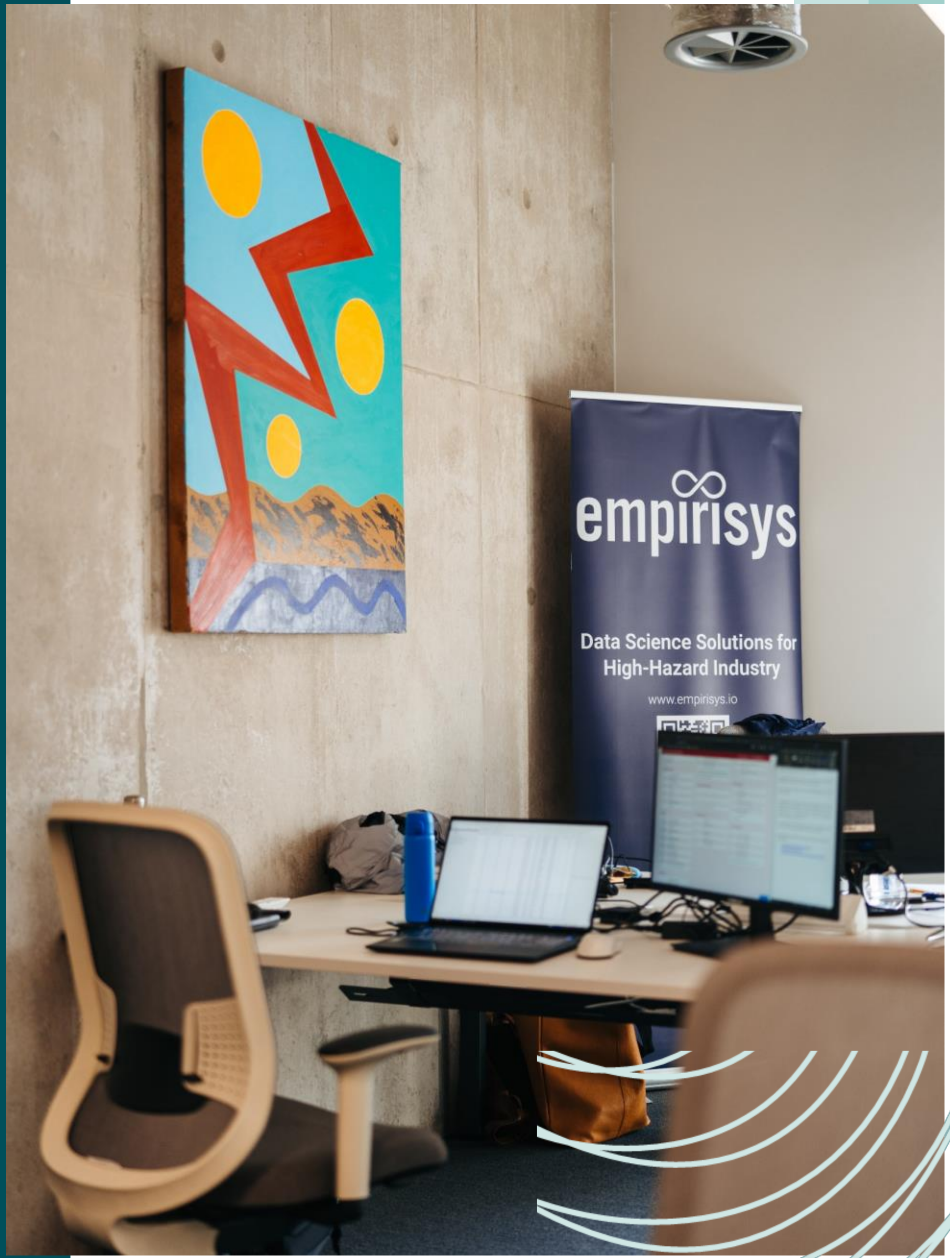
Extracting Performance Influencing Factors (PIFs) from Accident Reports

Richard Or, Andrea Rossi

empirisys



Executive summary

- Empirisys: who we are
- Extracting PIFs from accident reports
- Conclusions, future work, and challenges
- Our solution: DETECT

empirisys

"Helping high-risk organisations **save lives**, **avoid loss**, and **strengthen growth**"

Data Scientists

Process Safety Experts

Software Developers

The Team

Richard Or

MSc Data Science and Analytics
Cardiff University

Dr. Nyala Nöe

Principal Data Scientist
Empirisys

Andrea Rossi

Product Manager
Empirisys

Dr. Oktay Karakus

Lecturer
School of Computer Science and Informatics - Cardiff University

Context

Why PIFs?

- **Human error** is often identified as a **root-cause** in accident reports
- Rooted **Performance Influencing Factors (PIFs): subtle**, difficult to **spot** and often have their origins **deep** within the organisation and **far** from the point of the event.
- PIFs make up **more than 50%** of the root causes of accidents (HSE, 2019).

