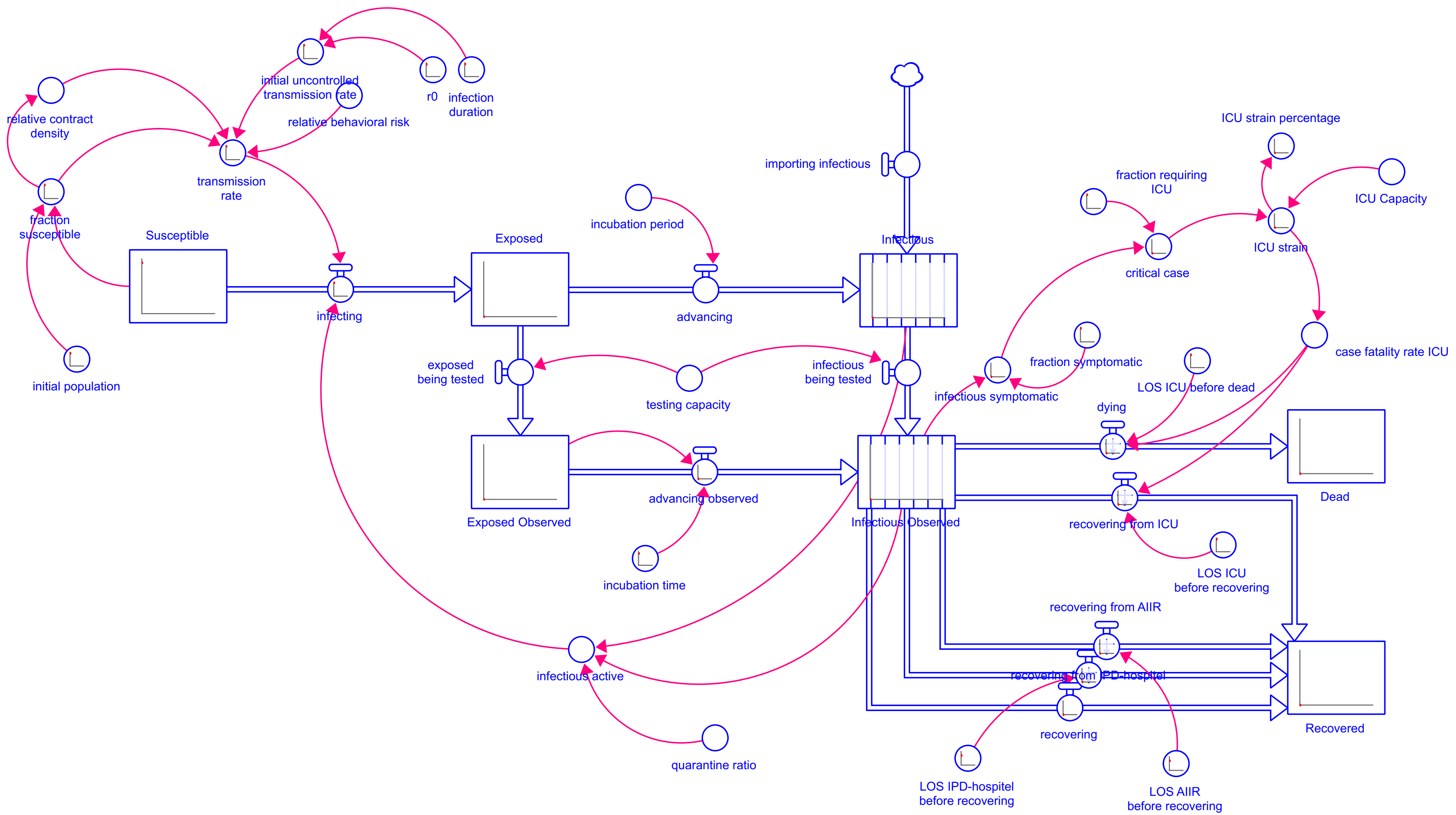

Figure 1 Structure of the Model

Table 1 Assumptions of COVID-19 Epidemic in Thailand and policy effectiveness	
Basic reproduction number (R_0) of COVID-19 epidemic in Thailand before any intensive interventions (January to March 2020)	2.2
Closing pub, bar, and restaurant	Reducing transmissions by 25%
Promoting mask and personal hygiene	Reducing transmissions by 25%
