A data driven approach to Asset Management decision making

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Axiom Engineering Associates Ltd
Maximising Assets - Minimising Risk

Introduction

- Brief Introduction to Axiom
- Our inspection methodology
- The dataset
- Mining, sifting and sorting. What's in there?
- Conclusions

About Axiom

- Formed in 2003
- Serves the High Hazard Process Industry, Pharma and Power Generation Sectors
- We offer:
  - Mechanical Engineering
  - Materials Engineering
  - Inspection & NDT
- NEPIC Engineering Firm of the Year 2019

Inspection, periodicities, RBI and decision making

- Traditionally inspection types & intervals were (and still are) set by
  - Rules based codes, standards and guides
  - Developed by technical committees by industry bodies (e.g. SAFed, EEMUA, CEA, etc)
  - Encompassing good practices but tends to be experience-led rather than data-led

- Risk Based Inspection (RBI) methodology
  - Uses a limited dataset when developing individual inspection plans – usually based upon operator's own history
  - But uses factors from codes (API 580/581, ASME PCC-3 etc) based on much broader datasets mostly based on refinery data
  - May seek to test assumptions after each inspection & validate the inspection plan

Purpose of the study

- To aggregate our own dataset

- See if we can answer particular questions
  - How often do we find problems
  - See if Technical Committee based rules are backed up by data

- Can we draw any conclusions?

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Limitations of the study

- Based upon different plant types with different operating & maintenance regimes
- Inspection data collection does not follow the scientific method
  - Cost limitations
  - Successful RBI reduces data collection size and frequency
  - We seldom hear if equipment is repaired or replaced until the next inspection occurs
  - Not all data are available
  - Gaps are unknown

Our Inspection Methodology

- All inspections follow the same methodology
- We develop a WSE for each item of equipment
- Each item of equipment identifies (amongst other things):
  - The equipment
  - The equipment type
  - Date manufactured
  - Design conditions
  - Materials of construction
  - Process fluids

Our Inspection Methodology

- Each item of equipment identifies (continued):
  - The damage mechanisms that the equipment is considered to be vulnerable to
  - An inspection requirement to detect each type of damage mechanism. This includes a description of the work to be carried out, the techniques used and acceptance criteria
  - How often the inspection is to be carried out (the interval), we can specify up to four inspection types for each item of equipment

Our Inspection Methodology

- All inspections follow the same methodology
- Each scheduled examination is carried out to the WSE
- The requirement for each inspection listed in the WSE is linked to a specific section on the inspection report. If the WSE requires it the inspection report automatically specifies it
- In the report the inspector specifies if the result is satisfactory
- If the defect is warrants intervention then recommendations are made to resolve it. Mandatory actions are raised for really bad defects

Our Inspection Methodology

- In summary the condition of the equipment is specified as
  - Acceptable - no deterioration
  - Acceptable - deterioration noted
  - Acceptable - remedial work required
  - Unacceptable - repair required
  - Unacceptable - no longer fit for use

- Follow up inspections are carried out when repairs have been completed & actions signed off

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Data structure

WSE

Unique ID
Design data
Process data
Construction data
Year built
Inspection Intervals

Damage mechanism 1

Damage mechanism 2

Damage mechanism 3

Inspection requirement 1
Component
Inspection description
Inspection techniques
Acceptance criteria
To be done when (Full, Int, etc)

Inspection requirement 2
Component
Inspection description
Inspection techniques
Acceptance criteria
To be done when (Full, Int, etc)

Inspection requirement 3
Component
Inspection description
Inspection techniques
Acceptance criteria
To be done when (Full, Int, etc)

One to many

One to one

Inspection Report

Date inspected
Summary
Changes to intervals needed?
Changes to WSE needed?
…

Inspection results 1
Unsatisfactory
Description of inspection results
Photos of defects
Measurement results

Inspection results 2
Unsatisfactory
Description of inspection results
Photos of defects
Measurement results

Inspection results 3
Satisfactory
Description of inspection results
Photos of defects
Measurement results

Inspection results n
…

Other observations
NDT reports
Supporting certificates and evidence

One to many

Action

Description
Due date
Priority
Action type
Recommendation or Mandatory
Status (open, complete, hold, deleted)

Action

Description
Due date
Priority
Action type
Recommendation or Mandatory
Status (open, complete, hold, deleted)

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The dataset

- Total dataset size: **72.7** Gb
- Document based philosophy as opposed to table based
- **458,254** documents in the dataset
- **393,008** documents related to actual inspections carried out

The dataset

- Axiom-written inspection records date from 26th July 2004 to 5th February 2019 (**14.5** years)
- Earlier inspection records from other sources (e.g. historical inspection records from 3rd parties) are excluded from analysis **(3066)**
- Also: **305,853** images; **97,370** documents (pdf, drawings, etc)

- Let's dive in and see what we have…

Equipment type distribution

Equipment Type	%
Piping or piping component	29%
Pressure Vessel	28%
Protective Device	21%
Storage Tank	18%
Other Item	2%
Boilers or Fired Equipment	1%
Structure	1%
Total	100%

Material Types

- Material of the main containment envelope

Material Type	%
Carbon/low alloy steel	47%
Stainless steels	31%
Non-metallic materials	8%
Nonferrous alloys	6%
Mixture of materials	5%
Lined carbon steel	3%

Age Profile

- Oldest built in: 1936, newest: 2018
- Average age of a sample of equipment:

Equipment Type	Average Age
Tank	32 years
Sphere	42 years
Pressure vessel	24 years
Piping system	29 years

