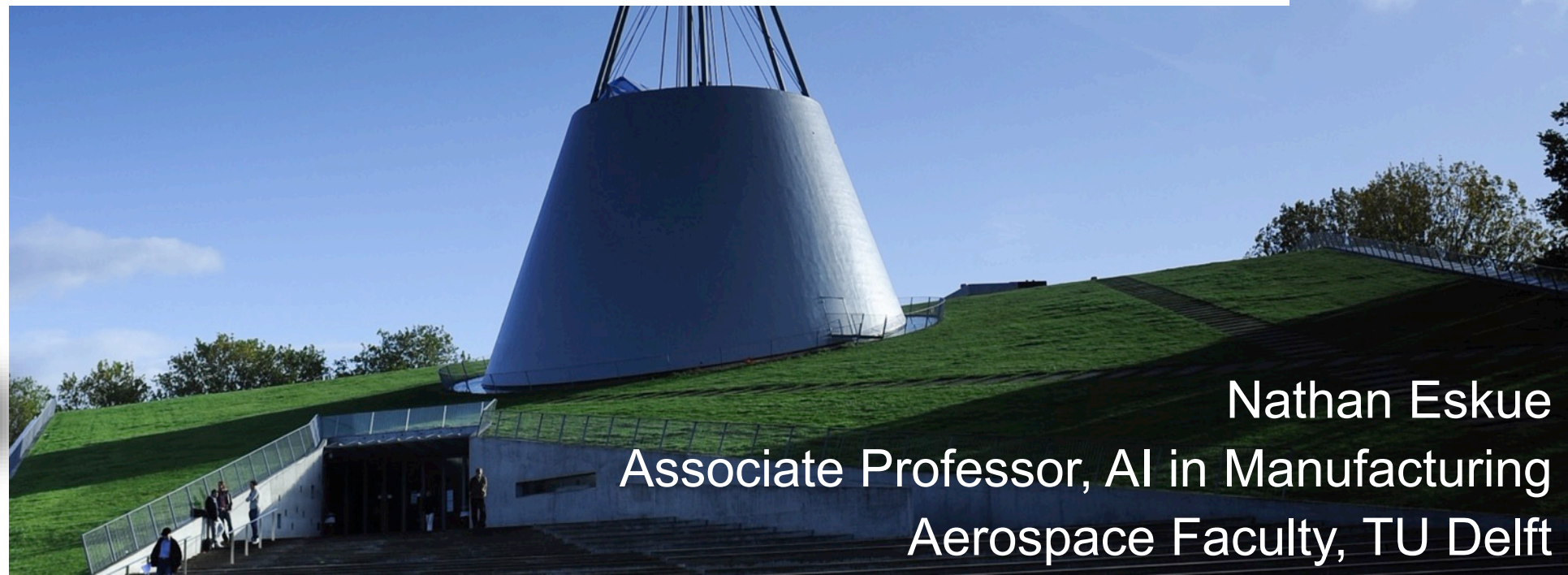
Predictive Maintenance:
An Uncomfortable Introduction

NAG Predictive Maintenance Conference



Nathan Eskue
Associate Professor, AI in Manufacturing
Aerospace Faculty, TU Delft

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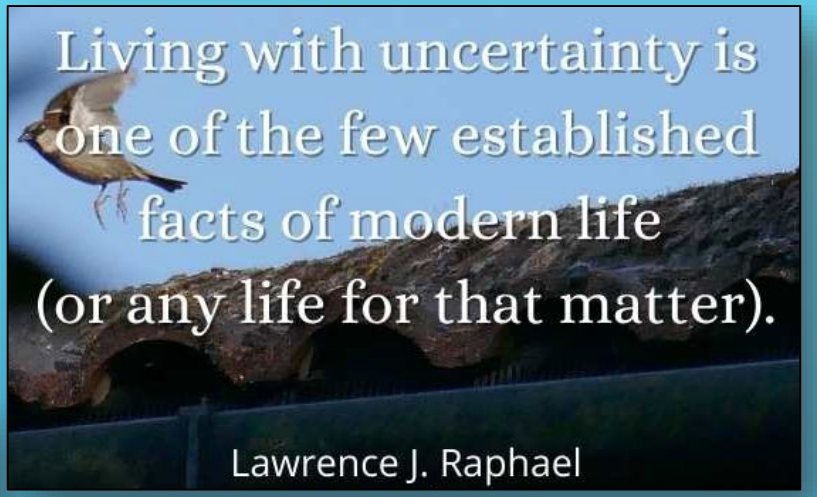
"WHEN NOTHING IS SURE, EVERYTHING IS POSSIBLE."

