Deep Learning Gas Engine Health Assessment

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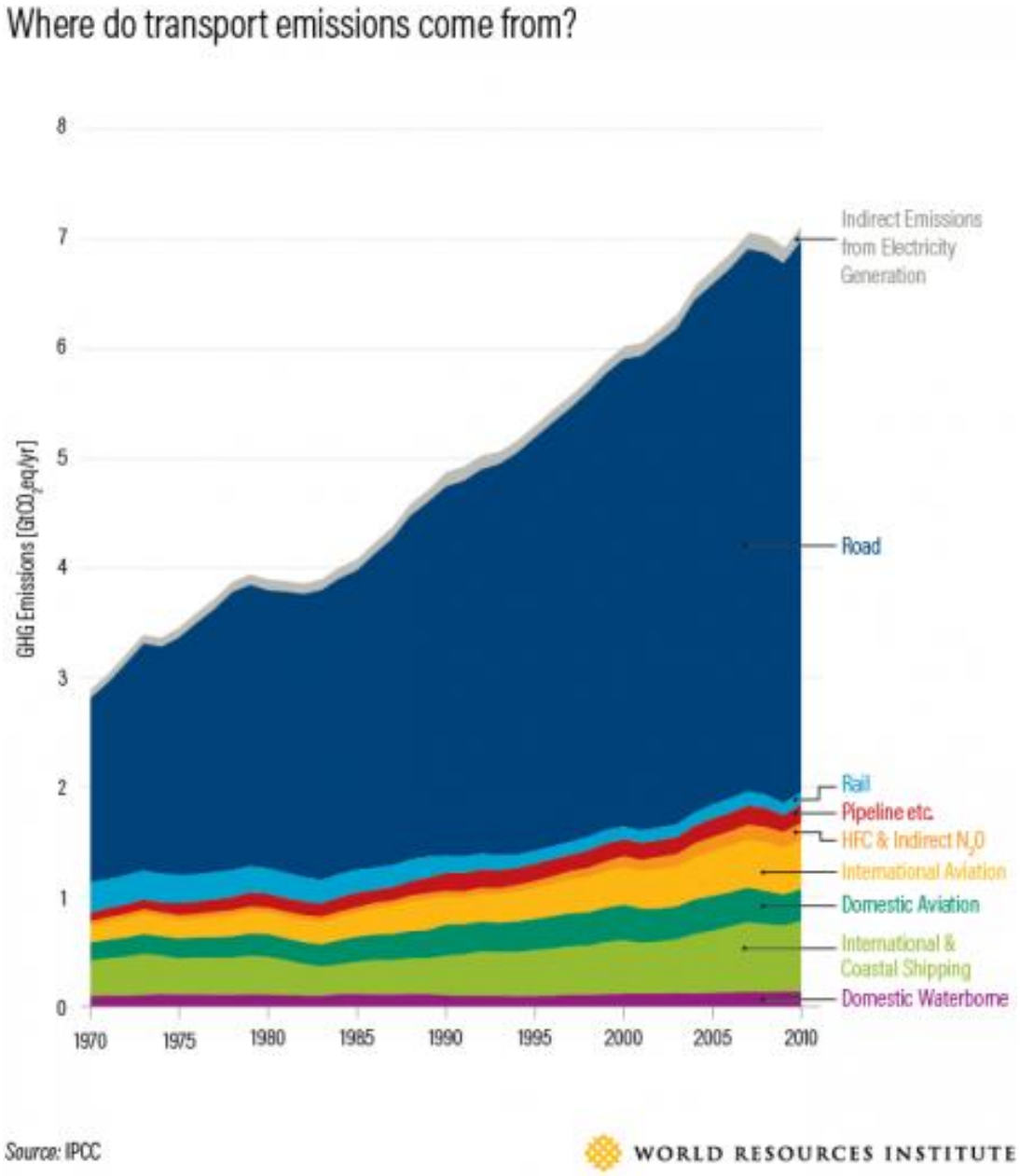
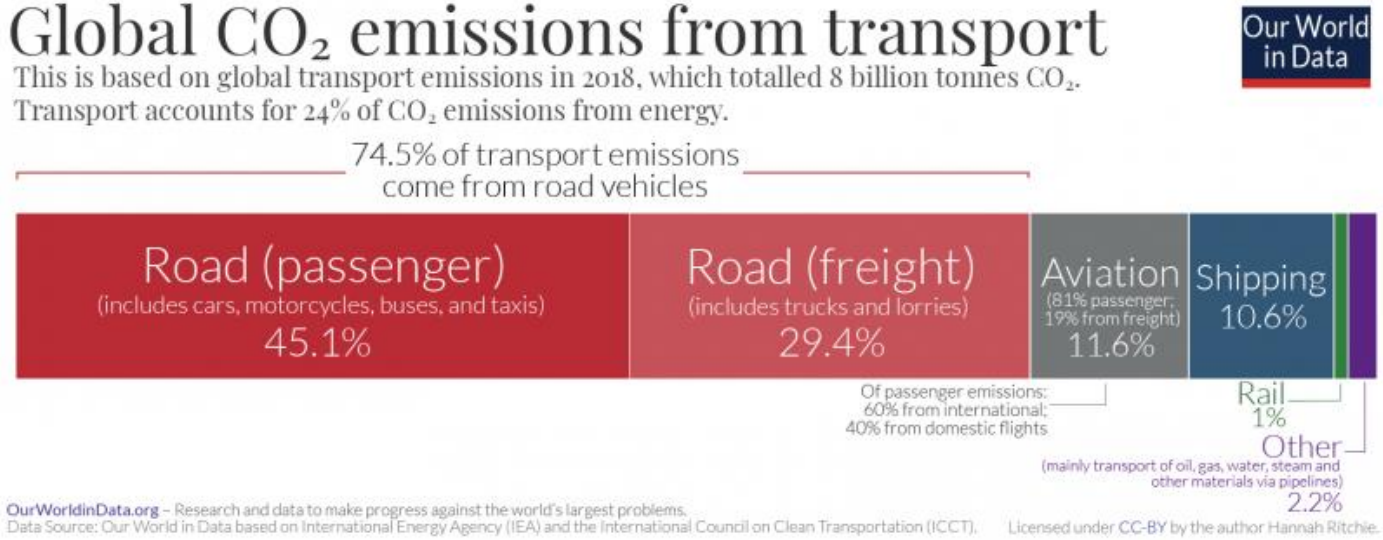
Topics

- Introduction
- Gas engine under study
- Methodology
- Results and discussion
- Conclusions

