

# Optimisation of control strategies against foot-and-mouth disease

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# Outline

- Introduction
- Materials and methods
- Results
- Discussion

# FMD control and eradication

- Principles:

- quarantine
- surveillance
- depopulation
- (vaccination)



- Stamping-out has been the 'traditional' approach in FMD free countries
- Post UK 2001 epidemic (US\$ 12 billion), much discussion of the role of vaccination as an alternative 'default' control strategy

# Disease modelling

- New Zealand Standard Model (InterSpread Plus)
  - a spatial and stochastic state-transition simulation model of infectious disease
  - input parameters developed for FMD spread in New Zealand



# Disease modelling

## Scenario (example)

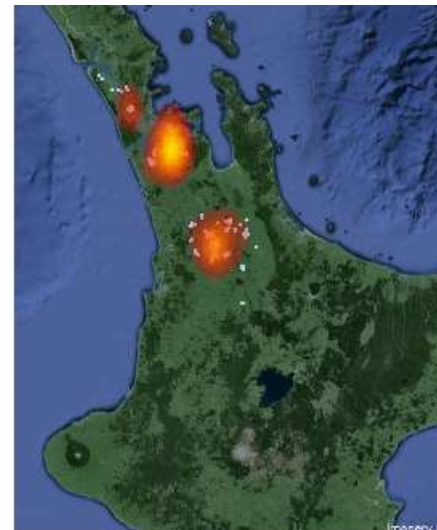
- FMD incursion in a hobby farm in South Auckland
- Controlled by MPI's default strategy



# Disease modelling

## Outcomes (example)

- 396 IPs
- 114 days
- US\$182 million control cost
- US\$10.2 billion GDP loss
- US\$10.4 billion total cost



# Decisions to make

- What would be the **optimal** control strategy should there be an FMD outbreak in New Zealand?
  - Should vaccination be used?
  - If vaccination is used, when and where should it be applied?
  - How large should area for movement restriction be?
  - How intense should surveillance be?
- Constraints
  - resources
- So many options to consider...

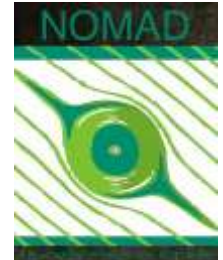


# Outline

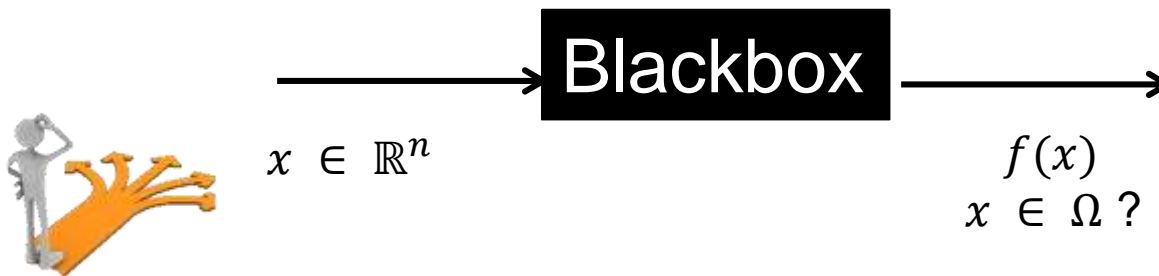
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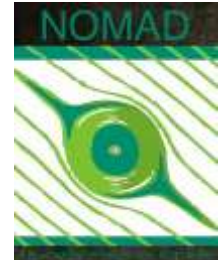
# Optimisation tool



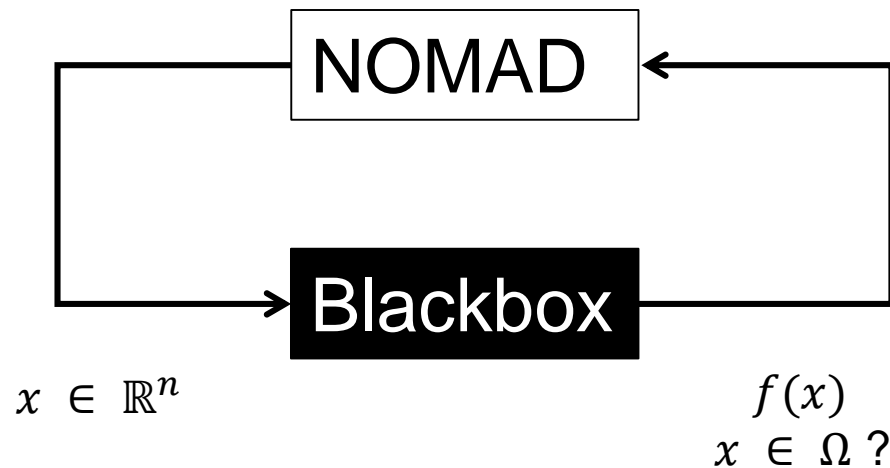
- NOMAD (Le Digabel et al. 2010)
  - Nonlinear Optimisation by Mesh Adaptive Direct Search
  - Designed to solve 'blackbox' optimisation problems