-MARGARET DRABBLE



THERE IS NOTHING CERTAIN, BUT THE UNCERTAIN

Proverb

Maturity is the capacity to endure uncertainty.

– John Finley

Uncertainty is the most stressful feeling.

AGENDA

- Definition
- Predictive Maintenance (PM): What problem are you trying to solve?
- Three ways to play the PM game
- How to approach PM
- Why pure PM is hopeless
- Why building to pure PM is still worth it: The Pareto Bicycle
- Conclusion

DEFINITION

- What is Predictive Maintenance?

DEFINITION

- **What is Predictive Maintenance?**

Predictive maintenance techniques are designed to help determine the condition of in-service equipment in order to estimate when maintenance should be performed.

This approach promises cost savings over routine or time-based preventive maintenance, because tasks are performed only when warranted. Thus, it is regarded as condition-based maintenance carried out as suggested by estimations of the degradation state of an item.

PREDICTIVE MAINTENANCE (PM): WHAT PROBLEM ARE YOU TRYING TO SOLVE?

- **Your thoughts? What is an accurate problem statement to which "predictive maintenance" is the solution?**

We will come back to this later

THREE WAYS TO PLAY THE PM GAME

PM is a lot like the card game blackjack

- Both gamble
- Both have costs on either side of action
- Both have a “sweet spot” that can be informed—but never certain
- Both have ways to increase your odds of winning

THREE WAYS TO PLAY THE PM GAME

Basic Rules

Let's play

- 1st round: How many cards?
- 2nd round: Informed at each turn
- 3rd round: Enhanced information

THREE WAYS TO PLAY THE PM GAME

Which set of rules would you like to use?

Which round guaranteed a win?

THREE WAYS TO PLAY THE PM GAME

- 1st round: Corrective Maintenance
  - Repair work after equipment outages occur
- 2nd round: Preventive Maintenance
  - Certain periodic intervals to prevent equipment failure before it occurs
- 3rd round: Predictive Maintenance
  - Engineering tools and statistical analysis to process the data and analyze health condition of equipment

Callback

PREDICTIVE MAINTENANCE (PM): WHAT PROBLEM ARE YOU TRYING TO SOLVE?

- Your thoughts? What is an accurate problem statement to which “predictive maintenance” is the solution?

PREDICTIVE MAINTENANCE (PM): WHAT PROBLEM ARE YOU TRYING TO SOLVE?

PM is about **uncertainty** and **gambling**.
Know your risks/odds
Know your costs
Know your rewards

Update/adjust in real time…

and you will have the best chance of "winning" (optimizing)

HOW TO APPROACH PM: KNOW YOUR RISKS

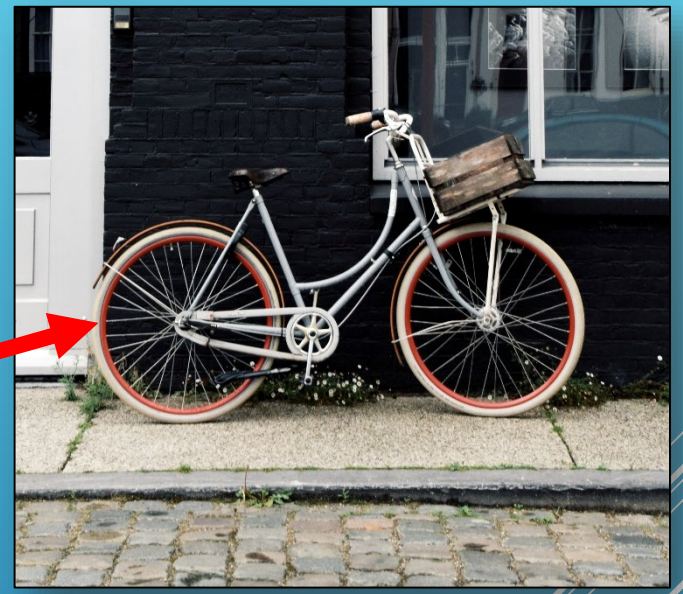
- This is the hardest
- This takes DATA
- This takes ANALYSIS
- This takes TECHNOLOGY

HOW TO APPROACH PM: KNOW YOUR RISKS

For just the rear wheel:

- what are the failure modes?
- how do they occur (gradual, suddenly, etc.)
- what indicators are present and what are the patterns?
- what sensors can measure this?
- what probabilistic distribution does this follow?
- Bonus: what ML algorithm can best accept feedback and update the model?

