Production service systems and Smart Maintenance

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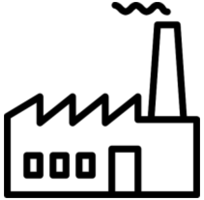
CHALLENGES AND OPPORTUNITIES

Need for a clear strategy to implement digitalization solutions

Cost of production disturbance ~106 Bn SEK



Overall Equipment Effectiveness (OEE) of industrial equipment ~50 %

PRODUCTION SERVICE & MAINTENANCE SYSTEMS

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Sets the agenda for Smart Maintenance

Data-driven decisions, human capital, internal and external integration

The link between maintenance and production

Together with industry

LEARNING OBJECTIVES

After this lecture, the students should be able to:

- ❑ Critically discuss problems with current definitions and views of maintenance
- ❑ Argue for key solutions to future challenges related to product and production maintenance
- ❑ Define the concept of Smart Maintenance
- ❑ Describe how a service-oriented organization can be applied to maintain a production system over its entire life-cycle

SHIFT TOWARDS A SERVICE-ORIENTED SOCIETY

What is a service?

Important components?

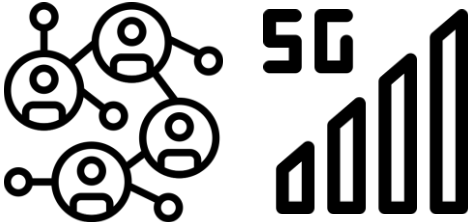
Impacts on a manufacturing company?

Examples?

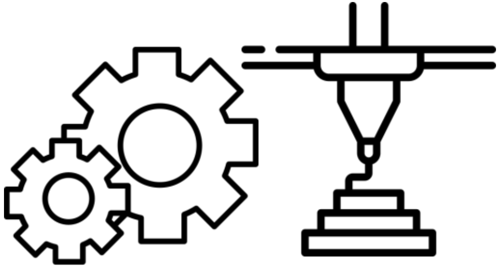
- Planning/monitoring
- Training
- Maintaining
- Upgrading
- Life-cycle responsibility
- Customer orientation
- New business models, e.g. leasing
- …

INDUSTRIAL DIGITALIZATION – ENABLING TECHNOLOGIES

Big Data & Artificial Intelligence



Connectivity & 5G



Additive Manufacturing

Collaborative Automation

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GRAND CHALLENGES

- Automated and autonomous equipment must work!
- Even more technology to maintain
- Upgrading old machines

POTENTIAL WITH MODERN MAINTENANCE

Highest-ranked use cases, based on survey responses	Use case type	Impact	Data richness
Predict failure and recommend proactive maintenance for production and moving equipment	Predictive maintenance	1.3	1.0
Optimize complex manufacturing process in real time—determine where to dedicate resources to reduce bottlenecks and cycle time	Operations/logistics optimization (real time)	1.1	1.0
Predict future demand trends and potential constraints in supply chain	Forecasting	0.8	0.7
Identify design problems in pre-production to reduce ramp-up time to maximum output (i.e., yield ramp)	Predictive analytics	0.6	0.3
Identify root causes for low product yield (e.g., tool-/die-specific issues) in manufacturing	Discover new trends/ anomalies	0.5	0.7

[McKinsey, 2016]

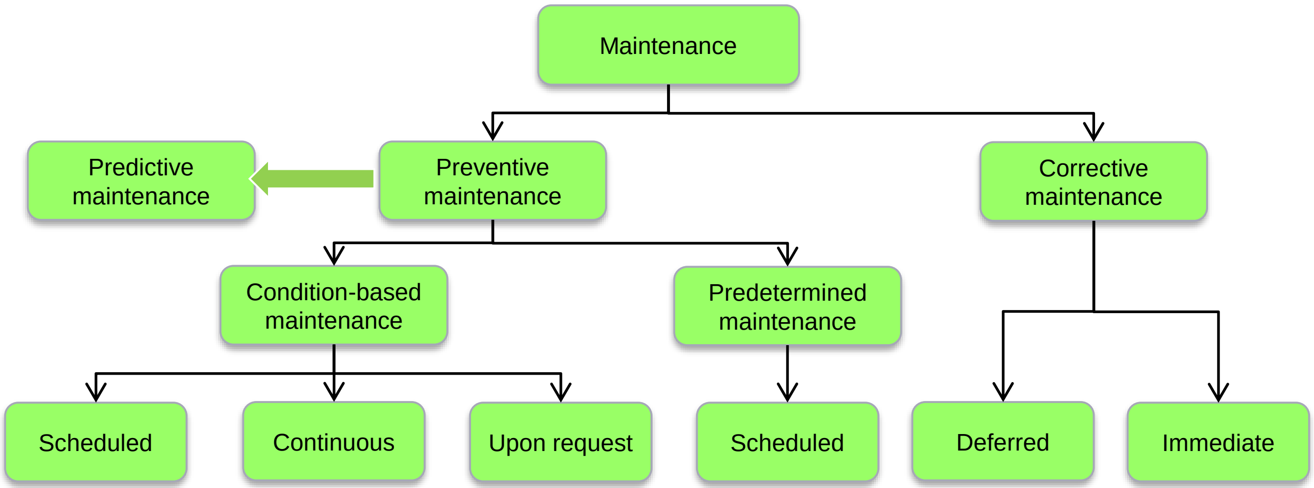
TRADITIONAL MAINTENANCE

MAINTENANCE DEFINITION

"A combination of all technical, administrative and managerial actions during the life-cycle of an item, and intended to remain it in, or restore it to a state in which it can perform the required function."

