ECN

Energy research Centre of the Netherlands

# Tools for Estimating O&M Costs of Offshore Wind Farms

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## Contents

- Approach for Modelling O&M aspects
- ECN’s tool in planning phase of wind farms
- Validation results
- O&M optimisation during operational phase

## Principles of Risk Based Maintenance

For wind turbines:

~~**Risk = Probability * Consequences**~~

**Annual O&M costs = Annual failure frequency * Repair costs**

# O&M Cost modelling offshore wind farms

**Annual O&M costs** = Ann. failure frequency * Repair costs

Collecting and analysing O&M data

1) Failure behaviour and maintainability

# O&M Cost modelling offshore wind farms

Annual O&M costs = **Ann. failure frequency** * Repair costs

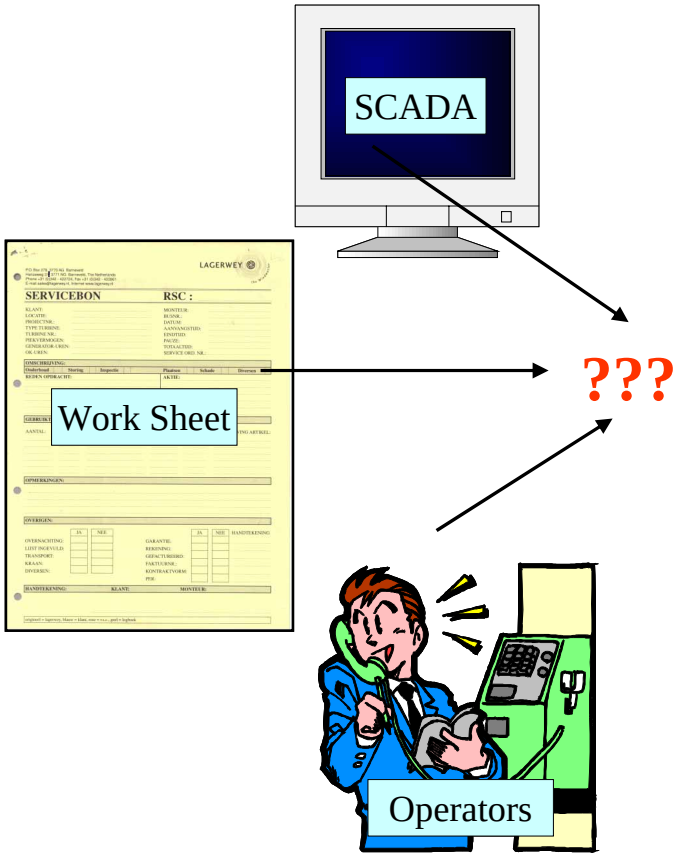
<u>Data originates from different sources</u>

- SCADA system
- Work sheets
- Operator information

<u>Data is meant for financial purposes</u>

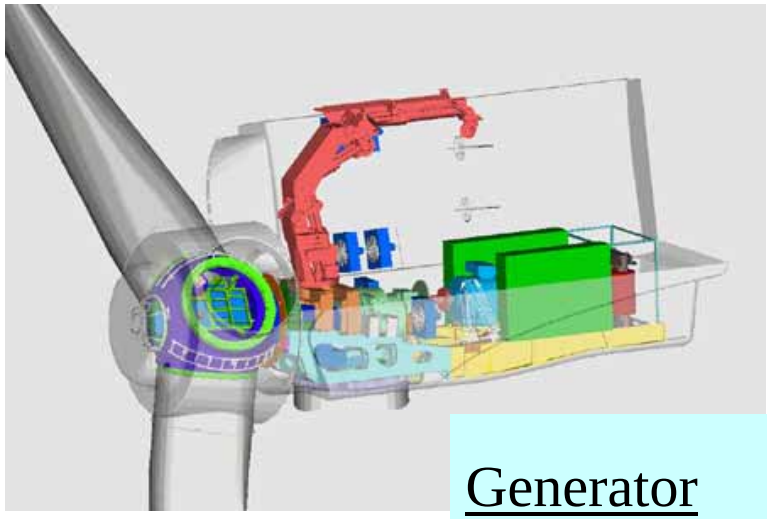
- Stock control
- Invoicing

**Usually not for reliability purposes!**



# O&M Cost modelling offshore wind farms

Failure data: Consider “small” and “large” failures



| Generator | | Repair Classes | |
|---|---|---|---|
| 1. Overheating alarm | → | 1. Alarm with remote reset | (0,5 /yr) |
| 2. Carbon brushes | → | 2. Repair and consumables | (0,2 /yr) |
| 3. Fan cooling broken | → | 3. Replacement (internal crane) | (0,05 /yr) |
| 4. Bearings damaged | → | 4. Replacement (hoisting outside) | (0,011/yr) |

