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Lean

Infectious Disease Modeling in

Healthcare

Problem

At the start of the COVID-19 pandemic, many countries made different decisions regarding policies towards this new coronavirus. Some of these decisions were risky, but all of them impacted their countries in many different sectors, including the political and economic. Quick responses were vital to control the spread of the disease.

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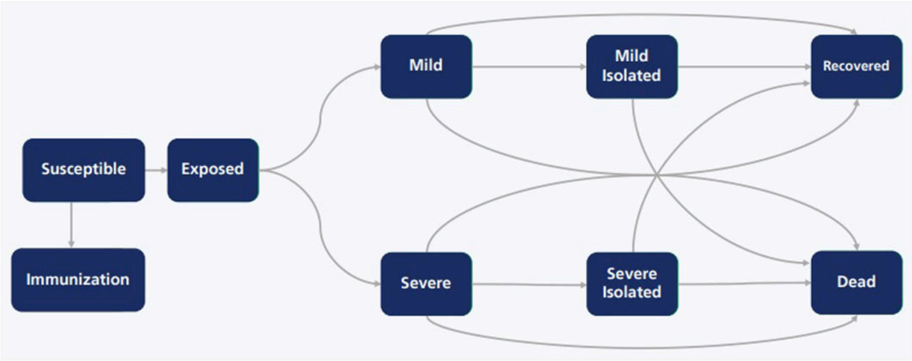
This simulation could help in capacity planning for health resources, which at the height of the pandemic were limited. Lean, therefore, built a simulation model using AnyLogic software to understand the spread of the disease and to identify how different policies could change the spread of the virus over time.

Solution

A SEIR(D) model is a mathematical model of the spread of an infectious disease. In a population, every individual exists in one of five states:

- Susceptible (S) to the disease.
- Exposed (E) to the disease.
- Infected (I) by the disease.
- Recovered (R) from the disease.
- Died (D) from the disease.

There is also immunization to consider. This is further split into multiple models as immunity fades away and if immunization is not as effective for all people.



SEIR(D) system dynamics model – simplified base model

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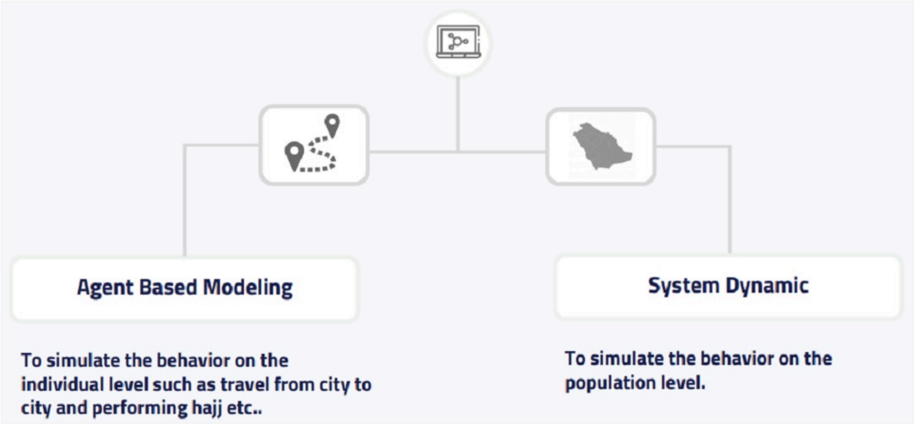
system dynamics part handled large amounts of information on the aggregate level. Combining these two increased the model flexibility to simulate various scenarios without delay.



Multimethod simulation model showing agent-based modeling and system dynamics

A multimethod model has 82 unique parameters and 20 health directorates or divisions. For each directorate there is a separate simulation model. Therefore, in total there are 1640 parameters, which are divided into 4 main categories:

1. Healthcare resources.
2. Disease behavior specifically related to COVID-19.
3. Population behavior.
4. Demographics.

From these unique parameters, there are 95 distinctive pathways again multiplied by the 20 directorates creating 1900 dynamic events. Pathways in this case are events, and these can be based on if statements,

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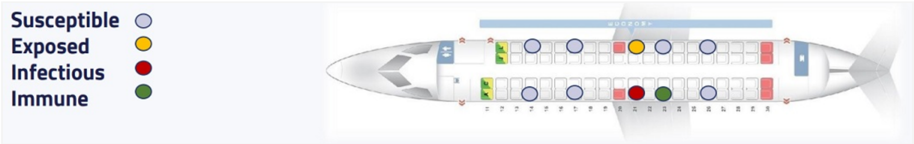
was built into the model and included such resources as nurses, ICU beds, doctors, and so on.

