UNIVERSITEIT TWENTE.

Workshop Design-for-Maintenance

WCM Summer School 2014 – Breda – 21 August 2014

Prof.dr.ir. Leo A.M. van Dongen & Ir. Wienik Mulder

Chair of Maintenance Engineering – Faculty of Engineering Technology

Maintenance Engineering at University of Twente

www.utwente.nl/ctw/opm/research/maintenance_engineering/
&
www.utwente.nl/time

Rob Basten – *Level of repair analysis and spare parts: quantitative optimization*

Jan Braaksma – *Asset information management*

Adriaan Goossens – *Maintenance policy selection using the analytical hierarchy process*

Wienik Mulder – *Design-for-maintenance in industrial equipment development*

Farzad Pargar – *Development of an asset life cycle plan (with Prorail)*

Jorge Parada Puig - *Supportability analysis : communality & LRU definition (with NedTrain)*

Richard Ruitenburg – *Asset life cylce management (with Liander)*

Schedule of the workshop

08:30 – 09:30 / (11:00 – 12:00)

- Maintenance challenges for rolling stock of Netherlands Railways.
  Leo van Dongen
- Theory on design for maintenance
  Wienik Mulder
- Explanation of case study: Trade-off decision on air-conditioning units
  Leo van Dongen
- Questions & answers

09:30 – 10:30 / (12:00 – 13:00)

- Working on the case study
- 2 Minute pitches on the results

Contents

- General information of Netherlands Railways
- NedTrain organisation and maintenance approach
- Rolling Stock Life Cycle Costs
- Design for Maintenance
  - Some history
  - Present approach
- Some design examples
- Chain of innovation in society
- Cooperation between operators, maintainers and manufacturers
- Maintenance Engineering making the connections

NedTrain

Netherlands Railways in Numbers

- 390 • stations in operation in NL (500 in UK)
- 5.000 • services per day in NL
- 30.000 • employees at NS & subsidiaries
- 250.000 • passenger seats in NL
- 1.100.000 • passengers per day in NL; 650.000 abroad
- 160.000.000 • net result in €
- 4.600.000.000 • operating income in €
- 16.300.000.000 • passenger km/year

High density service
- Intercity lines every 15 minutes
- Commuter lines every 30 minutes

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NedTrain Characteristics

100% NS subsidiary
Rolling stock maintenance company
€ 425 million yearly turnover
2.850 units in coaches, train sets and locomotives
3.100 staff
Sites across the Netherlands:

- 35 Service areas
- 4 Depots
- 2 Overhaul workshops

7x24 staff availability!

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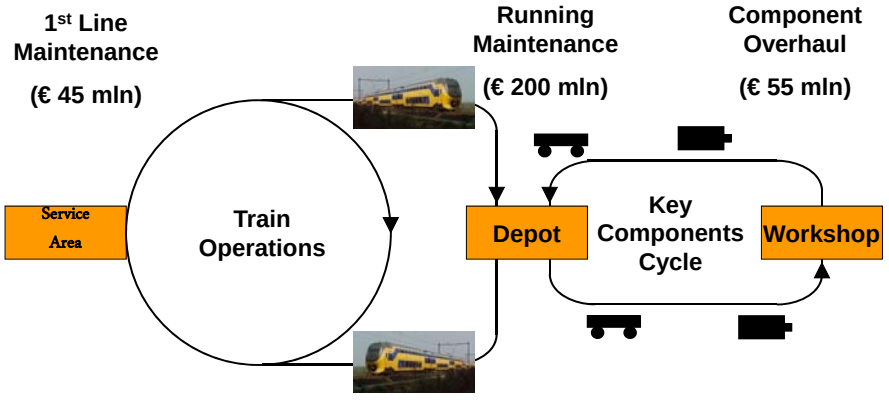
NS/NedTrain Maintenance Logistics



NedTrain

Overhaul & Modernization

Actual DDZ Project:

- **Modernization of exterior and interior**
- **Conversion from commuter train to intercity train**
- **Long term overhaul, extension of lifespan of 15 years**
- **Basic scope of 240 coaches**
- **Contract value: 200+ m€**

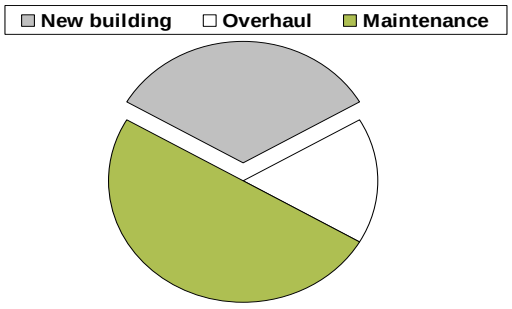
Annual (investment) costs for NS fleet: € 100 mln