Enforcing physical distancing behaviours	Reducing transmissions by 20%
Asking/Enforcing people to stay home	Reducing transmissions by 20%
Bans of mass gathering, including department stores	Reducing transmissions by 10%
Closing schools and universities	Reducing transmissions by 10%
Curfew from 10PM-4AM)	Reducing transmissions by 5%

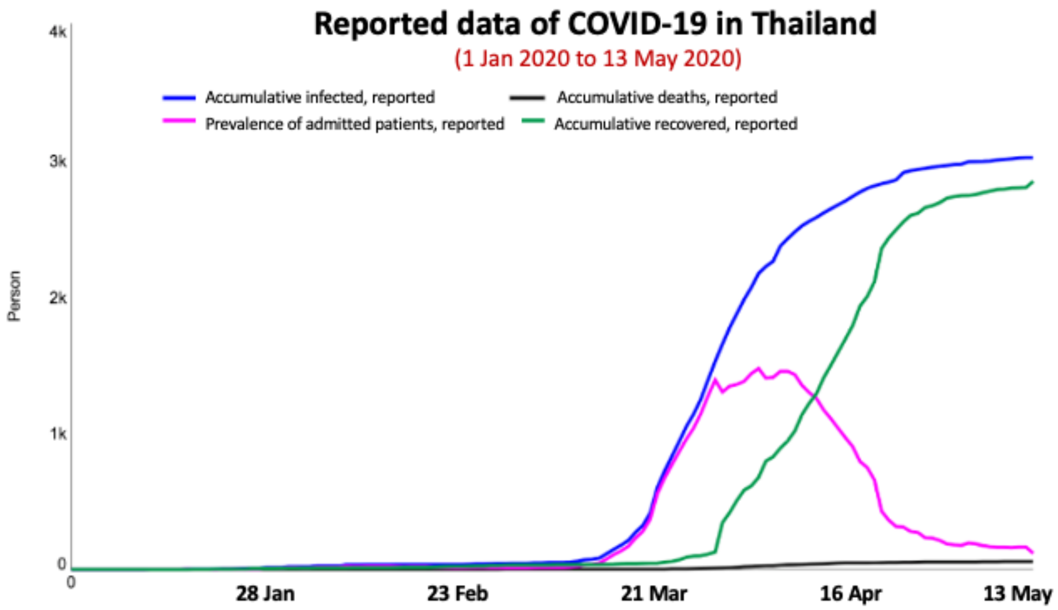

Figure 2a Reported data of COVID-19 in Thailand (Jan 1, 2020 to May 13, 2020)

