# The Diaries During and After the Lockdown Project

# Technical Details of a Model for Communicating COVID-19 Dynamics

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**Project Synopsis:** In April of 2020 we began a project designed to communicate insights from a system dynamics model of the COVID-19 project to a non-modeling audience. We began with a simulation model, CORONA1, built and calibrated to Iran. We wrote and published 20 stories in a blog-like format under the title of “Diaries During Lockdown”. Another 6 were published as “Diaries After the Lockdown”. The current model exists as 11 modules that develop insights about the pandemic in a step-by-step process. We have experimented with several social media platforms and are currently engaged to an effort to transform the project into curriculum aimed at system dynamics students.

**Focus of This Paper at the ISDC (4 of 4)**: We have prepared two applications papers and two work-in-progress papers to present this work at the 2021 ISDC. The four paper foci are (1) A Description of our overall story telling approach, ***(2) A presentation of the technical details of the 12 modules in our current model (this paper),*** (3) A report on several experiments with social media and online presentations, and (4) A proposal to develop curriculum aimed at students of system dynamics.

A system dynamics model is developed to represent the spread of corona virus and reactions of public and governments to manage it. The model contains interaction among many variables through feedback loops that generate the dynamic of the pandemic. This paper present the development of the model in several steps. In each step a module that contains a specific feedback mechanism and the dynamic implication of it is presented. After the first module, the structure that added to model in the next step is shown by red color. Total population is the model in 80 million and remain constant except death rate from the disease that decreases it.

The first module contains a susceptible population and a group of people who are infected and asymptotic. a positive loop that causes the exponential growth of asymptotic infected persons and a negative loop that that eventually control that growth. As people get infected they move from susceptible to infected and when there is not enough susceptible to support exponential growth, infection rate declines and when all susceptible become infected infection rate becomes zero. Figures 1a and 1b show the causal loop and flow diagram of module 1 and Figure 2 shows the behavior of the model.

In the second module, a negative loop is added to decrease the number of asymptotic as the symptoms become appear. Figures 3a and 3b show the causal loops and flow diagram of the

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second module respectively. The red color show the addition structure to the first module that created the second module. Figures 4a and 4b shows the behavior of module 2. The new structure depletes asymptotic patients into a cloud. Symptom appearance follow incident rate with a delay and asymptotic people approaches zero. A new structure should be added to follow patients who flow out of asymptotic.

In the third module, symptomatic people are added to the model. As symptoms become appear patients move from asymptotic to symptomatic and a fraction of symptomatic patients recover and accumulate in recovered patients and a fraction die who add to cumulative deaths. Figures 5a and 5b show the causal loops and flow diagram structure of module 3. Figures 6a and 6b show the behavior of the module. As seen in the behavior, susceptible move to asymptotic and then to recovered and cumulative deaths. At the end all susceptible are infected and then either recovered or died.

In module 4, recovered people lose their immunity after 6 month and become susceptible again. Figures 7a and 7b show the causal diagram and flow diagram of Modules 4 respectively. Figures 8a and 8b show the behavior of Module 4. As recovered persons become susceptible, they become infected and flow to asymptotic and then become symptomatic and a fraction of the die and a fraction recover. As shown in Figure 8a, the cumulative deaths keep rising because as recovered people recycle and become susceptible and infected again, a fraction of them die in each cycle and increase cumulative deaths. In Module 4 people don't react to death rate and the number of infected asymptotic peaks at about 45 million.

In Module 5, as people perceive the death rate from the disease to be more than a threshold that make them sensitive, they are intelligent and try to decrease their contacts with each other. Therefore, there is a feedback from the death rate to the number of contacts per day in addition to Module 4 structure. Figures 9a and 9b show the causal diagram and flow diagram of Modules 5 respectively. Figures 10a and 10b show the behavior of Module 5. As feedback from death rate to number of contacts become active the cumulative death during 180 days drop from 4about 4 million to 450000 persons. Asymptomatic peaks drop from about 40 million people in module 4 to 350000 persons in Module 5. The feedback improves the behavior considerably. Addition of the negative feedback loop create a cyclical behavior and waves of pandemic.

In Module 6, people become more intelligent and there is another feedback from death rate to hygienic behavior of people. As death rate increases infectivity decreases due to self-protection. Figures 11a and 11b show the causal diagram and flow diagram of Modules 6 respectively. Figures 12a and 12b show the behavior of Module 6. The behavior in terms of cumulative deaths that drops from about 650000 at day 360 in Module 5 to about 200000 at the same day in Module 6. The second negative feedback loop make the cyclical behavior more visible.

In Module 7, hospitalization of a fraction of symptomatic who need hospital is added. If hospital availability drops, fraction of symptomatic who die will increase. Figures 13a and 13b show the causal diagram and flow diagram of Modules 7 respectively. Figures 14a and 14b show the behavior of Module 7. Since the impact of hospital availability on death rate is added, cumulative deaths in Module 7 is a little more than it was in Module 6. In Module 6, cycles in the number hospitalized patient that reflects wave of pandemic is very visible.

In Module 8, quarantine is added. A fraction of symptomatic patients go to quarantine and as a result number of contacts between infected and susceptible would decrease. Figures 15a and 15b show the causal diagram and flow diagram of Modules 8 respectively. Figures 16a and 16b show the behavior of Module 8. Cumulative death because of quarantine is 170000 at day 360 less than 250000 in Module 7 at day 360.

In Module 9, fatigue is added to the model. As pandemic continues and people have a lower contacts and less socialization, they get tired and lose the restrictions. Figures 17a and 17b show the causal diagram and flow diagram of Modules 9 respectively. Figures 18a and 18b show the behavior of Module 9. In Module 9 cumulative death rise more than in Module 8 reaches to 380000 at day 360.

In Module 10, as government perceives observes high death rate he enforce social distancing to fight the pandemic. Figures 19a and 19b show the causal diagram and flow diagram of Modules 10 respectively. Figures 20a and 20b show the behavior of Module 10. Government enforcement through a negative loop that initiates from death rate has two impacts. First it decreases the cumulative death to about 75000 at day 360. Second, the new negative loop in the model increases cyclicality of the behavior shown in behavior of infected asymptomatic and symptomatic patents.

In Module 11, testing is added to identify asymptomatic and put them into quarantine. Figures 21a and 21b show the causal diagram and flow diagram of Modules 11 respectively. Figures 22a and 22b show the behavior of Module 11. Because of testing and separating asymptotic patients spread of the disease drops and the cumulative death drops to about 55000 until day 360.

In Module 12, vaccine become available. Susceptible are divided into two groups and move between the two depending on the perception of the death rate from the disease. One group is willing to take the vaccine and the other is not willing.  The fraction of willing to take the vaccine would increase when the death rate rises. Figures 23a and 23b show the causal diagram and flow diagram of Modules 12 respectively. Figures 24a and 24b show the behavior of Module 10. Although the vaccine is available from the beginning of simulation, vaccination capacity has to be built up. As shown in Figure 24a it takes about 100 days to build vaccination capacity to its maximum of 1.5 million persons per day. Because of vaccination, cumulative death reaches to only 30000 persons during the 360 days much less of the previous Module.

The model can be considered as a generic model of a pandemic that infected people do not show a symptom at the beginning and a fraction of patients may die due to the disease. It can be used to show different scenario for different ways that a society react to the spread of the disease, different government policies for enforcing lock down, different reaction people to vaccination and also to the government policy making vaccination available to the public. It also can be used to analyze policies with regard to allocation of hospital capacity to the patients when there is shortage of such capacity in general.