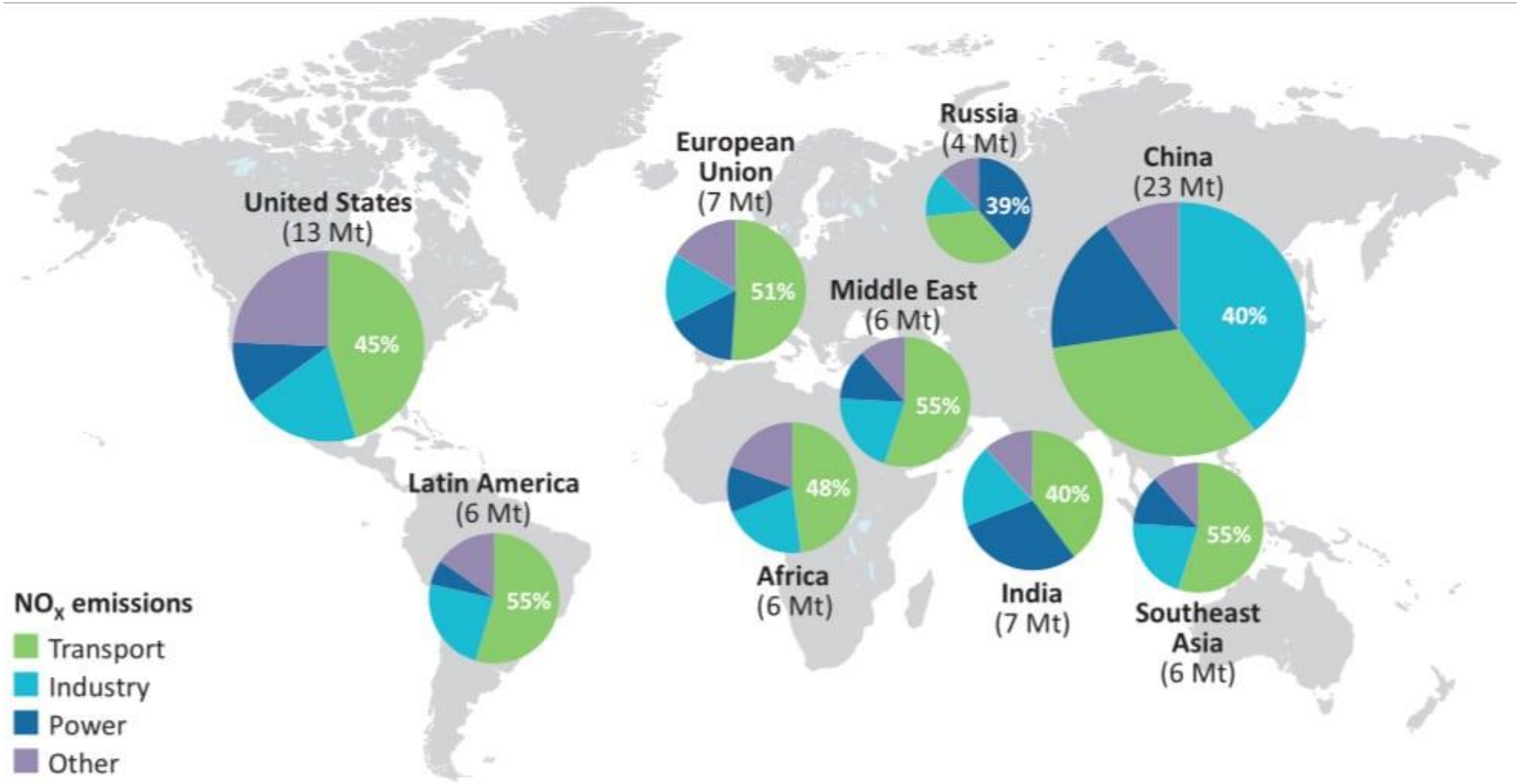
Introduction

Motivation

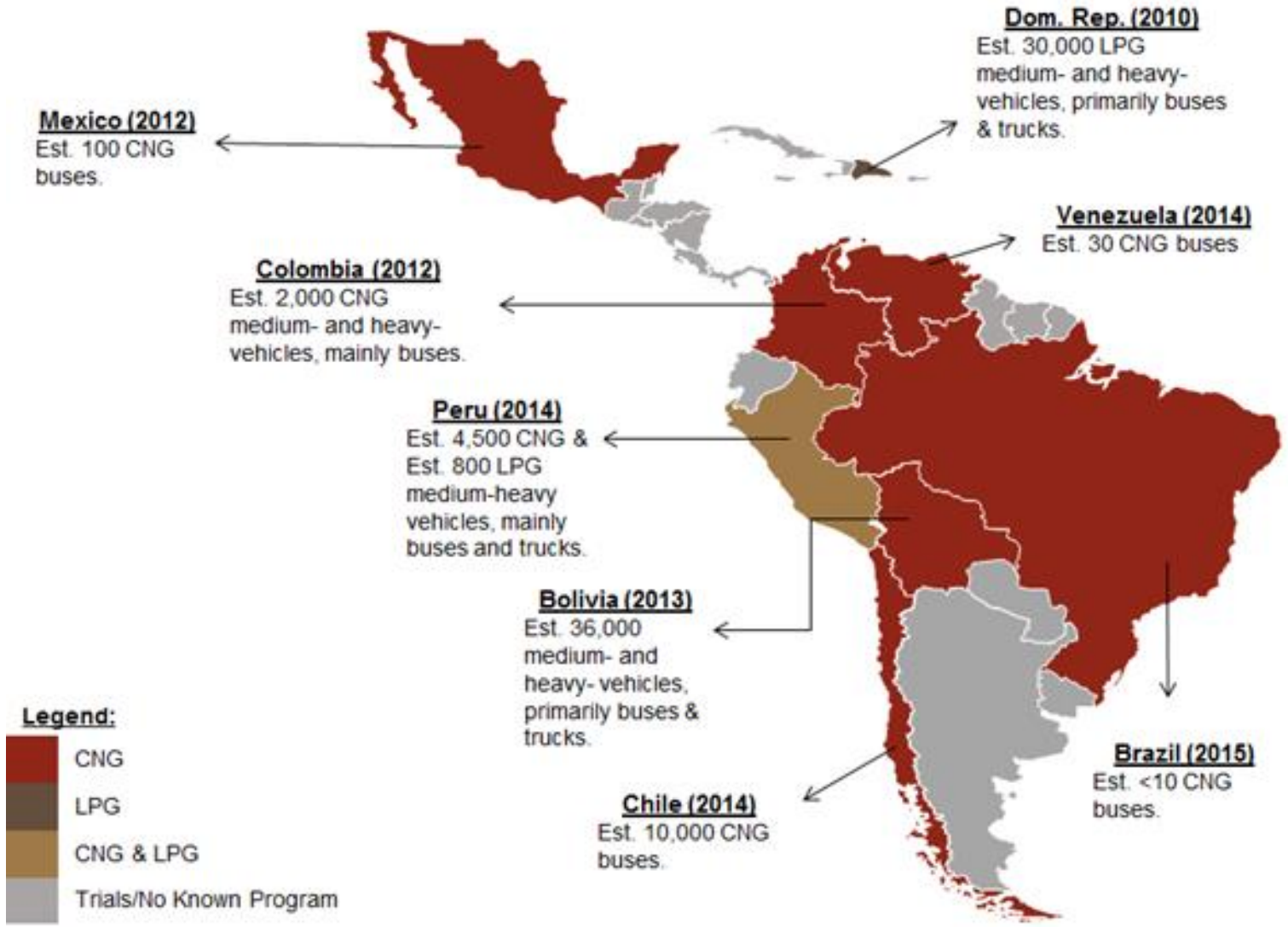

Where do transport emissions come from?
GHG Emissions [GtCO2eq/yr]
8
7
6
5
4
3
2
1
0
1970
1975
1980
1985
1990
1995
2000
2005
2010
Indirect Emissions from Electricity Generation
Road
Rail
Pipeline etc.
HFC & Indirect N2O
International Aviation
Domestic Aviation
International & Coastal Shipping
Domestic Waterborne
Source: IPCC
WORLD RESOURCES INSTITUTE


