Model for implementation of predictive maintenance in an Industry 4.0 context

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Agenda

- Introduction
  - Tom Ivar
  - BRU21 research project
- Industry 4.0
- Predictive Maintenance (PdM)
- Proposed model
- Q&A

Introduction – Tom Ivar

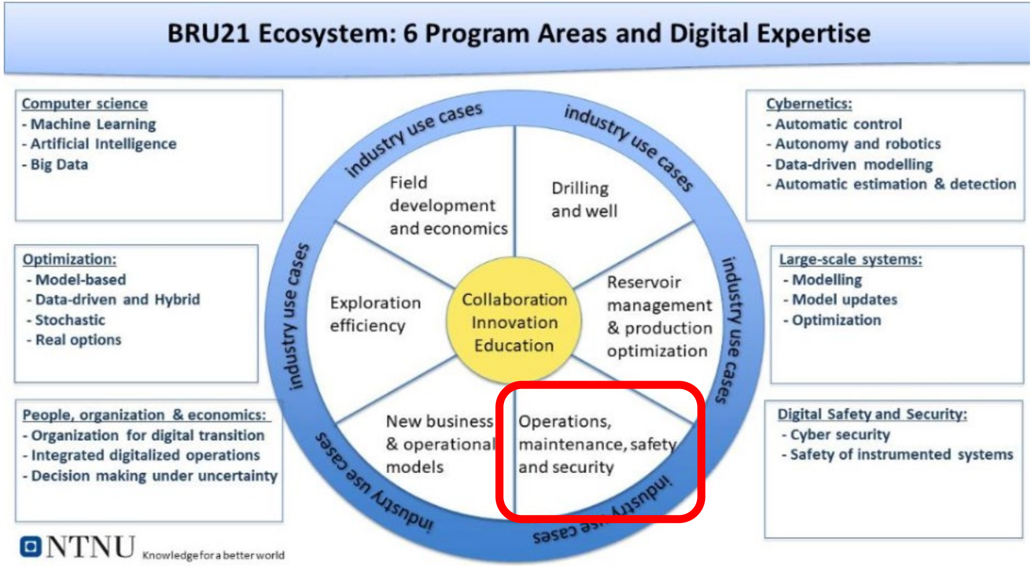
- PhD-project: **Industry 4.0 and smart predictive maintenance**
- Funded by: **NTNU**
- Part of: **BRU21**
- Industry Partner: **Lundin**
- Main supervisor: **Jørn Vatn**
- Co supervisor: **Per Schjølberg**

Lundin
Norway

BRU21
Better Resource Utilization in the 21st century

BRU21: Better Resource Utilization in the 21st century

BRU21 objective: “to boost efficiency and enable new technologies for oil and gas industry through digital and automation solutions” (NTNU, 2017,p.50).



www.ntnu.edu/bru21

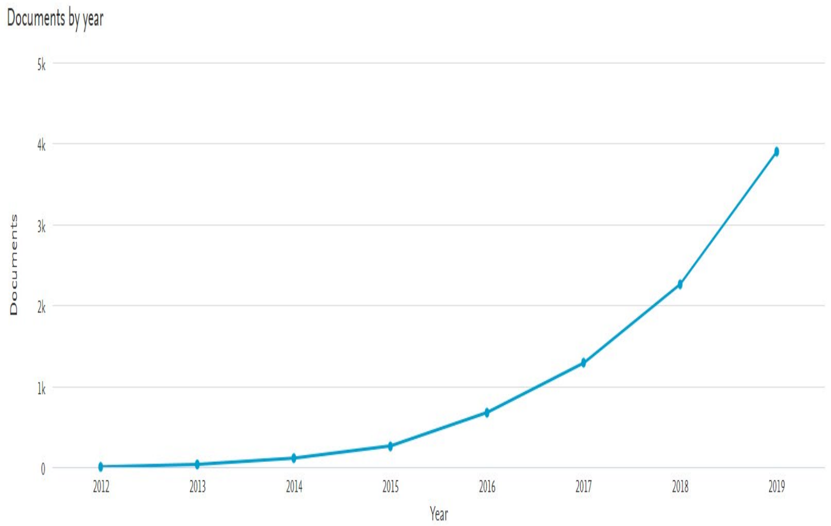
BRU21: Background

- In order to secure the future of this industry:
  - cost efficiency (break even less than 30 USD/bbl.)
  - high safety and environmental standards
- Digital solutions are important in order to face these challenges (KonKraft, 2018; NTNU, 2017)
- Upstream oil and gas is lagging other industries, e.g. manufacturing (NTNU, 2017).

