



WORMS and Work in the time of Coronavirus



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BLUF (Bottom Line Up Front)



- **NPS data farmable pandemic model:**
stochastic, discrete-event epidemic simulation model
 - Reveals risks (fizzles and flares), **not just average** disease propagation
 - Scalable from small to large populations
 - Data farmable (easy to gain insights from large-scale simulation experiments)
 - Assess risks / benefits of various interventions (mitigation / relaxation)
- **Data farming and YOUR models:**
 - Efficient design of experiments (DoE)
 - Structured “what if?” analysis
 - Let your model work for you!
 - Resources / examples at <https://harvest.nps.edu>



Compartmental Models

Categorize individuals into subsets reflecting their current status.

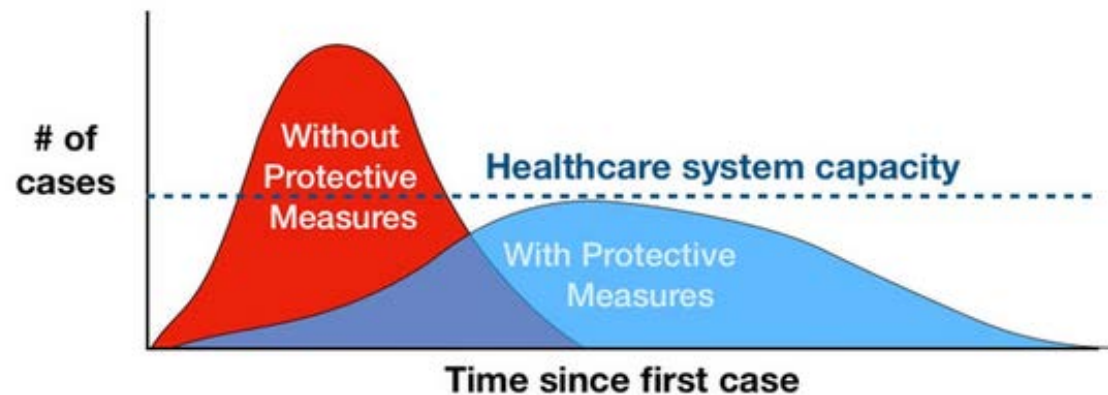
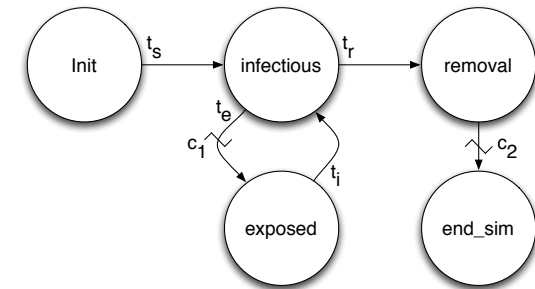
One popular model is SEIR

S: Susceptible

E: Exposed

I: Infectious

R: Removed (recovered or dead)



Adapted from CDC / The Economist

<https://www.nytimes.com/article/flatten-curve-coronavirus.html>

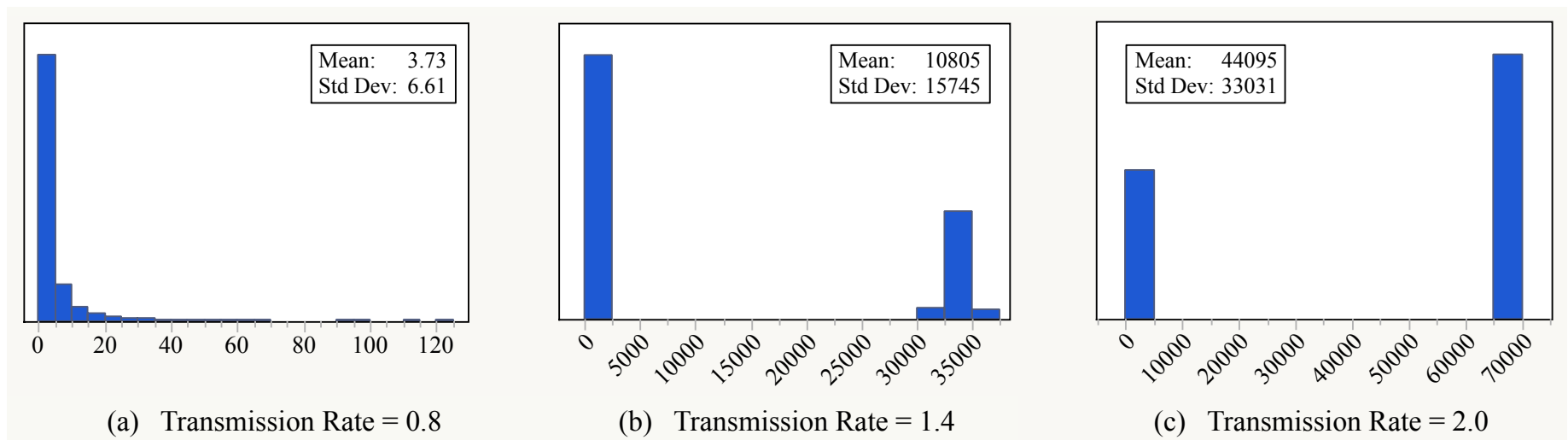
Caution: like other SEIR models, ours is not a predictive tool, but a model for gaining insight



NPS Pandemic Model Behavior



Stochastic model exhibits fizzle and flare behaviors, with outcomes that change based on the overall transmission rate