HOW TO APPROACH PM: KNOW YOUR COSTS



What are the costs of maintenance?

What are the costs of failure?

Relate this to a manufacturing line—what matters?

CAPTURE DIRECT AND INDIRECT!

HOW TO APPROACH PM: KNOW YOUR REWARD

What are the rewards of avoiding breakdowns?

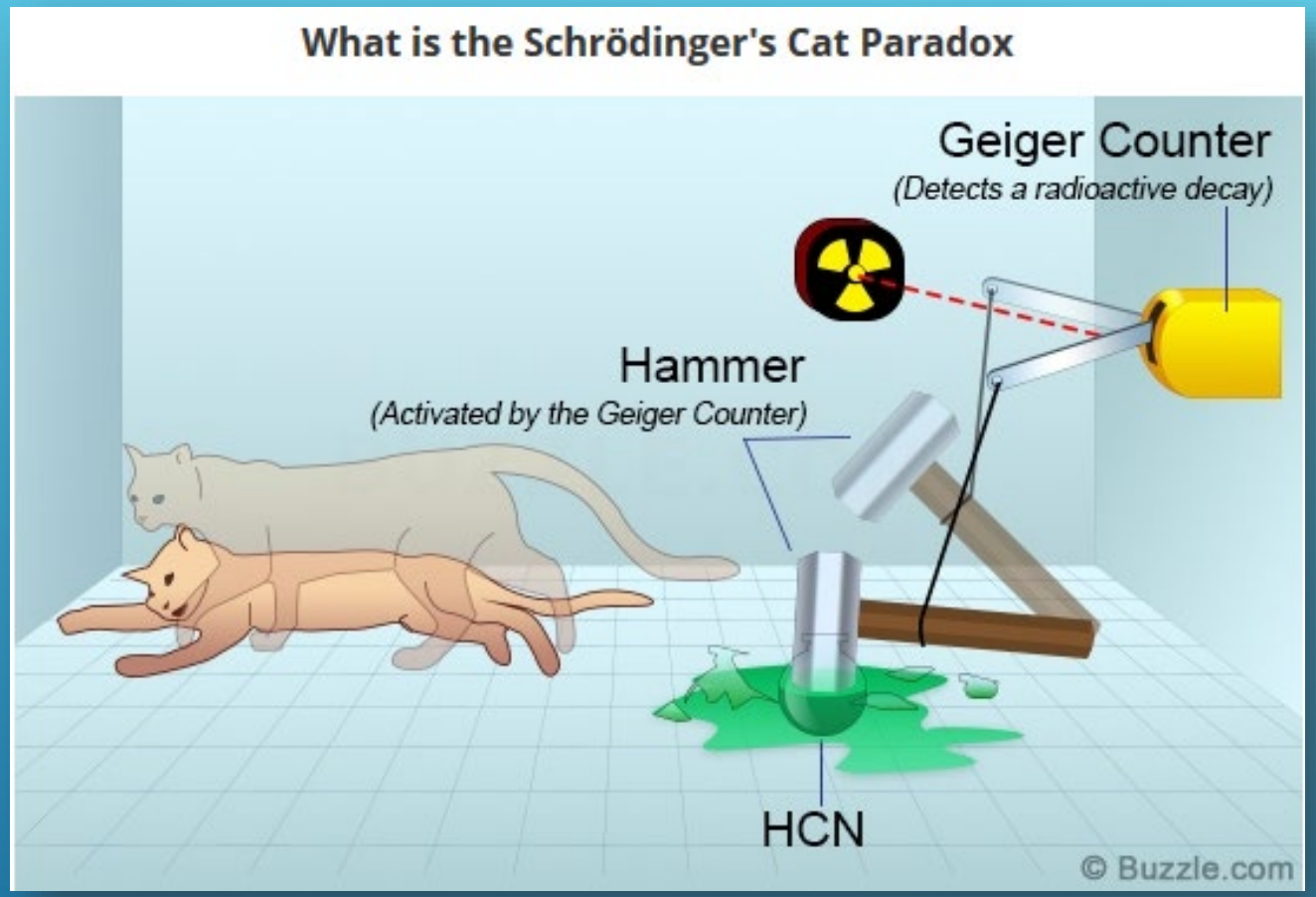
Relate this to a manufacturing line—what matters?

