Best Machine Ever

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Business Problem

How can we reduce the frequency of factory machine failures by identifying and addressing the most impactful failure causes?

- Reducing the frequency of factory machine failures is crucial for the efficiency and reliability of machines
- Identifying the most impactful failures is important for productivity, optimizing costs, and better allocation of resources
- By addressing machine failures we can help find ways to reduce downtime and ensure safer and better quality machines

Background

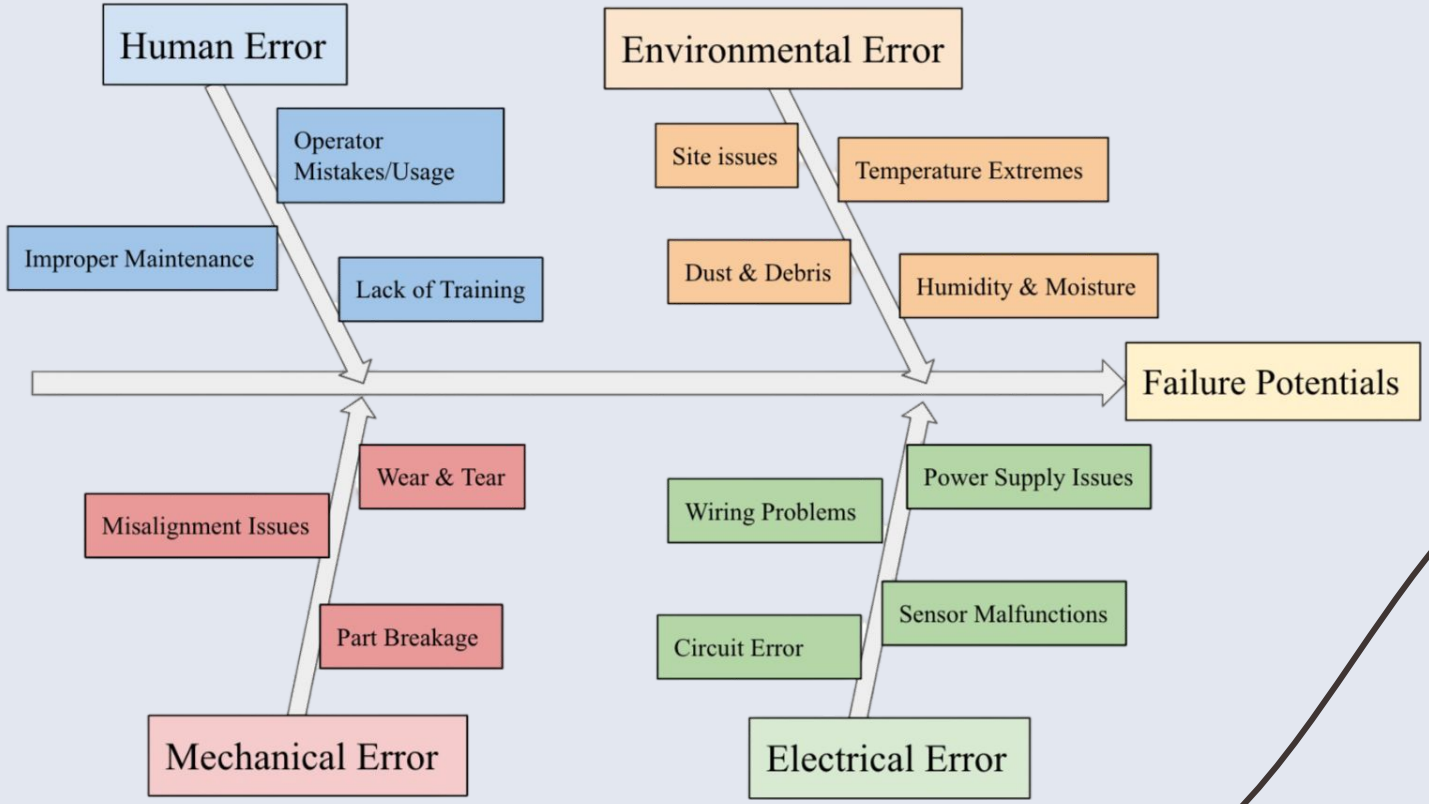
- On average, large manufacturing plants lose 323 production hours per year
- Average downtime cost is $532,000 per hour
- In the automotive sector, downtime cost can be as much as 20% of revenue
- This increases costs of products and reduces profit margins