NedTrain

NS Total Expenses: € 1.650 million/year

NedTrain

RS Expenses mainly after Implementation



Illustrative

Life cycle costs rolling stock

New building car:	**€ 2 million**
Maintenance: € 0,4 car/km x 250.000 = 0,1 mio/ year x 30	**€ 3 million**
Overhaul and modifications	**€ 1 million**

Total	**€ 6 million**

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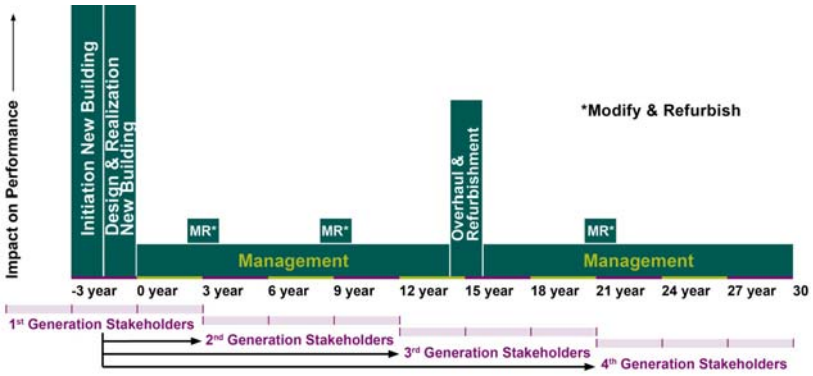
Design and Construction Determine LCC



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Up Front Investment in Capital Assets

From "technically oriented" services (up to 1990):

- **Technical designs and demands**
- **Integrating coordination between different suppliers**
- **Influence on design with respect to maintenance**
- **Integral approach and shared risks**

To customer based services (1990-2005):

- **Focus on core business: technology on the back ground**
- **Investment based on functional demands**
- **Lawyers in the chain: effort or performance contracts**
- **No RAMS/LCC approach**

Nowadays: technology and RAMS/LCC back on agenda!
See: public transport & energy sector (infrastructure interests)

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Taylor-Made Motor Car (1990)

mDDM Motor car for suburban double-deckers
Taylor-made by and for Netherlands Railways
NS as project director together with several (sub)suppliers

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Up to 2000 – Technical Orientation

Several orders of new IC double deckers (VIRM - 1994)

Functional and technical demands
- **NS prescribed maintainability in design & construction phases**
- **Verification and validation from initial design up to introduction**
- **NS in fact "system integrator" between suppliers**
- **All necessary information available and approved in time**
- **Maintenance staff training in cooperation with suppliers**

Train sets "constructed for the workshop processes"!

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2000 – 2009: Market Orientation

Sprinter LighTTrain

- **Functional specifications**
- **High pressure lead time in contract award**
- **Inadequate (control of) performance specifications (RAMS/LCC)**
- **Insufficient and late involvement in system design and lay out**
- **Verification and validation proces after homologation**
- **Overdue delivery of information and documentation for training and spare parts control**

Cooperation to rules of contract: individual or common interests?

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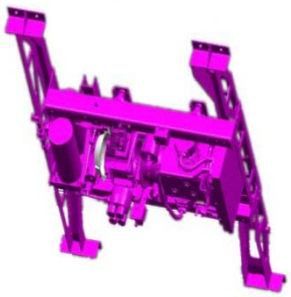
“Standard” Sprinter LighTTrain (2010)



Working on the edge of design and maintenance execution:

- **Design freeze interventions**
- **Modification of workshop pit tracks**
- **Manufacturability of maintenance manuals**

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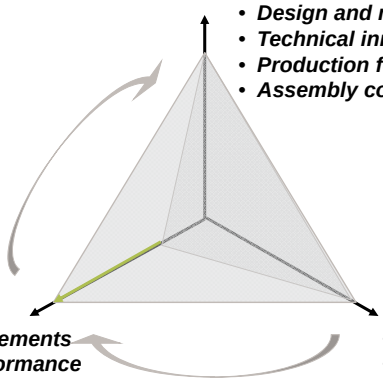
Improved Life-Cycle Performance



Supplier(s)

- ***Design and manufacturing***
- ***Technical innovation***
- ***Production focus***
- ***Assembly cost***

Maintainer

- ***Technical requirements***
- ***Installation performance***
- ***Maintainability***
- ***Cost***

User/owner

- ***Functional requirements***
- ***Low capital expenses***
- ***Low operational expenses***

