TECHNICAL WORKSHOP ON INFECTIOUS DISEASE MODELLING 25 NOVEMBER 2022

REPORT

HEALTH INTERVENTION AND TECHNOLOGY ASSESSMENT PROGRAM (HITAP), MINISTRY OF PUBLIC HEALTH

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The findings, interpretations and conclusions expressed in this report do not necessarily reflect the views of the funding or participating agencies.

List of Abbreviations

COVID-19	Coronavirus disease
HITAP	Health Intervention and Technology Assessment Program
HPV	Human papillomavirus
HIV	Human immunodeficiency viruses
GMB	Group model building
LMICs	Low- and middle-income countries
LSHTM	London School of Hygiene and Tropical Medicine
RCT	Randomized Controlled Trial
SAGE	Strategic Advisory Group of Experts
SIR	Susceptible, Infectious, Recovered
SEIR	Susceptible, Exposed, Infectious, Recovered
UNDP	United Nations Development Programme
WHO	World Health Organization

Introduction

Background

Infectious disease models can be used to forecast future outbreaks and estimate the impact of interventions to support policy. Although infectious disease modelling is a well-established method, it has recently gained prominence during the COVID-19 pandemic as an important tool to support decision-making. Most COVID-19 transmission models were initially developed for high-income settings, such as the United Kingdom (UK) and the United States (US) and were later adopted for use in low- and middle-income countries (LMICs). Without local technical capacity and an understanding of setting-specific contexts, models may produce inaccurate and non-robust results. Improving technical capacity for conducting infectious disease modelling remains a priority as part of the pandemic preparedness agenda for all countries.

The Health Intervention and Technology Assessment Program (HITAP) is a research unit in the Thai Ministry of Public Health and supports use of evidence for health policy. It has been collaborating with the London School of Hygiene and Tropical Medicine (LSHTM) to build capacity on infectious disease modelling and, in an effort to address the gap in capacity for infectious disease modelling in Thailand, hosted an introductory workshop.

Objectives

The objectives of this workshop were:

- To provide participants with an understanding of the basic concepts behind infectious disease modelling and hands-on experience developing a basic infectious disease model in Excel.
- To provide an overview of the infectious disease models used in the context of the COVID-19 pandemic response.
- To increase awareness of how infectious disease modelling can be used to inform policy.
- To facilitate networking between modelers, researchers from other disciplines, and other collaborators.

Format

The workshop was structured as a series of lectures, with a computer practical for all participants and a panel session followed by an open discussion with the audience. The sessions were conducted in English and translated into Thai by translators. The agenda for the workshop is provided in Appendix 1.

Participants

The technical workshop targeted participants expecting to conduct or use the outputs from infectious disease models to inform policy in their future work. While the workshop primarily sought to engage researchers from the Ministry of Public Health and academic institutions in Thailand, government and academic researchers from other South-East Asian countries and participants from funding agencies were also invited.

Most attendees were nominated from governmental organisations and academic research institutions by the organisation's leader. Other attendees self-registered after learning this workshop from the 17th Economic Evaluation Training held by HITAP in November 2023. Information of the workshop was disseminated to various organisations and institutes; the flyers in both Thai and English can be found in Appendix 2.

A total of 64 participants joined the workshop. The list of participants is shown in Appendix 3.

Support for workshop

This workshop was supported by the Rockefeller Foundation, the Thai Ministry of Public Health and the Access and Delivery Partnership (ADP).

Summary of Discussions

Opening Remarks

The opening remarks were given by Dr. Rungrueng Kitphati, Spokesperson of the Ministry of Public Health, Thailand, and Chair of this workshop. Dr. Rungrueng Kitphati highlighted the importance of the infectious disease modelling workshop and said that infectious disease modelling was one of the valuable knowledge assets or methods for supporting the decision-making during disease outbreaks. He noted that it has been used to assess disease control and prevention interventions in the past and could be used to plan for future public health threats preparedness and could, in fact, be regarded as a compass or a map to guide policymakers. Finally, he noted that the results from conducting infectious disease modelling are crucial for public communication to provide mutual understanding for pandemic preparedness.

Figure 1 – Dr. Rungruang Kitphati giving the opening remarks

Lecture session 1: Introduction to infectious disease modelling and use of the outputs in economic evaluation

The workshop began with a lecture delivered by Prof. Mark Jit, who shared the objectives and expectations of the workshop which aimed to understand:

- the value and limitations of models that can be used to predict disease outcomes;
- the purpose and characteristics of different types of disease models; and
- how to perform an economic evaluation alongside an infectious disease model.

The key points from his lecture were:

A model is a simplified representation of a more complex object/process, designed to address specific questions. The reason for using a model rather than conducting full experiments or making direct observations is to explore a range of possibilities in terms of options such as school closures, lockdown, vaccination, and consequences such as deaths, long-term sequelae, and herd effects. There are many cases in which Randomised Controlled Trials (RCTs) cannot provide an answer, but it can be simulated using a model, for example, by extrapolating outcomes not captured in the period of observation (such as long-term COVID-19) or instances in which it is too expensive or time-consuming to conduct population studies. As a result, mathematical models can be utilised in the decision-making process.

The decision process usually starts by gathering information from numerous fields, such as virology, immunology, and field epidemiology. Following this, a deliberative process employs this evidence for policy development. Typically, a multi-disciplinary committee evaluates the data and provides guidance. For example, WHO commissions a committee called 'SAGE' (the Strategic Advisory Group of Experts on Immunisation) for vaccination. This group evaluates the evidence from immunisation programmes worldwide and provides recommendations to WHO. After deliberation, legitimate decision-makers then make the final decision. This process is called the "Evidence-inform policy-making process". In summary, scientists generate evidence that is evaluated by an authorised committee which advises on which decision to make.

Type of models used in health

There are two types of mathematical models:

1) Empirical models: commonly used in trial-based economic evaluations; and
2) Theoretical models: apply simulation techniques.

During the policy-making process, **decision-analytic modelling** can be utilised to select the best intervention or policy option and forecast the outcomes of various choices. For example, a decision-tree diagram could be used for this purpose. Decision-analytic modelling is an interdisciplinary approach where experts from diverse fields collaborate to determine the most appropriate modelling method, structure, and parameterisation to inform a specific decision within the given constraints of time and resources. The goal is to collectively identify the best-suited modelling approach to effectively inform the decision-making process given the available time and resources.

Model structure

The model structure is usually determined by considering the relationship between model inputs and outputs. Examples of inputs and outputs used in the model structure can be summarised as follows:

- inputs usually relevant to the natural history of the disease, clinical pathways, intervention effectiveness,
- outputs that are most relevant to decision-makers, such as the number of cases, deaths, hospital admissions, life years gained, QALYs, DALYs, and so on.

An explicit process should be used to develop the model structure, such as expert consultations, influence diagrams, concept mapping, or similar methods.

When building an infectious disease model, the force of infection refers to the rate at which individuals susceptible to an infection become infected. In a static model, the point of infection remains constant and unchanging, whereas, in a dynamic model, the force of infection varies over time.

