One Minnesota: Using Information Modeling Amidst an H5N1 Outbreak to Combat Inequities

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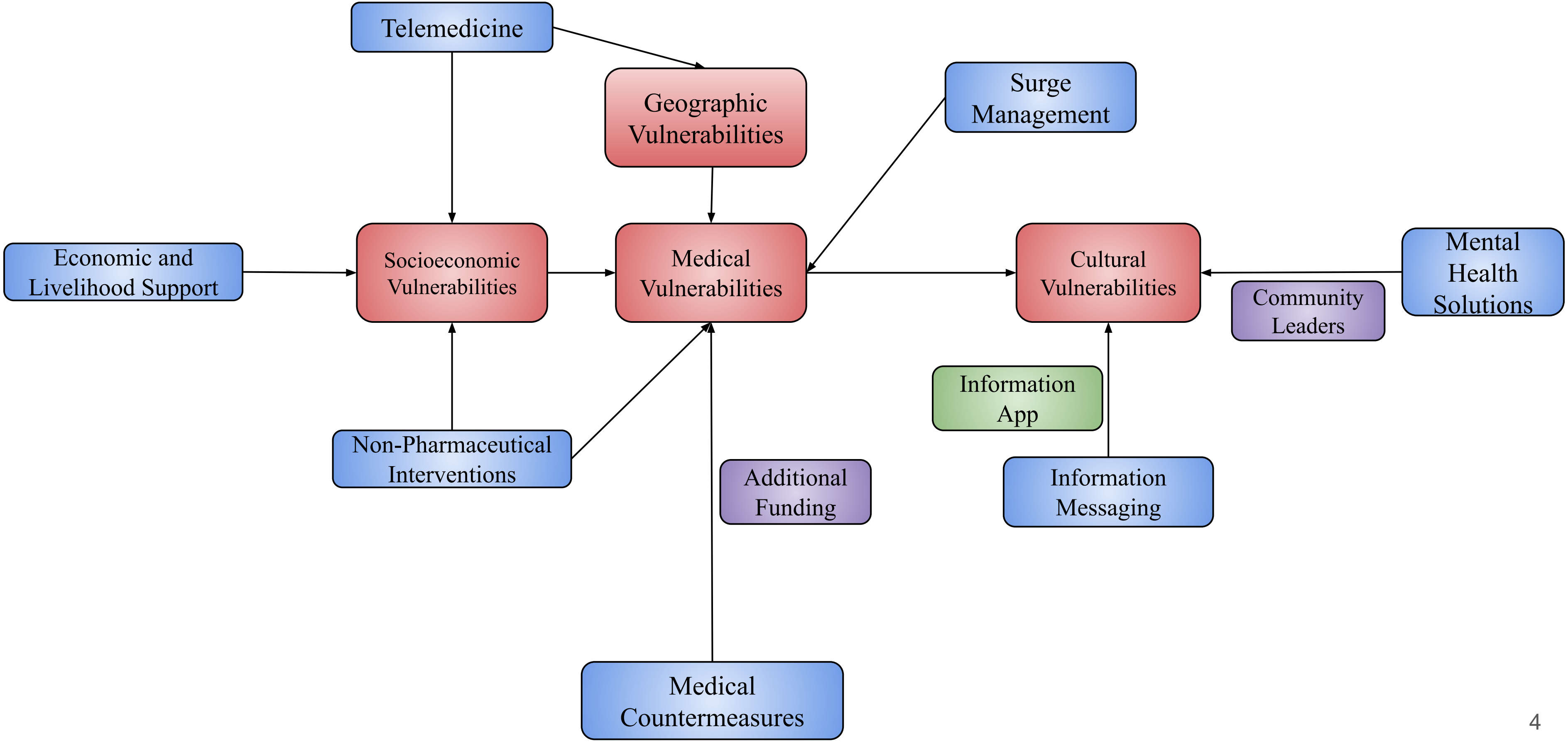
Understanding Disparities

Realizing the disparities and vulnerabilities to be addressed.