Who this affects

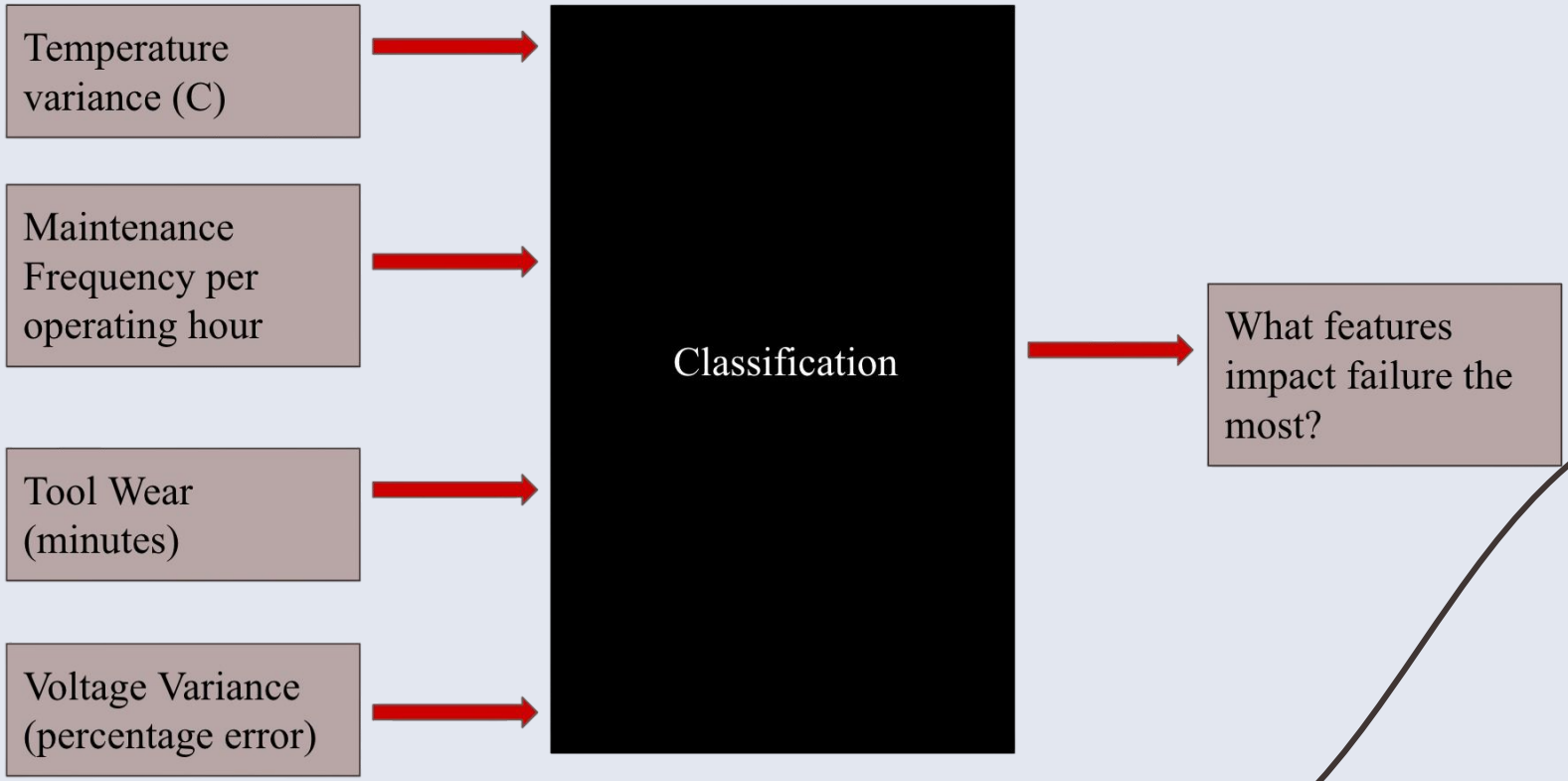
- Manufacturers through increased costs
- People who buy manufactured goods through higher prices for the same goods
- People who use services that rely on factory manufactured goods

So..... Everyone!