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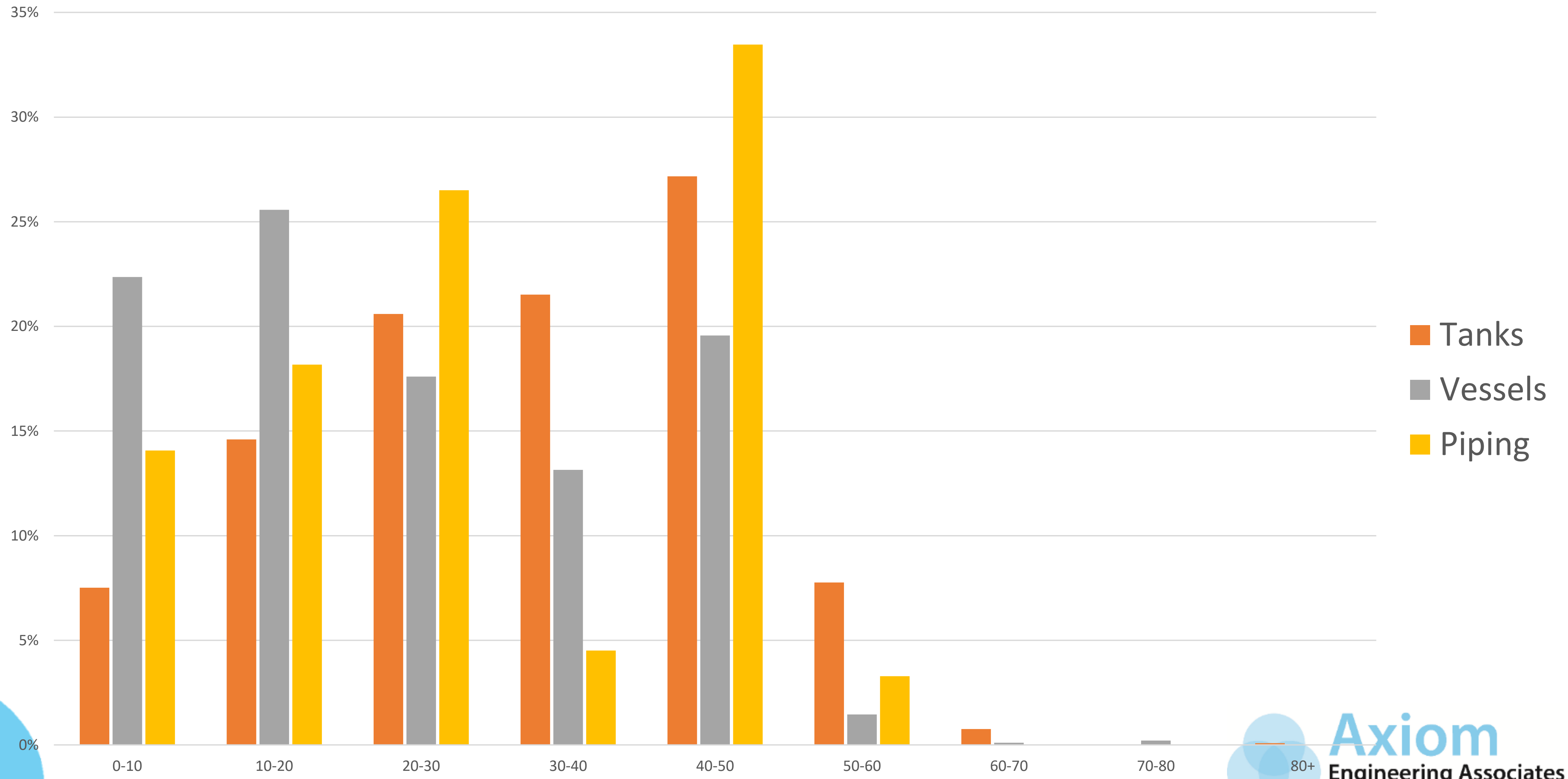
Age Range



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Full inspection intervals

Full Interval	Months
Average	59
Min	1
Max	300

Equipment Type (examples)	**Avg Full Interval (months)**
Storage tank	92.2
Pressure Vessel	66.1
Piping system	61.7
Relief system	35.6

Equipment Condition

- Equipment condition at freeze point

Condition	%
No deterioration noted	17%
Deterioration noted	45%
Remedial work identified	33%
Unacceptable - Repair	4%
Unacceptable - Unfit for service	1%

Deficiencies

- Components inspected: **118,706**
- Component found to have some form of deficiency: **15%**
- Stainless/nonferrous kit, **33,233** components, rate: **12%**
- Carbon/ferrous kit, **75,730** components, rate: **16%**

- **Mix of deterioration and other issues e.g. unsealed cladding, earth, flange defects, etc**