Disparities and Vulnerabilities Addressed in Our Solution

Geographic Disparity	Individuals who live in more remote areas have fewer options for healthcare and are further away from hospitals and ERs if they do have a medical emergency. They are also further away from social services to support them through times of medical or financial hardship.
Socioeconomic Disparity	Socioeconomic disparities are highlighted in access to healthcare and health insurance making it sometimes too costly to seek necessary care. They also have less access to healthy food and preventable care leading to a higher rate of adverse outcomes.
Cultural Disparity	Historically marginalized groups of people tend to have a greater instance of chronic medical conditions due to systemic inequalities which puts them at greater risk for adverse outcomes due to H5N1.
Medical Disparity	Individuals with high-risk conditions can make them more susceptible to acquiring the flu and can lead to higher rates of morbidity and mortality if they do contract the flu.

Response Solution Framework



The Model

Mathematical Modelling to Assist in H5N1 Surveillance, Diagnosis & Intervention

- We developed a predictive model to estimate the number of H5N1 cases at any point in time and the geographic spread patterns of the cases.
  - Fully functional AI model
- Ability to provide live-updates to case estimations and geographic spread estimation as data is gathered real time.
- Used to inform resource allocation.
- Data Gathering
  - Avian cases and human cases will be collected and reported alongside geographic location of case in database
  - Data is generated from self-reporting to the MDH website, based on healthcare-worker administered RT-PCR test results, and deployable Pod-guided test results (Pod details provided in Solution Six: Telemedicine).

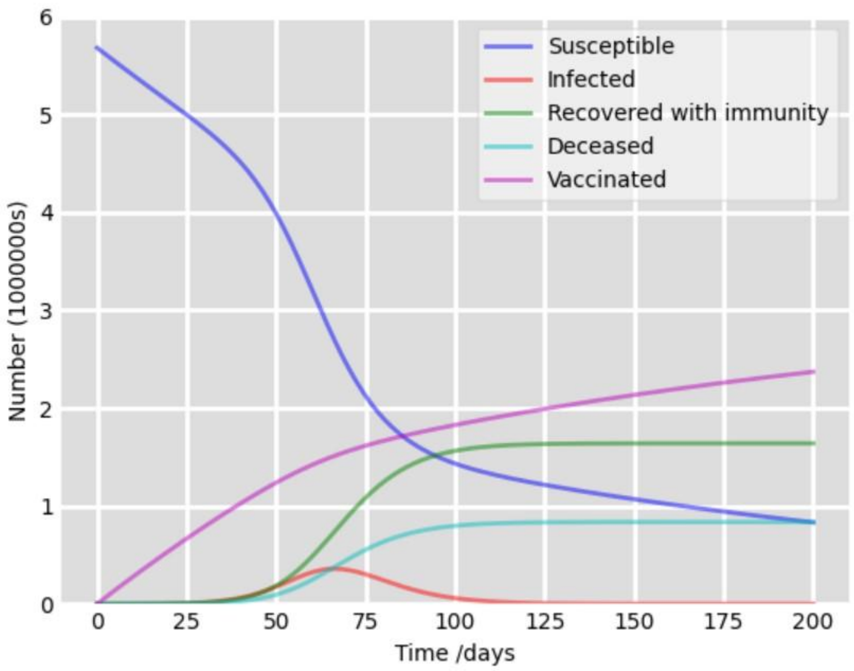


Exhibit A: Predictions for Case Counts at Start of Outbreak (No Real-Time Data Gathered)

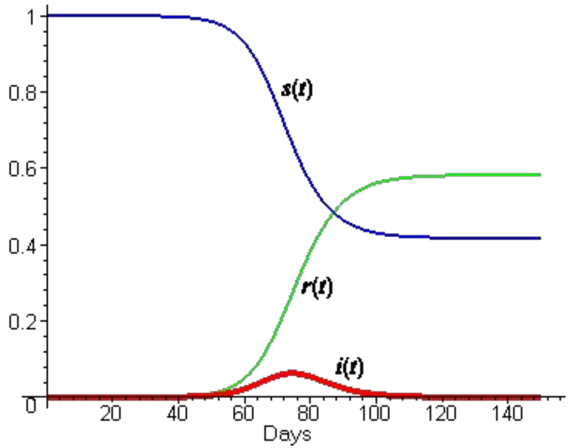
Introduction to the SIR model

- The SIR (Susceptible-Infected-Recovered) model is a mathematical representation of the spread of infectious diseases.
- Assumptions: No one is added to the susceptible group, since we are ignoring births and immigration. The only way an individual *leaves* the susceptible group is by becoming infected

