Data collection & analysis as input for O&M cost modelling

This paper was presented at Windpower Monthly Wind Farm Data Management & Analysis Forum, 20-21 November 2012, Hamburg, Germany

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Wind Farm Data Management & Analysis

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News

Unprecedented global partnership launched to champion green growth

22.10.2012 - The Green Growth Best Practice Initiative (GGBP) was launched last week. Designed to help...

>>

ECN RT @AgentschapNL: Verandert de rol van de overheid door inpassing van zon of andere duurzame energiebronnen in lokale initiatieven? sunday2012.nl

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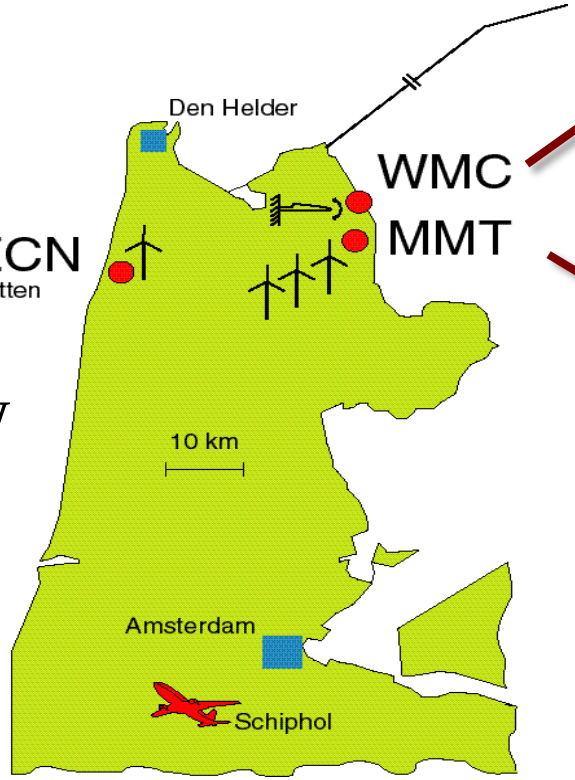
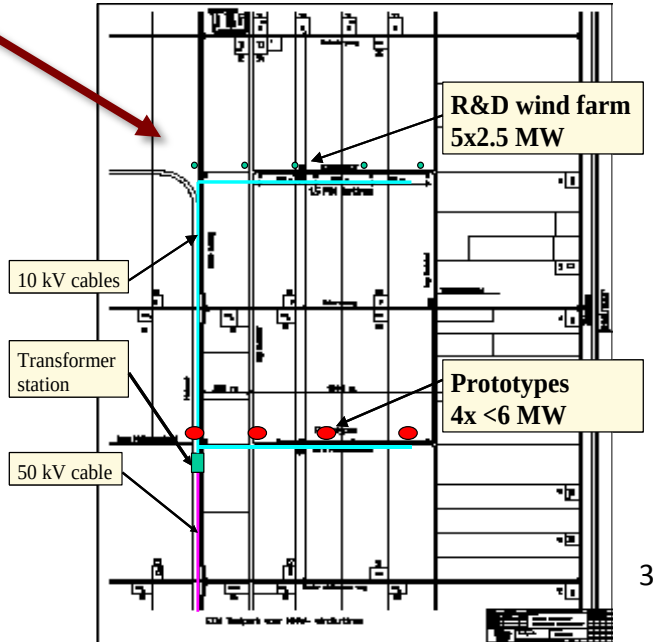
ECN Extra

2011 Highlights

annual report

ECN, locations





ECN Wind Energy (45 fte's)

- R&D programme:
  1. Rotor and wind farm aerodynamics
  2. Integrated wind turbine design
  3. **Operations and Maintenance**
  4. Measurements & Experiments

- Decision support tools
  - ECN O&M Tool
  - Operation & Maintenance Cost Estimator
- Diagnostics and condition monitoring
  - LoadWizard
    - Fibre optic blade monitoring (FOBM)
    - Analysis of load measurements
    - Fleet leader