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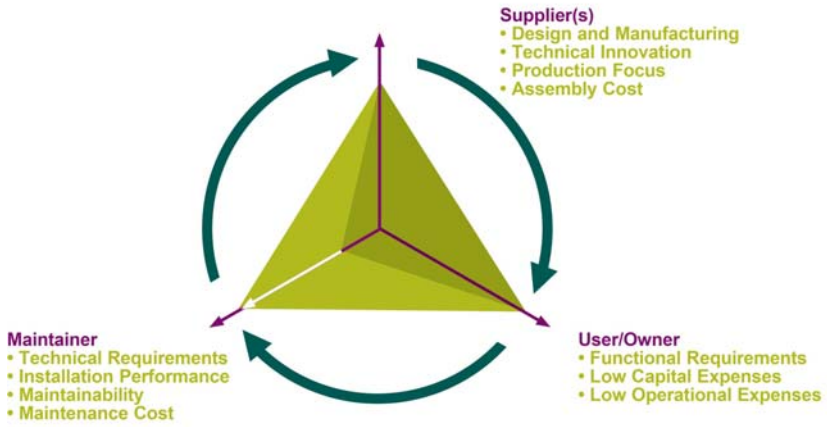
Improved Life-Cycle Performance



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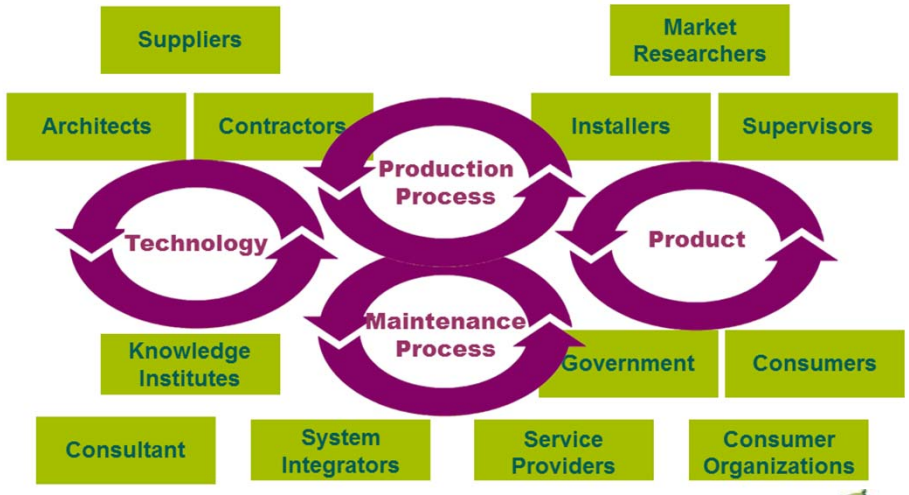
Alignment of Processes



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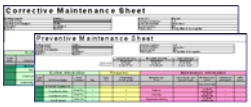
Since 2010 Modernization of DDZ



Double Decker Zones

- Experience based RAMS/LCC approach
- Clear RAMS/LCC specifications
- RAM/LCC calculation sheet
- Maintainability & availability design-guidelines
- Verification & validation methods




In house synergy at NedTrain!

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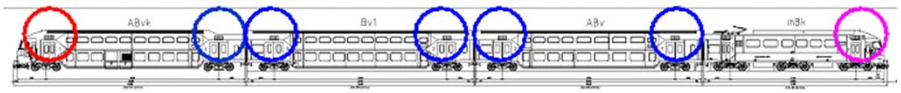
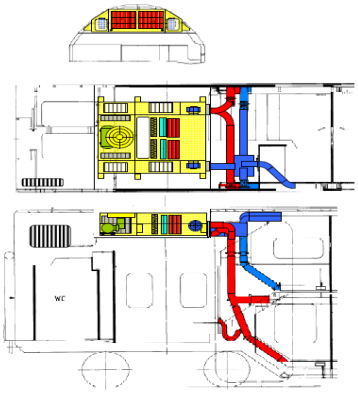
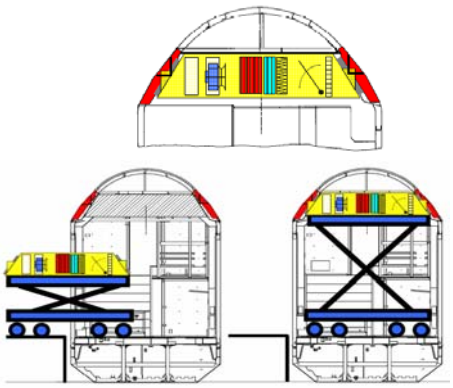
DDZ Airconditioning in Roof Area