Industry 4.0

- Believed to be the most prominent concept for performance improvements in the future (Buer, 2020)
- >9000 publications in Scopus with “Industry 4.0” or “Industrie 4.0” in headline, abstract or as keyword

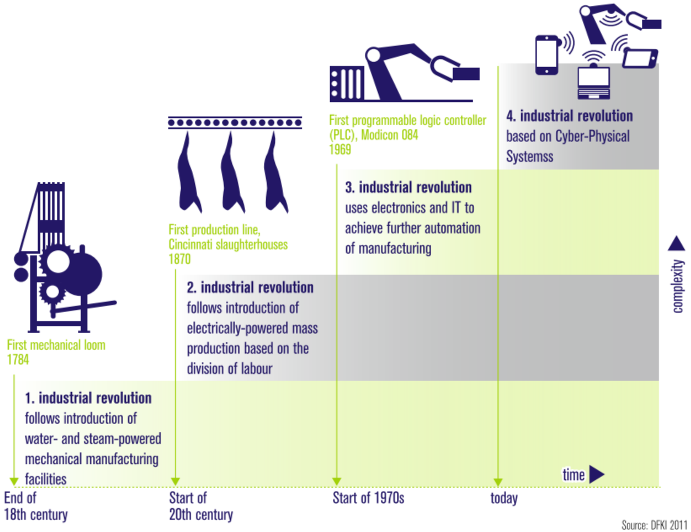
Documents per year (2012-2019)



Industry 4.0 - Introduction

- First introduced in 2011
- A fourth industrial revolution is coming as a result of the introduction of Internet of Things and Internet of Services into the manufacturing sector (Kagermann, Helbig et al. 2013)
- The key concepts in Industry 4.0 are (Kagermann, Helbig et al. 2013):
  - Horizontal and vertical integration of manufacturing systems.
  - End-to-end integration of engineering.

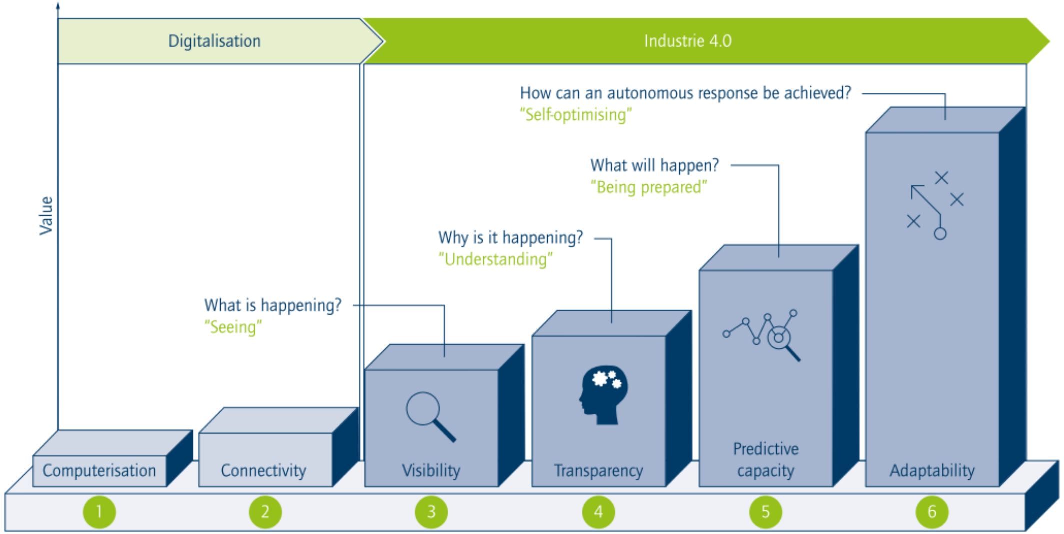
Figure 1:
The four stages of
the Industrial Revolution



Source: DFKI 2011

Potential benefit of Industry 4.0

- Definition
  - “real-time, high data volume, multilateral communication and interconnectedness between cyber-physical systems and people” (Schuh, Anderl et al. 2017, p. 10)



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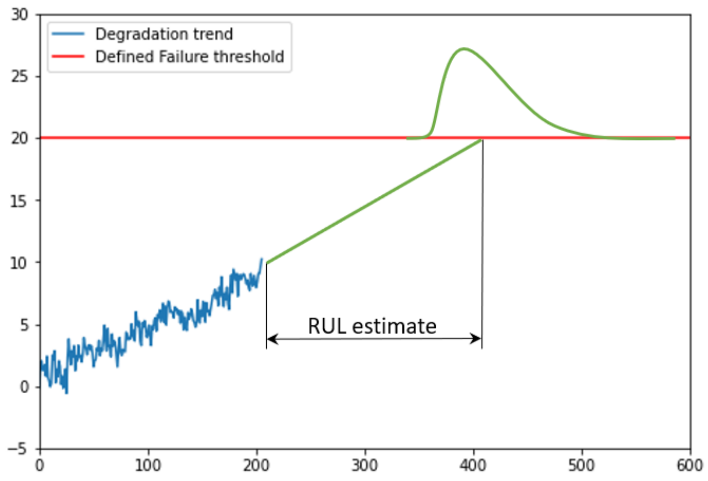
Industry 4.0 – Issues

- “has become a poorly defined buzzword for the future of production” (Buer et al. 2018)
- Not enough empirical evidence to give clear picture of effect on performance (Buer 2020)
- Manufactures struggle to understand the concept (Oztemel and Gursev, 2020).
- “industries are still holding doubts in implementing these new technologies” (Liao, Deschamps, Loures, & Ramos, 2017).
- There is a need in the industry for frameworks on how to implement solutions related to Industry 4.0 (Oztemel & Gursev, 2020).