Contents

- Introduction
- Structuring of raw data for O&M purposes
- Data analysis for reliability engineering and O&M optimisation
- Maintenance cost modelling
- Conclusions & acknowledgements

Introduction

Why O&M cost modelling:

- O&M costs offshore account for 25-30% of KWh costs
- Optimizing O&M is essential; requires accurate estimates of (1) averages and (2) uncertainties

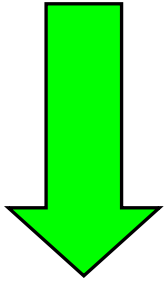
When O&M cost modelling:

- Deciding on new O&M contracts
  - Either OEM or owner/operator
- Making reservations for future O&M budgets
  - Either OEM or owner/operator (in-house maintenance)
- Optimise O&M at end of warranty period
  - Continue with OEM or maintenance in-house
- Periodically for optimisation of accessibility
  - Better vessels, new contract with shipowner

Introduction: O&M cost modelling

Principle of risk analysis / asset management:

Risk = Probability * Consequences



Corrective O&M of wind turbines:

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

Introduction: O&M cost modelling

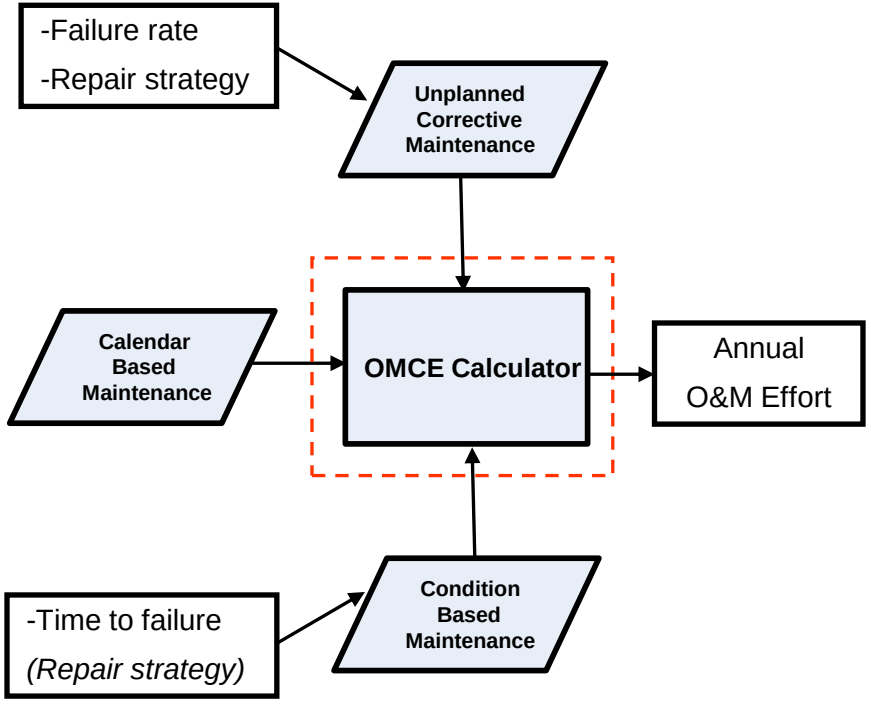
- Preventive: How often, how long?
- Condition based: Time to failure?
- Corrective: Failure frequencies of components

- Repair strategy:
  - maintenance actions *(reset, visit, repair, replacement?)*
  - # of maintenance actions
  - duration of maintenance actions
  - crew *(size, length of working days, shifts)*
  - types of access and hoisting equipment
  - spare parts used