Global CO_2 emissions from transport
This is based on global transport emissions in 2018, which totalled 8 billion tonnes CO_2.
Transport accounts for 24% of CO_2 emissions from energy.
Our World in Data
74.5% of transport emissions come from road vehicles
Road (passenger)
(includes cars, motorcycles, buses, and taxis)
45.1%
Road (freight)
(includes trucks and lorries)
29.4%
Aviation
(81% passenger; 19% from freight)
11.6%
Shipping
10.6%
Of passenger emissions:
60% from international;
40% from domestic flights
Rail
1%
Other
(mainly transport of oil, gas, water, steam and other materials via pipelines)
2.2%
OurWorldinData.org – Research and data to make progress against the world's largest problems.
Data Source: Our World in Data based on International Energy Agency (IEA) and the International Council on Clean Transportation (ICCT).
Licensed under CC-BY by the author Hannah Ritchie.

Motivation


United States
(13 Mt)
45%
European
Union
(7 Mt)
51%
Russia
(4 Mt)
39%
China
(23 Mt)
40%
Middle East
(6 Mt)
55%
Latin America
(6 Mt)
55%
48%
Africa
(6 Mt)
40%
India
(7 Mt)
55%
Southeast
Asia
(6 Mt)
NOx emissions
Transport
Industry
Power
Other

Motivation



Natural gas-based engines have become a crucial asset in the South American transportation sector. However, the share of natural-gas vehicles in the current vehicle market is still estimated to be below **5%.**

