# Predictive Maintenance Approaches and Goals

Lasman Parulian Purba
Industrial Engineering Department, Faculty of Engineering, Universitas Katolik Darma Cendika; Ph.D student in Industrial Engineering, Industrial and Systems Engineering Department ITS, Surabaya

Mokh. Suef, and Udisubakti Ciptomulyono
Industrial and Systems Engineering Department, Faculty of Industrial Technology and Systems Engineering, Institut Teknologi Sepuluh Nopember, Kampus ITS Sukolilo - Surabaya, East Java, Indonesia

*lasman.parulian@ukdc.ac.id ; Paper ID: 244

# *Table of contents*

01

10+ → 4

Approaches of PdM

02

20+ → 2

Goals of PdM

03

References:

10+ Scopus Quartile 1

# 01

10+ → 4

# Approaches of PdM

# PdM approaches from 10+ Scopus Q1 Articles:

There are at least 10 PdM approaches (next slide).

There are 4 main approaches, i.e.:

A. knowledge-based models,

B. physical models,

*C. data-driven models, and

D. hybrid models

* the most often used currently.

| Authors, Year | PdM approaches |
|---|---|
| (Florian et al., 2021) | data driven |
| (Pech et al., 2021) | data-driven model/approach (the most often use in the current development of PdM), experience-driven, physical model (mathematical modeling), knowledge-based model (reduces the complexity of the physical model) |
| (Arena et al., 2022) | data-driven, model-driven, hybrid |
| (Vrignat et al., 2022) | data-driven, hybrid |
| (Javed et al., 2017) | data-driven, physic based |
| (Olesen & Shaker, 2020)) | data driven, physical model-based, knowledge-based, hybrid |
| (Zonta et al., 2020) | data-driven, physical model-based, knowledge-based, hybrid |
| (Bousdekis et al., 2018) | data-driven, knowledge- based on prognosis, model-based prognosis |
| (Davari et al., 2021) | data-driven prognosis |
| (Molęda et al., 2023) | data-driven, physics of failure, knowledge-based, model-based, signal based, qualitative, quantitative model, ML, statistical and stochastic methods |
| (Vogl et al., 2019) | Data-driven, hybrid/fusion, physics-based modelling = physics-based prognostic = physic model approach, physics-of-failure-based (PoF-based) methods |

# A. PdM approach: knowledge-based models

*approaches that reduce the complexity of a physical model.

*often used as a hybrid strategy (Ayad et al., 2018; Wu et al.,2016):

1. expert systems, or
2. fuzzy logic

# B. PdM approach: physical models-based

**#main feature is mathematical modeling with reflexes the condition of a component**

**#needing the precision of the condition and measurement of failure, and statistical methods to limit these indices (Wu et al., 2017c)**

# C. PdM approach: data-driven models

#Approach based on data without prior knowledge of degradation conditions (Davari et al., 2021).

**#3 Fase mengimplementasikan:**

**1. Mendefinisikan model operasional dari komponen/sistem yang dianalisis & mode kegagalan dari komponen/sistem untuk menetapkan tujuan dari PdM (Jardine et al., 2006; Accorsi et al., 2017).**

# PdM approach: data-driven models

**2. Collect and manipulate the data (data selection, analysis, processing, modeling and evaluation for testing the feasibility of the predictive model).**

**3. The implementation of a DSS (decision support system) support the most proper maintenance action (Bousdekis, et al., 2018)**

Data-driven: models most found in the current evolution of PdM solutions are statistics-based, pattern recognition, or artificial intelligence(AI) and models based on machine learning algorithms (Zonta et al., 2020).

# D. PdM approach: hybrid models

#often used as a combination of several defined methods / approaches.

#Egs. (Zonta, et al., 2020; ):

- Cloud-based
- Deep learning-based
- IoT-based
- Fleet-based
- Time-based*

| Penulis, Tahun | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| Florian dkk. (2021) | data driven | | | | | | | | | |
| Pech et al., (2021) | data-driven model/approach (the most often use in the current development of PdM) | experiece-driven | physical model (mathematical modelling) | knowledge-based model (reduces the complexity of the physical model) | | | | | | |
| Arena dkk. (2022) | data-driven | | | | model-driven | hybrid | | | | |
| Vrignat dkk. (2022) | data-driven | | | | | hybrid | | | | |
| Javed et al., (2017) | data-driven | | physics based | | | | | | | |
| Olesen & Shaker (2020) | data driven | | physical-based model | knowledge-based model | | hybrid model | | | | |
| Zonta dkk. (2020) | data-driven | | Physical model-based | knowledge-based | | hybrid | | | | |
| Bousdekis dkk., (2018) | data-driven | | | knowledge-based prognosis | model-based prognosis | | | | | |
| Davari dkk., (2021) | data-driven prognosis | | | | | | | | | |
| Moleda dkk., (2023) | data-driven | | Physics of failure | knowledge-based | model-based | | signal-based | qualitative, quantitative model | ML | statistical and stochastic methods |
| | 10 | 1 | 5 | 5 | 3 | 4 | 1 | 1 | 1 | 1 |

