The Science of Better

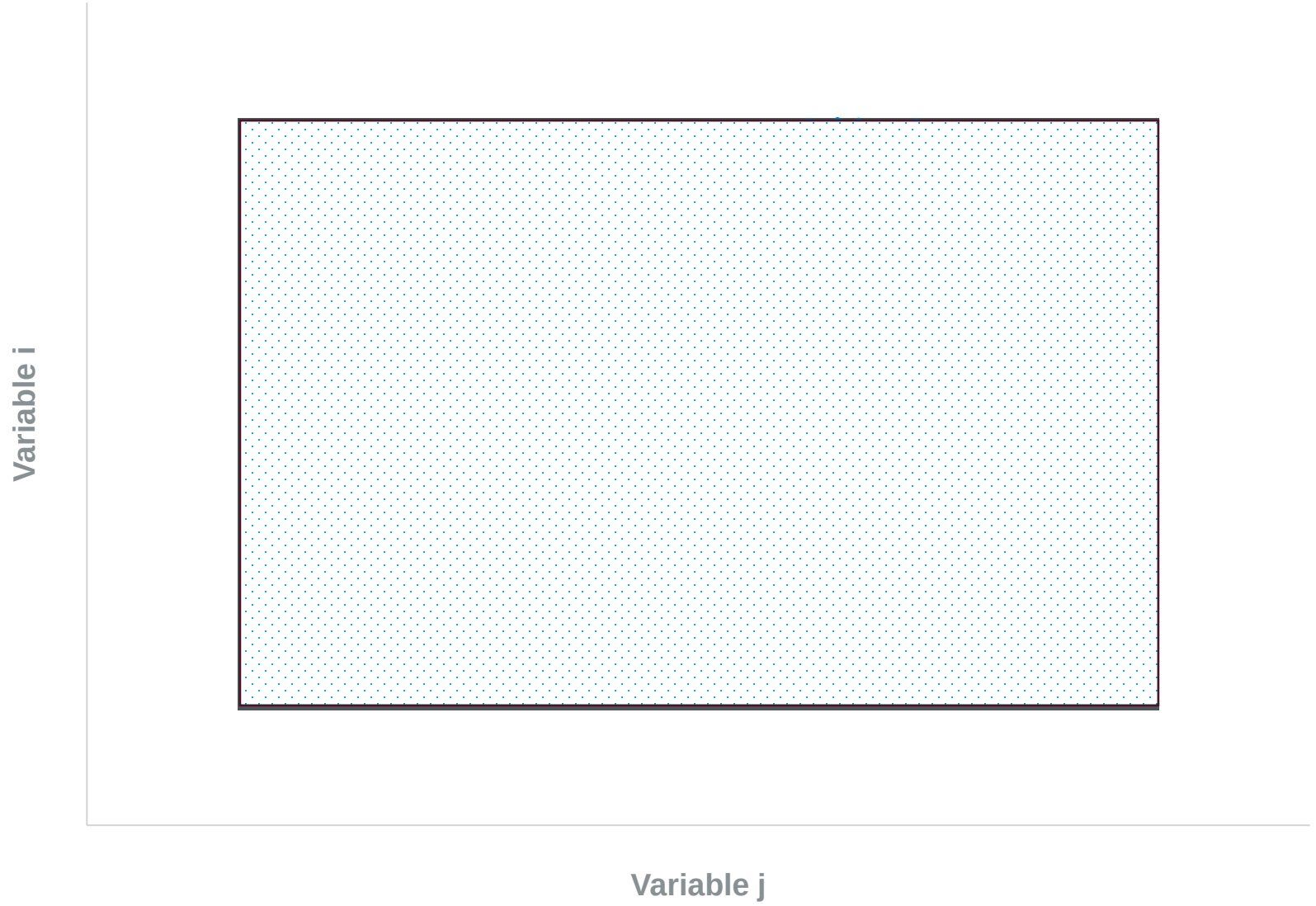
Dr Philip Venter

Photo by Stefan Els

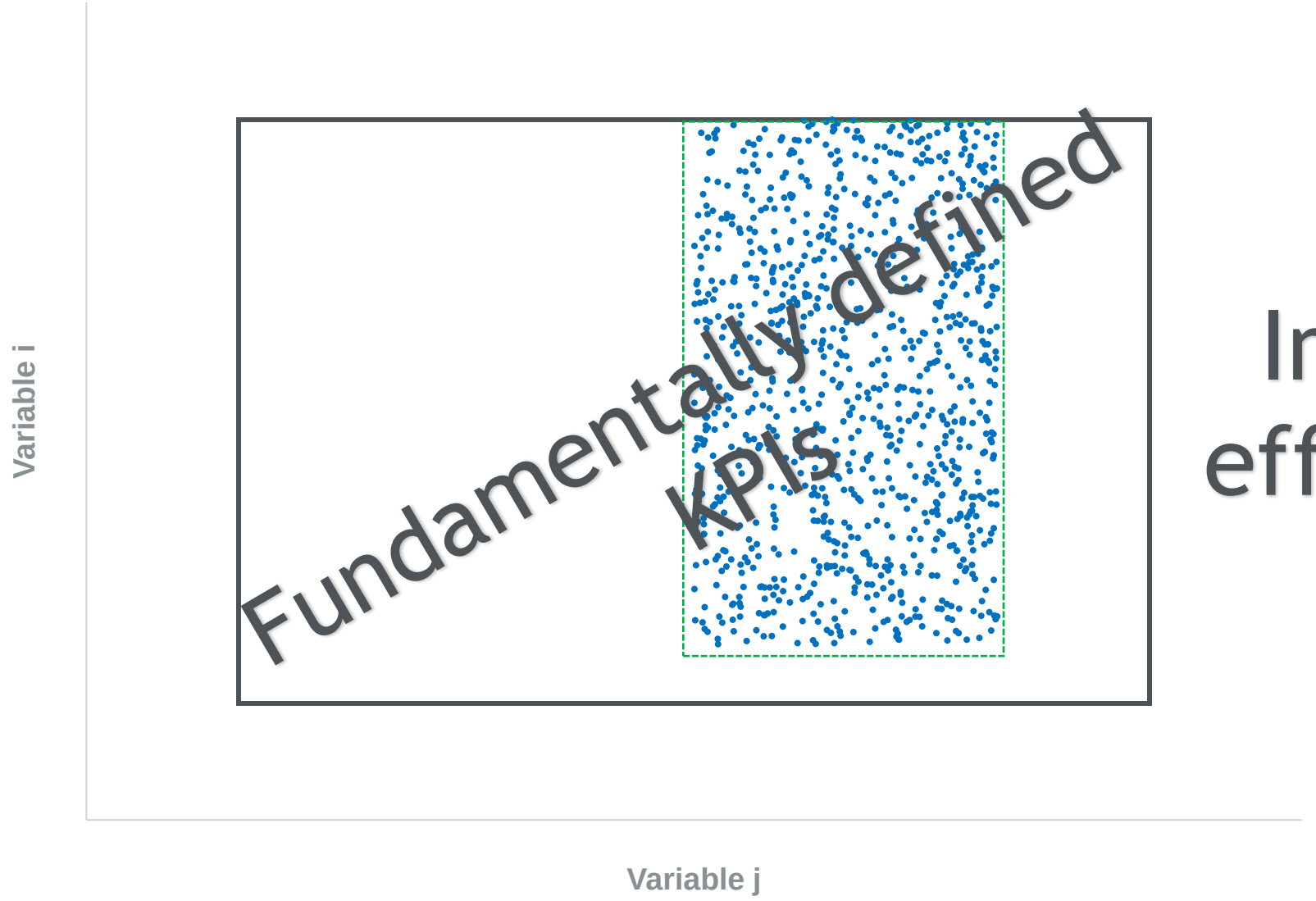
Layout

- Generic framework / approach.
- Boiler operational efficiency improvement.

Two conceptual variables' operational boundaries



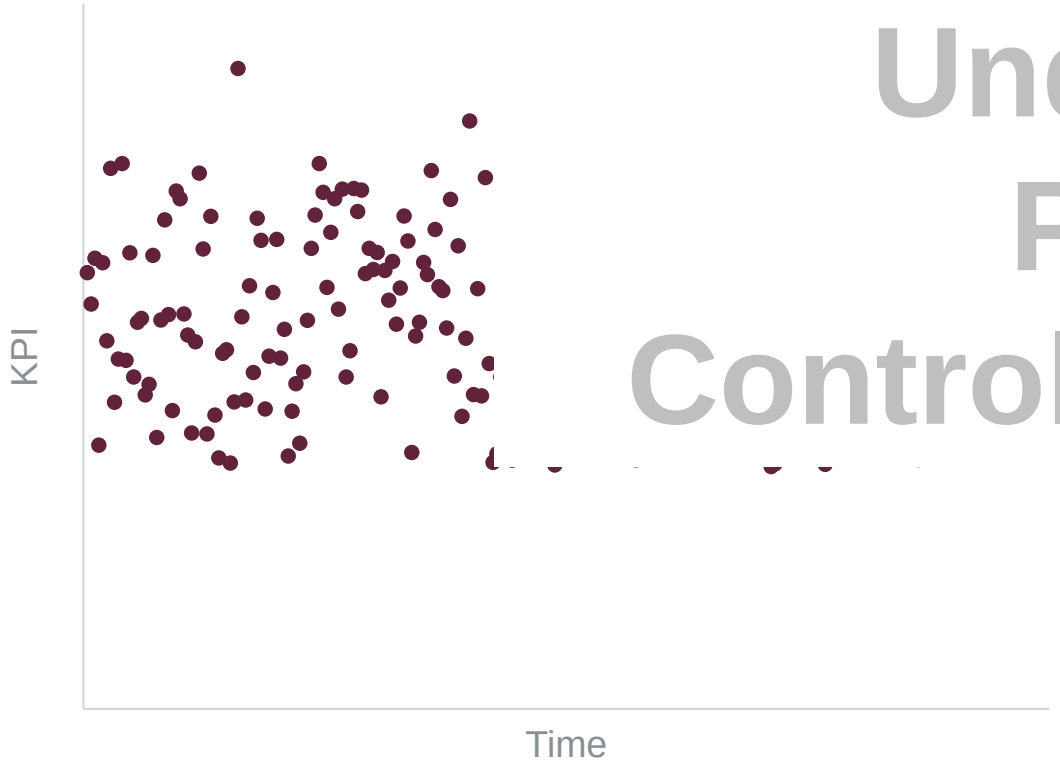
Time-in-State

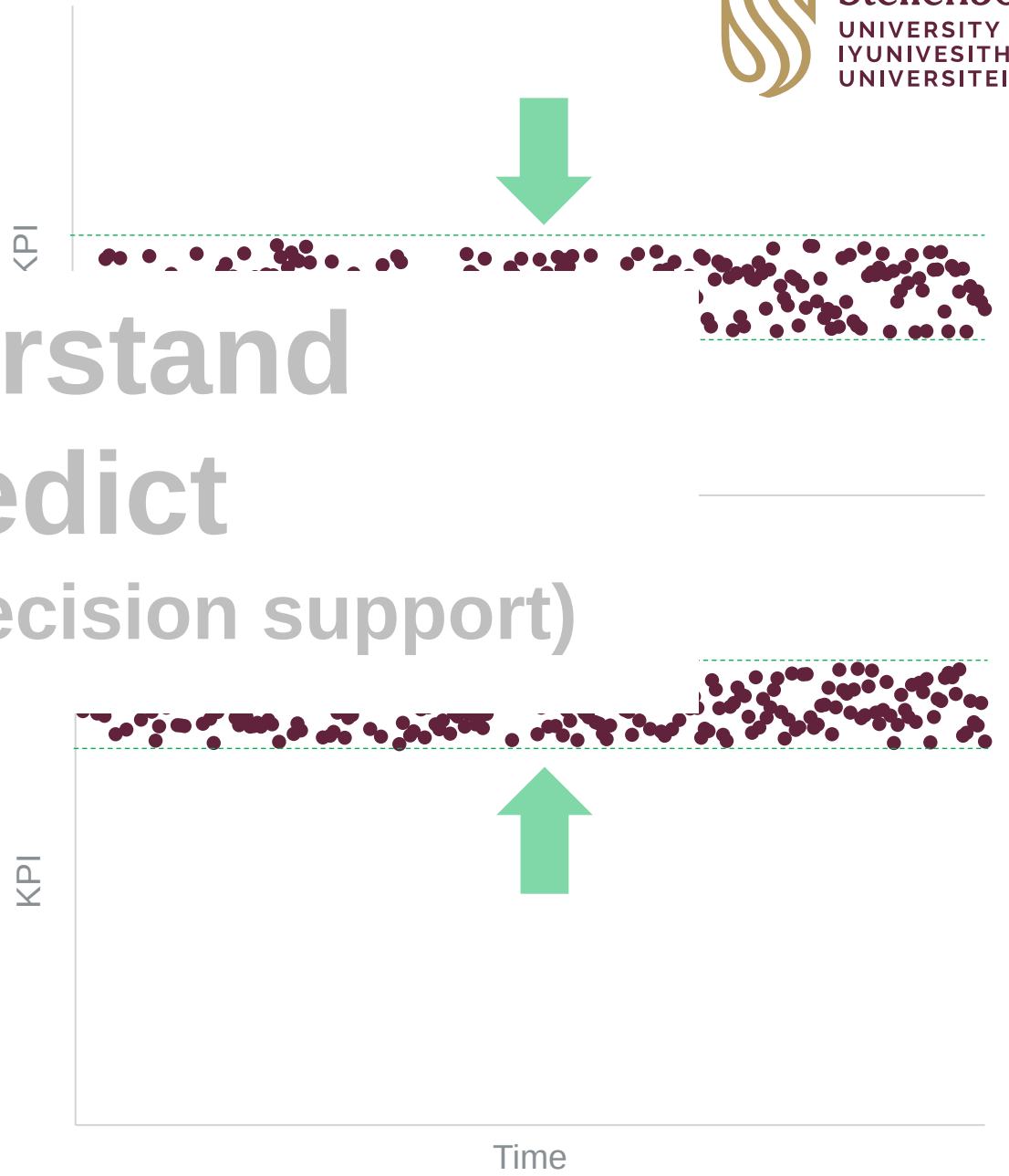


Improve efficiency?