[European Standard WI 319-003]

MAINTENANCE ACTIVITIES



MAINTENANCE GENERATIONS

Maintenance 1.0 (before 1950)
- Reactive actions

Maintenance 2.0 (1950 – 1975)
- Preventive maintenance
- Maintenance department created

Maintenance 3.0 (1975 – 2000)
- Academic interest
- Prevent effects of failures
- Condition-based maintenance
- Design for maintainability
- Collaboration, e.g. TPM

Maintenance 4.0 (20??)
- Design for eliminating failures
- Even more extensive collaboration, e.g. Asset Management
- Holistic view
- IT solutions
- Smart Maintenance

OEE – OVERALL EQUIPMENT EFFECTIVENESS

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Calculation of Overall Equipment Effectiveness - OEE

Planned production time

Actual Production time

1. Failure
2. Setup

Net Operating time

3. Idling and minor stoppage
4. Reduced speed

Valuable-operating time

5. Defects in process
6. Reduced yield

Availability =

$$\frac{\text{Planned Production Time} - \text{Downtime}}{\text{Planned Production Time}} * 100$$

Operational Efficiency =

$$\frac{\text{Design Cycle Time} * \text{Produced Amount}}{\text{Actual Running Time}} * 100$$

Quality rate =

$$\frac{\text{Produced Amount} - \text{Defect Amount}}{\text{Produced Amount}} * 100$$

OEE = **Availability** * **Operational Efficiency** * **Quality rate**

OEE FIGURES IN INDUSTRY

	1990's *(Ljungberg 1998)*	2006-2012 *(Ylipää et al)*
Planned stops	5%	6,6%
Unplanned stops	12%	9,6%
Set-ups	8%	11,5%
Availability	80%	78,9%
Utilization	77%	80,2%
Quality	99%	96,9%
OEE	***55%***	***51,5%***

Low availability and operational efficiency are two main contributors to OEE losses

SUMMARY OF CHALLENGES FOR MAINTENANCE ORGANIZATIONS

- Lack of systems perspective
- Preventive instead of reactive
- Quantification of maintenance effects
- Need for collaboration or integration
- Need for common goals
- Necessity for digitalized manufacturing

Data-driven decisions

Decisions based on data

External integration

Maintenance as an actor outside the factory

Smart Maintenance

Organizational design for maintenance in a digitalized manufacturing

Human Capital Resource

Maintenance practitioners' knowledge, competences and skills

Internal integration

Maintenance as a part of the whole factory

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Smart Maintenance

Data-driven decisions

Human capital resource

Internal integration

External integration

- Data collection
- Data quality
- Data analysis
- Augmenting human decision-making
- Automated decision making

Smart Maintenance

Data-driven decisions

Human capital resource

Internal integration

External integration

- Adaptability
- Analysis competence
- Business competence
- Social skills
- IT competence
- Domain expertise

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Smart Maintenance

Data-driven decisions

Human capital resource

Internal integration

External integration

- Cross-functional collaboration
- Internal flow of data, information, and knowledge
- Joint decision-making

Smart Maintenance

Data-driven decisions

Human capital resource

Internal integration

External integration

- External flow of data, information, and knowledge
- External flow of products and services
- Strategic partnerships with vendors
- Collaboration networks including different business