Analytic


Human Error
Operator Mistakes/Usage
Improper Maintenance
Lack of Training
Environmental Error
Site issues
Temperature Extremes
Dust & Debris
Humidity & Moisture
Failure Potentials
Wear & Tear
Misalignment Issues
Part Breakage
Mechanical Error
Power Supply Issues
Wiring Problems
Sensor Malfunctions
Circuit Error
Electrical Error

Black Box


Temperature variance (C)
Maintenance Frequency per operating hour
Tool Wear (minutes)
Voltage Variance (percentage error)
Classification
What features impact failure the most?

Data Summary

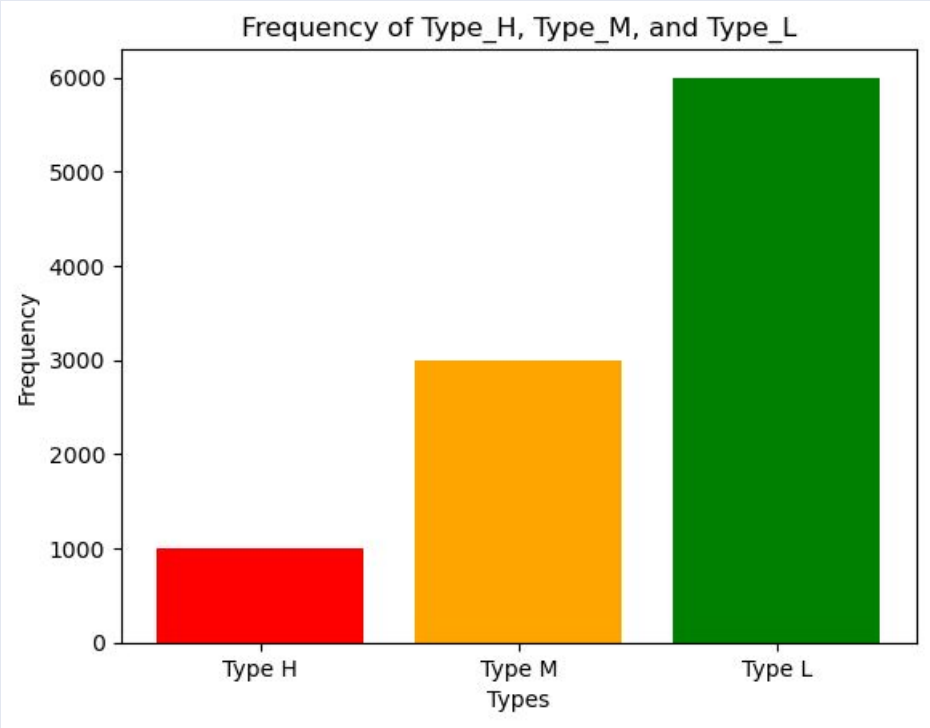
- **Name:** AI4I 2020 Predictive Maintenance Dataset
- **Original Data Set:** Matzka, Stephan. “Explainable Artificial Intelligence for Predictive Maintenance Applications.” *2020 Third International Conference on Artificial Intelligence for Industries (AI4I)* (2020): 69-74. (MLA)
- **Data File:** Excel Spreadsheet (2D Array)
- **Structure:** Tabular
- **Rows:** 10,000 rows
- **Features:** 15
- **Target:** possible feature(s) that caused failures