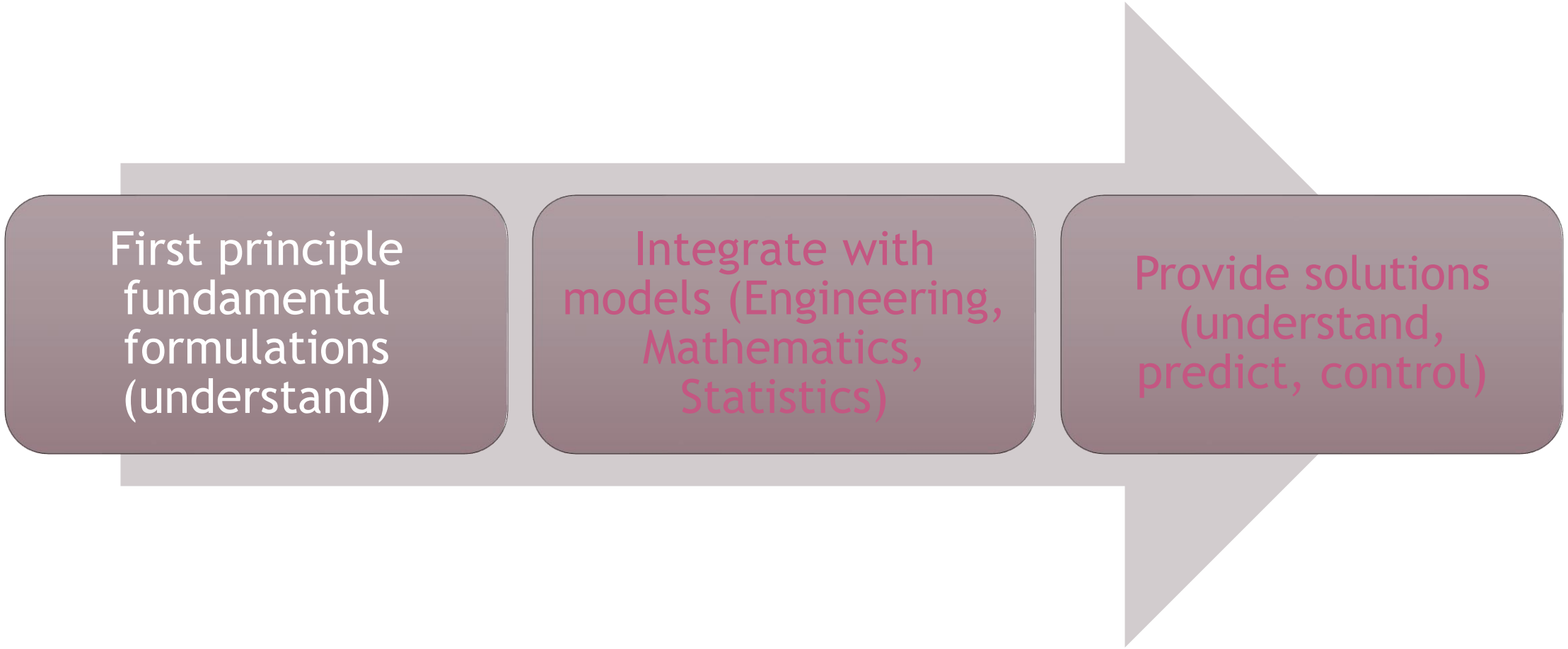
First principles fundamentally defined KPIs

Understand
Predict
Control (decision support)