Gas engine

Vehicle applications of gas engine

Medium-duty

Heavy-duty

Light commercial

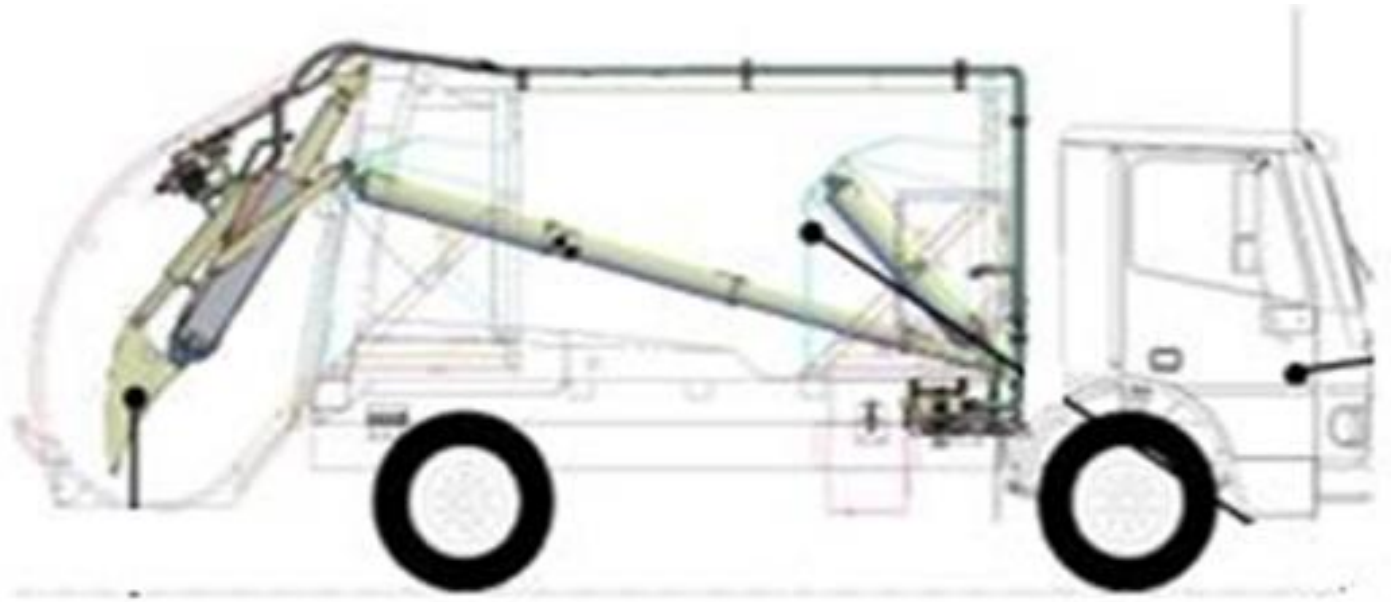
Vocational

Gas engine under study

248 Routes

Operation continues

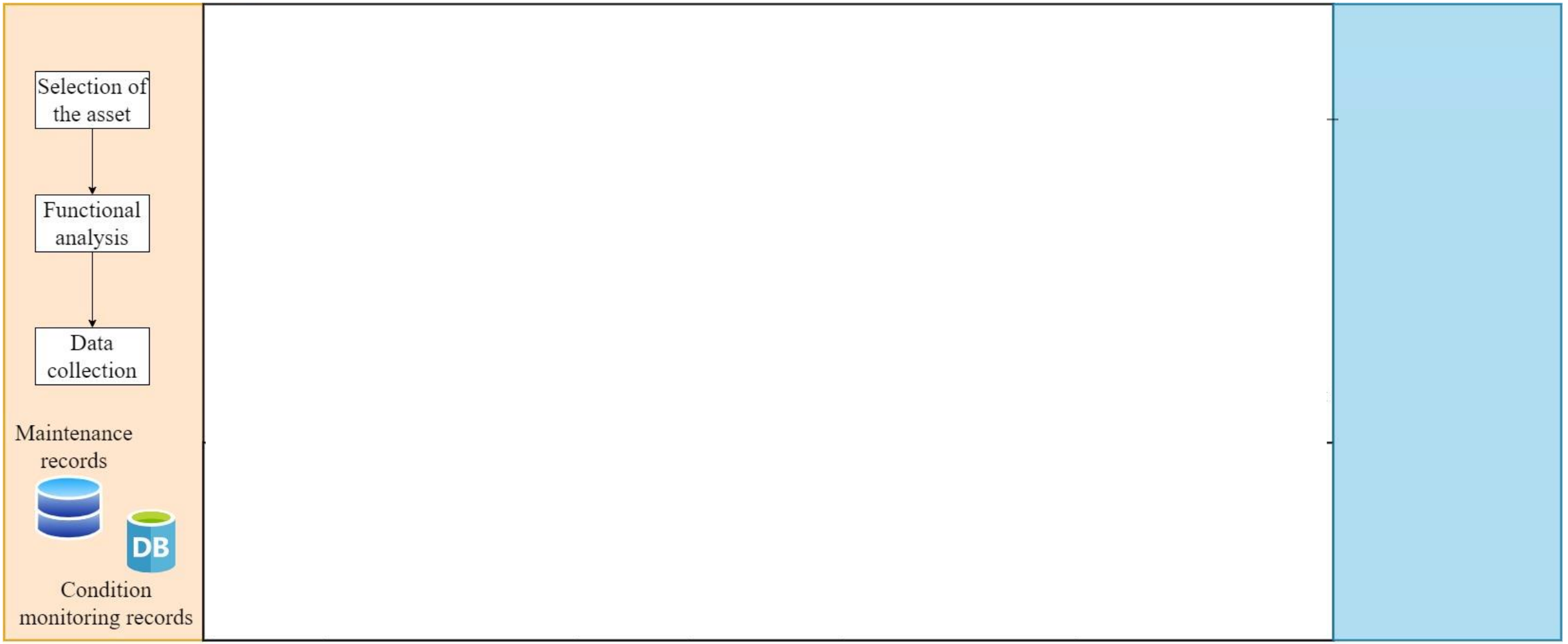
Complex operating conditions



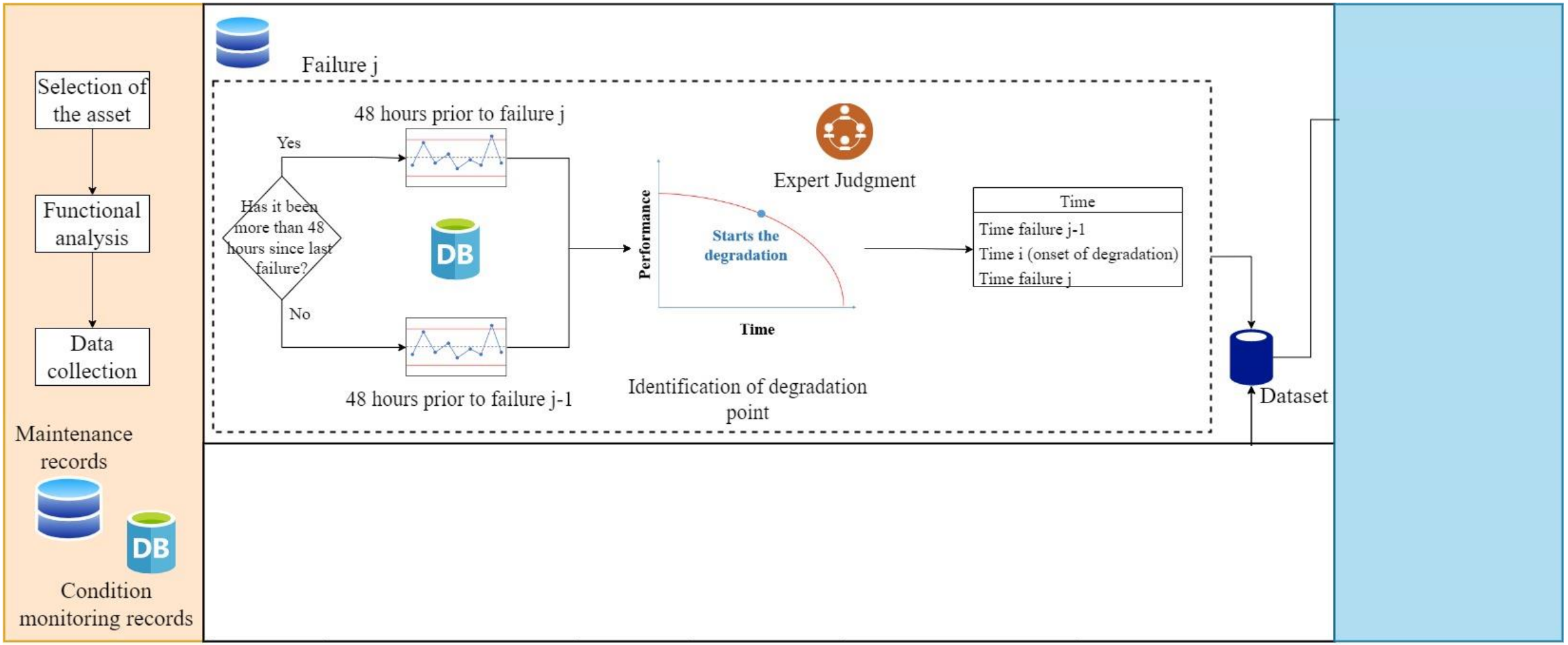
Operational data available

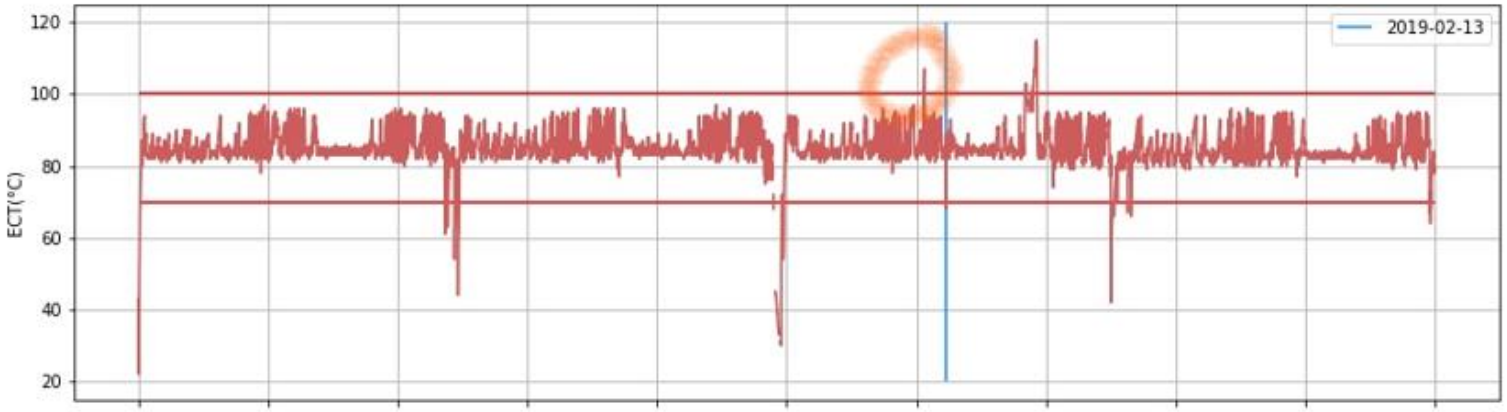
Abbreviation	Description	Unit	Operational Parameters	
			Minimum	Maximum
Altitude	The point reached by the vehicle in relation to sea level	meter	1100	1750
ODOM	Number of kilometres travelled by the vehicle (accumulated)	km	0	NA
ECT	Temperature reached by the coolant	ºC	70	100
RPM	Describes the rate at which the rotor is revolving, which is the number of times the rotor shaft completes a full rotation each minute	rpm	150	2200
ETBP	Turbo pressure	kPa	10	25
EIMT	Air intake temperature	ºC	60	120
TH	Number of hours operated by the vehicle (accumulated)	horas	0	NA
WVS	Speed reached by the vehicle	km/h	70	92.8
FDS	Fan Status	states	0	1
APP	Accelerator pedal position	%	0	100
ECL	Coolant level	%	80	100
EOP	Oil pressure	kPa	69	207
CC2	Cruise mode enabled	states	0	1
CC3	Brake pedal status	states	0	1

