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Predictive Maintenance

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What is Predictive Maintenance?

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

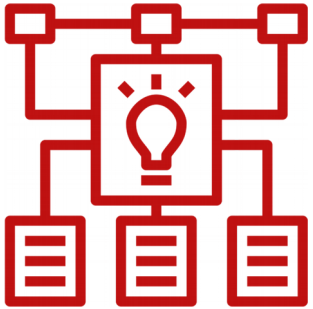
What questions can be answered from Predictive Maintenance?

What is the probability that a piece of equipment fails in the near future?

What is the remaining useful life of the equipment (RUL)?

What are the causes of failures and what maintenance actions should be performed to fix these issues?

Why Predictive Maintenance?



- Reduced equipment costs
- Reduces labor costs
- Reduces lost production time
- Increases safety
- Increases revenue
- Increases efficiency of employee time

Why Predictive Maintenance?

Reduced equipment costs :
Instead of replacement of the entire piece of equipment due to critical failure, a repair is made prior to failure and cost is minimized to the price of the component and the labor needed for the repair.

- According to a study by the Department of Energy (US), a facility that leans heavily on predictive (rather than reactive or preventative) APM methods can save 30-40% in equipment maintenance costs.

- The same DOE study mentioned above reports that proactive equipment maintenance costs about 20X less than reacting to broken machines.

Why Predictive Maintenance?

Reduces labour costs :

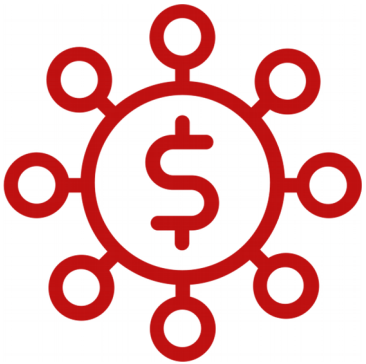
- When repairs are scheduled, the amount of time needed for repair is reduced because of a smaller number of component replacements instead of entire equipment replacement. Also, the frequency of repair for critical failure of equipment will be reduced and the amount of “critical callouts” will be greatly reduced.

- According to a journal of engineering and research (Vol. 18), applying predictive maintenance techniques in the chemical industry found an overall

    - Reduction of 23% in spare parts
    - Reduction of 16 % in labor costs

Why Predictive Maintenance?

Reduces lost production time :-



Component only replacement is scheduled with production to take place during scheduled downtime. Unscheduled downtime may cost thousands of dollars per hour. A proactive maintenance department can head off critical failure downtime by scheduling repair during non-productive times

According to a journal of engineering and research (Vol. 18), applying predictive maintenance techniques in the chemical industry found an overall 33% increase in lifetime of an equipment.

Why Predictive Maintenance?

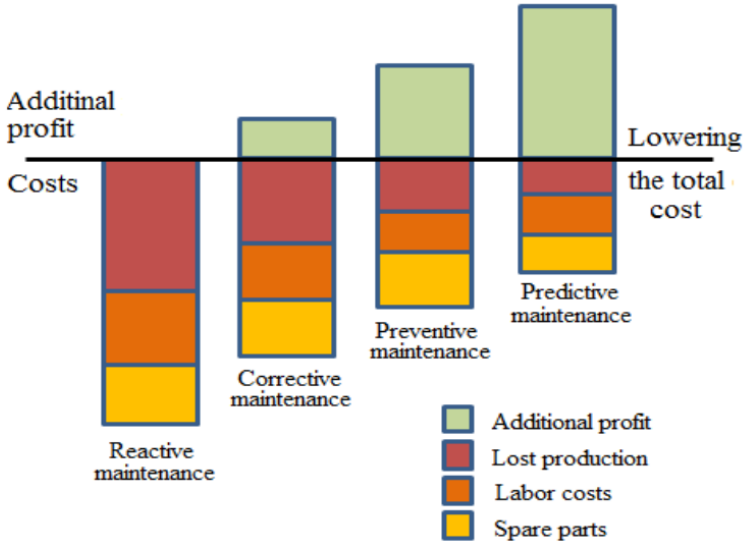
- **Increases Safety :**
- Predictive maintenance would allow potential problems to be fixed before failure occurs, which would create safer operating conditions for employees and customers.

- **Increases Revenue :**
- With less maintenance on good components and quicker repair of faulty components, repairs can be more effectively handled, thereby reducing repair time.

- **Increases efficiency of employee time :**

  By identifying the precise repair task needed to correct deficiencies, as well as the parts, tools and support needed to correct the problem can dramatically increase effective "wrench time."

Why Predictive Maintenance?



Savings obtained from the application predictive maintenance:

- Increased lifetime of process equipment: 33%;
- Increased productivity: 2%;
- Reduction spare parts: 23%;
- Reduction labor costs: 16%;
- Reduction waste: 2%;
- Other: 24%.

By implementing a predictive maintenance program, the profit grows having an increased production time, and the costs which are related to the breakdowns or to the stock of spare parts, of labor, or of energy consumption etc., are reduced.

Source: Theoretical Study about the influence of Predictive maintenance on equipment lifetime

Predictive Maintenance for Gas-Stations

- Total spent on parts-ordering = $31,896.5
- Total spent on labor = $45,320.5

Savings obtained if Predictive maintenance is implemented,

- Total maintenance expenditure in a year = $77,217
- 18% on parts ordered = $5741.37
- 13% on total labor = $5891.66