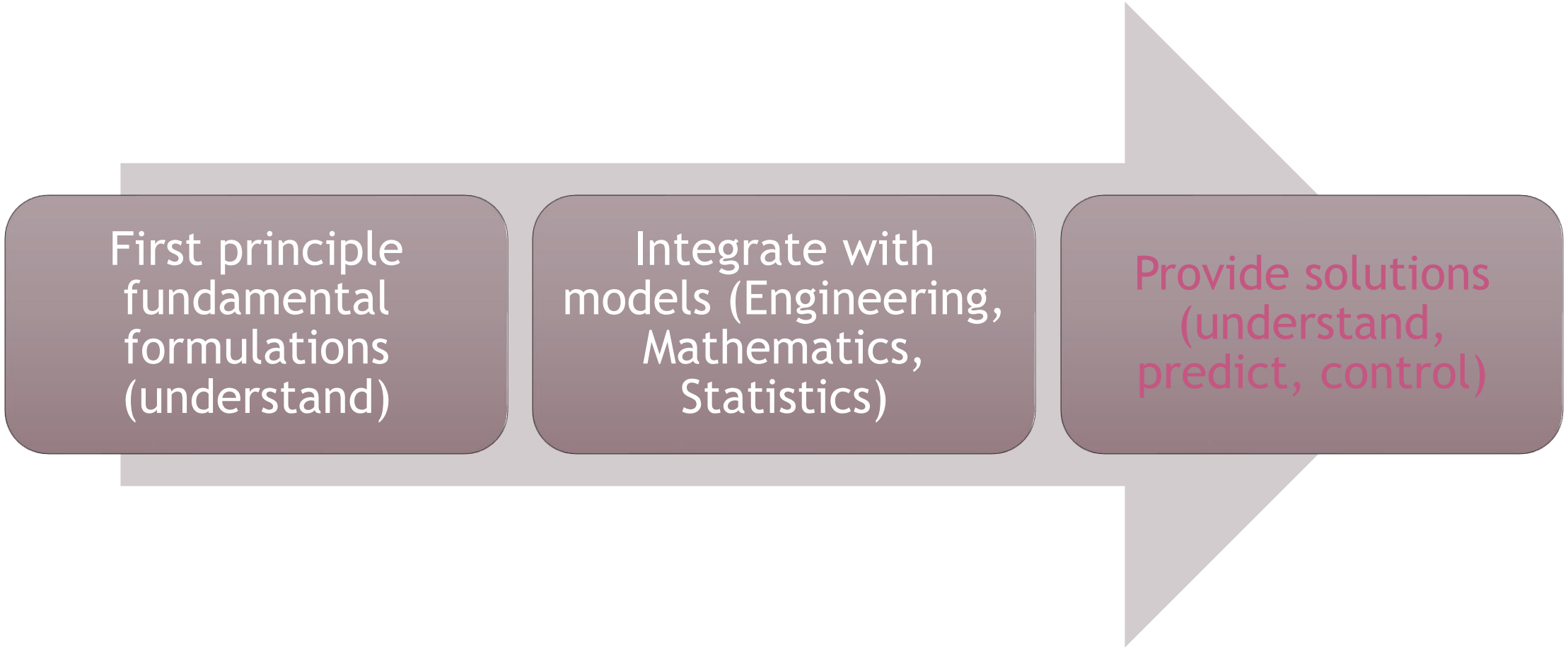




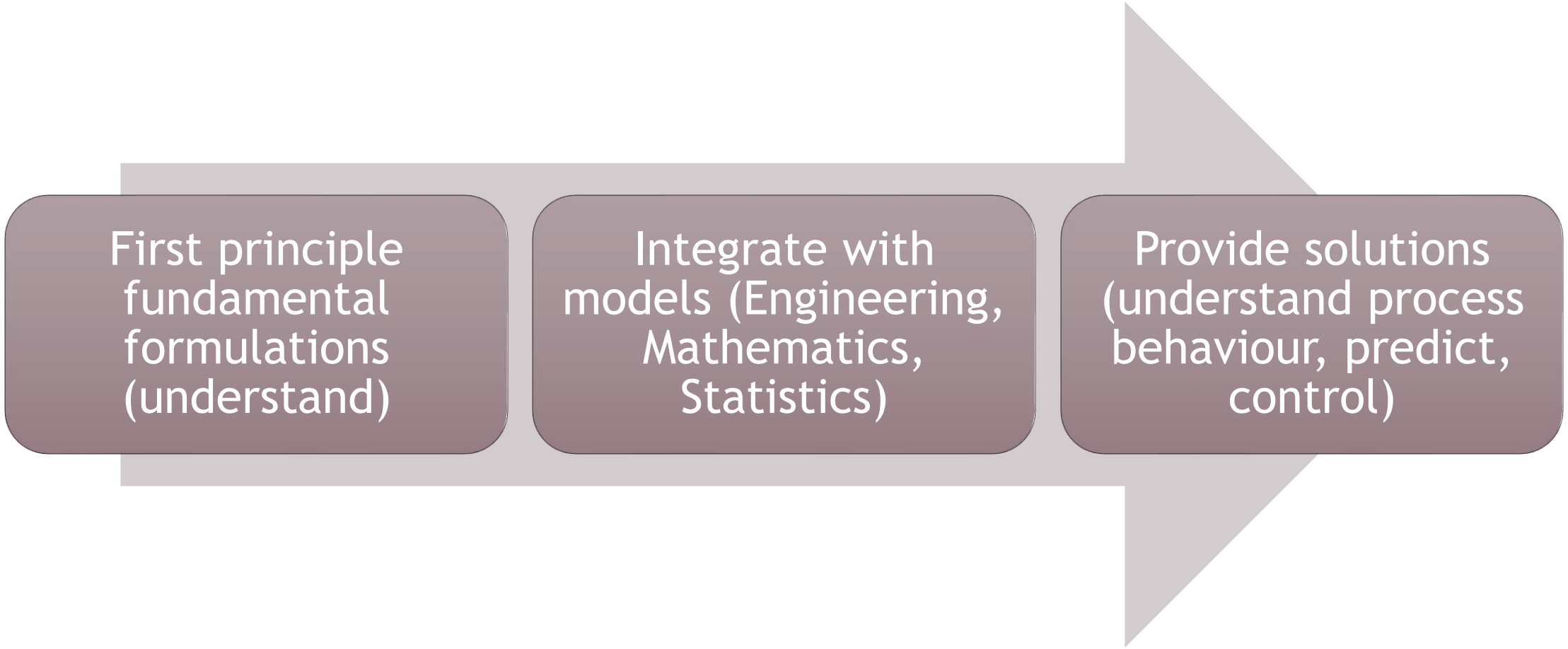
Problem solving process



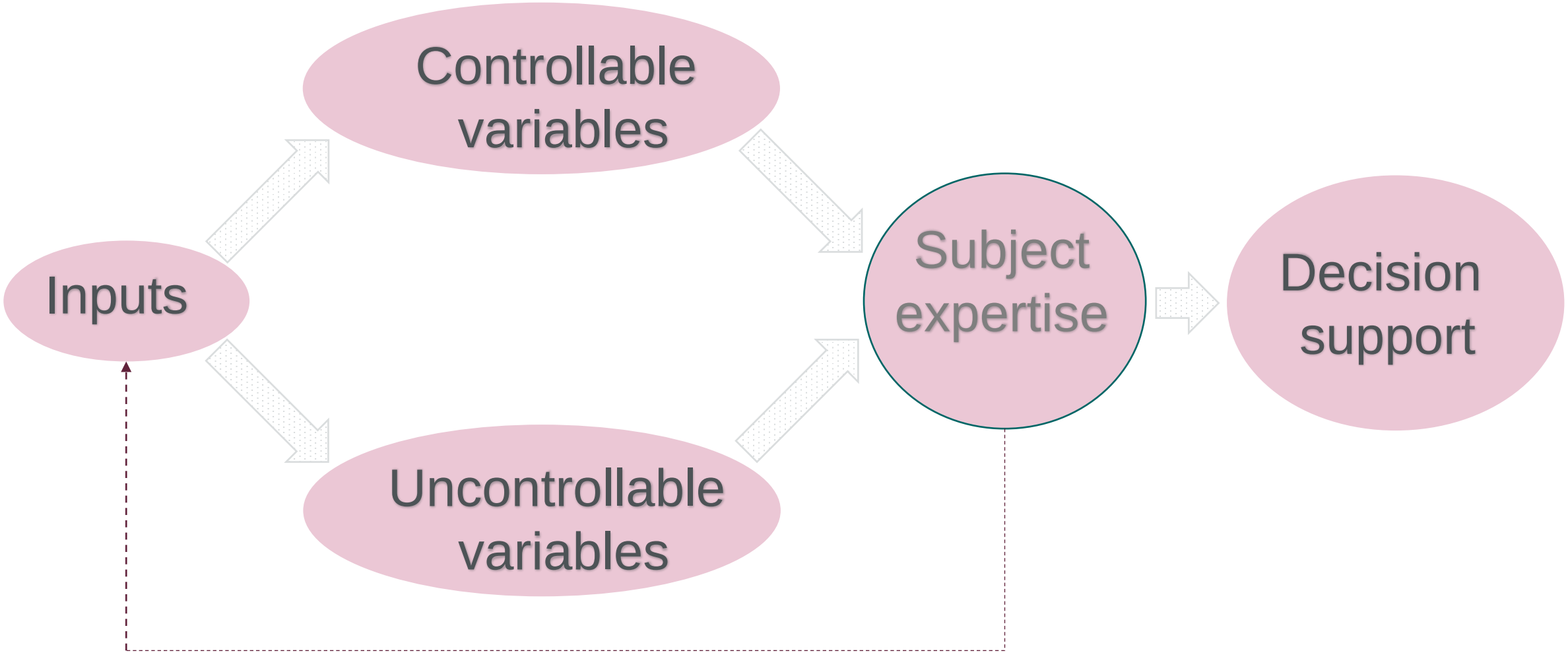
Problem solving process



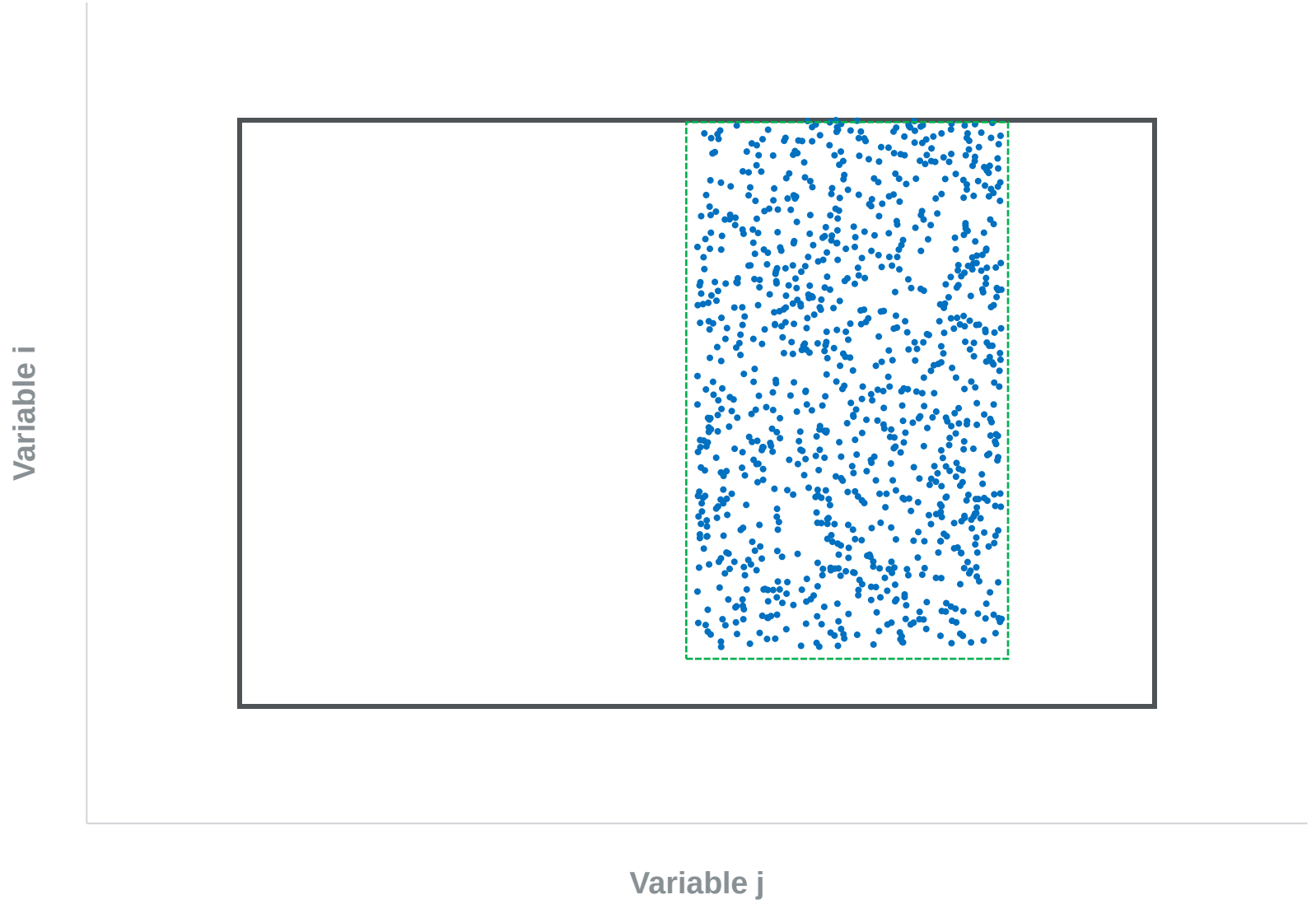
Problem solving process



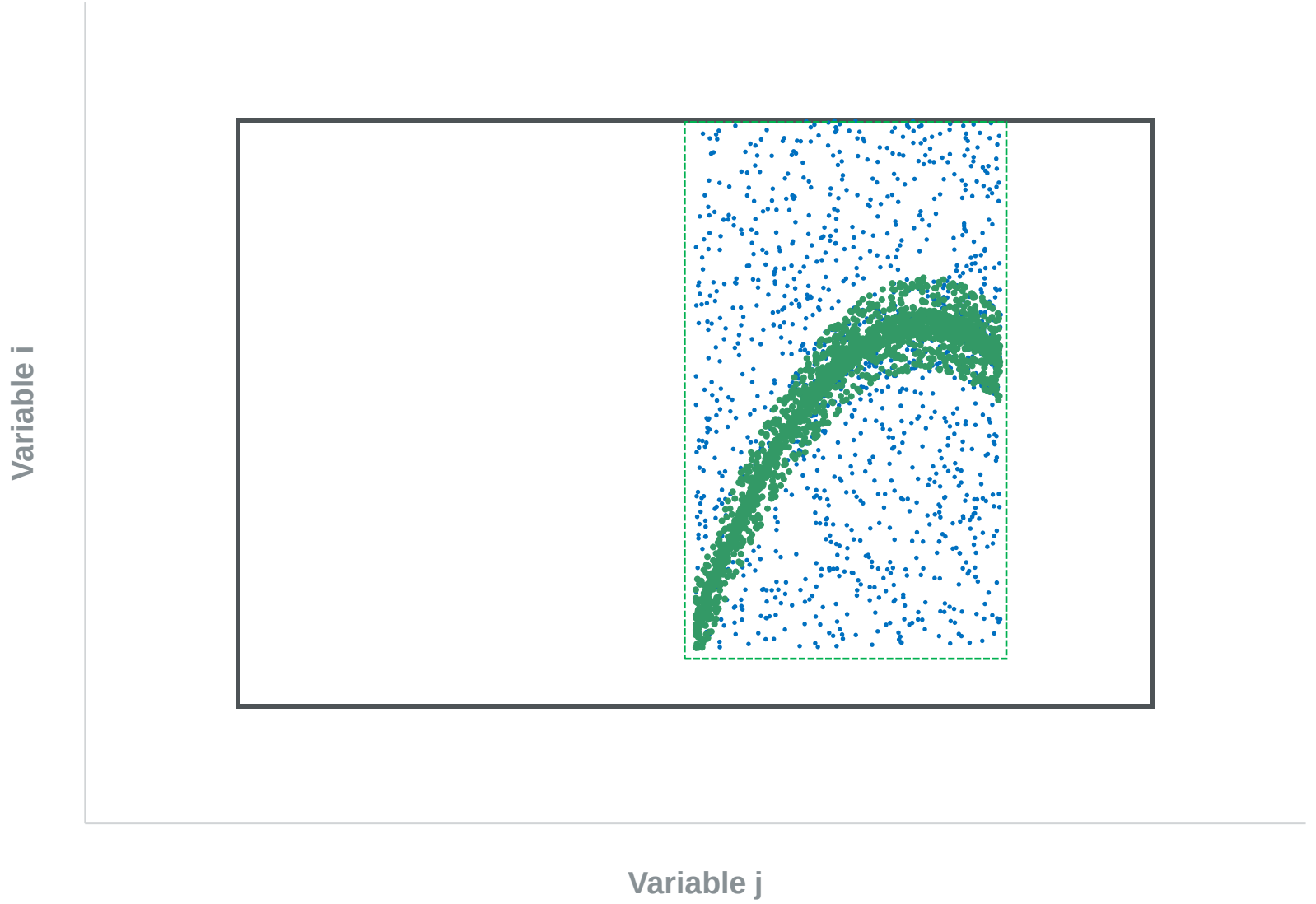
Solution process



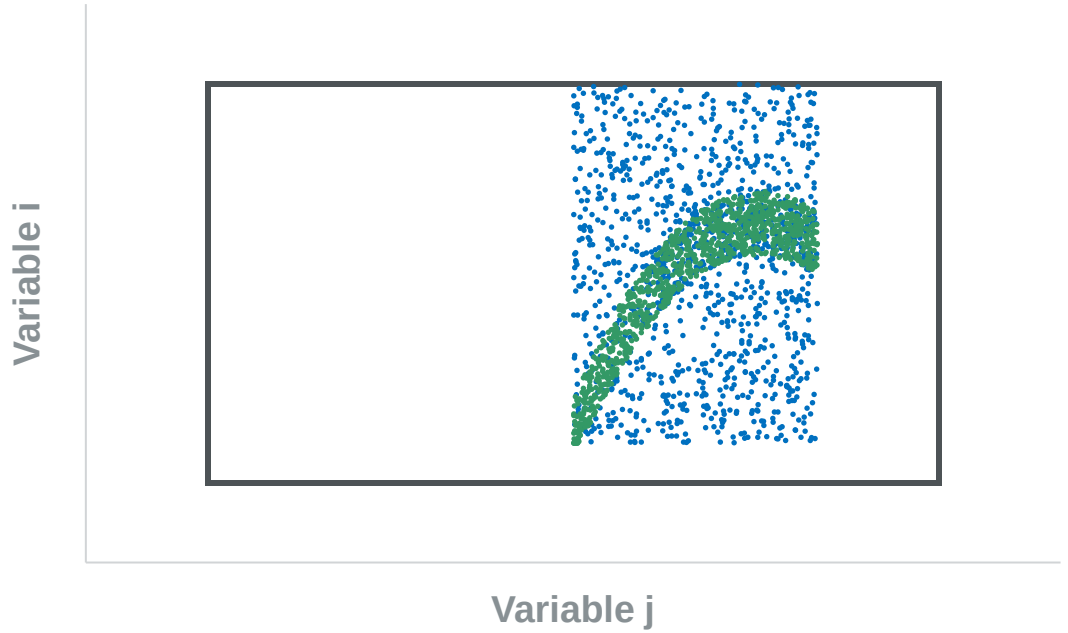
Time-in-State

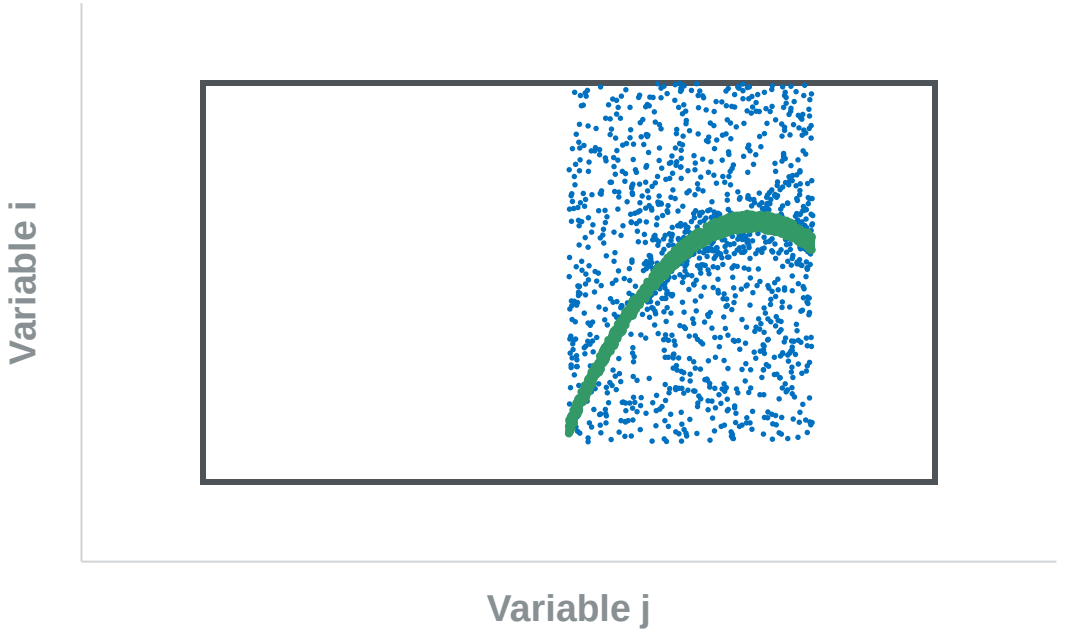


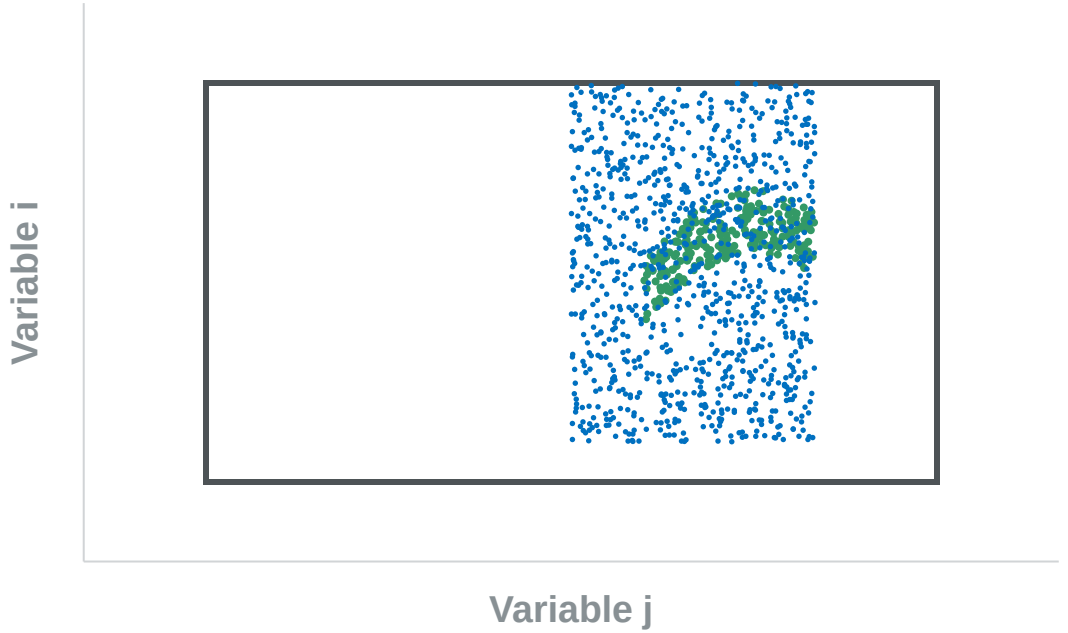
$$KPI = f(i, j, k, \dots)$$



$$KPI = f(i, j, k, \dots)$$



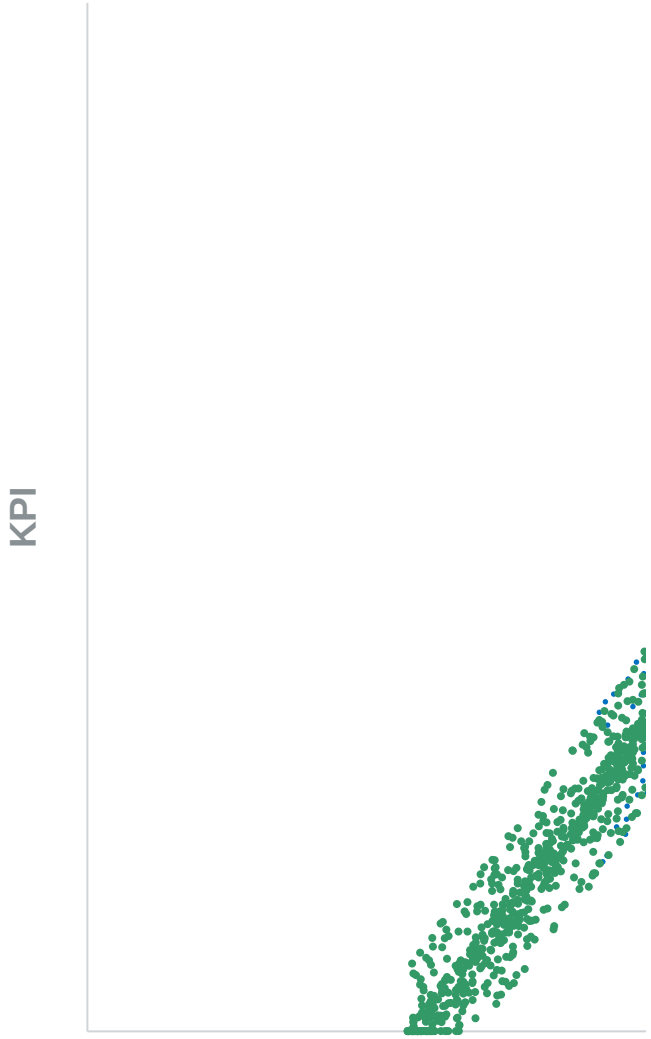