# 02

20+ → 2

## Goals of PdM

20+ → 2

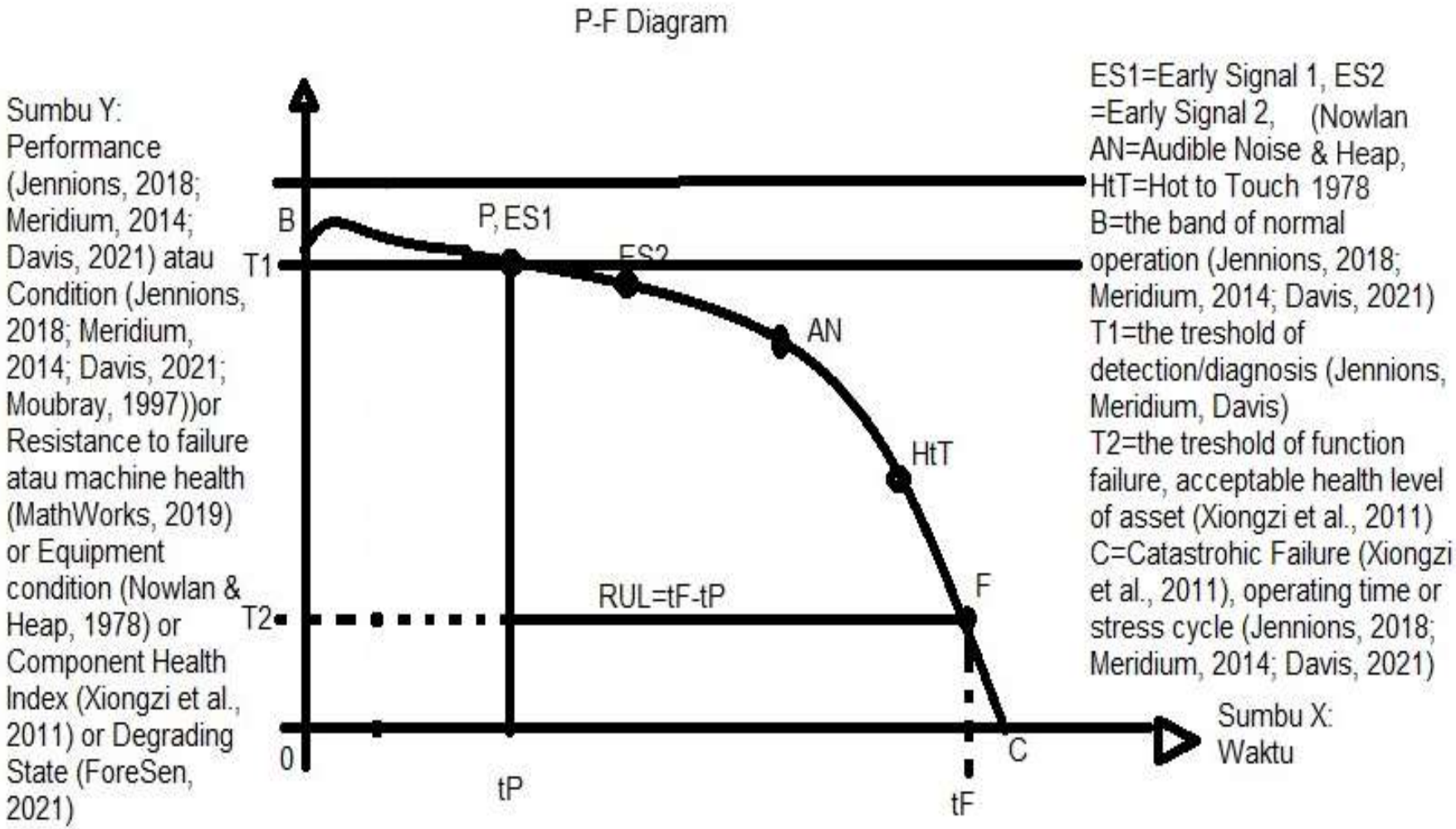
# Goals of PdM

It was found that there are 20+ PdM goals in the literatures surveyed.