empirisys

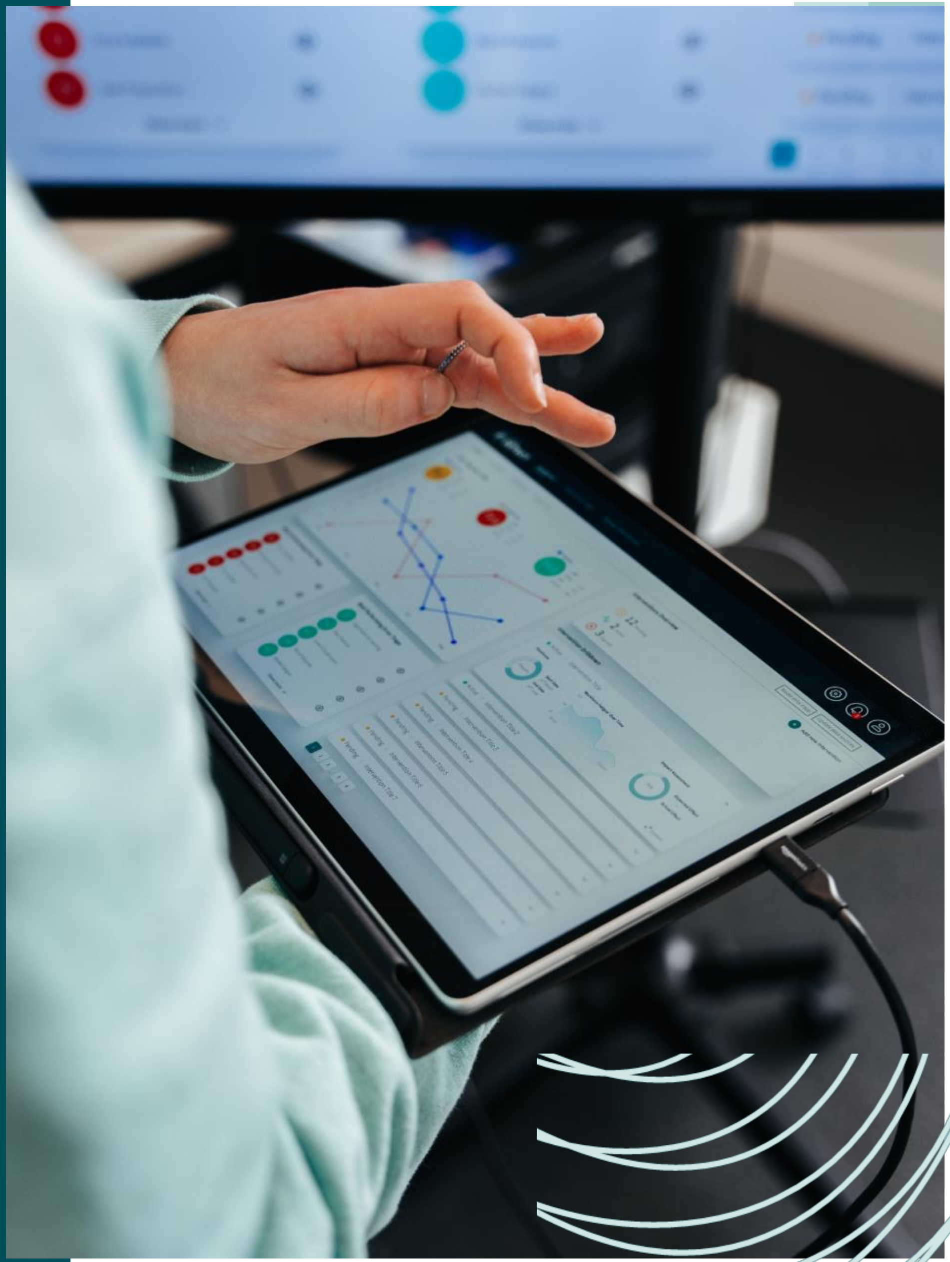
Purpose of the study

3 months research – MSc dissertation (Data Science and Analytics – Cardiff University)

Research questions:

1. Can we extract contributing factors from accident investigation reports?
2. Can we identify Performance Influencing Factors through the usage of Natural Language Process modelling techniques?

empirisys



Data source

- **Source:** Accident report from United States Department of Interior, Bureau of Safety and Environmental Enforcement
- **Period:** from 2014 to 2021
- **Number of reports:** 390
- **Identifiable accident causes:** 1356

Report sample

UNITED STATES DEPARTMENT OF THE INTERIOR
BUREAU OF SAFETY AND ENVIRONMENTAL ENFORCEMENT
GULF OF MEXICO REGION

ACCIDENT INVESTIGATION REPORT

For Public Release

1. OCCURRED
   DATE: **14-JAN-2019** TIME: **1500** HOURS
2. OPERATOR: **Walter Oil & Gas Corporation**
   REPRESENTATIVE:
   TELEPHONE:
   CONTRACTOR: **Seadrill Limited**
   REPRESENTATIVE:
   TELEPHONE:

- [ ] STRUCTURAL DAMAGE
- [ ] CRANE
- [ ] OTHER LIFTING
- [x] DAMAGED/DISABLED SAFETY SYS. **BOP/LMRP broke away from riser**
- [x] INCIDENT >$25K **BOP/LMRP broke away from riser**
- [ ] H2S/15MIN./20PPM
- [ ] REQUIRED MUSTER
- [ ] SHUTDOWN FROM GAS RELEASE
- [ ] OTHER

3. OPERATOR/CONTRACTOR REPRESENTATIVE/SUPERVISOR ON SITE AT TIME OF INCIDENT:
4. LEASE: **G20051**
   AREA: **GC** LATITUDE:
   BLOCK: **243** LONGITUDE:
5. PLATFORM:
   RIG NAME: **SEADRILL SEVAN LOUISIANA**
6. ACTIVITY:
   - [ ] EXPLORATION (POE)
   - [x] DEVELOPMENT/PRODUCTION (DOCD/POD)
7. TYPE:
   - [ ] HISTORIC INJURY
     - [ ] REQUIRED EVACUATION
     - [ ] LTA (1-3 days)
     - [ ] LTA (>3 days
     - [ ] RW/JT (1-3 days)
     - [ ] RW/JT (>3 days)
     - [ ] Other Injury
   - [ ] FATALITY
   - [ ] POLLUTION
   - [ ] FIRE
   - [ ] EXPLOSION

   LWC
   - [ ] HISTORIC BLOWOUT
   - [ ] UNDERGROUND
   - [ ] SURFACE
   - [ ] DEVERTER
   - [ ] SURFACE EQUIPMENT FAILURE OR PROCEDURES

   COLLISION [ ] HISTORIC [ ] >$25K [ ] <=$25K

8. OPERATION:
   - [ ] PRODUCTION
   - [ ] DRILLING
   - [ ] WORKOVER
   - [ ] COMPLETION
   - [ ] HELICOPTER
   - [ ] MOTOR VESSEL
   - [ ] PIPELINE SEGMENT NO.
   - [x] OTHER **Temporary Abandonment**
9. CAUSE:
   - [ ] EQUIPMENT FAILURE
   - [x] HUMAN ERROR
   - [ ] EXTERNAL DAMAGE
   - [ ] SLIP/TRIP/FALL
   - [ ] WEATHER RELATED
   - [ ] LEAK
   - [ ] UPSET H2O TREATING
   - [ ] OVERBOARD DRILLING FLUID
   - [ ] OTHER
10. WATER DEPTH: **3048** FT.
11. DISTANCE FROM SHORE: **91** MI.
12. WIND DIRECTION:
    SPEED: M.P.H.
13. CURRENT DIRECTION:
    SPEED: M.P.H.
14. SEA STATE: FT.
15. PICTURES TAKEN:
16. STATEMENT TAKEN:

For Public Release

17. INVESTIGATION FINDINGS:

On January 14, 2019, an incident occurred on the ultra-deep water rig Seadrill Sevan Louisiana working under contract for Walter Oil and Gas Corporation (WOG). The Sevan Louisiana was located at Green Canyon Block 243 OCS - G - 20051 at the time of the incident, and it had just completed a temporary abandonment of well SS002. While functioning the primary wellhead connector unlatch with the ROV, the riser adapter failed and ultimately allowed the blow out preventers (BOP's) to fall off the wellhead and lay partially buried in the mud on the seafloor. The well was secured via multiple plugs prior to the BOP's falling and no pollution was attributed to this incident.