$$\mathrm{KPI} = f(i, j, k, \ldots)$$

Stellenbosch UNIVERSITY IYUNIVESITHI UNIVERSITEIT

Boiler example



TiS boiler

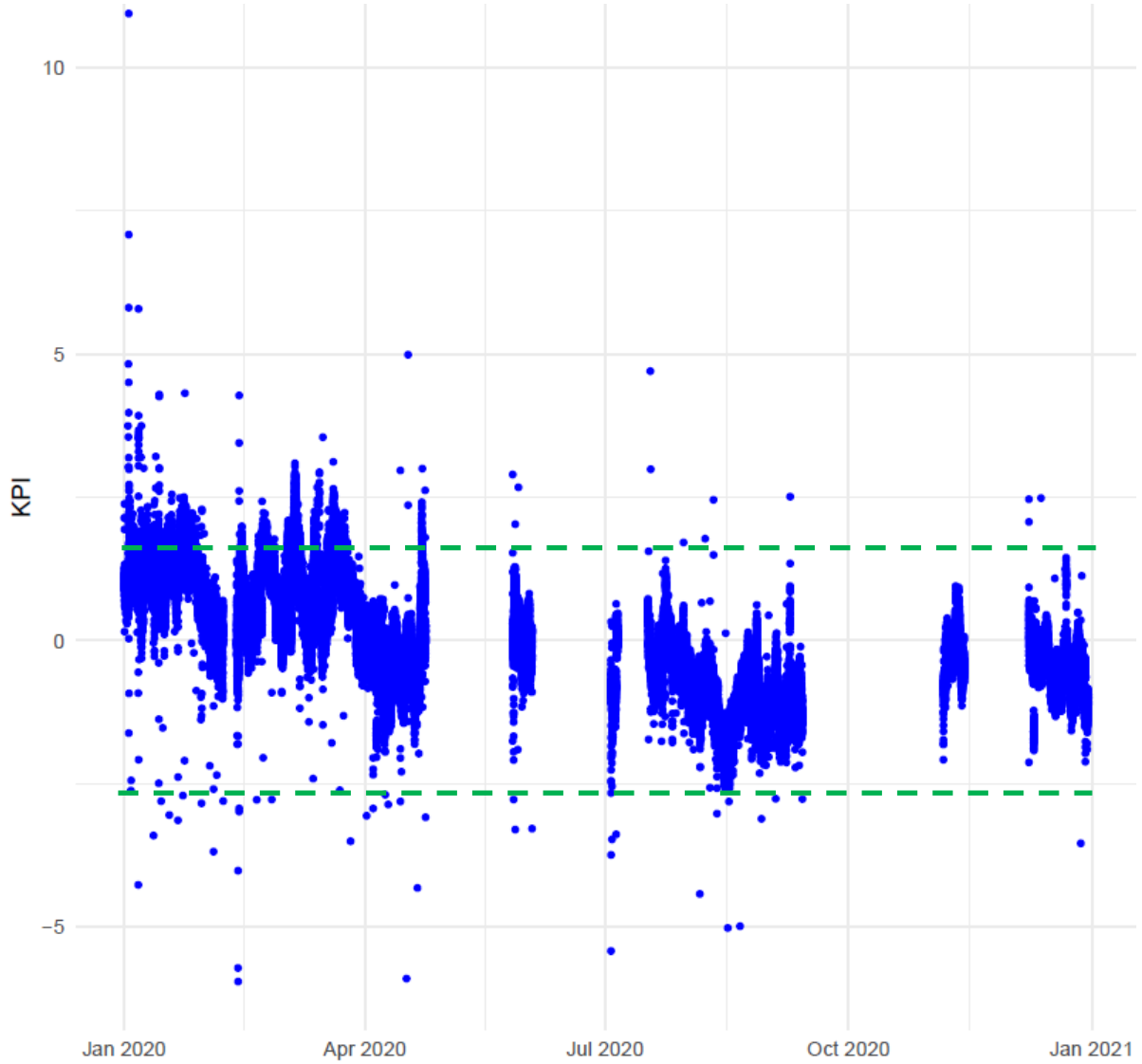
Rand saving per ton steam delivered.

Reduction in CO_2 per ton steam delivered.

Define Thermohydraulic KPI

- 7-dimensional KPI variable.
  - Ratio of energy inputs over *energy* delivered.
    - Energy inputs: coal flow.
    - Energy delivered: inlet water and superheated steam's temperature and pressure; inlet water flow rate; blow down rate.
  - ∴ KPI minimisation required.