Types of models

There are different types of decision-analytic modelling methods, including:

1. Proportionate outcomes model (decision tree): Decision trees are a graphical representation of a decision-making process. They depict a decision as a series of nodes, branches, and outcomes, with each possible action leading to a different outcome. This model is like a flowchart, used to answer specific questions that involve making a choice between various options. It is useful when the outcome is proportional to the intervention chosen, such as in deciding between radiotherapy or surgery for treating cervical cancer. The force of infection is fixed over time.
2. Markov model: Markov models are used to evaluate the outcomes of different interventions or treatments over time. These models are based on the concept of a Markov chain, where a system moves through a series of health states, with the transition between each state governed by probabilities. For instance, the human papillomavirus (HPV) infection progresses through different stages before developing into cervical cancer. A Markov model represents this progression from one stage to another. The force of infection is fixed over time.
3. Compartmental transmission dynamic model: This model uses different states to represent individuals with different health conditions. The transition from one state to another is based on the number of infected individuals, and hence the force of infection is dynamic. This model is suitable for situations where an intervention, like vaccination, changes the proportion of people infected with a disease over time.
4. Individual-based model: This model is a type of model where the force of infection changes over time and considers individuals separately instead of assuming that people within the same compartment are homogeneous. Unlike compartmental models, it is stochastic and requires more computing power because of its complexity.

SIR compartmental model

The 'Susceptible-Infected-Recovered' or SIR model has three main states. There are compartments for susceptible (S), infected (I) and recovered people (R). Additional states may be added to the SIR model depending on the natural transmission of the disease. For example, in some diseases, a Death compartment may be considered.

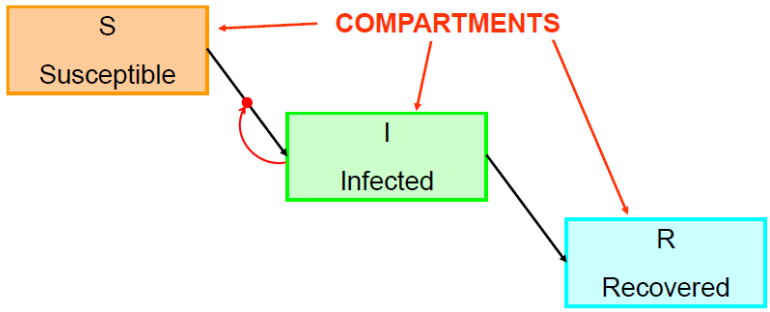


Figure 2 - SIR Model diagram

The model in Figure 2 can be expressed mathematically as a series of differential equations:

Susceptible → $S_{t+1} = S_t - \beta S_t I_t$ (β: Probability of transmission)

Infectious → $I_{t+1} = I_t + \beta S_t I_t - \gamma I_t$ (γ: Recovery rate)

Recovered → $R_{t+1} = R_t + \gamma I_t$

To illustrate one of the equations above, β depends on the kind of transmission or the kind of contact that is happening. If two people are hugging, the beta may be high; however, if they are on different sides of the room, wearing masks, or have received some form of vaccination, the beta may be lower since they are well protected from contracting an infection. Three factors (β, S_t, I_t) are multiplied to get the number of people infected.

Reproduction Number

The basic reproduction number, or R_0, indicates how fast a virus can spread. It represents the number of people one infected person will transmit the virus to, assuming everyone is susceptible. For example, if Mr M is the only infected person in a room, R_0 shows how many people Mr M will infect before he recovers. That is the reproduction number. A higher R_0 means the virus will spread faster, while a lower R_0 value will spread slower.

However, R_0 has limited use in practice because it is hard to find a completely susceptible population. As the disease spreads, a portion of the population will move from susceptible to infected and eventually recovered compartments. If the infection is immunising, a new value, the net reproduction number or R_n, should be used. R_n is the average number of secondary infections that results from each infectious person in a given population.

Lecture 1: Q&A session by Prof. Mark Jit

They key discussion points from Lecture 1 are summarised below:

Booster Dose in HPV Vaccine: The discussion revolved around the use of models to predict the effectiveness of booster doses in the HPV vaccine. The importance of determining the improvement in protection provided by the second dose was highlighted, considering the initial protection achieved through herd immunity and direct protection.

Commercial Software for Infectious Disease Modeling: The availability of commercial software for infectious disease modeling such as NetLogo and Berkeley Madonna were mentioned, but it was emphasized that some programming skills are still required. User-friendly software specific to certain diseases, like COVID-19, were also mentioned, but caution was advised to avoid incorrect inputs without proper expertise.

R_0 versus R_n: The use of R_0 (basic reproduction number) over R_n (effective reproduction number) was explained. R_0 represents the inherent characteristics of the disease and is used to determine the potential for spread before anyone is infected. Once people start getting infected, R_0 is no longer applicable, and Rn becomes more relevant in measuring the actual spread.

Choice of Models in Epidemic Outbreaks: The suitability of mechanistic and statistical models at the beginning of an epidemic was discussed. While statistical models can be used in the short term when the dynamics and behaviour change are minimal, mechanistic models are considered more appropriate for capturing long-term dynamics, including behaviour change, immunity, and interventions like lockdowns and vaccinations.

Gaining Trust in Models for Health Policymakers: Suggestions were provided on how to make health policymakers trust models. Transparency about model assumptions and limitations was emphasised, as decision-makers are more likely to trust a model when its workings and limitations are clearly explained rather than treating them as a "black box."

Incorporating Spatiotemporal Variables: The importance of incorporating spatial and temporal variability in infectious disease models, particularly for climate-sensitive diseases and those related to water, was discussed. Methods such as establishing relationships between variables and using metapopulation models are mentioned to account for spatial heterogeneity and similarities.

Combining Disease, Health Service, and Economic Models: The potential benefits of integrating disease models, health service resource models, and health economic models into a single model were acknowledged, highlighting the interactions among these factors. However, it was noted that computation becomes more complex when combining these different aspects.

Assessing the Quality of Infectious Disease Models: Criteria for evaluating different models of a particular infectious disease were discussed. Considerations include whether the model captures important disease characteristics, the assumptions made about the disease's natural history, and whether they align with the expertise of clinicians, epidemiologists, and microbiologists.

Getting Started with Infectious Disease Modeling: Advice for someone interested in entering the field of infectious disease modelling included working with modelling groups to understand applicable models for policymaking, seeking training opportunities, and considering enrolling in a PhD program to obtain a degree in infectious disease modelling to work independently as a modeler.

Data Challenges in Compartment Models: The situation of designing compartment models without sufficient data to fill them is addressed. It is recommended to consult specialists and incorporate their expertise in determining the range of data or relevant information that can be used. Additionally, conducting sensitivity analyses is suggested to assess the impact of data uncertainties.

Applicability of Models to Different Diseases: The use of infectious disease models for various diseases, including human immunodeficiency viruses (HIV) and other sexually transmitted diseases, was discussed. It was noted that models can be adapted and modified to suit different diseases, with examples given regarding the adjustment of the SEIR model for HIV, considering the longer duration of infectiousness compared to other diseases.