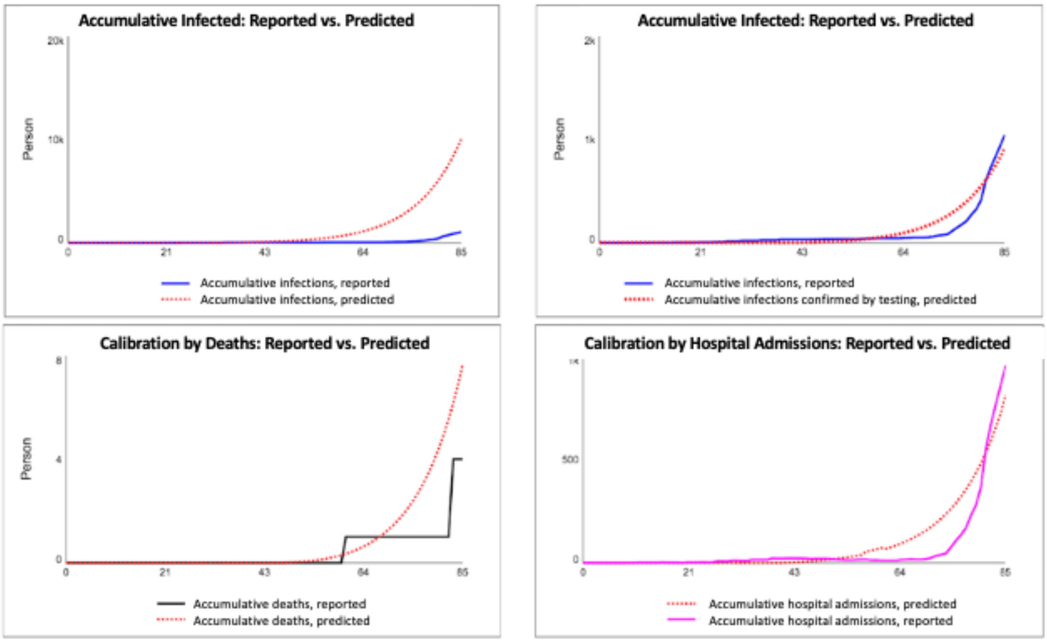

Figure 2b Comparison of predicted and reported data of COVID-19 in Thailand before implementing the intensive/lock-down/hammering policies (Jan 1, 2020 to Mar 26, 2020)

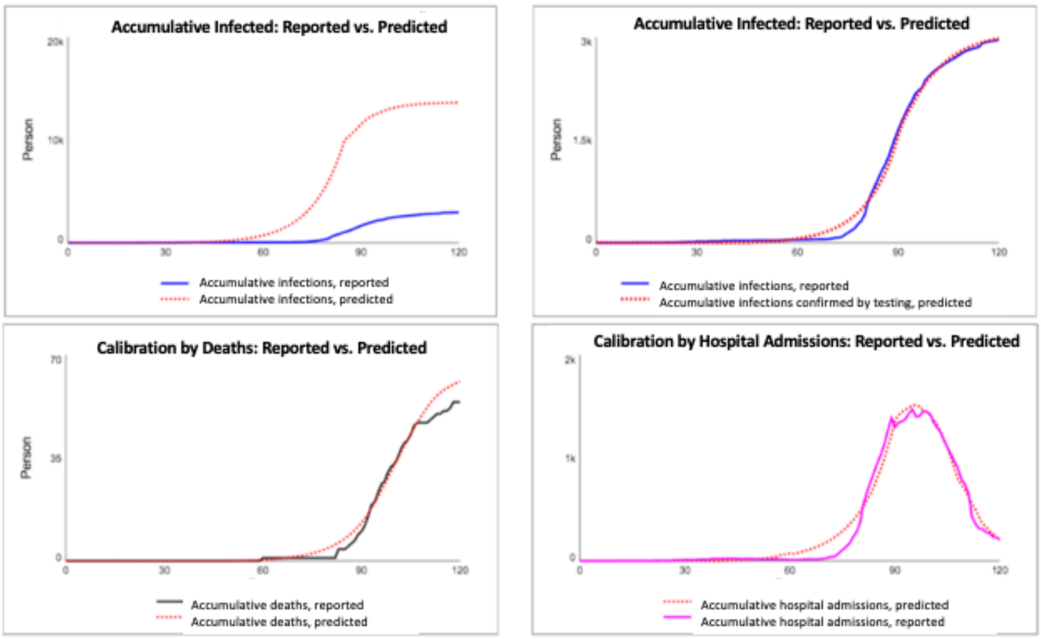

Figure 2c Comparison of predicted and reported data of COVID-19 in Thailand before and after implementing the intensive/lock-down/hammering policies (Jan 1, 2020 to May 13, 2020)

Using System Dynamics Models as Policy Decision Support Tools for the COVID-19 Epidemic Control in Thailand