KPI (scaled) over time



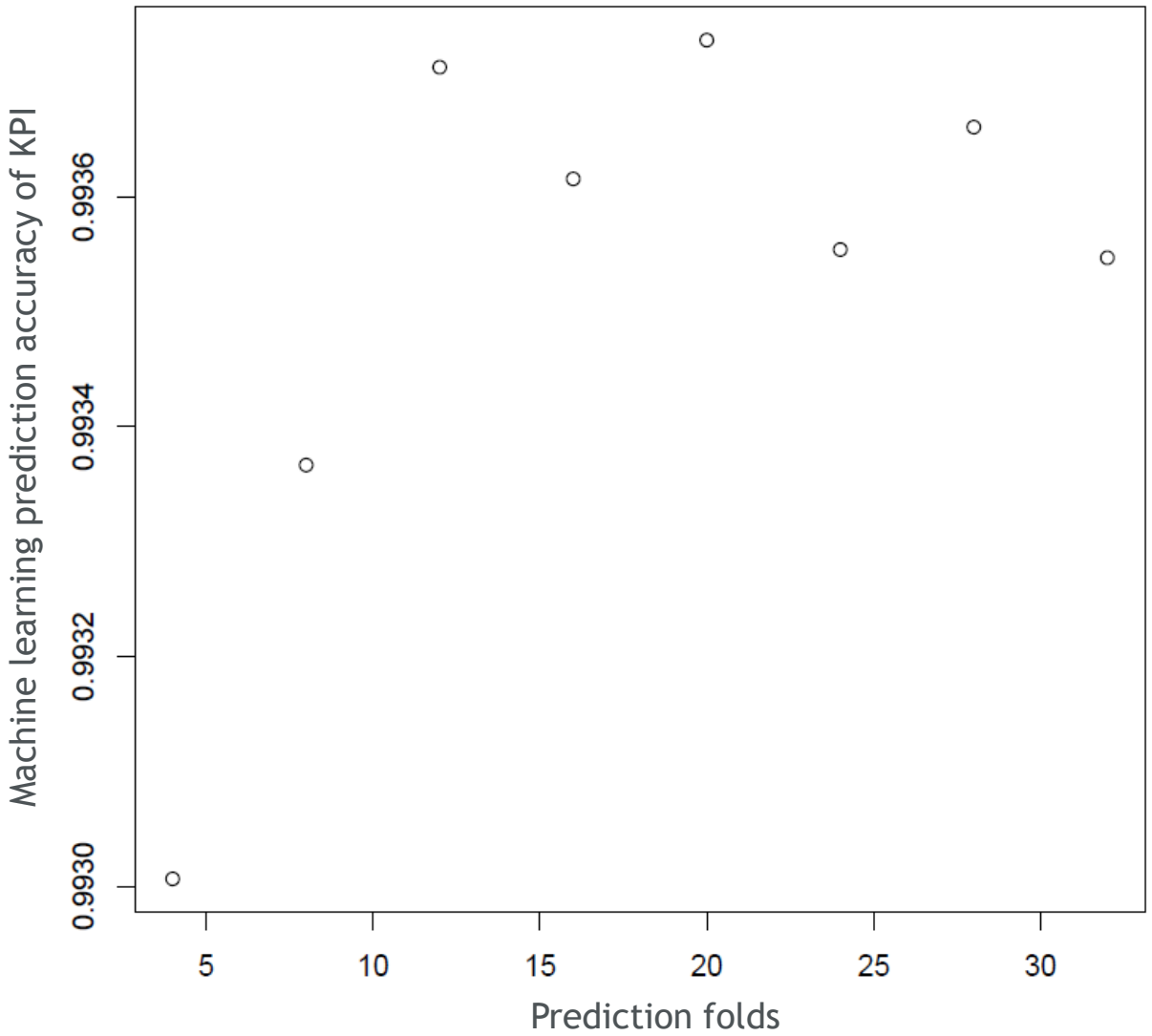
Machine Learning Accuracy

Predicting thermohydraulic KPI.

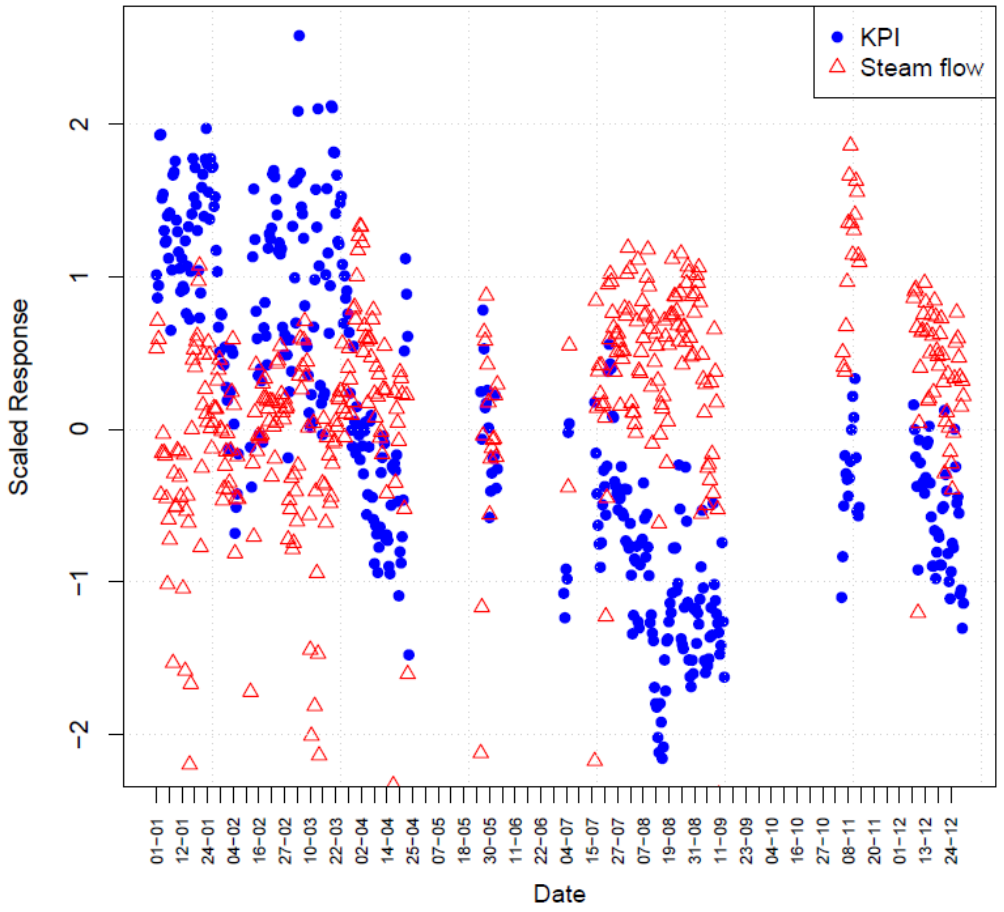
- Robust against prediction folds.

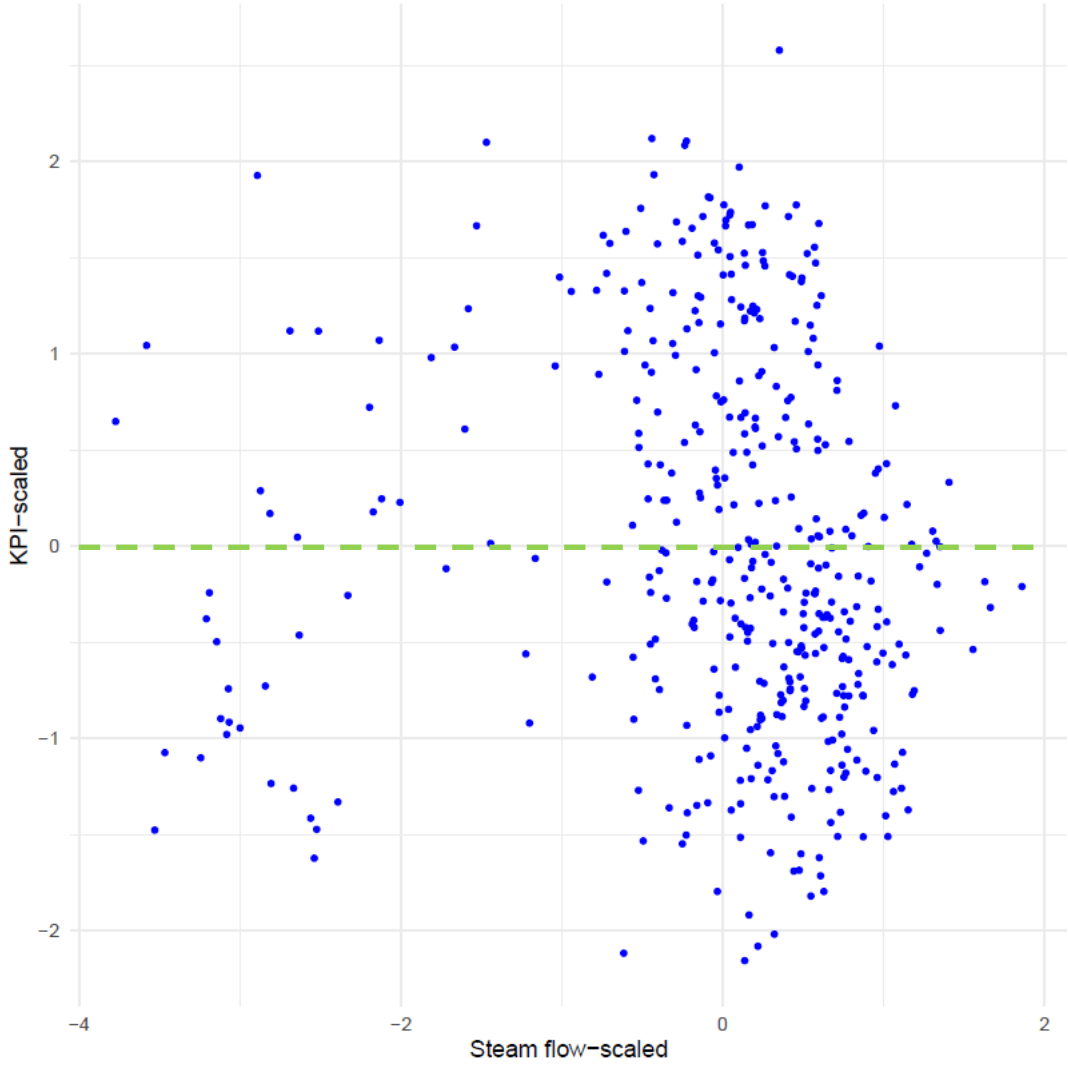
Decision support for control.

- Controllable variables.