Figure 3 – Prof. Mark Jit during the first lecture

Lecture session 2: COVID-19 mathematical models and the model development process

This lecture was delivered by Dr. Yang Liu. Through case studies, Dr. Yang Liu introduced some ideas on how mathematical models were developed for answering questions related to COVID-19. Generally, a model should be designed and driven by:

1. the nature and characteristics of the pathogen and disease one is working with;
2. the research/ policy questions one is considering; and
3. the principle of parsimony.

Dr. Yang Liu then walked through the following steps to explain how the structure of an SEIR model was developed for COVID-19, as well as the changes made to the model structure as new knowledge about the disease emerged.

1. The nature and characteristics of the pathogen and disease

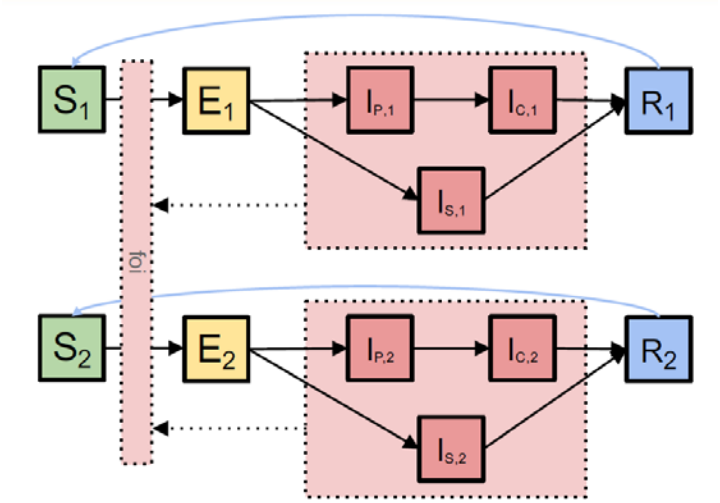


Figure 4 - The SEIR model diagram

The first step was adding an Exposed **E** compartment to SIR model described by Prof. Mark Jit. In the context of SEIR models, being exposed indicates that people are infected but not yet infectious. For COVID-19, the E compartment was added to reflect incubation time. Incubation time is the time between infection and becoming symptomatic.

Next, the infectious compartment (I) was separated into three different compartments.

1. I_p for infectious and preclinical.
2. I_c for Infectious and clinical.
3. I_s for infectious and subclinical.

Ip and I_c were separated to reflect an important characteristic of SARS-CoV-2, which is that infected individuals may not display symptoms. This feature poses a challenge in disease control because transmission events may have already taken place before the infected individuals is aware of their clinical condition. Another group called I_s was included as a subclinical group to represent people who have an infection but do not exhibit clinical symptoms.

Additionally, an age component was introduced to the model as there are indications from clinical studies that patients of different age groups may exhibit diverse responses and clinical presentations.

Older adults are more susceptible in this context, and adults are more likely to progress clinically. The model requires input parameters in the form of contact matrices to determine the level of contact between different age groups. Different pairs of age groups are a key input parameters to develop this age-specific model for COVID 19.

2. The research/ policy questions

Dr. Yang Liu then introduced the vaccine (V) compartment in the model based on current knowledge about vaccines. In addition, the issue around hybrid immunity was illustrated, which is defined as the immune protection in individuals who have had one or more doses of a COVID-19 vaccine and experienced at least one SARS-CoV-2 infection before or after the initiation of vaccination. Therefore, the model was extended to include the R compartment for those hybrid immunity groups.

The "calibration" process involves adjusting the model parameters that will allow one to reproduce observed phenomena by estimating and modifying model parameters to increase the concordance between the model output and collection of data.

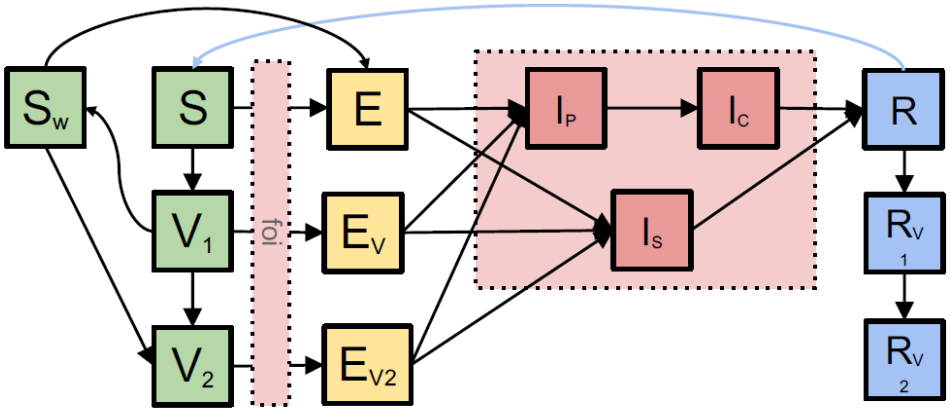


Figure 5 - The SEIR model diagram after adding vaccination

3. The principle of parsimony

Parsimony means the process of making the model as simplified as possible. For example, the model shown in the workshop did not account for breakthrough infections. Breakthrough infections are cases where a previously infected individual becomes infected again. This was done for the purpose of vaccine accounting and to ensure that the model results focused on the effectiveness of two-dose vaccinations.

Lecture 2: Q&A session by Dr. Yang Liu

In Lecture 2, the following key points were discussed:

Comparing Infectious Disease Models: A question was raised on whether it is possible to compare results across different infectious disease models, considering that these models can be modified over time. The speaker suggests that the comparability of models needs to be carefully reviewed by the modelers themselves. Factors to consider include the quality of assumptions, the implications of those assumptions, and any biases in the studies. Comparing models involves checking various outcomes generated by the models.

Advice for Beginners in Mathematics Modelling: The complexity of mathematical models can be intimidating for beginners. It was recommended to develop a basic understanding of different types of models and their strengths and weaknesses. This model literacy allows beginners to have a broader understanding of the questions that can be addressed and the overall landscape of modelling. While beginners may not know how to implement every aspect of a model, having a general knowledge of the available methods can be more achievable and helpful for selecting appropriate models for specific research questions.

Lecture session 3: Computer-based practical on infectious disease modelling

Dr. Kiesha Prem delivered a lecture to provide hands-on experience in using and adapting a compartmental dynamic model in Excel. The main objective of the session was to modify a simple model to estimate the potential benefits of COVID-19 vaccination over a year. Participants were given around 20 minutes to make changes to the vaccination model and evaluate the benefits in terms of; i) the number of COVID-19 cases and deaths averted, and ii) the percentage reduction in COVID-19 deaths due to vaccination. During this time, Dr. Prem and teaching assistants from HITAP observed and provided support while the audience interacted with the model and addressed their queries.