UT monitoring

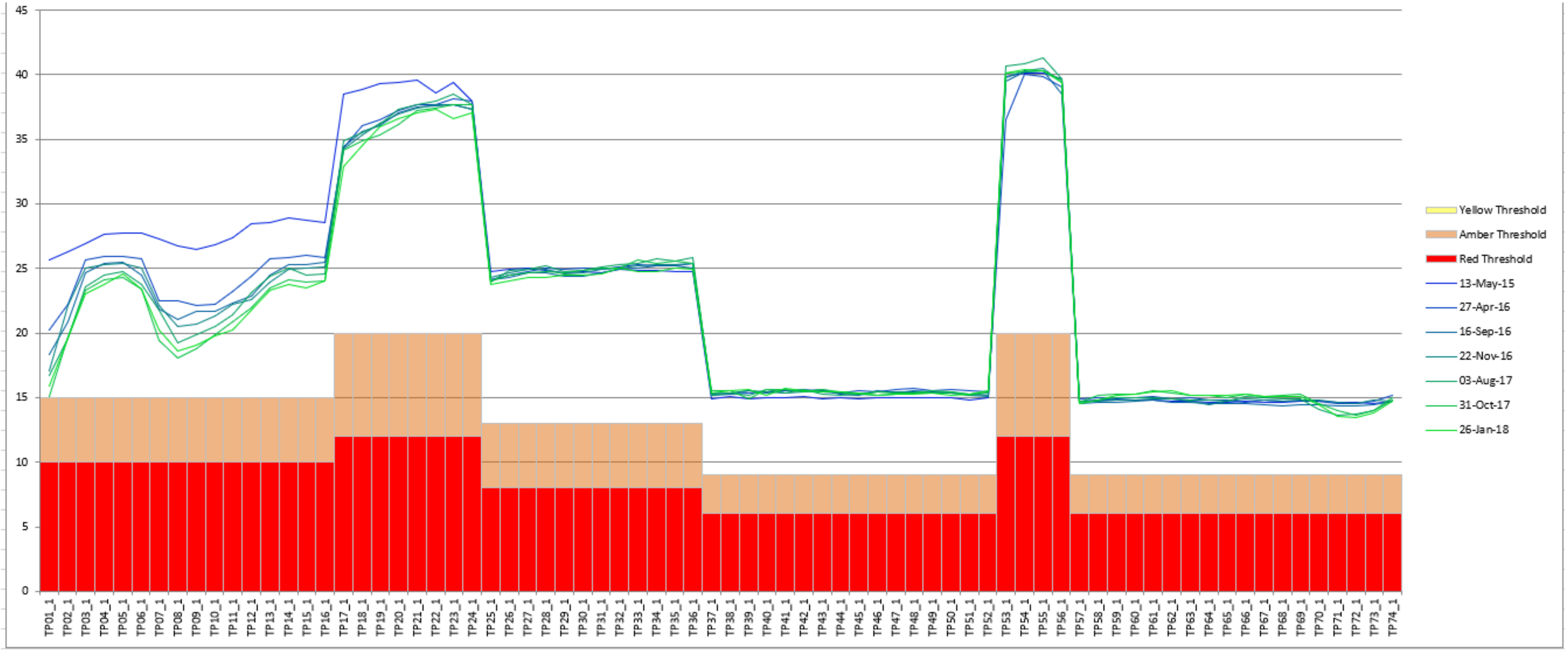
- Damage mechanisms e.g. erosion that warrant routine monitoring can be specified: Location, technique & threshold criteria.
- Physical measurements via UT done:

Number of locations:	**61,130**
Number of measurements taken:	**107,060**
Number outside the acceptance criteria:	**?**

799 (i.e. 0.7%)

Yellow: 447 (0.4%) **Orange: 206 (0.2%)** **Red: 146 (0.1%)**

UT monitoring, max deterioration rates



Highest measured short term corrosion rate: **27.9mm/yr**

Highest measured long term corrosion rate: **4.2mm/yr**

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What about crack detection?

- Flaw detection (MPI, DPI, UT flaw detection etc) results
- Note: Does **not** mean that cracks were always found but also includes pits, pores, LOF, etc.
  - Defects found 28% of the time
  - Most defects seen on storage tanks at 51% (c.f. pressure vessels at **11%**)

