

Professor Jian Lu's Interdisciplinary Approach to Modeling the COVID-19 Pandemic

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Editorial Our new column *Insights* is an ongoing series of interviews prepared by the *China CDC Weekly* team with researchers, policymakers, experts, and other leaders that strives to disseminate experiences, knowledge, and perspectives in global and public health with a wider community. At the discretion of the *Weekly's* team, these interviews will be written into articles, shared as videos, and/or presented as transcripts to best promote plain-language principles and to ease understanding of non-specialized academic readers.

Our first publication in *Insights* is an interview with Professor Jian Lu, the City University of Hong Kong's Chair Professor of the Department of Biomedical Sciences, Department of Material Science and Engineering, and Department of Mechanical Engineering, conducted on June 15, 2020. Prof. Lu has used his interdisciplinary expertise to create a new approach for modeling the COVID-19 pandemic by drawing comparisons between infection propagation and mechanical vibration. For more information, please read below.

As the coronavirus disease 2019 (COVID-19) pandemic was becoming a major public health emergency in late January 2020, Professor Jian Lu of the City University of Hong Kong was queried by friends in a WeChat group to predict the number of cases in the coming days. Prof. Lu, the chair professor of three departments including Biomedical Sciences, Material Science and Engineering, and Mechanical Engineering, saw in this academic challenge an opportunity to utilize his interdisciplinary expertise and contribute to the global understanding of the pandemic.

Where many existing models have relied on epidemiological and biostatistical principles to find an R_0 , the basic reproductive number indicating the number of infections coming from one case, Prof. Lu believed that the modeling of R_0 relied on many difficult-to-estimate parameters such as the effectiveness of social distancing measures and case-finding capabilities. Having a separate skillset, Prof. Lu saw a chance to use only publicly available case numbers to formulate the propagation of the COVID-19 pandemic analogously to a vibration mechanical system. Being an expert in fracture mechanics and experimental mechanics, Prof. Lu saw similarities to assessing the strength of new materials and Moore's Law, the observation that transistor density on a microchip doubles every two years but has no inherent material explanation, and applied these lines of thinking by viewing the country and regional health systems as pseudo-materials with the COVID-19 pandemic applying stress and propagating failure.

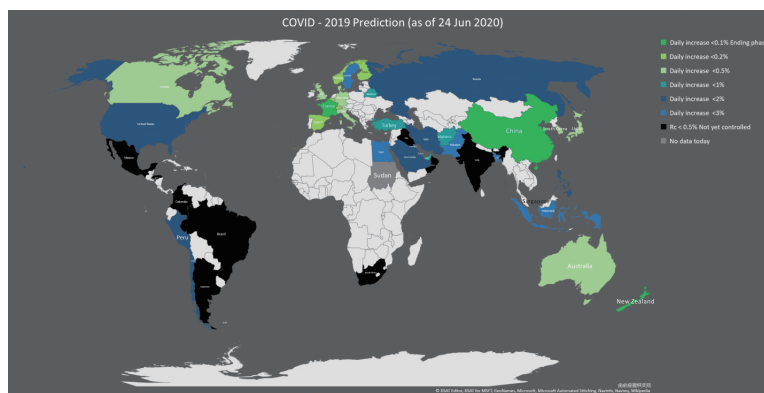
The following is his equation: $N(D_n)_{total} = N(D_{n-1})_{total} \times (R_{n-1} - R_c \times D_n)$; where D_n is the number of days starting from the first day of simulation to day n ; $N(D_n)_{total}$ is the total number of infected cases till day n ; R_{n-1} is the case increase rate prior to day n ; and R_c is the reduction coefficient of daily cases increase rate (I).

Prof. Lu's equation was used to display two vital components in his model: the rate of increase in daily cases and the reduction coefficient R_c of the increase rate in daily cases. As shown in Figure 1, the rate of increase in daily cases was mapped to display the rate of growth in individual countries and regions. Countries that were shaded green have reached the final stages of propagation and were close to overcoming the pandemic within their borders. However, countries that were bluer with rates of increase $<2\%$ and $<3\%$ were still experiencing high levels of growth, and countries that were shaded black have R_c 's that were $<0.5\%$, which indicates the pandemic was still not controlled within the country's borders. The countries modelled as having uncontrolled growth were, as of June 24, 2020, The Republic of Columbia, Republic of India, The Federative Republic of Brazil, Republic of the Philippines, Sultanate of Oman, The Republic of South Africa, The Republic of Honduras, The Republic of Argentina, and Republic of Iraq.

In his daily updates, Prof. Lu also included additional graphs modeling the propagation of COVID-19 at several

different R_c 's and tracked the real propagation within individual countries and several states of the USA. As shown in Figure 2, a higher R_c value indicated stronger control and the projected curves reached a lower cumulative number of cases. The red curve indicated the real progression of the pandemic using publicly available data and showed shifts in which R_c threshold the USA's curve was in, which intuitively suggested that the propagation of COVID-19 can alter based on the tightening or loosening of response measures. Prof. Lu's approach, therefore, means that R_0 can be considered as dynamic and as taking into account the response to virus propagation.

Prof. Lu and his team will diligently continue updating their modeling of these countries and regions until the end of the pandemic. For more detailed information, please visit their website: <http://personal.cityu.edu.hk/jianlu/>.