Total savings = $11,633.03

- Which is 15% of maintenance expenditure in a year

For a typical gas station,

- You can save up to 15% of your maintenance expenditure

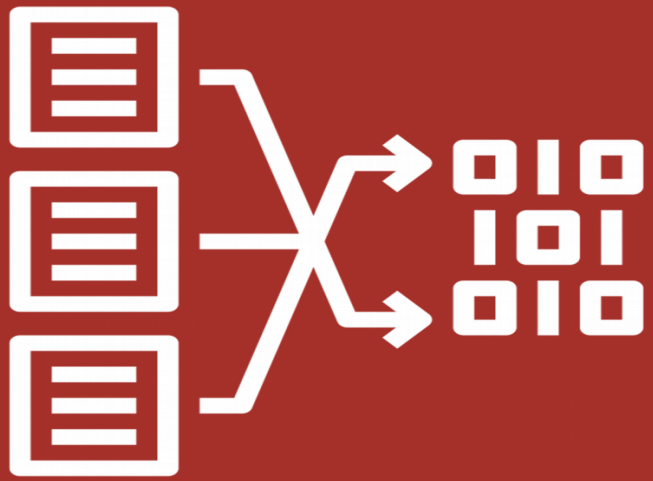
Qualification Criteria for Pdm

Maintenance records : asset ID, time and maintenance action columns

Failure records : asset ID, time and failure or failure reason columns if reason is available

Machine conditions : asset ID, time, equipment run-time.

Machine and operator data :asset ID, asset features, operator ID and operator features



- **Feature data or engineering : temperature sensor, vibration sensor, acoustic sensor, pressure sensor**

Three Levels in Predictive Maintenance

Level 1 : Basic Information

Level 2 : IoT Environment Sensor Data

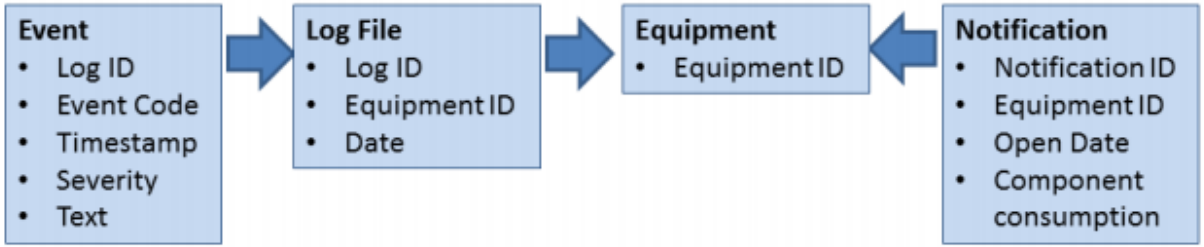
Level 3 : IoT Equipment Sensor Data

Three Levels in Predictive Maintenance

Level 1 : Basic Information and Event log

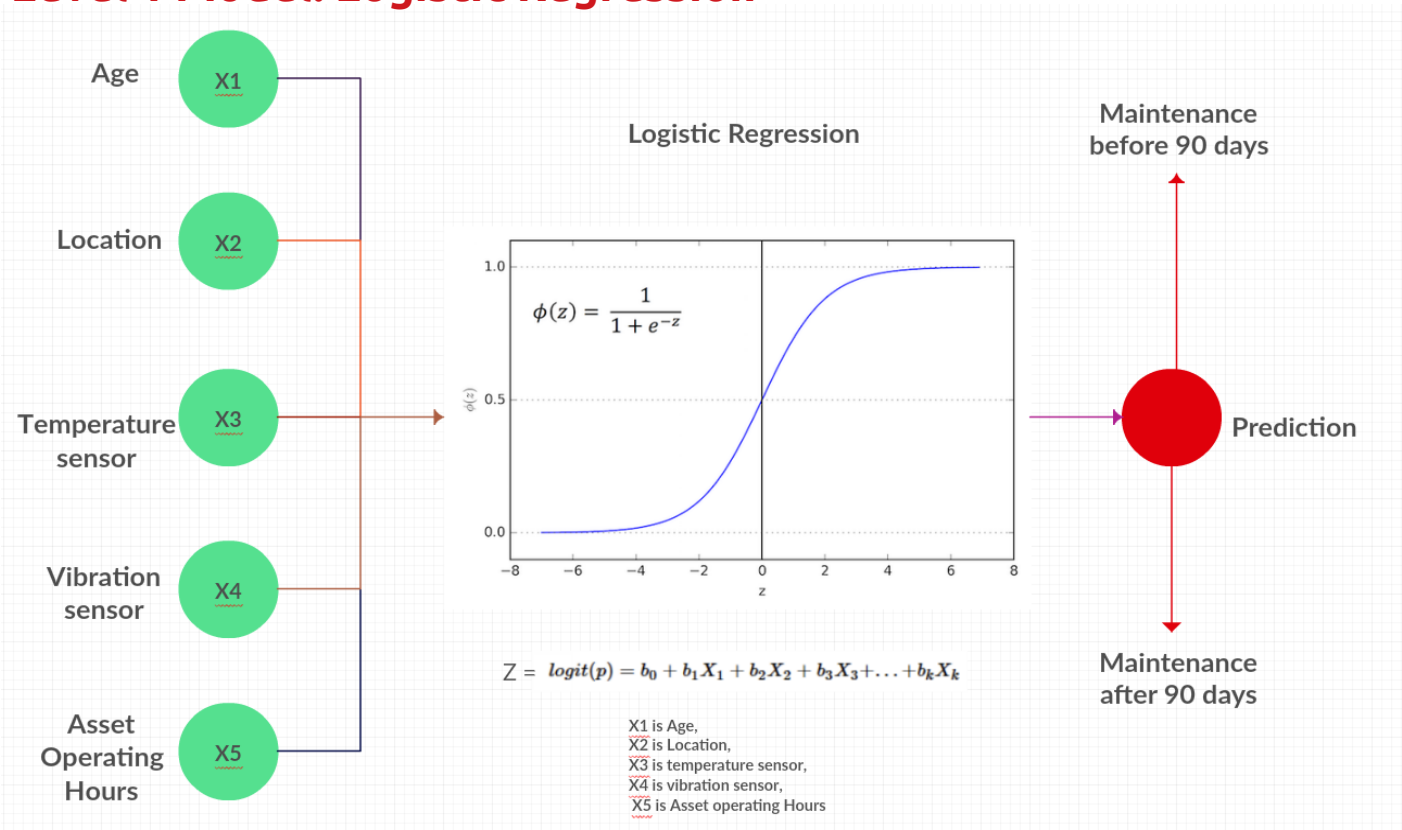
Data Required :
Asset/Equipment information by location. Eg: Asset ID, Make, model, location