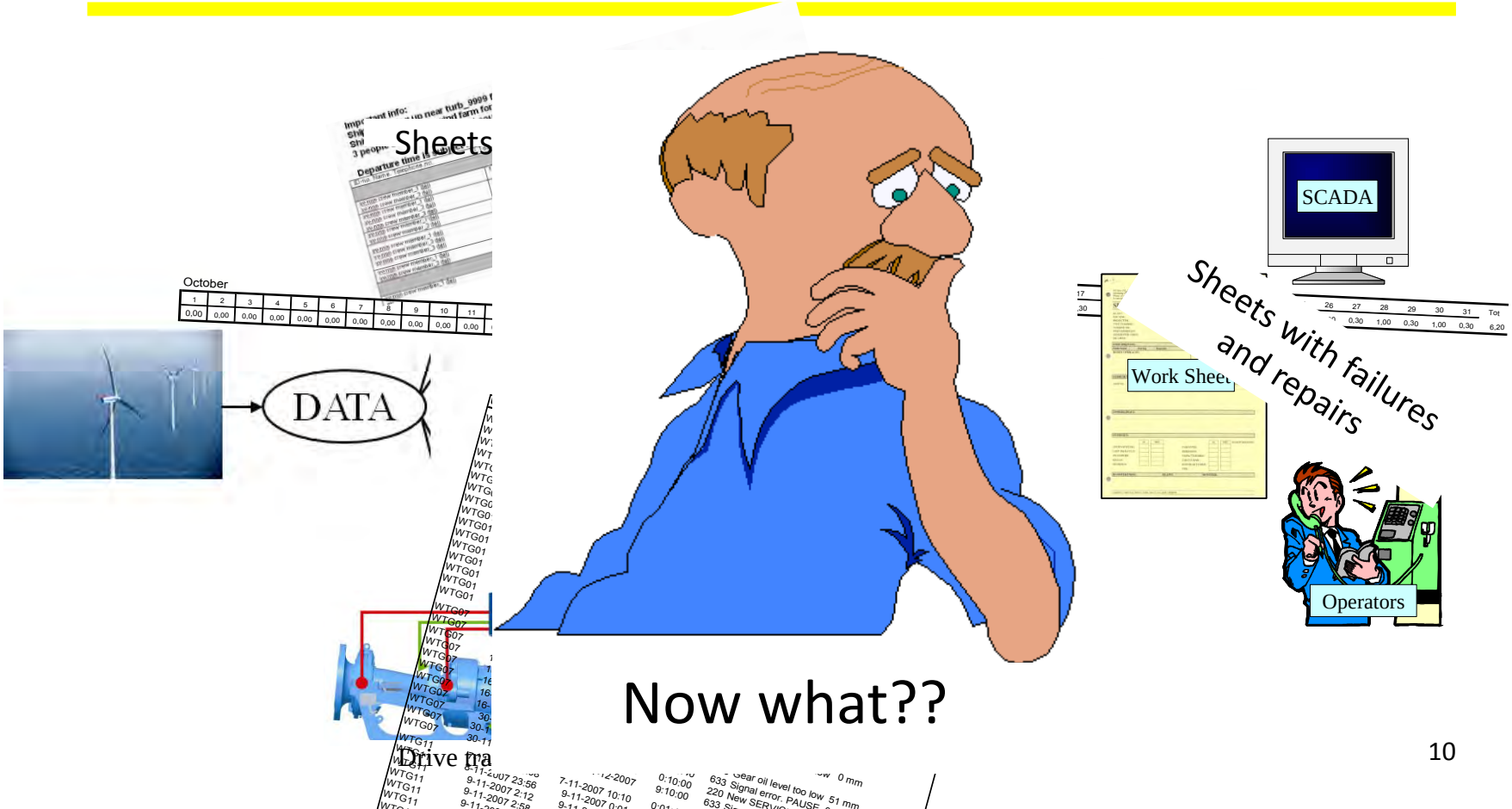
- Weather conditions (wind speed, wave height and direction, current)

Introduction: O&M cost modelling

Raw data



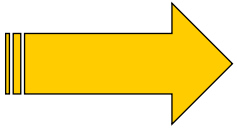
Structuring of raw data for O&M: Offshore wind farm data



Structuring of raw data for O&M: OMCE

ECN's conclusions from broad experiences

- Data from offshore wind farms is being collected, but in an unstructured way
- Data needs to be analysed for reliability engineering and O&M optimisation (**data ≠ information!!**)
- Operators and OEM's own the data → responsible for data collection and analysis
- ECN developments
  - procedures to structure the data collection *(opening/closing of workflow)*
  - tools to analyse the data
  - tool to estimate (near future) O&M costs