# O&M Cost modelling offshore wind farms

**Annual O&M costs** = Ann. failure frequency * Repair costs

Specifying lifting and access systems

1) Failure behaviour and maintainability

2) Characterisation of access and hoisting systems

# O&M Cost modelling offshore wind farms

Annual O&M costs = Ann. failure frequency * **Repair costs**

| **Supplier with Zodiac** | | |
|---|---|---|
| **Specification** | **Value** | **Remarks** |
| H max at transfer | 0. 5 m (- 0.75 m) | |
| V max at transfer | 6 m/s | |
| Travel time to turbine (one way) | 2 hrs | Supplier remains at site |
| Mobilisation time | 1 to 4 hrs | |
| Availability | Good | |
| Maximum size of repair crew | 10-20 | |
| Maximum weight of load | Medium size (with crane) | |
| Hourly rate | 1.200,- Euro | Rates may vary:<br>850,- to 1.600,- Euro |
| Mob/demob costs | Depends on contract | |
| | **Data:** | |

# O&M Cost modelling offshore wind farms

**Annual O&M costs = Ann. failure frequency * Repair costs**

| A2SEA | | |
|---|---|---|
| **Specification** | **Value** | **Remarks** |
| Hs max at positioning | 1 m | |
| Vs max at positioning | 12 m/s | |
| Hs max during hoisting | 1.5 m | |
| V max during hoisting | 8 m/s | Technically 12 m/s possible. Load close to tower. Additional features necessary for 12 m/s |
| Travel time to turbine | 2 hrs (max 15 km/h) | |
| Travel time back | 2 hrs | |
| Mobilisation time | 48 hrs | |
| Availability | limited, but getting better | |
| Maximum height of crane | 83 m | |
| Maximum weight of load | 100 ton | |
| Day rate | ???,- Euro | Not confirmed, best estimate |
| Mob + demob costs | | Unknown |
| Positioning | legs | |

Costs for large equipment are very uncertain, large variations!!

# O&M Cost modelling offshore wind farms

**Annual O&M costs** = Ann. failure frequency * Repair costs

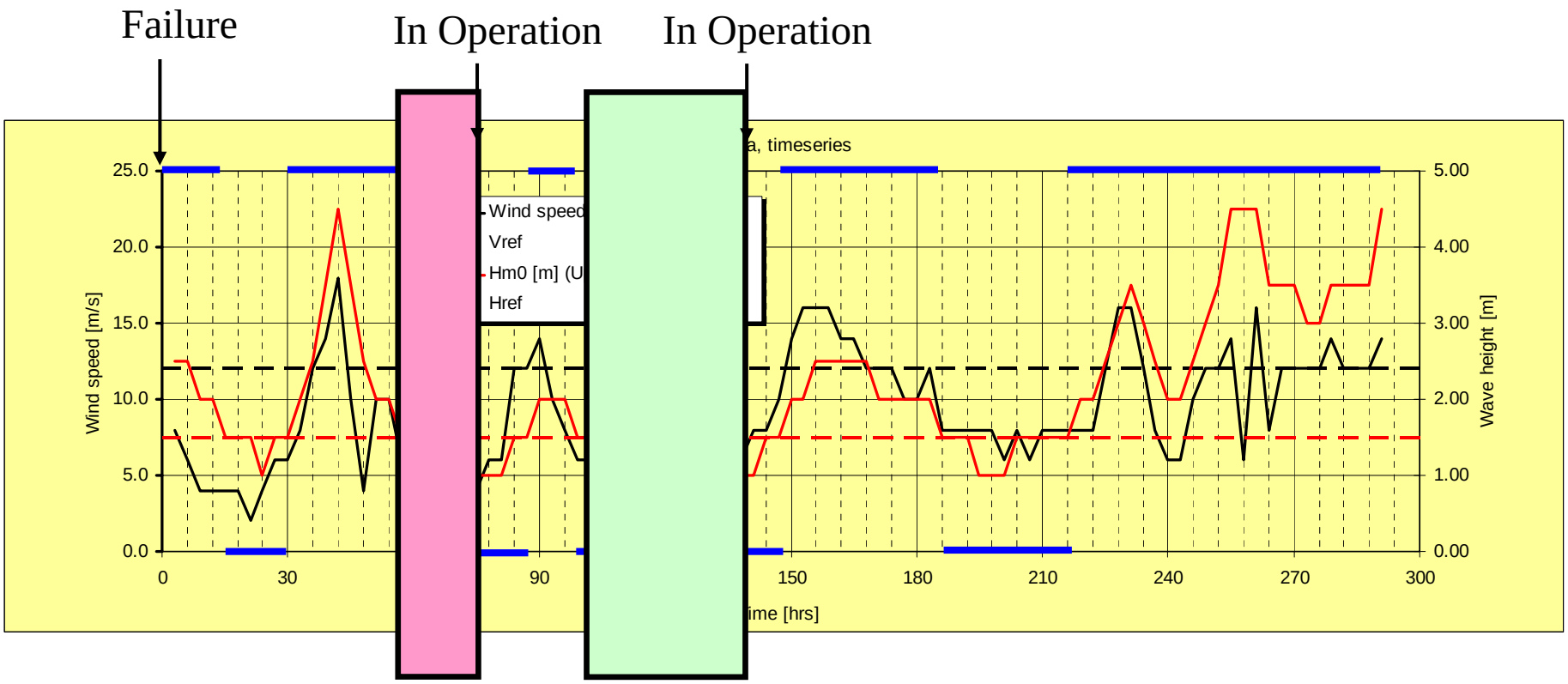
1) Failure behaviour and maintainability