# Optimisation tool

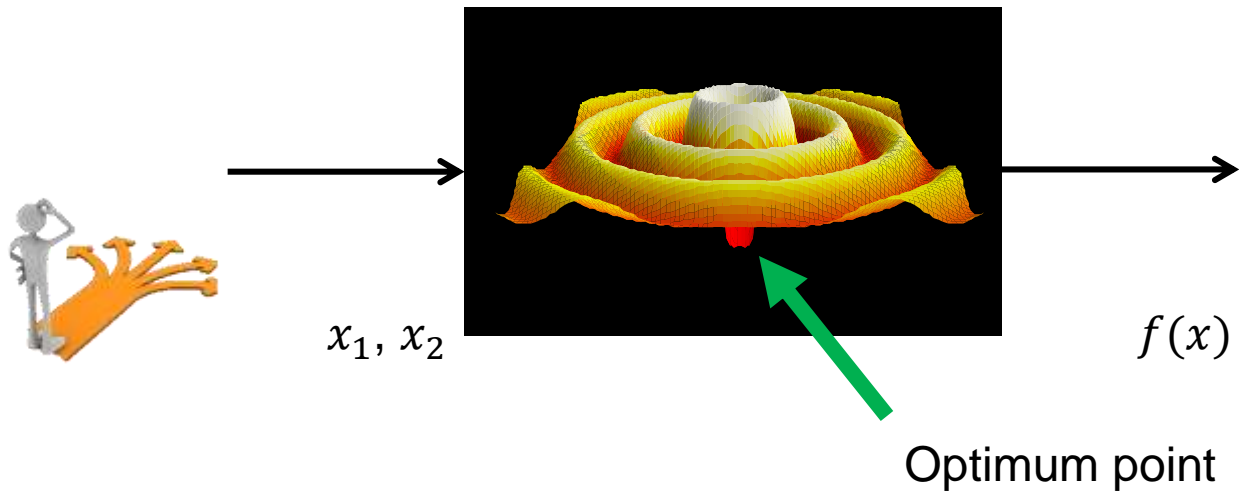
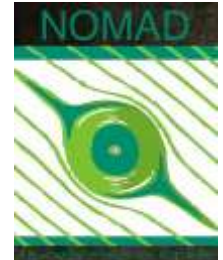


- NOMAD (Le Digabel et al. 2010)
  - Nonlinear Optimisation by Mesh Adaptive Direct Search
  - Designed to solve 'blackbox' optimisation problems
  - A blackbox may have no derivatives and may be contaminated by noise



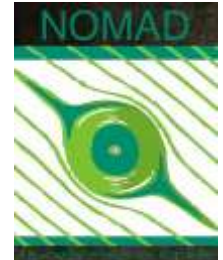
# Optimisation example

- objective:  $\min f(x)$
- constraints:  $x_1 \geq x_2$  and  $0 \leq x_i \leq 20$  ( $i = 1, 2$ )