Countries	Total No. of cases	Nn/Nn-1	New cases/day	
China	83,430	1.0001	12.0000	Daily increase <0.1% Ending phase
France	161,348	1.0005	81.0000	Daily increase <0.1% Ending phase
New Zealand	1,516	1.0007	1.0000	Daily increase <0.1% Ending phase
Spain	294,166	1.0011	334.0000	Daily increase <0.2%
Switzerland	31,376	1.0014	44.0000	Daily increase <0.2%
Belgium	60,898	1.0014	88.0000	Daily increase <0.2%
Finland	7,167	1.0017	12.0000	Daily increase <0.2%
Norway	8,788	1.0018	16.0000	Daily increase <0.2%
UK	306,862	1.0021	652.0000	Daily increase <0.5%
Italy	239,410	1.0024	577.0000	Daily increase <0.5%
Germany	193,254	1.0025	476.0000	Daily increase <0.5%
Canada	102,242	1.0027	279.0000	Daily increase <0.5%
Japan	18,024	1.0031	56.0000	Daily increase <0.5%
Australia	7,521	1.0039	29.0000	Daily increase <0.5%
South Korea	12,535	1.0041	51.0000	Daily increase <0.5%
Denmark	12,615	1.0043	54.0000	Daily increase <0.5%
Singapore	42,623	1.0045	191.0000	Daily increase <0.5%
Afghanistan	29,640	1.0054	159.0000	Daily increase <1%
Belarus	59,945	1.0077	458.0000	Daily increase <1%
Turkey	191,657	1.0078	1492.0000	Daily increase <1%
UAE	46,133	1.0099	450.0000	Daily increase <1%
Russia	606,881	1.0120	7176.0000	Daily increase <2%
Iran	212,501	1.0121	2531.0000	Daily increase <2%
Qatar	90,778	1.0134	1199.0000	Daily increase <2%
Chile	254,416	1.0146	3649.0000	Daily increase <2%
Philippines	32,295	1.0148	470.0000	Daily increase <2%
Peru	264,689	1.0149	3879.0000	Daily increase <2%
United States	2,462,554	1.0158	38386.0000	Daily increase <2%
Saudi Arabia	167,267	1.0190	3123.0000	Daily increase <2%
Kuwait	41,879	1.0206	846.0000	Daily increase <3%
Sweden	63,749	1.0210	1487.0000	Daily increase <3%
Pakistan	188,926	1.0210	3892.0000	Daily increase <3%
Indonesia	49,009	1.0232	1113.0000	Daily increase <3%
Egypt	59,561	1.0244	1420.0000	Daily increase <3%
Bangladesh	122,660	1.0290	3462.0000	Daily increase <3%
Mexico	191,410	1.0340	6288.0000	$R_c < 0.5%$ Not yet controlled
Oman	33,536	1.0353	1142.0000	$R_c < 0.5%$ Not yet controlled
Brazil	1,192,474	1.0356	40995.0000	$R_c < 0.5%$ Not yet controlled
India	472,985	1.0370	16870.0000	$R_c < 0.5%$ Not yet controlled
Honduras	13,943	1.0440	587.0000	$R_c < 0.5%$ Not yet controlled
Colombia	77,113	1.0481	3541.0000	$R_c < 0.5%$ Not yet controlled
South Africa	111,796	1.0536	5688.0000	$R_c < 0.5%$ Not yet controlled
Argentina	49,851	1.0561	2648.0000	$R_c < 0.5%$ Not yet controlled
Iraq	36,702	1.0638	2200.0000	$R_c < 0.5%$ Not yet controlled
Sudan	8,889	xx	xx	No data today

FIGURE 1. Professor Jian Lu's daily update of his COVID-19 pandemic model using publicly available data. The color scheme indicated the rate of increase in daily cases in countries and regions, and if the rate of increase had a significantly low reduction coefficient of the increase rate R_c , the country was shaded black.

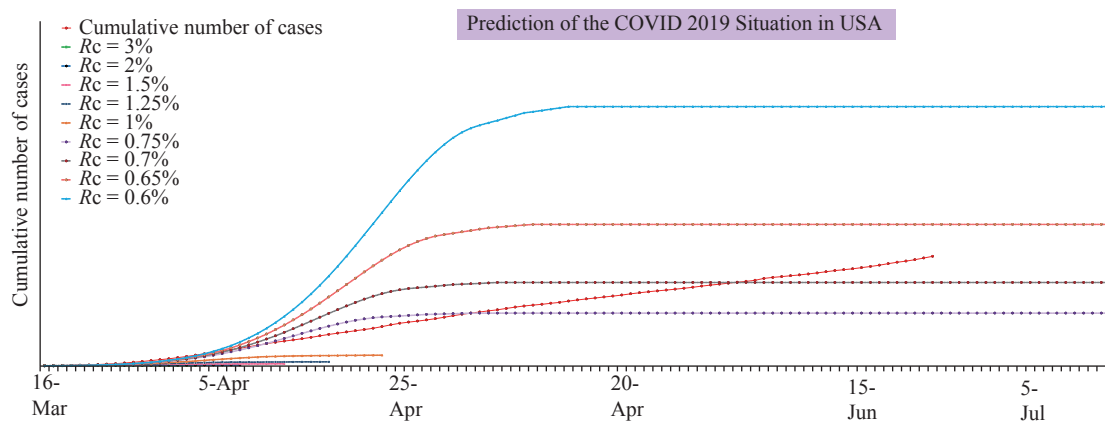


FIGURE 2. Professor Jian Lu's modeling of COVID-19 progression in the United States. The real progression was indicated by the red curve, and the other curves projected the progression at various reduction coefficients, R_c , of the rate of increase of daily cases. This curve indicated that COVID-19 is still not adequately controlled as the red line has exceeded the projected lines of $R_c=0.75\%$ and $R_c=0.7\%$. Professor Jian Lu's models of other countries and of several states in the USA are available at his homepage: <http://personal.cityu.edu.hk/jianlu>.

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