- Tank defect rate is worse for carbon steel at **61%**

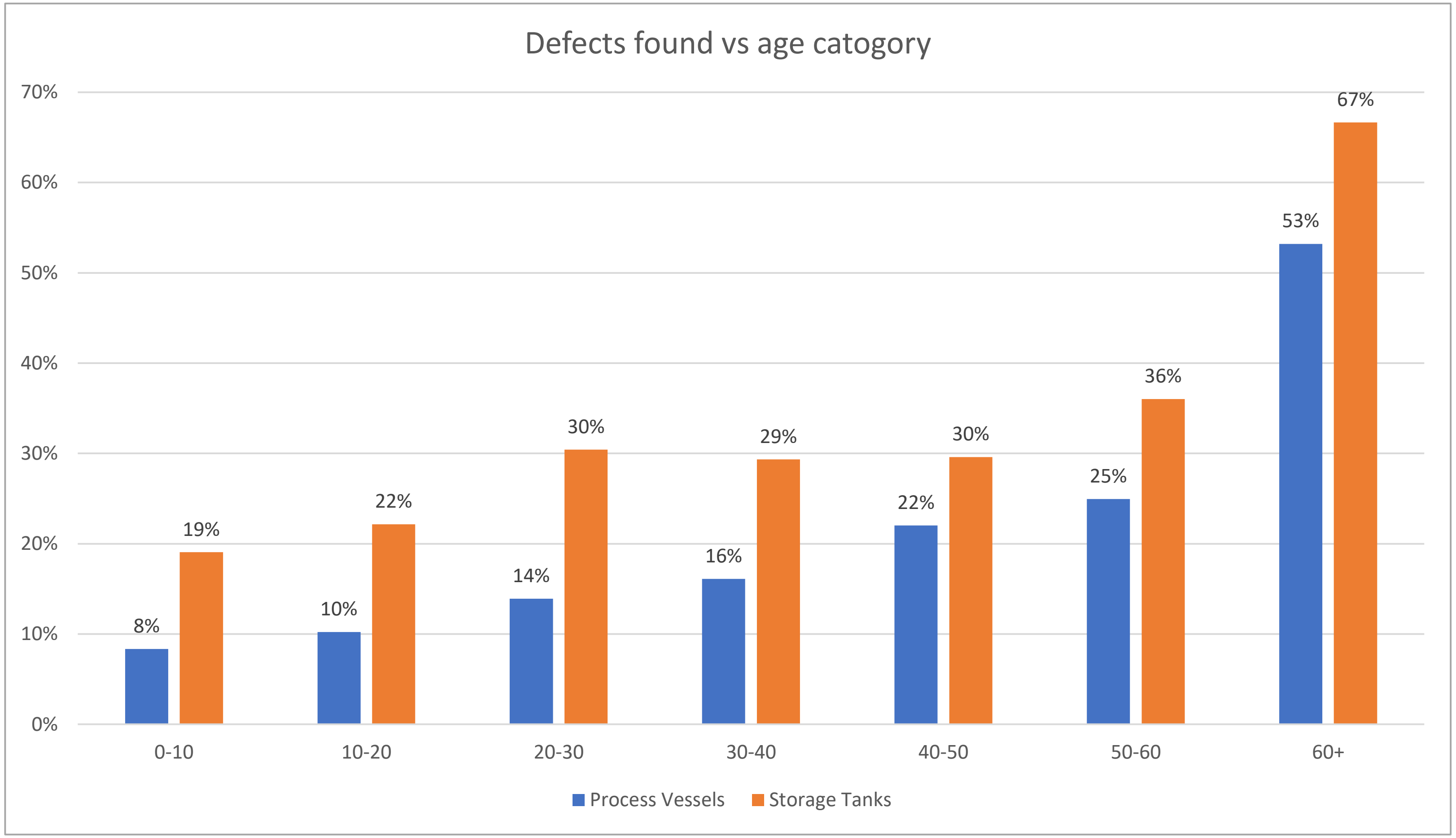
We’ve seen some horror shows

Defects rate found per inspection

- Comparing process vessels and tanks:

Type	%
Process vessels (reactors, vessels, heat exchangers, etc)	11%
Storage tanks	30%

Defects found per inspection vs age



Sample size: Tanks 1739, Vessels 2446

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What about piping?

Piping Action Type Breakdown

Action Type	% total	Comments
Painting	31%	Mainly due to corrosion defects
Mechanical Fitting	22%	Rejointing flanges, replacing supports
Fabrication	19%	Usually replacing sections of line
Lagging	9%	Repairing insulation defects
Assessment/Engineering	9%	e.g. Assessing remnant life
Civil	7%	Grouting, repositioning supports
Repair	3%	‘none of the above’
Modification	1%	

Mandatory action frequency for all defects: 11%

Piping defects

Piping defects

Focusing in on supports

- The break down in defect types seen on supports is as follows:

Type	Defect %
Corroded	63%
Inadequately supported	31%
Support missing	5%
Mechanical damage	1%
Pipe moved excessively	1%

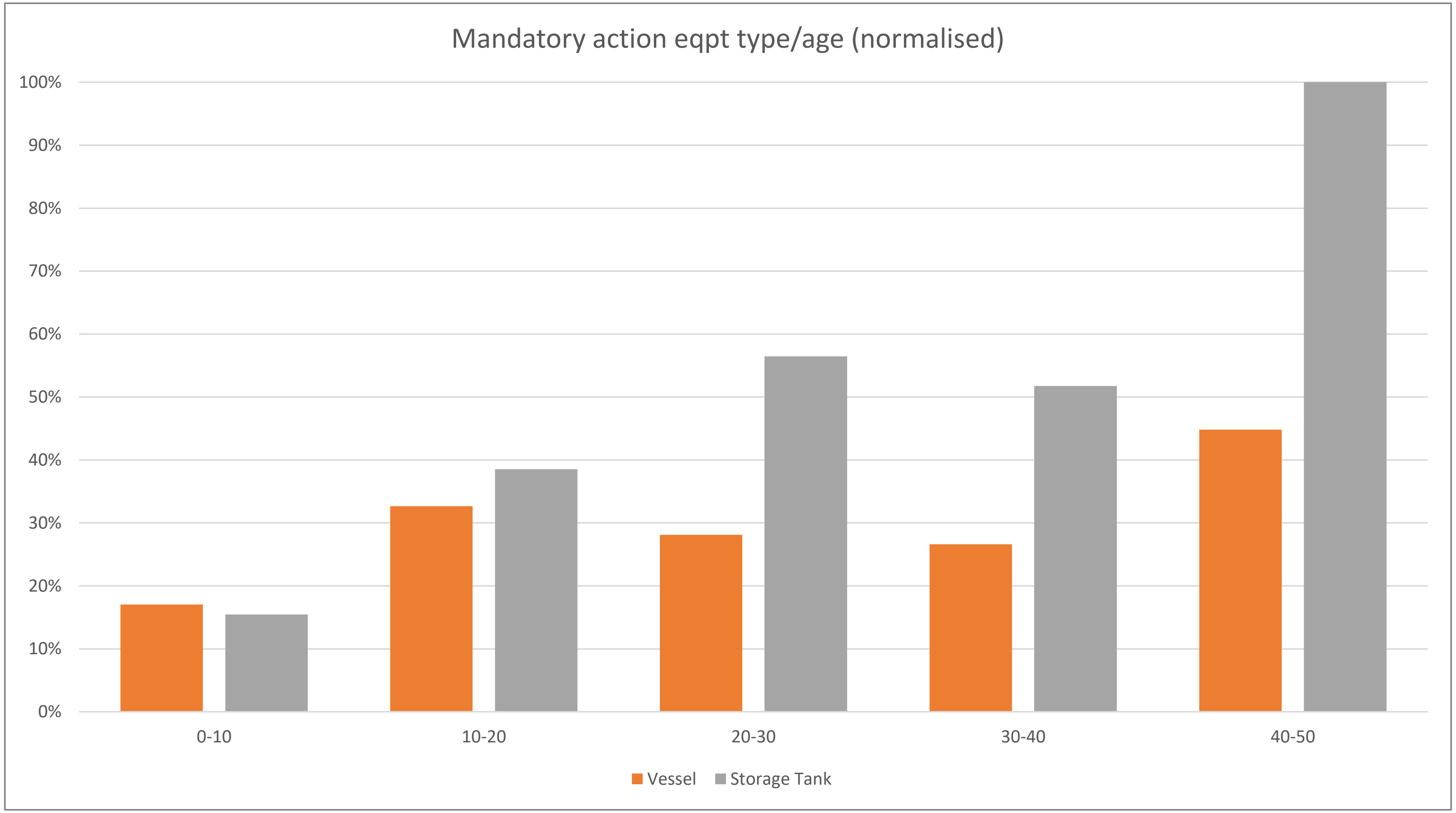
1st Inspection

- SAFed publication PSG01 *'Pressure systems Guidelines on Periodicity of Examinations'* section 1.2 suggests a 1st in service examination to be carried out within 2 years of commissioning.