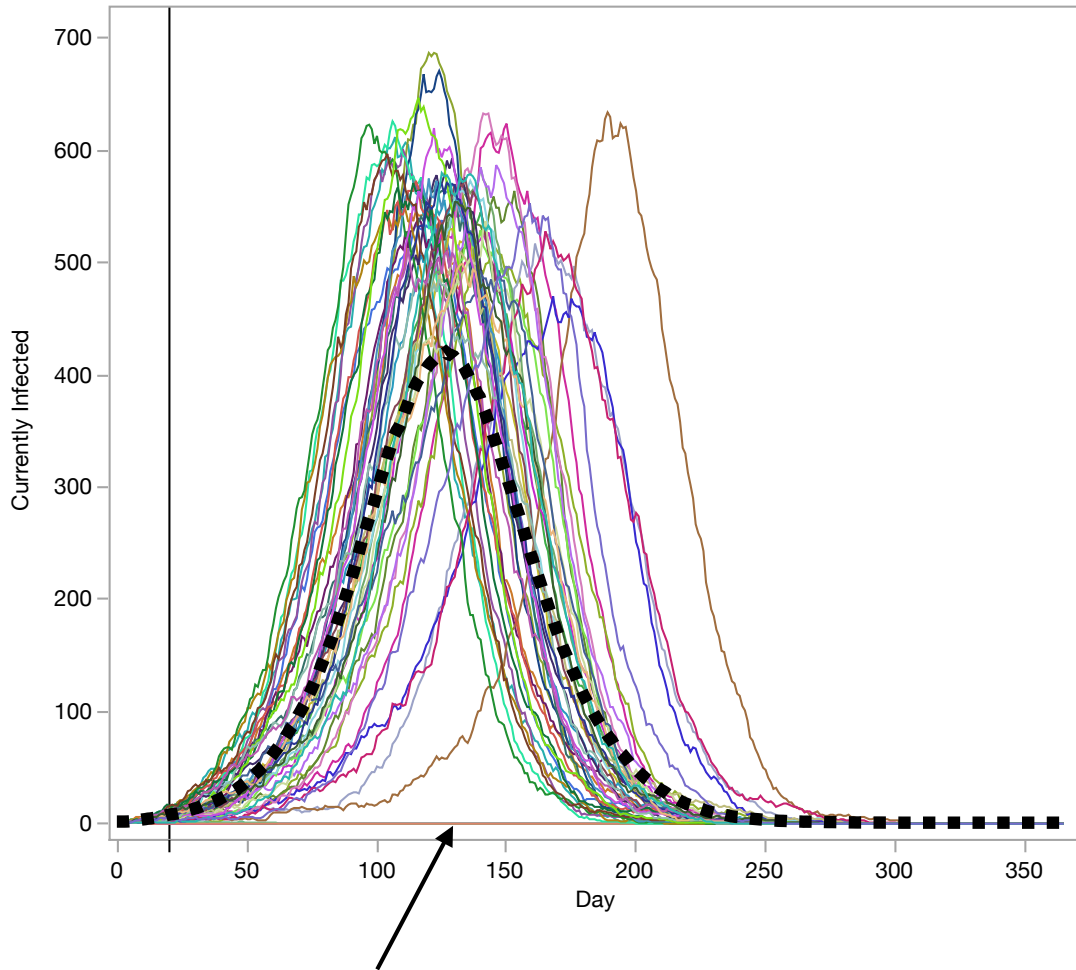


Graph from Sanchez, P.J. & Sanchez, S. M. (2015) "A scalable discrete event stochastic agent-based model of infectious disease propagation," *Proceedings of the 2015 Winter Simulation Conference*, available online at <https://www.informs-sim.org/wsc15papers/012.pdf>



Stochastic behavior

Infected over time



fizzles: minimal spread before dropping to zero

- Dashed line is the curve shown in typical “flatten the curve” graphs
- Each line is the result of a single run with the same underlying parameters
- Peak time and severity differ for individual runs
- Some fizzles, some flares...as we see in society

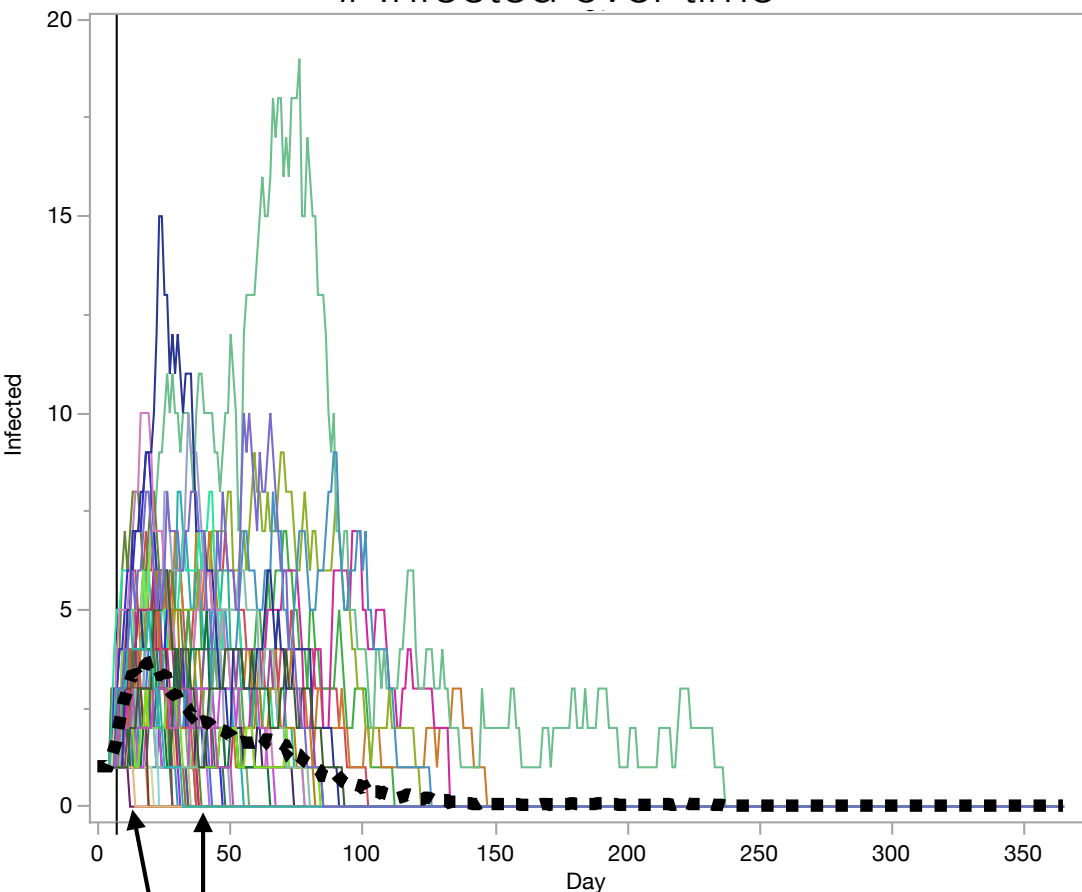
Initial excursion (NOTIONAL INPUTS):

population size: 4000
initial infected: 1
close contacts: Poisson(mean=10)
exposed (incubation): 3-7 days
infectious: 6-12 days
transition rate: 3.5 initially
intervention time: day 10
new transmission rate: 50% lower