Maintenance records, Failure records, Machine conditions to be recorded PER ASSET/EQUIPMENT



Three Levels in Predictive Maintenance

Level 1 Model: Logistic Regression



Three Levels in Predictive Maintenance

Level 2 : IoT Environment Sensor Data

Data Required :-

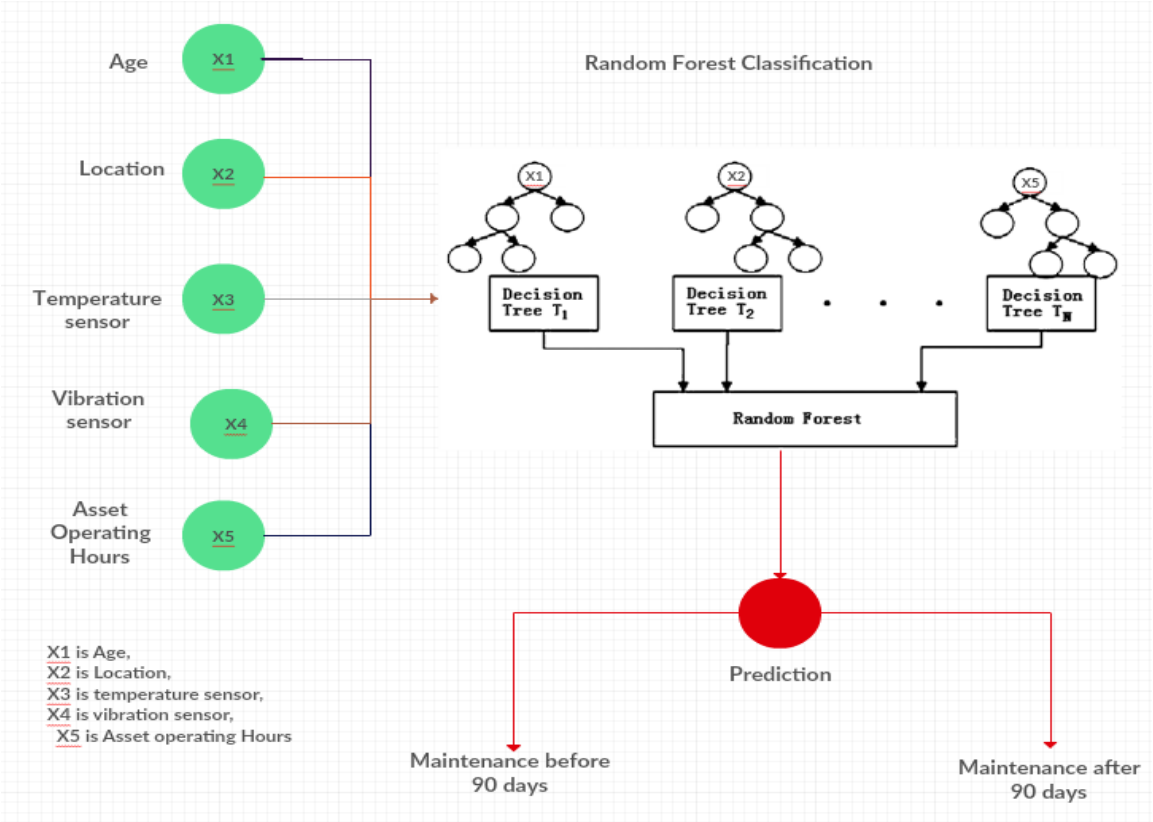
Asset/Equipment information by location. Eg: Asset ID, Make, model, location

Maintenance records, Failure records, Machine conditions to be recorded PER ASSET/EQUIPMENT

Sensor data by Location: eg: Weather, POS, Volumes, Flow, usage quantification

Three Levels in Predictive Maintenance

Level 2 Model: Random Forest Classification



Three Levels in Predictive Maintenance

Level 3 : IoT Equipment Sensor Data

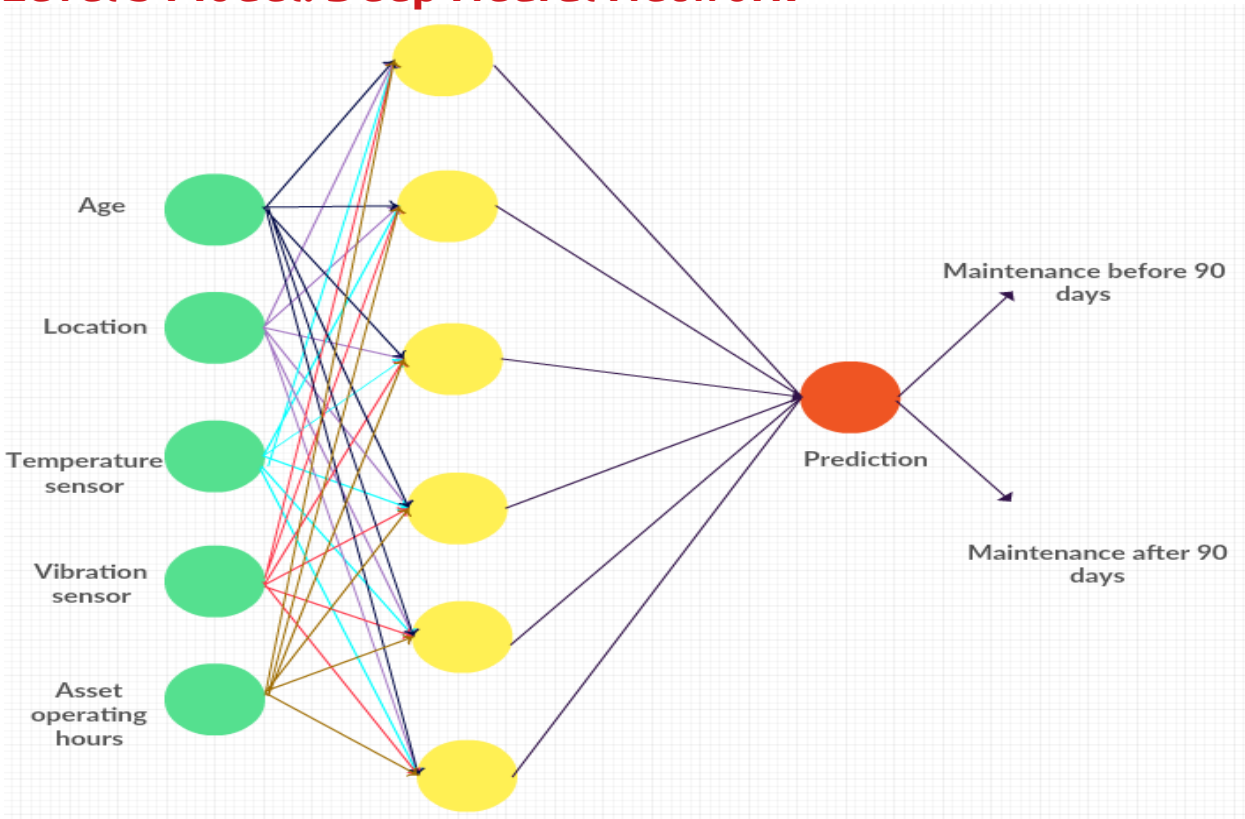
Data Required :