Data Features

	Feature Name	Data Type	Missing Values	Sample/Unique Values	Description
0	UDI	int64	0	5190	Unique identifier for each data point
1	Product ID	object	0	[H35323, L47249, M16184, L48676, L50791, L5103...	ID representing the product being manufactured
2	Type	object	0	[H, L, M]	Category of the product (H, L, M)
3	Air temperature [K]	float64	0	298.5	Temperature of the air in Kelvin
4	Process temperature [K]	float64	0	311.1	Temperature of the process in Kelvin
5	Rotational speed [rpm]	int64	0	1596	Speed of the machine in rotations per minute
6	Torque [Nm]	float64	0	72.0	Torque applied during operation in Newton-meters
7	Tool wear [min]	int64	0	210	Time of tool usage before wear in minutes
8	Machine failure	int64	0	0	Binary indicator of machine failure
9	TWF	int64	0	0	Tool wear failure indicator
10	HDF	int64	0	0	Heat dissipation failure indicator
11	PWF	int64	0	0	Power failure indicator
12	OSF	int64	0	0	Overstrain failure indicator
13	RNF	int64	0	0	Random failure indicator
14	diff	int64	0	0	Difference between computed values?

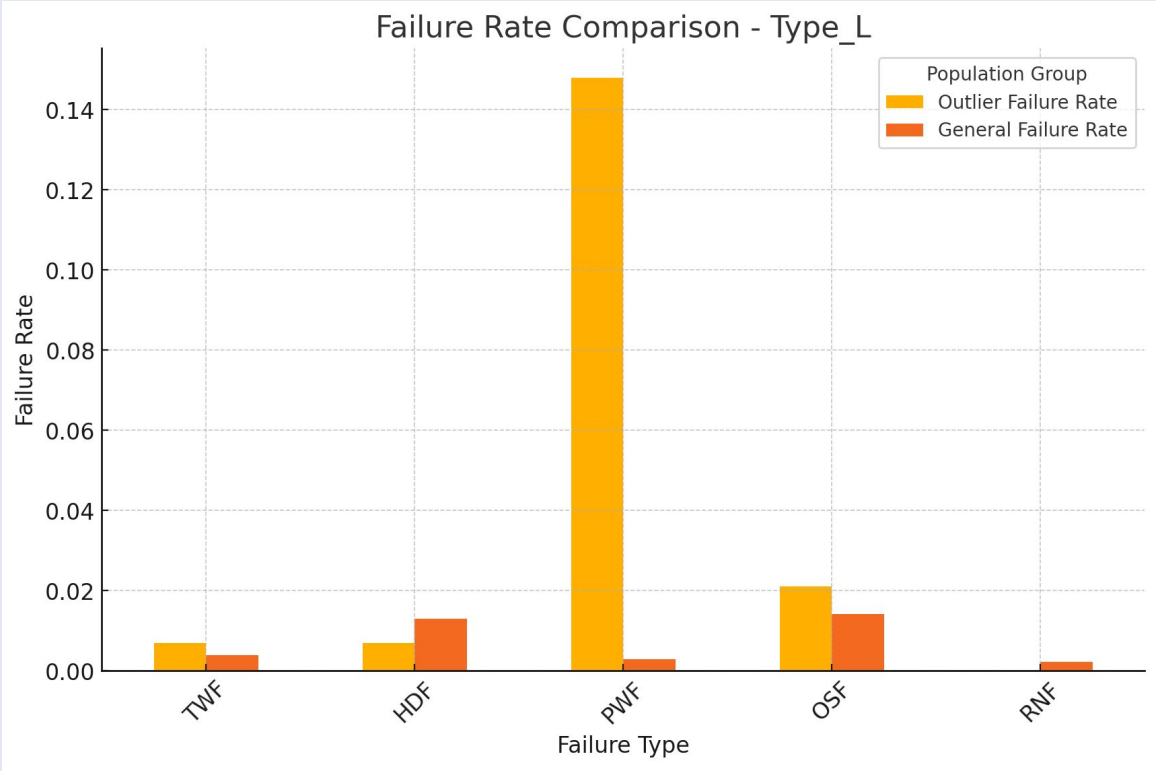
One-hot Encoding

- Processed machine type column (H/M/L) using one-hot encoding
- Updated failures to boolean