Methodology

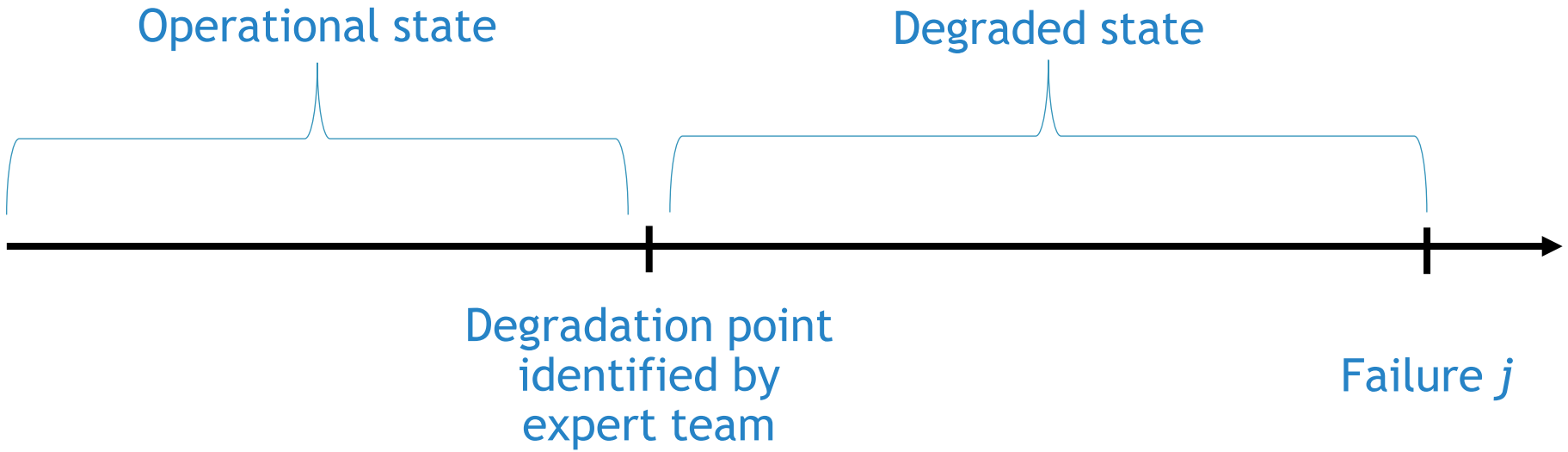


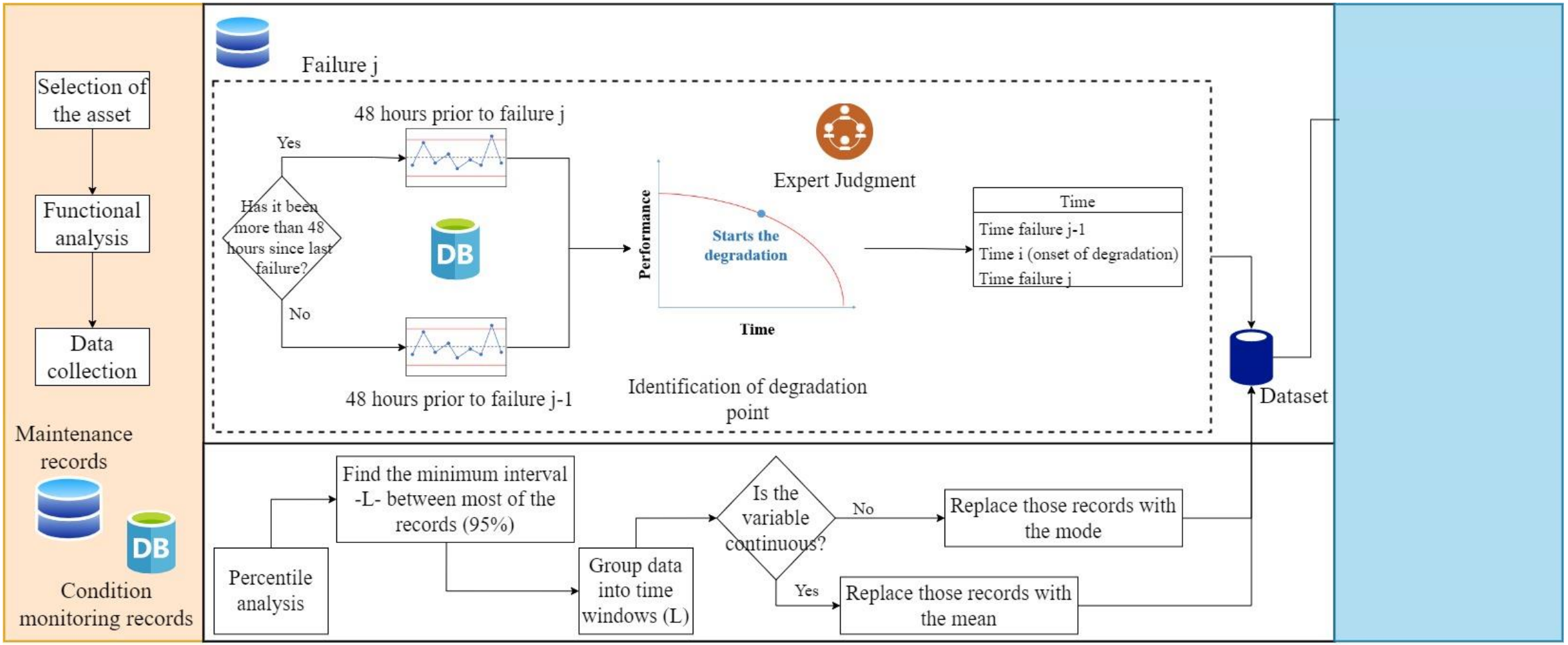
Problem setting | Data pre-processing | Data modeling


Selection of the asset
Functional analysis
Data collection
Maintenance records
DB
Condition monitoring records
Failure j
48 hours prior to failure j
Yes
Has it been more than 48 hours since last failure?
No
DB
48 hours prior to failure j-1
Expert Judgment
Performance
Starts the degradation
Time
Identification of degradation point
Time
Time failure j-1
Time i (onset of degradation)
Time failure j
Dataset
Problem setting
Data pre-processing
Data modeling



For each failure *j* the team of experts discussed from different points of view the relationship between the behavior of the variables and the type of failure reported by the maintenance team, to identify the abnormal behavior of the data that evidenced the beginning of the degradation of the system.

