Asset Management

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WCM Summer School 2014

Maintenance in the Dutch economy – Relevant ?

- Approx. 300.000 people work in the Dutch maintenance sector, or 4 % of the working population[1]
- The total size of the maintenance sector in financial terms: € 35 bln[1]
- 79% of the parties active in maintenance expect growth in the sector in the coming years[1]

What more?

Reasons for growth include:

- The process industry is the largest application area with the largest expected growth
- Industry in The Netherlands is (increasingly) automated using complex equipment
- Maintenance is getting more sophisticated. Companies are really beginning to see the value (and the cost)

What more?

[1] NVDO Onderhoudscompas, 2010

Asset (Life Cycle) Managemen

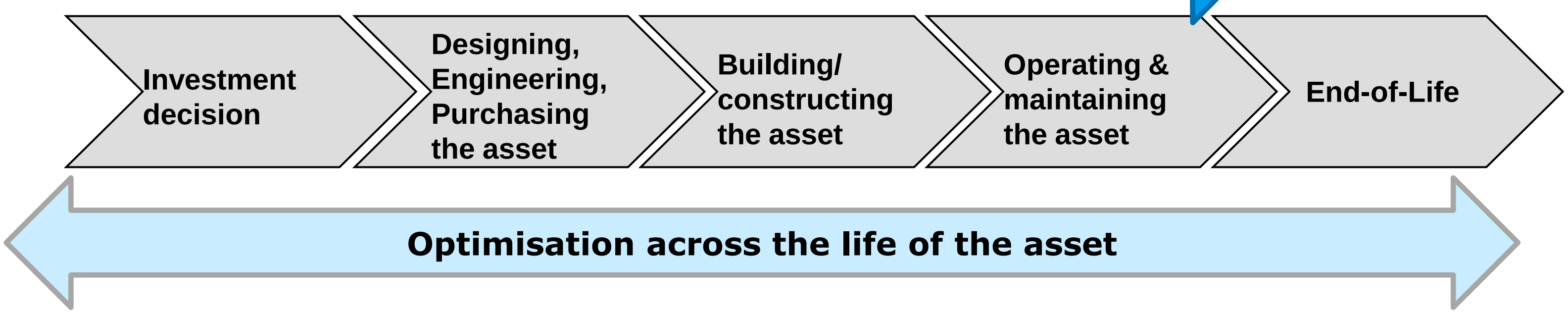
It does not consider reuse

› Complex and capital intensive equipment r
attention in all of the phases of the life cyc

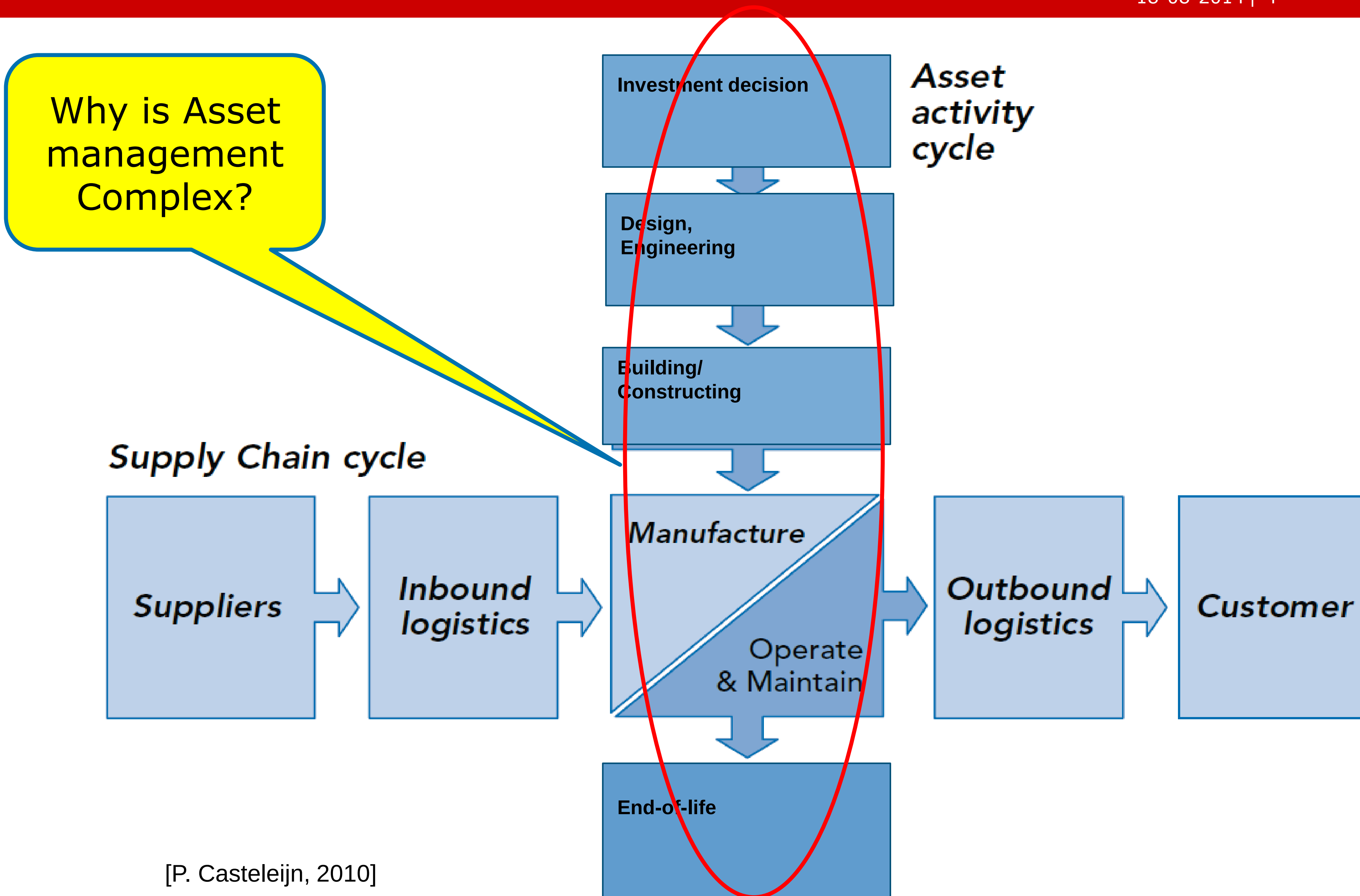
› The production asset is often the core of the o ation, e.g.

- Refinery
- Steel mill
- Gas processing plant
- Complex discrete production equipment

What is wrong With this picture?



Asset Management



[P. Casteleijn, 2010]

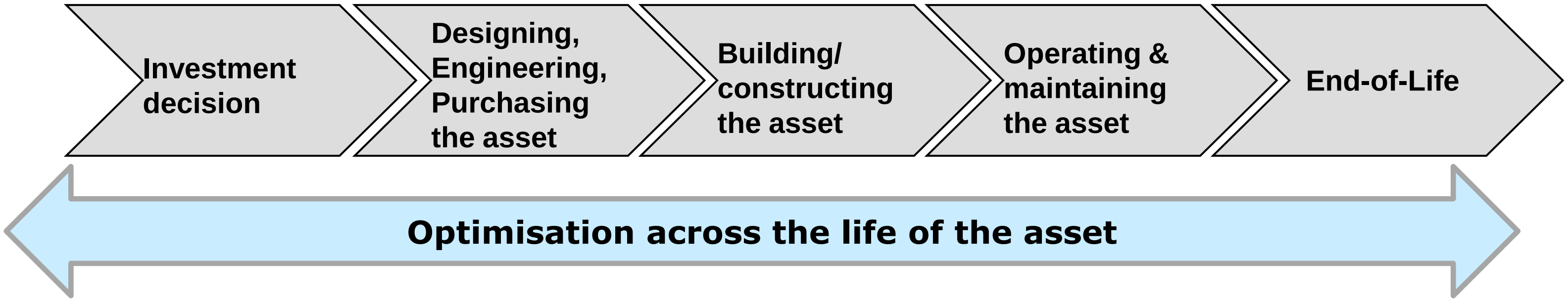
Asset Management is complex because:

Requires inter-disciplinary co-ordination:

- **Interdependency between phases** for optimisation
- Different disciplines are often carried out by **different parties** (departments, discipline specialists, contractors, equipment suppliers)

Health & Safety and Financial implications:

- To ensure **Health & Safety**, many technical, organisational (procedural) and information related aspects need to be co-ordinated
- The operations/maintenance costs tend to be **significant** and in the same order of magnitude as the of initial investment.



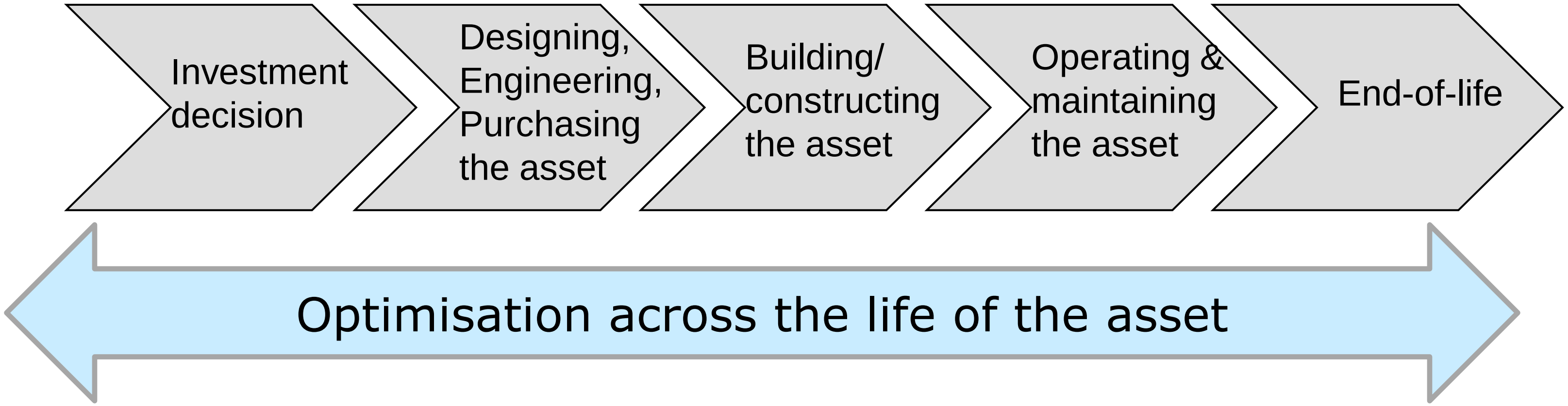
Co-ordination

- In each phase, there are multi-disciplinary decisions
  - Information for these decisions is often difficult to retrieve

- Across phases, decisions are interdependent
  - Information has to be transferred over a long period of time

Recall: "the information assumption"!

How long, for example?