Effects

Maintenance Performance

Production
Environment
Safety

Economy
Competition

Smart Maintenance

Data-driven decisions

Human capital resource

Internal integration

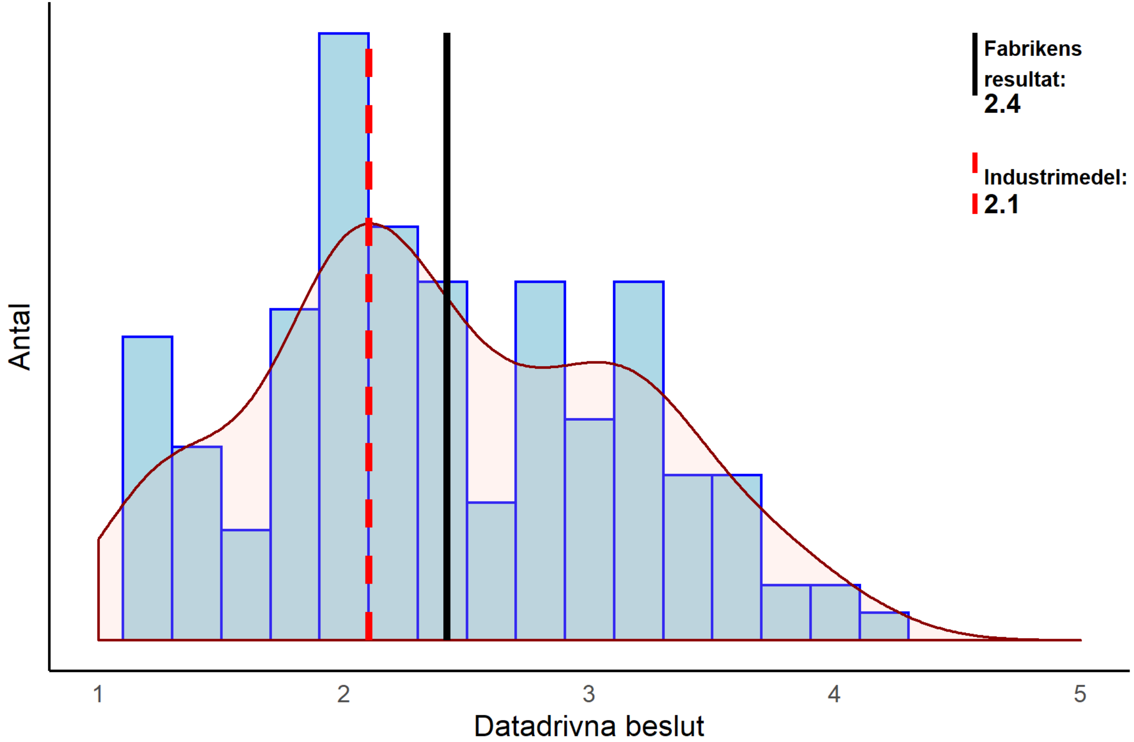
External integration

Influencing factors: education & training, corporate culture, leadership, cyber security, and etcetera

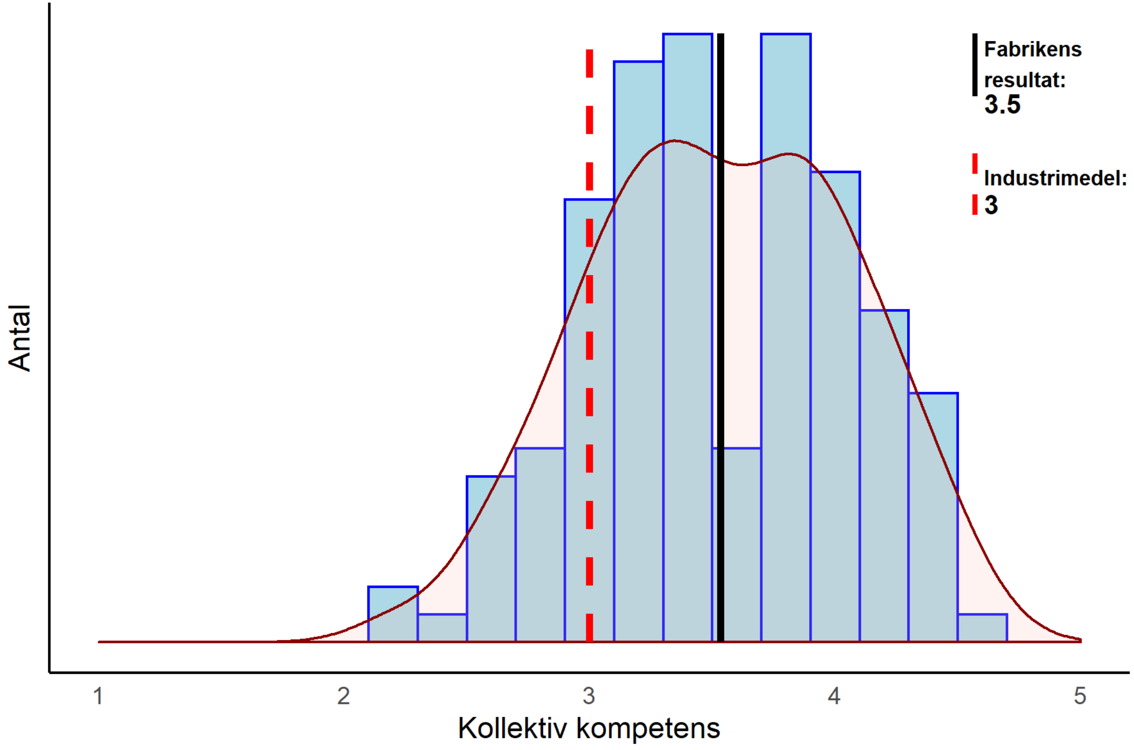
Maintenance prestanda in SMASh

1. Technical Availability
2. Mean Time Between Failure
3. Mean Time to Repaire
4. Mean Waiting Time
5. Un planned stopps
6. The number of unplanned maintenance tasks
7. Correctly executed both corrective and preventive maintenance
8. Maintenance work that caused downtime