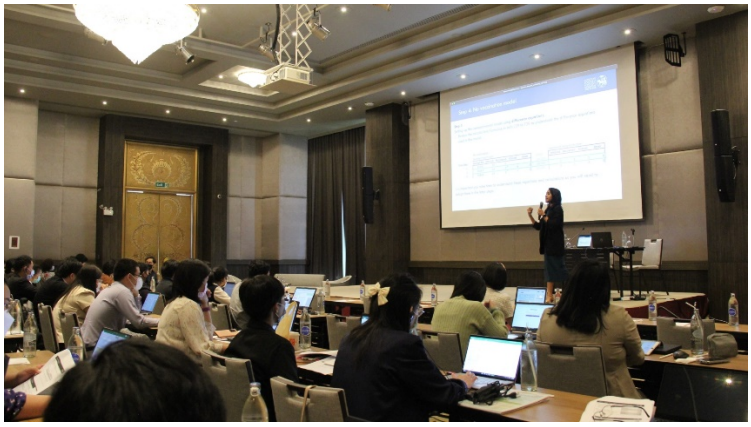


Figure 6 – Dr. Kiesha Prem describing the model at the start of the computer practice

Lecture session 4: The application of Modelling in the Context of SARS-CoV-2 and COVID-19

To demonstrate the wide variety of modelling approaches to address different policy questions during the COVID-19 pandemic, Dr. Yang Liu presented on a range of models in the literature, including models to understand the epidemiology of disease, models to plan interventions, and models to forecast future outbreaks. The intent was to show that while it may be enticing to apply one model, as with the saying “if all you have is a hammer, everything looks like a nail”, no single type of model is appropriate for all policy questions. It is therefore important to have a toolbox of modelling techniques and to critically assess which are best suited to the question at hand.

Figure 7 – Dr. Yang Liu during the lecture

Q&A session by Prof. Mark Jit, Dr. Kiesha Prem, and Dr. Yang Liu

After the fourth lecture had been completed, a group Q&A session with Prof. Mark Jit, Dr. Kiesha Prem, and Dr. Yang Liu was conducted by Dr. Pritaporn Kingkaew, the session's moderator.

In this discussion, the following key points were covered:

Vaccine effectiveness in infectious disease models: A question was raised about the vaccine effectiveness in infectious disease models and whether it only reduces the severity of the disease. Dr. Liu explained that in the model developed for WHO Europe, five types of vaccine effects were incorporated, including infection reduction, disease reduction, severity reduction, transmission blocking, and mortality reduction.

Evaluating the reliability of a proposed model: The question focused on what a policymaker with limited knowledge of modelling should consider when evaluating the reliability of a proposed model. Dr. Prem advised that policymakers should know whether the model is appropriate for the specific data, country context, or population under consideration. Additionally, the modeller should be able to describe the model assumptions in a non-mathematical way, avoiding complex equations.

Efficiency in using computing languages: The participants inquired about the time it takes to efficiently understand and use programming languages such as R, C++, and Python. Dr. Prem suggested that it is not necessary to fully understand every aspect of a language. Instead, one can focus on the code required to develop the model and work with a professional programmer who can provide guidance. Dr. Liu added that it is beneficial to experiment with different languages and choose the one that works best for individual preferences.

Appraising the quality of a study for decision makers: A participant asked for advice on how a decision maker with limited experience in dynamic modelling can quickly assess the quality of a study. Dr. Prem recommended to selecting a programming language that the decision maker is willing to learn. Dr. Liu expressed a preference for R programming in the context of public health, as it offers more access to cutting-edge development in methodology compared to Python, which is more production focused.

Figure 8 - Group discussion by Dr. Yang Liu, Dr. Kiesha Prem, Prof. Mark Jit and Dr. Pritaporn Kingkeaw (From left to right)

Policy Discussion

Dr. Borwornsom Leerapan, a physician-researcher from Mahidol University skilled in the analysis of health policies and the management of health services, began this session by discussing his experience on how he incorporated modelling in to inform policy recommendation. The topic titled "*Using System Dynamics Modelling as A Policy Decision Support Tool for the COVID-19 Epidemic Control in Thailand*". He first discussed why 'System Dynamics Modelling' is relevant for pandemic control in Thailand, highlighting the following three points:

1) System Dynamics Modelling links technicians with public health systems and it can assist policymakers in making more informed and better decisions.
2) Interconnected relationships influence epidemic and socioeconomic outcomes. Dr Leerapan shared that the COVID-19 outbreak's initial phase in 2020 and 2021 was a public health crisis, but its later phases in 2021 and 2022 appeared to be more of a socioeconomic crisis than a public health emergency.
3) This model helps to formulate policy interventions that may create optimal effects with the least negative consequences. Systems thinking can help policymakers avoid unintended consequences.

Then, Dr. Leerapan discussed a mathematical modelling approach for better strategic planning and decision-making in complex systems using group model building (GMB) methods, which was also carried out by Dr Leerapan's team, aimed at getting stakeholders to collectively consider the causes of complex problems. He then pointed out the importance of considering the perspectives of policymakers and other stakeholders to avoid the model being viewed as a black box. If the model does not support a policy that has already been decided upon ("Policy-based evidence making"), as stakeholders will be hesitant to use the model's result, or the model will be perceived as unreliable. Therefore, his model development team addressed those issues by inviting all stakeholders and policymakers to take ownership of the model, which was also helpful for making data accessible. Dr Leerapan showed the process to apply System Dynamics Modelling in health policy, as shown in Figure 9.

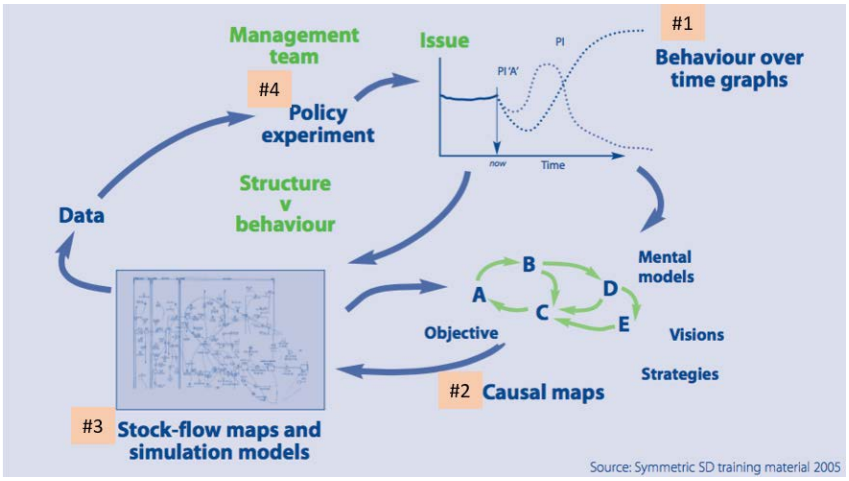


Figure 9 - System dynamics model building diagram

Figure 10 shows a Stocks-and-Flows Diagram used in simulation modelling, where population ratios alter over time rather than transitioning at a fixed rate as in a Markov model. The influx and outflow of population inside the model can be influenced by different policies.