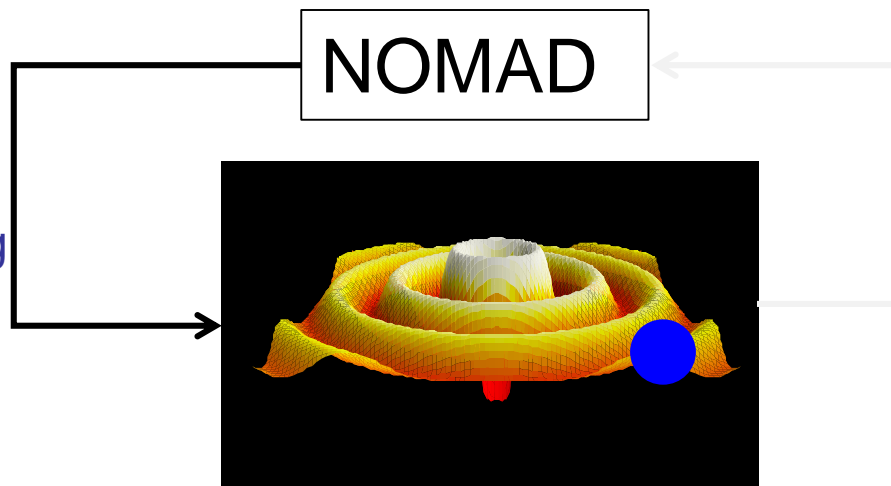


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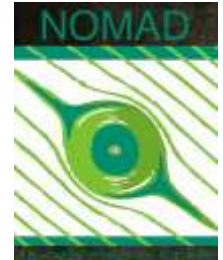
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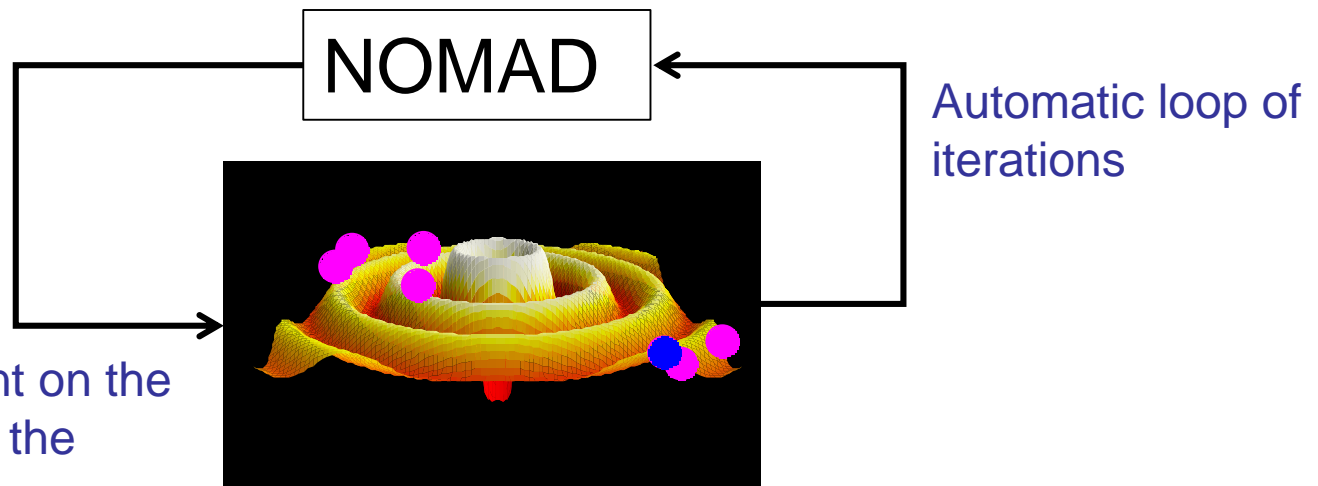
Given a starting  
point...



# Optimisation example



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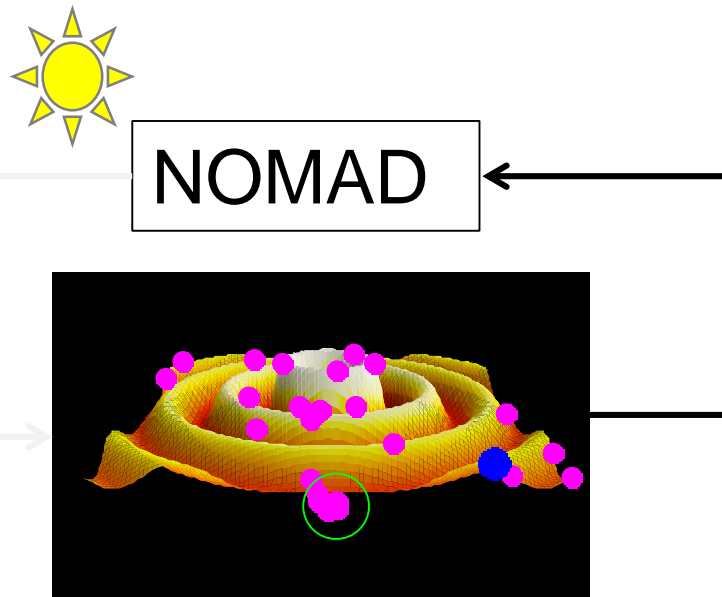
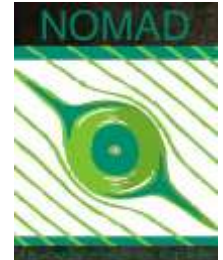