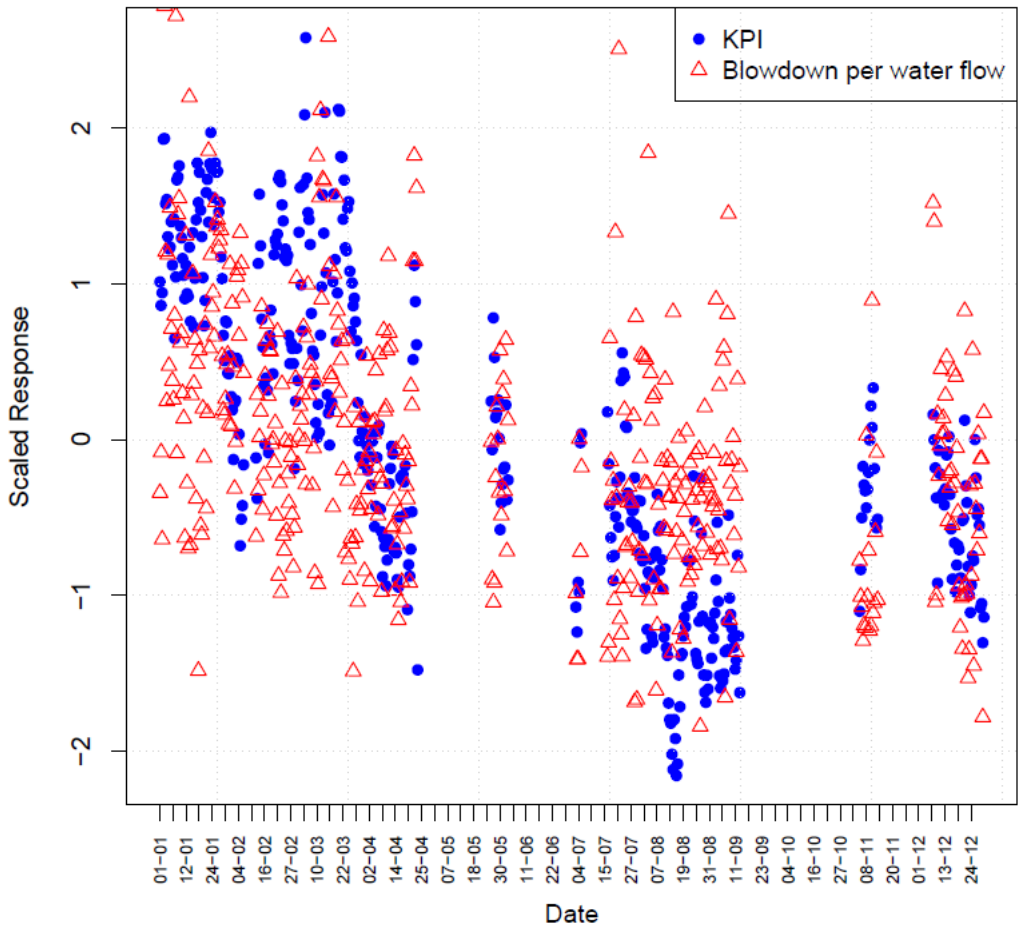


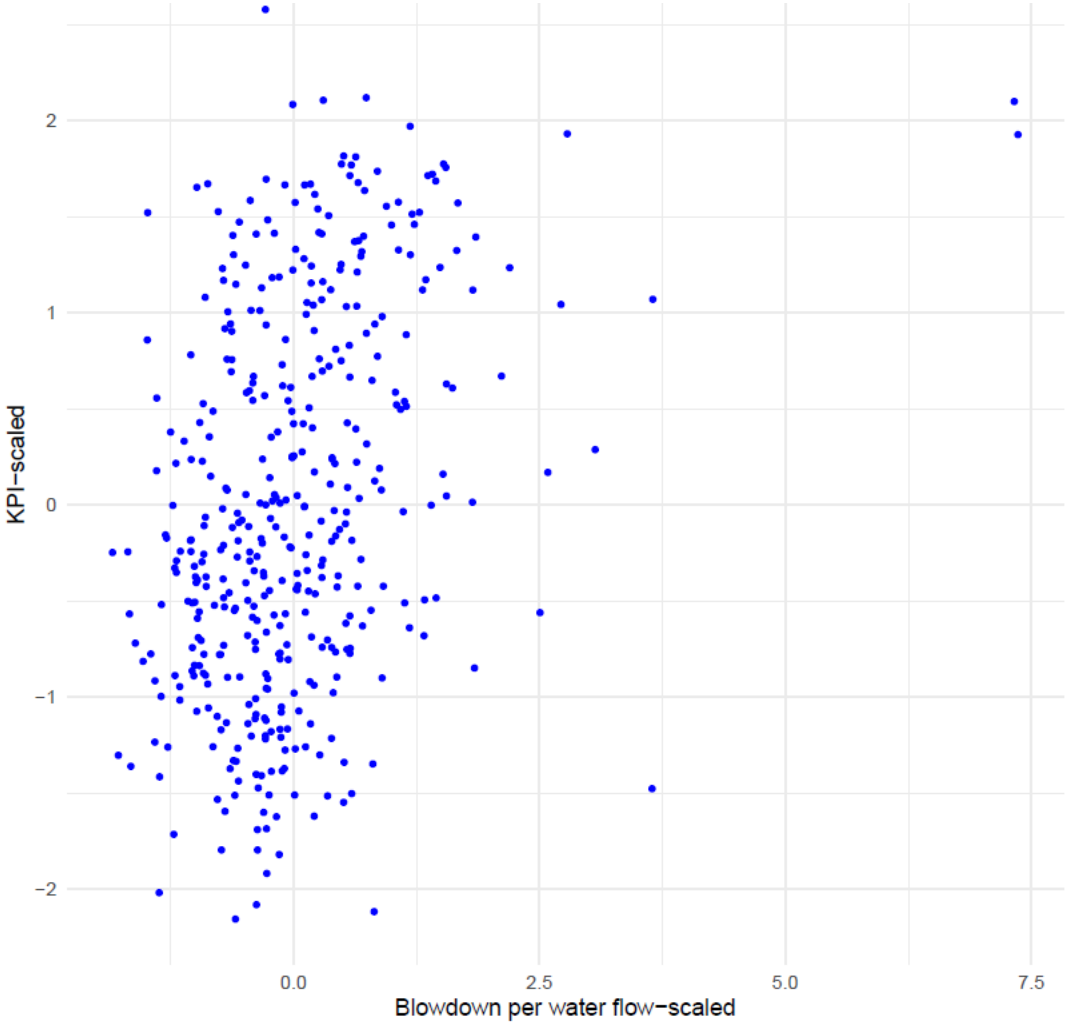
Steam flow vs KPI



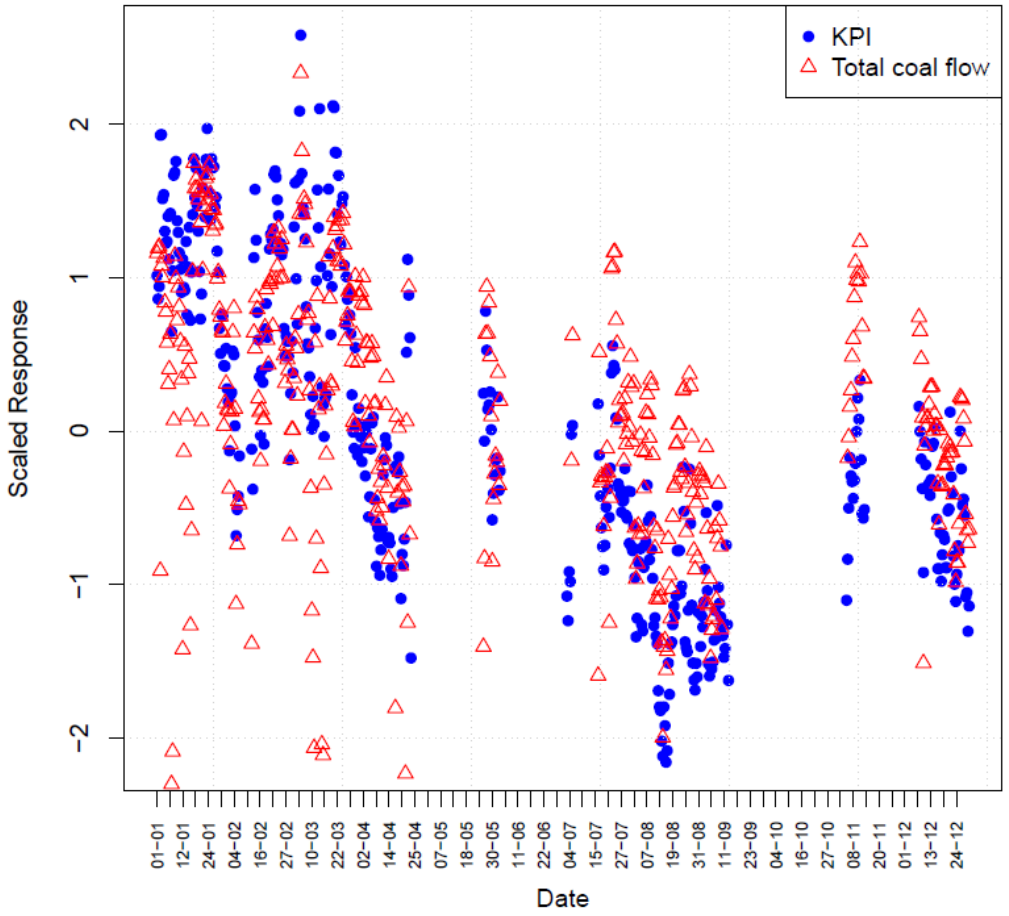


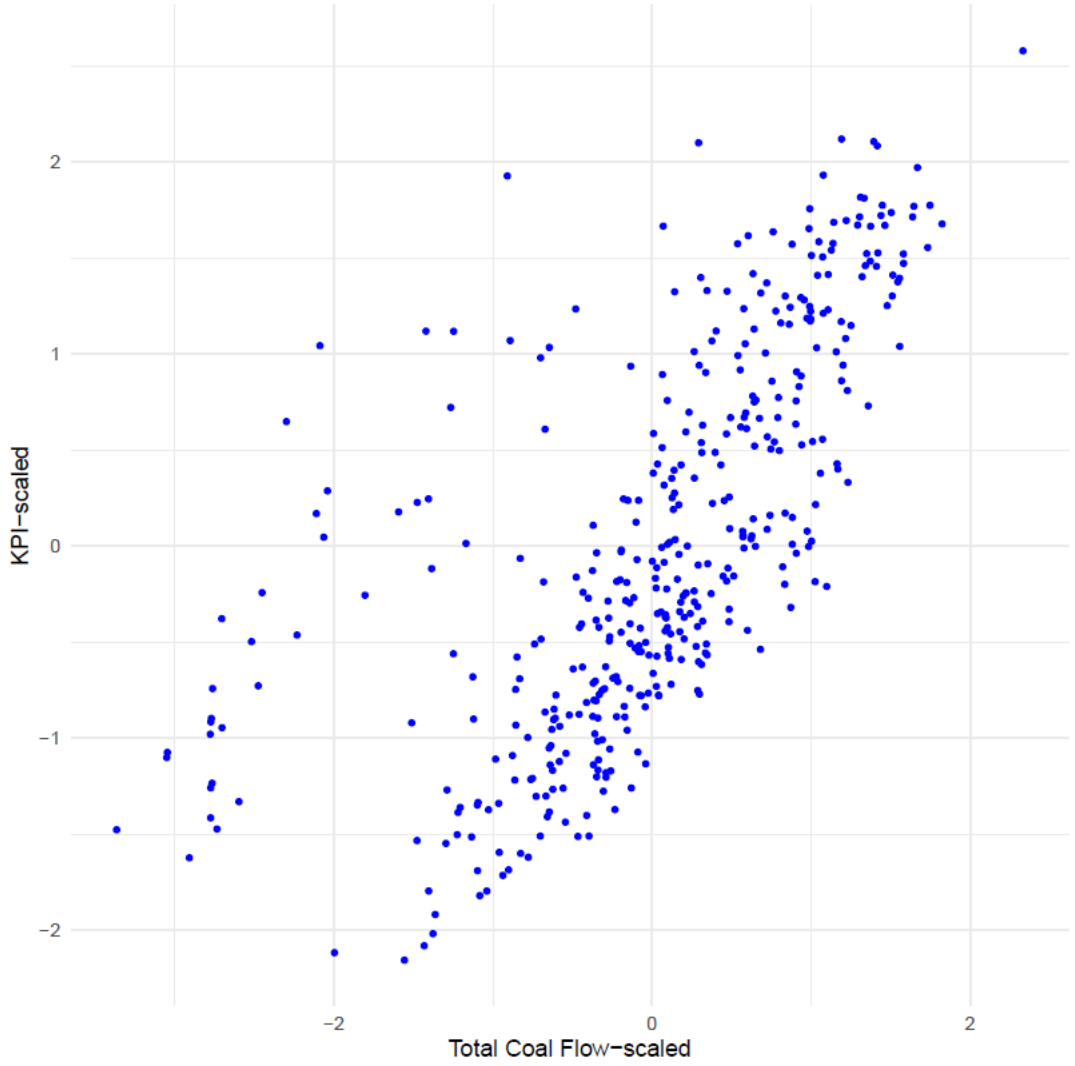
Blow down% (Blow down/Water inlet) vs KPI