Predictive Maintenance (PdM)

Definition:

“condition-based maintenance carried out following a forecast derived from repeated analysis or known characteristics and evaluation of the significant parameters of the degradation of the item” (CEN 2017).



CEN (2017). Maintenance terminology. **EN 13306:2017**.

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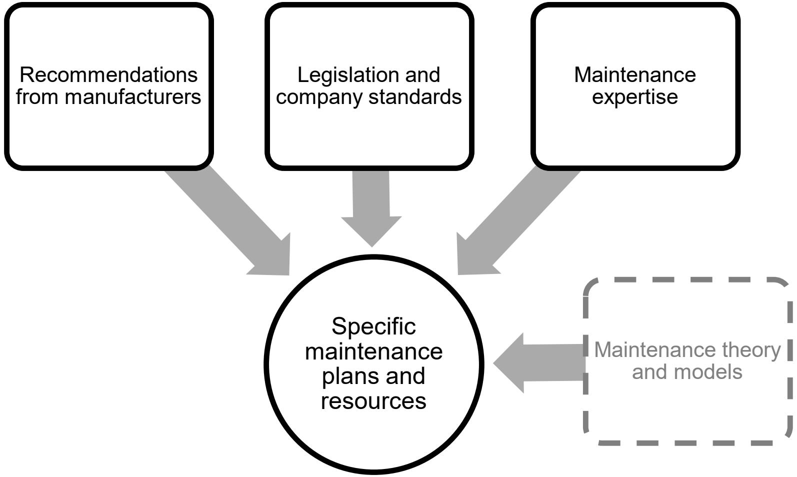
The potential of PdM? - Academic studies

- Limited empirical evidence of the effect of PdM in asset heavy industry. But some studies have been done:
- Case studies of Dutch process industry:
  - "all the firms claimed to be struggling with prognostic condition-based maintenance tasks" (Veldman et al., 2011)
  - companies has only "to a very limited extend" implemented "data-driven prognostics" (Van De Kerkhof et al., 2015)
- Interviews of maintenance experts from UK industry.
  - "full, predictive maintenance solutions were extremely challenging." (Golightly et al., 2018)

Challenges related to maintenance modelling

Traditional sources for maintenance plans



Adapted from Rausand and Høyland (2004, p. 401).

Vicious circle of data collection and model development

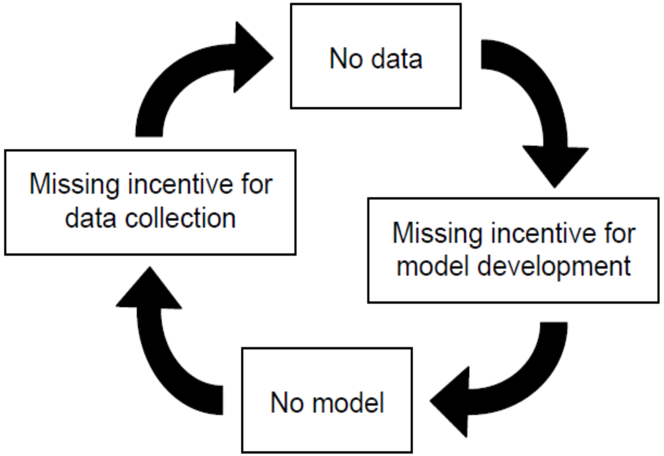
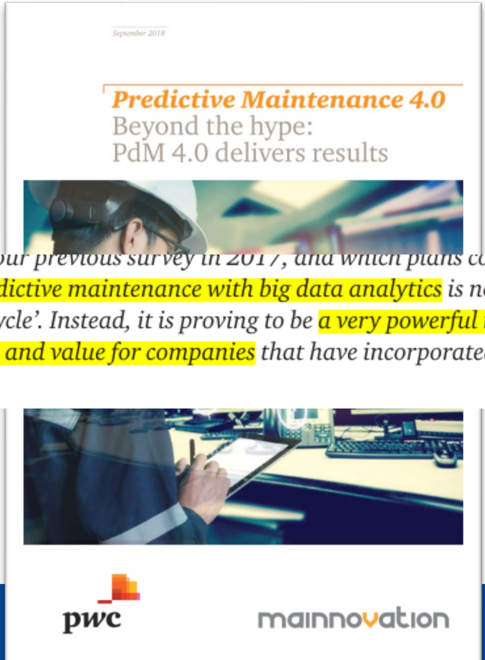