On the morning of January 14, 2019, Walter Oil and Gas completed the temporary abandonment (TA) operation of the SS002 well. The surface bridge plug was set at 3,330 feet with cement placed on top and pressure tested as permitted by BSEE. After completing the pressure test against the Lower Blind Shear Rams and performing a full BOP function test, the drill crew displaced the riser's 11.0 pounds per gallon (PPG) Calcium Chloride with 8.6 PPG seawater. WOG had approval from BSEE to hop the BOP stack to the next well, and part of the stack hop procedure was functioning the wellhead connector open with the ROV by supplying pressure/fluid through the hot stab for the wellhead primary unlatch port. Step one of the procedure was to set a pre-determined weight down on the BOP stack by slacking off the riser tensioner system. The ROV placed the flying lead hot stab into the wellhead primary unlatch port and applied 2100 psi to the unlatch function. Moments after the function was complete, the BOP stack started to tilt. The ROV backed away from the stack and inspected the BOP stack and riser. The ROV observed the BOP stack was off the wellhead, barely resting on top of the connection and found the riser adapter partially ruptured. Seventeen hours later, the riser adapter fully parted and the BOP stack fell off the wellhead and came to rest on the sea floor.

The Bureau of Safety and Environmental Enforcement (BSEE) investigation team conducted the initial onsite investigation on January 14, 2019. The team collected evidence, videos, interviewed personnel, and wrote down statements from all involved. The investigation team noted that the procedure stated to apply a predetermined weight down on the BOP stack by slacking off the riser tensioners, but did not provide a specific weight. Through interviews, it was learned that 150,000 thousand pounds (150 KIPS) was the predetermined weight that was to be applied by slacking off the riser tensioners. The Subsea Supervisor, the Drilling Section Leader (DSL) and the Company Representative all agreed that 150 KIPS was the weight needed to hold down the BOP stack when opening the primary connector unlatch. The Subsea Supervisor, who was responsible for adjusting the riser tensioners, adjusted the tensioners from the electrical technician's office located on the drill floor. The controls in the drill floor electrical technician's office has the functionality to display the tensioner weight information. According to the digital graphs that were acquired by the investigation team, the initial weight was approximately 805 KIPs before the Subsea Supervisor slacked off of the riser tensioners thereby increasing the weight pushing down on the BOP stack. The top tension was reduced to approximately 440 KIPS instead of 650 KIPS as had been agreed. The ROV operator positioned the ROV in front of the BOP's and inserted the flying lead into the hydraulic stab on the BOP ROV panel and proceeded to unlock the primary connector from the wellhead. Once completed, the ROV flew around to the opposite side for verification of the function, when unexpectedly the BOPs tilted approximately 45 degrees, putting significant stress on the beveled area of the riser adapter, causing it to rupture. The BOP stack rested in this precarious position on the wellhead for approximately 17 hours before the riser adapter fully failed and the BOP stack fell to the seafloor. During this time, Walter Oil and Gas contacted BSEE Houma District and started working on plans to recover the BOP stack while it was still on the wellhead. Unfortunately, the BOP stack fell to the seafloor before it could be recovered.

Report sample

For Public Release

On February 2, 2019, qualified personnel recovered the BOP stack and transported the stack to Cameron (the equipment manufacturer) to be thoroughly cleaned, inspected, and repaired as necessary. Qualified personnel sent the riser adapter to Stress Engineering Services (SES) for further analysis. SES visually inspected the riser adapter and determined it was mechanically sound and did not have any pre-existing degradation that would have led to this incident. Utilizing finite element (FE) analysis modeling, SES determined that the riser adapter failed due to reduced top tension while unlatching the wellhead connector. The FE analysis took into account the actual weights that were used at the time of the incident (as well as the environmental conditions). With the top tension reduced to 440 KIPS, the FE models documented that tilting of the BOP stack was the likely outcome if the wellhead connector were to be functioned open at that reduced tension. The tiltin stack caused the lower flex joint to kink and the riser adapter and botto of riser to experience significant bending loads. It was determined thro that the bending load on the riser adapter was sufficiently high such tha the riser adapter was likely to be the outcome. The SES report documents actual failure of the riser adapter was consistent with their FE analysis failure was the likely outcome at the reduced top tension of 440 KIPS.

The BSEE investigation team agrees with SES' report in determining the pr of this incident to be reduced top tension while unlatching the wellhead The BSEE investigation team concludes that poor procedures led to this in procedure simply stated to "set a pre-determined weight down on the stack off the tensioners," and "ensure the pre-determined set down weight is we buckling tension on the riser." During a meeting held between BSEE Houma WOG, and Seadrill, the investigation team learned the following: 1) The r free will to determine the set down weight, and 2) There was no known eng analysis and/or simulation performed to aid the operational personnel to maximum or minimum set down weight. The Subsea Supervisor applied more w agreed upon. However, WOG and/or Seadrill did not give the rig guidance set down weight. Furthermore, the safe working parameters for this opera established. The lack of analysis into safe parameters for setting down slacking off the riser tensioners allowed substantial errors to be made. stated that they plan to further study what the safe parameters should be for each of their rigs, but the current preventative action is to limit all of their rigs to 50 KIPS when disconnecting from wells. This weight (50 KIPS) has been frequently used by Seadrill and has a history of success.

18. LIST THE PROBABLE CAUSE(S) OF ACCIDENT:

1) **The reduction in riser tension was substantial enough to place the entire riser system in compression, causing significant stress on the riser adapter when the wellhead connector was functioned open.**

19. LIST THE CONTRIBUTING CAUSE(S) OF ACCIDENT:

1) **Poor procedure. The procedure did not state a specific weight to be applied by slacking off the riser tensioners.**

2) **Lack of safe operating parameters when setting down weight with the riser tensioners.**

20. LIST THE ADDITIONAL INFORMATION:

21. PROPERTY DAMAGED:

Riser Adapter

ESTIMATED AMOUNT (TOTAL): **$13,000,000**

NATURE OF DAMAGE:

Riser Adapter broke off from the Subsea BOP stack.