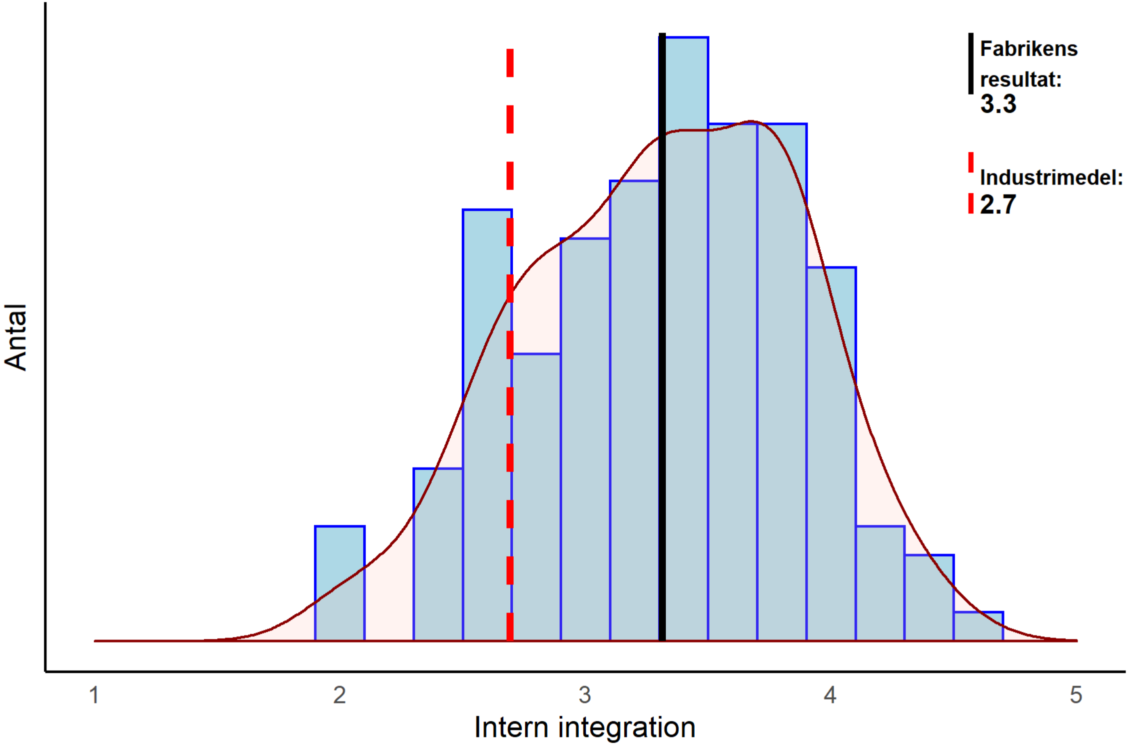
DATA-DRIVEN DECISIONS



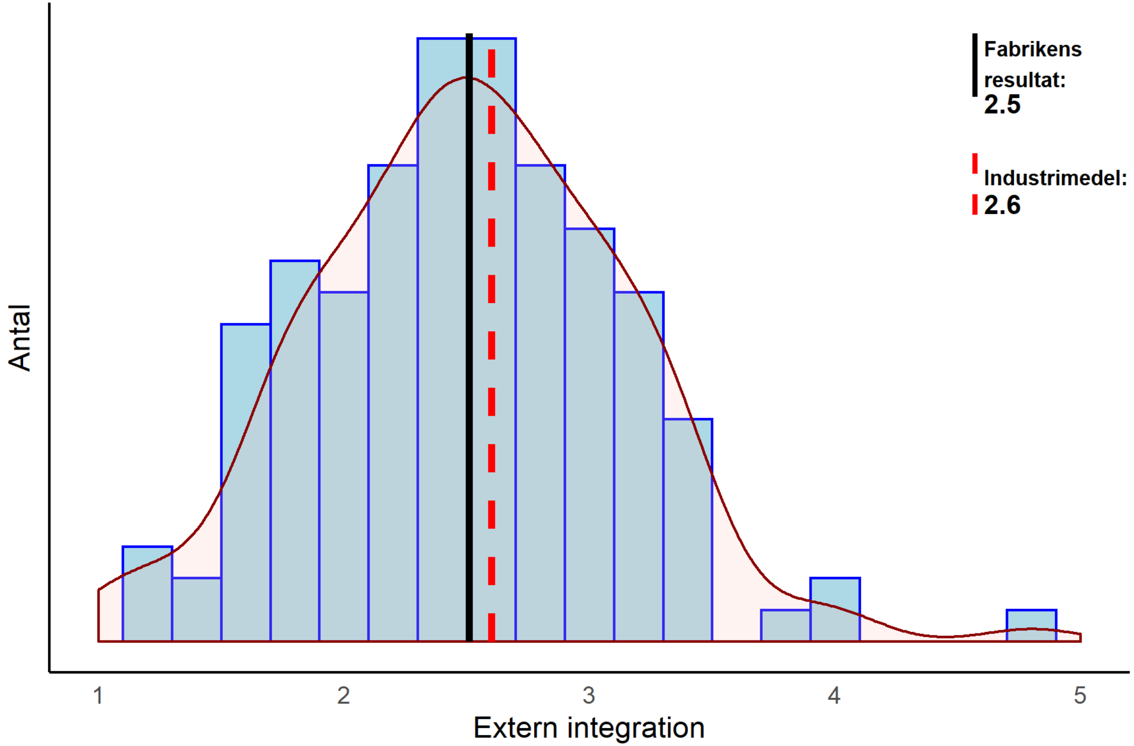
HUMAN CAPITAL RESOURCE



INTERNAL INTEGRATION



EXTERNAL INTEGRATION



IMPORTANT LEARNINGS

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- The link between performance and level of Smart Maintenance is scientifically proven
- Performance comes with the symbiosis of all four dimensions
- One dimension cannot compensate for another
- Investments in a ”non-bottleneck” dimension is waste of resources