CAPTURE DIRECT AND INDIRECT!

WHY PURE PM IS HOPELESS: A MULTIVERSE PRIMER

- Case study on an aerospace product line, measuring top level risks and opportunities to overall Estimate at Complete (EAC)

QUANTUM PRIMER PART 1: THE CAT



"I don't like it, and I'm sorry I ever had anything to do with it." - Erwin Schrödinger

QUANTUM PRIMER PART 1: THE CAT

- **Standard EAC analysis for the cat:**
  - **Risk: Dead cat**
  - **Probability: 50%**
  - **CEAC (cat estimate at complete): 0.5 cats**

- **Surely there is a better way. . .**

QUANTUM PRIMER PART 2: THE MULTIVERSE

- Quantum theory gives us the answer, which makes more sense:
  - The cat is both alive and dead--until we observe reality
  - The probability determines, on average, what will happen
  - However, the cat will be 100% alive or 100% dead
  - This requires the universe to split
    - In one universe, there is a live cat
    - In another, there is a dead cat

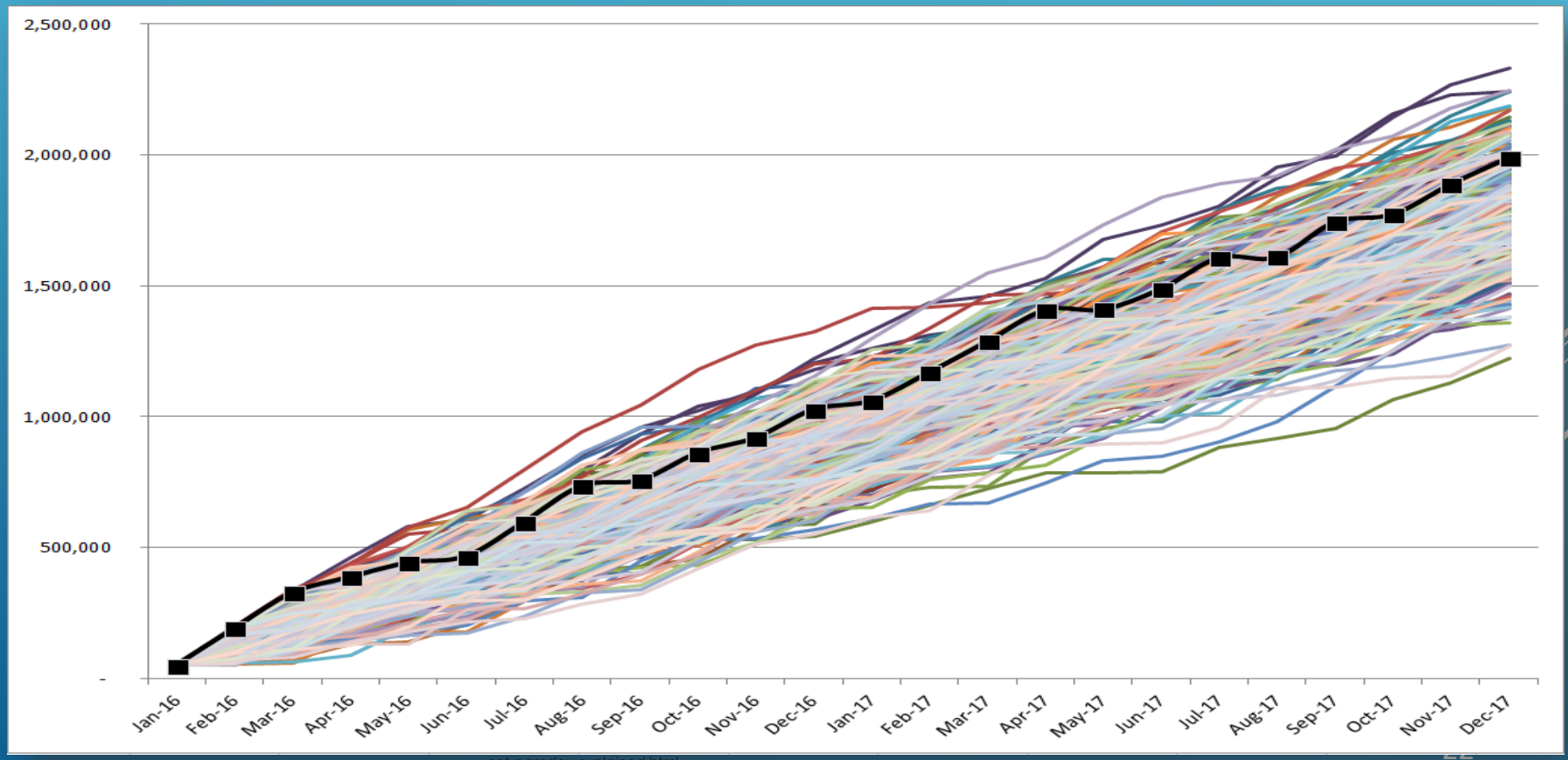
There is not a universe where there is 0.5 cats