Option A: Positioning and maintenance on the roof



Option B : Positioning and maintenance from interior



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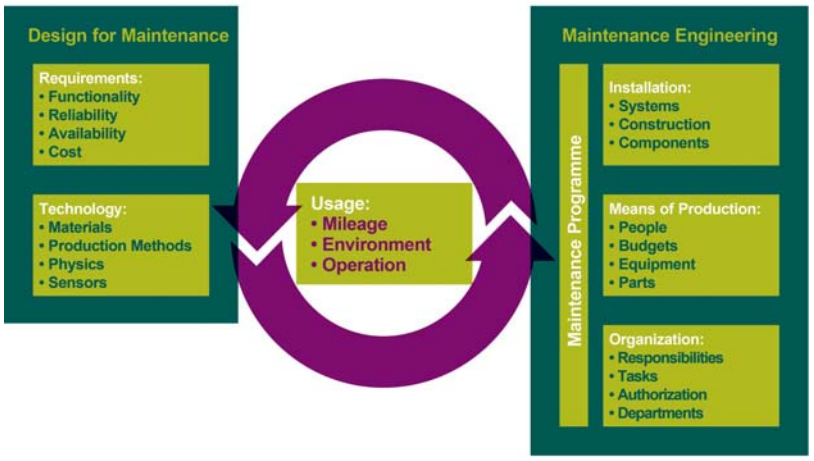
Connect Design to Maintenance Experience



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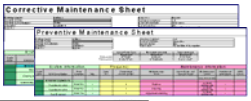
2012 Sprinter Next Generation

Sprinter Next Generation

- RAMS/LCC approach of supplier
- RAMS/LCC specifications (SMART)
- RAMS/LCC prediction & calculation sheet
- Maintainability & availability questionnaire
- Design reviews and First Article Inspections
- Verification & validation
- Information & documentation of all suppliers



Open collaboration in supply chain!

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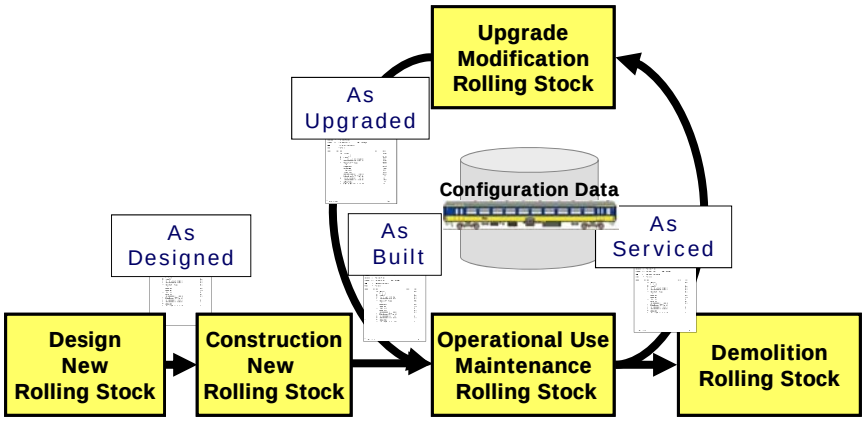
Configuration Management: Hygienics!



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Final Remarks

RAMS/LCC management requires:

- **Open cooperation in supply chain: "Rhenish model"**
- **Technology back into the board room**
- **Collective innovation: product, process and technology**
- **Bridging gaps between owners, operators, maintainers, system integrators, equipment manufacturers, suppliers and consultants**
- **Design for Maintenance on basis of business cases, optimizing investment and operational costs**
- **Maintenance Engineering makes connections**

Better performance ánd lower costs!

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THEORY ON DESIGN FOR MAINTENANCE

Wienik Mulder

Design-for-Maintenance

A number of theoretical concepts / an abstract view from a design perspective

1. Product (/equipment) properties
2. Development activities
3. Design support

Particularly concepts for development of equipment/systems







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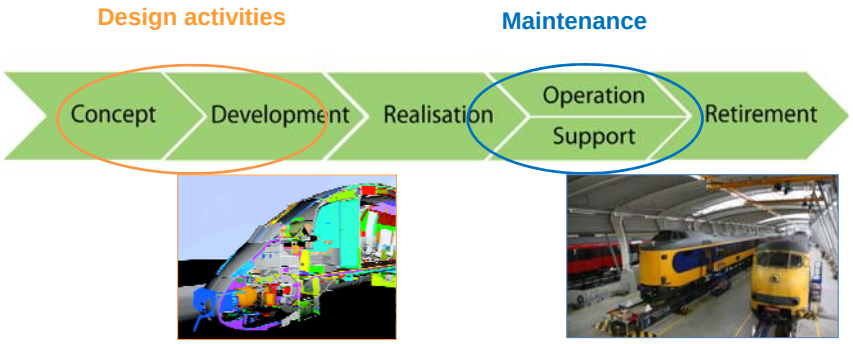
Definition

A design approach targeting the specific goal to optimize the product properties that influence the maintenance activities.