- What the defect rate for inspection of pressure vessels below 26 months?

17%

Actions breakdown by equipment age – tanks & vessels



Conclusions

- Storage tanks tend to be the items that we find most defects and insist on having actions done (perhaps because they're not PSSR?)
- Flaw detection & visual inspection of welds should be included in any inspection programme, especially tanks
- Worth while reviewing your UT programme to concentrate on known problem areas to optimise spend
- Step up in maintenance requirements for equipment over 20 years old
- Inspecting your equipment within the first 26 months is justifiable

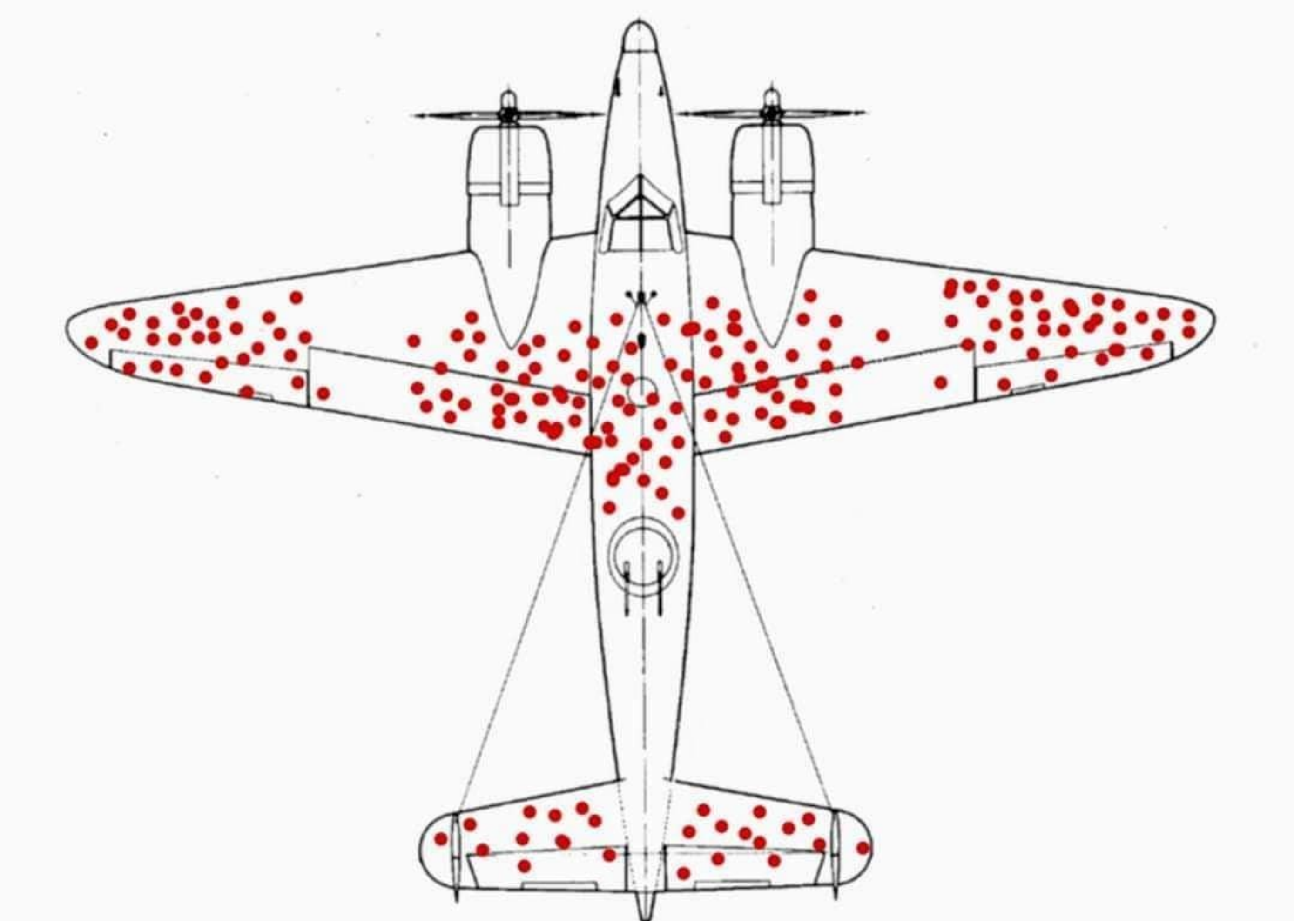
Let's be critical of the data

- Survivorship bias
- Weaknesses in underlying data
  - Sometimes the fundamentals are not present (drawings, specs)
  - History is missing
- Weaknesses in the data collection method chosen
  - Natural consequence of RBI process & commercial considerations
- Differences in maintenance management strategy across dataset
  - May introduce bias in the results