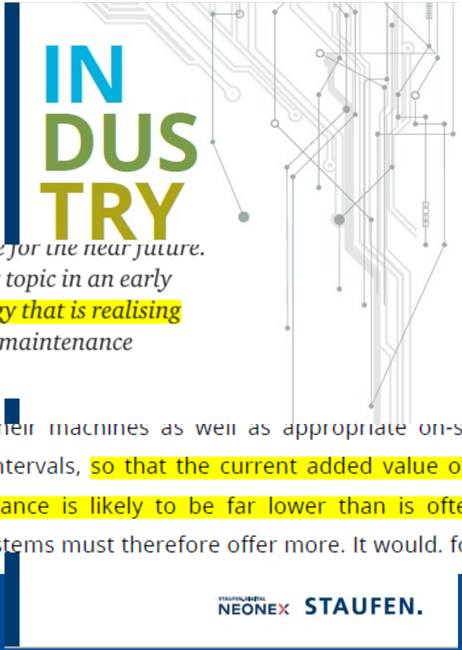
Figure from Welte (2008, p. 63)

The potential of PdM? - Other sources

- There are however an abundance of reports and white papers from consultancy firms
- However, surveys of companies show mixed results:



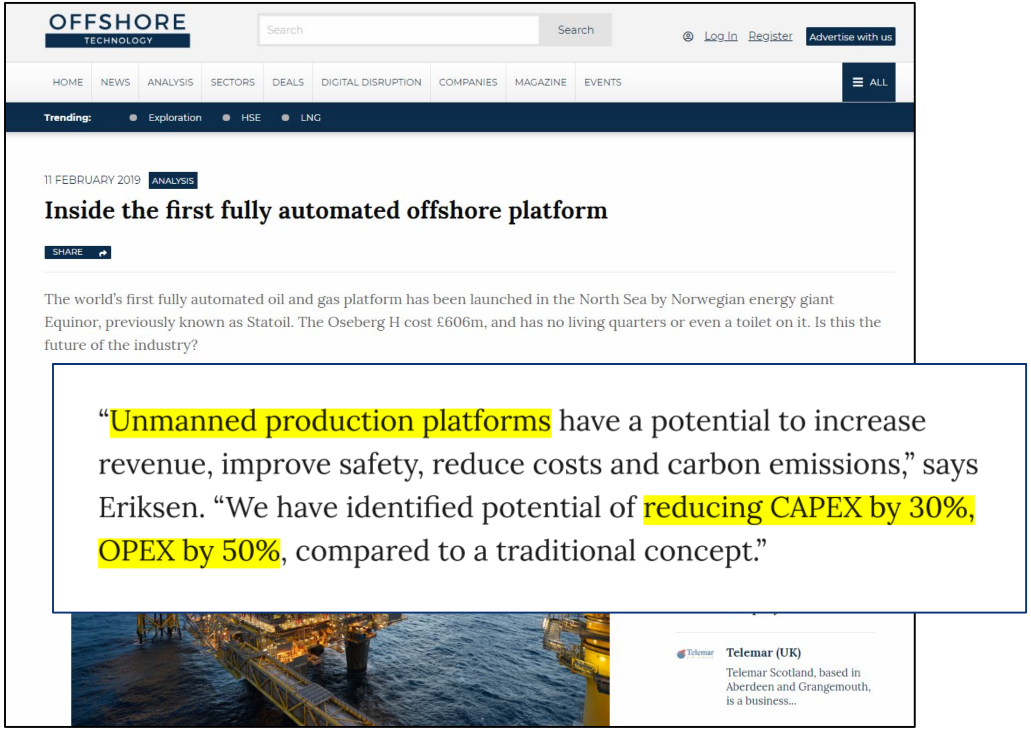
has changed since our previous survey in 2017, and which plans companies have for the near future. It appears that predictive maintenance with big data analytics is not just a fancy topic in an early stage of the 'hype cycle'. Instead, it is proving to be a very powerful new technology that is realising tremendous results and value for companies that have incorporated it into their maintenance operations.



ing of their machines as well as appropriate on-site mainte-nance intervals, so that the current added value of predictive maintenance is likely to be far lower than is often claimed. Such systems must therefore offer more. It would, for example,

The potential PdM in O&G industry

- PdM with accurate RUL-predictions allow for longer mobilization times for maintenance without affecting availability.
- Potential for considerable savings in remote locations like offshore oil platforms. (Offshore-technology, 2019).



Offshore-technology. (2019). "Inside the first fully automated offshore platform." Retrieved January 7th. , 2019, from https://www.offshore-technology.com/features/inside-the-first-fully-automated-offshore-platform/.

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THE PROPOSED MODEL

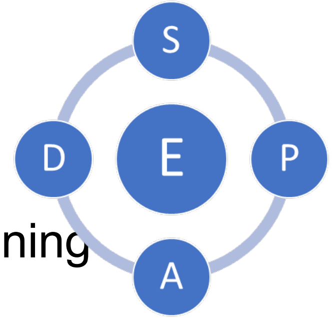
The proposed model

RATIONALE FOR THE MODEL

Division of the model in three levels strategic, tactical and operational

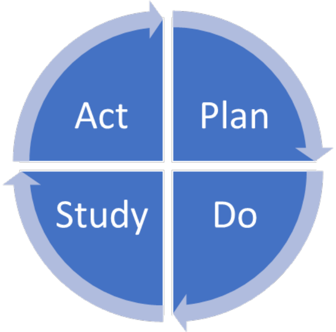
- “predictive solution might take 5 years to prove its worth” (Golightly et al., 2018)
- “the initial period (…) require significant extra resource as people had to learn new technology, conduct manual analysis to interpret new data streams” (Golightly et al., 2018)
- Individual implementation of PdM will probably not pay of from purely operational perspective