NCA Resultat:
Datadrivna beslut (DDD): **35**
Kollektiv kompetens (HCR): **60**
Intern integration (INI): **45**
Extern integration (EXI): **19**
Underhållsprestanda (MAIN): **61**

NCA Analys:
I nuläget är fabrikens flaskhalsar DDD och EXI. Dessa måste förbättras för att möjliggöra högre nivåer av MAIN. HCR och INI är inte flaskhalsar i nuläget, men deras nivåer måste bibehållas för att investeringar i DDD och EXI skall ha någon effekt.

NCA Rekommendationer:
För att förbättra DDD och EXI rekommenderas följande:
- Rekommendation #1
- Rekommendation #2
- Rekommendation #3

För att bibehålla HCR och INI rekommenderas följande:
- Rekommendation #1
- Rekommendation #2
- Rekommendation #3

MAIN	DDD	HCR	INI	EXI
0	NN	NN	NN	NN
10	NN	NN	NN	NN
20	NN	NN	NN	NN
30	8.4	NN	NN	NN
40	16.8	11.9	5.5	NN
50	25.3	24.1	15.3	6.0
60	33.7	36.3	25.0	17.7
70	42.2	48.6	34.8	29.4
80	50.6	60.8	44.5	41.1
90	59.1	73.1	54.2	52.7
100	67.5	85.3	64.0	64.4

* NN = Not Necessary (”ej nödvändigt”)

Projekt Nytt Felkodsträd

Syfte

- Få en bättre uppföljning på avhjälpande fel för att hitta rätt förebyggande åtgärder och även kunna använda underlaget vid reinvesteringar för val av maskintyper.
- Skapa förutsättningar för att med underhållsdata kunna verifiera Machine Learning modeller

Mål

- Ta fram specifika felkoder (Problem, Orsak och Åtgärd) per Inventarietyp
- Underlätta hög kvalitet på återrapportering av avhjälpande underhåll (100% återrapportering av felkod och timmar)

ØRESUNDSBRON

Vi styr mot Smartare UH

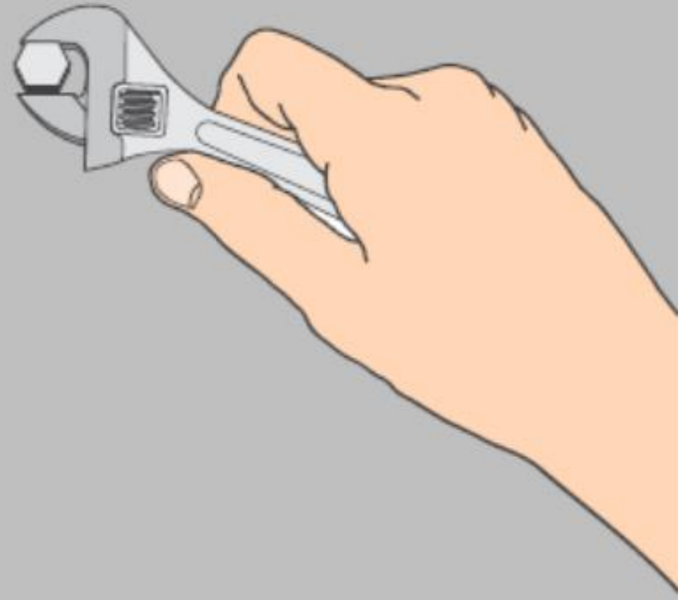
Typ av Underhåll	Undergrupp	Nytt KPI
Avhjälpande UH (AU)	Akut	
	Uppskjutet	
Förebyggande UH (FU)	Förutbestämd	
	Tillståndsbaserad, man	
	Tillståndsbaserad, data	**Datadrivet UH (DDUH)**
Prediktivt UH (PU)	Machine learning, AI	

Varför ändrade vi våra felkoder?

- Dålig återrapportering av felkod
- Det gamla felkodsträdet hade brister:
  - Utnyttjade inte alla nivåer i systemet
  - Alltför generella koder
  - Möjligt att ange "Null"
  - Otydligt om det var fel eller inte

➢ Mycket information om fel i huvudet på tekniker.
  - ➢ Dålig statistik
  - ➢ Försvårar analys och långsiktiga åtgärder baserat på fakta