Abstract

Epidemiological modeling can be a critical tool for planning disease control strategies. However, the COVID-19 pandemic is a complex problem, with the interconnectedness of health and socioeconomic issues. Systems thinking can help create well-rounded policy options by investigating all interconnected relationships that can influence both epidemic and socioeconomic outcomes. We conducted system dynamics models of the COVID-19 epidemic control in Thailand to support policy decisions on mitigation strategies and minimizing socioeconomic impacts. Our ongoing analyses point out that many problems can be a result of adaptations of stakeholders. For instance, after the clustered epidemics at pubs, bars, and a boxing stadium in March 2020, policymakers implemented closing workplace, stay-at-home, work-from-home, and travel bans policies nationwide. Our model revealed these intensive measures cut off 77% of community transmissions within two months, but the prolonged policies created adverse socioeconomic outcomes. We also found the relaxation of control measures since May 2020 can increase domestic infections in late 2020, but still within the national healthcare capacity. Therefore, policymakers may use intensive disease control strategies only for a limited time to avoid the negative impacts on the economy and society while maintaining sufficient disease control.

Keywords: COVID-19, pandemic, epidemiology, epidemic control, mitigation strategies, socioeconomic impacts of disease control, systems thinking

Introduction

The global spreading of COVID-19, caused by the novel coronavirus 2019 that eventually became a global pandemic, has resulted in many complex problems affecting people in different countries worldwide. Policymakers in each country have to be responsive to planning disease control strategies, healthcare resource management to support patients, and reducing mortality from COVID-19. Problems also arose from economic and social impacts from disease control policies that have caused a slowdown in economic activities.

Thailand was one of the first countries that imported the COVID-19 cases from Wuhan, China, and has urgently developed policies to tackle the COVID-19 outbreak within the country. The Emergency Decree on Public Administration has been declared throughout the Kingdom to control the epidemic of COVID-19 since March 26, 2020. It was expected that such a hammering policy would lead to a rapid reduction in the number of viral infections as observed by the lockdown that was imposed after the world's first outbreak was observed in the COVID-19 epidemic control of Wuhan, China (1,2).

But the framework that Thailand's policymakers used to determine the strategic direction of dealing with the COVID-19 pandemic has its root in the paradigm of knowledge-building and problem-solving in Thai society. The mainstream knowledge-building process focuses on separating science into different fields, relying on experts with in-depth knowledge such as experts in infectious diseases, epidemiologists, economists, or public health law, etc. Thus, the policy decision-making process to tackle the COVID-19 epidemic can result from compartmentalized thinking [3,4]. Policy decisions may be split; namely, 1) the disease control measures (e.g., increasing physical distance, community density reduction, quarantine, contact tracking, isolation), 2) the healthcare resource management measures (e.g., enhancing the capacity of the intensive care unit in each area), and 3) remedy measures (e.g., compensations to those who were worse-off by unemployment or slowing down of economic activities). Hence, researchers can apply systems thinking (5,6) to analyze policy options for addressing the COVID-19 epidemic more comprehensively by seeing the epidemic as a part of a complex and adaptive social phenomenon and understanding the relationships between all the elements of the health and non-health systems are connected.

Methods

Model structure:

We developed system dynamics models (7) to be used as the policy decision support tools for the covid-19 epidemic control in Thailand. Our system dynamics models were based on the Susceptible-Infectious-Recovered (SIR) compartmental model put forth by Kermack and McKendrick since 1927(8). Nonetheless, we did not aim our model to be only an epidemiological exercise, but to capture an in-depth understanding of the structure of complex systems that are the source of both desirable and unwanted behaviors of stakeholders of the COVID-19 containment and mitigation policies before testing such approaches in simulation modeling. Hence, additional stocks and flows were added into the model structure.

The structure of the model is shown on Figure 1. The stocks of the “Exposed” were added to reflect the knowledge of the incubation period, as three was a delay between the populations being exposed to the virus and infected and the “Infectious or Contagious” populations showing symptoms and being contagious. The imported infectious variable were added to the domestic Infectious or Contagious populations to represent the ongoing imported cases into the country by the inbound international traveling. The Death were added to reflect the need to monitor the system outcomes of not only the disease control but also the quality and adequacy of the healthcare delivery systems.