The model interface is very user-friendly, giving users the possibility to change the parameters, policies, and importantly, even the population. As a result, the model can be applied to other countries.

There were also just agent-based models designed for specific simulations such as in an airplane. Here, there is clear and specific behavior for each agent, or passenger. On an airplane, for example, two people can sit next to each other and if one is infectious, then the other could be susceptible. As a result, the chance of spreading the disease is higher than if those people were not sitting next to each other.



Simulation, using the SEIR(D) model, showing agents traveling in an airplane

Notably, Lean built a separate agent-based model for the Hajj, the annual Islamic pilgrimage to Mecca, Saudi Arabia. Different policies or precautions were taken to understand the impact of each, for example, taking 2 swabs instead of 1 swab before the Hajj, or if there would be isolation for people at home or at Makkah.

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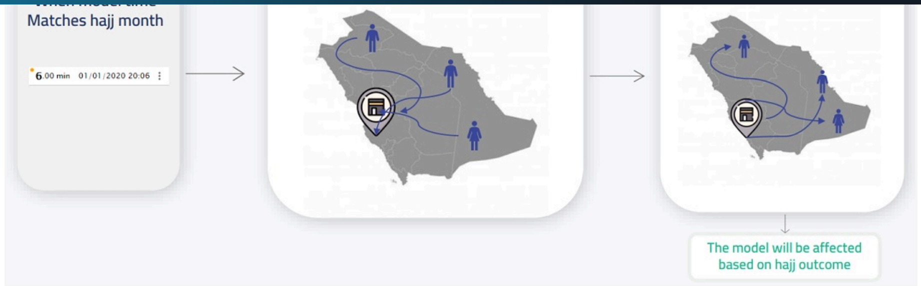
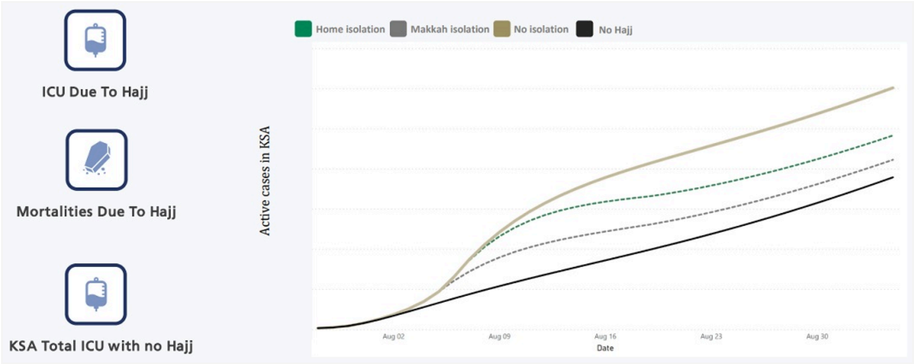


Hajj integrated with the model. Assumptions for the Hajj scene

Results

After running the models, Lean could provide detailed reports, including the forecasted numbers of cases for the next week or next month, the predicted outcome of schools returning to face-to-face learning, the mortality rate due to COVID-19, the impact of the Hajj, and so on.



Example report of the impact of an isolation policy on ICU and mortalities after a month

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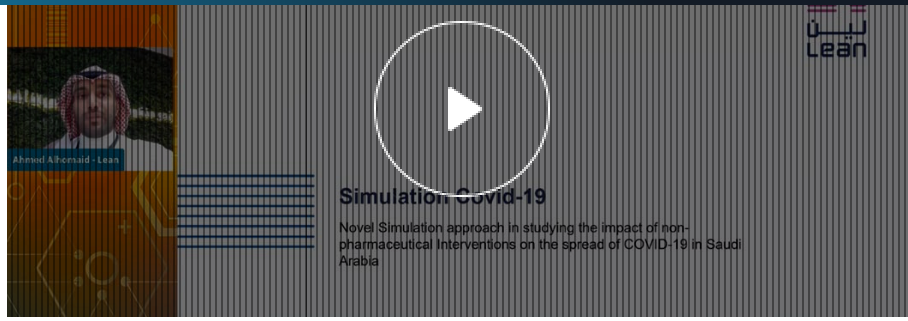

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