Why systems engineering and SPADE as starting point



- The basic idea of Industry 4.0 is to improve performance by combining many parts into one system.
  - Systems engineering is relevant.
- Implementation of Industry 4.0 and PdM will affect many actors and require collaboration with other organizations (Golightly et al., 2018, Schneider, 2018).
  - SPADE is a simple and jargon free model that can be useful for communication to a wide audience.
- “The key challenges for businesses include understanding what Industrie 4.0 means to them and systematically developing a corresponding implementation strategy.” (Schuh et al., 2017)
  - Focus on the underlying principles.

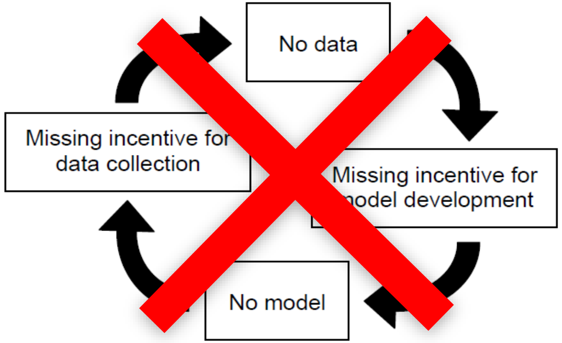
Why PDSA in the tactical level



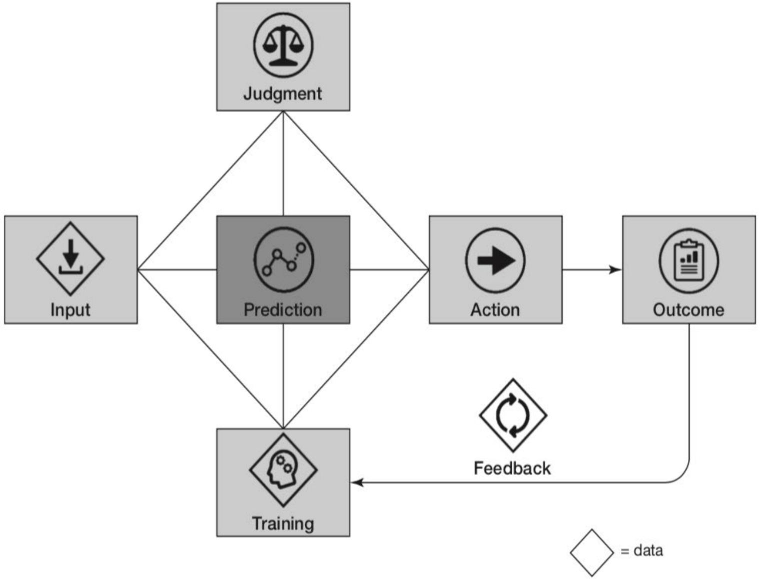
- Why PDSA in the tactical level
  - organization that succeeds with digital transformation have «an expanded appetite for risk” and “rapid experimentation” (Kane, 2016).
  - Importance of iterative approach is also pointed to by other (Schneider, 2018)
- Plan-Do-Study-Act-cycle (PDSA) is an established tool for iterative improvement by testing ideas in practice (Hayes, 2010, p. 375),

The operational level

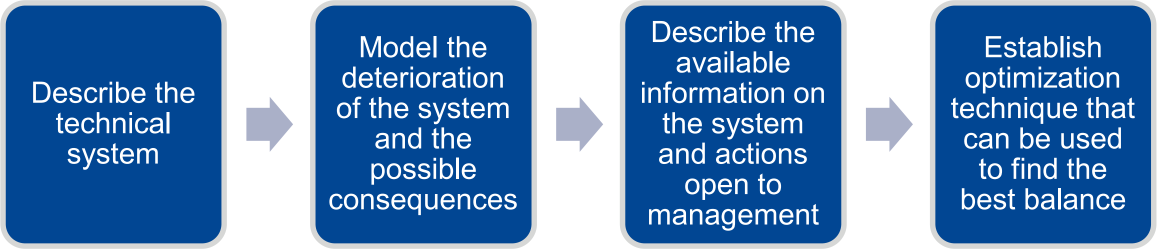
- Break the “vicious circle of data collection and model development”



Prediction Machines (Agrawal, Gans, & Goldfarb, 2018)



Maintenance optimization



Four steps to establish a maintenance optimization model. Based on Dekker (1996).