18. LIST THE PROBABLE CAUSE(S) OF ACCIDENT:

1) **The reduction in riser tension was substantial enough to place the entire riser system in compression, causing significant stress on the riser adapter when the wellhead connector was functioned open.**

19. LIST THE CONTRIBUTING CAUSE(S) OF ACCIDENT:

1) **Poor procedure. The procedure did not state a specific weight to be applied by slacking off the riser tensioners.**

2) **Lack of safe operating parameters when setting down weight with the riser tensioners.**

empirisys

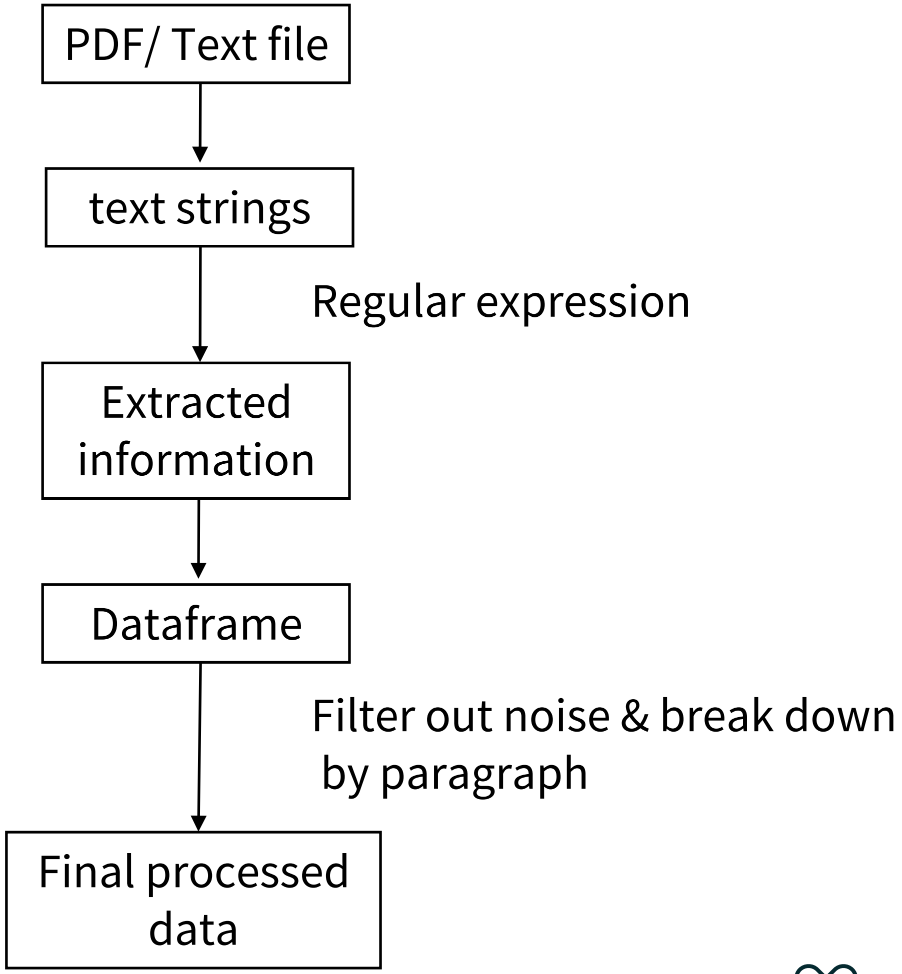
Data preparation

Probable/ Contributing	Causes	Date	Operator	Contractor
P	Kimray Temperature Controller malfunctioned.	02-FEB-2015	Stone Energy Corporation	
P	Temperature Safety High (TSH) on BAP-1500 did ...	02-FEB-2015	Stone Energy Corporation	
P	High Temperature caused the Glycol and Antifre...	02-FEB-2015	Stone Energy Corporation	
P	Unforeseen loop currents, up to 5 knots, ulti...	26-MAR-2015	Shell Offshore Inc. CONTRACTOR: NOBLE DRILLIN...	NOBLE DRILLING (U.S.) INC.
P	*Signalman left the sight of the crane operato...	12-APR-2018	ANKOR Energy LLC	
...	...	...	...	...
C	Inadequate JSA: The JSA that was done failed...	12-DEC-2014	ANKOR Energy LLC	
C	There was a deviation by the driller and sub-s...	30-JAN-2016	LLOG Exploration Offshore, L.L.C.	Seadrill Limited
C	Lack of understanding of the mechanics of the ...	30-JAN-2016	LLOG Exploration Offshore, L.L.C.	Seadrill Limited
C	The Step-by-Step stack hop procedure did not s...	30-JAN-2016	LLOG Exploration Offshore, L.L.C.	Seadrill Limited
C	This was the first time for this crew to perfo...	30-JAN-2016	LLOG Exploration Offshore, L.L.C.	Seadrill Limited

empirisys

Data preparation

Causes
Kimray Temperature Controller malfunctioned.
Temperature Safety High (TSH) on BAP-1500 did ...
High Temperature caused the Glycol and Antifre...
Unforeseen loop currents, up to 5 knots, ulti...
*Signalman left the sight of the crane operato...
...
Inadequate JSA: The JSA that was done failed...
There was a deviation by the driller and sub-s...
Lack of understanding of the mechanics of the ...
The Step-by-Step stack hop procedure did not s...
This was the first time for this crew to perfo...



empirisys

PIF Categories

- **Initial approach:** categorise PIFs as the ones provided by Health and Safety Executive (HSE).
- **Challenge:** Accuracy limited by the content from the reports.
- **Final approach:** use higher level categories (U.S. Department for Energy)

HSE

Health and Safety Executive

Performance Influencing Factors (PIFs)

Performance Influencing Factors (PIFs) are the characteristics of the job, the individual and the organisation that influence human performance. Optimising PIFs will reduce the likelihood of all types of human failure.
NB. This list is not exhaustive

Job factors

- Clarity of signs, signals, instructions and other information
- System/equipment interface (labelling, alarms, error avoidance/ tolerance)
- Difficulty/complexity of task
- Routine or unusual
- Divided attention
- Procedures inadequate or inappropriate
- Preparation for task (e.g. permits, risk assessments, checking)
- Time available/required
- Tools appropriate for task
- Communication, with colleagues, supervision, contractor, other
- Working environment (noise, heat, space, lighting, ventilation)

Person factors

- Physical capability and condition
- Fatigue (acute from temporary situation, or chronic)
- Stress/morale
- Work overload/underload
- Competence to deal with circumstances
- Motivation vs. other priorities