➢ Omöjligt att träna algoritmer för datadrivet UH



Gammalt felkodsträd

Felkod	Problem	Orsak	Åtgärd
ÖSB	FH-P03 - Utebliven/obefogad/felaktig	-	-
Felkod Saknas	FH-P02 - Öppnar/startar/sluter inte	O-05 - Åldring/Slitage	Å-03 - Reparerad/Justerad
	FH-P04 - Felaktig reglering	O-10 - Mjukvarufel	Å-02 - Omstartad/Återställning
	FH-P01 - Stänger/stoppar/bryter inte	O-02 - Miljö	Å-01 - Kontrollerad
	FH-P07 - Incident	O-15 - Okänd	Å-04 - Utbytt ny
	FH-P05 - Läckage	O-01 - Konstruktion	Å-10 - Annan åtgärd/beskriv i fritext
	FH-P06 - Jordfel	O-04 - Montage	Å-06 - Rengjort
	FH-P10 - Smutsigt	O-12 - Parameterfel	Å-05 - Byte likvärdig
	FH-P08 - Dålig bildkvalitet	O-09 - Handhavande	Å-09 - Ingen åtgärd/Felet försvann
	FH-P11 - Väg-/järnvägshinder	O-13 - Underhåll	Å-07 - Smörjt
	FH-P09 - Vilt/djur	O-14 - Följdskada	Å-08 - Ytbehandlat
	-	O-08 - Olyckshändelse	Å-11 - Förbättringsförslag
		O-06 - Skadegörelse/Klotter	
		O-03 - Tillverkning	
		O-11 - Applikationsfel	

Exempel på ny felkodsstruktur

Class (Asset type/Inventarietyp)

Category	Class
R	Axelräknare
R	Balis
R	Befästning
R	Brygga
R	Circuit Breaker
R	Earthing
R	Gummiplattor
R	Kontaktledning
R	Network Device
R	Partikelmagnet
R	Power Supply
R	Räl
R	Signal
R	Signalställverk
R	Skarv
R	Sliper
R	Spår
R	Spårledning
R	Spårväxel
R	Övergångsrister

Problem (Problem)

- External
- Mechanical

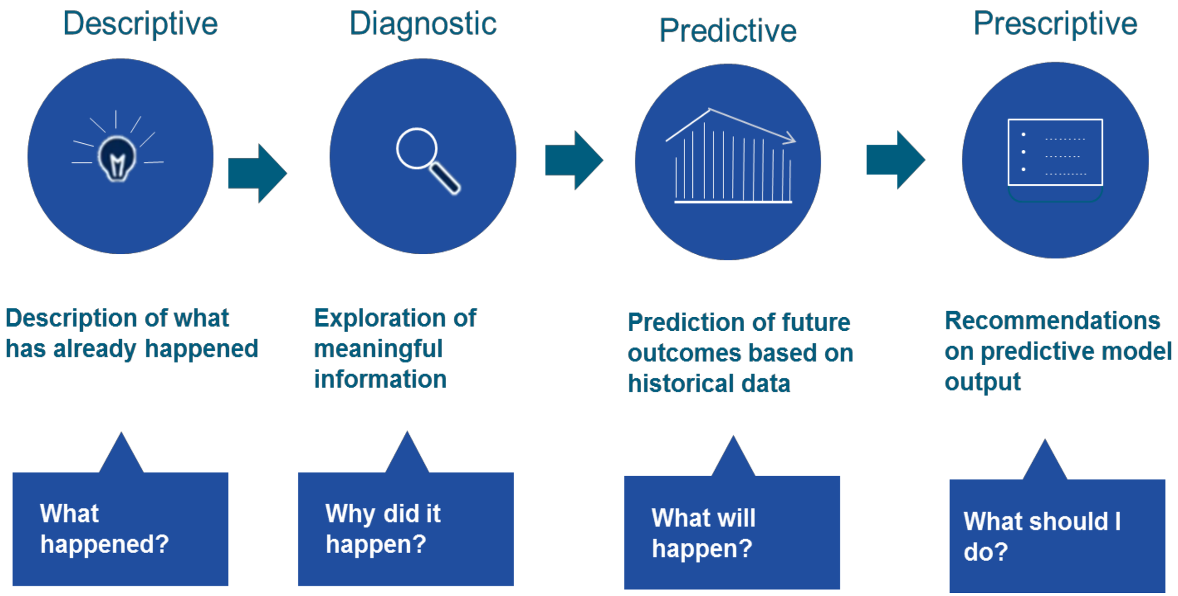
Cause (Orsak)

- Broken
- Fallen cargo
- Foreign object
- Ice coating
- No fault
- Poor drainage
- Sabotage
- Snow or ice
- Weather
- Wheel flat spot
- Work machines
- Work of outsiders