Example of model

- Not a good model for communication:
- Phases:
  - Condition monitoring
  - Diagnosis
  - Prognosis
  - Maintenance recommendation

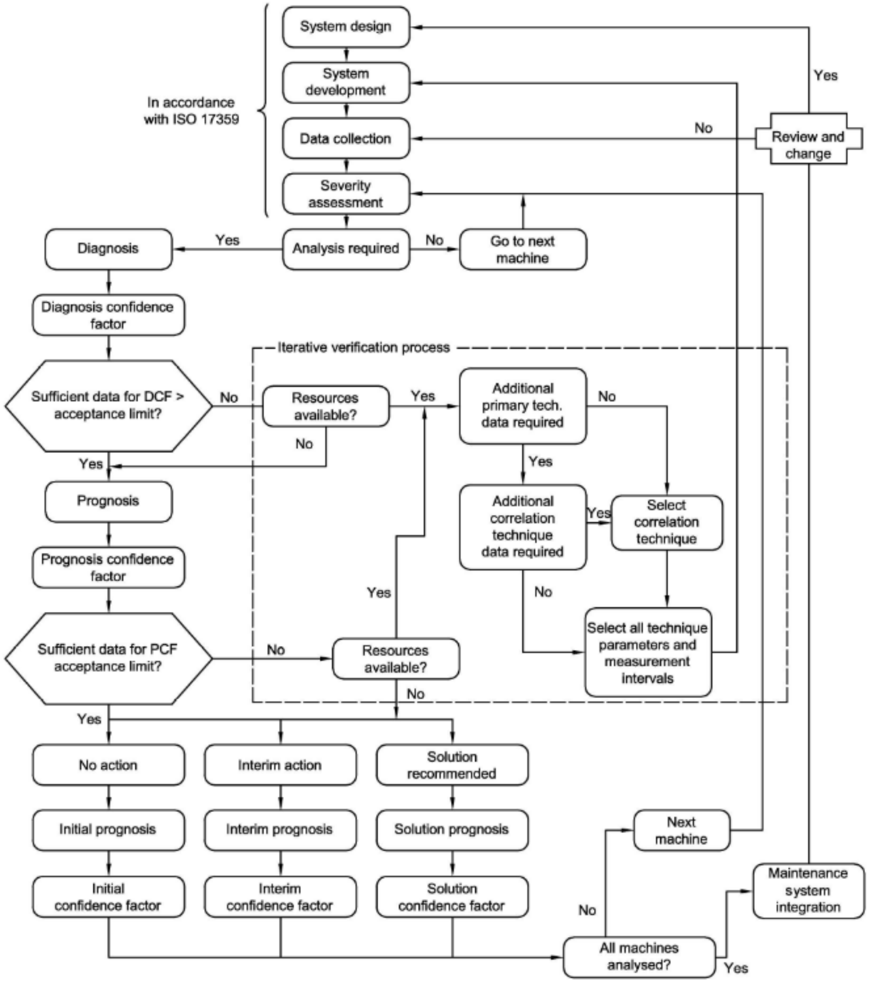


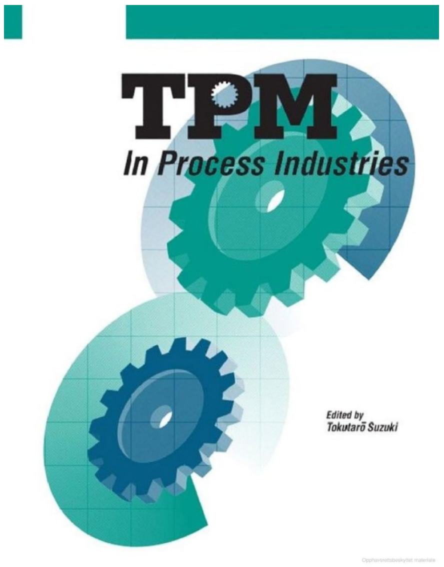
Figure A.1 — Condition monitoring flow chart

Condition monitoring and diagnostics of machines — Prognostics — Part 1: General guidelines. **ISO 13381-1:2015**.

The Four Phases to Zero Breakdowns

It is impossible to succeed with PdM if not basic maintenance activities are in place (Suzuki, 1994).

1. Stabilize failure intervals
2. Lengthen equipment life
3. Periodically restore deterioration
4. Predict equipment life



Suzuki, T. (1994). TPM in process industries. Portland, Or, Productivity Press.

The Four Phases to Zero Breakdowns (1)

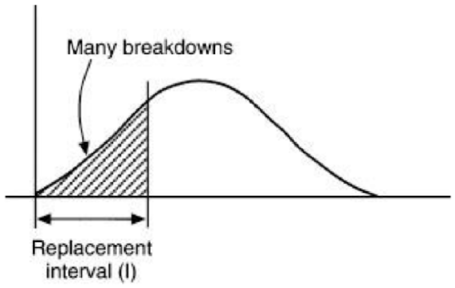


Figure 3-6. Reducing Variation in Failure Intervals (Phase 1)

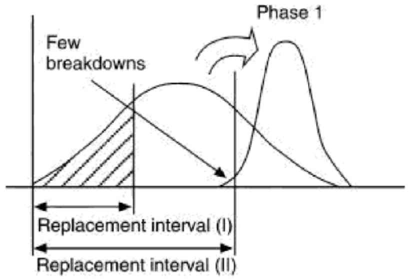


Figure 3-7. Lengthening Lifetimes (Phase 1)