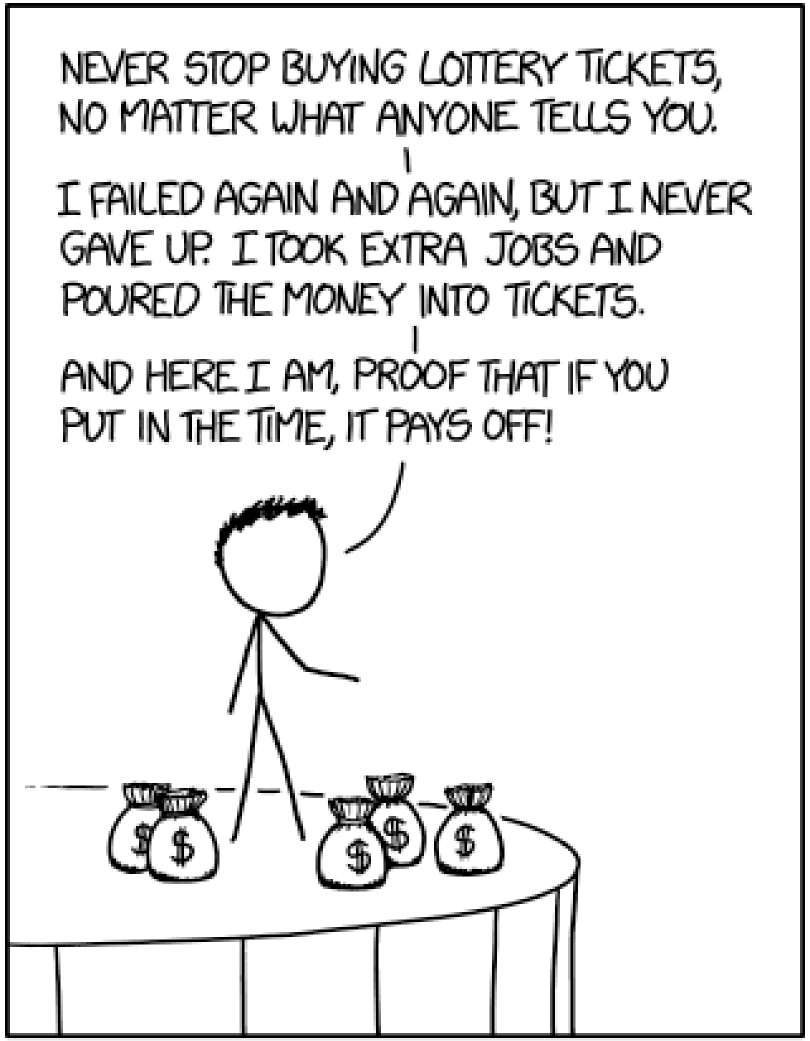
Finally

Any Questions?

Survivorship Bias

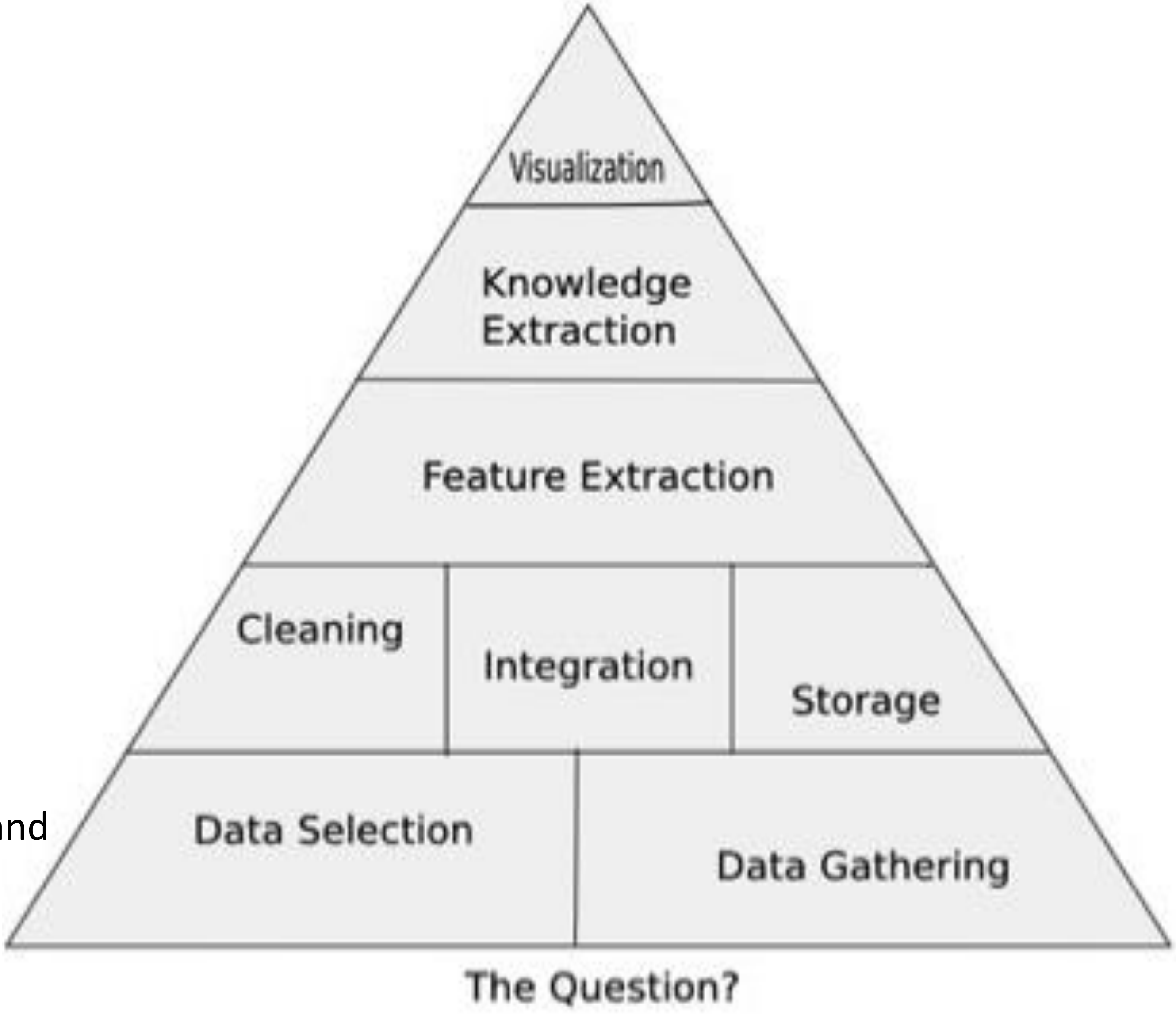


Survivorship Bias (xkcd version)



EVERY INSPIRATIONAL SPEECH BY SOMEONE SUCCESSFUL SHOULD HAVE TO START WITH A DISCLAIMER ABOUT SURVIVORSHIP BIAS.