Asset/Equipment information by location. Eg: Asset ID, Make, model, location
Maintenance records, Failure records, Machine conditions to be recorded PER ASSET/EQUIPMENT
Sensor data by Location: eg: Weather, POS, Volumes, Flow, usage quantification

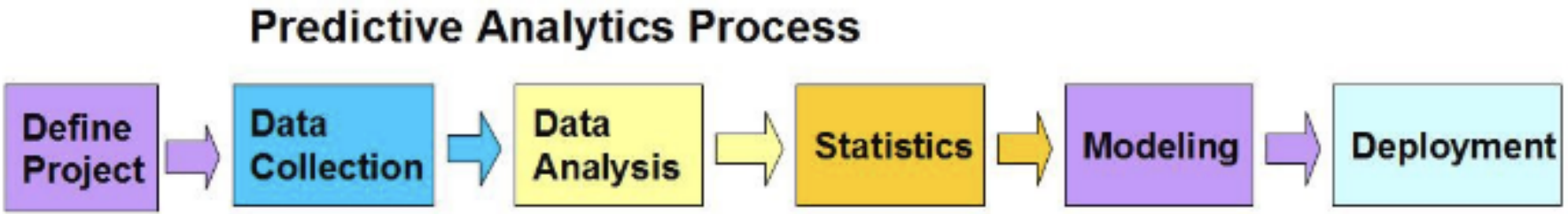
Sensor data by Equipment: eg: temperature sensor, vibration sensor, acoustic sensor, pressure sensor etc.

Three Levels in Predictive Maintenance

Level 3 Model: Deep Neural Network



Analytical Model and Predictive Process



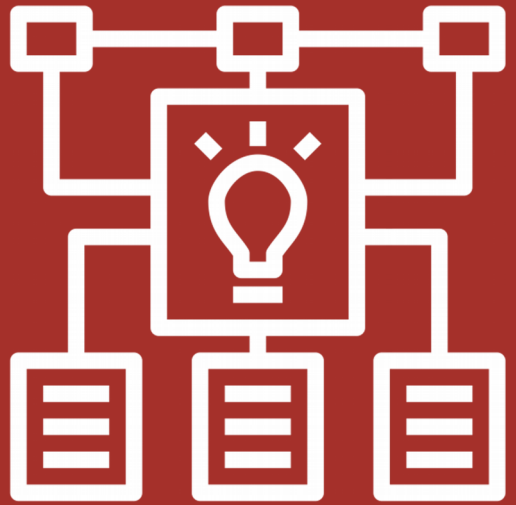
Analytical Model and Predictive Process

Define Project :

The project clearly needs to indicate the questions it needs to answer from the predictive model. There are two main types of questions that can be answered from the model.

What is the probability that a piece of equipment fails in the near future?

What is the remaining useful life of the equipment (RUL)?



Analytical Model and Predictive Process

Data Collection:

The second step in the process is usually all about data filtering and structuring. Many data sources are often quite large and unstructured. So this step is all about extracting structured data from sources.

In terms of predictive maintenance, the data sources can be maintenance records, failure records, machine operating data and feature data

Analytical Model and Predictive Process

Data Analysis and Statistics:

Relevant numerical and categorical variables (independent variables) are then identified which have predictable properties to the target variable (dependent variable).

In terms of predictive maintenance of certain gas-station assets, the independent variables can be Gas station location, the equipment part, the type of problem (eg: Electrical, mechanical, leaks etc), sensor data attached to the equipment.

The dependent variable is the number of days since last maintenance. This variable is calculated from the maintenance log of the particular equipment.

Various statistical techniques are used to ensure the data can account for variance, false positives, and other issues which often crop up from real world data.

Analytical Model and Predictive Process

Model the data:

This step is fundamental as it allows to structure the data in such a way that one can start recognizing patterns that potentially allow to extract future trends.

Models help in formally describing the data. This is helpful in understanding the results from data analysis but is also a good starting point when it comes time to visualise the results.