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Topic I – Product properties

Eigen-properties

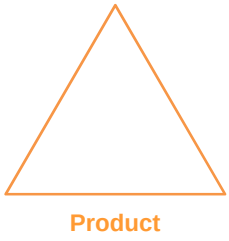
Properties that a product has of itself, that can be observed without additional efforts

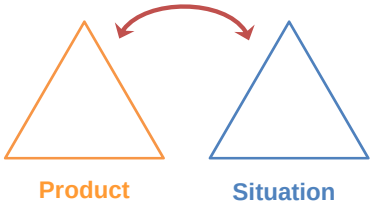
Structure, form, dimension, surface, material, etc.

Relational properties

Properties that are carried by a product in relation to a particular situation

Manufacturability, sustainability, maintainability, costs, etc.





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Properties related to maintenance

Property	Measures
1. Product reliability	Failure rate, time between failures, time to failure, etc.
Related to *usage profile* and *operating conditions*	
2. Product maintainability	Maintenance time, labour hours, costs, etc.
Related to *maintenance process* and the *maintenance equipment*	
3. Product supportability	Time to support, etc.
Related to the *support process* and the *support equipment*	

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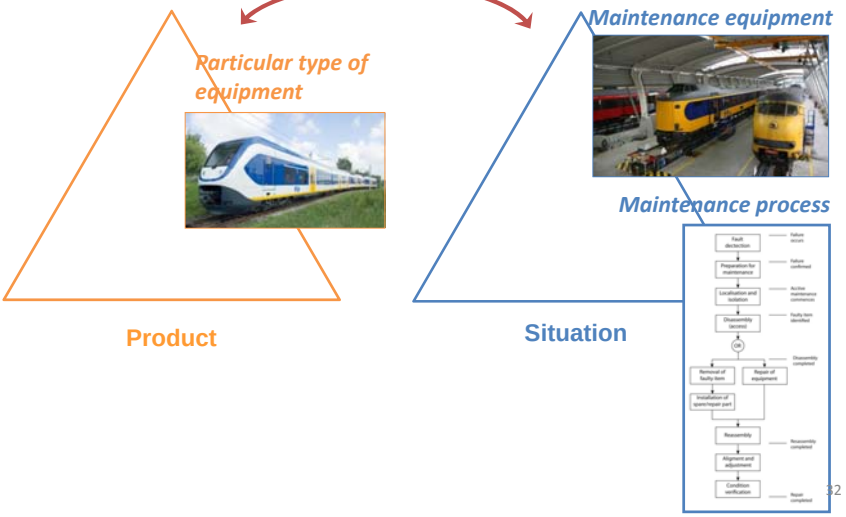
Example maintainability

Measures – times, labour hours, costs, etc.



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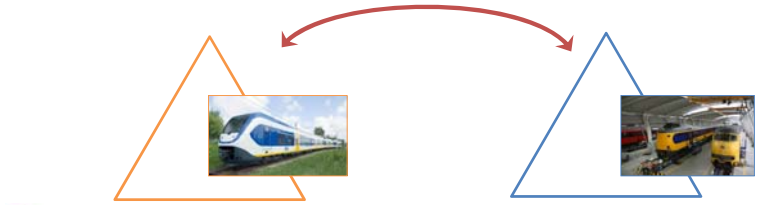
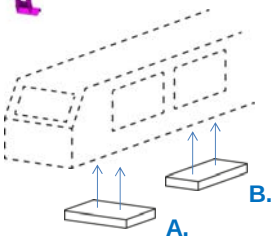
Example maintainability





A.

B.

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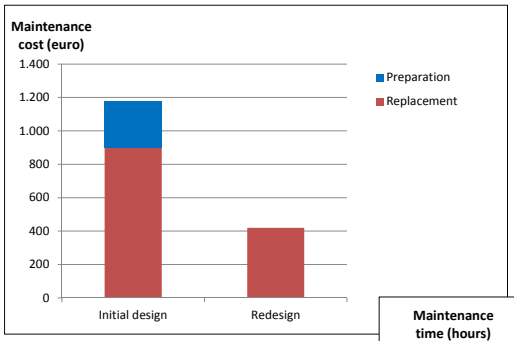