$$\frac{dS}{dt} = -\beta IS$$

$$\frac{dI}{dt} = \beta IS - \gamma I$$

$$\frac{dR}{dt} = \gamma I$$



ODEs to Simulate H5N1 Dynamics

- We developed a hybrid SIR model to account for vaccination and death.
- S, I, R, D, V, are all time-dependent functions.
  - S: Number of people susceptible;
  - I: Number of people infected;
  - R: Number of people recovered:
  - D: Number of people deceased;
  - V: Number of people vaccinated;
- The model uses the following parameters;
  - N: Population size
  - β: Dynamic infection rate
  - γ: Recovery rate
  - μ: Mortality rate
  - ν: Vaccination rate

$$\frac{dS}{dt} = \frac{-\beta SI}{N} - \nu S$$

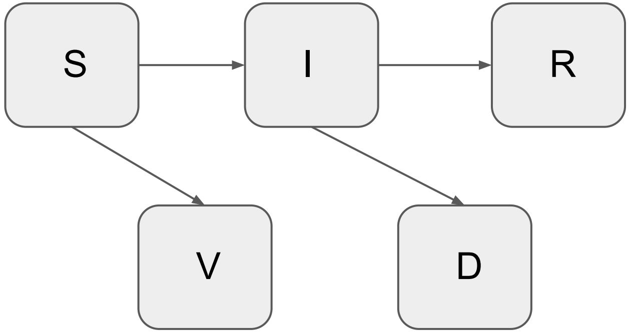
$$\frac{dI}{dt} = \frac{\beta SI}{N} - (\gamma + \mu)I$$

$$\frac{dR}{dt} = \gamma I$$

$$\frac{dD}{dt} = \mu I$$

$$\frac{dV}{dt} = \nu S$$

Simulation of the SIRDV ODEs



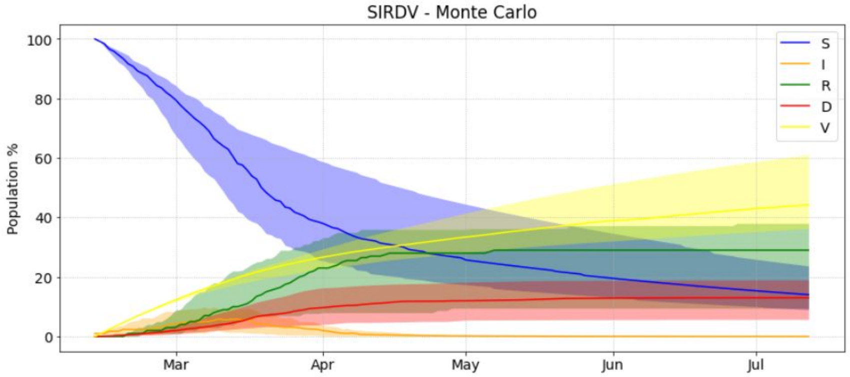

```
#equations
self.N = pcm.equation(lambda: self.S() + self.D() + self.I() + self.R() + self.V())

#flows
self.Fsi = pcm.flow(lambda: self.b()*self.S()*self.I()/self.N(), src=self.S, dest=self.I)
self.Fir = pcm.flow(lambda: self.g()*self.I(), src=self.I, dest=self.R)
self.Fid = pcm.flow(lambda: self.m()*self.I(), src=self.I, dest=self.D)
self.Fsv = pcm.flow(lambda: self.v()*self.S(), src=self.S, dest=self.V)
```

Incorporation of Stochastic Elements and Monte Carlo

- We first incorporated stochastic elements by taking our parameters, β, μ, from a random sample based on normal distributions.
- The flows were modified using binomial RNG to generate a discrete, random number of new infections and deaths.
- With variability based on the uncertainty in our parameters, and randomness in flow, we create a Monte Carlo simulation with 100 repetitions, and plot the middle 50% of the distribution, or the interquartile-range.

```
#random sample
self.b = pcm.sample(lambda: rng.normal(self.b_m(), self.b_s()))
self.m = pcm.sample(lambda: rng.normal(self.m_m(), self.m_s()))
```




```
self.Fsi = pcm.flow(lambda: rng.binomial(self.S(), self.b()*self.I()/self.N()), src=self.S, dest=self.I)
self.Fir = pcm.flow(lambda: rng.binomial(self.I(), self.g()), src=self.I, dest=self.R)
```

How is the Data Collected?