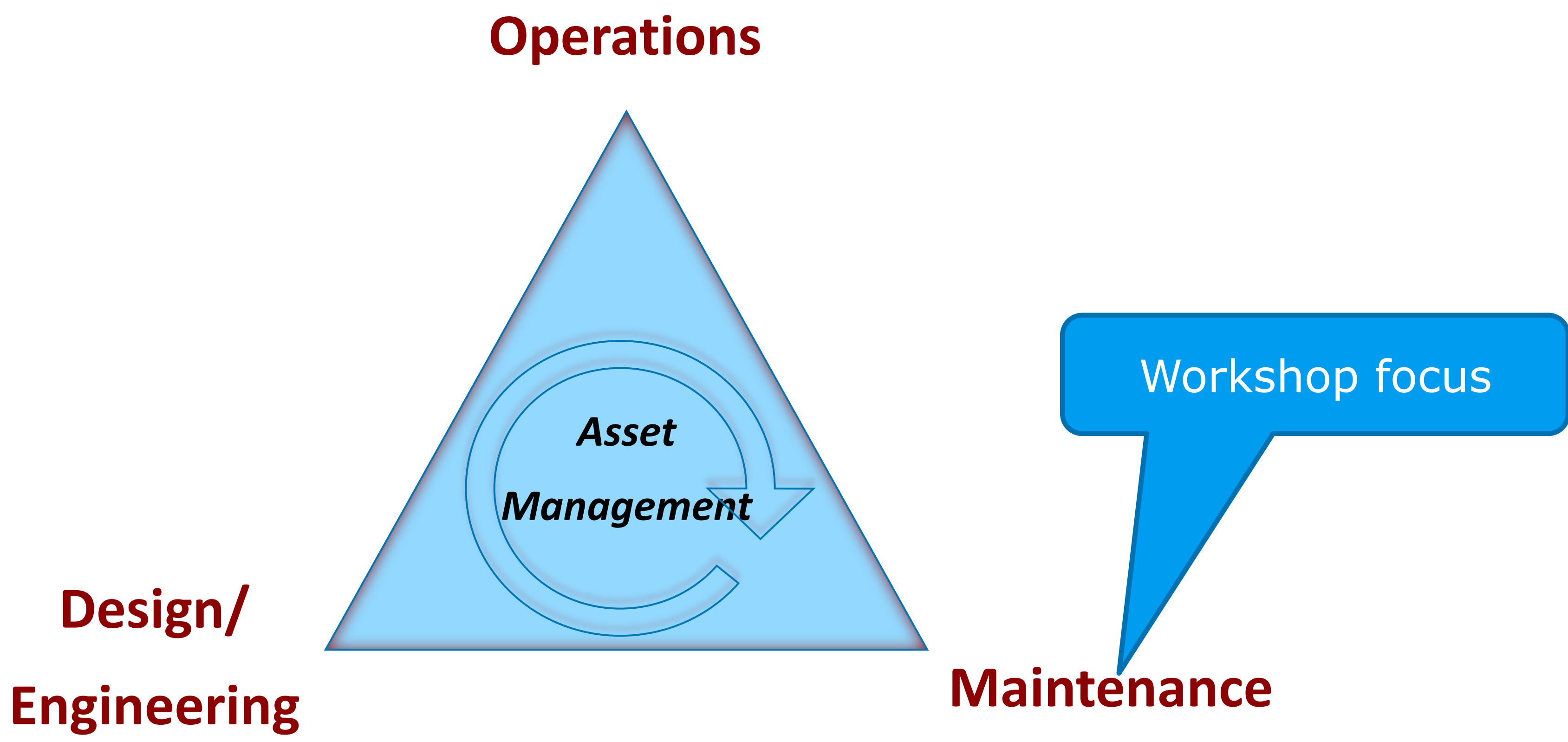


Significant Implications

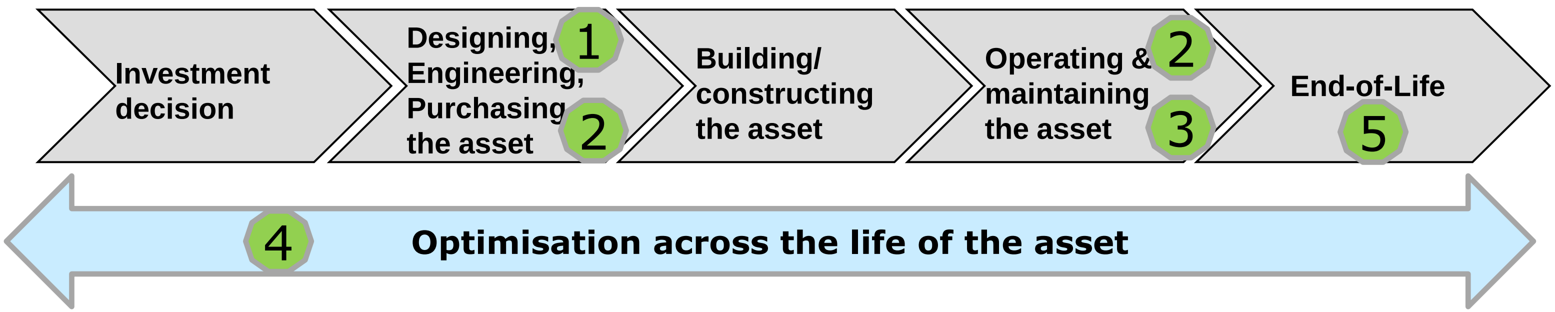
› Financial: total costs of ownership (TCO)
  - Maintenance costs over the life cycle
    - Same magnitude as initial investment
  - Costs of non-availability (e.g. shutdown)
  - Costs of decommissioning

› Health, Safety and Environment: HSE
  - Moral issues at personal level
  - Corporate social responsibility
  - Corporate sustainability strategy

Asset Management



Topics in this workshop



Topics:

1. Designing a maintenance programme
2. Maintenance Concepts
3. Maintenance Planning
4. Asset Information Systems
5. Link with sustainability

- General knowledge and
- Research findings University of Groningen

Designing a maintenance programme

RCM

1. Select equipment

FMEA

2. Determine functions
3. Describe failures
4. Describe failure modes
5. Describe effects

6. Select appropriate maintenance actions (or engineering actions); determine task frequencies

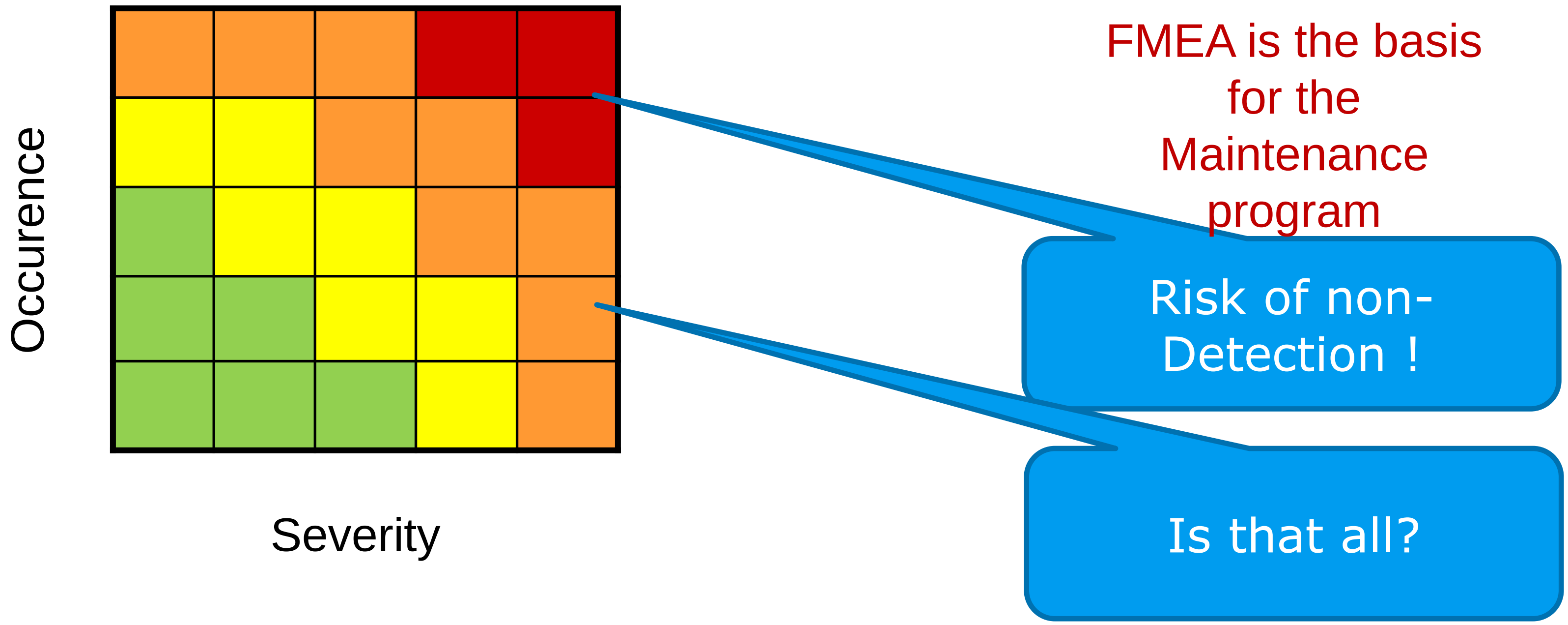
7. Document results and Commence monitoring

RCM = Reliability Centered Maintenance

FMEA = Failure Modes & Effects Analysis

Risk-based Maintenance

- Focus your resources on the situations with the highest Risk of failure
- Risk in terms of Severity and Occurrence
- Visualization of priorities through colours



Failure Mode & Effect Analysis (FMEA)

- Risk of non-detection should be taken into account!

Recall the information assumption

- Steps in FMEA:

1. Identify 'failure-modes'
2. Rank the effects based on a Risk Priority Number

   RPN = S x O x D

   Is that all?

   S= Severity; O=Probability; D= detection

   These are estimated (0..10) by experts
3. Outcome: ranking of importance of (investments in) maintenance
4. See next slide

Failure Mode & Effect Analysis (FMEA)

Rating	Description	Definition
10	Dangerously high	Failure could injure the customer or an employee.
9	Extremely high	Failure would create noncompliance with federal regulations.
8	Very high	Failure renders the unit inoperable or unfit for use.
7	High	Failure causes a high degree of customer dissatisfaction.
6	Moderate	Failure results in a subsystem or partial malfunction of the product.
5	Low	Failure creates enough of a performance loss to cause the customer to complain.
4	Very Low	Failure can be overcome with modifications to the customer's process or product, but there is minor performance loss.
3	Minor	Failure would create a minor nuisance to the customer, but the customer can overcome it in the process or product without performance loss.
2	Very Minor	Failure may not be readily apparent to the customer, but would have minor effects on the customer's process or product.
1	None	Failure would not be noticeable to the customer and would not affect the customer's process or product.

Extensions of FMEA

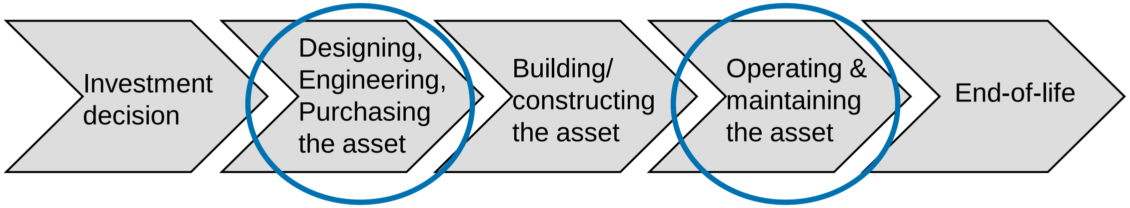
Failure mode and <u>mechanisms</u> & effects analysis (FMMEA)

- Traces back to the sources of failure modes
- Identifies and studies the failure mechanisms
- Expands the analysis by understanding the mechanisms

Failure mode & effect <u>criticality</u> analysis (FMECA)

- Investigates deeper the consequences of failures
- Pays much more attention to the criticality
- May include criticality in the Risk Priority Number

These extensions are useful but do not change the advantages or shortcomings



Benefits and drawbacks of FMEA

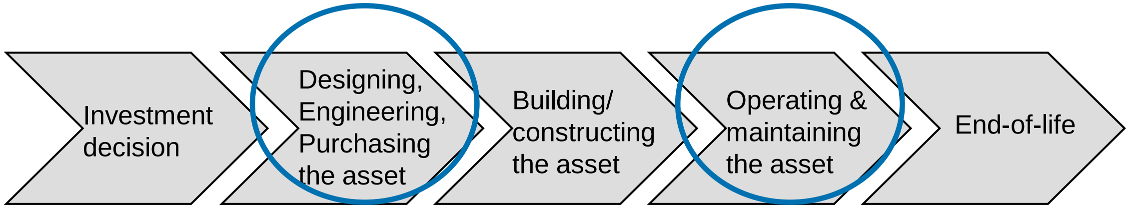
Benefits/strengths of the procedure

- Structured & robust procedure for making a maintenance program
- Based on the relationship between causes of failures and effects
- Can in principle be carried out without the availability of measured data

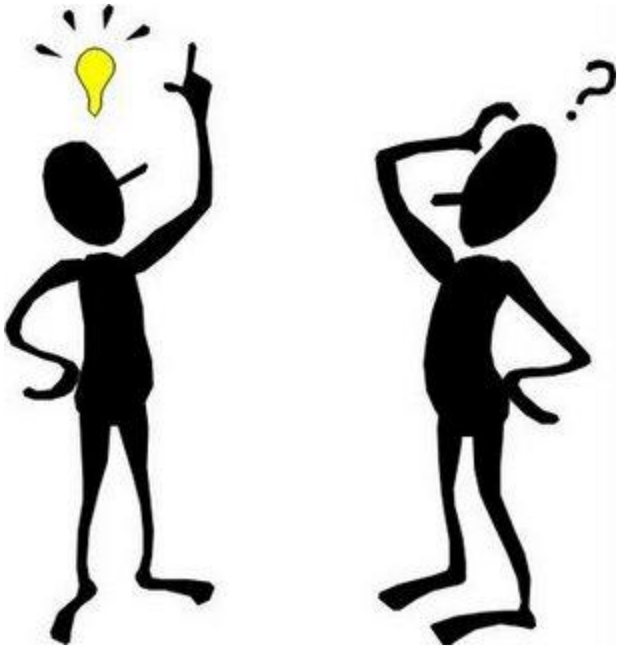
Recall the information assumption

Drawbacks:

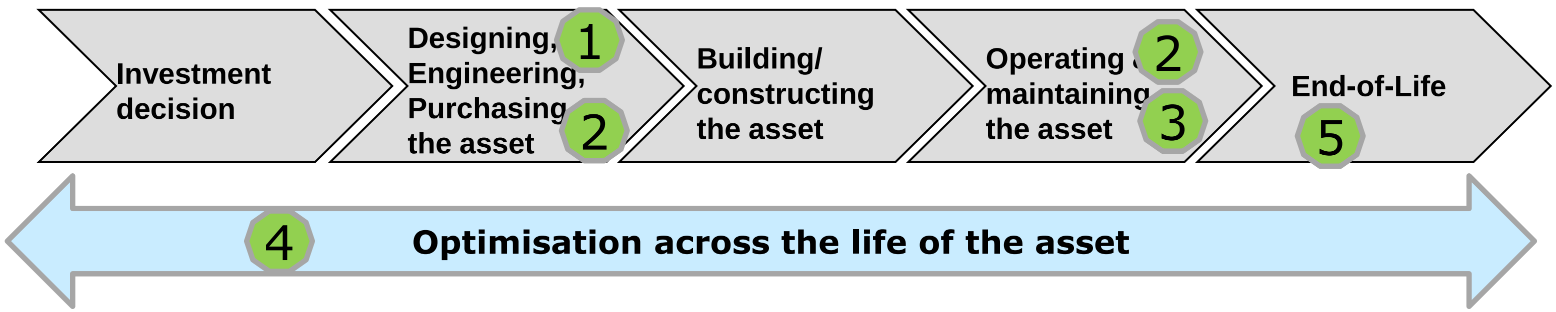
- Subjectivity of the analysis (expert opinion)
- No use of measured data, a potentially rich source of information
- Costs are not included
- Limited possibilities for updating as design engineers (initial experts) may not be available during operational phase.