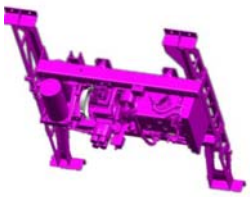

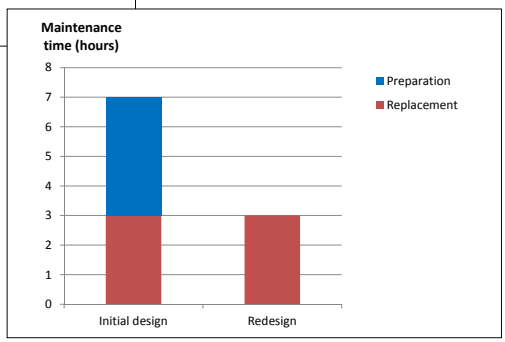

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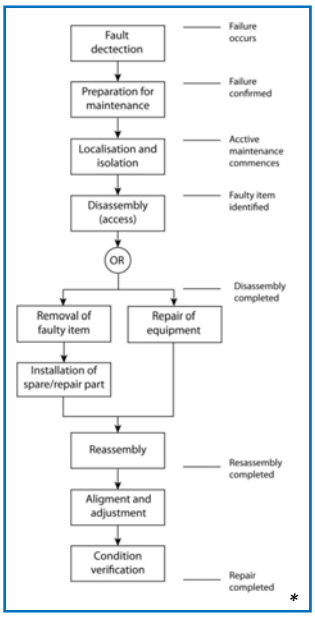
Maintenance process (corrective)



Preparation
Diagnostics

Repair/replacement

Recovery

Easily readable gauges
Instalment sensors
Transparant covers

Position of components
Choice of fasteners
Weight and size of components

Understandable displays
Test programs (software)
Shape components

** Blanchard, Fabrycky, 2011, Systems Engineering and analysis*

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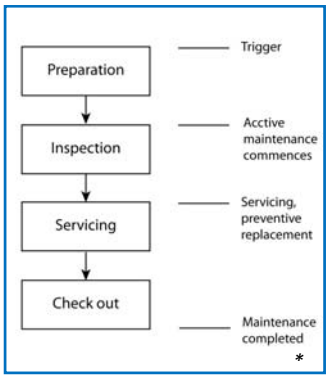
Maintenance process (preventive)



Preparation

Servicing/replacement

Recovery

** Blanchard, Fabrycky, 2011, Systems Engineering and analysis*

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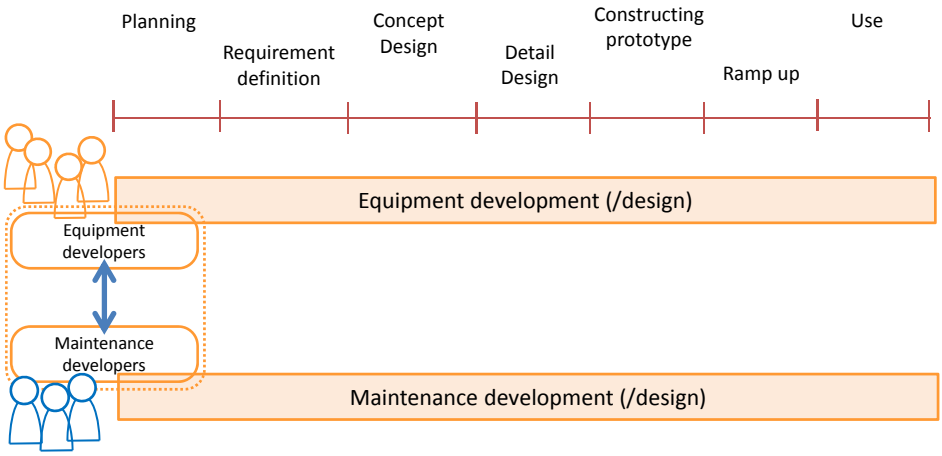
Topic II – Development process



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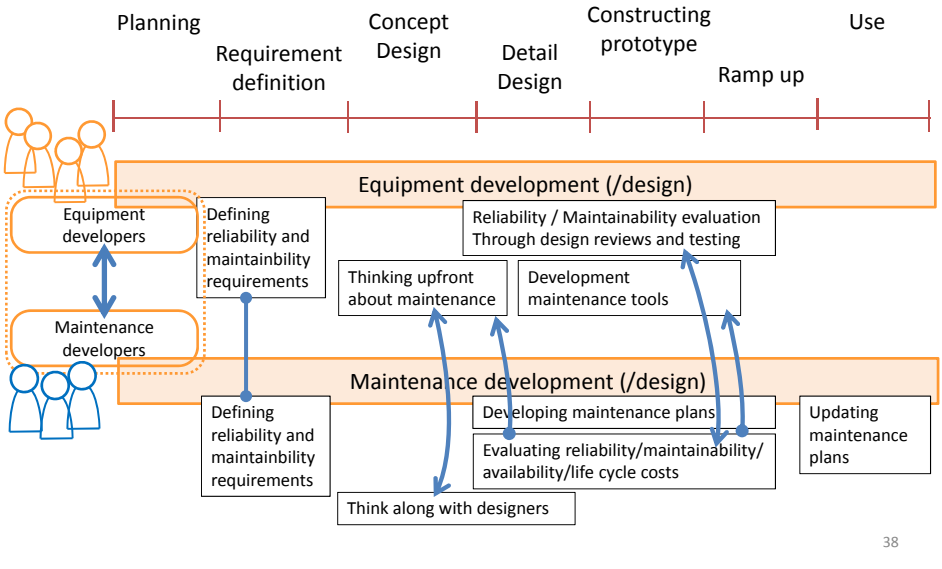
Development activities