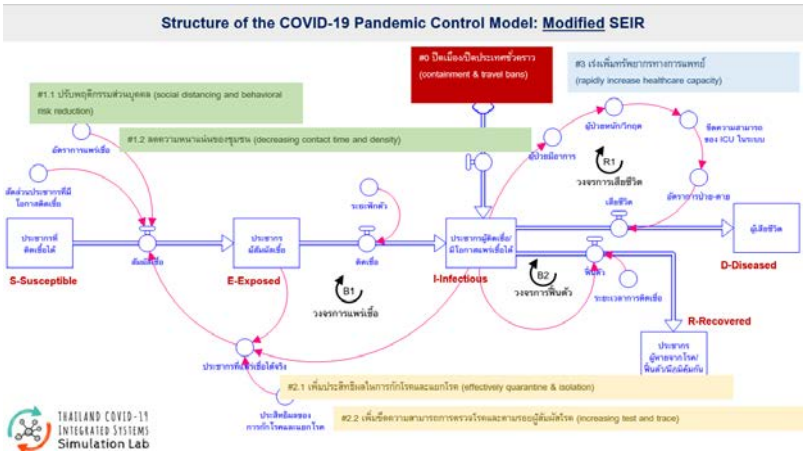


Figure 10 - The model diagram described by Dr Borwornsom Leerapan for the control of COVID-19 in Thailand

Figure 10 incorporates the SEIR model and considers the effect of different policy interventions. For instance, the infectious compartment can be adjusted by containment and travel bans. The summary of all flows enables us to manage the population's growth or decline in each direction. System Dynamics Modelling can also be used as a systems map to mutually identify goals, critical process, and relevant stakeholders and communicate with the public.

Dr Leerapan also demonstrated the following policy recommendations that were generated by the preliminary analysis:

- Need for more hospital/hospital beds and staff for both disease control and treatment in the next 30-45 days. In some scenarios, the hospital bed inventory ~28,147 beds (data as of 20 April 2021) might be inadequate for the increasing prevalence of COVID-19 infections, which peaked approximately in the middle of May the same year.

- The number of available ICUs/ventilators should be adequate.
- Surge capacity of hospital beds required nationwide (both existing hospitals and field hospitals) should be increased to at least 32,000 beds.
- Health workforce can be “the bottleneck” of the surge capacity of both disease isolation and treatment.
- Assuming no additional waves/clusters of new epidemics in the communities and provided that the work-from-home measures are effective as planned, the demand for hospital beds will gradually decrease until around the end of May.

Lastly, Dr Leerapan talked about lessons learned and the next steps for modellers. His model has been featured in various media sources. Structured systems mapping techniques can be used by other press or organisations to support activity in the community as a response to the outbreak, such as organising charity channels for COVID-19 victims. Additionally, this system mapping enables decision-makers to conceptualise issues and broaden their thinking process so they can react to policies in a more proficient way. The policy can lead to issues if it is not carefully thought out. As an example, when Bangkok was placed under lockdown throughout the Songkran festival, people lost their jobs and moved to other provinces, which caused the virus to spread over the entire country. International collaboration for model development and evaluation is necessary to standardise the local model. Thailand, likewise, needs a working group to support decision markers, similar to SAGE in the UK. To summarise, in each and every step of the policy-making process, systems thinking is crucial.

The policy discussion ended with an interactive session conducted by Assoc. Prof. Dr Wanrudee Isaranuwatchai, HITAP’s Program Leader and Senior Researcher, outlining the common modelling questions in a section on ‘Myths or Facts?’. She encouraged the participants to realise the importance of using academic data to support policy makers. In the first part of her session, she incorporated a survey application called ‘Menti’ to present a series of statements, and asked the audience to choose whether each statement is a myth or fact. The statements covered model inputs, policy questions during the COVID-19 outbreak, and interdisciplinary modelling. Situations and policies change dynamically, leading to a rapid accumulation of large amounts of information being scattered and because of this, cooperation between the government and the scientific community is essential.

Moderated Policy Discussion

In this open discussion on the use of modelling in the policy, moderated by Dr. Pritaporn Kingkeaw, the following key points were covered:

Encouraging Policy Adoption of Complex Models: A question was raised on how researchers can encourage policymakers to adopt complex models. Dr. Leerapan and Assoc. Prof. Isaranuwatchai emphasized the importance of avoiding the display of complex models to policymakers. Instead, the focus should be on presenting accurate and reliable information that addresses the policymakers' needs. Transparency, compliance with established guidelines, and clear sourcing of data were highlighted as essential factors in presenting models effectively.

Quality and Availability of COVID-19 Data: There were concerns about the changing quality of COVID-19 data sources during the pandemic. Dr. Leerapan mentioned the need to ensure the underlying logic of the model is correct and highlighted the importance of gathering fresh data when needed. Assoc. Prof. Isaranuwatchai emphasized the usefulness of individual data collected by public agencies but stressed the need to prioritize data privacy and confidentiality. Access to data for research purposes was acknowledged as a complex issue.

Building Networks and Collaborative Modelling: The question focused on how to build networks and collaborative modelling in emergency situations, citing the example of the Scientific Advisory Group for Emergencies (SAGE) in the UK. Dr. Leerapan suggested the importance of long-term measures to establish adequate infrastructure and institutions for collaboration. The COVID-19 outbreak was mentioned as a catalyst for policy-related work reform. Assoc. Prof. Isaranuwatchai highlighted the need to create a community of learners and emphasised the potential impact of collaboration on society and future generations.

Figure 11 - Policy discussion by Dr Borwornsom Leerapan, Assoc. Prof. Wanrudee Isaranuwatchai and Dr. Pritaporn Kingkeaw (From left to right)

Closing remarks

The workshop ended by closing remarks given by Eric Arndt, Director, Asia Regional Office from the Rockefeller foundation. He emphasised the Rockefeller Foundation's support to HITAP on the development of capacity building for better pandemic preparedness. In his remarks, he said, "*I would like to congratulate the Ministry of Public Health, HITAP, LSHTM, and other partners who are organising today's event. I hope you found this to be an enriching experience to enhance the ability to anticipate and respond to the effects of infectious diseases. As The Rockefeller Foundation, we are very proud to support this endeavour through our partnership with HITAP Thailand.*"

Figure 12 - Eric Arndt, Director of Asia Regional Office, Rockefeller Foundation, giving the closing remarks

Figure 13 - Group photo

Additional information

Summary of the workshop evaluation from the participants

In total, the workshop was attended by 64 participants. Most participants were professors, physicians, academics, etc. After the workshop, participants were asked to complete the workshop evaluation form. Forty-four participants (69%) completed the full form.

The questionnaire was developed on SurveySparrow to survey the feedback from workshop participants. A descriptive analysis of the results has been conducted and summarised below. Please note that all the responses were originally in Thai and have been translated into English.

The first section consisted of four questions, including (1) knowledge and understanding "before" the workshop, (2) knowledge and understanding gained “during” the workshop, (3) whether there was enough opportunity to express their opinions, and (4) knowledge and understanding "after" the workshop. There are five levels for participants to rate, including 5 = Excellent, 4 = Good, 3 = Average, 2 = Below Average, and 1 = Poor. Most participants indicated that their knowledge of infectious disease modelling before the workshop was “below average” (45%). They gained knowledge from attending this workshop in a good amount (64%), with excellent opportunities to express their opinions (61%).