Generate a trial point on the mesh that improves the current best solution

Automatic loop of iterations

# Optimisation example

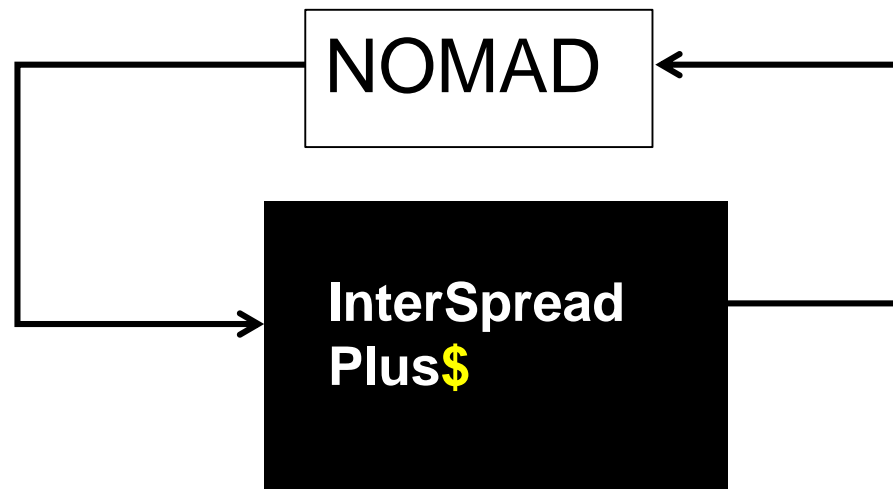
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Found a solution that  
minimised the objective  
function and satisfied the  
constraints!

# Optimisation of FMD control strategy

<b>Objective:</b>	Minimise the total cost of an epidemic (\$ billion)	$f(x)$
<b>Variables/</b>	Vaccination delay (days)	$x_1$
<b>constraints:</b>	Vaccination radius (km)	$x_2$
	Vaccination coverage (%)	$x_3$
	Protection zone (PZ) radius (km)	$x_4$
	Control area (CA) radius (km)	$x_5$
	Control costs (\$ million)	$c(x)$



# Protocols

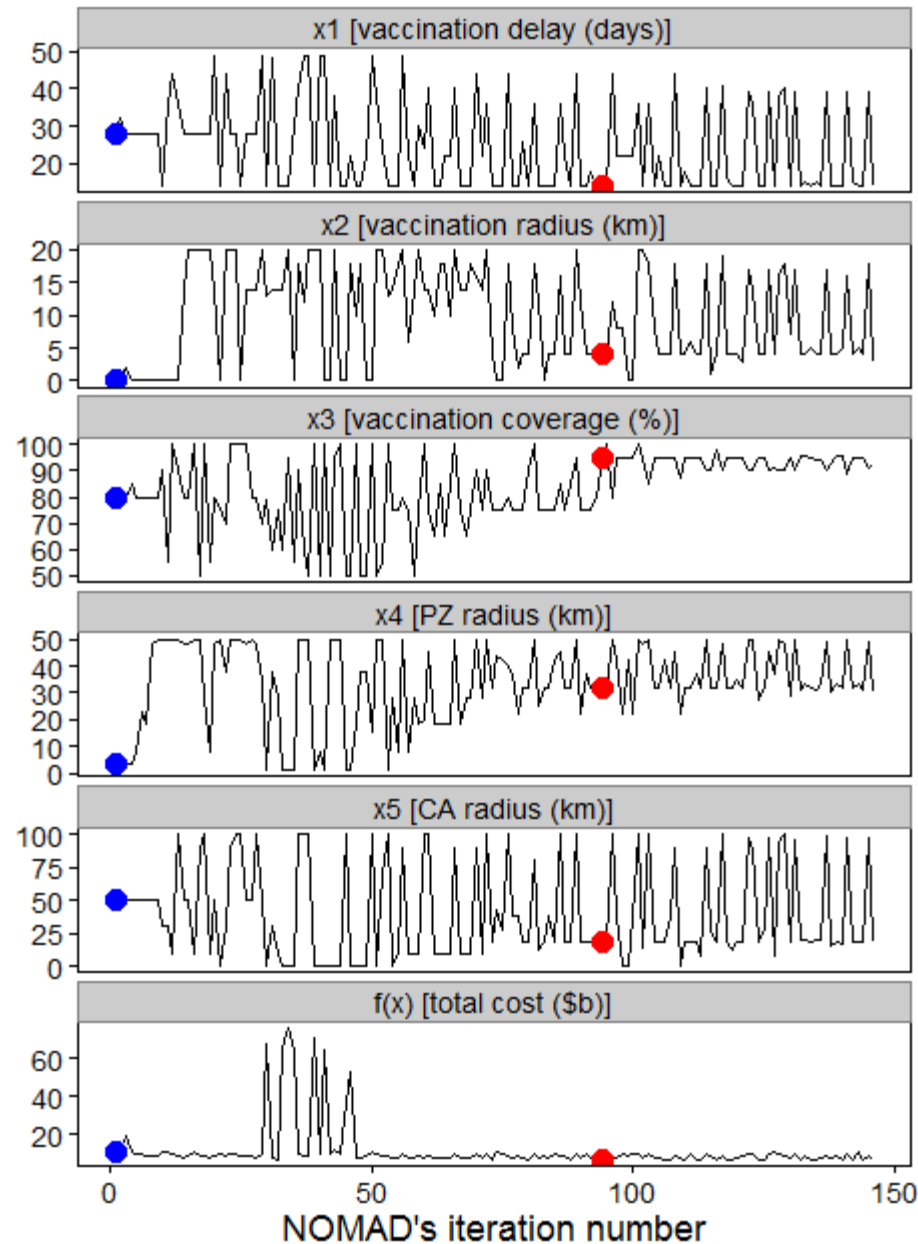
- Run NOMAD 40 times with different starting points
  - Check precision in solutions
- Check if the NOMAD solution makes sense by comparing with partial rank correlated coefficients (PRCCs) (Blower and Dowlatabadi, 1994)