QUANTUM PRIMER PART 2: THE MULTIVERSE

- **Key takeaways**
  - **Every decision causes a split in the universe**
  - **Each path is then faced with a new set of decisions, each of which causes a new split**
  - **The probability of each outcome determines how many alternate universes have that version of reality**
  - **Being able to take a step back and see all possibilities would allow you to have a much better understanding of what actions to take today**

EAC MULTIVERSE VISUALIZED

- Multiverse Result
  - If every possible combination of outcomes were mapped and tracked, it would look like:

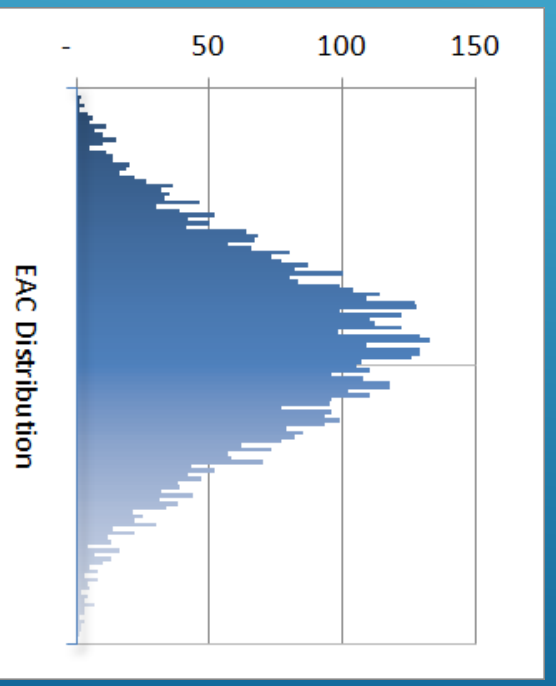


cat-paradox-explained.html

EAC MULTIVERSE VISUALIZED

- EAC Multiverse Result
  - If we did this over and over again, accounting for the probability of each R/O and therefore the probability of each individual path, we'd be able to determine with very strong certainty:

EAC RESULTS	
68% likely to fall between	$ 1,590,000
and	$ 2,030,000
95% likely to fall between	$ 1,380,000
and	$ 2,250,000
EAC without R/O	**$ 2,030,000**
Best Case	**$ 1,380,000**
Worst Case	**$ 2,250,000**
Most Likely	**$ 1,810,000**



PREDICTIVE MAINTENANCE (PM): WHAT PROBLEM ARE YOU TRYING TO SOLVE?