Screening & Diagnosis of Human Cases

- H5N1 will be screened via **RT-PCR testing**; most larger labs will have a PCR machine but if they don't then we will send PCR tests to St. Cloud hospital via courier since they are the biggest hospital in the affected counties.
- Antigen detection tests will not be used due to unknown sensitivity and specificity.
  - Low sensitivity to detect H5N1 virus
  - Minimizing potentially missing cases via false negative results

- Isolate confirmed cases
- Contact tracing initiation and suggest quarantine
- Report confirmed cases to the Minnesota Department of Health (MDH) for continuous monitoring

Reservoir Monitoring

- Reservoir of influenza H5N1: Aquatic birds and Domestic poultry
- MDH will send out staffs from Zoonotic Diseases Unit under the Infectious Disease Epidemiology, Prevention and Control (IDEPC) Division to **monitor/test/detect** birds for sign of sickness
- Require **reporting** to MDH for any unusual birds illnesses or deaths
- Require **isolation** of sick birds to minimize transmission to healthy birds
- Require **depopulate** the affected flock(s)
- **Disinfect** any clothing or tools that had a contact with sick birds to minimize contamination
- **Vaccinate** birds to prevent spread of virus
- Surveillance of poultry establishments by MN Department of Health inspectors to ensure that required changes to the poultry establishments are followed.
- This surveillance system could be applied to any other potential animal vectors in order to minimize spread of H5N1

How is the Data Used?

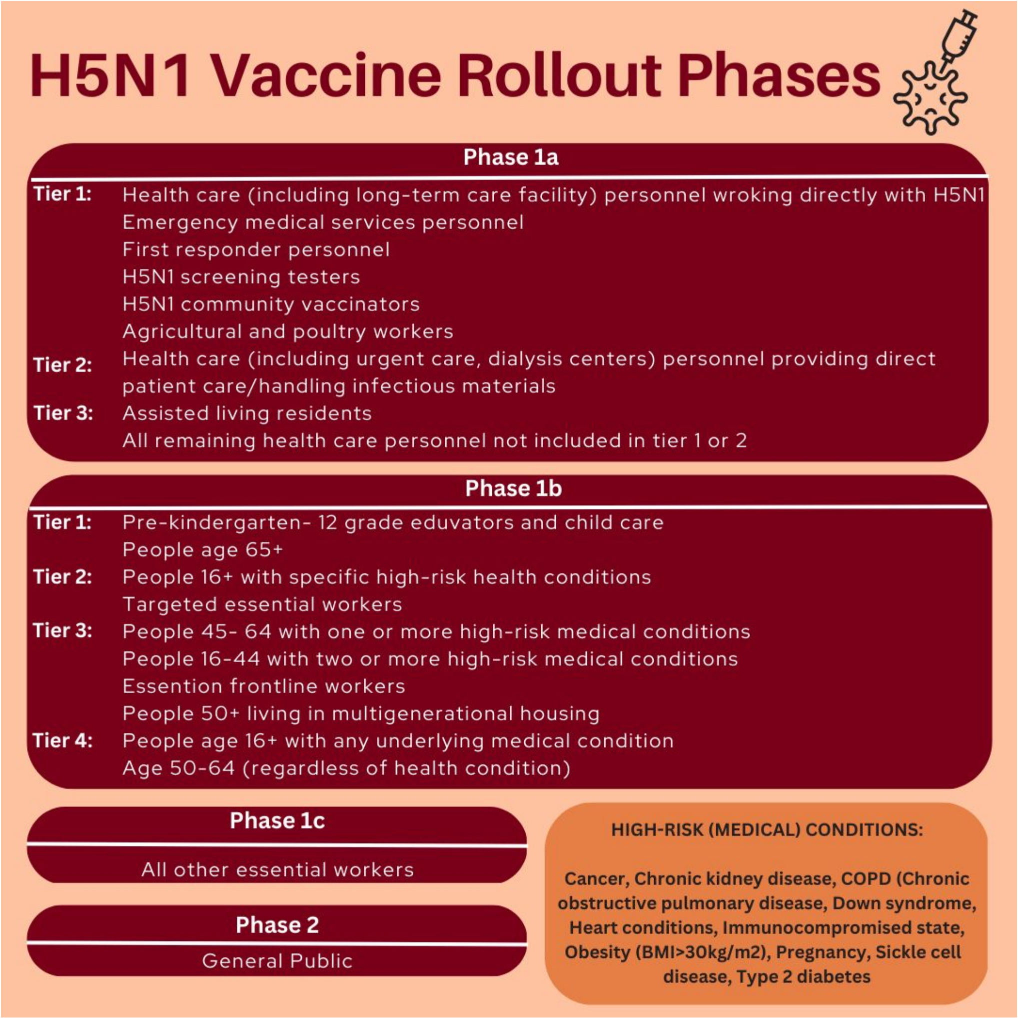
Non-Pharmaceutical Interventions (NPIs) & Community Mitigation Strategies