The second section included three questions relating to; (1) the benefits they received from the workshop, (2) whether the content is consistent with their job, and (3) whether the content is consistent with the meeting’s objectives. There are five levels of satisfaction for participants to rat,e including: 5 = Very satisfied, 4 = Satisfied, 3 = Neutral, 2 = Less satisfied, and 1 = Poor. The majority of the attendees were very satisfied (48%) with the benefits they received from attending the workshop. They were confident that the workshop content was relevant to their job (45%) and very satisfied that the content aligned with the objectives of the workshop (50%).

Section 3 asked how they plan to use the knowledge gained from the workshop in their current and/or future work. There were various answers, and participants said they would, for example, apply the knowledge gained to other types of modelling, conduct research, develop a sensible vaccine policy and better health care intervention and apply to HIV modelling and end AIDS by the year 2030, to assist in further assessment and development of disease control policies.

The fourth section asked participants to indicate their satisfaction with the lecture sessions. The section covers four issues, including (1) content, (2) time spent in the lectures, (3) media used during the lectures (e.g., pictures, slides), and (4) benefits gained from the lectures. There are five level of satisfaction for participants to rate, including: 5 = Very satisfied, 4 = Satisfied, 3 = Neutral, 2 = Less satisfied, and 1 = Poor. Most of the participants were very satisfied with the content (55%), media used during the lectures (55%), benefits gained from the lectures (52%) and satisfied with the time spent in the lectures (39%).

In the next section, participants were asked to indicate their satisfaction with the panel discussion. This section covers the same four issues and has level of satisfaction for participants to rate as the previous section. Most of the participants were very satisfied with the content (48%), time spent in the lectures (43%), benefits gained from the lectures (55%) and satisfied with the media used during the lectures (50%).

In response to questions in Section 6, which allowed the participants to suggest other issues on the content and speakers from every session, there were also words of appreciation such as" *"Thank you so much. Not only knowledge but also inspiration", and "Good content, world-class speakers, presents things that are actually used to make the picture more visible".* Participants were asked about their satisfaction in terms of the venue, time, and food in section 7. They were satisfied with the venue and environment appropriateness (45%) and appropriateness of food and beverages (50%). They were very satisfied with the availability of audio-visual equipment (50%),and overall service satisfaction (48%). Notably, participants were satisfied with the expertise of lecturers, staff, knowledge they gained, management of the organiser, content, and the model etc.

In terms of other suggestions regarding the overall of this workshop, many participants requested to extend the time, to have more kinds of this workshop, to have more details in other disease groups that are related to other factors, especially behavioural diseases, to have more exercises, to conduct a hybrid workshop, and to use economic evaluation of disease modelling using R. They also suggested that the room using for lecture might affect participants who have respiratory symptoms as it was cold. The lighting was not appropriate for the lecture.

Participants were asked to suggest workshop topics that would align with or benefit their jobs. Participants highlighted a wide variety of topics, including the use of different IT applications for cost-effectiveness analysis, early HTA, econometric evaluation, how to produce a policy brief, modelling, health economic analysis, policy evaluation and analysis, public health and policy maker. However, some suggested that they wanted this kind of workshop but with more time. Other topics suggested were on policy analysis and learning to use the R program.

As a way forward, the workshop organiser will incorporate the feedback received and take them into account to enhance the contents as well as how the workshop is organised in future. The survey results also outline topics for future workshops.

Appendices

Appendix 1: Concept note

Technical Workshop on Infectious Disease Modelling

8.00-17.00, 25 November 2022

Venue: Tippawan 1 room, Grand Richmond Hotel, Nonthaburi, Thailand

Background

Infectious disease modelling can be used to forecast future outbreaks and estimate the impact of interventions to support policy. Although infectious disease modelling is a well-established method, it has gained prominence during the COVID-19 pandemic as an important tool to support decision-making. Most COVID-19 transmission models were initially developed for high-income settings, such as the UK and the US, and were later adapted for use in low and middle-income countries (LMICs). [1] However, without local technical capacity and an understanding of setting-specific contexts, models may produce inaccurate and non-robust results. Improving local technical capacity for conducting infectious disease modelling remains a priority as part of the pandemic preparedness agenda for all countries.

The Health Intervention and Technology Assessment Program (HITAP) has invited research staff from the London School of Hygiene and Tropical Medicine (LSHTM) with joint appointments at the National University of Singapore (NUS) and the University of Hong Kong (HKU) to deliver a technical workshop on infectious disease modelling to improve local technical capacity among researchers from Thailand and other South-East Asian countries to build and adapt infectious disease models to inform policy.

This workshop is supported by The Rockefeller Foundation. For more information on other pandemic preparedness initiatives by The Rockefeller Foundation, click here. Partners for the workshop include the Access and Delivery Partnership (ADP) and the Ministry of Public Health, Thailand.

Objectives

This workshop has the following objectives:

1. To provide participants with an understanding of the basic concepts behind infectious disease modelling and hands-on experience developing a basic infectious disease model in Excel;
2. To provide an overview of the infectious disease models used in the context of the COVID-19 pandemic response.
3. To increase awareness of how infectious disease modelling can be used to inform policy; and
4. To facilitate networking between modellers, researchers from other disciplines, and other collaborators.

Expected outcomes

1. Participants have a basic understanding of infectious disease models, their applications and limitations.
2. Creation of a multi-disciplinary network for collaboration on current or future infectious disease modelling efforts.

Lecturers

1. Prof. Mark Jit, London School of Hygiene and Tropical Medicine (LSHTM), UK, and the University of Hong Kong (HKU)

2. Assistant Prof. Dr. Yang Liu, London School of Hygiene and Tropical Medicine (LSHTM), UK
3. Assistant Prof. Dr. Kiesha Prem, London School of Hygiene and Tropical Medicine (LSHTM), UK, and National University of Singapore (NUS)

Panellist

1. Associate Prof. Dr Borwornsom Leerapan, M.D., Faculty of Medicine Ramathibodi Hospital, Mahidol University
2. Associate Prof. Dr Wanrudee Isaranuwatchai, HITAP Program Leader

Target audience

This is a technical workshop for participants who expect to conduct or use the outputs from infectious disease models to inform policy in their future work. Whilst the workshop is primarily aimed at researchers from the Ministry of Public Health and academic institutions in Thailand, there are a limited number of places for government and academic researchers from other South-East Asian countries and participants from funding agencies.

Pre-requisites

Whilst no formal training in infectious disease modelling is required for this workshop, meeting participants are expected to have a basic knowledge of statistics and Microsoft Excel. All participants are expected to bring their own laptops with Microsoft Excel installed.

Fees

Workshop participation is free of charge. However, participants are expected to cover the cost of their own travel arrangements.