Questions



Topics in this workshop



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- General knowledge and
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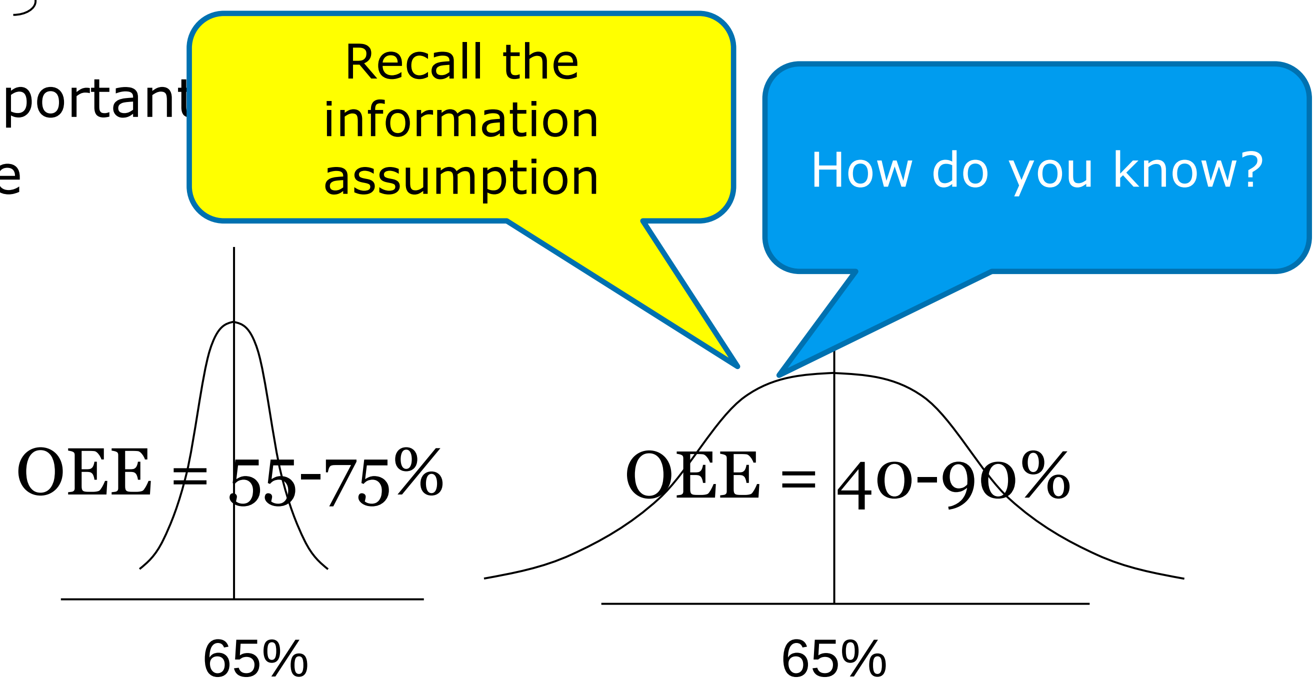
Maintenance – KPI: OEE

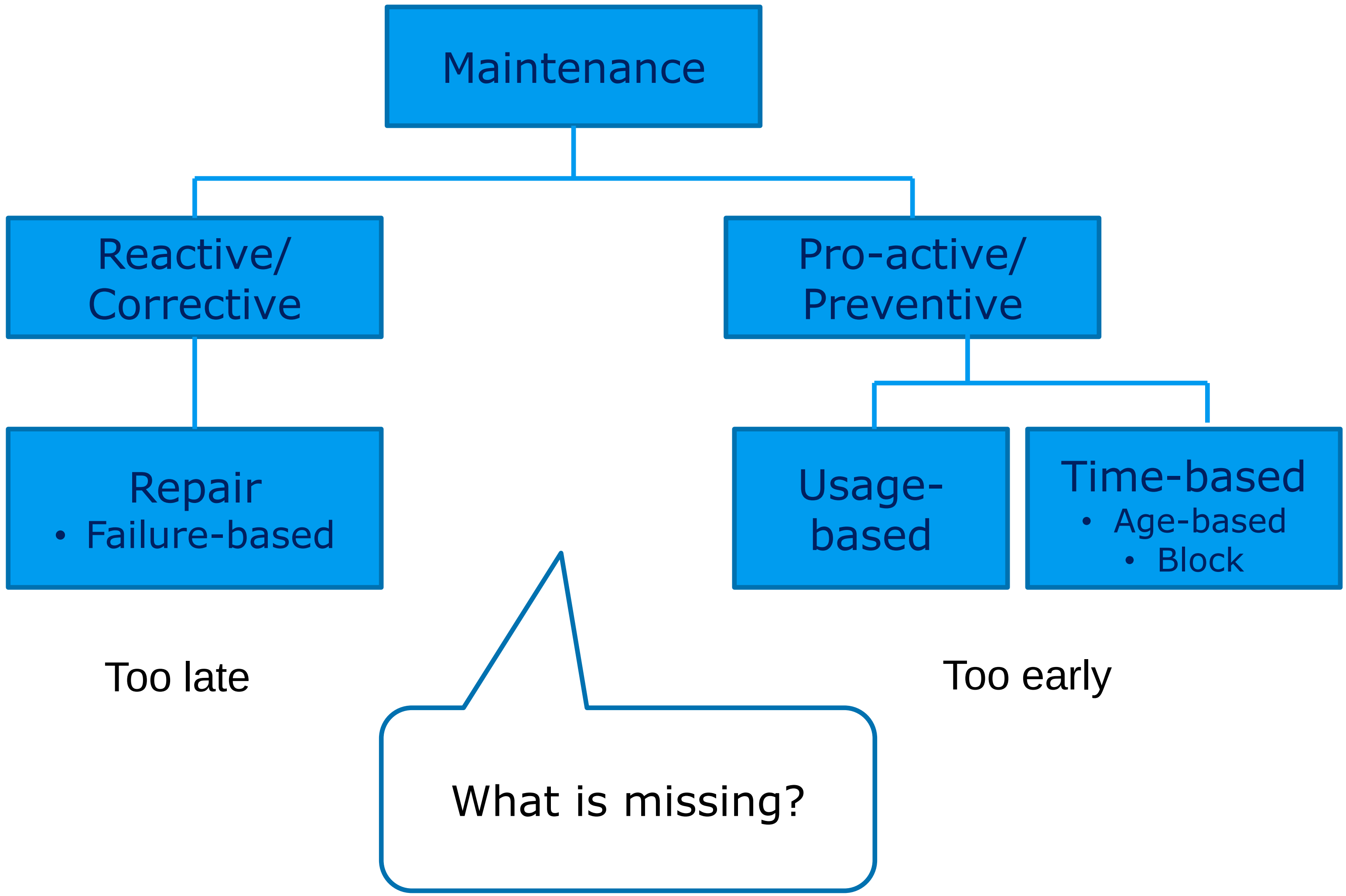
- A good production performance starts with reliable production processes
  - Availability
  - Capacity
  - Quality

  Overall Equipment Effectiveness (**OEE**)

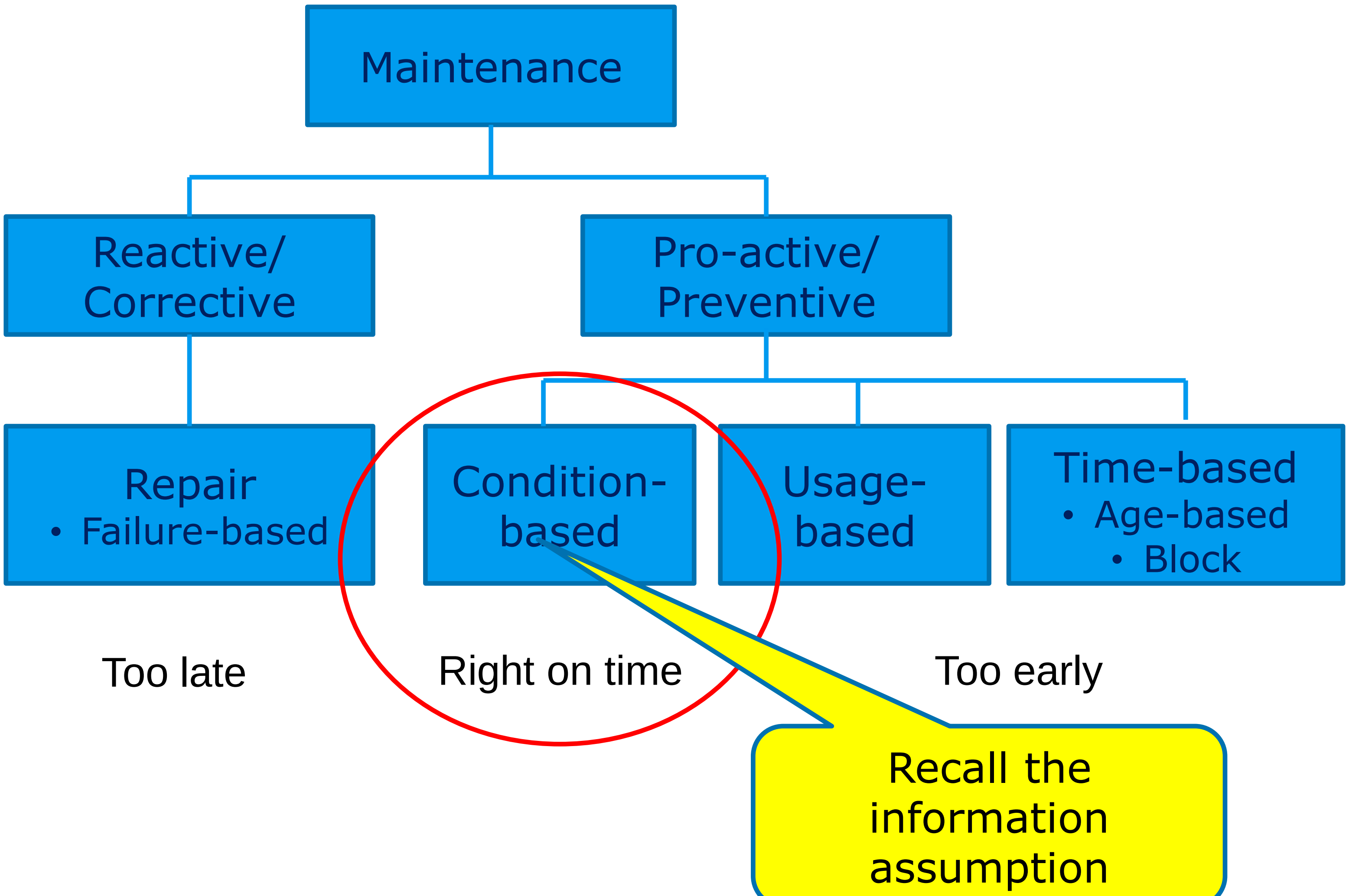
- Two aspects important
  - Average value
  - Variation



Maintenance concepts



Maintenance concepts



Maintenance/Reliability Engineering

"**Maintenance Engineering** is the discipline and profession of applying engineering concepts to the optimization of equipment, procedures and use of budgets to achieve better maintainability, reliability, and availability of equipment." (Wikipedia)

Responsibilities of a **Maintenance Engineer** include:

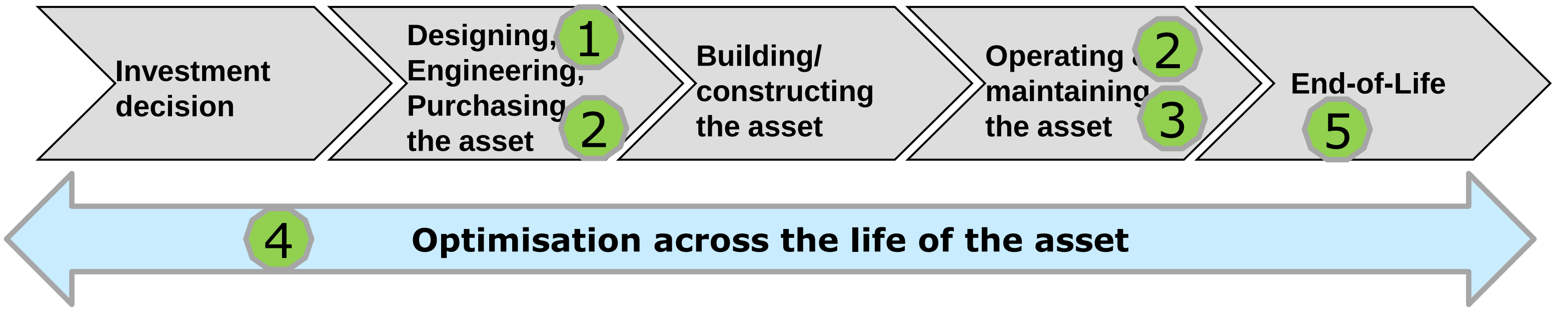
- Analysis of equipment failures
- Developing the maintenance plan, estimation of maintenance costs
- Forecasting of spare parts requirements
- Establish equipment replacement programs when due
- Developing tools/ methods to do all this

Recall the information assumption

Reliability Engineer: focus on reliability trends, data analysis

Safety Engineer: focus on systems safety, safety risk minimization

Topics in this workshop



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Corrective Maintenance

Characteristics:

- Unplanned
- A breakdown occurs

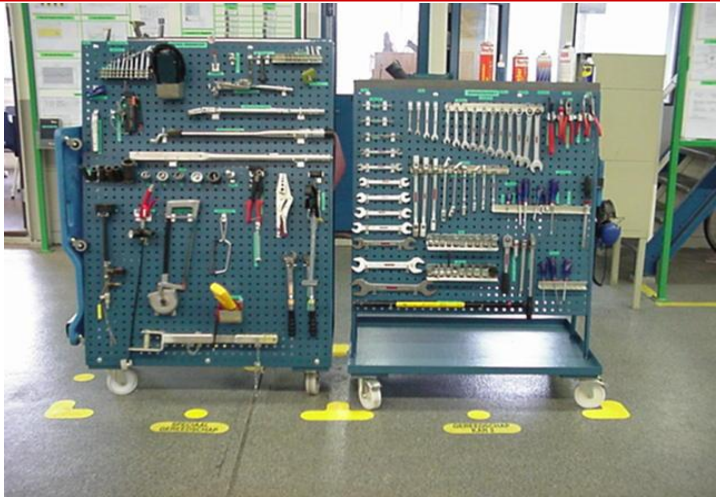
Consequences may include:

- Safety issues
- Machine damage
- Machine availability <100%
- Extra cost due to emergency repair

Can we do something about that without moving to a different maintenance concept?