2) Characterisation of access and hoisting systems

3) Characterisation of weather conditions
- wind
- waves
- lightning
- visibility

Analysis of weather windows, waiting time, and repair strategy

# O&M Cost modelling offshore wind farms




Mission time: - 40 hrs: $T_wait_{40\ hrs} = 96$ hr

- 20 hrs: $T_wait_{20\ hrs} = 56$ hr

# O&M Cost modelling offshore wind farms

## Analysis of weather windows and waiting time

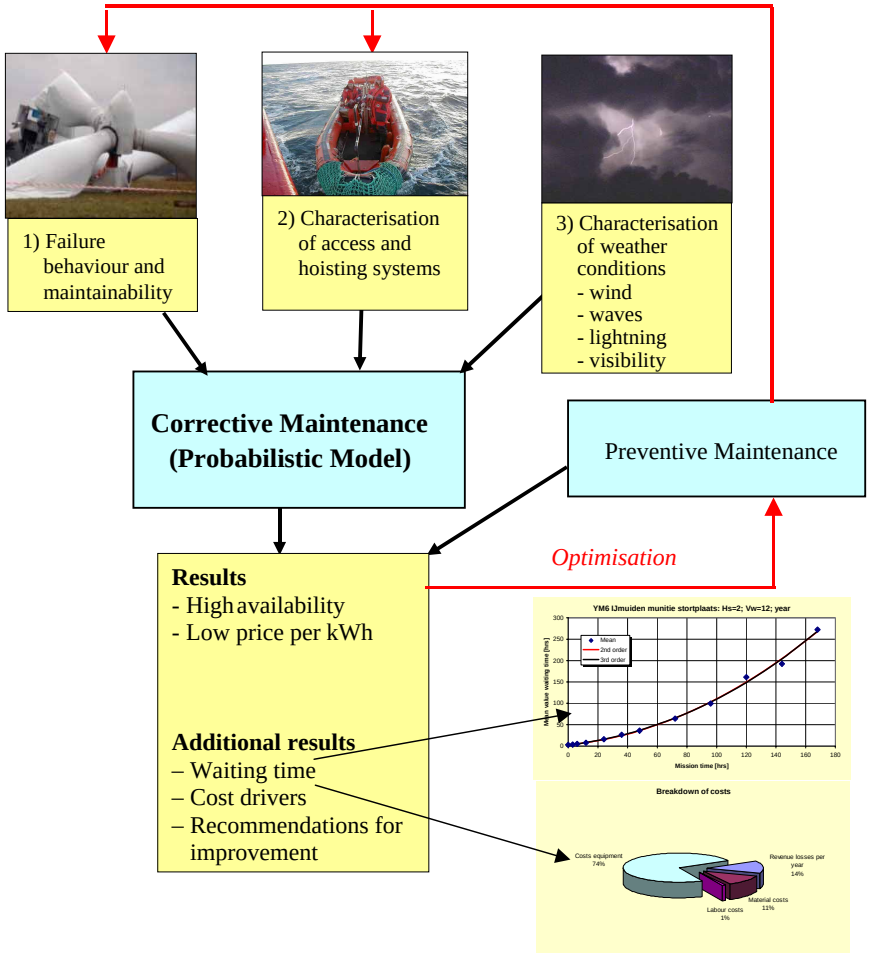
Failure → Turbine in Operation

| ***Time To Repair (TTR)*** | | | |
|---|---|---|---|
| *T_logistics* | *T_wait* | *T_mission* | |
| | | *T_travel* | *T_repair* |
| Arrangement of device, personnel and spare parts | Waiting due to bad weather conditions | Trip to failed WT | Repair of WT |