[Figure 1 here]

The separated stocks and flows of the tested and reported infections were constructed to reflect the nature that we can only identify the infected populations by testing, and therefore the observed infections were determined by the testing facilities and contact tracing capacity of the outbreak investigators available in the country at the moment. The Infectious were also categorized by the severity of the infected and contagious populations to reflect the demands for health care faculties that can serve each severity group, including outpatient visits, coward ward, airborne infection isolation room (AIIR), and intensive care unit (ICU). The data used as an model parameter were acquired from the administrative data set of Thailand’s Ministry of Public Health.

Model assumptions:

We assumed the basic reproduction number (R_0) of COVID-19 epidemic in Thailand from early January to late March 2020 is 2.2. After the Emergency Decree on Public Administration has been declared throughout the Kingdom to control the epidemic of COVID-19 since March 26, 2020, the intensive or “hammering” policy packages were introduced nationwide. After consulting with the expert in the Ministry of Public Health’s Department of Disease Control, we assumed the effectiveness of each item of the hammering policy as shown on Table 1.

[Table 1 here]

Policy experimentation:

The policies for controlling COVID-19 in Thailand in early 2020 can be categorized into four major categories, including 1) Intensive/Hammering policies, 2) Physical distancing behaviors policies, 3) quarantine & isolation policies, and 4) rapidly increasing healthcare capacity.

Findings

Our ongoing analyses point out that many problems can be a result of adaptations of stakeholders. For instance:

1. We compared our simulated findings with the outbreak's actual data after intensive disease control measures were applied. The Emergency Decree on Public Administration in Emergency Situations was declared on March 26, 2020. The intensive mitigation and containment measures, such as closing workplace, stay-at-home, work-from-home, and travel bans policies, were implemented nationwide. Within two months, our model found a 77% decrease in community transmission of COVID-19 outside quarantine or isolation systems than before intensive disease control measures were implemented. Such effectiveness was attributed to all policy interventions combined.
2. Thanks to the intensive mitigation and containment measures, Thailand has successfully avoided the peak of new infections in the 1st wave that could have overrun our healthcare systems, as previously projected by our model around Day 177th outbreak or around the end of June 2020. The peak arrived on the 89th day of the country's epidemic with less than 200 new infections per day, limiting the number of critically ill patients who required the intensive care units.
3. Our models revealed a potential outbreak after intensive COVID-19 control measures were lifted (e.g., reducing the time of announcing curfew, then lifted a cross-provincial public transport ban in May 2020, or the school reopened in July 2020). The simulated number of new infections was forecasted to peak at 144 people, and critically ill patients occupied 105 beds in the intensive care unit at the end of September 2020. The manageable number allowed policymakers to consider several policy options for lifting the disease control disease measures.

[Figure 2a, 2b, 2c here]

Discussions and conclusion

The COVID-19 pandemic is a very complex problem, interconnected with health and socioeconomic issues (9). Policy decision-making with compartmentalized thinking can have adverse effects on disease control. It could make policies ineffective for tackling health and socioeconomic problems arising from the COVID-19 pandemic due to unforeseen policy negative consequences. For instance, lockdowns can create inaccessibility to health services for non-COIVD-19 patients.

In reality, however, Thailand's policymakers decided to lift the intensive measures gradually. Hence, the mitigation policies were prolonged for more than six months, significantly creating adverse socioeconomic outcomes. A loss of ten million international tourists was estimated to reduce Thailand's GDP growth by at least 3%(10). Therefore, policymakers may use intensive disease control strategies only for a limited time to avoid the negative impacts on the economy and society while maintaining sufficient disease control.

Our ongoing analyses point out that many problems can be a result of adaptations of stakeholders. For instance, after the clustered epidemics at pubs, bars, and a boxing stadium in March 2020, policymakers implemented closing workplace, stay-at-home, work-from-home, and travel bans policies nationwide. Our model revealed these intensive measures cut off 77% of community transmissions within two months, but the prolonged policies created adverse socioeconomic outcomes. We also found the relaxation of control measures since May 2020 can increase domestic infections in late 2020, but still within the national healthcare capacity. Therefore, policymakers may use intensive disease control strategies only for a limited time to avoid the negative impacts on the economy and society while maintaining sufficient disease control.

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