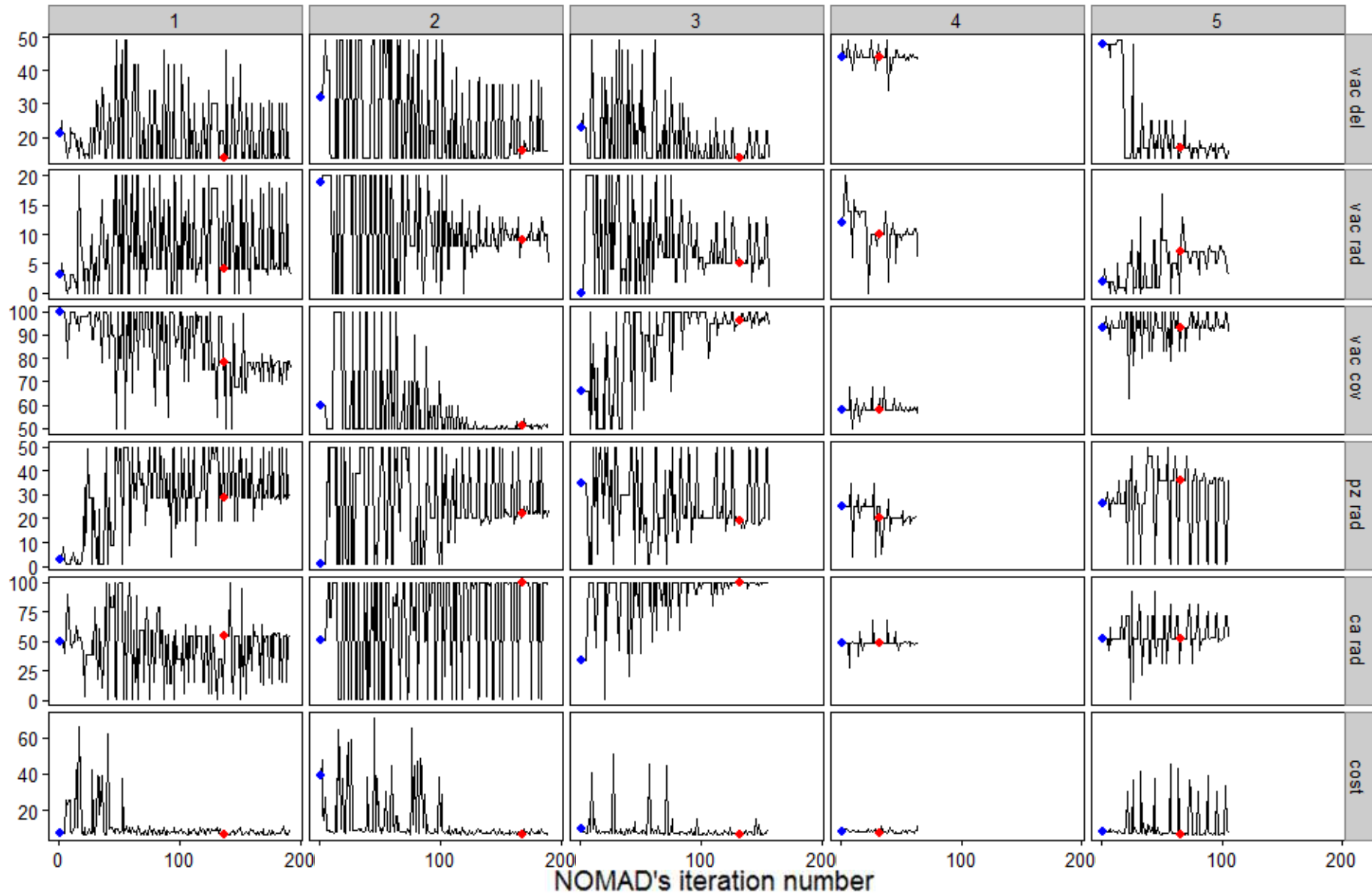
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## NOMAD's process of searching for an optimum point (1 run)