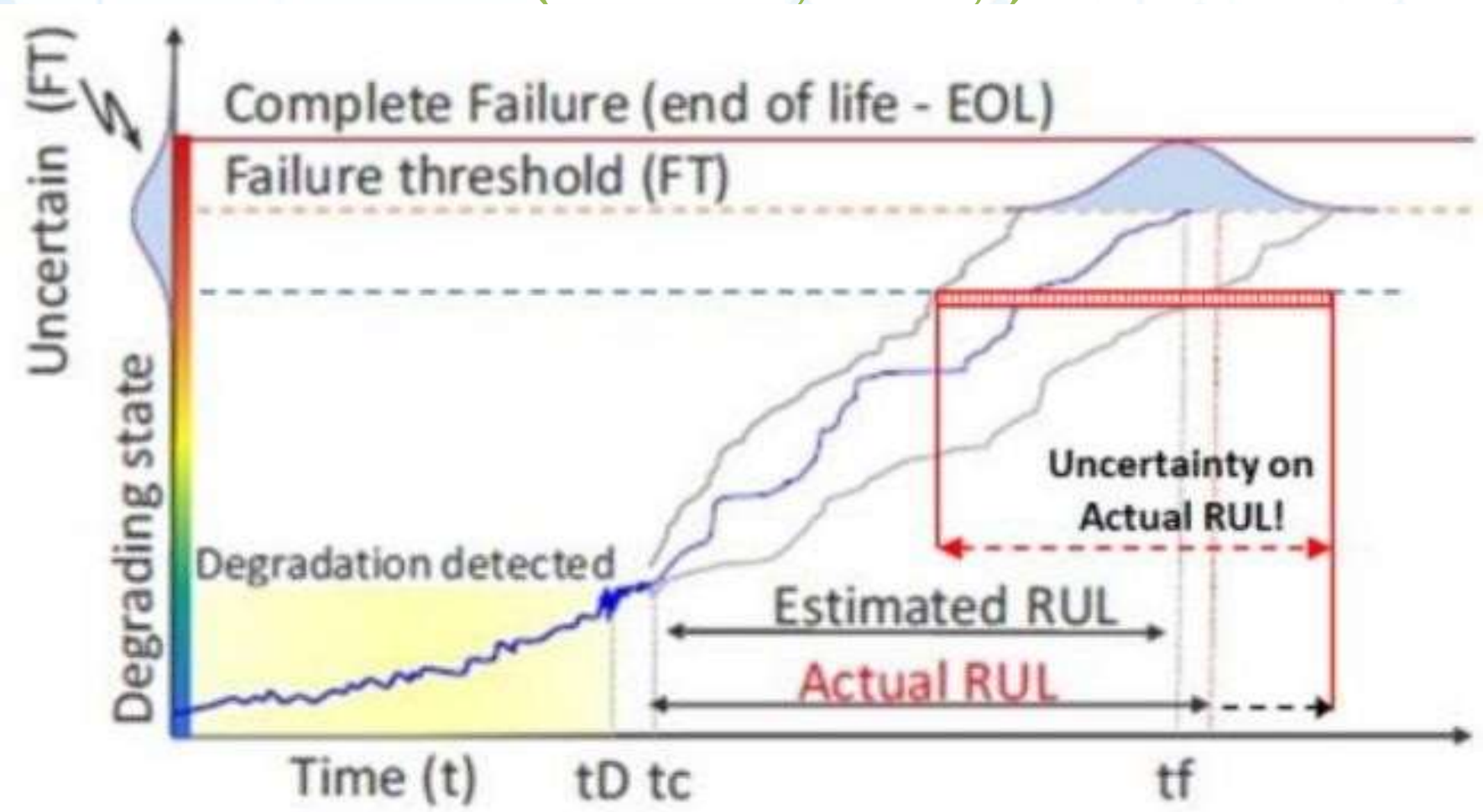
The first two of the PdM goals: RUL prediction followed by failure prediction.

| Penulis, Tahun | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Florian dkk. (2021) | | define whether the data sample in the time-series signals the occurrence of a failure or not. | | | | | | | | | | | |
| Pech et al., (2021) | failure prediction | health status | alarm | | anomaly | RUL | | | | | | | |
| Arena dkk. (2022) | faults diagnosis | | | prognosis | | RUL estimation | | | | | | | |
| Vrignat dkk. (2022) | | | | | | RUL prediction | efficient maintenance | | | | | | |
| Javed et al., (2017) | | | | | | RUL prediction | | | | | | | |
| Olesen & Shaker (2020) | failure prediction | health status | false/true alarm | | detection of anomaly | RUL | | degradation pattern prognostics | | | | | |
| Zonta dkk. (2020) | | | | | | | | | improve productivity | downtime | reduce maintenance cost | improve quality | |
| Bousdekis dkk., (2018) | > 20 goals/outputs pairs with inputs inluding: estimation of RUL, failure prediction, TTF, optimal maintenance policy, reliability , etc. | | | | | | | | | | | | |
| Davari dkk., (2021) | failure prediction | | | | | RUL prediction | | | | | | | |
| Moleda dkk., (2023) | Fault detection | Fault classification | | | Anomaly detection | RUL prediction | | | | | | | Root cause analysis |
| | 2nd | | | | | 1st | | | | | | | |

# RUL prediction: P-F Diagram



# Estimated RUL with uncertainty: P-F diagram (ForeSee, 2021; ).



# Fault / failure prediction

- Assessment of current equipment diagnostic conditions (sequence/data pattern) can be considered as the basis for fault/failure prediction.

# 03

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10+ Scopus
Quartile 1

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