Stochastic behavior

Infected over time



fizzles: minimal spread before dropping to zero

- Dashed line is the curve shown in typical “flatten the curve” graphs
- Each line is the result of a single run with the same underlying parameters
- Peak time and severity differ for individual runs
- Some fizzles, some flares...as we see in society

Aggressive Excursion **(NOTIONAL INPUTS):**

population size: 4000

initial infected: 1

close contacts: Poisson(mean=10)

exposed (incubation): 3-7 days

infectious: 6-12 days

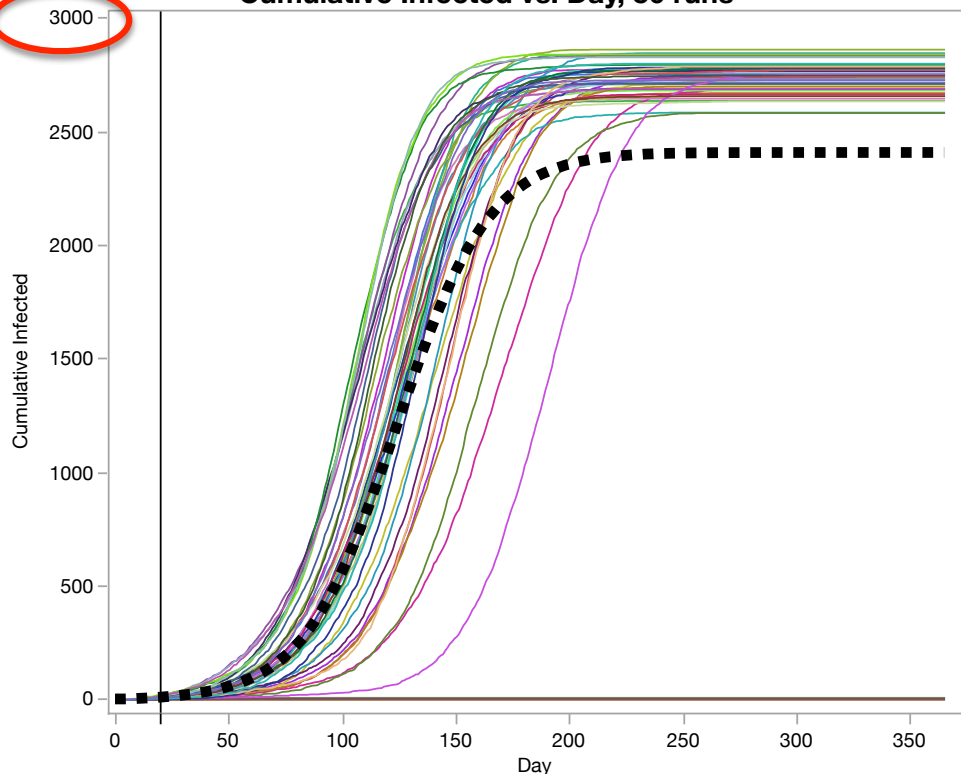
intervention time: day 7

new transmission rate: 75% lower



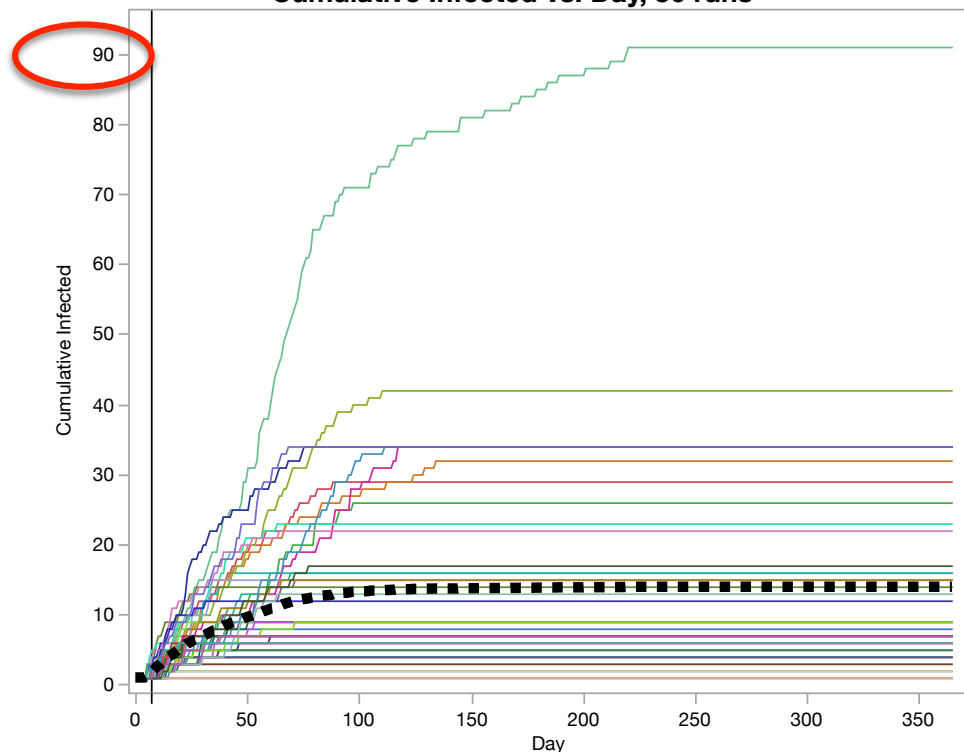
Mitigation effects

Cumulative Infected vs. Day, 50 runs



Initial excursion: if we can achieve a 50% drop in transmission rate from day 10 onwards

Cumulative Infected vs. Day, 50 runs



Aggressive excursion: if we can achieve a 75% drop in transmission rate from day 7 onwards



Data Mining vs. Data Farming



- Miners seek valuable buried nuggets
 - Miners have no control over what's there or how hard it is to separate it out
 - Data Mining seeks valuable information buried within massive amounts of data
- Farmers cultivate to maximize yield
 - Farmers manipulate the environment to their advantage: pest control, irrigation, fertilizer, etc.
 - Data Farming manipulates simulation models with designed experimentation

One way of thinking of big data...any data set that pushes against the limits of currently available analysis technology



Large-scale computational experiments are transformative

“Petaflop machines like Roadrunner have the potential to fundamentally alter science and engineering...[allowing scientists to] perform experiments that would previously have been impractical.”