Yes we can

Effective corrective maintenance



- ✓ Housekeeping of tools
- ✓ Proper administration of spares
  (e.g. also with shadow boards)
- ✓ Emergency response team (think Formula-I-pit-stop)
- ✓ Autonomous maintenance (= by production operators).

  Example:
  - exchange of spares by production operator
  - equipment to facilitate autonomous maintenance
  - exchange of spares based on SMED principles
- ✓ In general: excellent coordination between production and maintenance

Preventive Maintenance

Preventive

- “Prerequisite for a good operational performance”. Why?
- Replacement of a well functioning part?
- When? Every month, after 10,000 km, ….?
- Which machines and which parts?

Possible dilemma’s:

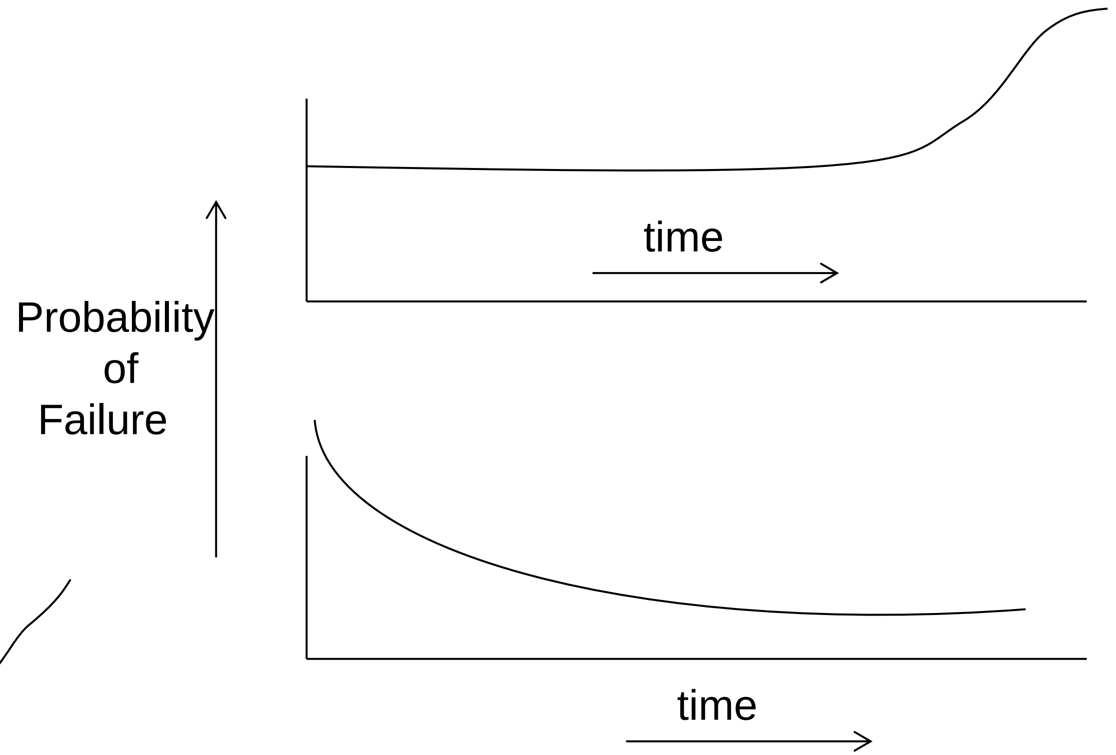
- To estimate the time until failure
- Cost, benefits, risk
- Only key machines?

Failure patterns – see next slide

Failure rate

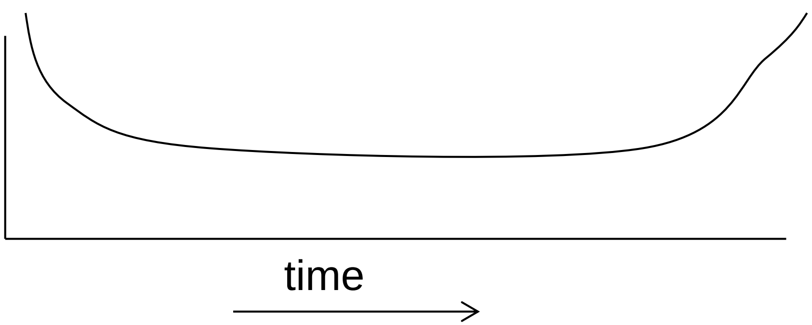
Definition: the **failure rate** of a station:

The ‘probability’ that a station breaks down in some period (day/week/month/year), given that the station is still up at the start of that period.



› **Increasing**
› **Decreasing**
› **Constant** failure rate

When should we perform preventive maintenance?



Planned Maintenance

The aim is to prevent (or postpone the moment of) failure.

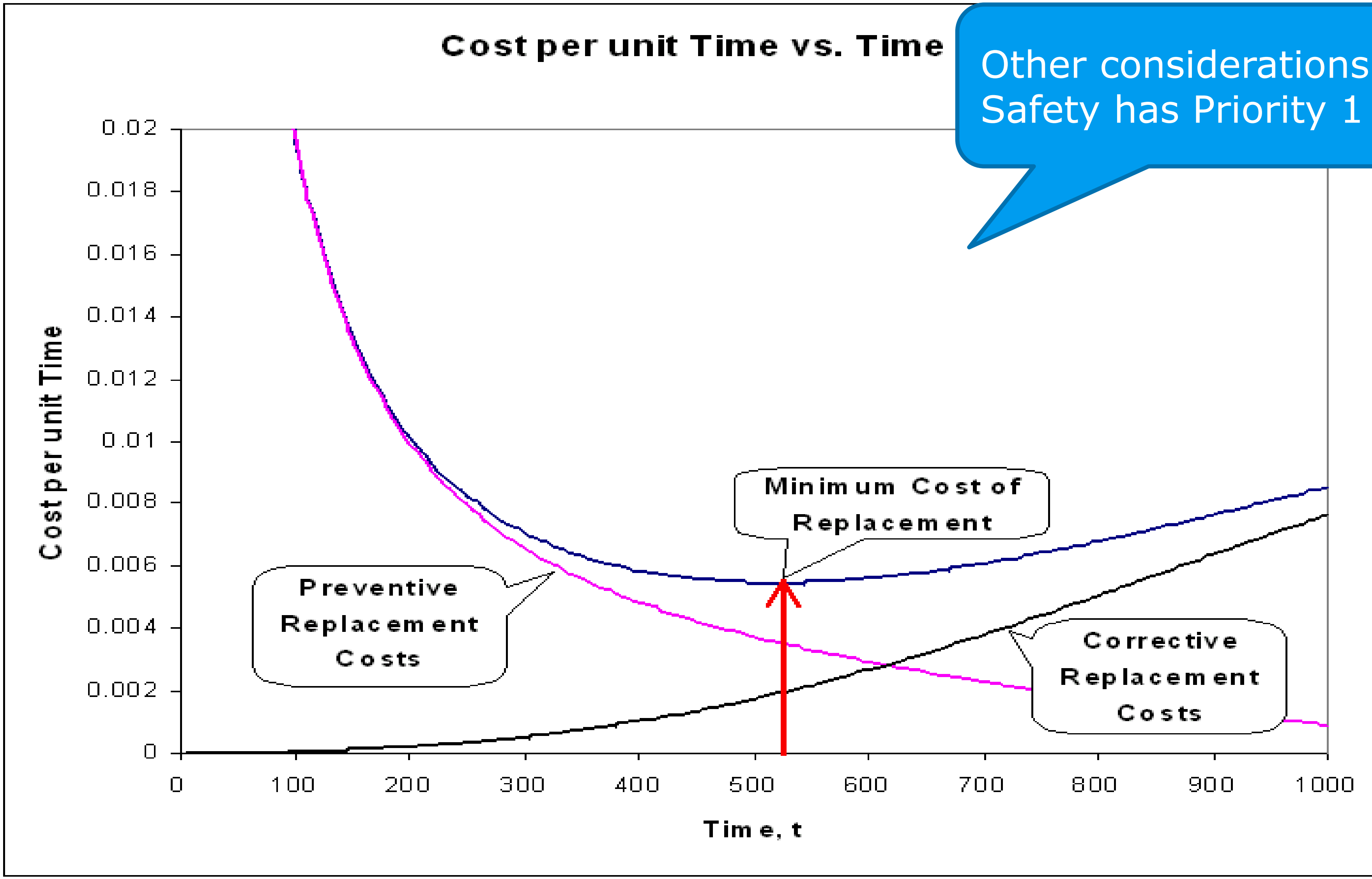
Characteristics:

- Still failures to be expected (planning interval usually not (entirely) deterministic)
- A fully functional machine is "repaired". Waste?
- Planned maintenance only makes sense if failure can be predicted, and if the preventive action makes the machine more reliable (i.e. the chance of a breakdown after the maintenance action is diminished).
- The planning should be determined based on time, usage, …

In terms of planning, "Mean Time Between Failures" (MTBF) can provide some guidance

Often a mix between maintenance types is selected, based on costs, benefits (savings) and risks.

Maintenance Cost Optimization



Other considerations:
Safety has Priority 1

Beware of Censored data

Censored duration: A duration that does not end with the failure of the station.

There are two types of censored durations:

› The duration that ends with a **preventive maintenance** action.

› The duration from which the end is not observed because the **time window** (observation window) ends.

By omitting censored durations, the reliability of a station will be **underestimated** (because longer durations have a higher probability to be censored than shorter durations

Certain techniques can/should be used to incorporate the censored data to determine the MTBF, the relative frequency histogram and the reliability/survival function.

Conclusion

No, you have to take into account the variance of TBF

- Works well if you know the mean time between failure (MTBF)

Really?

- But what if you don't?

Recall the information assumption

Condition-based Maintenance (CBM)

Preventive *and* corrective, not planned but based on condition of the equipment – “just-in-time”

Best of both worlds so it will always be used?

Recall the information assumption

CBM can be appropriate when:

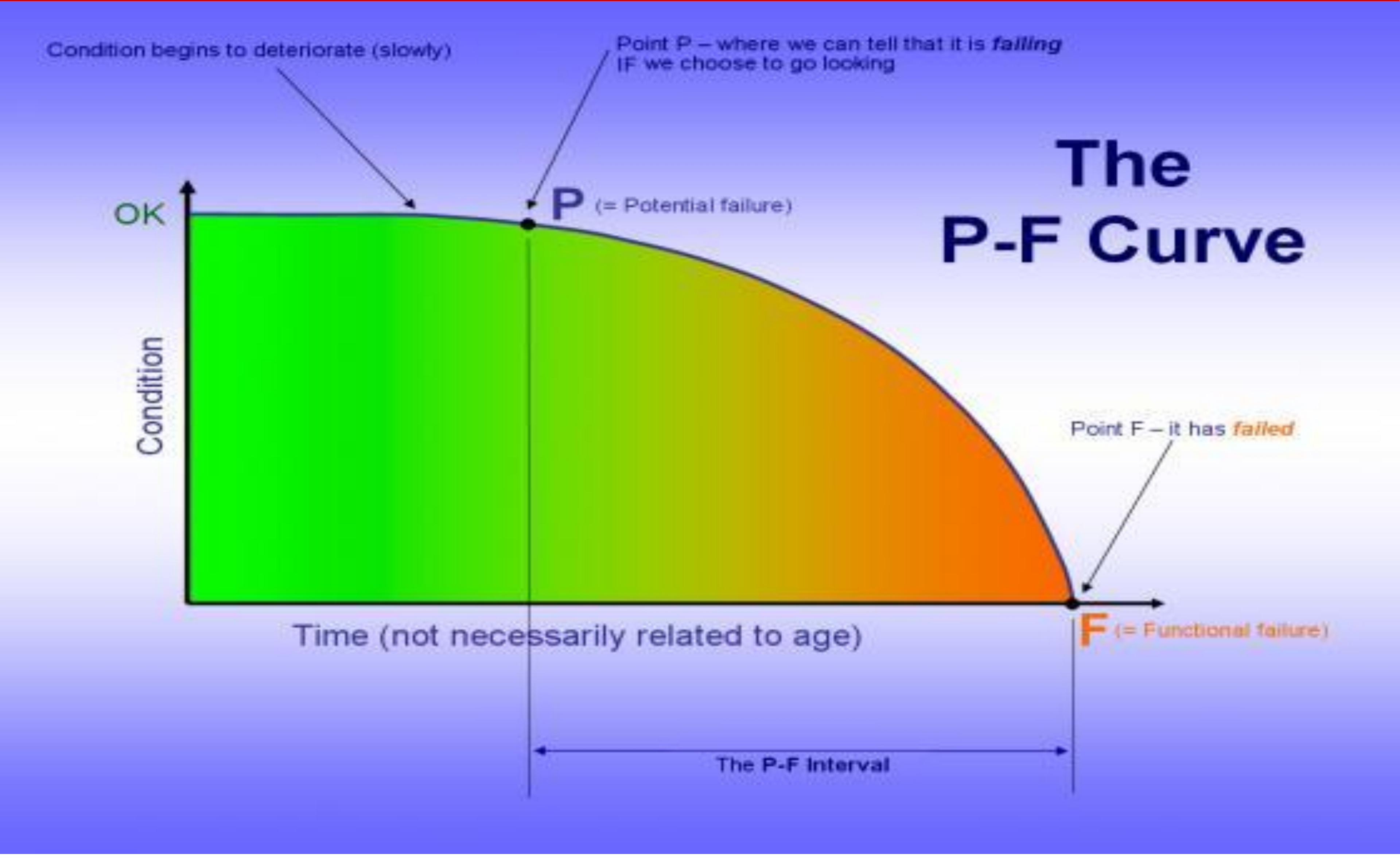
(1) A measurable parameter which correlates with the onset of failure can be identified;