- Clearing, lubricating, comply with conditions of use
- Abolish environments that cause accelerated degradation

The Four Phases to Zero Breakdowns (2)

- Correct design and fabrications weaknesses
- Prevent operation and repair errors
    - Training and procedures

- Side note:
- Limited value of PdM partly because: "many production downtimes are still often due to operating errors that cannot be ruled out by maintenance systems" (STAUFEN.AG, 2018)

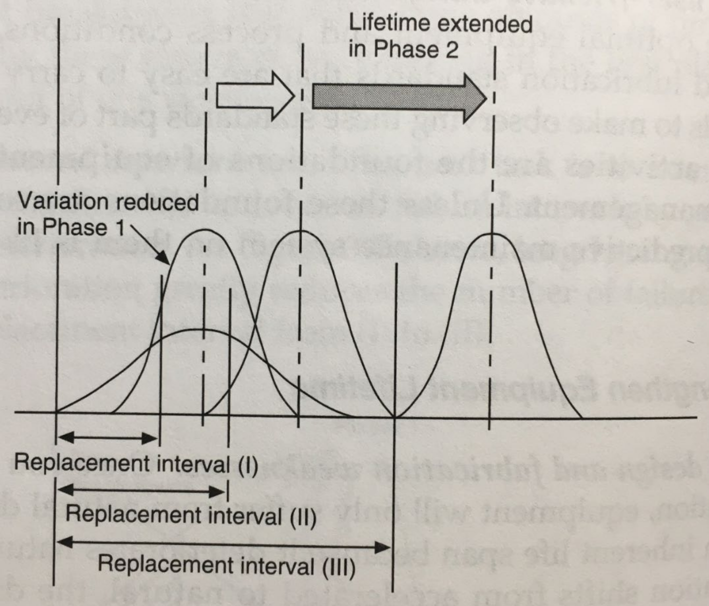


Figure 3-8. Lengthening Lifetimes (Phase 2)

The Four Phases to Zero Breakdowns (3)

- Perform periodic servicing and inspection
  - Failure in one component can cause failure up- and down-stream
- Identify health indicators

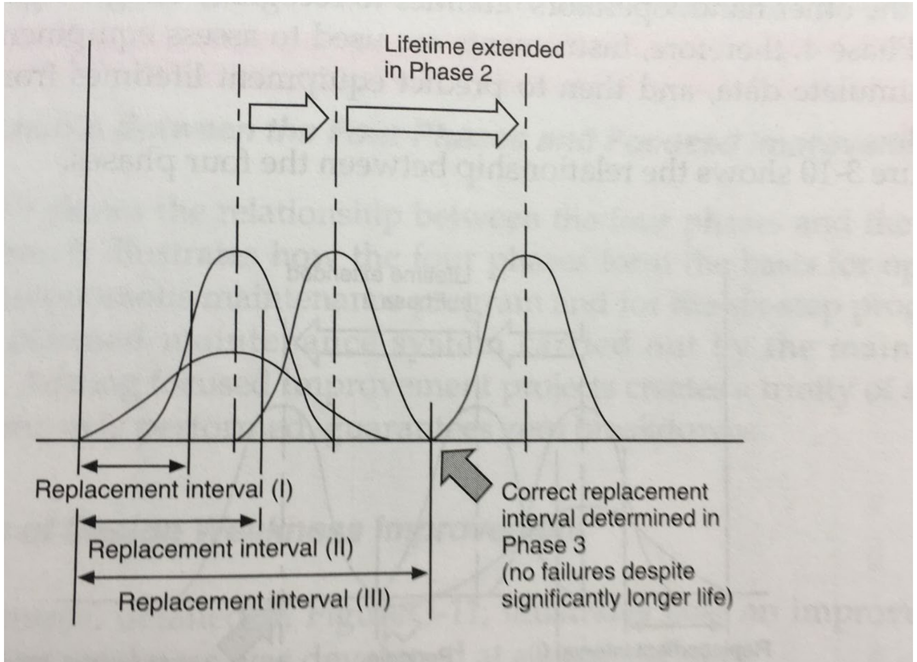


Figure 3-9. Periodically Reversing Deterioration (Phase 3)

The Four Phases to Zero Breakdowns (4)