**Waiting time is a function of mission time**

*(different for each vessel!)*

# O&M Cost modelling offshore wind farms



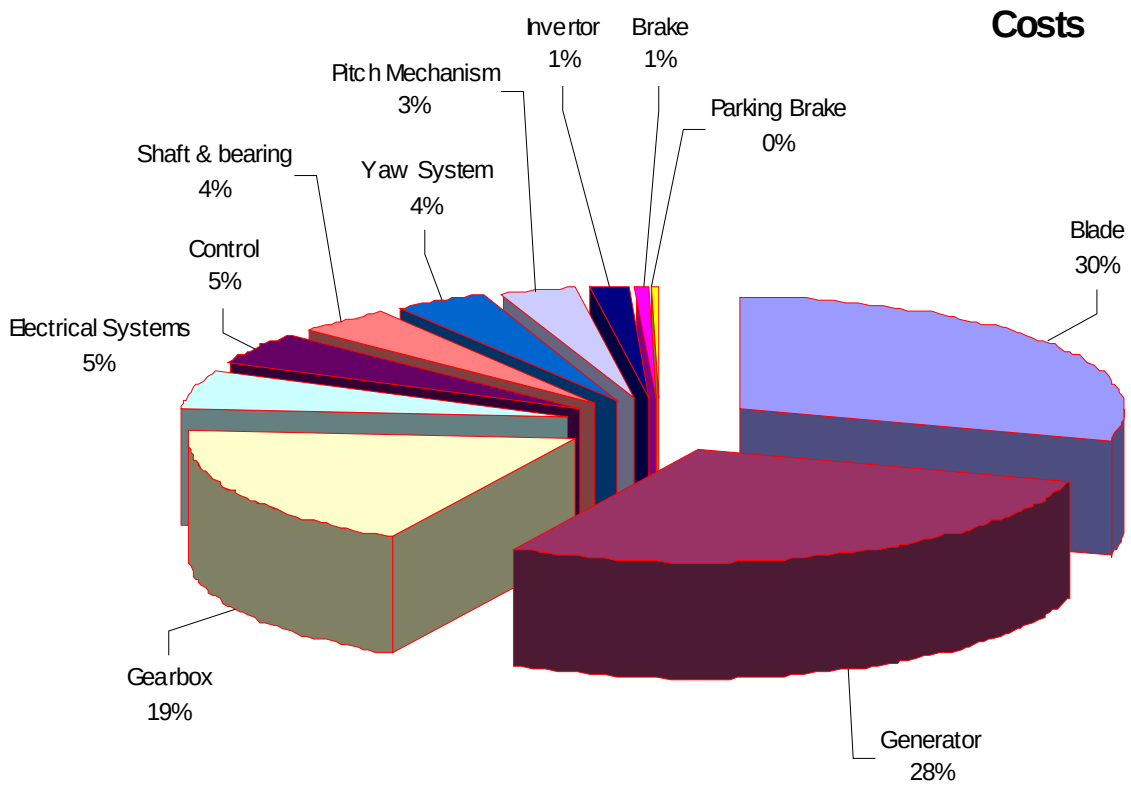

Challenge: Discuss and agree upon starting points, repair strategies, vessels etc.!!

Model: assists in structuring discussions and assess impact of assumptions!!

Reporting: as important as calculations!!

# O&M Cost modelling offshore wind farms

## Typical results




Cost Model

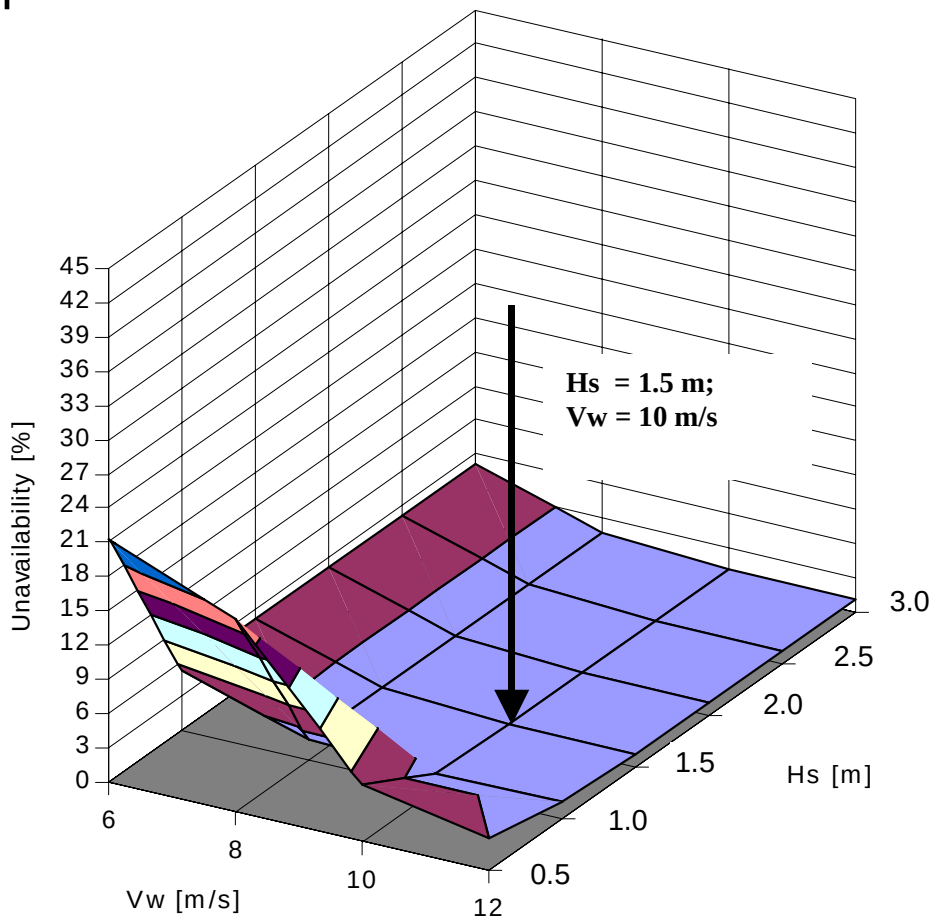
Typical Results

**- Cost Drivers**

- Waiting Time
- Price (per kWh)
- Scenario studies
- Optimisation of access systems