(2) It is possible to determine a threshold value (warning limit) for that parameter;

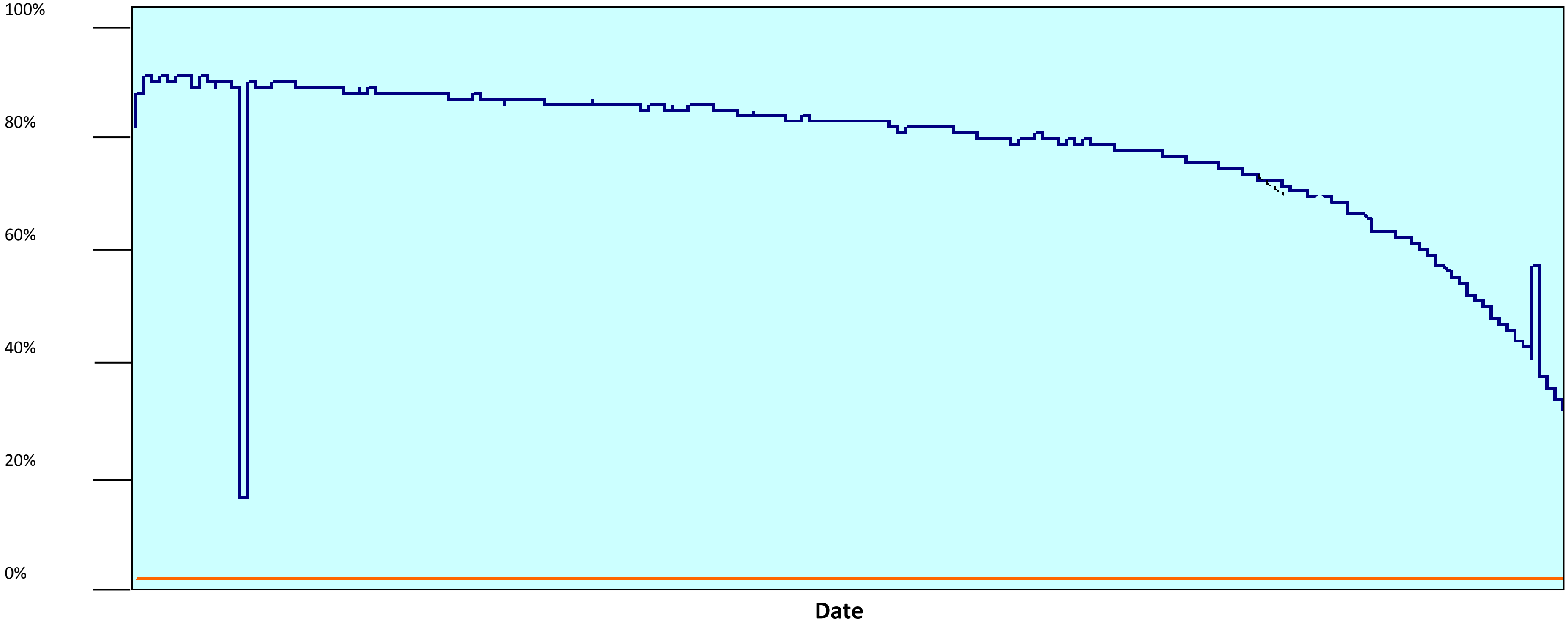
(3) Prevention through time-directed maintenance is not possible, or the impact of a failure is too much to bear

(Tsang et al., 2006).

Condition-based Maintenance (CBM)



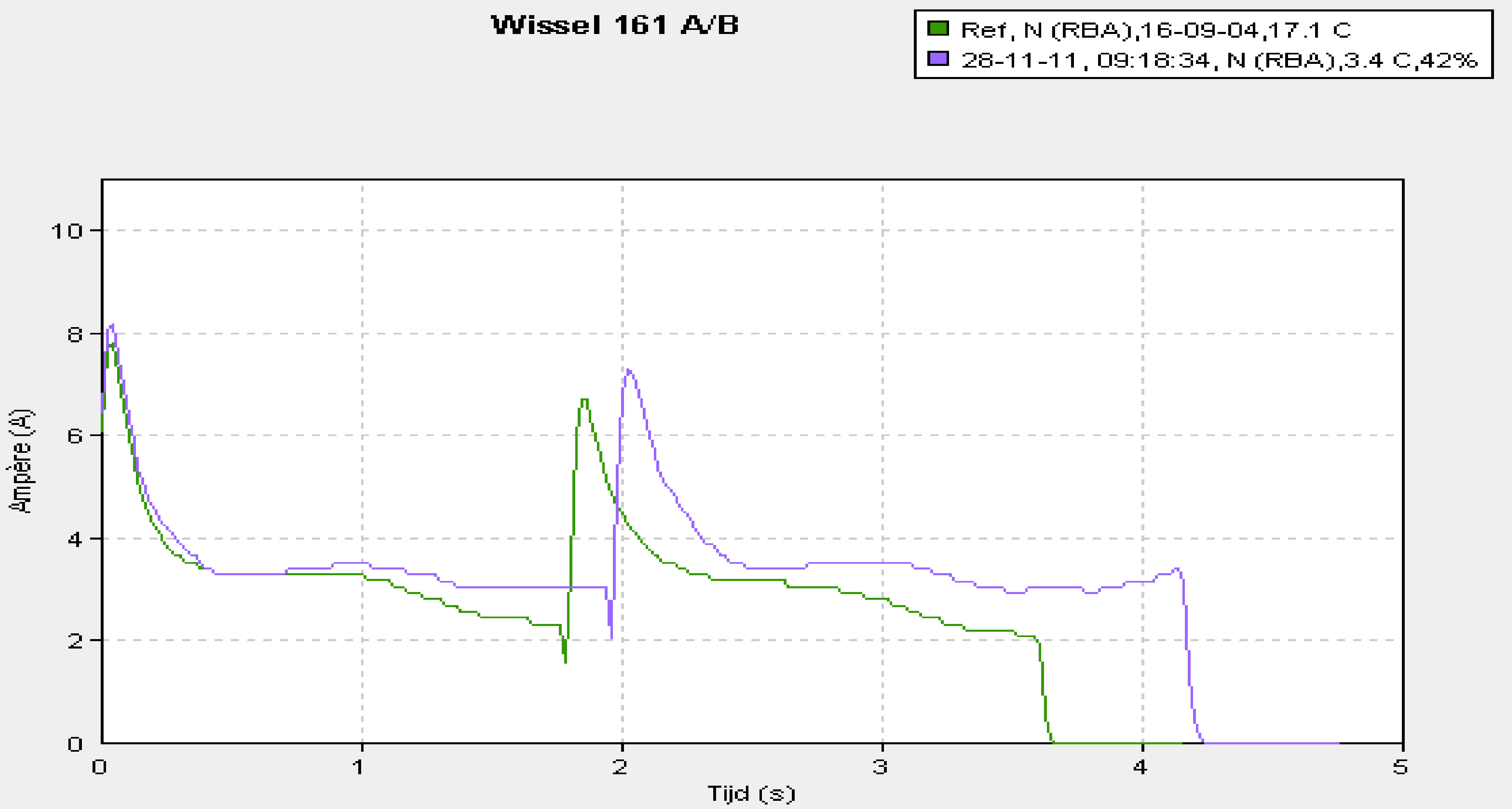
CBM Example 1



P-F curve of ion exchange module

CBM Example 2

Energy usage by rail track



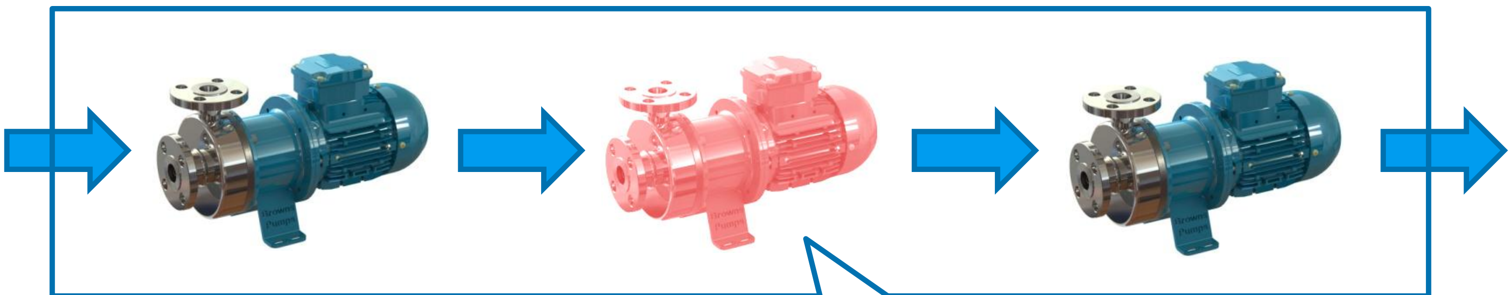
Condition-based Maintenance (CBM)

The view of CBM mostly found in the literature:

Condition-based maintenance of a single machine leads to:

- Less unplanned downtime
- Better quality
- Lower maintenance cost

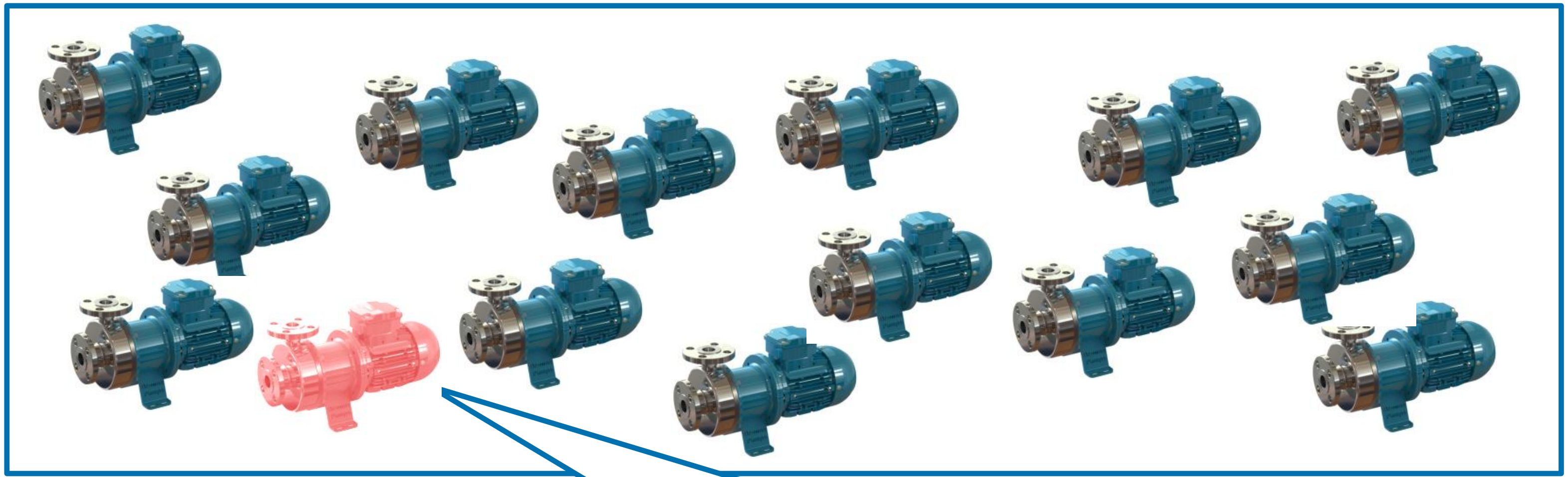
The view of the Operations Manager (example)



"If we carry out maintenance on one pump, we will effectively shut down the process!"

Can we plan and coordinate this?

The view of the Operations Manager (another example)



"*What about:*
- *Optimizing maintenance?*
- *Fixed vs. Variable costs? Safety?*
- *Example: plant shutdown, set-up cost for maintenance"*