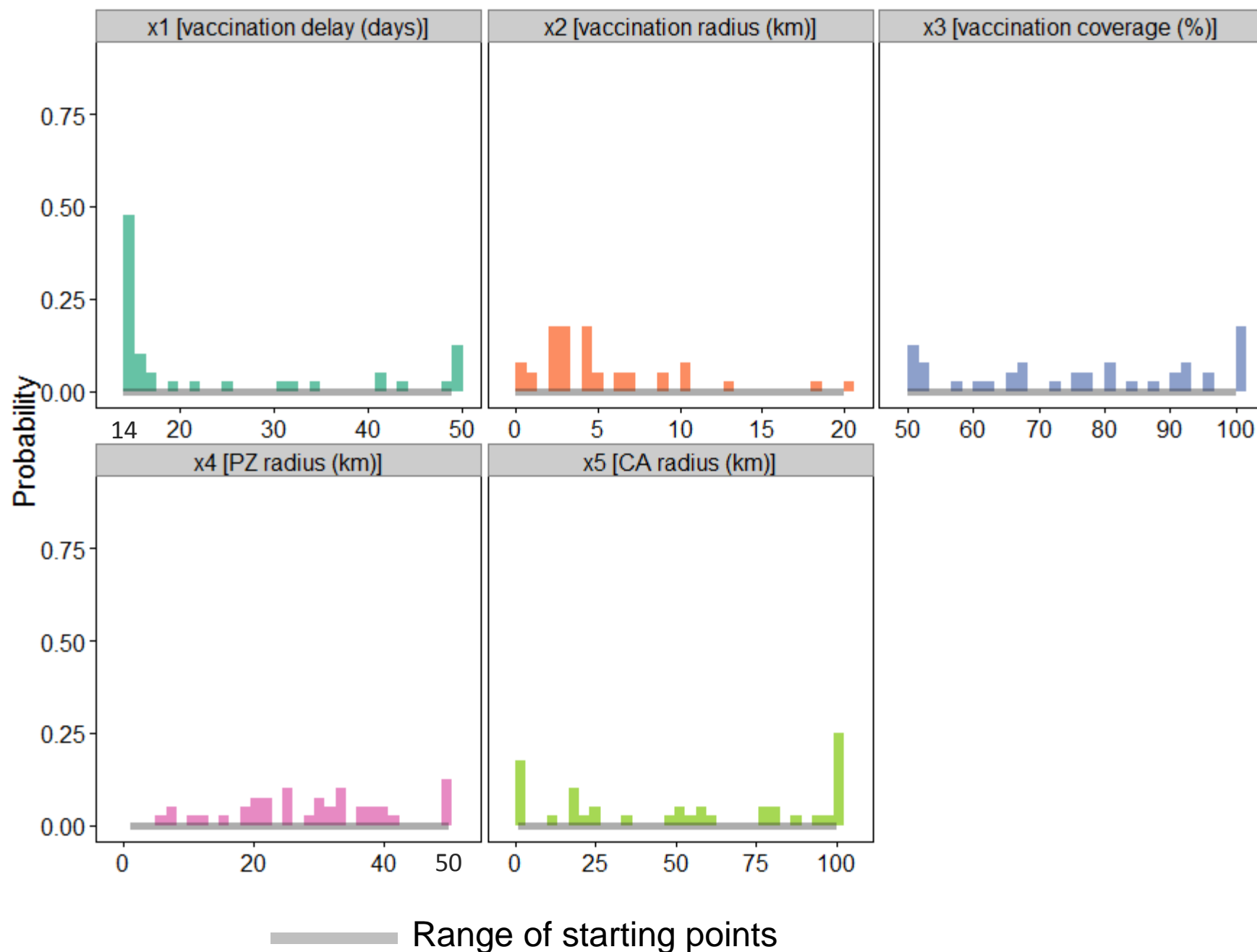


## NOMAD's process of searching for an optimum point (5 runs)

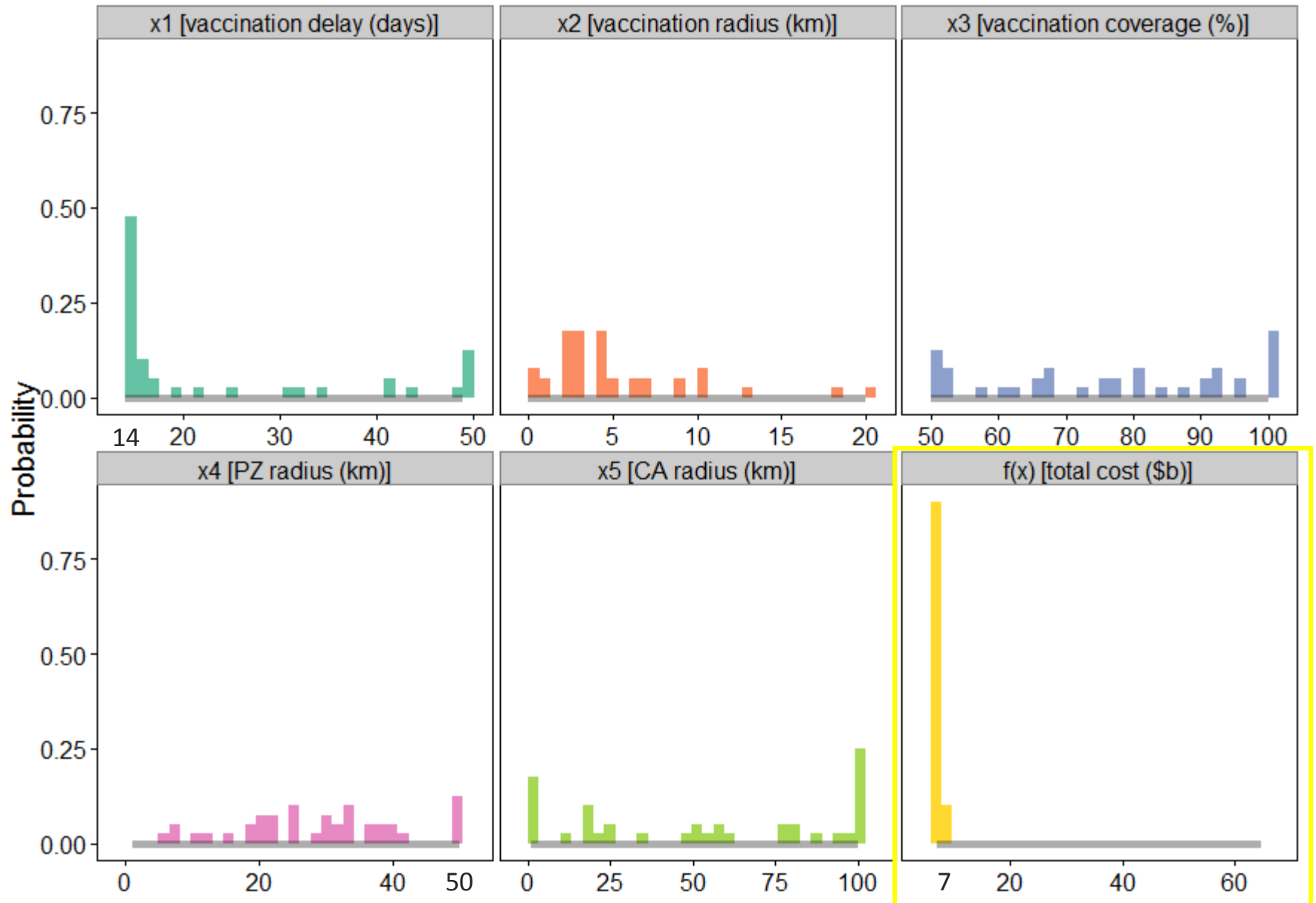


● Starting point ● Optimum point

Distributions of NOMAD's optimal points with different starting points (40 runs)