The New York Times, June 9, 2008

Experimentation is hard: “ 2^{100} is forever”

—Maj Gen Jasper Welch

*Even with today’s most powerful computers, brute force exploration of 100 variables at 2 levels for a simulation that runs in one second would take **many times the age of the universe**... so **we need to be smart!***

Moore’s Law is not enough!

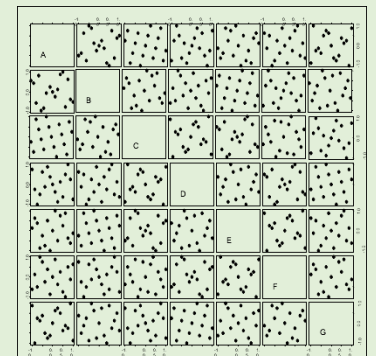
The “curse of dimensionality” cannot be solved by hardware alone.



Petaflop = 1 quadrillion ops/second
Cost of “Roadrunner”= \$133 million

Data farming helps overcome the curse of dimensionality...

With large-scale efficient experimental designs, we generate “better big data” and regularly study hundreds of factors for longer-running simulations in hours, days, or weeks on high-performance computing clusters...



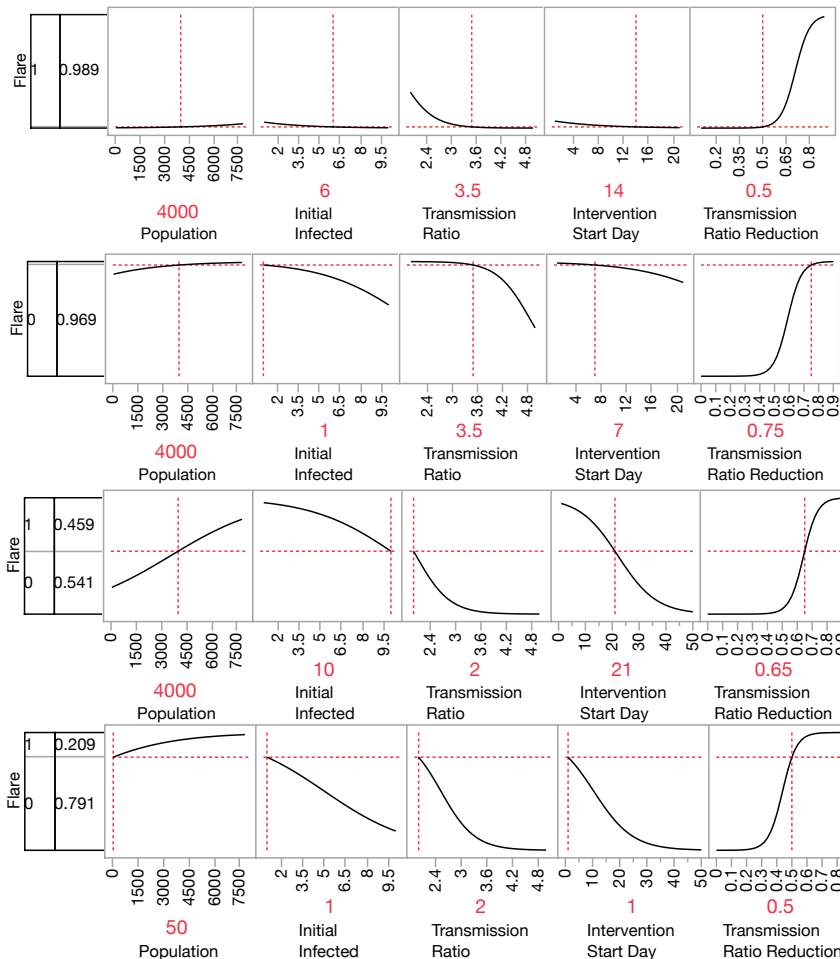


Metamodels

Data farming lets us quickly run designed experiments

50 replications of 1089 excursions took **< 3 minutes**

Can fit metamodels to characterize model's output behavior...



Initial excursion: 99% chance of flare

Aggressive excursion: 3% chance of flare

More initial infected, lower transmission ratio and ratio reduction: 46% chance of flare

Small population, 1 initial infected, lower transmission ratio: 21% chance of flare