Clustering CBM-activities

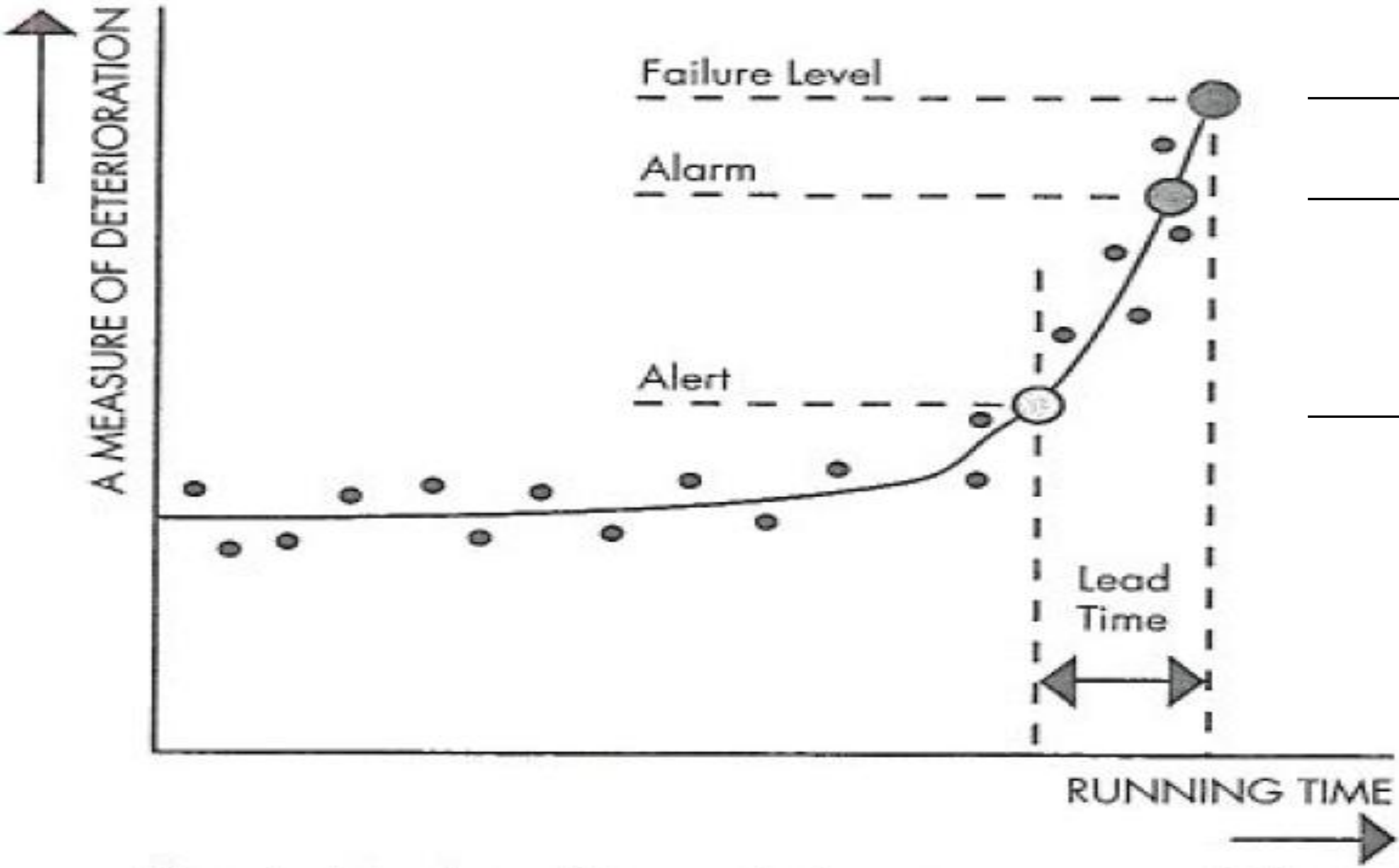
Research Project RuG

› Starting point: a case study

› Clustering of maintenance activities may be beneficial:
- Safety: minimising the number of site visits
- Cost: maintenance carries set-up cost (fixed cost)

Clustering CBM-activities

Research Project RuG



The principle of condition monitoring measurements which give an indication of the deterioration of the equipment

Maintain

Alarm

Alert

Observations

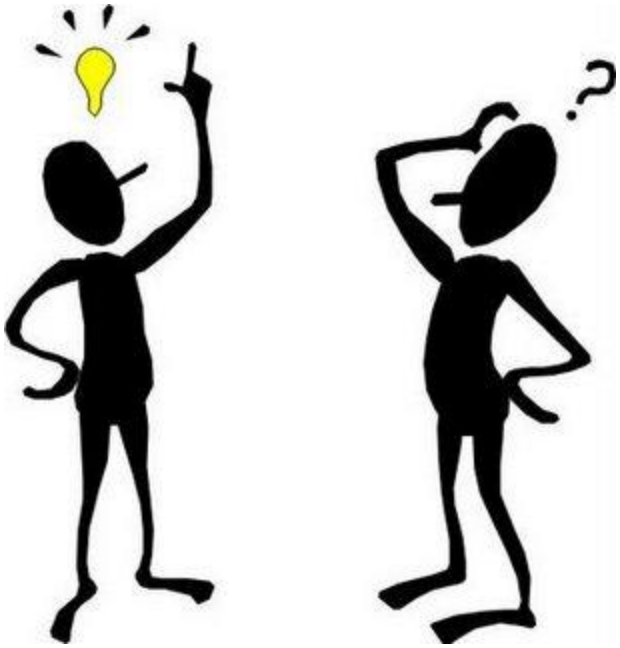
- If fixed cost are low (compared to variable cost), Alarm clustering (2) performs better. If fixed cost are high, Alert clustering (3) performs better.

- Alarm clustering performs better compared to Alert clustering with an increasing number of units.

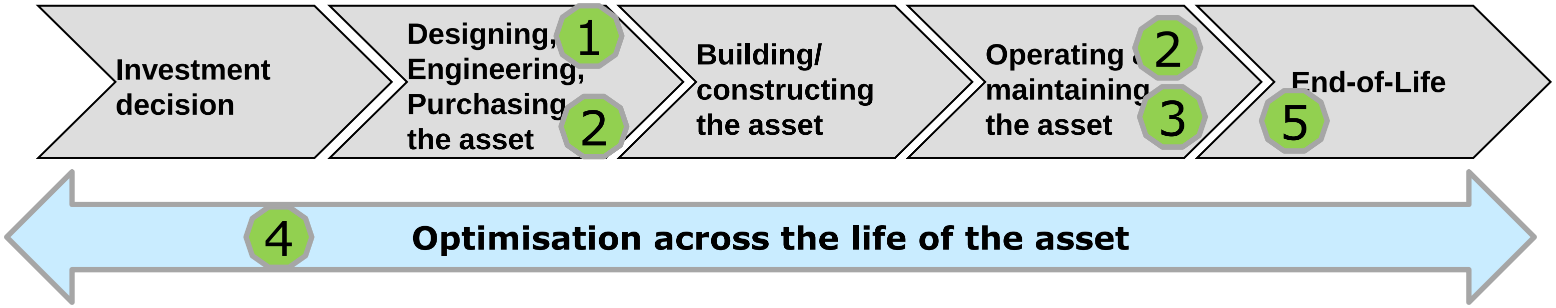
Conclusions

- Clustering maintenance activities based on condition monitoring in a way creates a hybrid form: condition-based and opportunistic.
- Sharing maintenance fixed cost is weighed against sacrificing remaining useful life.
- Clustering is beneficial in many cases, also for low values of fixed cost.
- A number of policies are conceivable.

Questions



Topics in this workshop



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› General knowledge and
› Research findings University of Groningen

Components of Asset Information Systems

- Specialized Engineering tools

- Document & Data Management systems

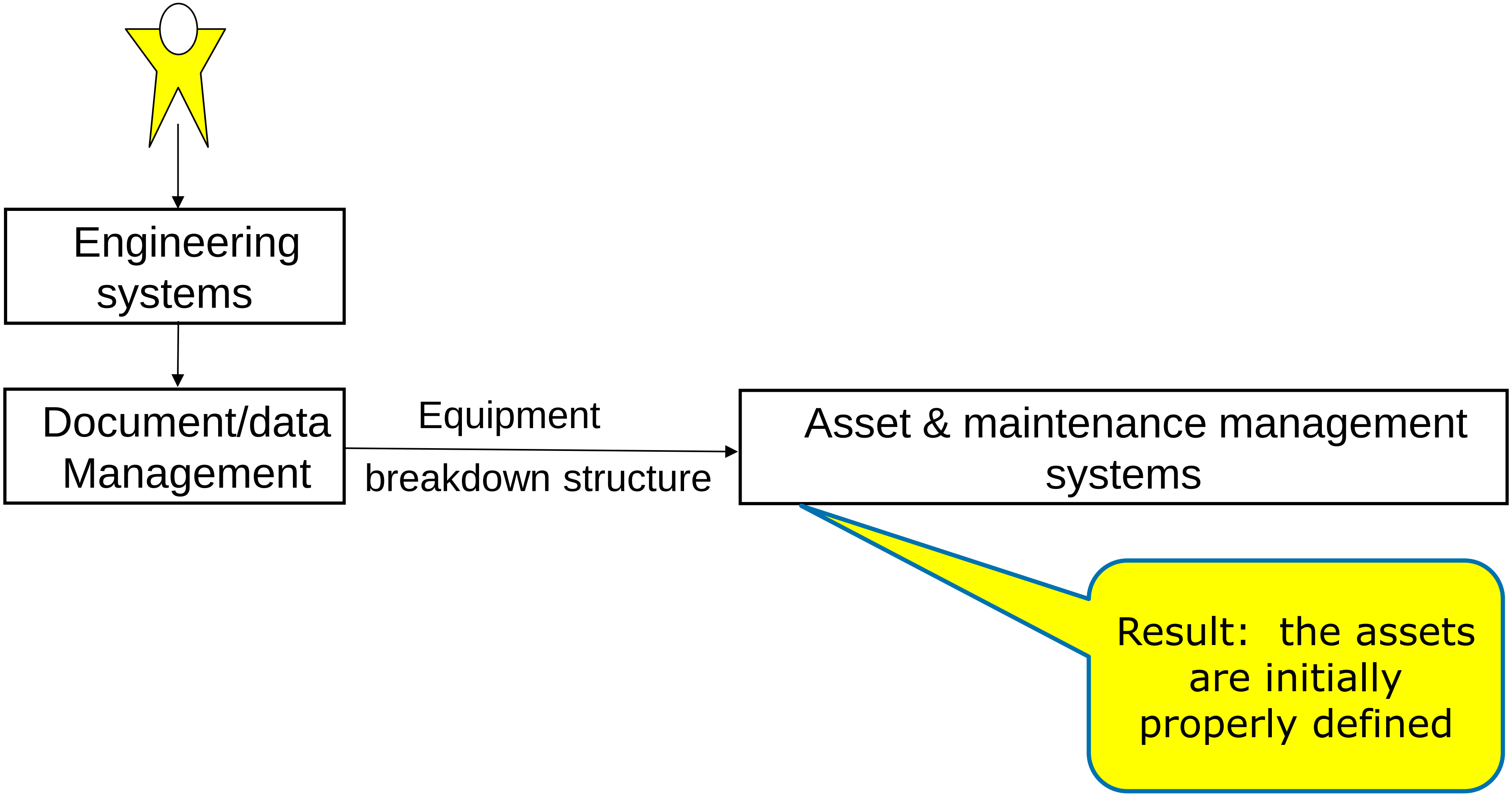
- Asset & Maintenance Management Systems

Components of Asset Information Systems

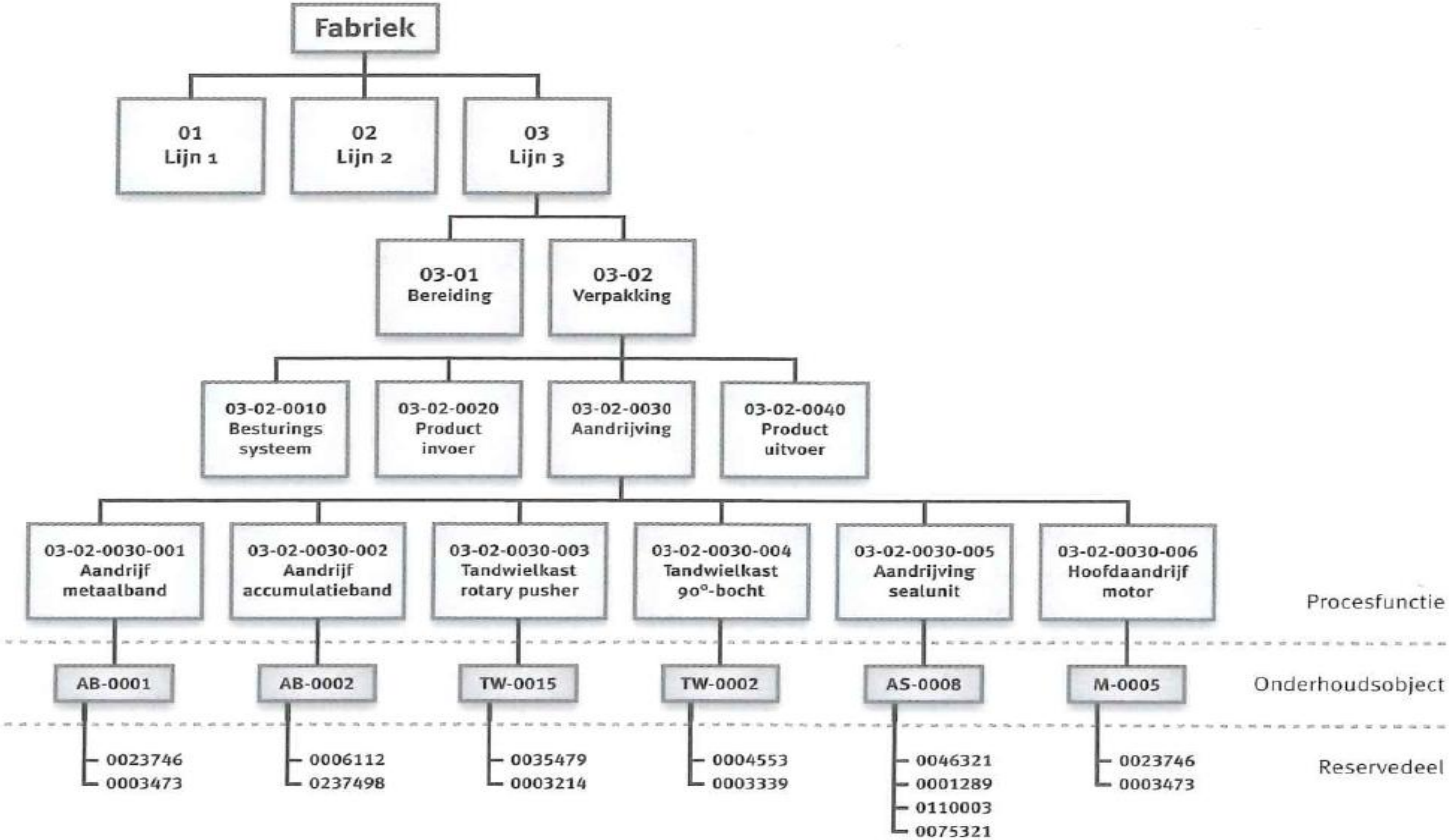
- Specialized Engineering tools (e.g. Dassault, AutoCad, ….)
  - Computer-aided Design (CAD)
  - Plant analysis
  - Often called *Computer-aided engineering (CAE)*
- Document & Data Management systems (e.g. Enovia, Sharepoint, Lifelink)
  - Configuration management of plant equipment breakdown structure, drawings, design specifications, metadata
  - In Engineering often called *Product Data Management (PDM)*
- Asset & Maintenance Management System (e.g. Maximo, SAP PM), comprising e.g.
  - Asset master file (including equipment breakdown structure)
  - Maintenance Work order management
  - Spare Part Logistics
  - Finance
  - Maintenance resources management
  - Generically called *Transactional Systems* (often implemented by ERP)