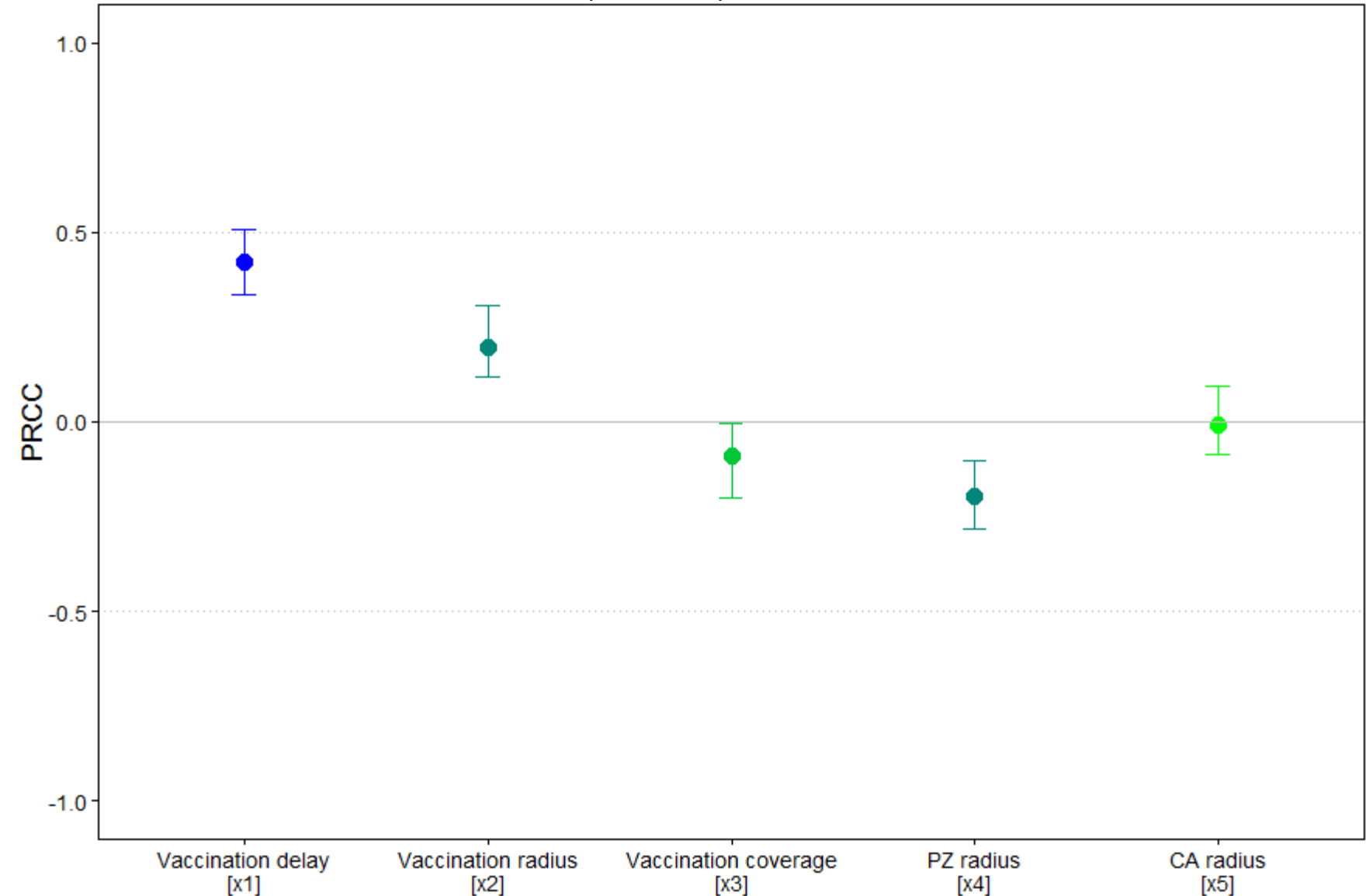


Distributions of NOMAD's optimal points with different starting points (40 runs)



— Range of starting points

Which variable is more influential on the output?:  
Partial rank correlation coefficients (PRCCs)



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# Discussion

- Took ~120 iterations (~ 6 hr) of NOMAD to optimise 5 variables
  - It would take 1100 yr to test all ~200 million possible variable combinations!
- All 40 solutions gave reasonably small objective functions
- There were some variations in the NOMAD's optimised solutions, but...
  - The blackbox (InterSpread Plus\$) is highly noisy
  - PRCCs indicate changes in 2/5 variables will not greatly influence the output



# Discussion

- Will disease decision makers trust an optimisation tool when the heat is on?
  - probably not
- So what's the point?
  - focus their attention when planning prior to the heat being turned on
  - another way for modellers to check if the model is doing OK

# Acknowledgement

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  - Hokkaido University (Japan)
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