Organisation factors

- Work pressures e.g. production vs. safety
- Level and nature of supervision / leadership
- Communication
- Manning levels
- Peer pressure
- Clarity of roles and responsibilities
- Consequences of failure to follow rules/procedures
- Effectiveness of organisational learning (learning from experiences)
- Organisational or safety culture, e.g. everyone breaks the rules

empirisys

Final Categories

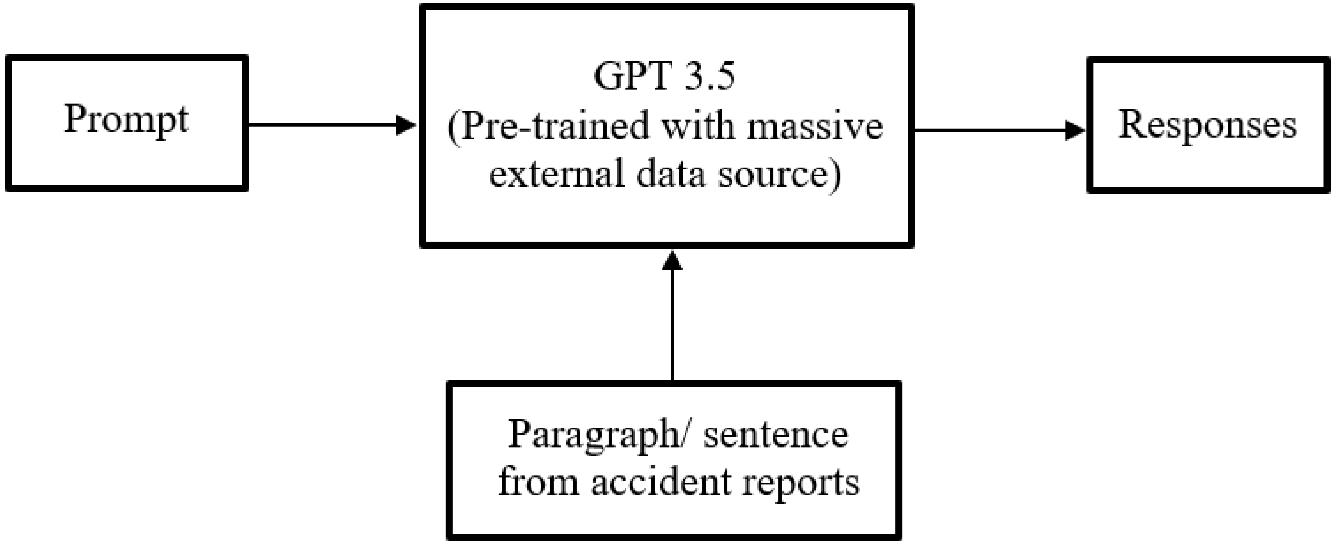
Higher level categories (U.S. Department of Energy 2009):

- Software failure
- Equipment failure
- Procedures violation
- Lapses
- Organisational factor
- No PIF (to filter out extraneous texts)

empirisys

Methodology

- Generative Pre-trained Transformer
- Artificial intelligence model
- Specifically designed to understand and generate human-readable text



Prompt formulation

Consist of three parts:

1. A fixed string detailing the six pre-defined categories alongside their definitions.
2. A variable string incorporating text from the data frame.
3. A fixed string constraining the output to a singular category name.

Performance evaluation

- Randomly drawn **25** samples from each **category** based on the result -> **139** samples in **total**
- Manual **annotation** from **Empirisys SME** and comparison to GPT 3.5's outputs for **alignment**.
- **Accuracy** is calculated by the **proportion** of matching **result**.

RESULTS

- GPT 3.5 misclassified 42 out of 139 validation samples.

Accuracy = 70%

empirisys

Prompt formulation

Prompt 1 - fixed string detailing the six pre-defined categories alongside their definitions.

```
Read the following definition of different category of accident causes:
Software Failure: Malfunction or incorrect operation of computer programs or software systems that are integral to the functioning of industrial processes.
Software failures can cause disruptions in control systems, communication breakdowns, and lead to unsafe.

Equipment Failure: Machinery, tools, or devices used in industrial operations break down or malfunction unexpectedly. Such failures can result from wear and tear,
lack of maintenance, manufacturing defects, or other technical issues.

Procedures Violation: Failure to follow established guidelines, protocols, or safety procedures during industrial operations. This can occur due to negligence,
lack of awareness or shortcuts.

Lapses: Inadvertent errors made by individuals without intent. These mistakes occur due to factors such as lack of training, fatigue, distractions,
or wrong judgments.

Organizational Factor: Organizational factors encompass aspects of an industrial environment that can influence safety and accident risk. These factors
include management practices, work culture, communication systems, resource allocation, and safety policies.

No PIF: if there is no clue about the cause of the accident

and categorize the following accident cause:
```

Prompt 2 - A variable string incorporating text from the data frame.

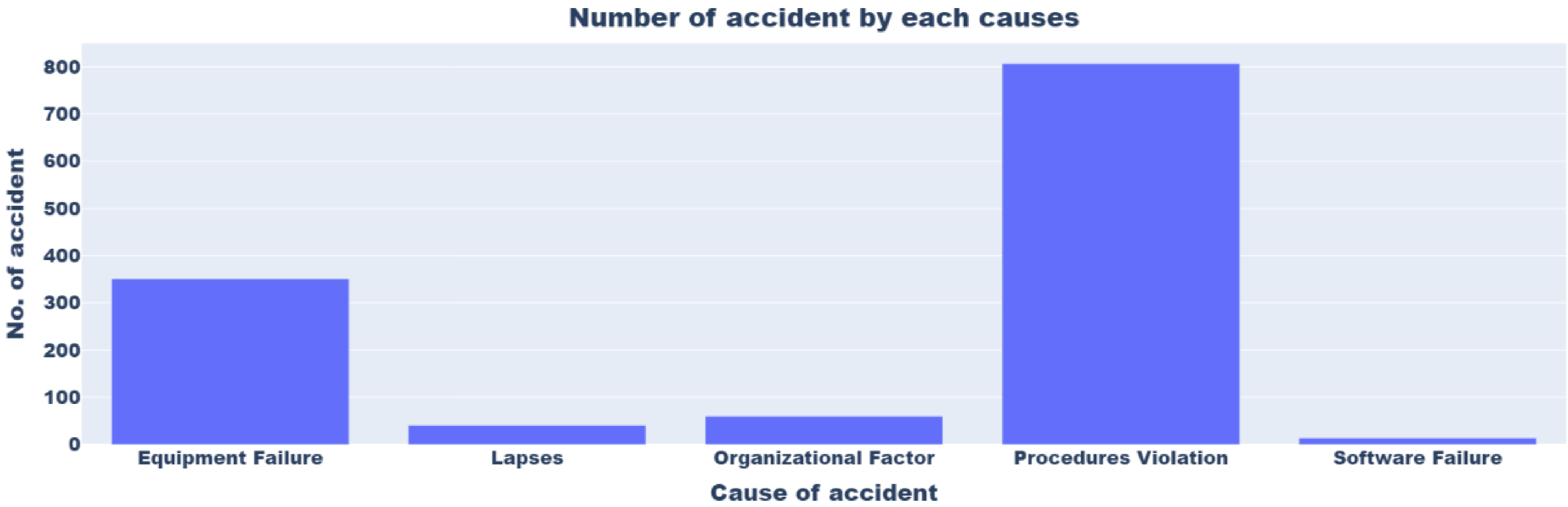
```
p2="The boom hoist limit device failed to function, thus allowing the boom to exceed itsmaximum angle height and contact the boom stops
```