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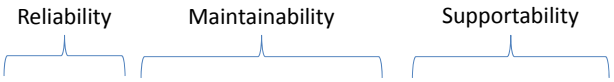
Development strategies

Design strategies
1. Design-out maintenance
2. Design for the ease of maintenance

Design objectives
- Trade-offs between
  1. Product performances: functionality/quality, availability, reliability, safety, costs, etc.
  2. Development / manufacturing costs and time

Example product performance:



Availability = Failure rate x (active maintenance time + logistic support time)

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Possible aspects of improvement

Organizational	Knowledge	Communication
"Pressure" of company management	Knowledge about relation "System performance and use conditions"	Quantity of communication
Awareness of design-for-maintenance aspects	Knowledge about relation "System performance and maintenance environment"	Quality of communication
		Availability of "common language"

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Topic III – Design support

Possibilities to support

1. Integrate an expert
   - Reliablity engineer
   - Maintenance engineer

2. Integrate multi-expert
   - RAMSHE expert

3. Integrations by methods and tools

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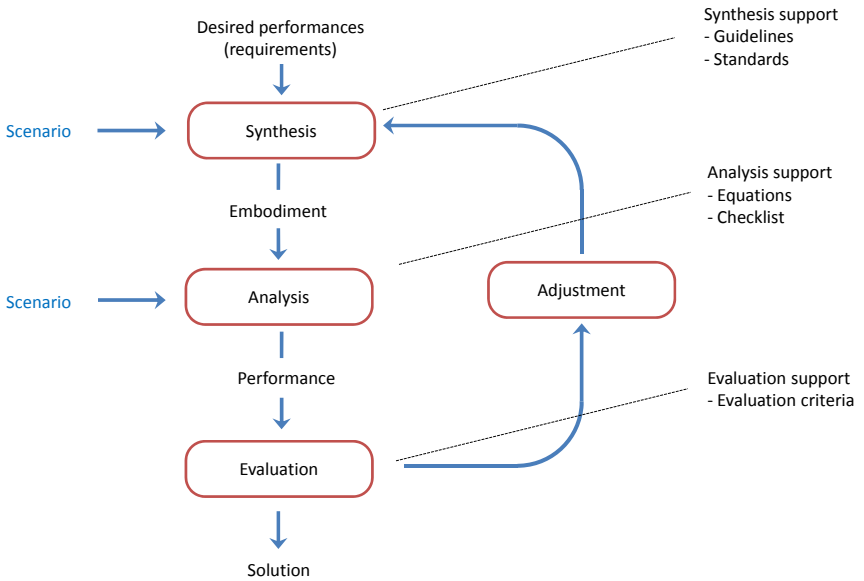
Design method and tools



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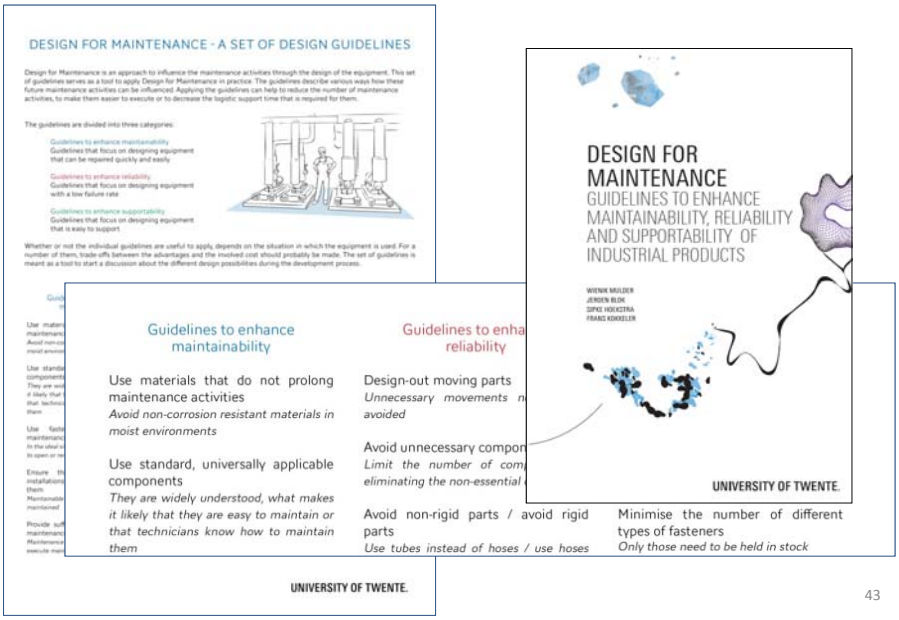
Example design tool