Approach: Operation & Maintenance Cost Estimator (OMCE)

Structuring of raw data for O&M: OMCE

Raw data

Event list Structured data

BB Operation & Maintenance

BB Logistics

BB Loads&Lifetime

BB Health Monitoring

-Failure rate

-Repair strategy

-Time to failure

(Repair strategy)

Unplanned Corrective Maintenance

Calendar Based Maintenance

Condition Based Maintenance

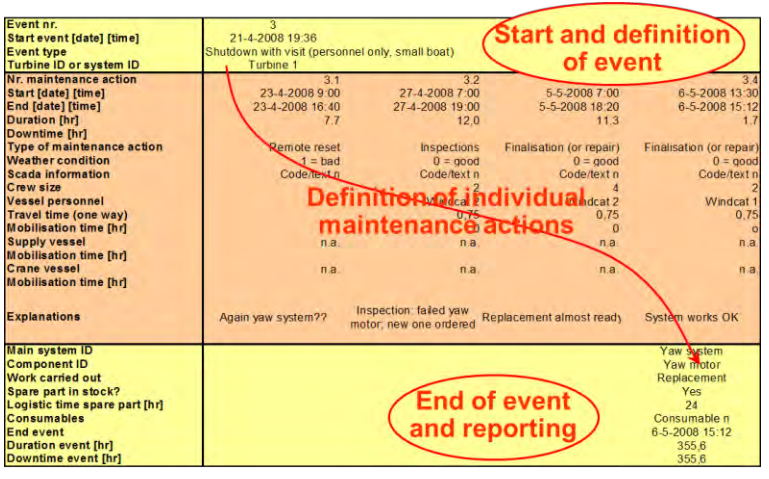
OMCE Calculator

Annual O&M Effort

Structuring of raw data for O&M: Event List

- Event definition:
  - Within the context of the OMCE, an Event is defined as a (sequence of) maintenance action(s) to prevent or to correct malfunctioning.

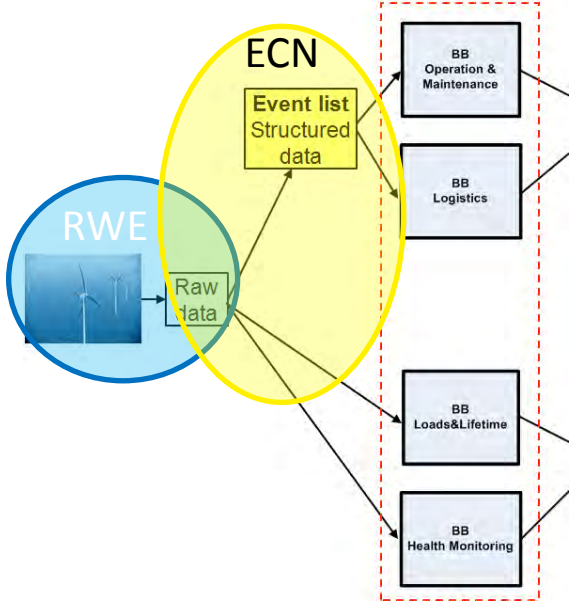
- Requirements:
  - Combine data from various data sources
  - Relations between event and maintenance action(s)
  - Events per turbine in chronological order
  - Contain sufficient details to determine OMCE input parameters
  - Integrated in works management system (e.g. SAP, Ultimo)