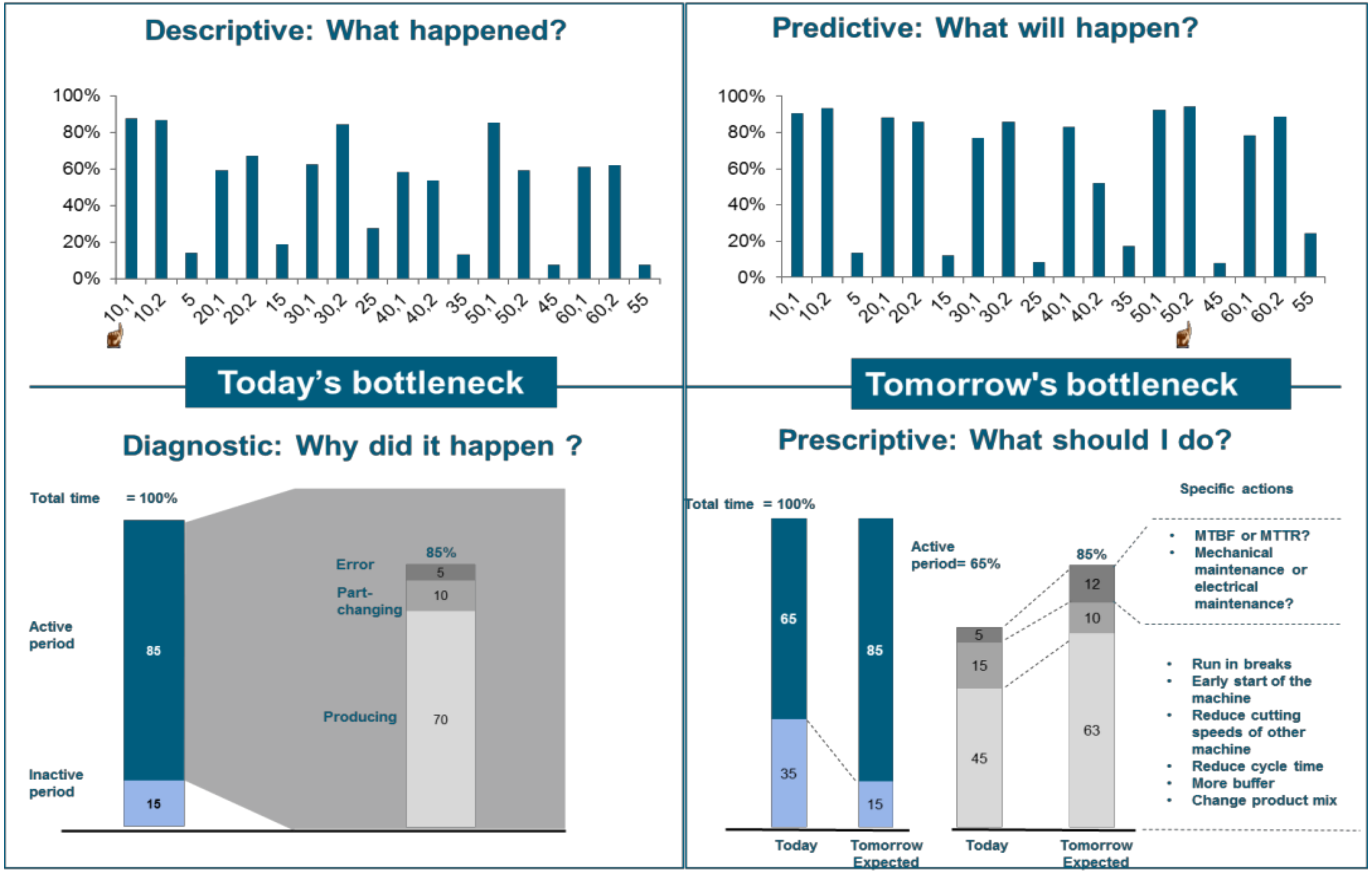
Remedy (Åtgärd)

- Adjust
- Control
- No fault
- Repair
- Replacement
- Temporarily decommissioned

LEVEL OF DATA ANALYSIS



EXEMPLE FROM SCANIA



SERVICE ORIENTED ORGANIZATIONS

THE INTEL USE CASE

[Peng 2000]

In the 1990’s, Intel started a reorganization of production maintenance of a testing facility for computer processor.

High pressure on the production system due to new product launch. Traditional maintenance could not meet the challenges.

NEW VIEW OF MAINTENANCE & EXTENDED RESPONSIBILITIES

- Started with a highly manual ordering system between production and a traditional maintenance department
- Changed name to Equipment Engineering Service (EES)
- From reactive maintenance to include engineering improvements
- Service-oriented organization with equipment users as customers
- Maintenance shop moved to the production shop-floor
- Maintenance no longer used as a word at Intel

IT SUPPORT SYSTEMS

- Developed relevant KPIs for the EES department
- Developed a basic computerized order handling system
- Evolved to a new Equipment Management System
  - Real-time monitoring
  - Weekly reports
- Analyzed down-time trends, identified improvement projects, required resolutions from equipment vendors
- Similar trends in other companies and on product monitoring

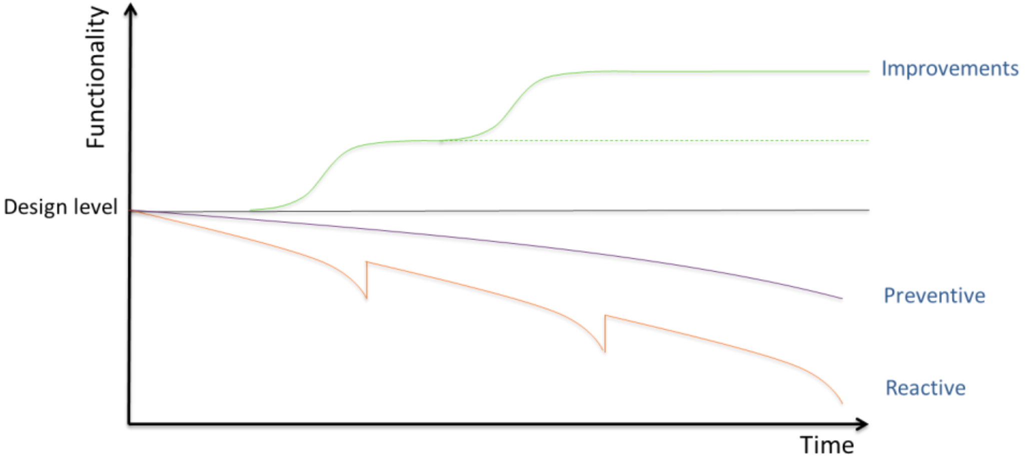
A good IT system did not solve all challenges!