Analytical Model and Predictive Process

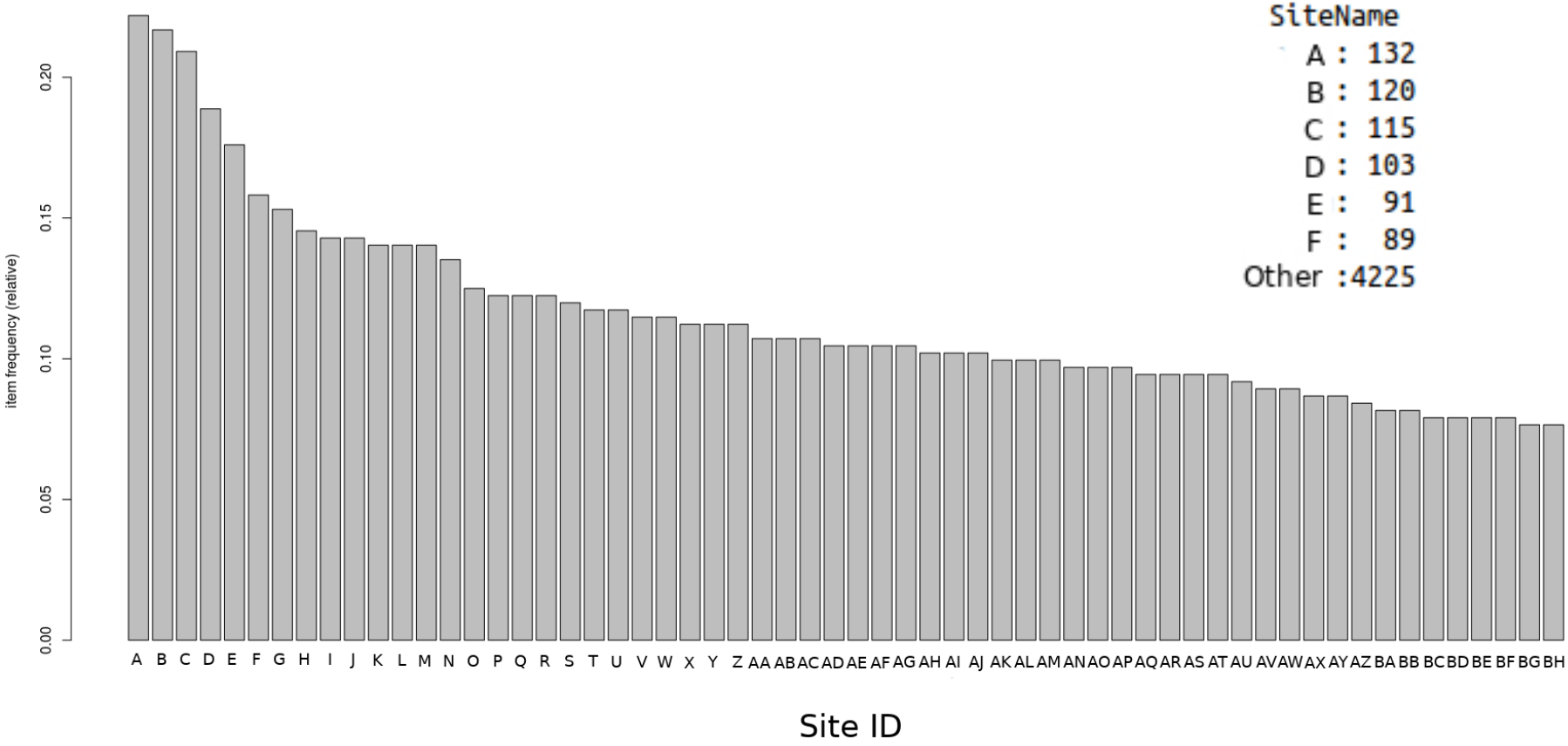
Deployment :

Once the data is extracted, cleaned, quality checked, and fits the model, the test data can be applied to the model to check when a particular asset will fail.

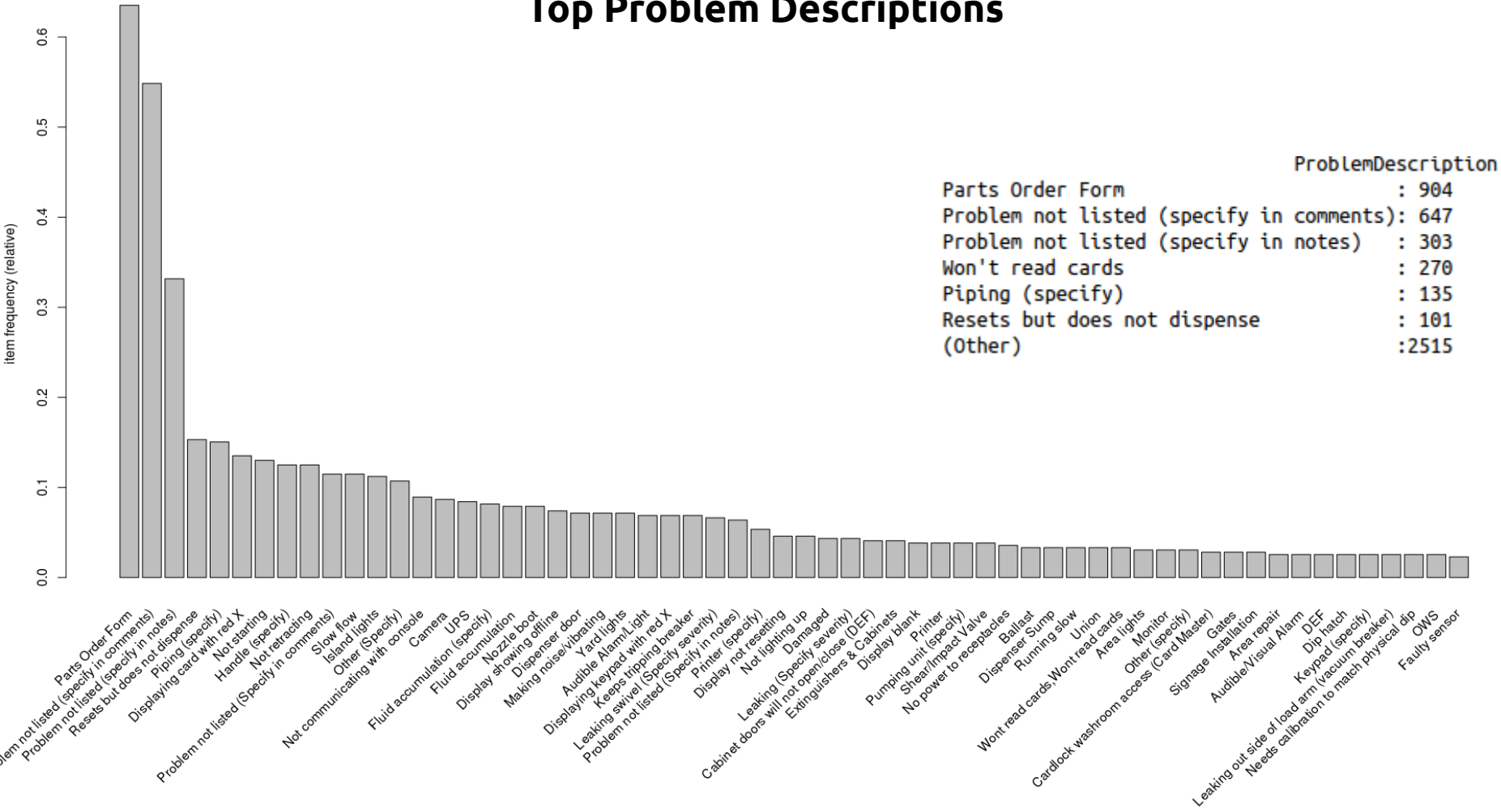
This will help the company to make arrangements beforehand and get the necessary maintenance before the equipment actually fails.