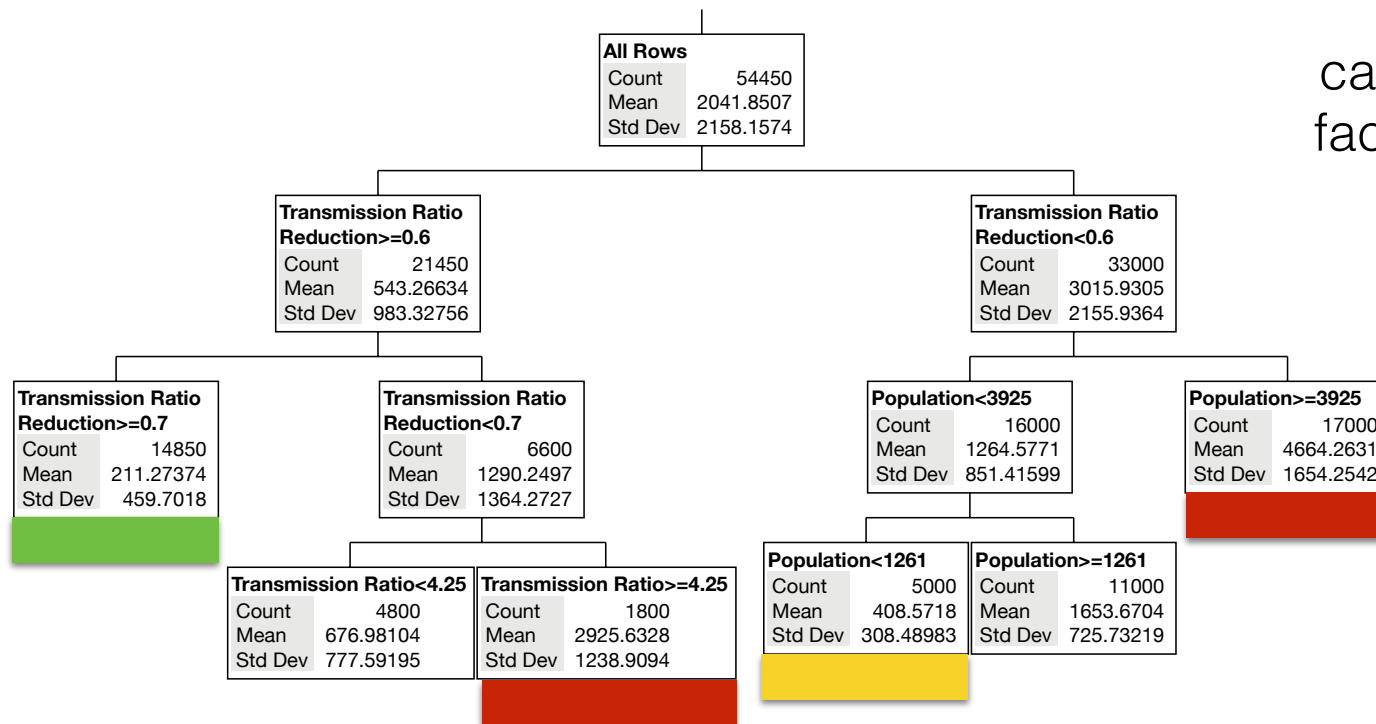


Decision support

Partition Tree for Total Infected
R-squared = 0.757

quick way of revealing the trade space

can be made using all factors or just decision factors





Next steps...



Our plan

- Enhancing model (some underway)
 - who to test? when? how often?
 - transmission rate probabilities (demographics)
 - intervention timing / length / triggers
 - effectiveness of diagnostic testing
 - reduced contact tracing time
 - increasing or reducing movement restrictions
 - additional categories beyond SEIR
- Data farming assessments
 - identify factors and interactions that drive model outcomes
 - assess robustness of model results to its components (unknown disease / demographic characteristics, etc.)
 - support decision making under uncertainty about ground truth



Next steps...



Your plan?

- Data farming your models → INSIGHTS!
- We're here to help
- Tutorial papers, software, theses, many other resources available at <https://harvest.nps.edu>
updates, draft coronavirus paper coming soon
- Contact SEED Center Co-directors
Susan Sanchez (ssanchez@nps.edu) or
Tom Lucas (twlucas@nps.edu)
for more information



Part II

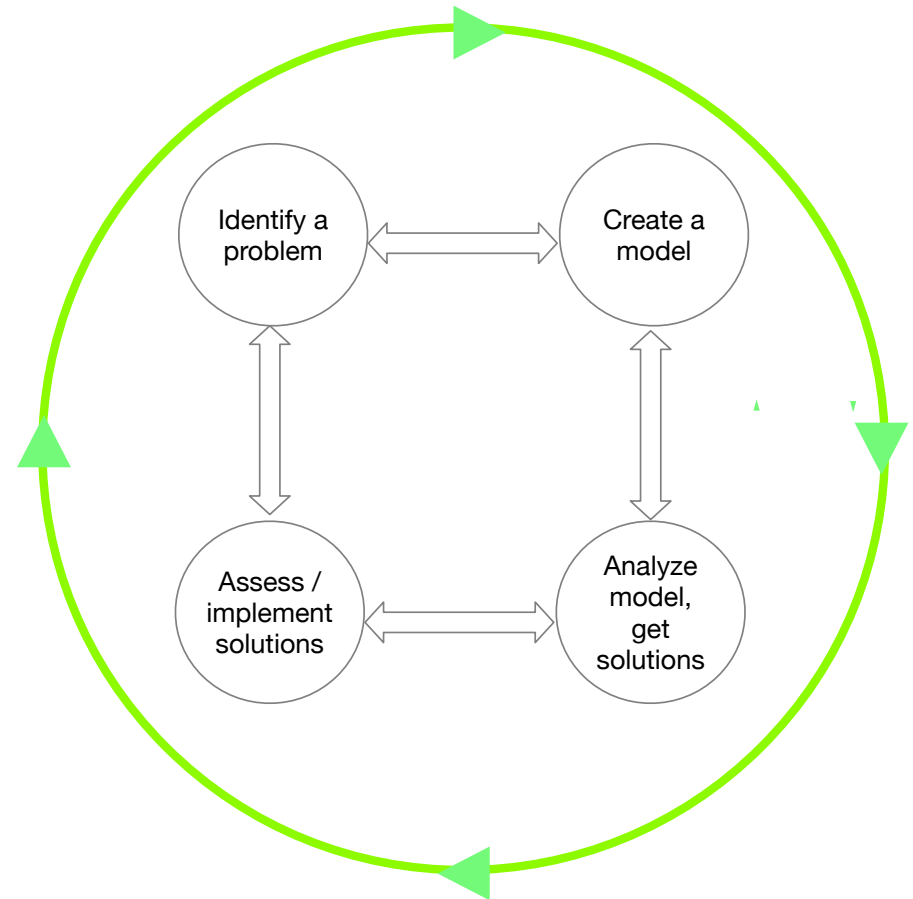
What's WORMS got to do with it?

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OR principles

- Operations research is a discipline that deals with the application of advanced analytical methods to **help make better decisions.** (Wikipedia)
- Operations Research & Analytics are proven scientific mathematical processes that enable organizations to **turn complex challenges into substantial opportunities** by transforming data into information, and information into insights that **save lives, save money and solve problems.** (INFORMS)





OR lessons learned

- Tackle the right problems

How do I achieve work/life balance?



How do I do more with less sleep?

How should my organization set up employees for success?

The New York Times | <https://nyti.ms/3dpAAs>

Nearly Half of Men Say They Do Most of the Home Schooling. 3 Percent of Women Agree.