Event nr.	3			
Start event [date] [time]	21-4-2008 19:36			
Event type	Shutdown with visit (personnel only, small boat)			
Turbine ID or system ID	Turbine 1			
Nr. maintenance action	3.1	3.2		3.4
Start [date] [time]	23-4-2008 9:00	27-4-2008 7:00	5-5-2008 7:00	6-5-2008 13:30
End [date] [time]	23-4-2008 16:40	27-4-2008 19:00	5-5-2008 18:20	6-5-2008 15:12
Duration [hr]	7.7	12,0	11.3	1.7
Downtime [hr]				
Type of maintenance action	Remote reset	Inspections	Finalisation (or repair)	Finalisation (or repair)
Weather condition	1 = bad	0 = good	0 = good	0 = good
Scada information	Code/text n	Code/text n	Code/text n	Code/text n
Crew size		2	4	2
Vessel personnel		Windcat 1	Windcat 2	Windcat 1
Travel time (one way)		0,75	0,75	0,75
Mobilisation time [hr]			0	0
Supply vessel	n.a.	n.a.	n.a.	n.a.
Mobilisation time [hr]				
Crane vessel	n.a.	n.a.	n.a.	n.a.
Mobilisation time [hr]				
Explanations	Again yaw system??	Inspection: failed yaw motor; new one ordered	Replacement almost ready	System works OK
Main system ID				Yaw system
Component ID				Yaw motor
Work carried out				Replacement
Spare part in stock?				Yes
Logistic time spare part [hr]				24
Consumables				Consumable n
End event				6-5-2008 15:12
Duration event [hr]				355,6
Downtime event [hr]				355,6

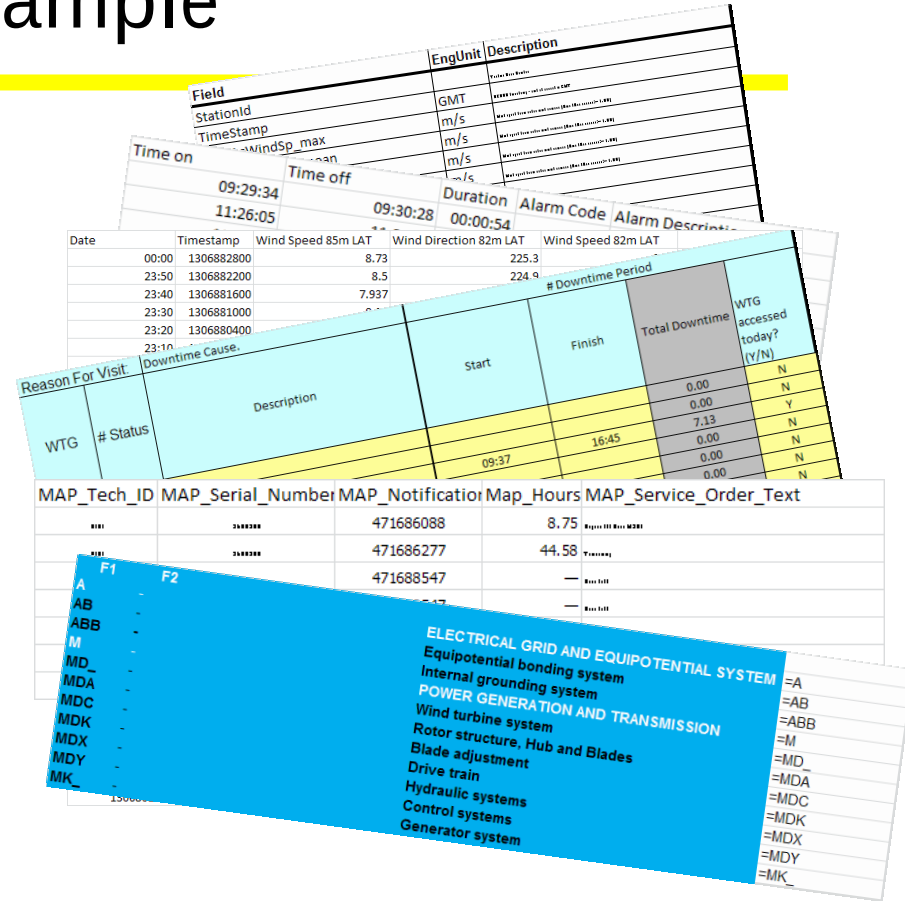
Structuring of raw data for O&M: Event List, practical example

- In context of Dutch FLOW research programme a project defined with partner RWE
- Project goal: Apply OMCE baseline model in an offshore wind farm and assess the contribution in realisation of cost reductions.
- WP 1: Structured data collection
  - 3 months data from offshore wind farm supplied by RWE as input
  - ECN: Assess suitability O&M data for further analysis and development of Event List



Structuring of raw data for O&M: Event List, practical example

- Data sources supplied by RWE:
  - List of SCADA parameters
  - Alarm list
  - Meteo and wave data
  - Monthly downtime summary reports
  - Daily work reports
  - Turbine breakdown in RDS-PP coding
- Observations:
  - Many different data sources stored independently
  - Format of data sources is different (e.g. reported per turbine, chronological, per month, for 3 months etc.)