Descriptive Statistics on Maintenance Data for Gas-Stations

Top Sites with most Maintenance tickets



Top Problem Descriptions

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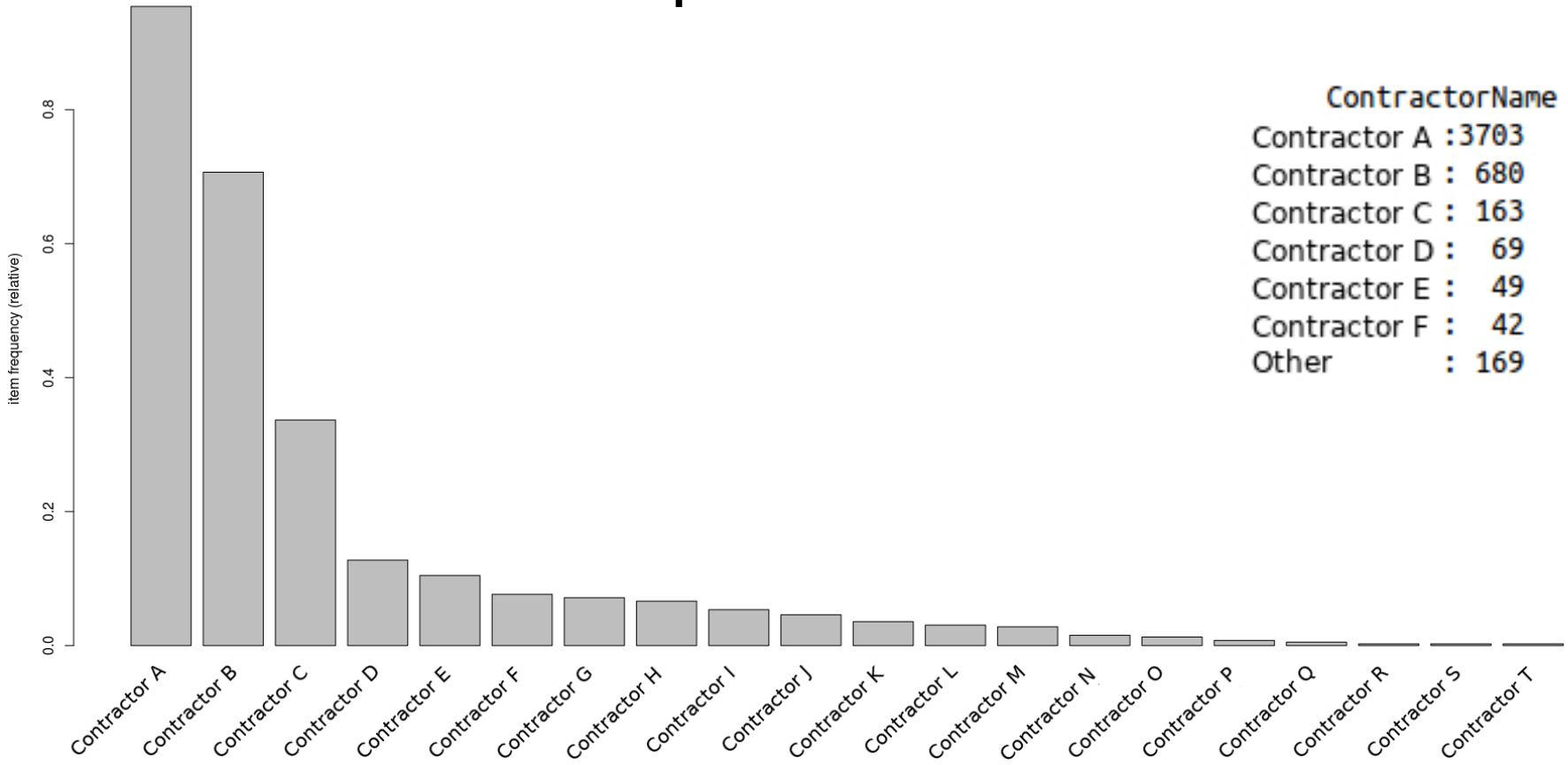
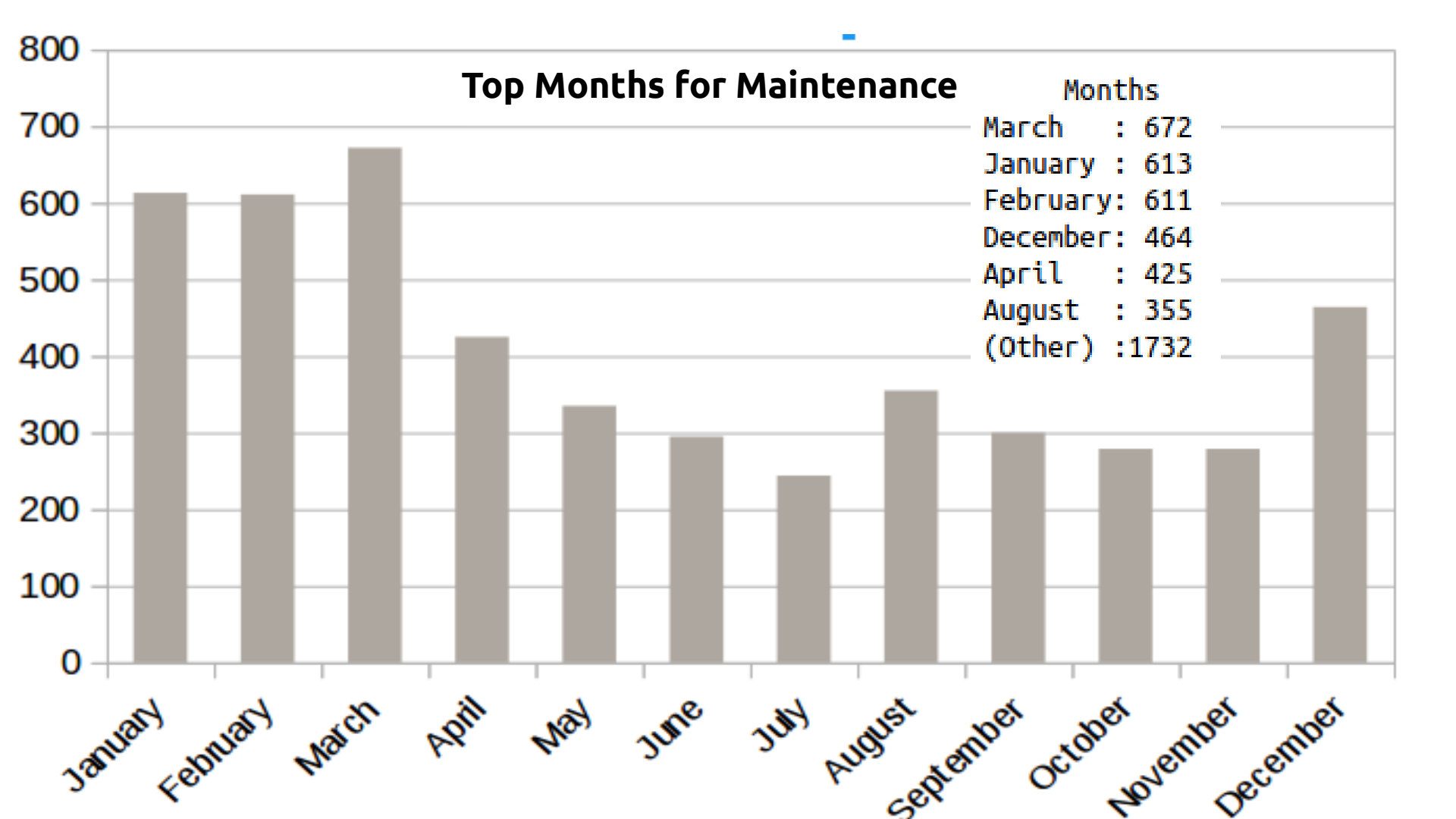
                                                ProblemDescription
Parts Order Form                                          : 904
Problem not listed (specify in comments)                  : 647
Problem not listed (specify in notes)                     : 303
Won't read cards                                          : 270
Piping (specify)                                          : 135
Resets but does not dispense                              : 101
(Other)                                                   :2515
```

Top Contractors



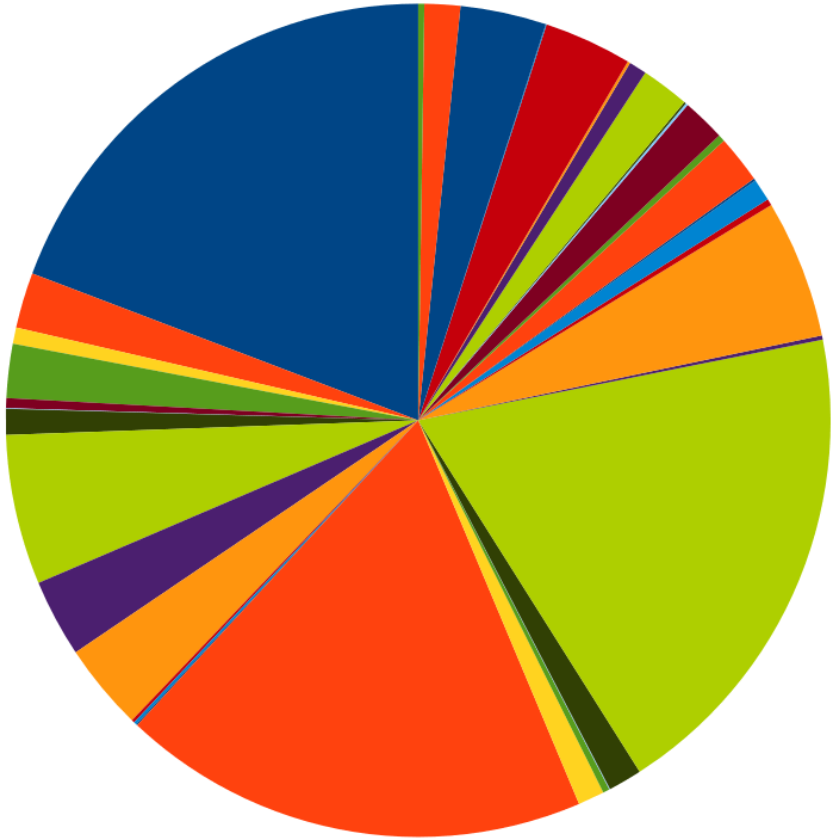
ContractorName	
Contractor A	3703
Contractor B	680
Contractor C	163
Contractor D	69
Contractor E	49
Contractor F	42
Other	169


Top Months for Maintenance
Months
March : 672
January : 613
February: 611
December: 464
April : 425
August : 355
(Other) :1732
800
700
600
500
400
300
200
100
0
January
February
March
April
May
June
July
August
September
October
November
December

Important Statistics on Maintenance Data for Gas-Stations

Contractors	Average cost / ticket
Contractor A	3594.91
Contractor B	1628.89
Contractor C	927.71
Contractor D	879.39
Contractor E	1249.83
Contractor F	92.97
Contractor G	526.17
Contractor H	754.63
Contractor I	595.07
Contractor J	342.75
Contractor K	224.30
Contractor L	109.16
Contractor M	96.93
Contractor N	65.86
Contractor O	14.52
Contractor P	11.11
Contractor Q	0.00
Contractor R	0.00
Contractor S	0.00
Contractor T	0.00

Cost-breakdown for all Equipment



Parts Ordered
Other
A/G piping
A/G tanking
Access/Egress
Alarm System
Back Office
Bulk Loading
Bulk Pump
Cardlock Islands
CCTV
Cladding
compliance
Dispenser
Electrical
Fences
Flooring
HVAC
Illuminated Signage
Island Terminals