Workload to extract & create meaningful information from data



The bulk of the time and effort here

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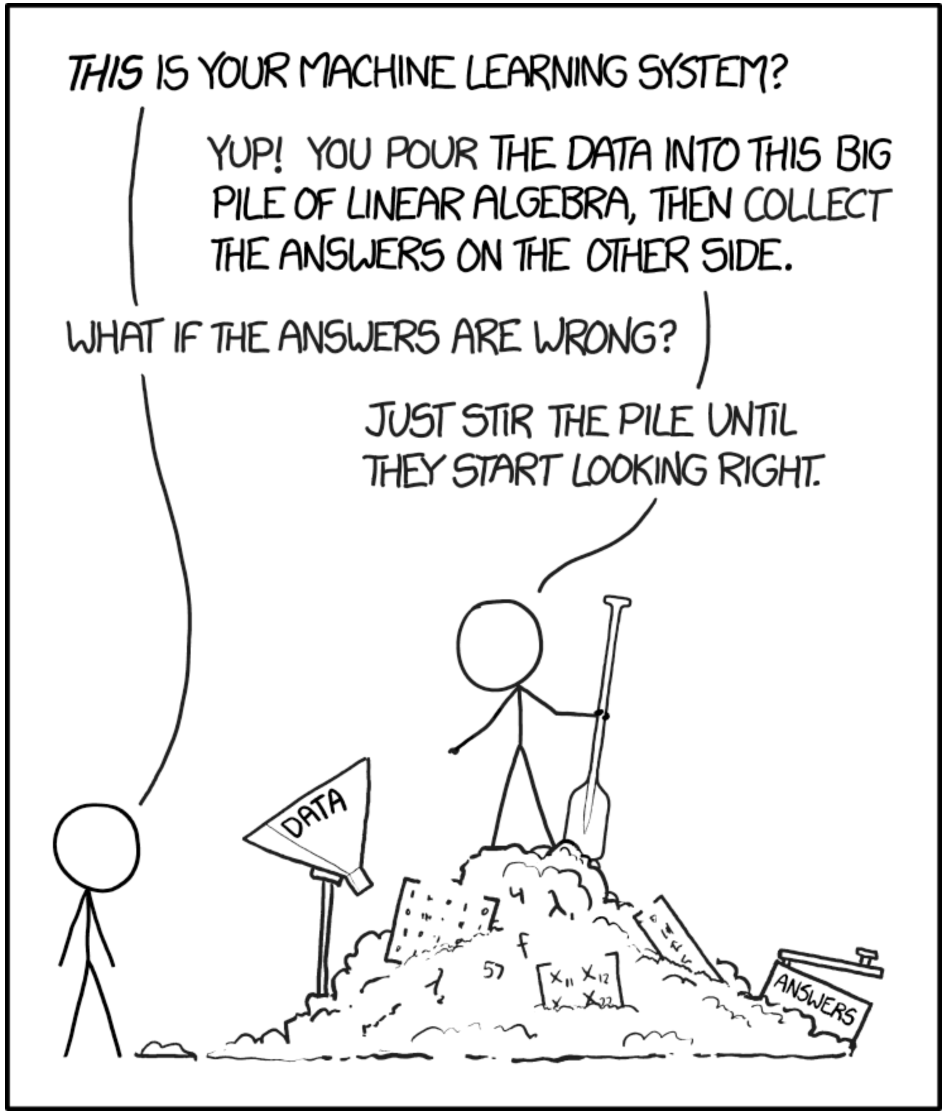
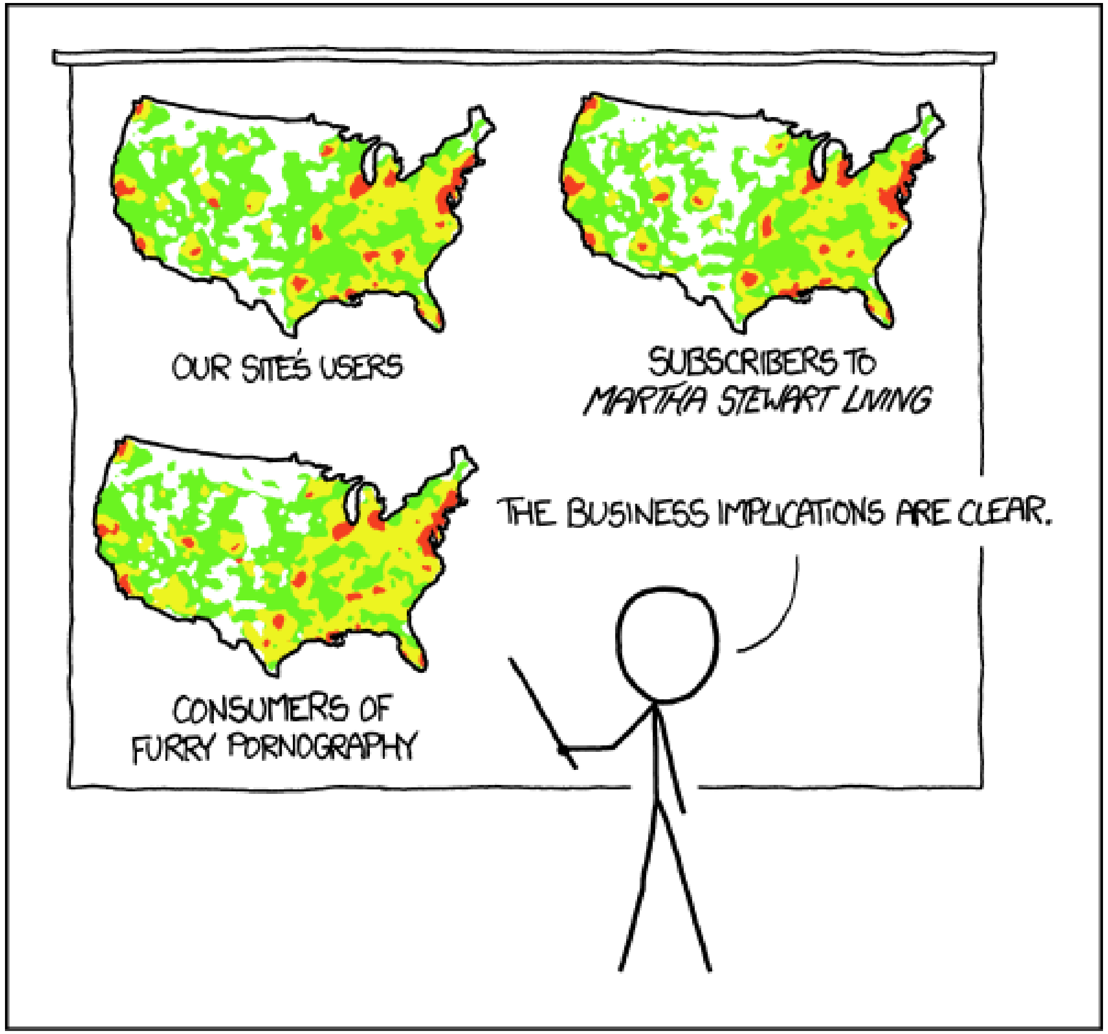
Be aware: the data extraction & analysis method may skew your results