Asset & maintenance management systems

Asset information systems - core

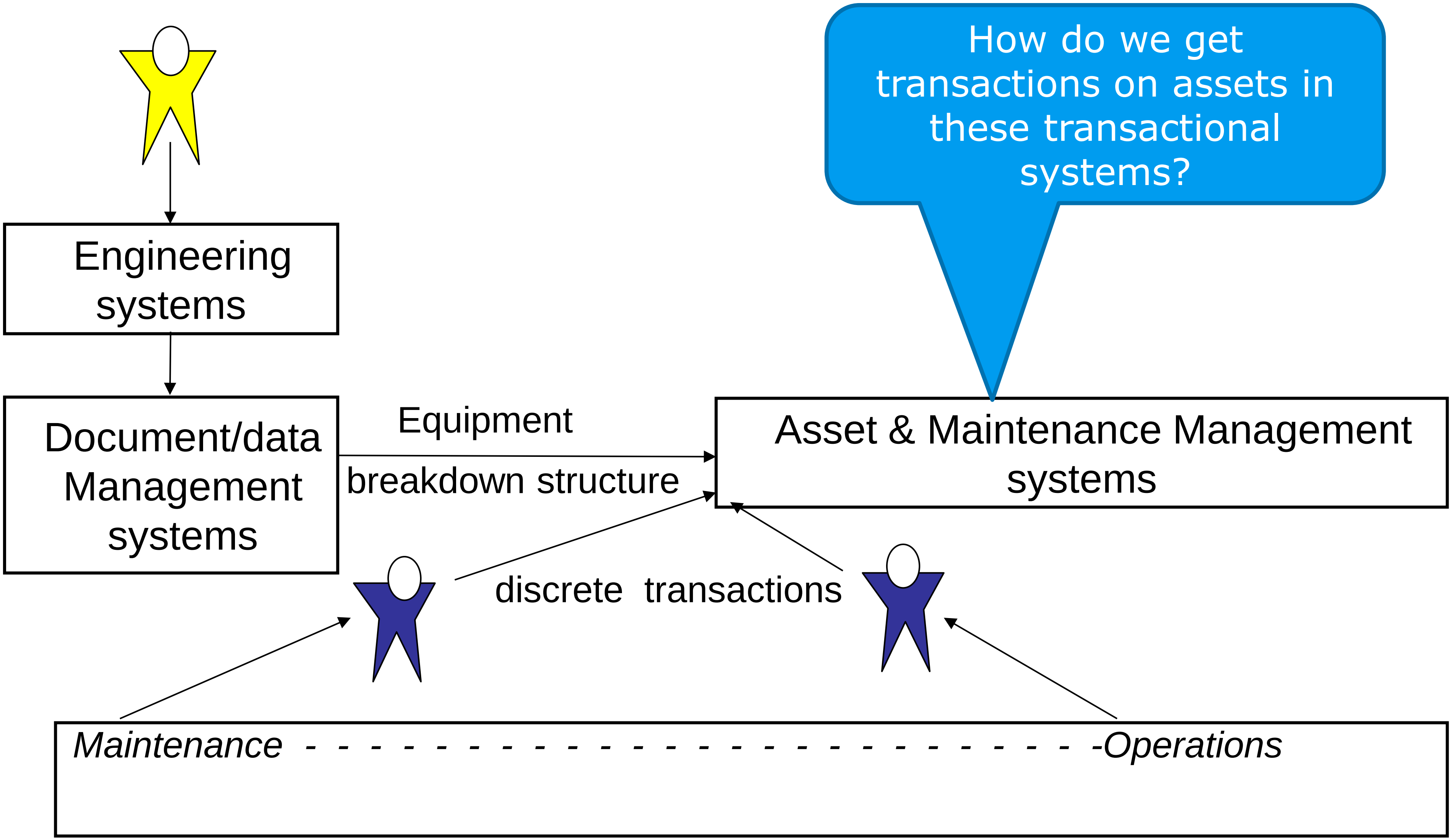


Equipment breakdown structure



Equipment breakdown structure (Haarman & Delahay 2005)

Asset information systems - core



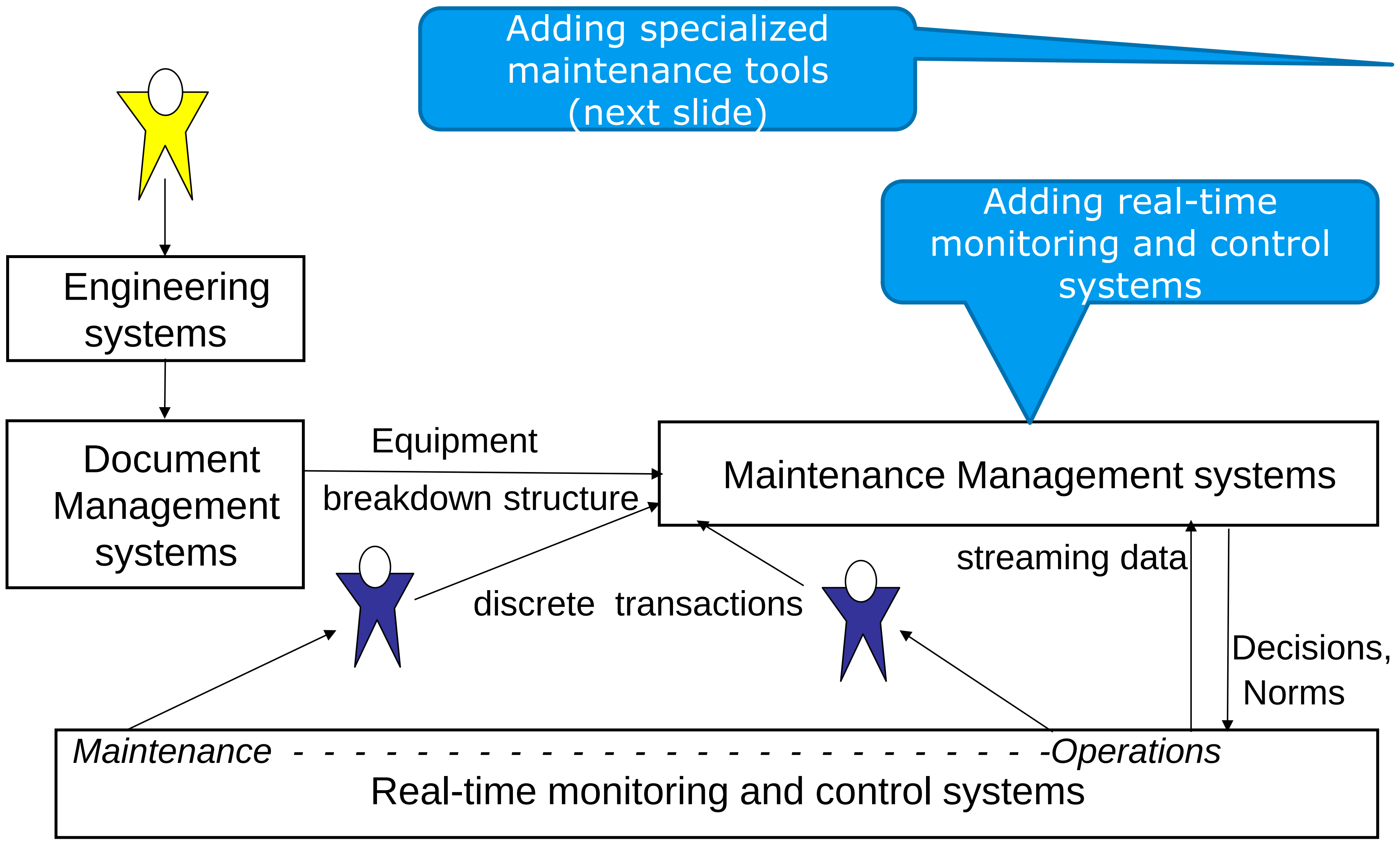
More Components of Asset Information Systems

- Process automation (real-time monitoring and control systems)
  - Support or control of the operation processes
  - Will take huge growth, and yield massive amounts of data

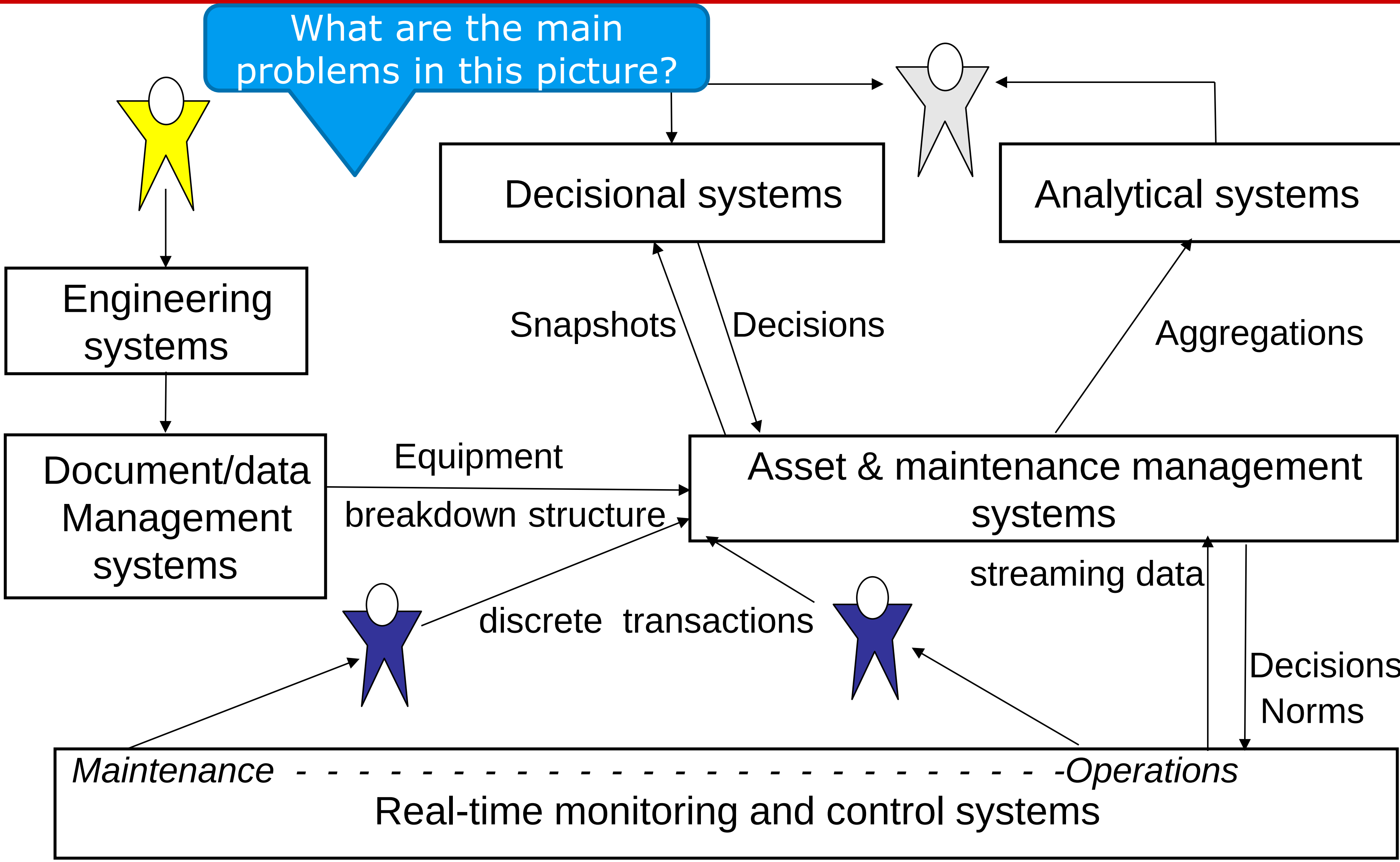
- Specialized Maintenance tools
  - Handling big data for reliability and safety engineering and analysis, reporting and archiving
    - Generically called *Analytical Applications*
  - MTBF analysis, MTTR analysis, simulation, optimization
    - Generically called *Decision Support Systems*

- (In addition to
  - Maintenance Management System
  - Document & Data Management (PDM or PLM) systems
  - Specialized Engineering systems
-)