Line Safety
Lightning
Loss Investigation
Main Controller/Box
Mechanical Gauge
Oil water Separator
Paving
Plumbing
Probe
Product Down
Roofing
Sensor
Site Down
Stairs/Platform/Ladder
Sumps
Tank farm
Transfer Pump
U/G Tank
Warehouse
WasteOil
Windows

Parts Ordered	19.27%
Island Terminals	19.08%
Dispenser	18.32%
Bulk Loading	5.82%
Lightning	5.38%
Sumps	3.45%
Cardlock Islands	3.39%
Transfer Pump	3.37%
Bulk Pump	3.02%
Other	2.16%
A/G tanking	2.09%
Sensor	1.88%
Oil water Separator	1.86%
Probe	1.69%
U/G Tank	1.40%
Illuminated Signage	1.32%
Electrical	1.03%
Back Office	1.00%
Main Controller/Box	0.87%
Site Down	0.70%
A/G piping	0.63%
Access/Egress	0.39%
Plumbing	0.27%
Fences	0.26%
Loss Investigation	0.25%
WasteOil	0.24%
Line Safety	0.16%
CCTV	0.11%
Cladding	0.11%
Stairs/Platform/Ladder	0.11%
Product Down	0.09%
Mechanical Gauge	0.09%
Roofing	0.08%
compliance	0.05%
Tank farm	0.03%
HVAC	0.03%
Alarm System	0.02%
Flooring	0.00%
Windows	0.00%
Warehouse	0.00%
Paving	0.00%

PdM Level-1 Data Collection Process

For each type of equipment that needs to be predictively maintained, two essential documents need to be made with data regarding that particular type of equipment from ALL sites.

Two Essential Documents needed :

Event Log : This document will report on different types of events affecting the equipment with other independent variables influencing its health.

Dependent Variable Log : This document will report on our predictive variable. The level-1 predictive variable is “Days between maintenance”.

Event Log

Equipment ID	Event ID	Type of Equipment	Subrepair part	Type of Event	Severity	Reason (Code)	Location	Date
Asset01	Event01	Dispenser	Pumping unit	Breakdown trigger	Level 1	A	Vancouver	2018-01-01
Asset02	Event02	Dispenser	Temperature probe	Time Trigger	Level 2	B	Calgary	2018-01-02
Asset03	Event03	Dispenser	Shear/Impact Valve	Usage Trigger	Level 3	C	Winnipeg	2018-01-03
Asset04	Event04	Dispenser	Dispenser door	External Event Trigger	Level 2	D	Halifax	2018-01-04