- Personal
  - Masks, Hand sanitizer, Test kits
- Community
  - Social distancing
  - Alternative housing for households with more than one family (migrant workers)
    - Mobile, inflatable tents from federal stockpile (no-cost option for those interested in moving to an independent location).
    - Set up by local volunteers recruited with the help of local leaders.
  - Cultural shift to prevent spread
    - Discouraging plane travel by affected areas
- Environmental
  - Sanitation workflow changes including increasing PPE wear at work and ensuring space is well ventilated

Exhibit D: Categorization of NPIs by Organizational Level

Medical Countermeasures: Vaccine Rollout and Development

- Novel, H5N1-Specific Model
  - Input from interviews with MDH officials, epidemiological experts, and corporate scientists/representatives
- United States Federal Government Involvement
  - Funding opportunities for vaccine production
  - Biomedical Research and Development Authority utilization
- Distribution of Vaccines
  - Collaboration with local leaders
  - Volunteer organizations
  - Distribution pattern based on medical metric-based high risk individual identification and our developed model for geotemporal spread and case count



Vaccine Rollout Phases and Information

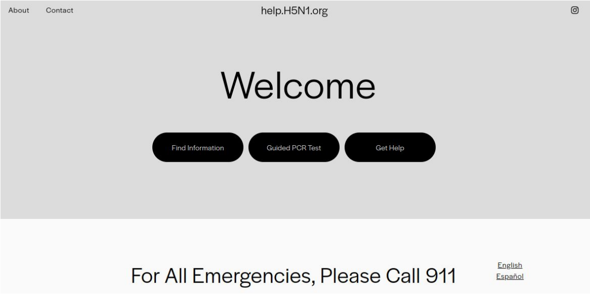
General Surge Management Responses

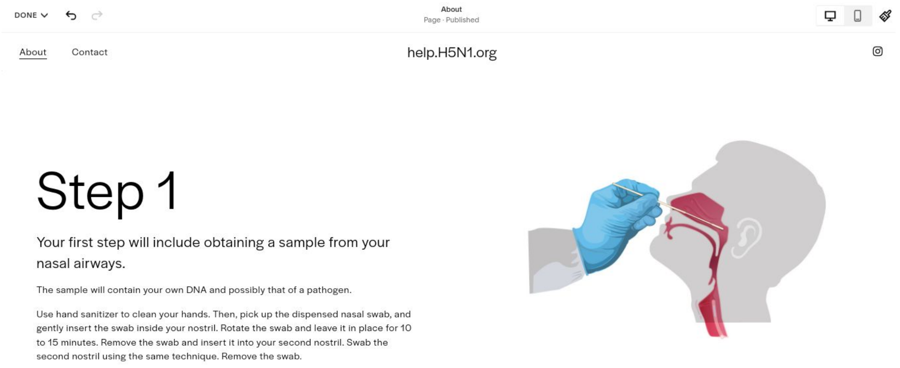
- As cases begin to increase per our predictive model we will begin to implement surge preparedness measures so that we are ready for an increasing number of hospitalizations.
- Staffing
    - Ensure all the beds in affected counties (1469 beds in total) are amply staffed before the surge begins.
        - Reallocation of healthcare workers from unaffected areas.
- Triage Model
    - Guides resource allocation that will take into account social determinants of health so that vulnerable populations are protected.
- Set up non-infectious wards in hospitals
    - Maintain integrity of care for non-flu emergent patients
- Work with Minnesota's joint Statewide Healthcare Coordination Center (SHCC) to assist with resource allocation and help assign one hospital in the metro area as the overflow H5N1 hospital so that infected patients are not being spread throughout multiple hospitals. .