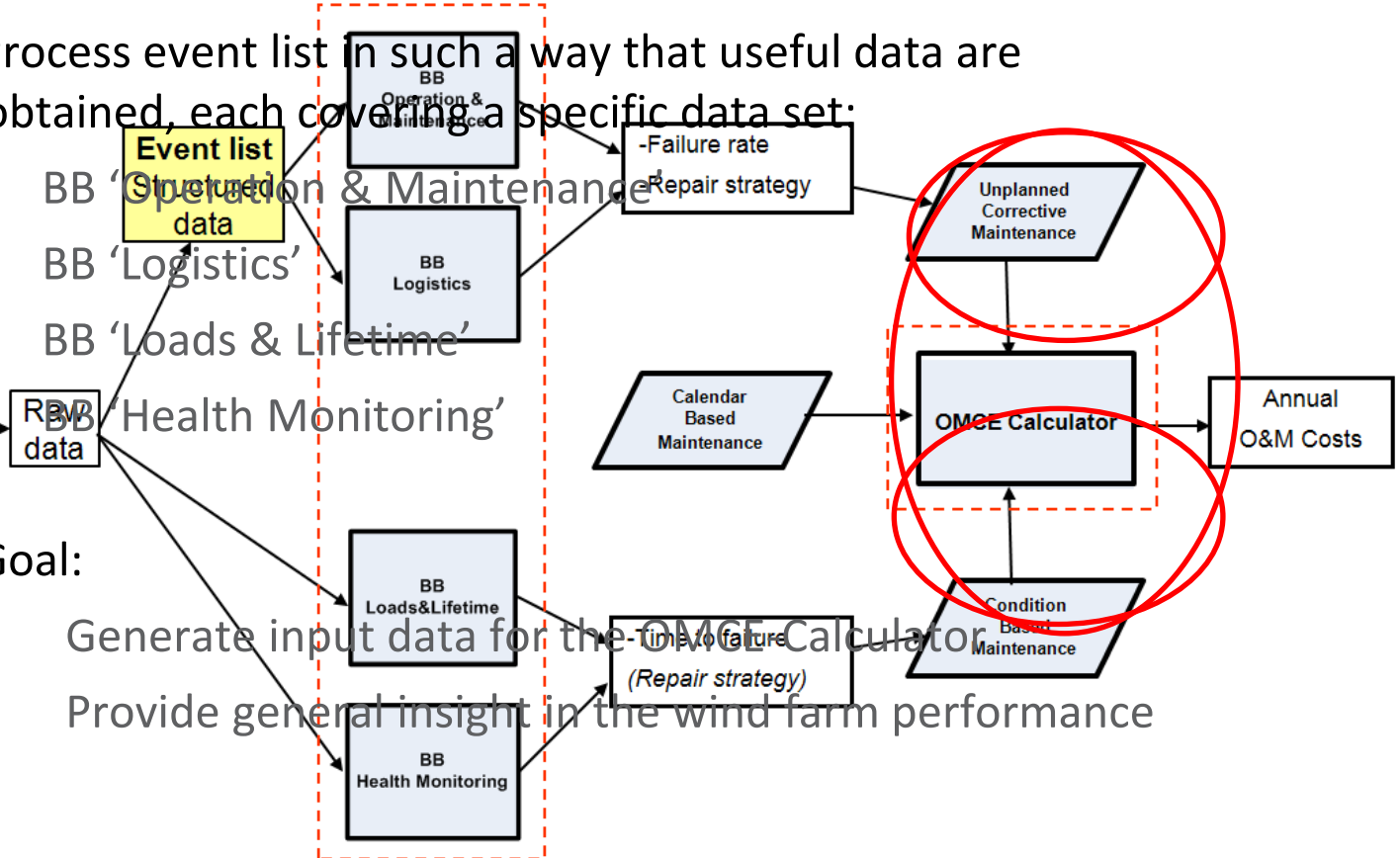
Structuring of raw data for O&M: Event List, practical example