Asset information systems - core



information systems overview



Two challenges

› Integration & interfaces

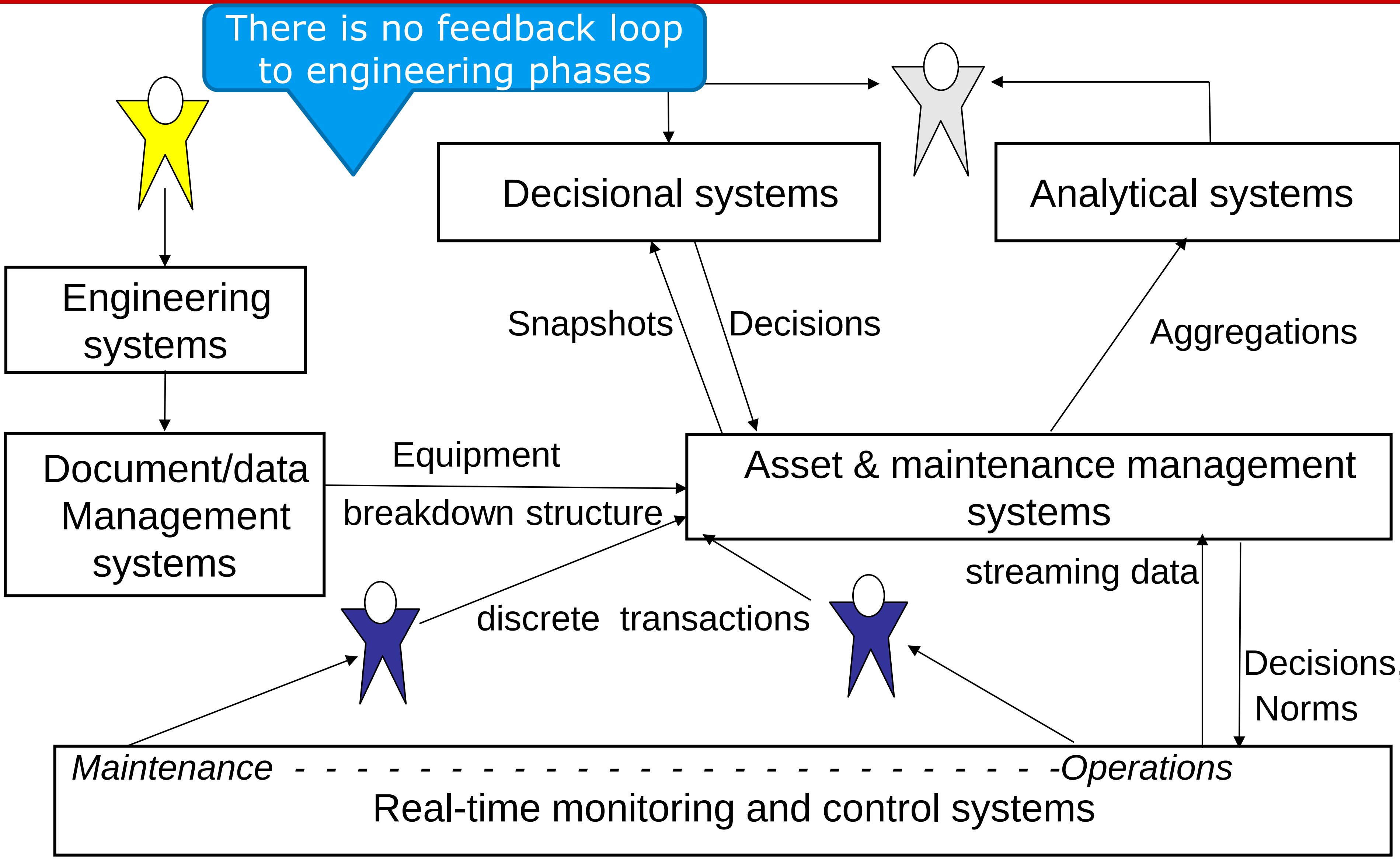
- Between asset life cycle phases
- Between systems
- Hand-over of information (e.g. between engineering and maintenance)
- Standardization of asset information (e.g. numbering, documents, systems)

› Maintenance of the data

- Version control / configuration management
- As-built, As-maintained

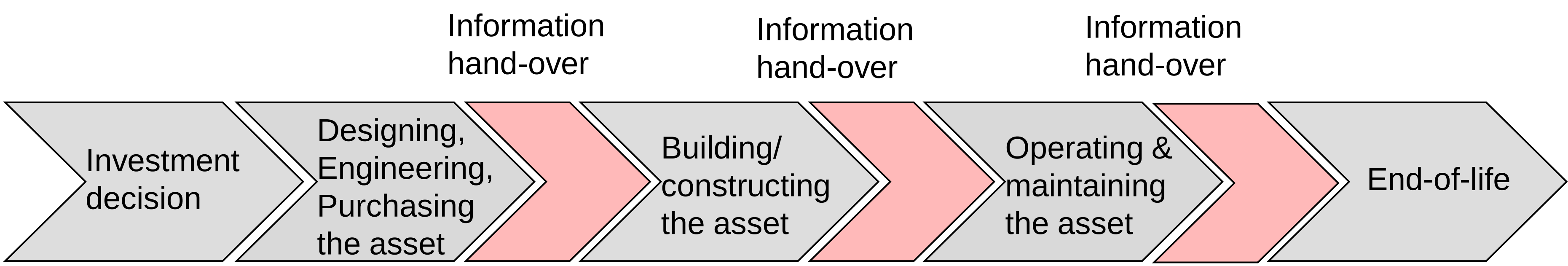
Recall the information assumption

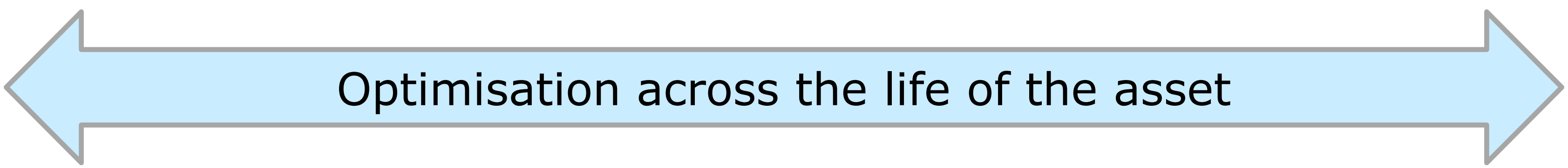
information systems overview



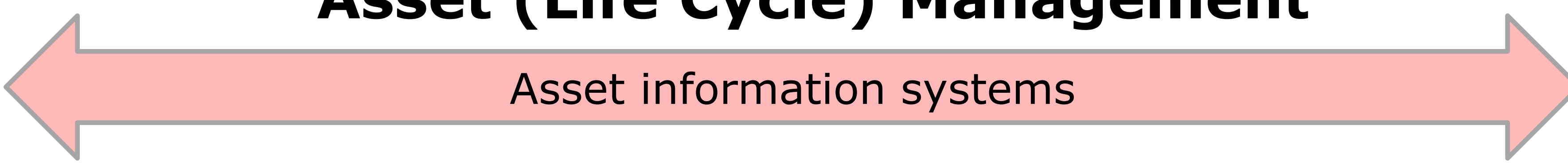
No feedback in the life-cycle

Information hand-over goes one-way only

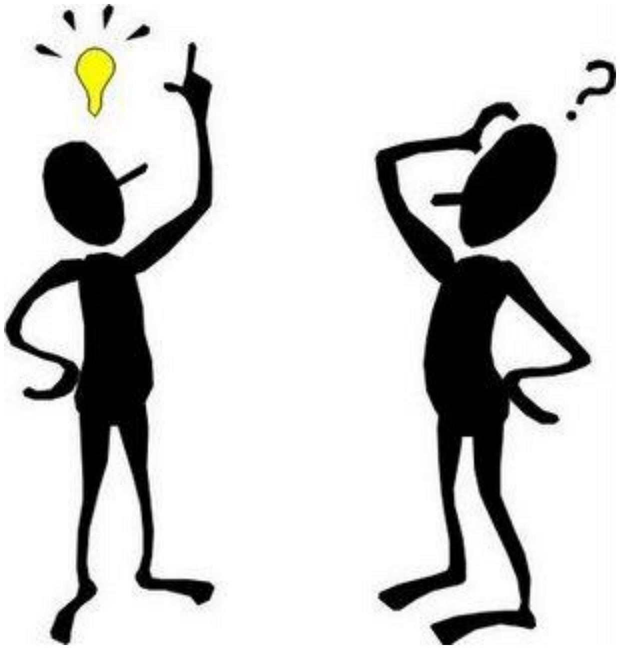




Asset (Life Cycle) Management



Questions



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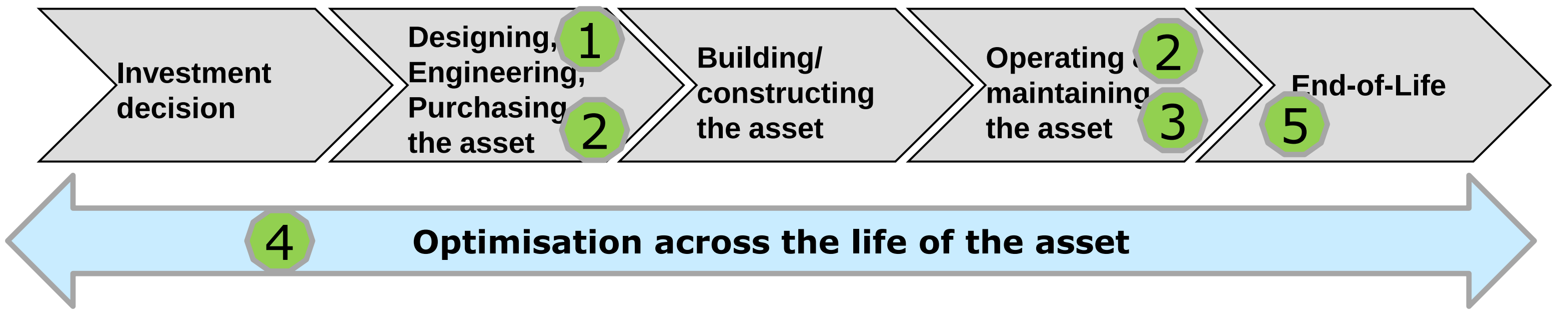

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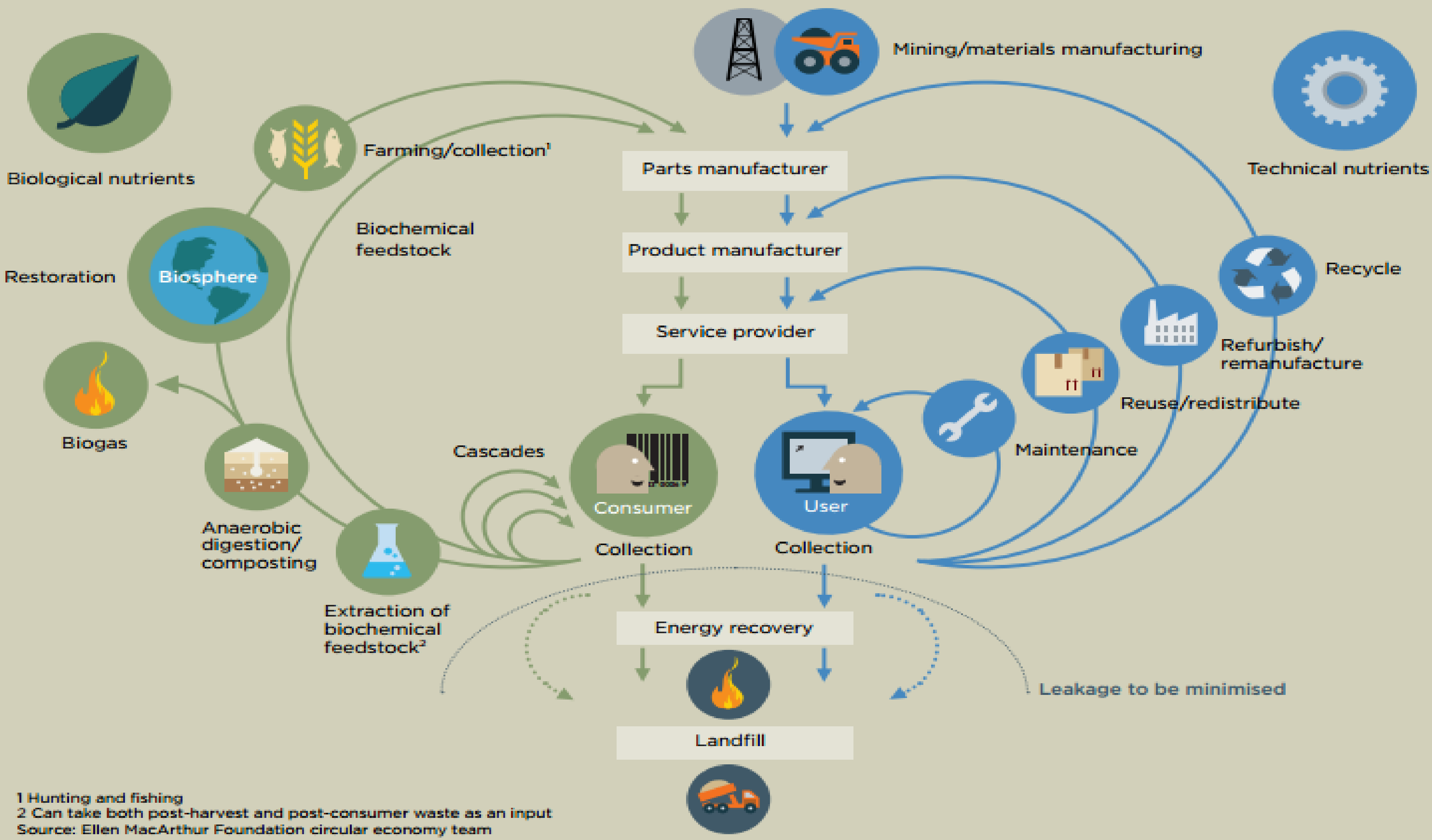
Sustainability and asset management

- Sustainability is an extremely wide subject:
  - People
  - Planet
  - Profit

- Asset management is closely related to sustainability of the planet
- In the view of the circular economy, maintenance is the best option for planet sustainability
- Reuse is next, followed by Refurbishment

Circular economy

FIGURE 6 **The circular economy—an industrial system that is restorative by design**



1 Hunting and fishing
2 Can take both post-harvest and post-consumer waste as an input
Source: Ellen MacArthur Foundation circular economy team

Sustainability and asset management

- At RuG, the project DoSyM studies sustainability for vendor companies (such as IEO transformers)

- Main findings:
  - Such vendors cannot attain ultimate sustainability of their products by merely product re-engineering
  - Rather, it requires rethinking of the business models. They have to collaborate with their customers, such as Alliander.

- To conclude:
- Optimization of products over the life cycle, including total cost of ownership, brings a new partnership to vendors and customers
- This hooks into servitization of physical products. Vendors and customers should be prepared to engage in lif-cycle oriented services
- Information sharing between vendors and customers is a prerequisite.

Recall the information assumption

Questions