# O&M Cost modelling offshore wind farms

## Typical results



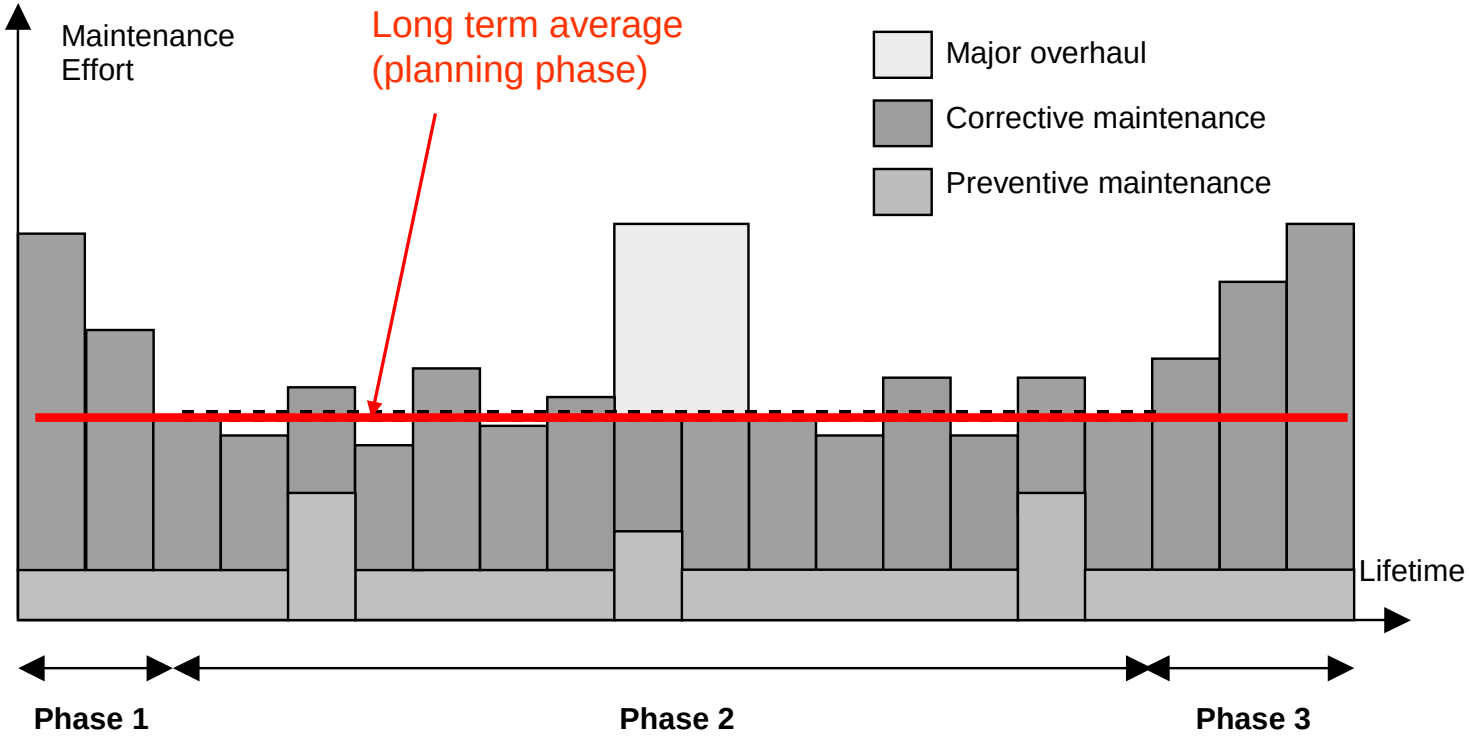

Cost Model

Typical Results

- Cost Drivers
- Waiting Time
- Price (per kWh)
- Scenario studies
- **Optimisation of access systems**

# O&M Cost modelling offshore wind farms

## Typical results



## Validation of software by GL

Assessment of

1. Plausibility
2. Required input fields and level of detail
3. Functionality
4. Recommended reporting format
5. Limitations and identification of possible areas for improvement

**Positive conclusions!**

# <u>O&M Cost Estimator (OMCE)</u>:

to estimate the future (say 2 to 10 years) O&M costs based on operational data and measured loads

***or: How many gearboxes do we need to replace in the next coming years??***

# OMCE: Long-term average → Time dependent O&M Costs

**Planning phase**

Cost estimate based on:

- Average values
- Historical generic data
- Design (calculated) loads
- Same loading and O&M for all turbines

**OMCE**

Cost estimate based on:

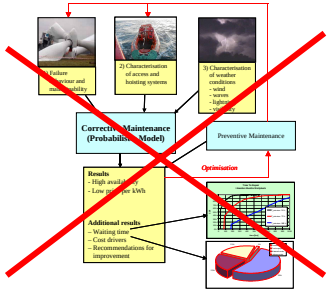
- Values time depend
- Actual specific wind farm data
- Measured loads
- Loading and O&M turbine specific

Results:

- Long term annual average values

Results:

- Values time dependent




**OMCE Cost Model**

# OMCE: How does it look like?

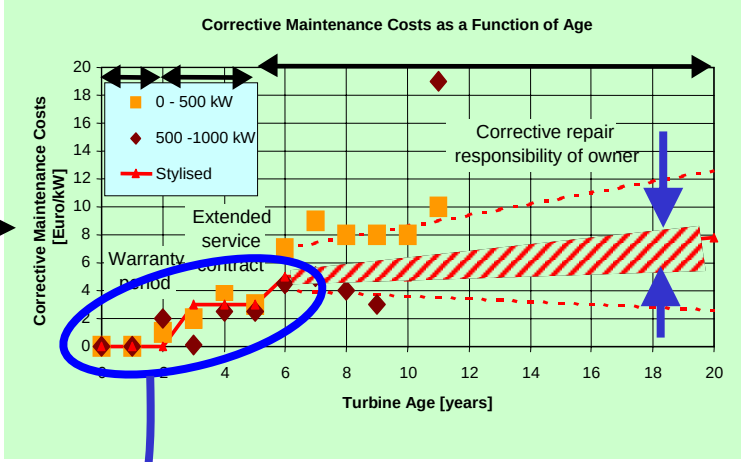
**1. Building Block**
**O&M data**

**2. Building Block**
**Loads & lifetime**

**3. Building Block**
**CM & SCADA**

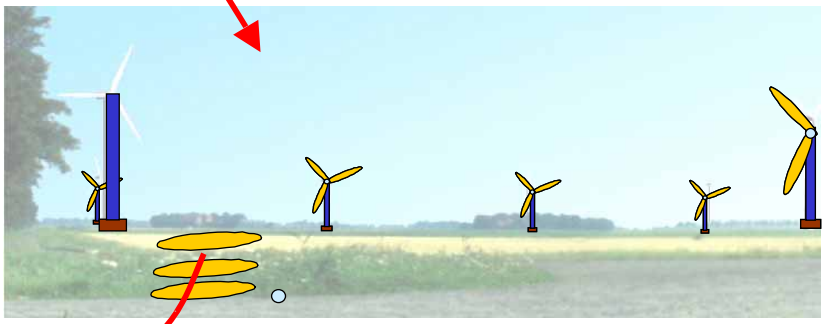
**4. Building Block**
**…….**

**OMCE**
**Cost Model**



**1. Building Block O&M data**

- Large amounts of information “hidden” in maintenance sheets
- Change from “free format” to “pre-defined answers” by performing FMEA prior to data collection