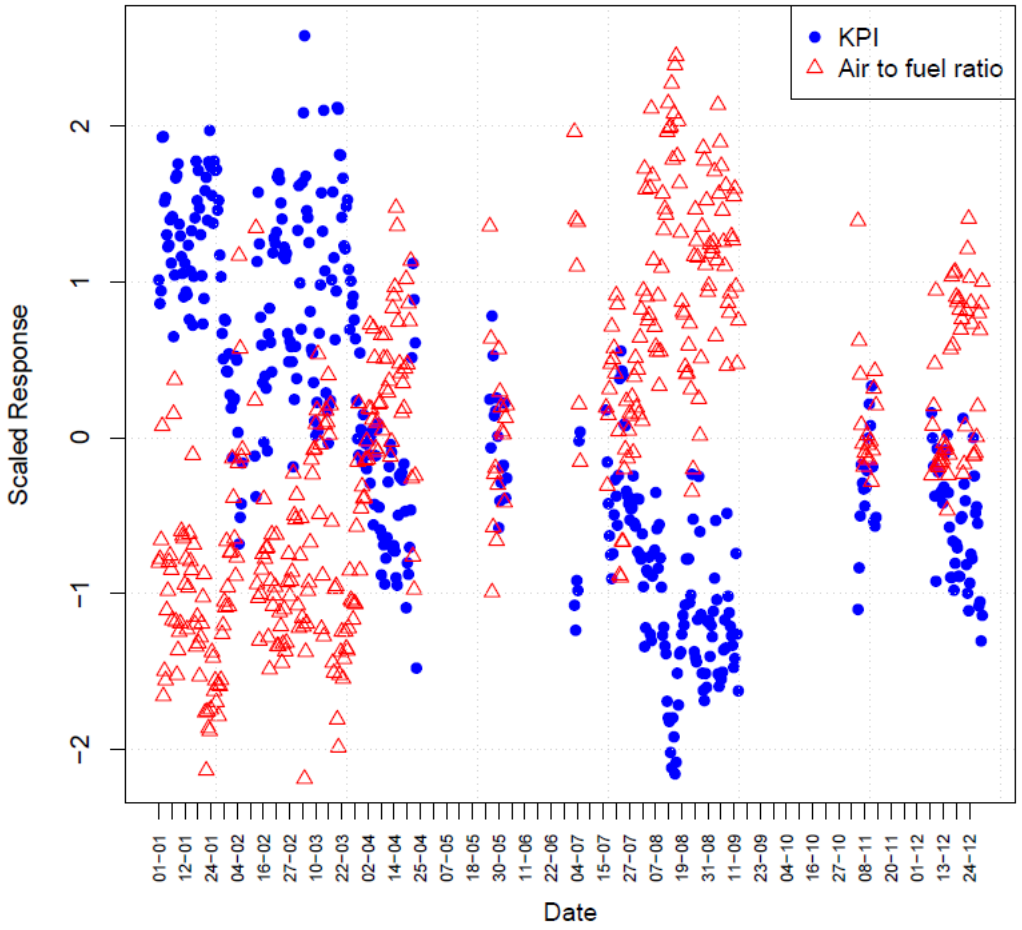


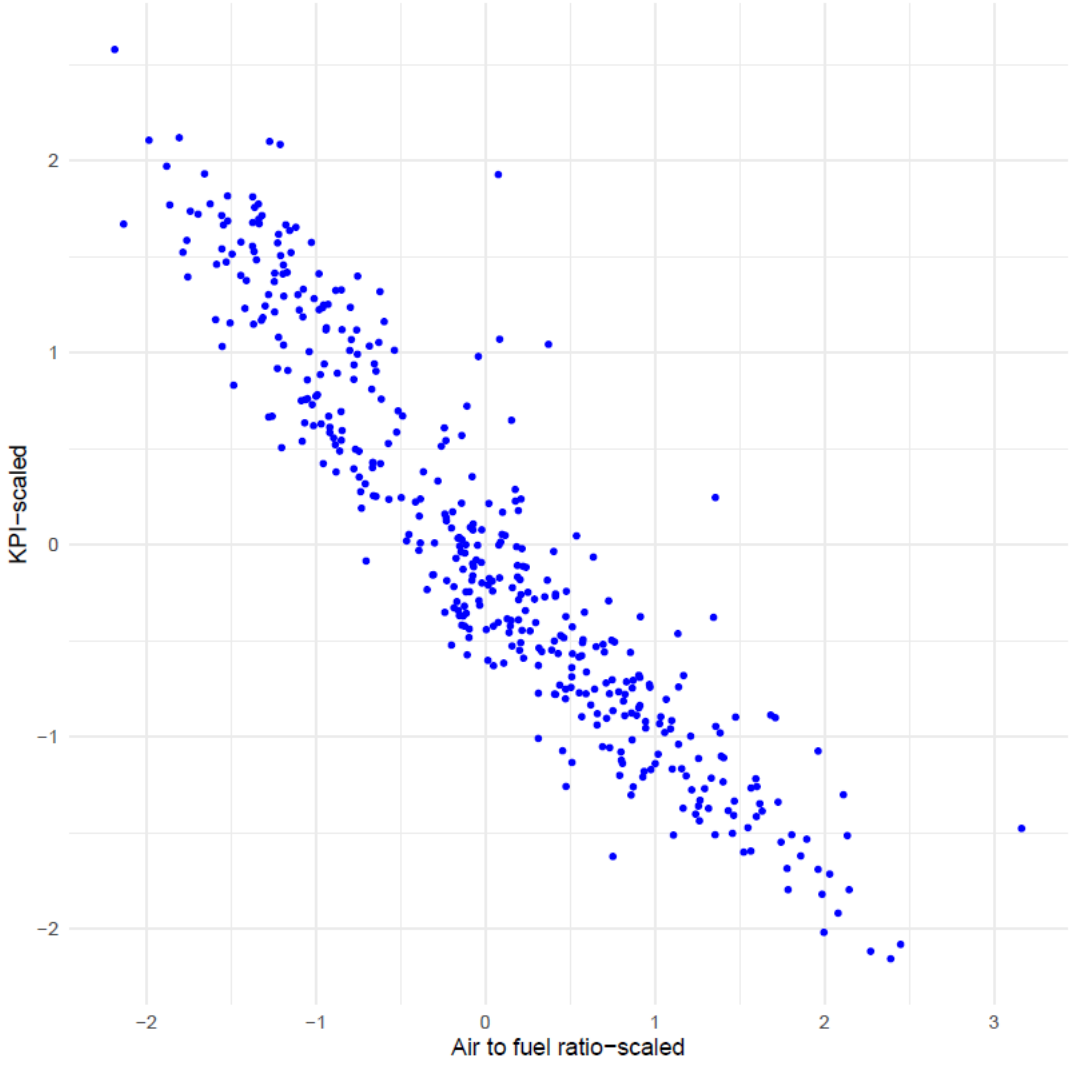
Coal flow vs KPI





Air to fuel (coal) vs KPI

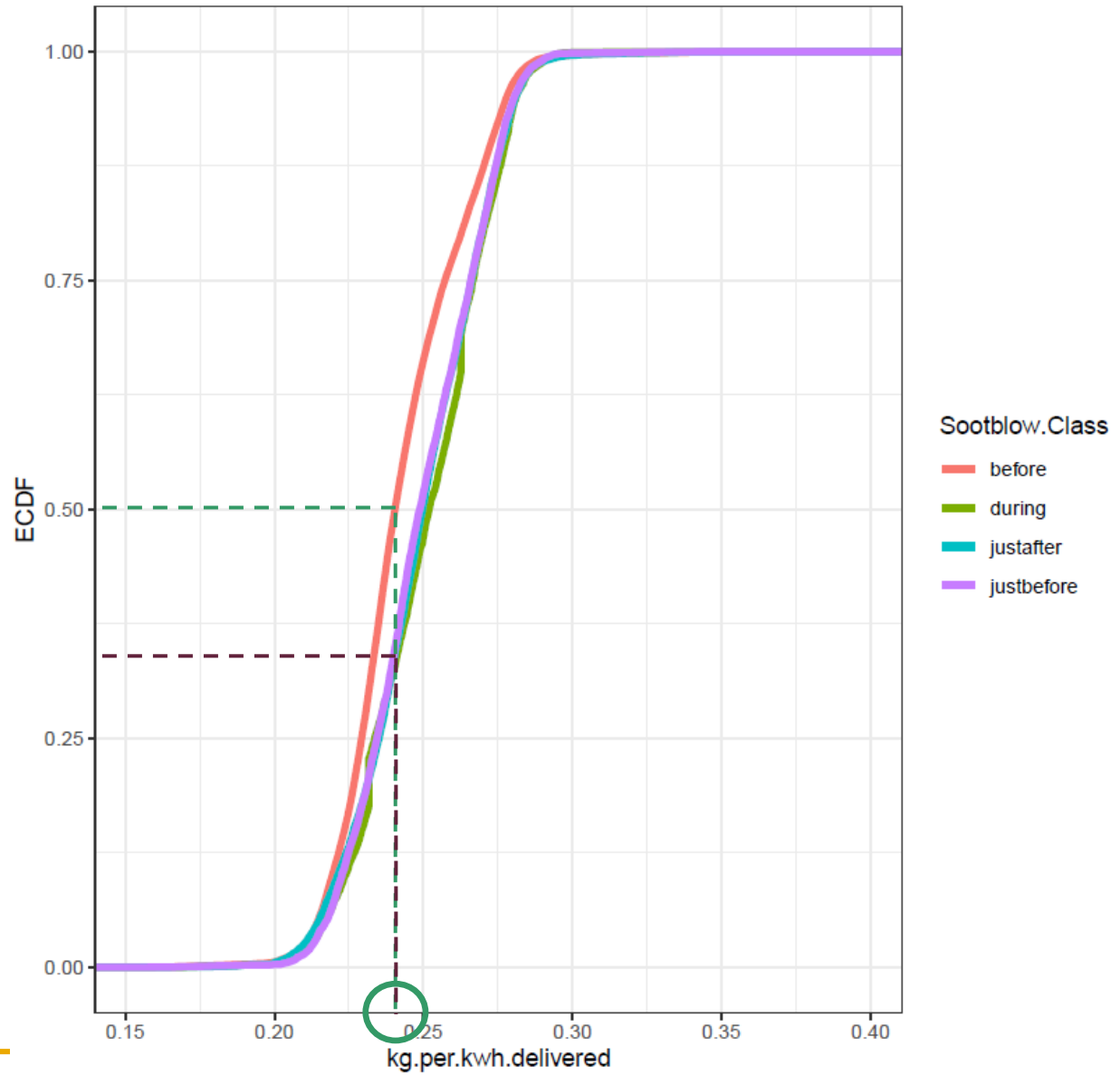




CDF

Probability that
$\mathrm{KPI} \leq 0.24$?

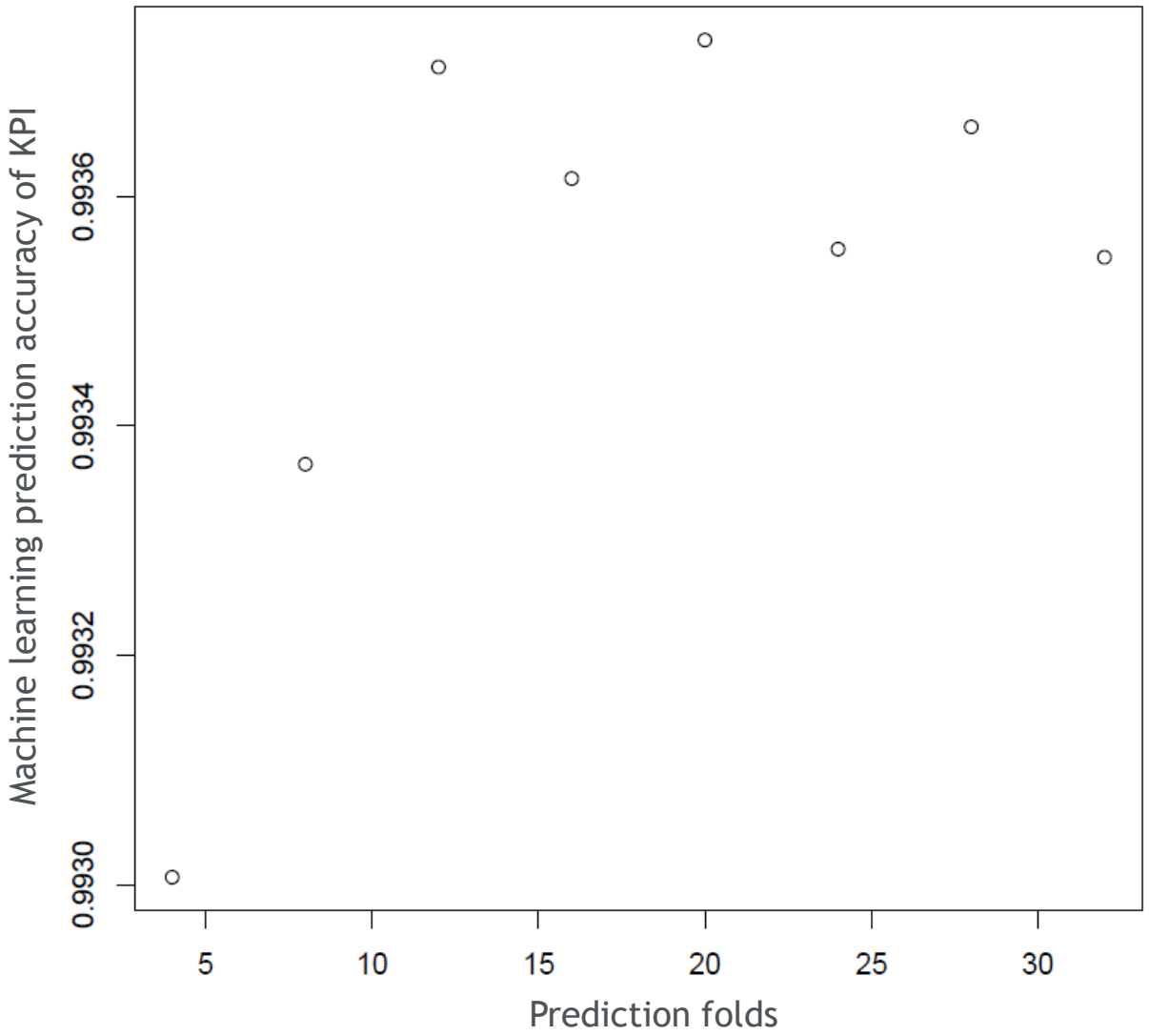
- Around soot blowing
  - 35%
- Rest of time
  - 50%