A survey suggests that pandemic-era domestic work isn't being divided more equitably than before the lockdown.

By Claire Cain Miller

Published May 6, 2020 Updated May 8, 2020, 3:35 p.m. ET

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Sheryl Sandberg: The coronavirus pandemic is creating a 'double double shift' for women. Employers must help

BY SHERYL SANDBERG AND RACHEL THOMAS

May 7, 2020 4:15 AM PDT

"I worry about our junior faculty in the midst of this"



OR lessons learned



- Modeling assumptions matter

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Organization Science

Publication details, including instructions for authors and subscription information:
<http://pubsonline.informs.org>

Women Don't Mean Business? Gender Penalty in Board Composition

Isabelle Solal, Kaisa Snelman

To cite this article:
 Isabelle Solal, Kaisa Snelman (2019) Women Don't Mean Business? Gender Penalty in Board Composition. Organization Science 30(6):1270-1288. <https://doi.org/10.1287/orsc.2019.1301>

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O.R. Makes List of Top 5 STEM Professions Employing Women

Over the past year operations research, management science and analytics have been showing up in important rankings. In March 2015 U.S. News & World Report named operations research No. 4 in its list of best business jobs, No. 8 in its list of best STEM jobs and No. 20 in its list of 100 best jobs. Pretty impressive! More recently, as you'll see below, the profession made two USA Today rankings: O.R. made the list of top five best jobs for women and management science made the list of 25 best STEM majors.

Visit the INFORMS Newsroom at www.informs.org for additional news about analytics and INFORMS press releases about intriguing scholarship appearing in INFORMS journals.

Following are excerpts from INFORMS in the news.

O.R. Makes List of Top 5 STEM Professions Employing Women

Have a look for yourself at the five jobs with the highest percentage of women working in the profession ...

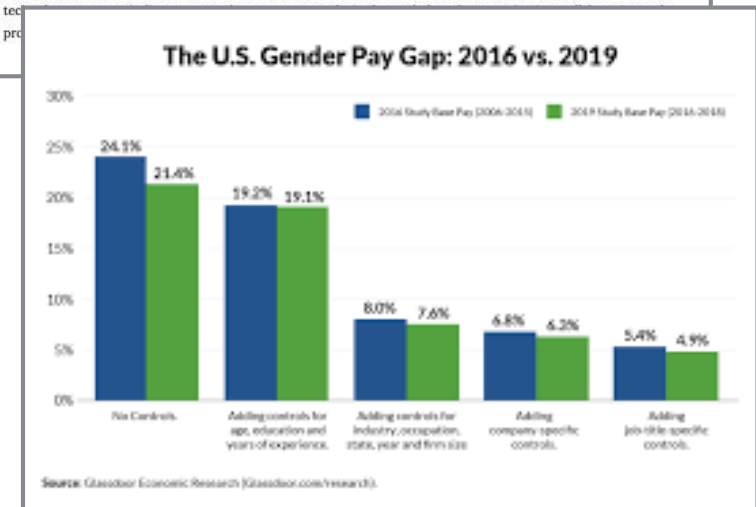


3. Operations Research Analysts
 - Percentage of women employed: 55.4 percent
 - Mean annual wage: \$82,940

These analysts use mathematical and analytical methods to help organizations solve complex problems, from using statistics to help inform decisions to gathering input from employees. Most operations research analysts have master's degrees in operations research, engineering, computer science, mathematics or physics. Some entry-level positions are open to those with bachelor's degrees.

Women hold 55 percent of STEM jobs.

This field only has 55.4 percent female workers, but that is still a considerable amount when looking at women in STEM. The reason for this, says analyst Laurie M. Orlov in her article on cio.com, is that jobs in the business





OR lessons learned

- Choose the right objective function

Avoid “Type III” errors¹



¹I.I. Mitroff, I.I. and T.R. Featheringham. 1974. On systemic problem solving and the error of the third kind, Behavioral Science 19: 383–393.

See also Lucas, T. W., W. D. Kelton, P. J. Sanchez, S. M. Sanchez, and B. L. Anderson. 2015. “Changing the paradigm: Simulation, now a method of first resort.” *Naval Research Logistics* 62: 293-205.



OR lessons learned



- Integrity matters
 - in modeling
 - in data
 - in communication

Members of the Institute for Operations Research and the Management Sciences (INFORMS) advance the science and practice of quantitative decision-making via operations research and analytics. We recognize a responsibility to uphold high ethical standards on behalf of society, our organizations, and the profession.

The following ethical guidelines are intended to be aspirational, something INFORMS members should attempt to follow throughout their career.

JOIN THE ETHICS IN O.R. & ANALYTICS GROUP on INFORMS Connect! Go to "All Communities" and click the blue Join button.



ETHICS GUIDELINES

SOCIETY

Whereas operations research and analytics can have a deep impact on society, with applications ranging from medical decisions to national defense, business strategy, public policy, and many other contexts, we aspire to be:

- Accountable for our professional actions and the impact of our work.
- Forthcoming about our assumptions, interests, sponsors, motivations, limitations, and potential conflicts of interest.
- Honest in reporting our results, even when they fail to yield the desired outcome.
- Objective in our assessments of facts, irrespective of our opinions or beliefs.
- Respectful of the viewpoints and the values of others.
- Responsible for undertaking research and projects that provide positive benefits by advancing our scientific understanding, contributing to organizational improvements, and supporting social good.

OUR ORGANIZATION

Whereas our work influences the success and standing of our organizations (universities, businesses, government, and nonprofit agencies) as well as our constituencies (students, clients, customers, and suppliers), we aspire to be:

- Accurate in our assertions, reports, and presentations.
- Alert to possible unintended or negative consequences that our results and recommendations may have on others.
- Informed of advances and developments in the fields relevant to our work.
- Questioning of whether there are more effective and efficient ways to reach a goal.
- Realistic in our claims of achievable results, and in acknowledging when the best course of action may be to terminate a project.
- Rigorous by adhering to proper professional practices in the development and reporting of our work.