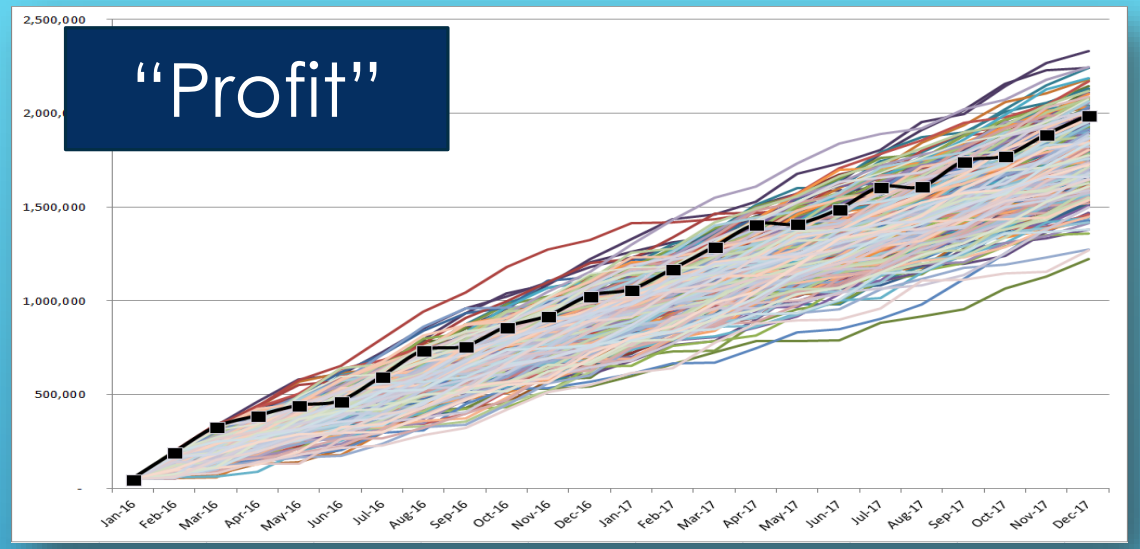
PM is about **uncertainty** and **gambling**.
Know your odds
Know your costs
Know your rewards

Update/adjust in real time…

and you will have the best chance of "winning" (optimizing)

The problem to be solved is: "What is the most important action I can take RIGHT NOW that will increase my chances of winning?

PURE PM VISUALIZED



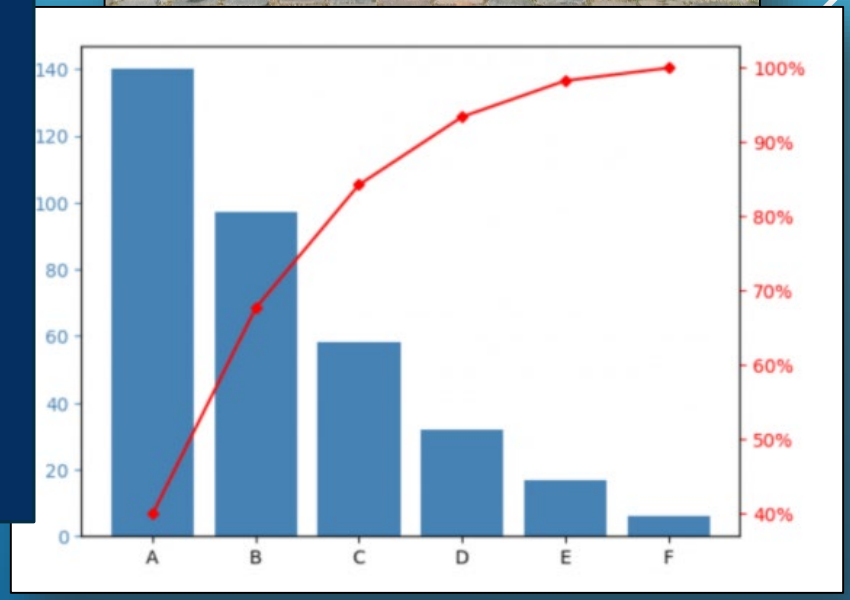
Pure PM is impossible because the multiverse is infinite

WHY BUILDING TO PURE PM IS STILL WORTH IT: THE PARETO BICYCLE

Start with the biggest drivers

Develop a system that can measure and analyse key metrics…

THEN work on the multiverse



CONCLUSION

Predictive Maintenance is about:

- Knowing the drivers, measuring the drivers, and understanding the multiverse of risks (not the average)
- Knowing the costs
- Knowing the rewards
- Solving the biggest problem:
  For EACH MOMENT, what is the most important action I need to take?

QUESTIONS?

LinkedIn

Nathan Eskue
n.d.eskue@tudelft.nl
+01 480 528 2097
+31 06 34 21 53 61