Prompt 3 - A fixed string constraining the output to a singular category name.

```
p3="return only the name of one best fit category"
```

empirisys

Results



empirisys

Performance evaluation

Human annotation / GPT result	Lapses	Organizational failure	No PIF	Total
Equipment failure	1	2	4	7
Lapses	-	12 b	1	13
Organizational failure	0	-	5	5
Procedures violation	3	5	4	12
Software failure	0	1	2	3
No PIF	0	2	-	2
Total	4 c	22	16 a	42

Breakdown of incorrectly classified accident causes:

a. The model forces the classification of PIFs - 16/42 (**38%**) belong to NO PIF category

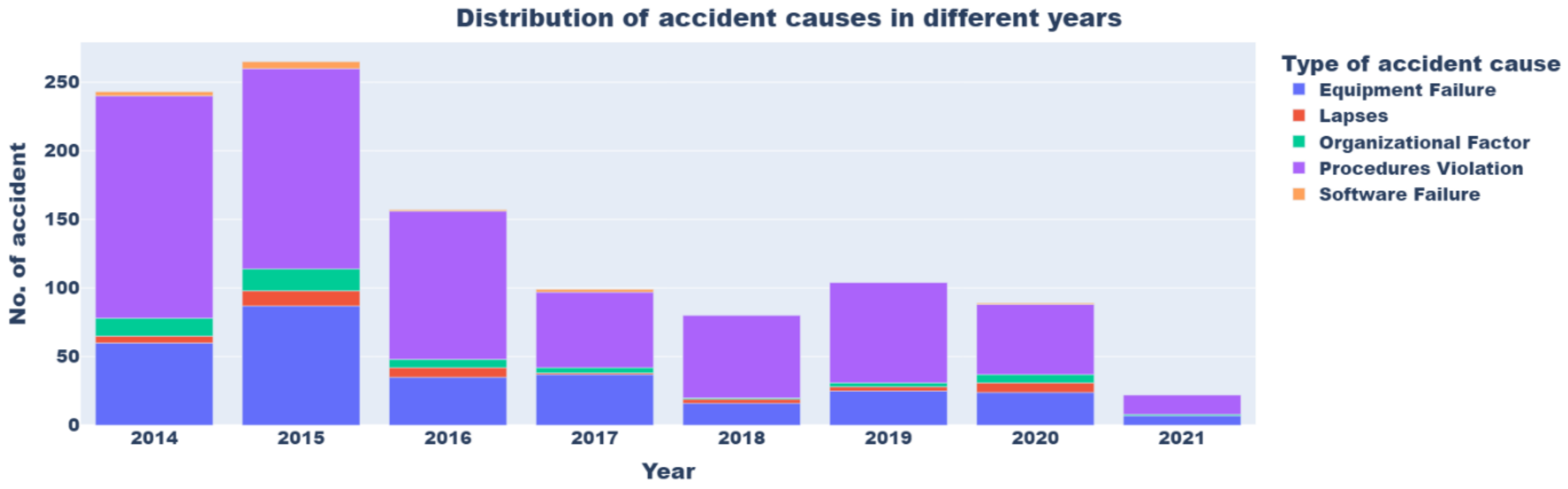
b. 12/22 (**54.5%**) Organisational failures misclassified as Lapses by the model

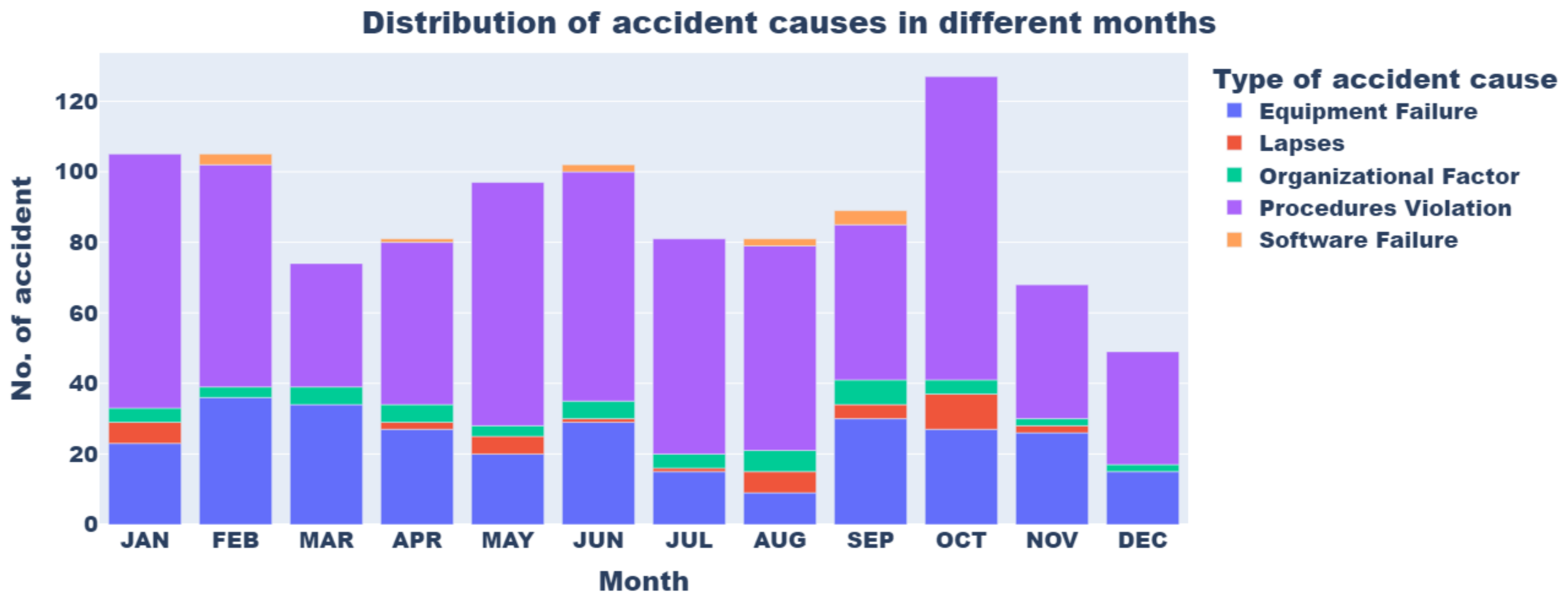
c. Lapses were hardly misclassified 4/42 (**9.5%**)