- Fill & review Event List format
  - Use available maintenance data sources to fill fields of Event List format
- Observations:
  - This is a manual step due to assumptions required (engineering judgement)
  - Not all information according to Event List specifications available
- Future work (FLOW):
  - Review Event List format
  - Automate procedures to capture data

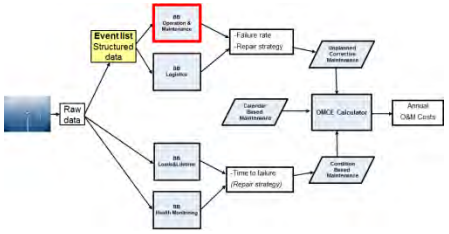
Event nr.		*7*	
Start event [date] [time]		[redacted]	
Event type		Calendar based maintenance (other)	
Turbine ID or BOP ID		[redacted]	
Nr. maintenance action		1	2
Start	[date/tim	[redacted]	[redacted]
End		[redacted]	[redacted]
Duration	[h]	6.85	6.17
Downtime	[h]	6.85	6.17
Type of maintenance		Preventive maintenance	Preventive maintenance
Weather condition		0 = good	0 = good
Scada alarm code		[redacted]	[redacted]
Scada description		[redacted]	[redacted]
Reported labour hours	[h]	44.58	5.34
Crew size			
Vessel personnel			
- sailing time (heading out)	[h]		
- sailing time (return)	[h]		
Supply vessel			
- travel time (one way)	[h]		
- mobilisation time	[h]		
Crane vessel			
- travel time (one way)	[h]		
- mobilisation time	[h]		
Explanations		[redacted]	[redacted]
Main system_ID		MD_ - Wind turbine system	
Component ID			
Work carried out		Preventive maintenance	
Spare part in stock		n.a.	
Logistic time spare part	[h]		
Consumables		n.a.	
# consumables			
Total labour hours	[h]	*49.92*	
End event		[redacted]	
Duration event	[h]	*55.45*	
Downtime event	[h]	*55.45*	

Data analysis: Building Blocks

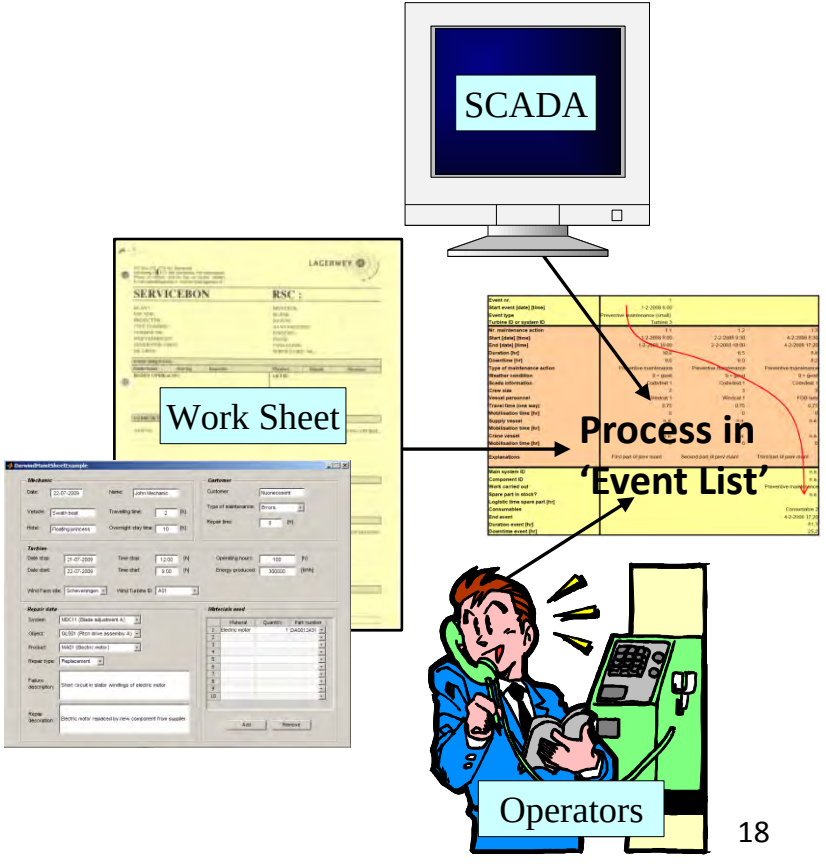
- Process event list in such a way that useful data are obtained, each covering a specific data set:
  - BB 'Operation & Maintenance'
  - BB 'Logistics'
  - BB 'Loads & Lifetime'
  - BB 'Health Monitoring'
- Goal:
  - Generate input data for the OMCE Calculator
  - Provide general insight in the wind farm performance