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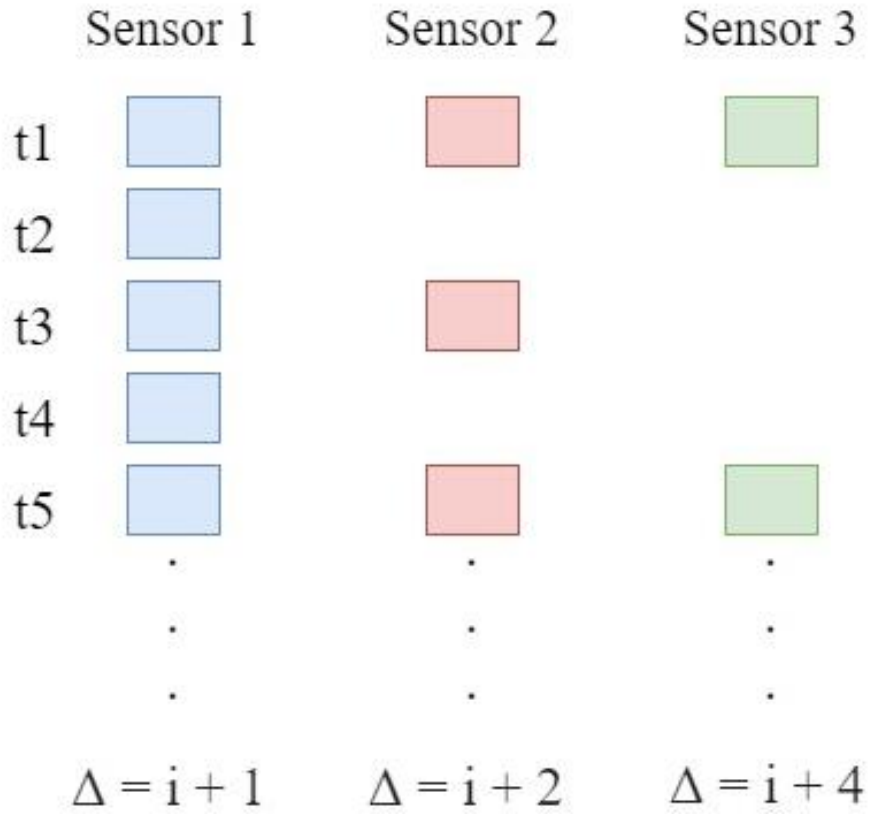
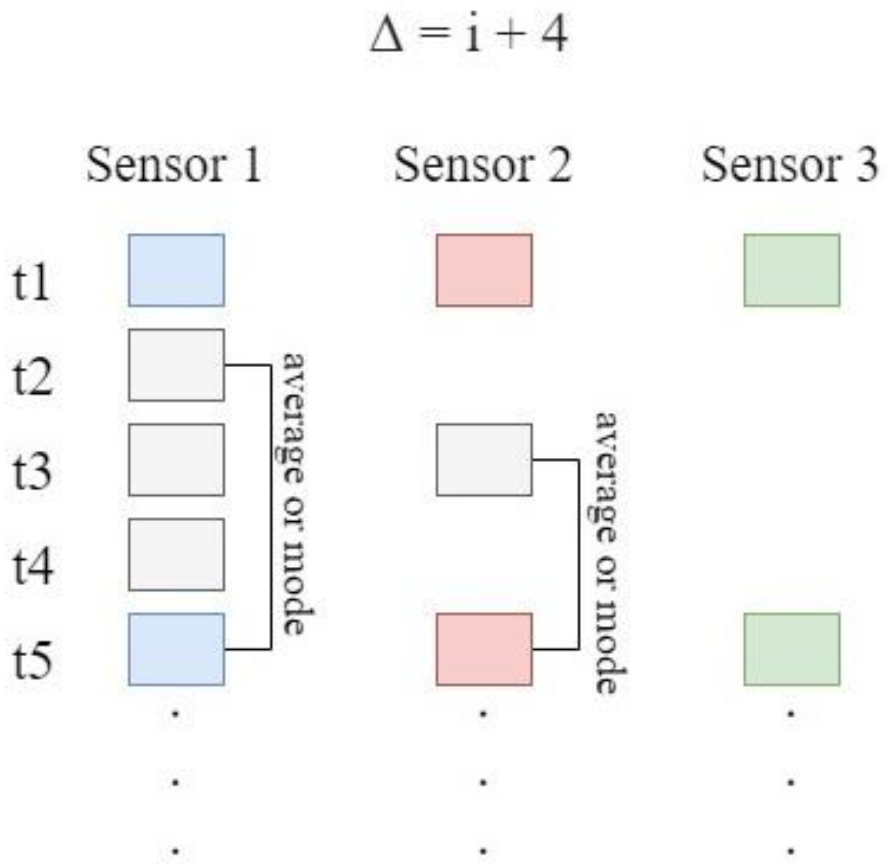
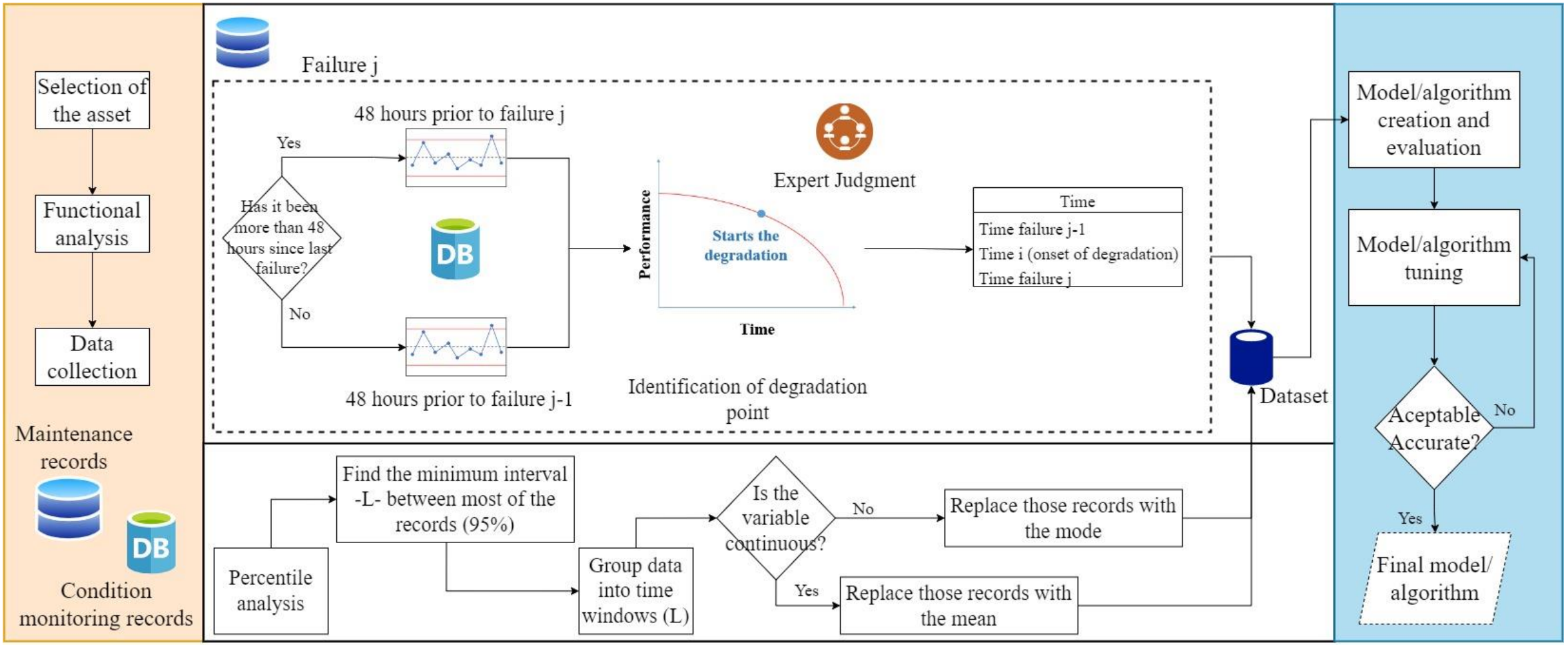
Time i (onset of degradation)
Time failure j
Dataset
Percentile analysis
Find the minimum interval -L- between most of the records (95%)
Group data into time windows (L)
Is the variable continuous?
No
Replace those records with the mode
Yes
Replace those records with the mean
Problem setting
Data pre-processing
Data modeling