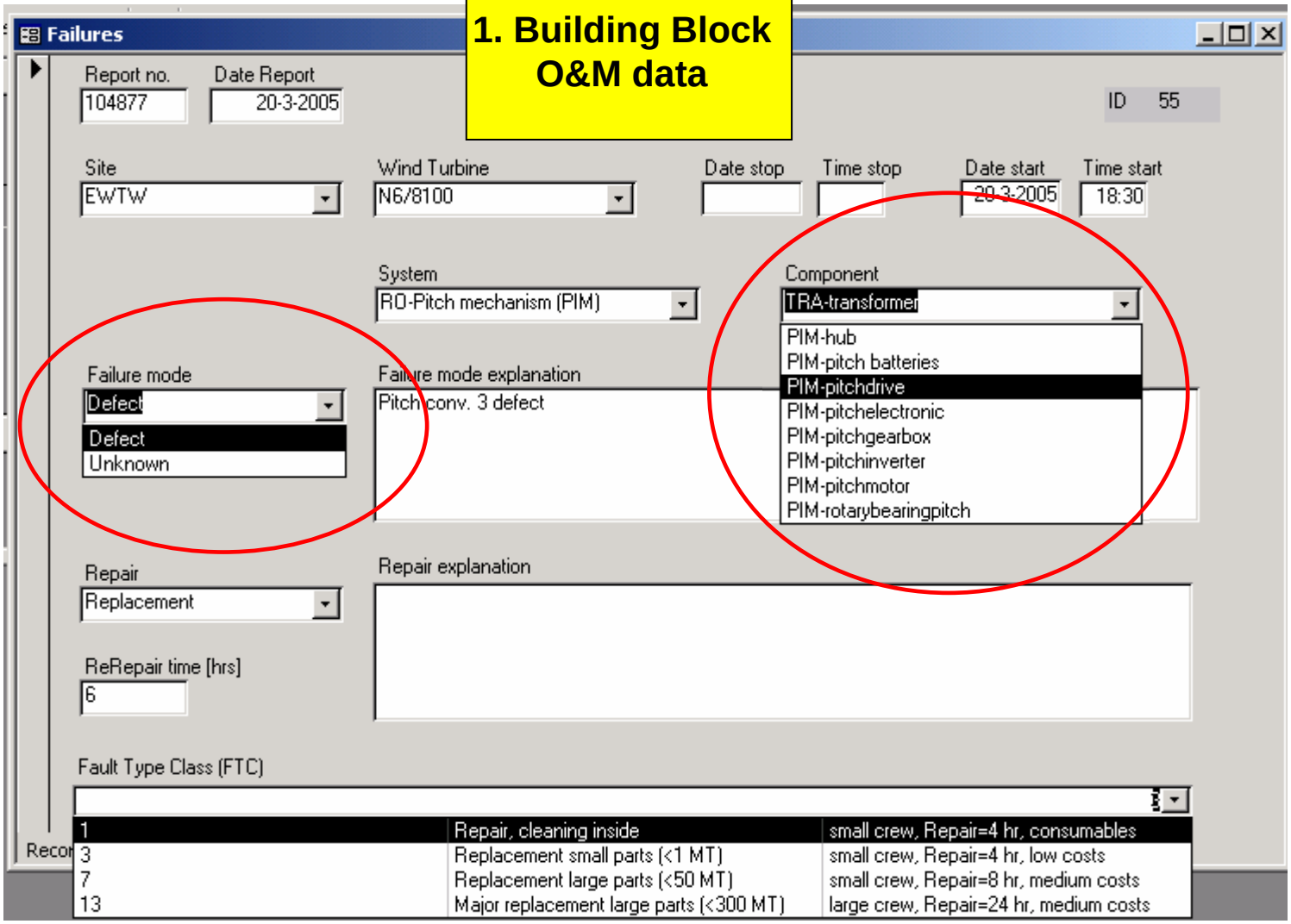


**Blade**

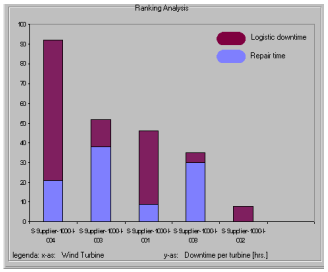
Failure modes: - cracks in skin
- local damage
- …..

Repair actions: - repair
- replacement
- …..