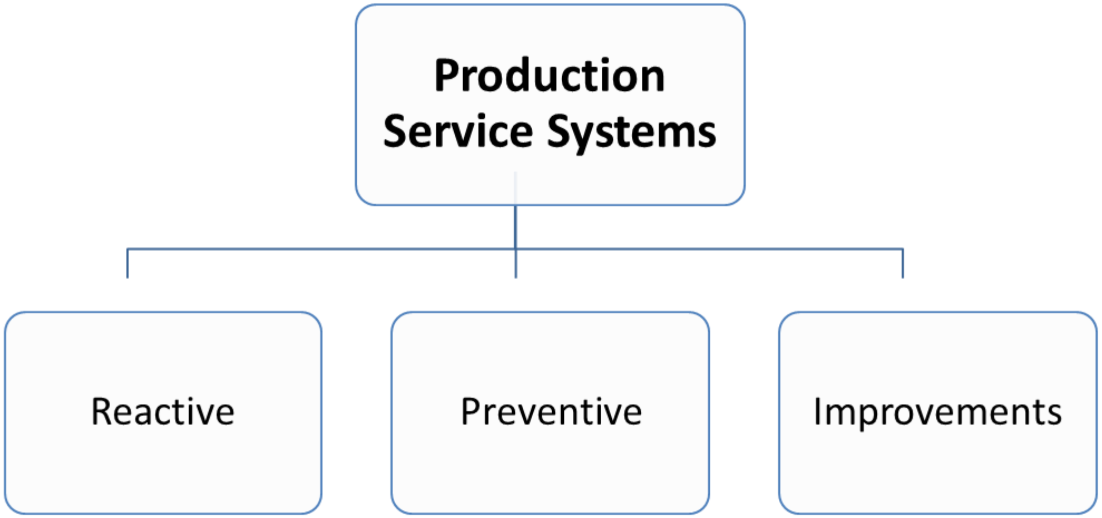
ORGANIZATIONAL CHANGE

- In late 1990's, the EES department integrated upwards in the organization
- Turned into "Platform Engineering (PE)" together with R&D/manufacturing engineering
- Employees at PE became equipment owners
- Delivered "uptime" of the equipment
- Substantial freedom in the way of working
- Examples of work-tasks:
  - Coordination of equipment purchase
  - Equipment installation and acceptance
  - Equipment support structures
  - Negotiated service contracts
  - Wrote repair instructions
  - Trained production operators

PRODUCTION SERVICES SYSTEMS

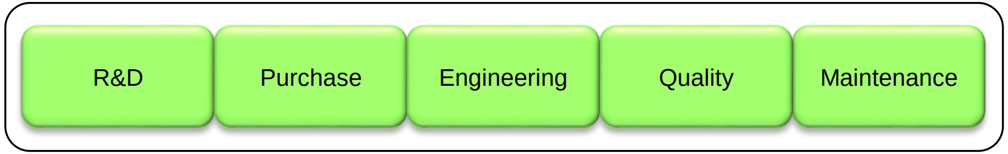
Production service activities aim to retain, restore, and improve production systems relative inherent or agreed specifications during their entire life cycles. Reactive and preventive maintenance as well as improving activities are applied to increase system dependability and thereby economical, ecological and social sustainability.



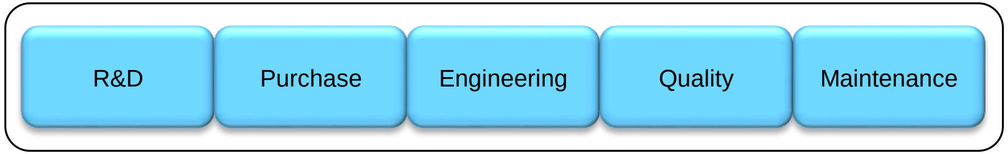


Examples:	Immediate Deferred	Predetermined Condition-based Predictive	Upgrades Replacements Remanufacturing

PRODUCTION SERVICE SYSTEMS



Multi-disciplinary team delivering production of product A as a service over its entire life-cycle



Multi-disciplinary team delivering production of product B as a service over its entire life-cycle

MANAGING OPPORTUNITIES AND RISKS OVER ENTIRE LIFE-CYCLES

The Product & Production Service Systems course is about:

- ❑ Understanding and bringing value from servitization
- ❑ Understand how servitization can be appied to both product and production systems
- ❑ Understand the role of maintenance in service systems

- ➢ Detecting risks
- ➢ Quantifying risks
- ➢ Predicting risks
- ➢ Preventing disturbances
- ➢ Reacting on disturbances
- ➢ Elimination of root-causes
- ➢ Provide services and added value to customers

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