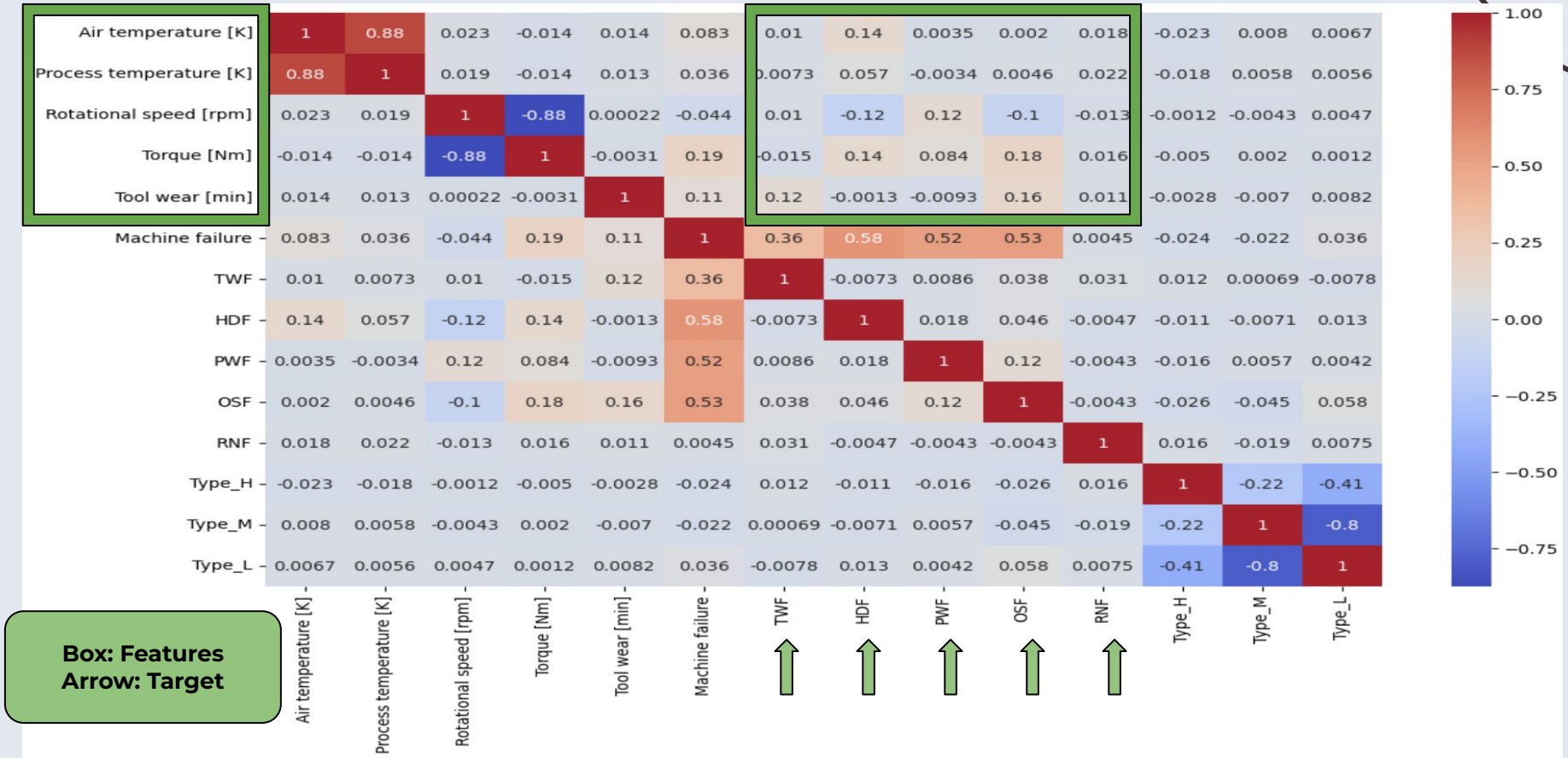


Outliers

1. Torque [NM] 25
2. Rotational speed 136
3. remove/not remove
4. Relevant/Correlate with failure type.
5. Important predicts outcome.
6. Decision / effect # failure type.