Asset05	Event05	Dispenser	Piping	Condition based trigger	Level 3	E	Montreal	2018-01-05

Each type of equipment will have its own event log documenting that type of equipment from ALL sites.

From the figure above, each event needs to be classified with its severity and its reason. Any other variables which affect the equipment and the event need to be classified into codes as shown above.

The top independent variables which can affect the life of the equipment or event from the log above are “Type of Event”, “Severity”, “Reason” and “location”.

For every new event relating to any equipment ID, A new row documenting the event is to be created.

The point of choosing the right independent variables is to find accurate correlations towards the dependent or predictive variable (Days between Maintenance).

Dependent Variable Log

Equipment ID	Days Between Maintenance	Type of Equipment	Date of last maintenance	Date of current maintenance	Days in Service
Asset01	35	Dispenser	2017-01-02	2018-01-01	250
Asset02	45	Dispenser	2017-04-02	2018-01-02	300
Asset03	55	Dispenser	2017-05-03	2018-01-03	365
Asset04	15	Dispenser	2017-06-04	2018-01-04	400
Asset05	240	Dispenser	2017-07-05	2018-01-05	175

Each type of equipment will have its own dependent variable log documenting that type of equipment from ALL sites.

From the figure above, each asset needs to be classified with its type of equipment, Days between maintenance, Date of last maintenance, Date of Current maintenance and Days in Service.

For every new maintenance event relating to any equipment ID, A new row documenting the maintenance event is to be created.

The days between maintenance is the predictive variable the level-1 model is based on.

Predictive Maintenance Workflow

Dispenser_Event_Log

Dispenser_Dependent_variable_Log

SQC

Site Quality Control

PREDICTION

Maintenance before x days

Maintenance after x days

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