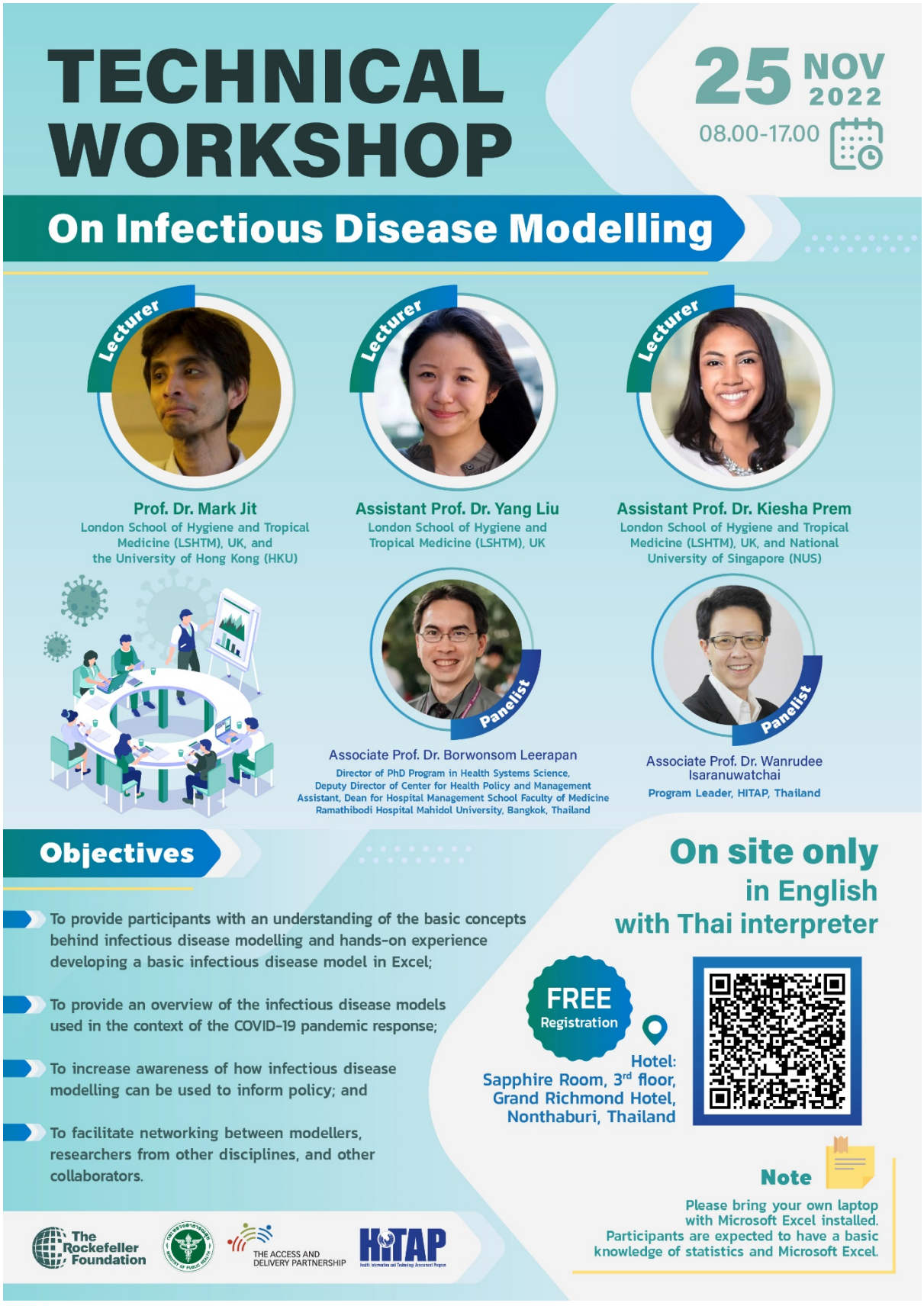
AGENDA

Time	Session	Speaker
08:00 – 08:30	Registration and welcome	
08:30 – 08:45	Opening remarks and course introduction	Dr Rungrueng Kijphati, MoPH, Thailand
08:45 – 10:45	Introduction to infectious disease modelling and use of the outputs in economic evaluation	Prof Mark Jit (LSHTM/HKU)
10:45 – 11:00	*Coffee Break*	
11:00 – 12:00	COVID-19 mathematical models and the model development process	Dr Yang Liu (LSHTM)
12:00 – 13:00	*Lunch break*	
13:00 – 14:00	Computer-based practical on infectious disease modelling	Dr Kiesha Prem (LSHTM/NUS)
14:00 – 14:30	An overview of different model types in the context of COVID-19	Dr Yang Liu (LSHTM)
14:30 – 15:00	*Coffee Break*	
15:00 – 16:30	Policy discussion on utilising the outputs from COVID-19 vaccine modelling to inform policy	Panellists include. 1. Dr Borwornsom Leerapan, Mahidol University 2. Dr Wanrudee Isaranuwatchai, HITAP Program Leader
16.30 – 16.45	Post-training survey	
16:45 – 17:00	Closing remarks	Eric Arndt, Director, Asia, The Rockefeller Foundation

Appendix 2: Flyer

Thai Version

English Version



Appendix 3: Participant list

(The participant' names are provided in local language in line with the application form)

No.	ชื่อ - นามสกุล	หน่วยงาน	Position
1	กนกวรรณ วรปัญญา	Department of disease control, Division of AIDS and STIs	Registered Nurse (K1)
2	Puttarin Kulchaitanaroaj	Mahidol Oxford Tropical Medicine Research Unit	Health Economist
3	Christopher Chew	Mahidol Oxford Tropical Medicine Research Unit	Clinical Researcher
4	วีรากร ธิจุมปา	Mahidol Oxford Tropical Medicine Research Unit	PhD student
5	วิริยดา ปานงาม	Mahidol Oxford Tropical Medicine Research Unit	Professor
6	ภาวดี ช่วยเจริญ	Mahidol Oxford Tropical Medicine Research Unit	Post-doctoral student
7	วีระยา พุ่มจันทร์	Division of AIDS and STIs, Department of Disease Control, Ministry of Public Health	Public Health Technical Officer
8	บัณฑิตา บุญเฉลียว	National Vaccine Institute	Vaccine technical officer
9	ณัฐญา อนุรัฐพันธุ์	National Vaccine Institute	Vaccine Technical Officer
10	เบญจวรรณ ไทยงามศิลป์	National Vaccine Institute	Research coordinator
11	ผาณิตา โกมลมาลย์	National Vaccine Institute	Vaccine Technical Officer
12	วรวิช บุณยาทิษฐาน	National Vaccine Institute	Vaccine Technical Officer
13	ภาณุวัฒน์ นราอาจ	The office of disease prevention and control 11	Public health technical officer, professional level
14	ปราชญ์ปฐม สายพฤกษ์	Division of Innovation and Research (DIR) Department of Disease Control, Ministry of Public Health	Public Health Technical Officer (Professional Level)
15	จิตรลดา จันทศิลา	Division of Innovation and Research (DIR) Department of Disease Control, Ministry of Public Health	Public Health Technical Officer
16	ดร.ภญ.นัยนา ประดิษฐ์สิทธิกร	Division of Innovation and Research (DIR) Department of Disease Control, Ministry of Public Health	Public Health Technical Officer (Professional Level)
17	ภานุกร รักกลิ่น	Division of Innovation and Research (DIR) Department of Disease Control, Ministry of Public Health	Public Health Technical Officer
18	โยษิตา ฐิติวัฒนา	Division of Innovation and Research (DIR) Department of Disease Control, Ministry of Public Health	Public Health Technical Officer (Professional Level)
19	ชนะสาร แสวงผล	Bureau of Epidemiology, Department of Disease Control, Ministry of Public Health	Medical doctor