- Introduce condition-based and predictive maintenance

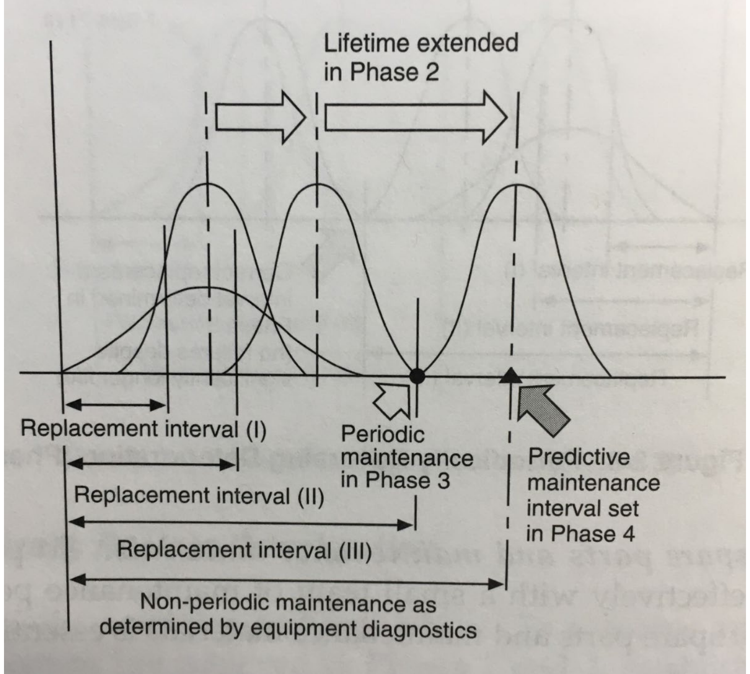


Figure 3-10. Predicting Lifetimes (Phase 4)

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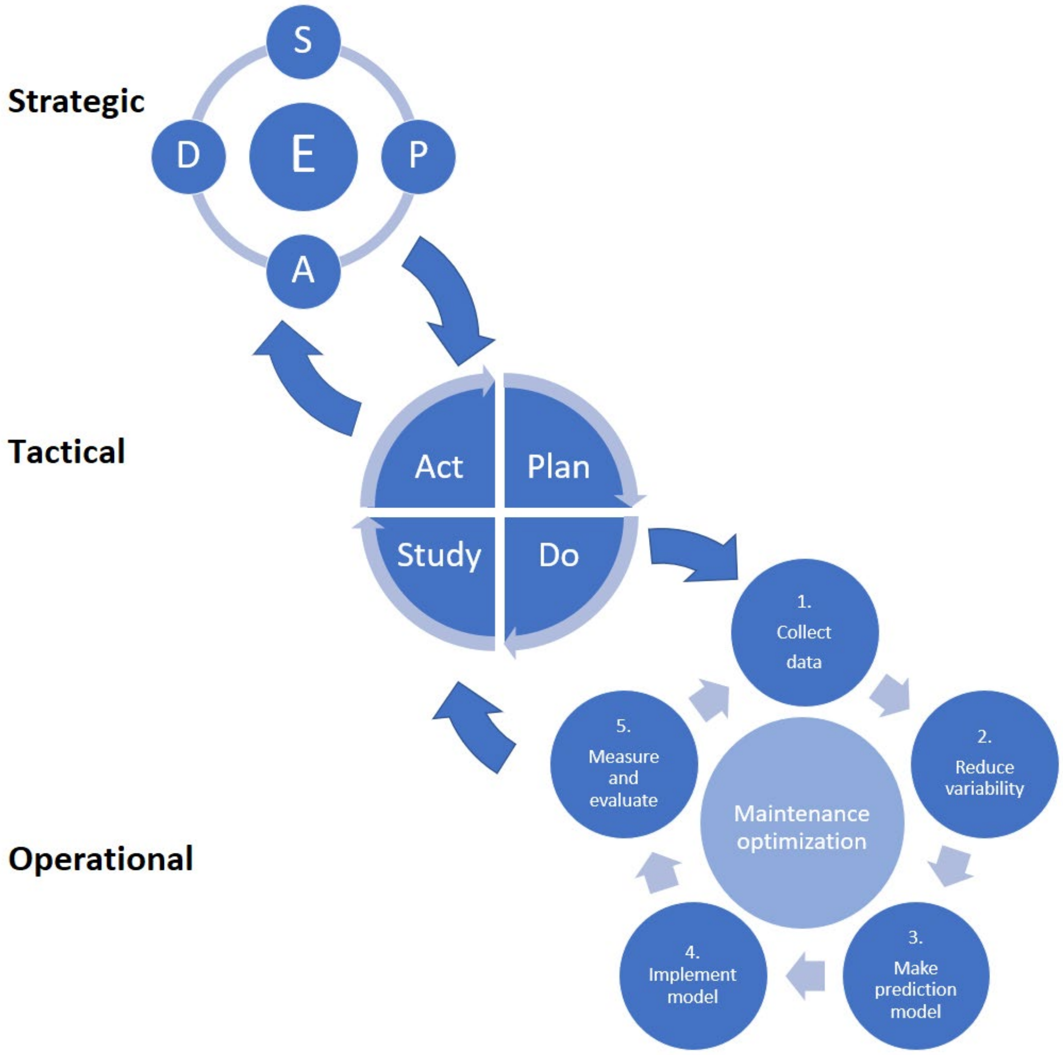
The proposed model



Discussion and conclusion

- Challenges related to profitability, safety and environmental performance must be met.
- “Industrie 4.0 is still in the future” (Drath and Horch, 2014).
- There is a need in industry of concepts on how to implement digital solutions.
- Hopefully, the proposed model can be of help.

QUESTIONS?

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