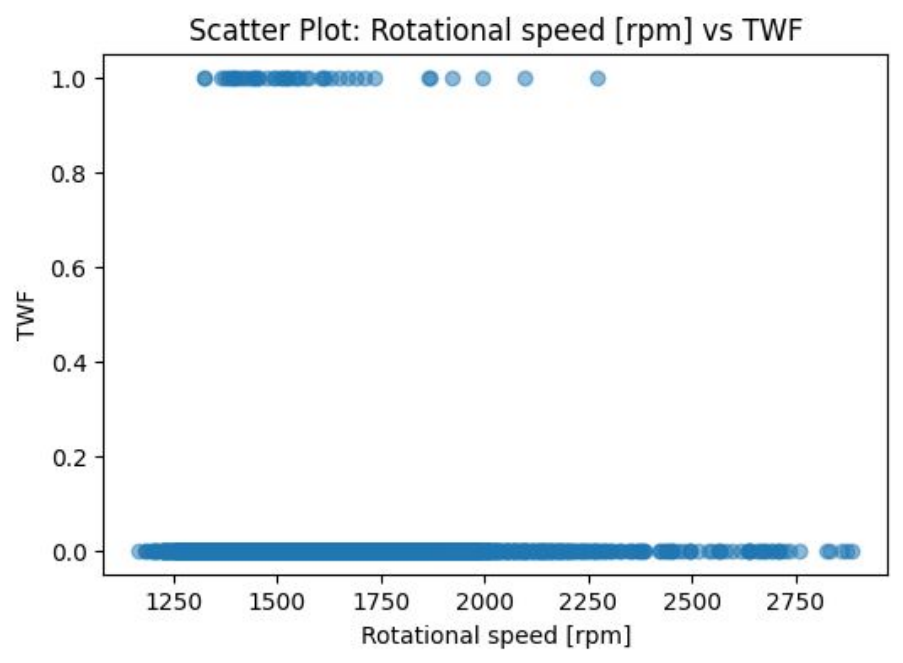


Correlation Matrix



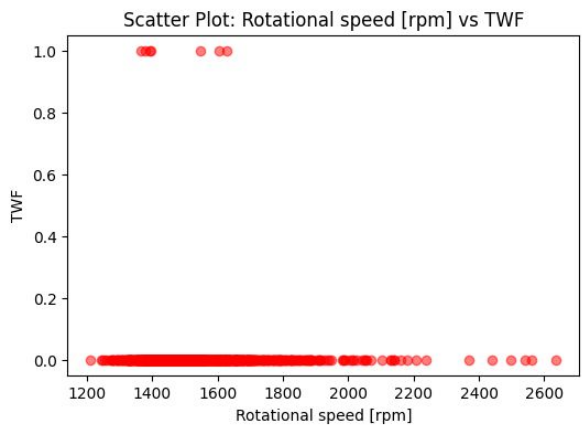
Box: Features
Arrow: Target

Assumption by Type_X feature (H, M, L)

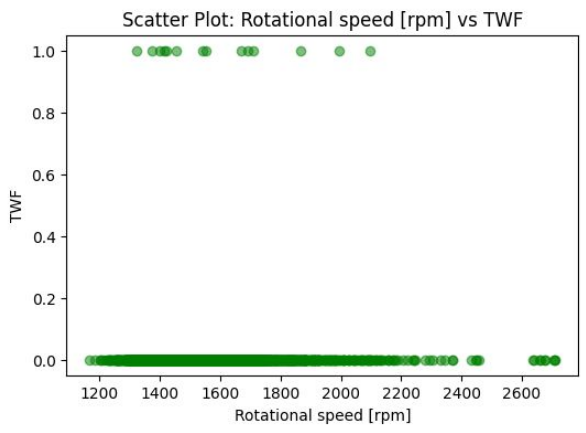


Range in 1250 to 1750 of RPM may cause Tool Wear Failure.