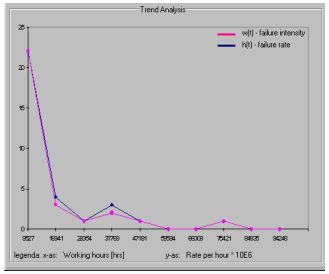
# 1. Building Block O&M data



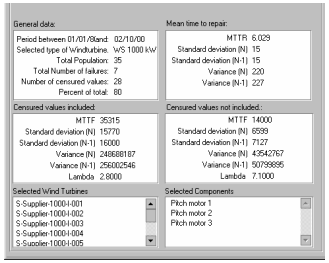

## Ranking



## Trends

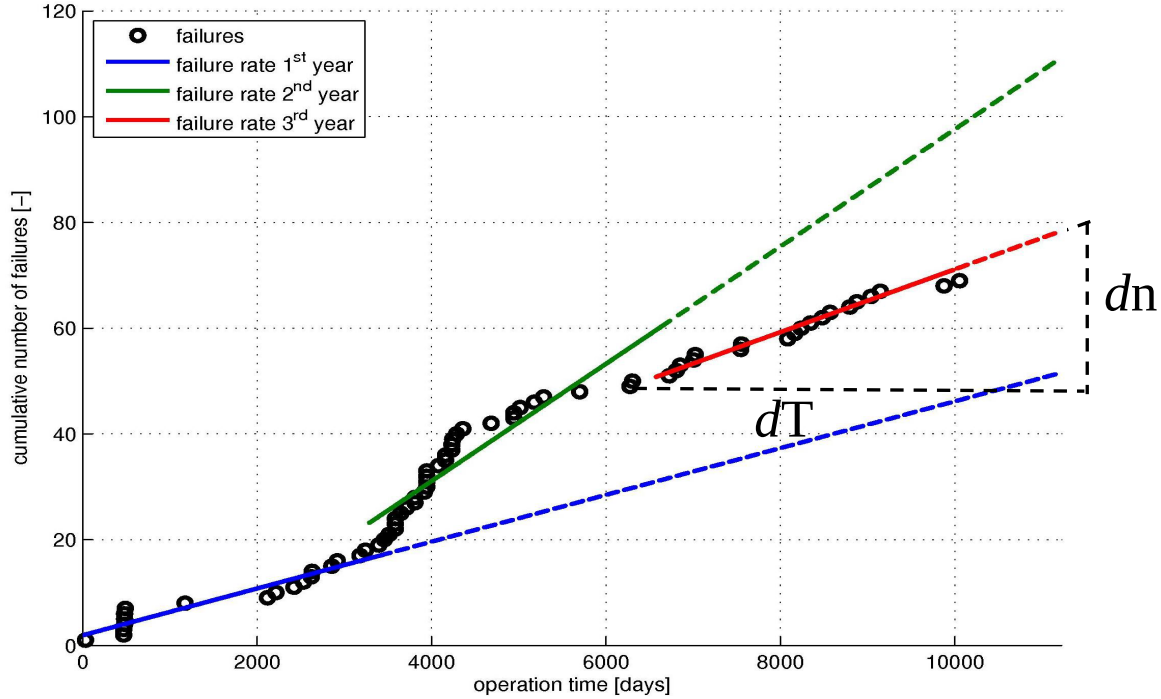


## Reliability Fig.

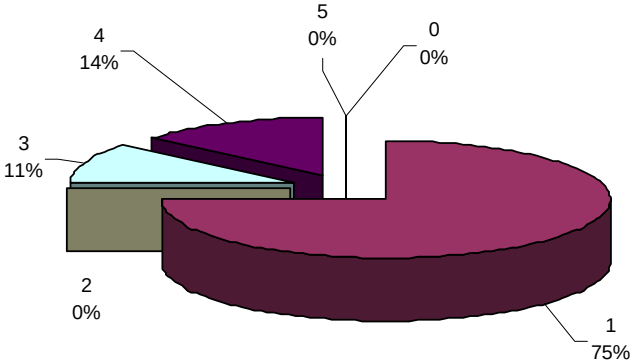


**1. Building Block O&M data**

**Example**: 9 turbines, 3 years of operational data for certain component




Distribution of maintenance classes 1 to 6

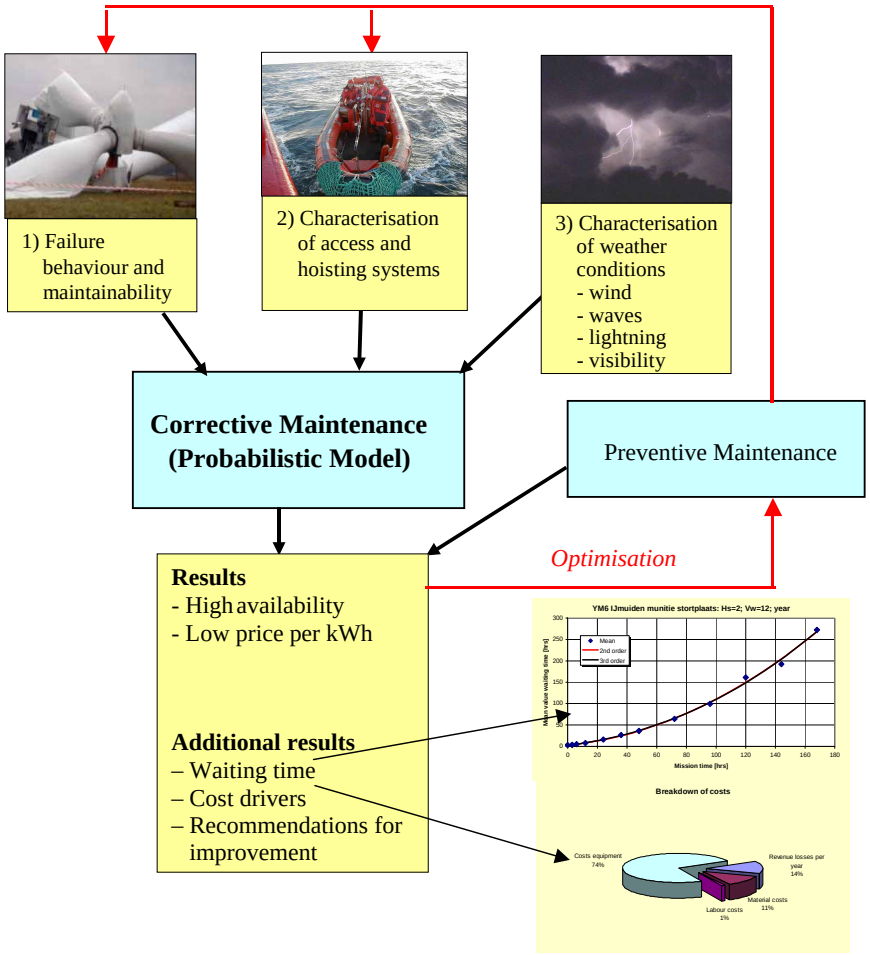



Determine failure frequency, ***dn/dT*,**

- per component
- per maintenance class (if necessary).

# O&M Cost modelling offshore wind farms

- Excel sheets + Visual Basic (+@Risk)
- To be applied in planning phase
- Models commercially available (*including training and advise*)
- 7 licenses sold
- Validated by Germanischer Lloyd



# Questions??