THE PROFESSION

Whereas we are part of the profession of operations research and analytics and have an obligation to help advance the profession and to uphold high standards on behalf of our colleagues and future generations, we aspire to be:

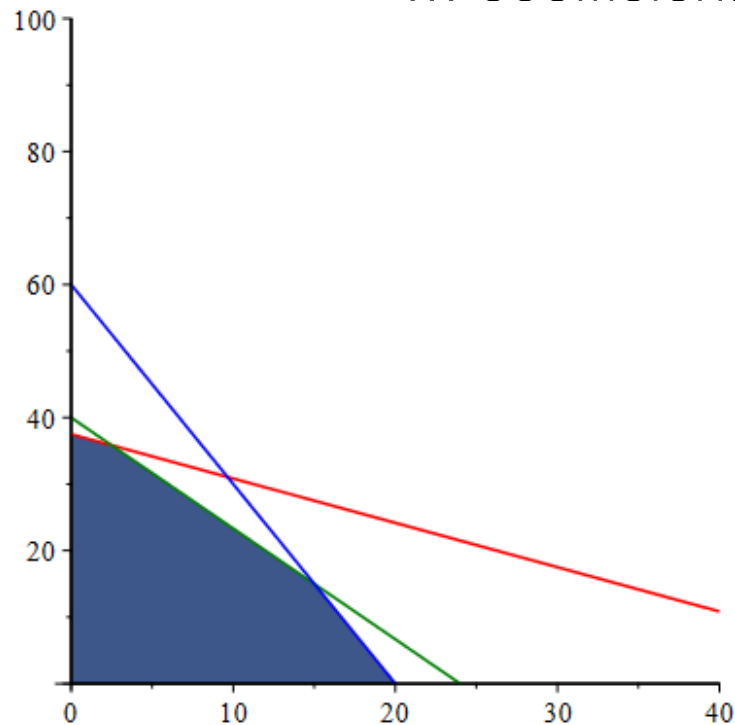
- Cooperative by sharing best practices, information, and ideas with colleagues, young professionals, and students.
- Impartial in our praise or criticism of others and their accomplishments, setting aside personal interests.
- Inclusive of all colleagues, and rejecting discrimination and harassment in any form.
- Tolerant of well-conducted research and well-reasoned results, which may differ from our own findings or opinions.
- Truthful in providing attribution when our work draws from the ideas of others.
- Vigilant by speaking out against actions that are damaging to the profession.



OR lessons learned

- Greedy algorithms are (usually) sub-optimal

... coefficients can change

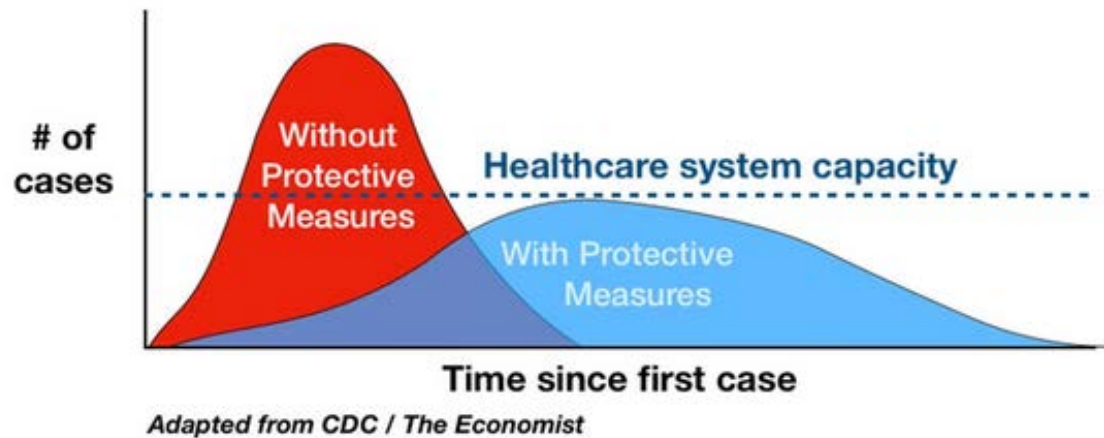


https://en.wikipedia.org/wiki/Knapsack_problem



OR lessons learned

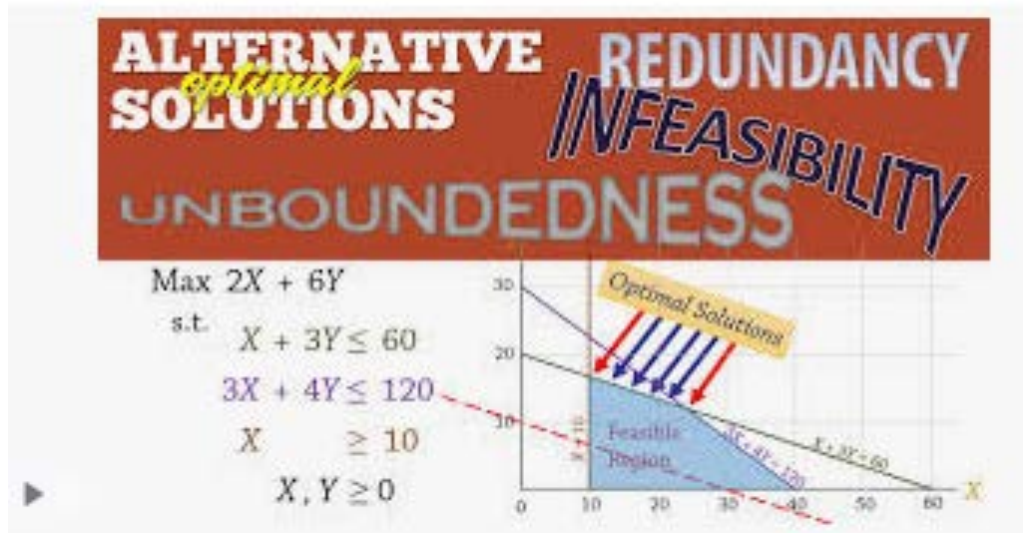
- Short term and long term solutions differ