No.	ชื่อ - นามสกุล	หน่วยงาน	Position
20	ธนวดี จันทร์เทียน	Bureau of Epidemiology, Department of Disease Control, Ministry of Public Health	Medical doctor (Professional Level)
21	ชนกานต์ ดวนใหญ่	Bureau of Epidemiology, Department of Disease Control, Ministry of Public Health	Medical doctor (Professional Level)
22	ปภานิจ สวงโท	Division of AIDS and STIs, Department of Disease Control, Ministry of Public Health	Public Health Technical Officer)
23	ณิชกุล พิสิฐพยัต	Bureau of Epidemiology, Department of Disease Control, Ministry of Public Health	Medical doctor (Professional Level)
24	วาสินี ชลิศราพงศ์	Division of common disease, Department of Disease Control, Ministry of Public Health	Medical doctor (Professional Level)
25	อภิญญา นิรมิตสันติพงศ์	Division of national Vector borne diseases prevention and control program, Department of Disease Control, Ministry of Public Health	Medical doctor (Professional Level)
26	ณัฐณิชาช์ วิบูลย์วัฒนกุล	Division of AIDS and STIs, Department of Disease Control, Ministry of Public Health	Pharmacist (Professional Level)
27	ภัทร์ศยา มุกลีมาศ	Division of AIDS and STIs, Department of Disease Control, Ministry of Public Health	Medical Technologist (Professional Level)
28	สุวลี แจ้งขำ	Division of AIDS and STIs, Department of Disease Control, Ministry of Public Health	Medical Technologist
29	อัครินทร์ หิรัญสุทธิกุล	Faculty of Medicine at Chulalongkorn University	Medical professor
30	นพ.พลกฤต ขำวิชา	Faculty of Medicine, Prince of Songkla University	Medical professor
31	รศ.พญ.รัศมี โชติพันธุ์วิทยากุล	Faculty of Medicine, Prince of Songkla University	Associate Professor
32	ดร.นพ.ชนนท์ กองกมล	Faculty of Medicine, Prince of Songkla University	Medical professor
33	ศ.พญ.กมลวิช เลาประสพวัฒนา	Faculty of Medicine, Prince of Songkla University	Medical professor
34	นพ.ณัฐวุฒิ เอี่ยงธนรัตน์	Faculty of Medicine, Ramathibodi Hospital, Mahidol University	PhD student
35	พญ, นามล สวรรค์ปัญญาเลิศ	Department of medical science, Ministry of Public Health	Medical officer
36	ชลวัชร ชัยชาญ	Faculty of Medicine Vajira Hospital, Navamindradhiraj University	Medical professor
37	วชิราภรณ์ วนิชนพรัตน์	Faculty of Medicine Vajira Hospital, Navamindradhiraj University	Medical professor
38	ศุภทัต ชุมนุมวัฒน์	Faculty of Pharmacy, Mahidol University	Assistant professor

No.	ชื่อ - นามสกุล	หน่วยงาน	Position
39	ธีรวิชญ์ อัชฌาศัย	Faculty of Pharmacy, Mahidol University	Instructor
40	กมลภัทร ไชยกิตติโสภณ	Faculty of Pharmacy, Silpakorn University	Instructor
41	ผศ.ดร.ภญ.ณัฏฐิญา ค้าผล	Faculty of Pharmacy, Silpakorn University	Assistant professor
42	ผศ.ดร.ภญ.น้ำฝน ศรีบัณฑิต	Faculty of Pharmacy, Silpakorn University	Assistant professor
43	ผศ.ดร.วารณี บุญช่วยเหลือ	Faculty of Pharmacy, Silpakorn University	Assistant professor
44	นายแพทย์ธันดร งามประเสริฐชัย	Faculty of Tropical Medicine, Mahidol University	Medical professor
45	รศ.ดร.พญ. วีรวรรณ ลุวีระ	Faculty of Tropical Medicine, Mahidol University	Medical professor
46	POJ INTALAPAPORN	Internal Medicine department, Rajavithi Hospital	Assistant Professor
47	เพ็ญนภา กวีวงศ์ประเสริฐ	Health System and Policy department, Faculty of Medicine Siriraj Hospital	Medical professor
48	ภาณุวัฒน์ วงษ์กุหลาบ	Rajavithi Hospital	Medical doctor (Senior Professional Level)
49	ธาดารัตน์ พลชัย	Rayong Hospital	Pharmacist (Professional Level)
50	ศิวนัย ดีทองคำ	Nakhon Pathom Hospital	Pharmacist
51	ผศ.ดร.วิริยะ มหิกุล	Princess Srisavangavadhana College of Medicine, Chulabhorn Royal Academy	Assistant professor
52	พิริยะ วตะกูลสิน	The office of disease prevention and control 2	Medical doctor (Professional Level)
53	ชัยวัฒน์ พูลศรีกาญจน์	National Institute of Health of Thailand, Department of Medical Sciences, Ministry of Public Health.	Medical Scientist (Senior Professional Level)
54	ธนวันต์ กาบภิรมย์	Institute for Urban Disease Control and Prevention, Department of Disease Control, Ministry of Public Health	Public Health Technical Officer (Professional Level)
55	ณัฐธยา สง่า	Institute of Medical Research & Technology Assessment (IMRTA)	Public Health Technical Officer
56	สิริอร เผ่าพันธ์	Department of Medical Sciences, Ministry of Public Health	Public Health Technical Officer (Practitioner Level)
57	พญ.ฝนทิพย์ วัชราภรณ์	Institute for Urban Disease Control and Prevention	Medical doctor
58	นายพฤกษ์ศราวุฒิ จักร์สวย	The office of disease prevention and control 1	Public Health Technical Officer (Professional Level)
59	ปรียานุช ดีบุกคำ	GSK	Market Access Manager

No.	ชื่อ - นามสกุล	หน่วยงาน	Position
60	Doungporn Leelavanich	MSD	Market Access & HEOR Specialist
61	ทิวาภรณ์ อุปพลเถียร	The office of disease prevention and control 4	Public Health Technical Officer (Practitioner Level)
62	นางสาววนิดา เสนาพรม	The office of disease prevention and control 4	Public Health Technical Officer (Practitioner Level)
63	คณิต พิศวงศ์	International Health Policy Program	Pharmacist
64	ชิดชนก อนุตระกูลชัย	Program Management Unit (PMU)	Project analysis officer