All human annotated procedure violations were correctly identified by the model

empirisys

Trends over time





empirisys

Conclusions

- LLMs techniques have proven effective in extracting key information from accident reports
- Reports don't provide an accurate description of 'how' and 'why' an accident has unfolded, so the correct identification of Human Factors from accident reports is limited

There are two ways to address this problem

empirisys

Reactive vs Proactive

1. Write better accident reports:
   - Reactive approach
   - Requires operational change on a global scale
   - High effort, low impact

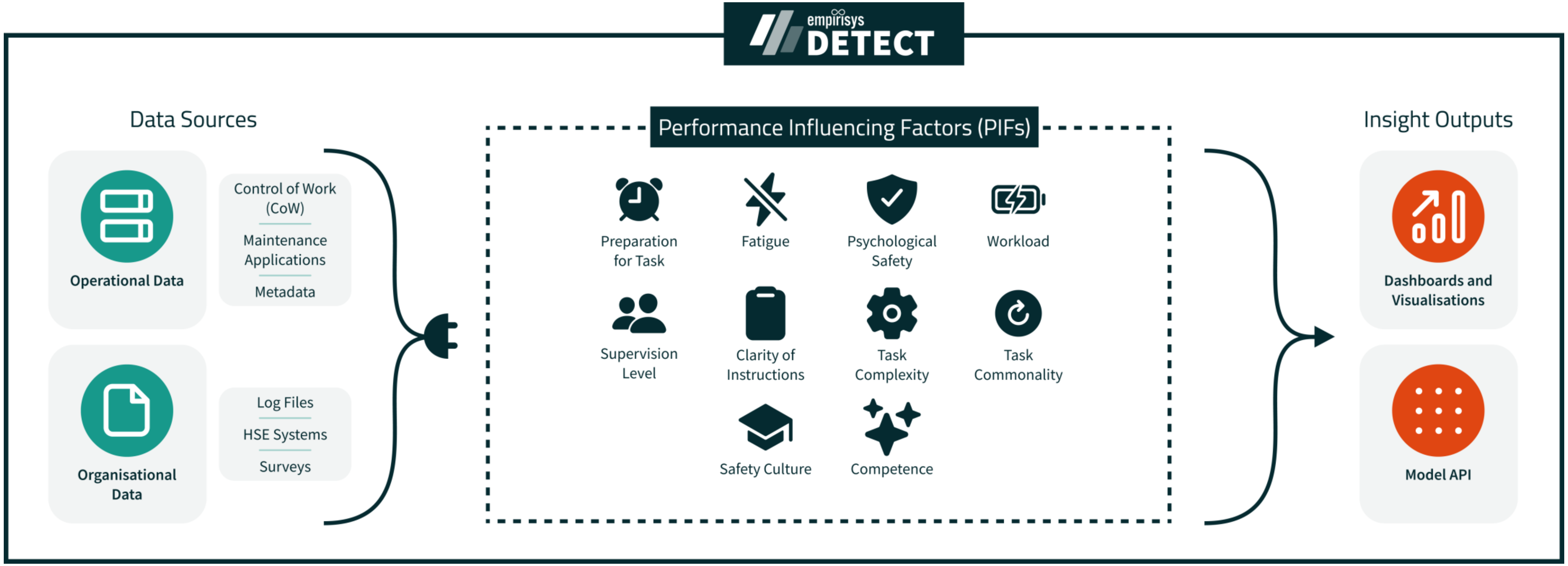
2. Systematically and continuously extract, identify and analyse Human Factors from existing Operational and Organisational data sources
   - Proactive approach
   - Requires strategic change of perspective
   - Medium effort, very high impact

empirisys

Our Solution

AI-powered **Human Factors** solution designed **for** and **by** and for Process **Safety** Professionals.

Make your organisation **safer**, **more reliable**, and **more competitive** by systematically managing your organisation's Performance Influencing Factors.



Our research partners: Cardiff University Prifysgol Caerdydd, HSE Health & Safety Executive, Robert Gordon University Aberdeen