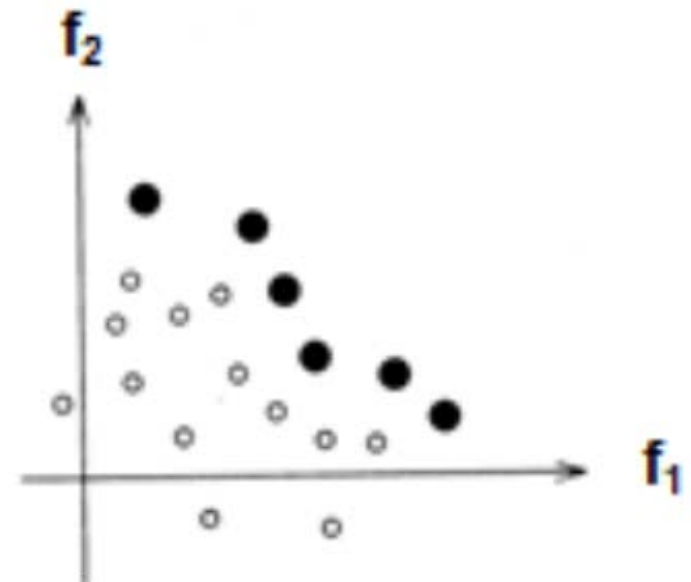


OR lessons learned

- Multiple solutions exist



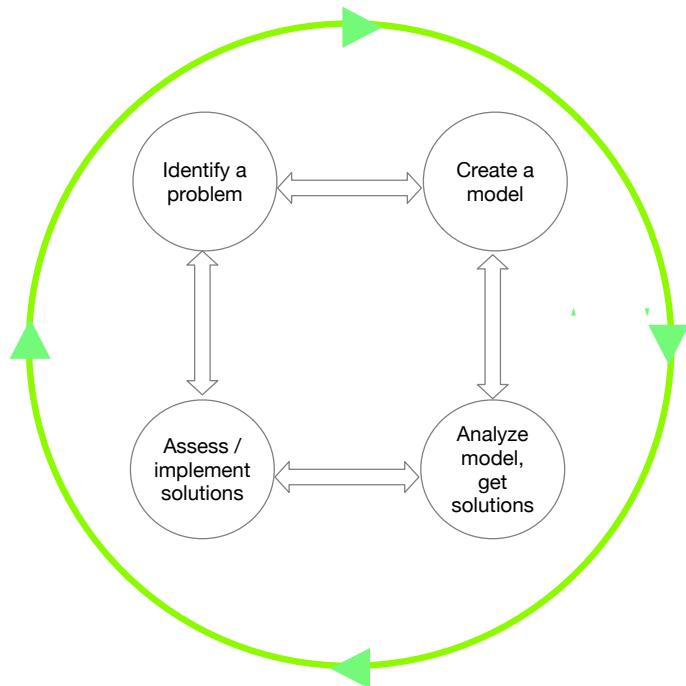
https://www.youtube.com/watch?v=_eMA0LWsRQQ





OR lessons learned

- It's an ongoing process



The New York Times

ECONOMIC VIEW

A Family-Friendly Policy That's Friendliest to Male Professors

Esther Loh

By Justin Wolfers

June 24, 2016

[f](#) [t](#) [v](#) [r](#) [b](#) [39](#)

The underrepresentation of women among the senior ranks of scholars has led dozens of universities to adopt family-friendly employment policies. But a [recent study](#) of economists in the United States finds that some of these gender-neutral policies have had an unintended consequence: They have advanced the careers of male economists, often at women's expense.



OR lessons learned

- When the going gets tough, the tough get going

What is?

What if?

What matters?

What could be?

What should be?

How might we get there?

Climate change

Public health

Innovation

Global migration

Humanitarian assistance

New materials

New physics

Defense & national security

Public policy

Economic systems

Supply chain / logistics

Methodological development

Methodological testing

Robust solutions

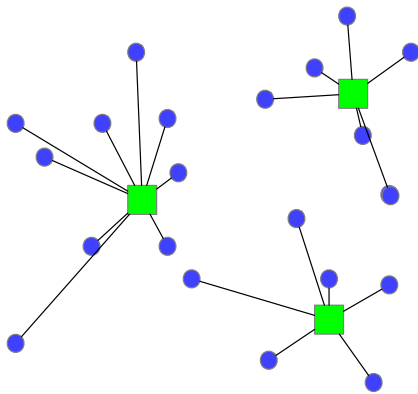
...

“think big!”



OR lessons learned

- Proactive is better than reactive



NOW is the time to
support our junior colleagues
and
set up for future success

$$\begin{aligned} \min_{x \in \mathbb{R}^n} \quad & g(x) = c^T x + E_\xi[Q(x, \xi)] \\ \text{subject to} \quad & Ax = b \\ & x \geq 0 \end{aligned}$$

where $Q(x, \xi)$ is the optimal value of the second-stage problem

$$\begin{aligned} \min_{y \in \mathbb{R}^m} \quad & q(\xi)^T y \\ \text{subject to} \quad & T(\xi)x + W(\xi)y = h(\xi) \\ & y \geq 0 \end{aligned}$$

https://en.wikipedia.org/wiki/Stochastic_programming#Two-stage_problems




OR lessons learned


- Communication is key
 - With team
 - With supervisors
 - With stakeholders
 - In society

Let's change the dialogue:
If you don't ask,
the answer is "no"

EDITORS' PICK | 7,618,701 views | Apr 13, 2020, 08:27am EDT

What Do Countries With The Best Coronavirus Responses Have In Common? Women Leaders

 **Avivah Wittenberg-Cox** Contributor ©
Careers
I write about creating gender-balanced countries, companies & couples.



Germany Taiwan New Zealand
Iceland Finland Norway Denmark

Political Leaders Showing the Way 20-FIRST

<https://www.forbes.com/sites/avivahwittenbergcox/2020/04/13/what-do-countries-with-the-best-coronavirus-reponses-have-in-common-women-leaders/#654d72cb3dec>

Truth, Decisiveness, Tech, & Love



OR perspective on work/life balance

- Tackle good problems
- Choose the right objective function
- Make appropriate modeling assumptions
- Analyze with integrity
- Greedy algorithms may be sub-optimal
- Short-term and long-term solutions differ
- Multiple solutions may exist
- Persevere: things change
- Be proactive
- Great challenges => great opportunities
- Communication is key



**What do you need?
What will you do?**

...at home...

...in your workplace...

...in your community



Next steps?