Self-explanatory really:



PET PEEVE #208:
GEOGRAPHIC PROFILE MAPS WHICH ARE BASICALLY JUST POPULATION MAPS

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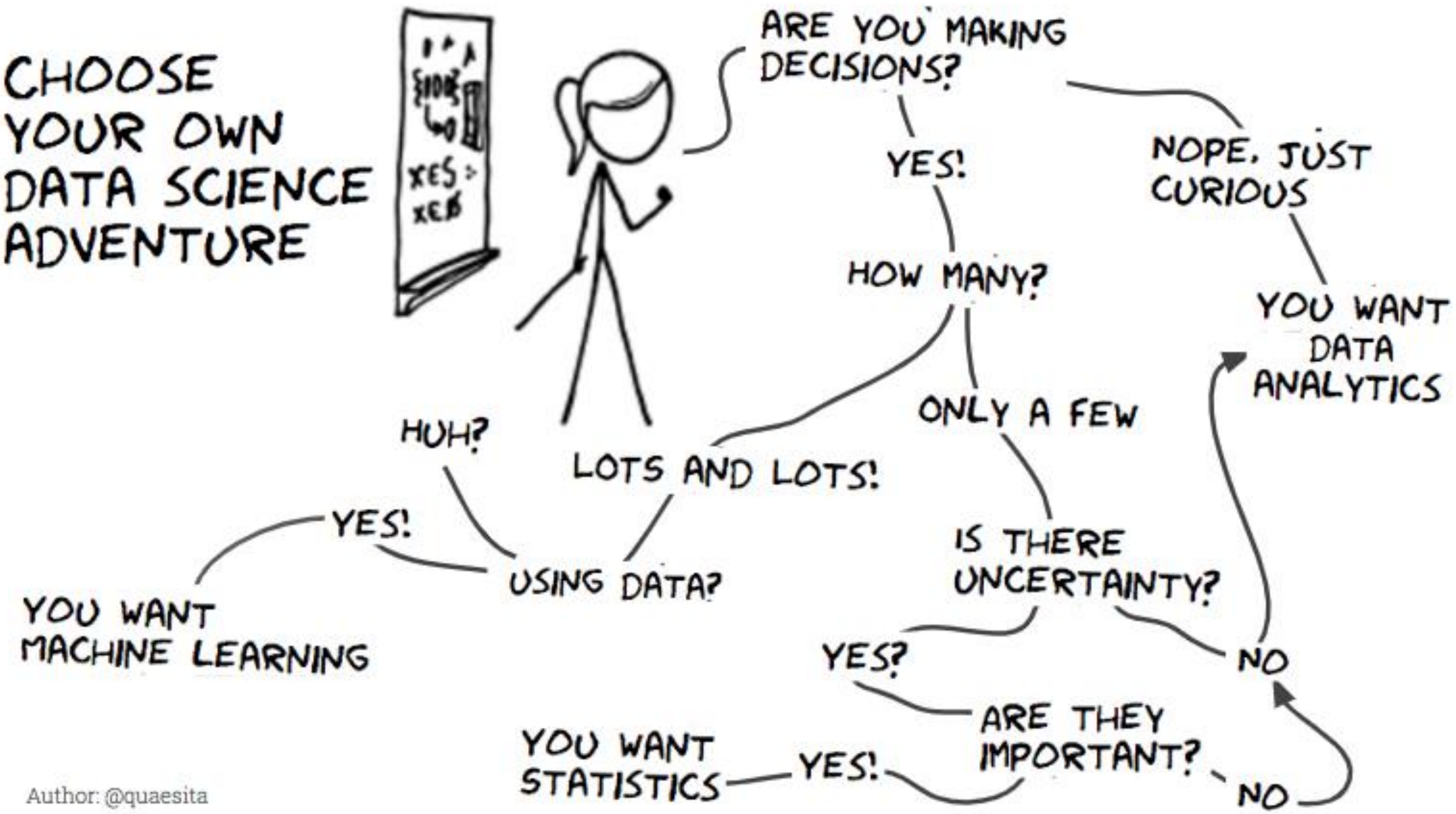

Disclaimer: **not** xkcd