1.3338.9849

[38] Y. Wang, Z. Chen, Y. Zhang, X. Li and Z. Li. "Remaining useful life prediction of rolling bearings based on the three-parameter Weibull distribution proportional hazards model". *Insight: Non-Destructive Testing and Condition Monitoring*, vol. 62(12), pp. 710-718, 2021. doi: 10.1784/INSI.2020.62.12.710

[39] W.-S. Lei, Z. Yu, P. Zhang and G. Qian. "Standardized Weibull statistics of ceramic strength". *Ceramics International*, vol. 47(4), pp. 4972-4993, 2021. doi: 10.1016/j.ceramint.2020.10.073

[40] K. Semrád, K. Draganová, P. Koščák, and J. Cernan. "Statistical prediction models of impact damage of airport conveyor belts". *Transportation Research Procedia*, vol. 51, pp. 11-19, 2020. doi: 10.1016/j.trpro.2020.11.003

[41] B. Belhadj, L. Abdelkader and A. Chateauneuf. "Weibull probabilistic model of moisture concentration build up in a fiber graphite/epoxy polymer composite under varying hydrothermal conditions". *Periodica Polytechnica Mechanical Engineering*, vol. 65(1), pp. 27-38, 2021. doi: 10.3311/PPme.13653

[42] S. Guo, X. Wang, Y. Liu, X. Zhu and Y. Zhai, "A comparison study of three types of parameter estimation methods on weibull model". *Advances in Intelligent Systems and Computing*, vol. 1244 AISC, pp. 706-711, 2021. doi: 10.1007/978-3-030-53980-1_103

[43] M. Sumair, T. Aized, S.A.R. Gardezi, S.U.U. Rehman and S.M.S. Rehman. "A novel method developed to estimate Weibull parameters". *Energy Reports*, vol. 6, pp. 1715-1733, 2020. doi: 10.1016/j.egyr.2020.06.017

[44] H. Saboori, G. Barmalzan and S.M. Ayat. "Generalized Modified Inverse Weibull Distribution: Its Properties and Applications". *Sankhya B*, vol. 82(2), pp. 247-269, 2020. doi: 10.1007/s13571-018-0182-1

[45] L. Hongxiang, F.P. Shan and S. Baofeng. "A comparative study of modified Weibull distributions in proportional hazards models". *AIP Conference Proceedings*, vol. 2266, 090011, 2020. doi: 10.1063/5.0018428

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