identify the minimum interval representing 95% of the data collected by each sensor

Select the maximum among the minimums





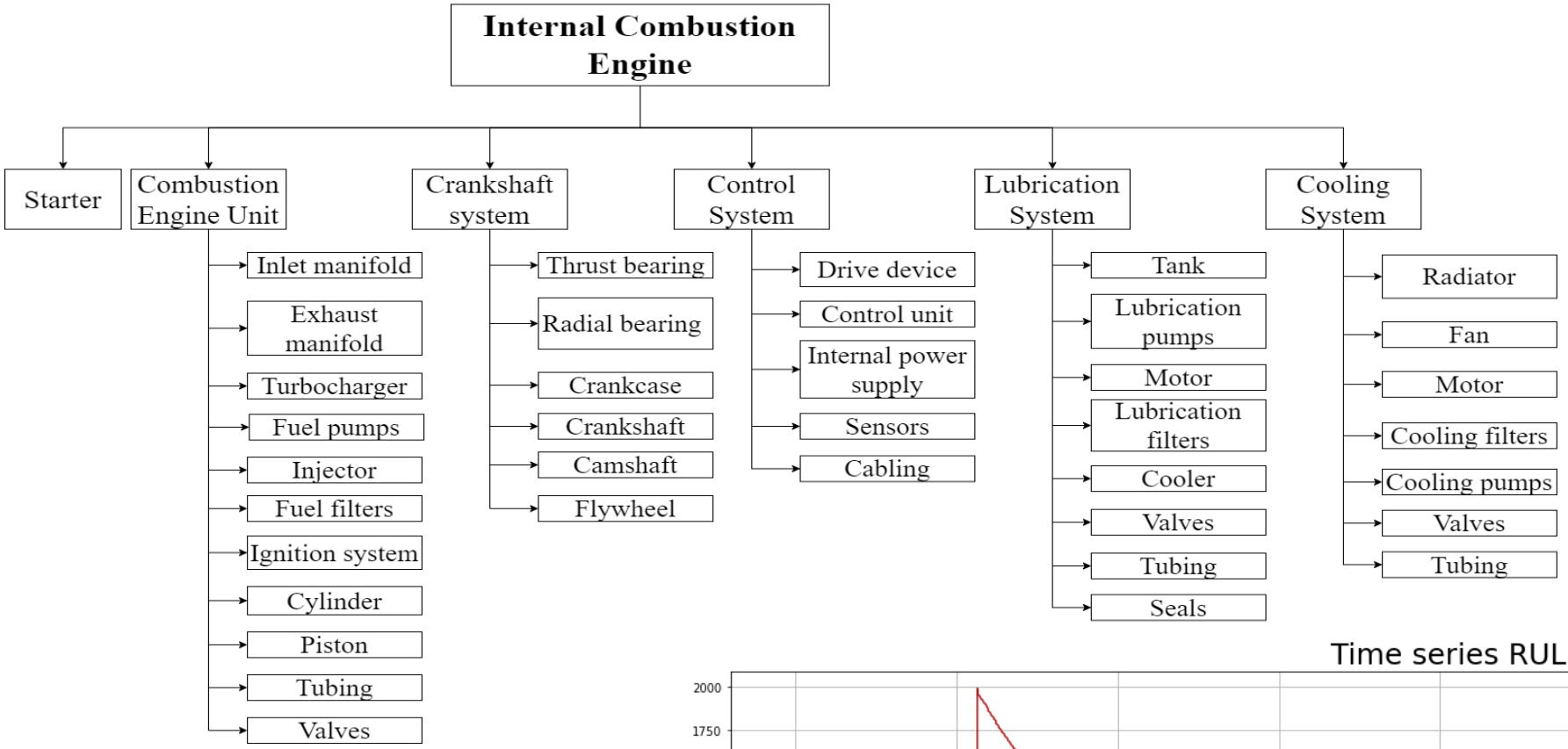
Problem setting

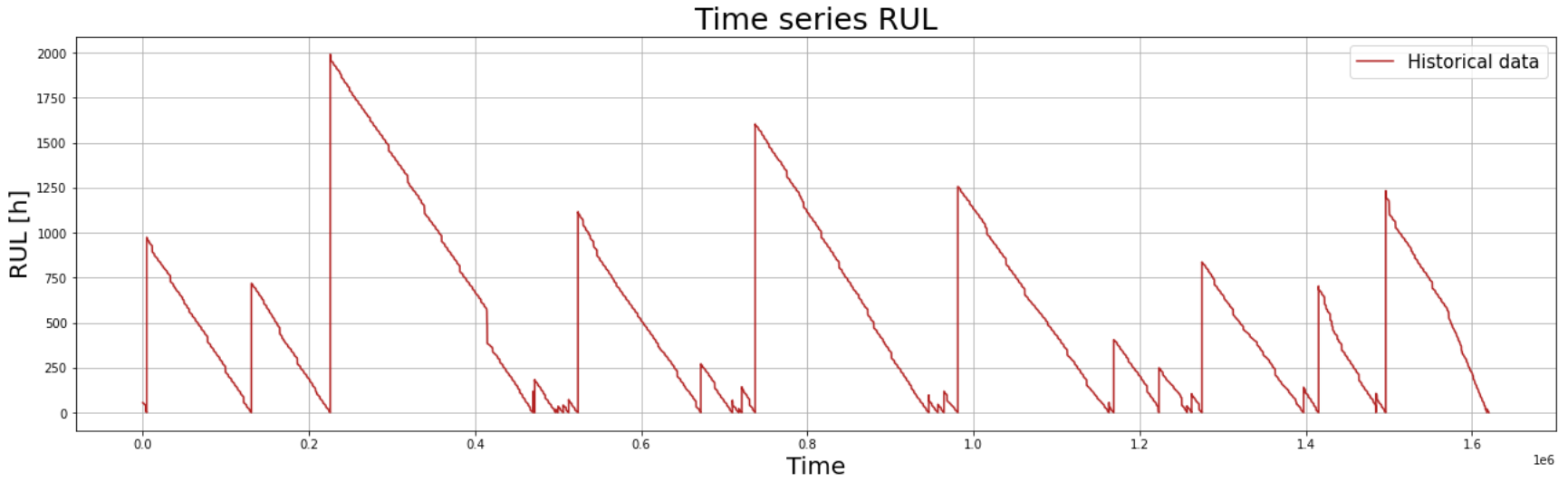
Data pre-processing

Data modeling

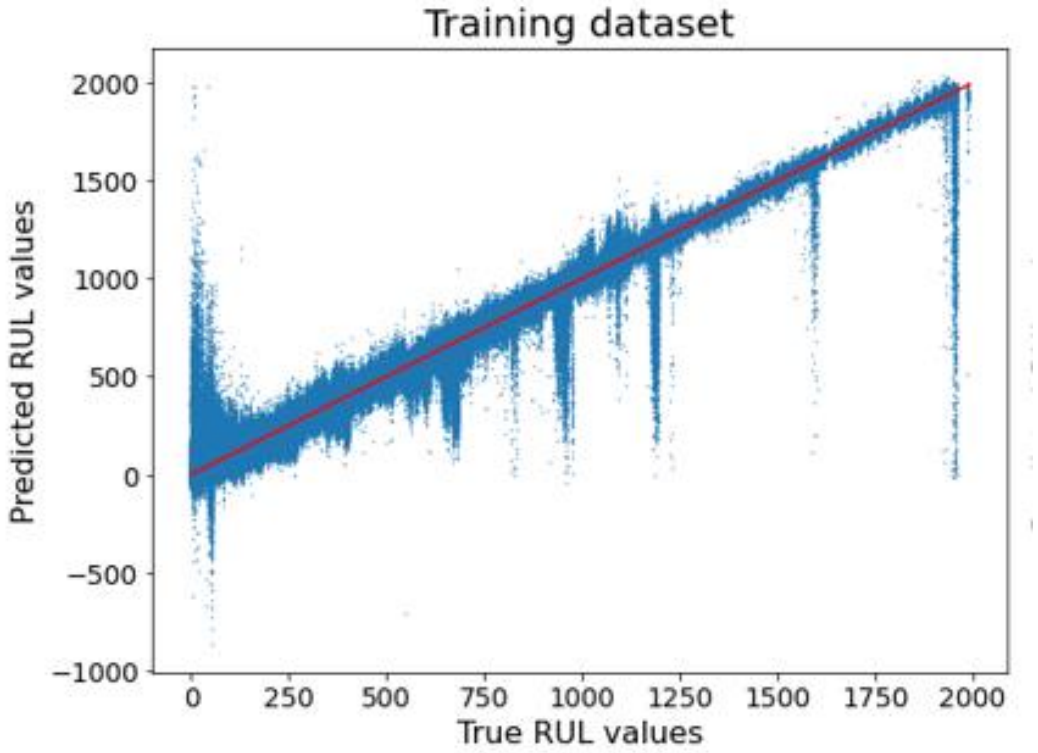
Results and discussion

Results

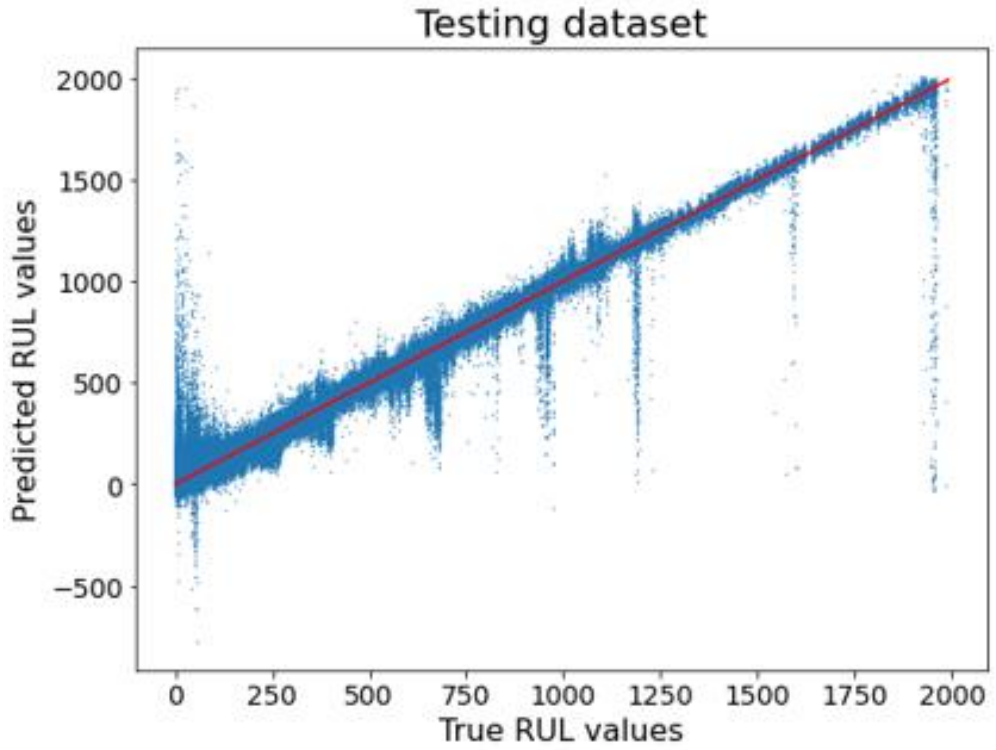

Internal Combustion Engine
Starter
Combustion Engine Unit
Crankshaft system
Control System
Lubrication System
Cooling System
Inlet manifold
Exhaust manifold
Turbocharger
Fuel pumps
Injector
Fuel filters
Ignition system
Cylinder
Piston
Tubing
Valves
Thrust bearing
Radial bearing
Crankcase
Crankshaft
Camshaft
Flywheel
Drive device
Control unit
Internal power supply
Sensors
Cabling
Tank
Lubrication pumps
Motor
Lubrication filters
Cooler
Valves
Tubing
Seals
Radiator
Fan
Motor
Cooling filters
Cooling pumps
Valves
Tubing


Time series RUL
Historical data
RUL [h]
Time
1e6
2000
1750
1500
1250
1000
750
500
250
0
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6

References



	Training	Test
RMSE	52.58	55.04
RUL average	546.91	545.79



Conclusions

- The proposed methodology presents alternatives to overcome common challenges in data preprocessing from real engineering systems.

  - The study showed the relevance of data analysis to evaluate the side effects of strategic decisions on the company's assets.

- The maintenance team can prepare for HDT's gas engine failures knowing that these types of failures occur every 544.07 hours on average

Main conclusions and remarks

In methodological terms, the authors recognize that there are still important challenges that need to be faced in the application of DL-PHM models in real life. Therefore, it is recommend involving the operational and maintenance team of the system during the initial phases of the study

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