Leading Healthcare Coordination Organizations by Region

Deployable Pod

- Deployable hub for providing remote assistance to areas understaffed with or isolated from healthcare workers.
  - Applicable to rural and sparsely populated regions.
  - Some Pods with PCR testing capabilities to be used in regions where immediate testing results would be beneficial. This model of the Pod would be manufactured in a limited number relative to the standard model to ensure cost-effectiveness.
- Very low-cost to manufacture and is an effective solution to a staffing shortage.
- The device is deployed with necessary materials, such as first aid supplies and PCR test kit supplies.
  - The screen is used to give instructions, provide information, and can connect users with a remotely located physician if needed.
- Self-sanitation features included (timed UV-C radiation aimed towards screen and buttons.





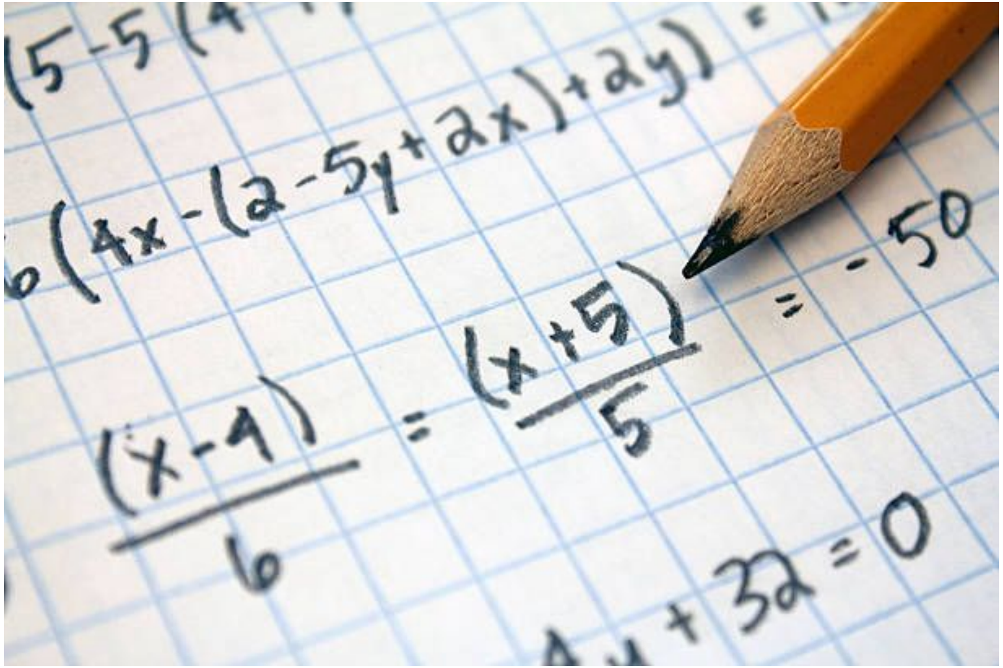
Why Math Modeling?

Why is Math Modeling Useful

- Practicing math modeling from a young age can help prepare you for the future
- Math modeling helps create a new generation better equipped for success

Incorporation into Education

- It’s never too late (or too early) to start math modeling
- Applicable to numerous scientific and real-life scenarios
- Can improve analytical thinking, decision making, and objective-approach thinking.



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Source Credits

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