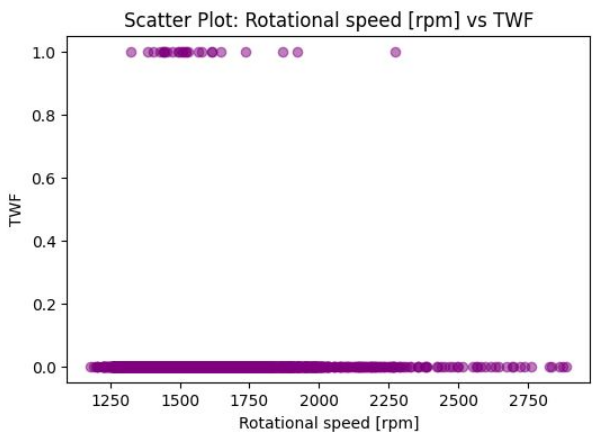
Assumption by Type_X feature (H, M, L)



High quality



Medium quality



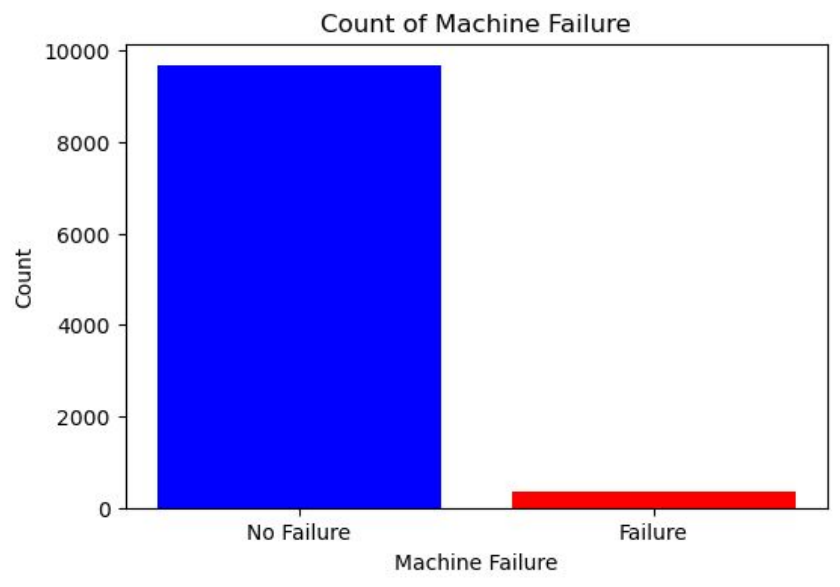
Low quality

Lower the cost of the part causes more failures.

Answer to assumption: For the RPM part, we use high quality of parts to reduce the chance to be failed by Tool Wear Failure.

Future Work

Imbalance



No Failure
96.61%

Failure
3.39%

Scaling

	Air temperature [K]	Process temperature [K]	Rotational speed [rpm]	Torque [Nm]	Tool wear [min]
count	10000.000000	10000.000000	10000.000000	10000.000000	10000.000000
mean	300.004930	310.005560	1538.776100	39.986910	107.951000
std	2.000259	1.483734	179.284096	9.968934	63.654147
min	295.300000	305.700000	1168.000000	3.800000	0.000000
25%	298.300000	308.800000	1423.000000	33.200000	53.000000
50%	300.100000	310.100000	1503.000000	40.100000	108.000000
75%	301.500000	311.100000	1612.000000	46.800000	162.000000
max	304.500000	313.800000	2886.000000	76.600000	253.000000

Feature Selection

- Type_X (H, M, L)
- Air temp (K)
- Process temp (K)
- Rotational speed (rpm)
- Torque (Nm)
- Tool wear (min)

tool wear failure (TWF): the tool will be replaced of fail at a randomly selected **tool wear** time between 200 mins to 240 mins
heat dissipation failure (HDF): heat dissipation causes a process failure, if the difference between **air- and process temperature** is below 8.6 K and the tool's **rotational speed** is below 1380 rpm.
power failure (PWF): the product of **torque** and **rotational speed** (in rad/s) equals the power required for the process.
overstrain failure (OSF): if the product of **tool wear** and **torque** exceeds 11,000 minNm for the L product variant (12,000 M, 13,000 H), the process fails due to overstrain.
random failures (RNF): each process has a chance of 0,1 % to fail regardless of its process parameters. **(19/339 = 5.6% of all) TBA**

Citations

*We also used Professor Holly Russo's CDS 303-001 slide deck

Matzka, Stephan. "Explainable Artificial Intelligence for Predictive Maintenance Applications." 2020 Third International Conference on Artificial Intelligence for Industries (AI4I) (2020): 69-74.

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Questions