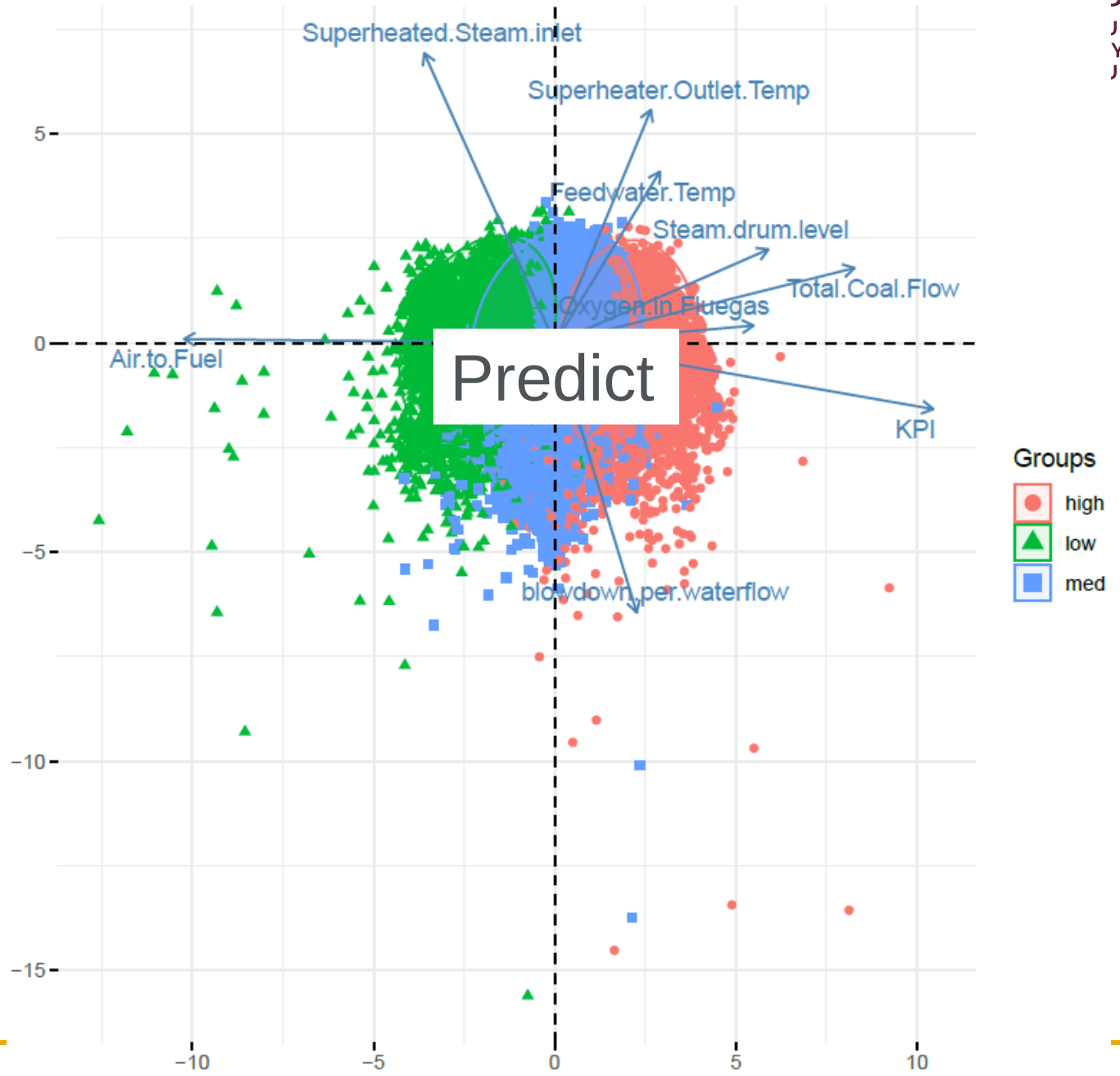
Machine Learning Accuracy

Explore statistical significance between relevant variables.

Multivariate approach.



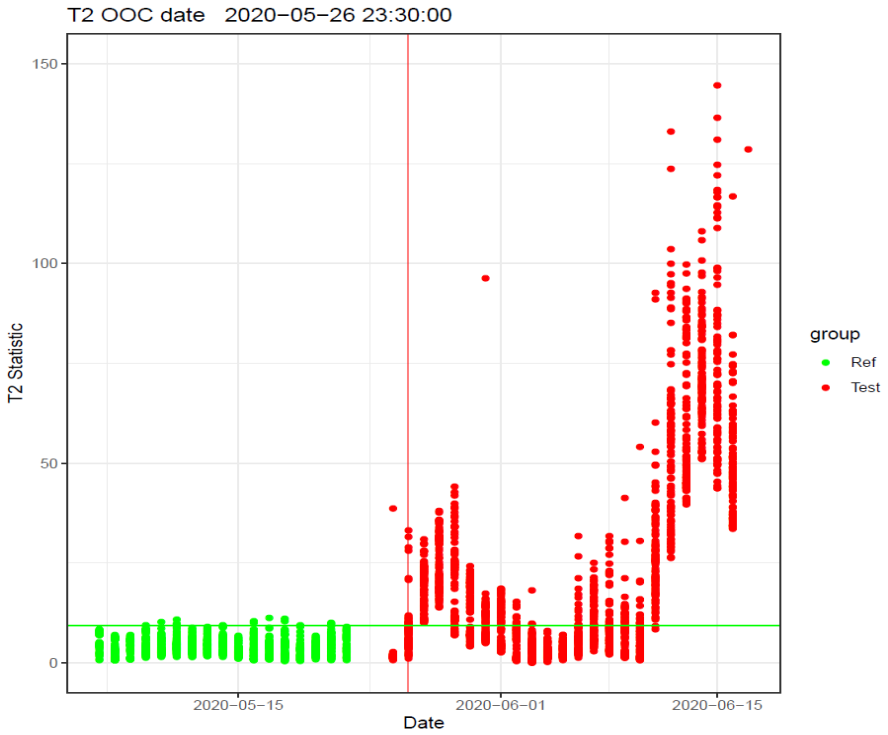
PCA with KPI

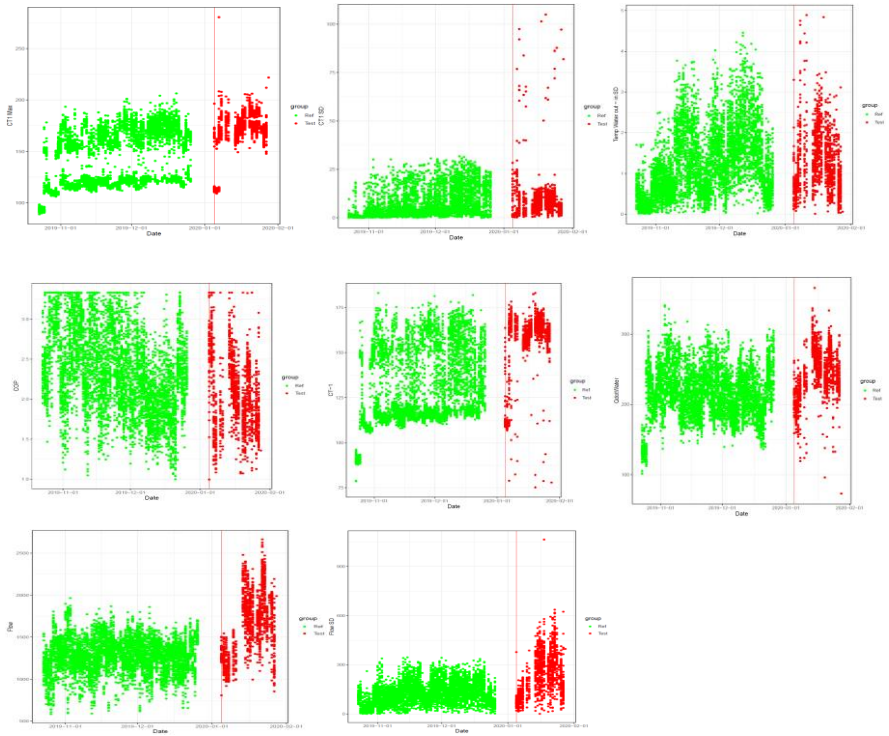

Superheated.Steam.inlet
Superheater.Outlet.Temp
Feedwater.Temp
Steam.drum.level
Total.Coal.Flow
Oxygen.In.Fluegas
Air.to.Fuel
Predict
KPI
blowdown_per.waterflow
Groups
high
low
med
5
0
−5
−10
−15
−10
−5
0
5
10

Improved control

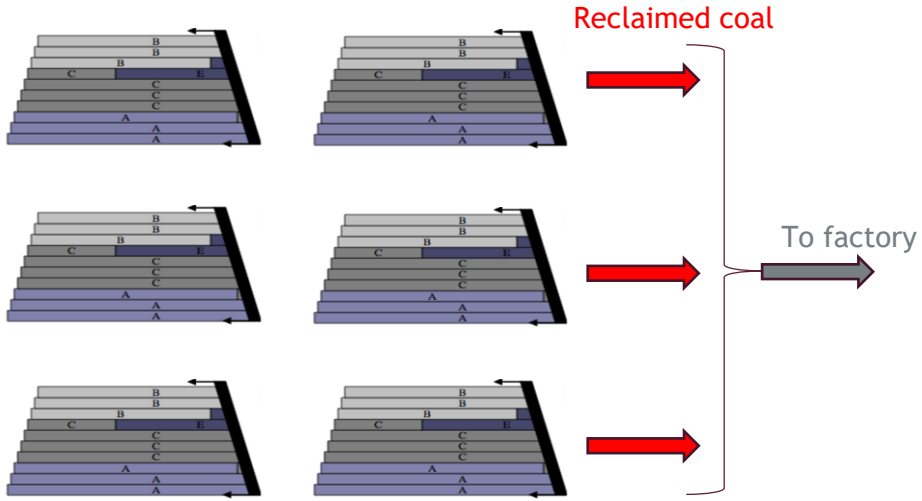
- Improved control is a function of how delicate the boiler can be controlled:
  - How accurate is the feedwater mass flows?
  - How accurate can coal feed be controlled?
  - How accurate can air flow to the boiler be controlled?
  - How accurate is the temperature measurements for the superheated outlet steam delivered to the Works?

Condition monitoring under fluctuation





Reclaiming Optimisation Model



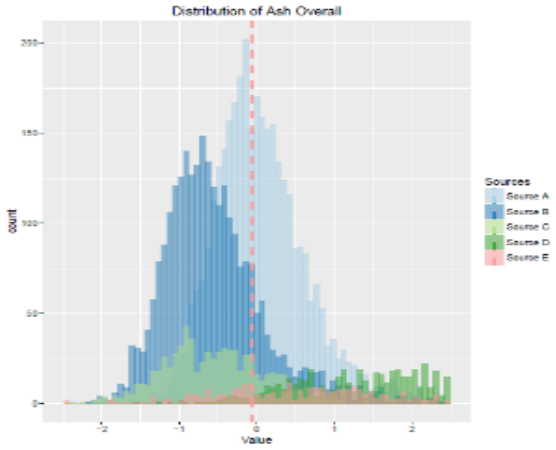
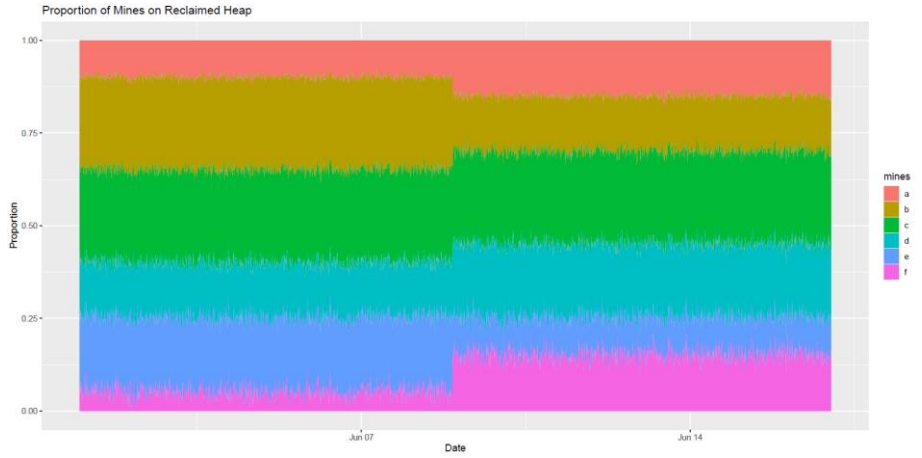
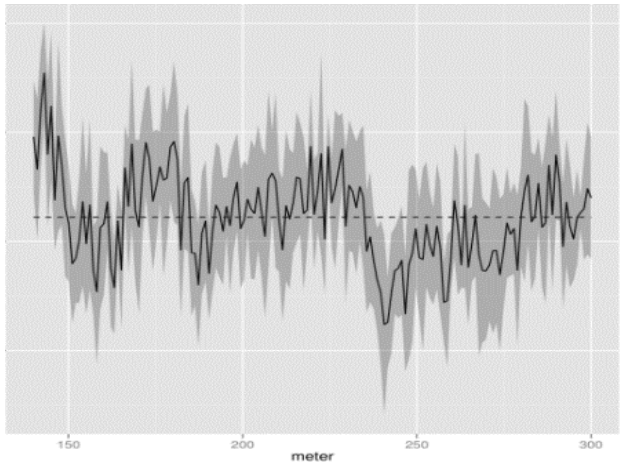


Figure 4: Histogram of Overall Ash (values coded)





Stellenbosch
UNIVERSITY
IYUNIVESITHI
UNIVERSITEIT

Thank you
Enkosi
Dankie

Photo by Stefan Els