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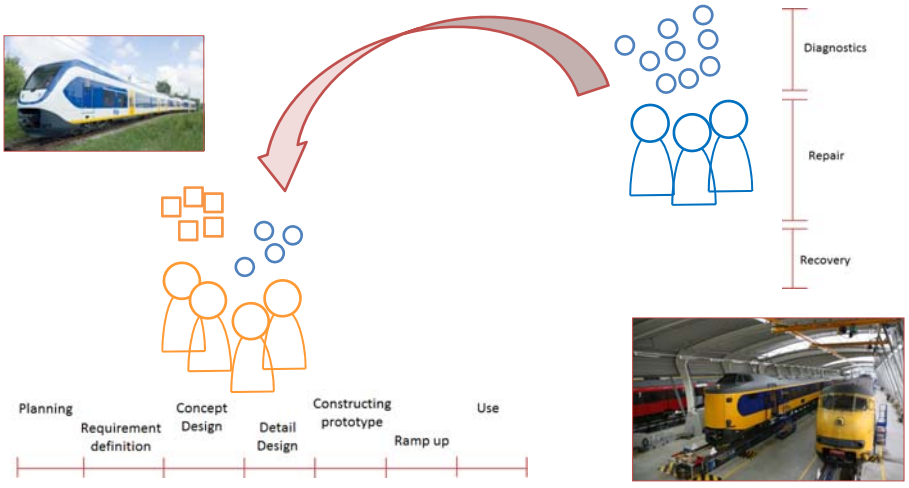
Concluding remarks



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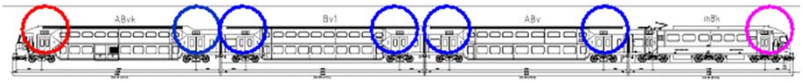
UNIVERSITEIT TWENTE.

CASE STUDY
TRADE-OFF DECISIONS ON AIR-CONDITIONING UNITS

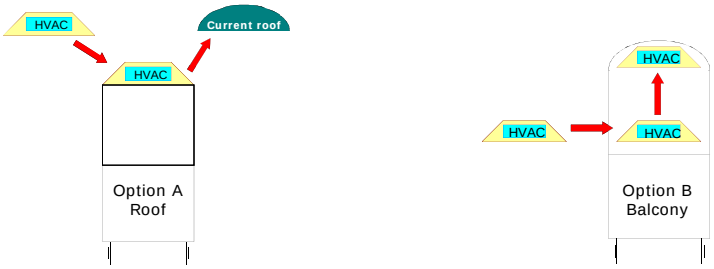
Overhaul DDARm

Installation of airconditioning units

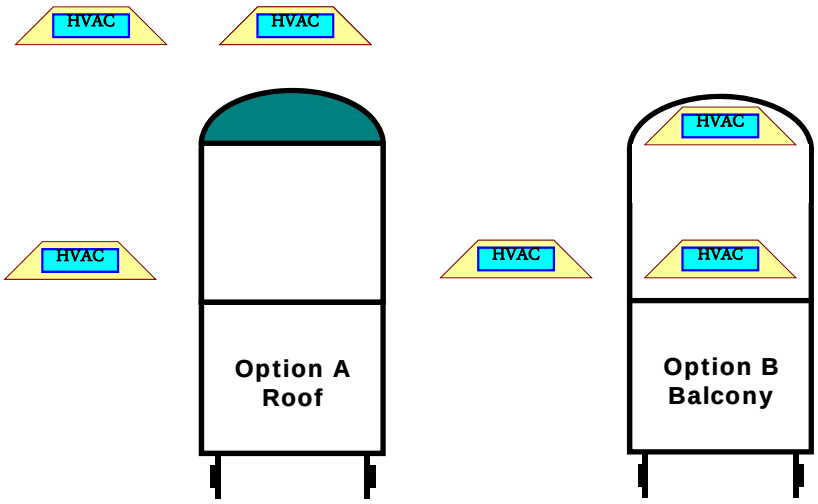
Units need to be installed at various locations



There are two options, with different pros and cons over the life cycle



Two options visualized



Airconditioning unit

Dimensions:

- Weight: 540 kg
- Length: 2200 mm
- Width: 1800 mm
- Height: 580 mm

The way in which the unit is installed and its location have huge consequences; because of all the interfaces (physically and organisationally)

Due to weight and size, the location above the balcony is the only option

Assignment

Which of the two options do you prefer?

Consider that the remaining life time is about 15 years: each option has (dis)advantages in the various stages of the life cycle

List the trade-off factors to consider and estimate their influence

You have 45 minutes to prepare a 2-minute presentation