Developed in collaboration with: bp

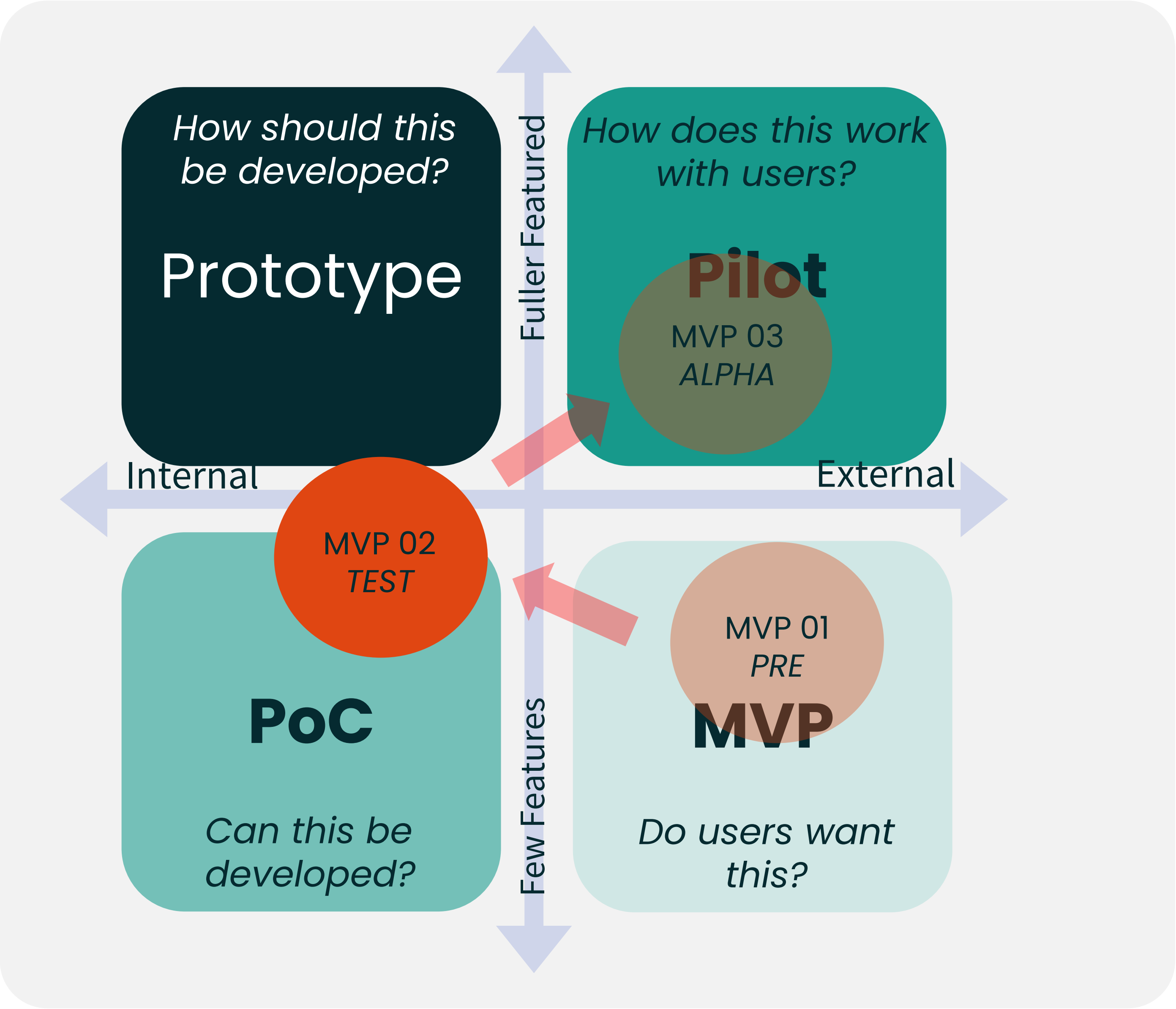
empirisys

Our approach

MVP1 (Apr – Jun '23)
Based on initial wireframes to establish user needs.
Goal: Desirability.

MVP2 (Jul – Oct'23)
Based on initial r&d, real output, manual effort.
Goal: Feasibility.

MVP3 (Nov '23 – Mar'24)
Based on end-to-end production deployment, to establish practical usability in the field.
Goal: Viability.



Get involved!

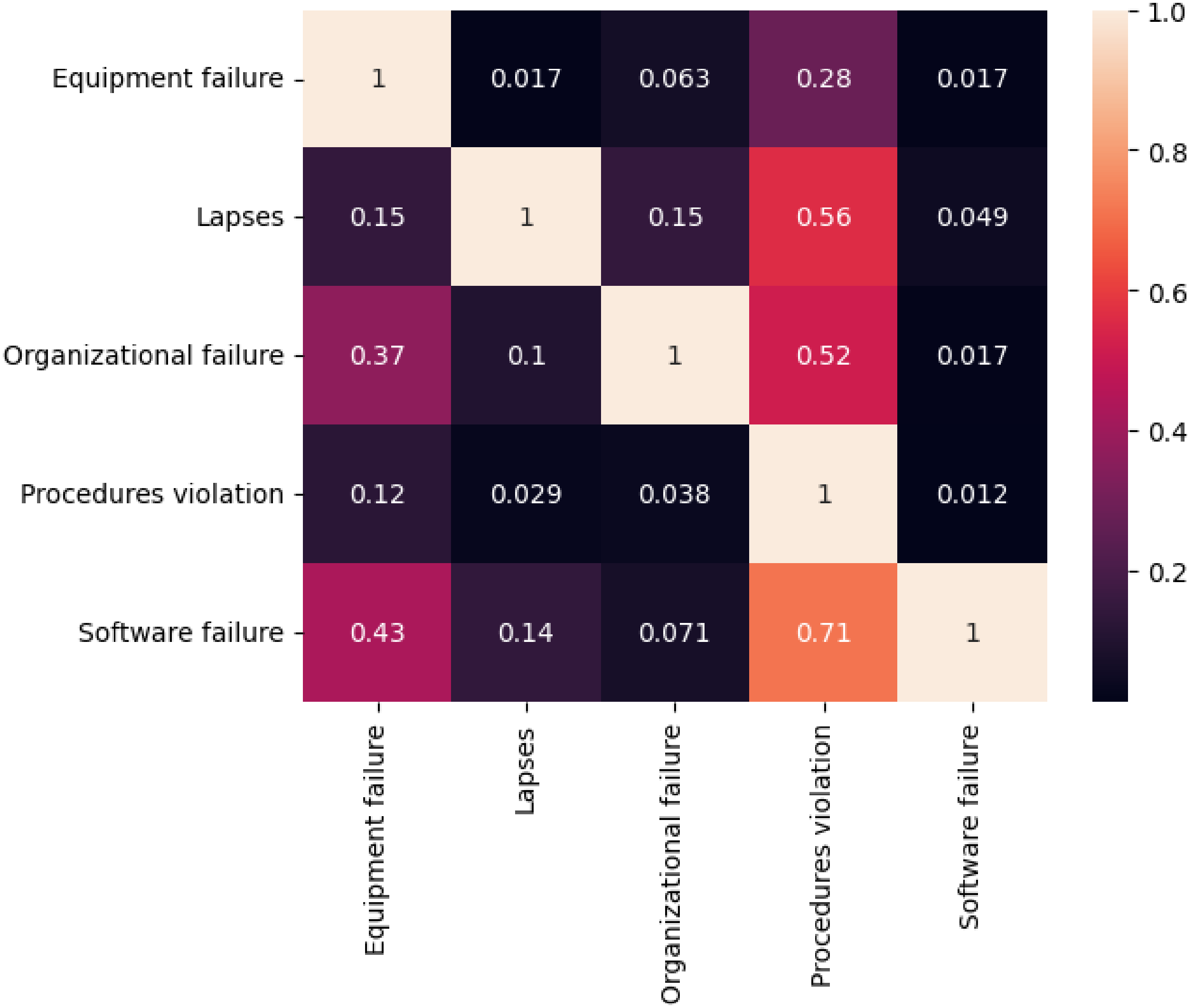
We're looking for collaborators and early adopters to help us shape the direction of DETECT.

- Visit us at our **Empirisys stand** to have a chat and see a **demo** of our second MVP
- Contact us at **detect@empirisys.io**

empirisys

Appendix

Correlation between each category



Correlation index:

$$\frac{No.\ of\ instances\ with\ the\ corresponding\ combination}{No.\ of\ instances\ with\ the\ primary\ cause}$$

empirisys