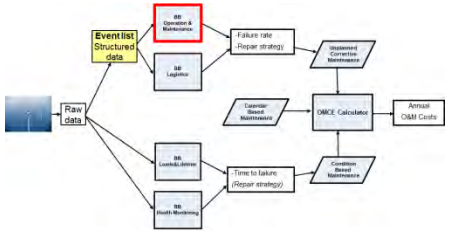
Data analysis:
Building Block ‘O&M’



- Goal:
  - Estimate failure frequencies of the different wind turbine components
- Method:
  - Structured collection of O&M data in ‘Event list’
  - Ranking of systems
  - Trend analysis using CUSUM-plots
  - Determine failure frequencies & confidence intervals



Data analysis:
Building Block 'O&M'



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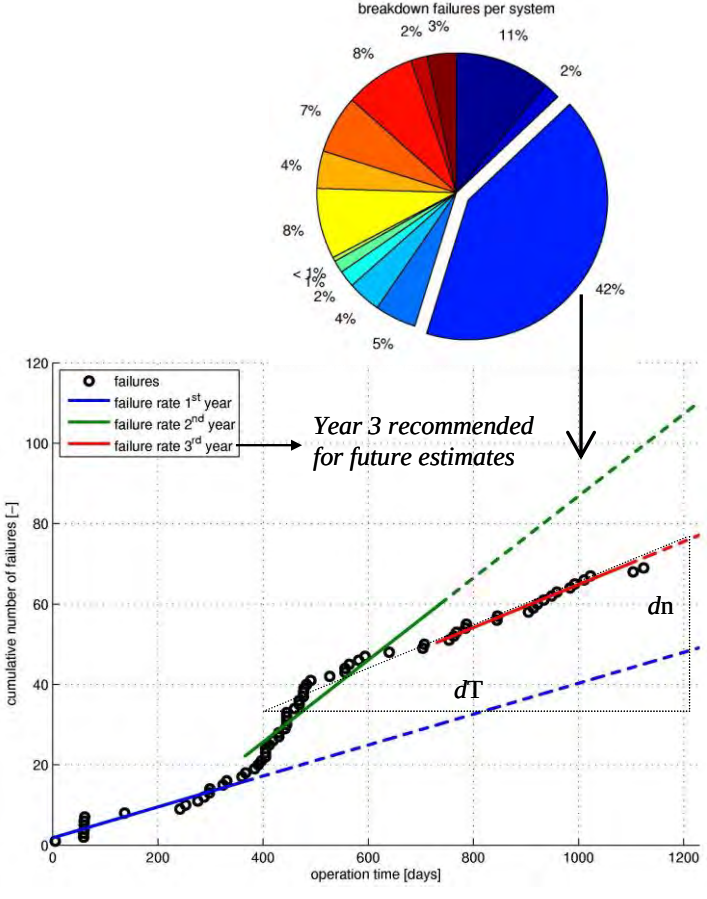
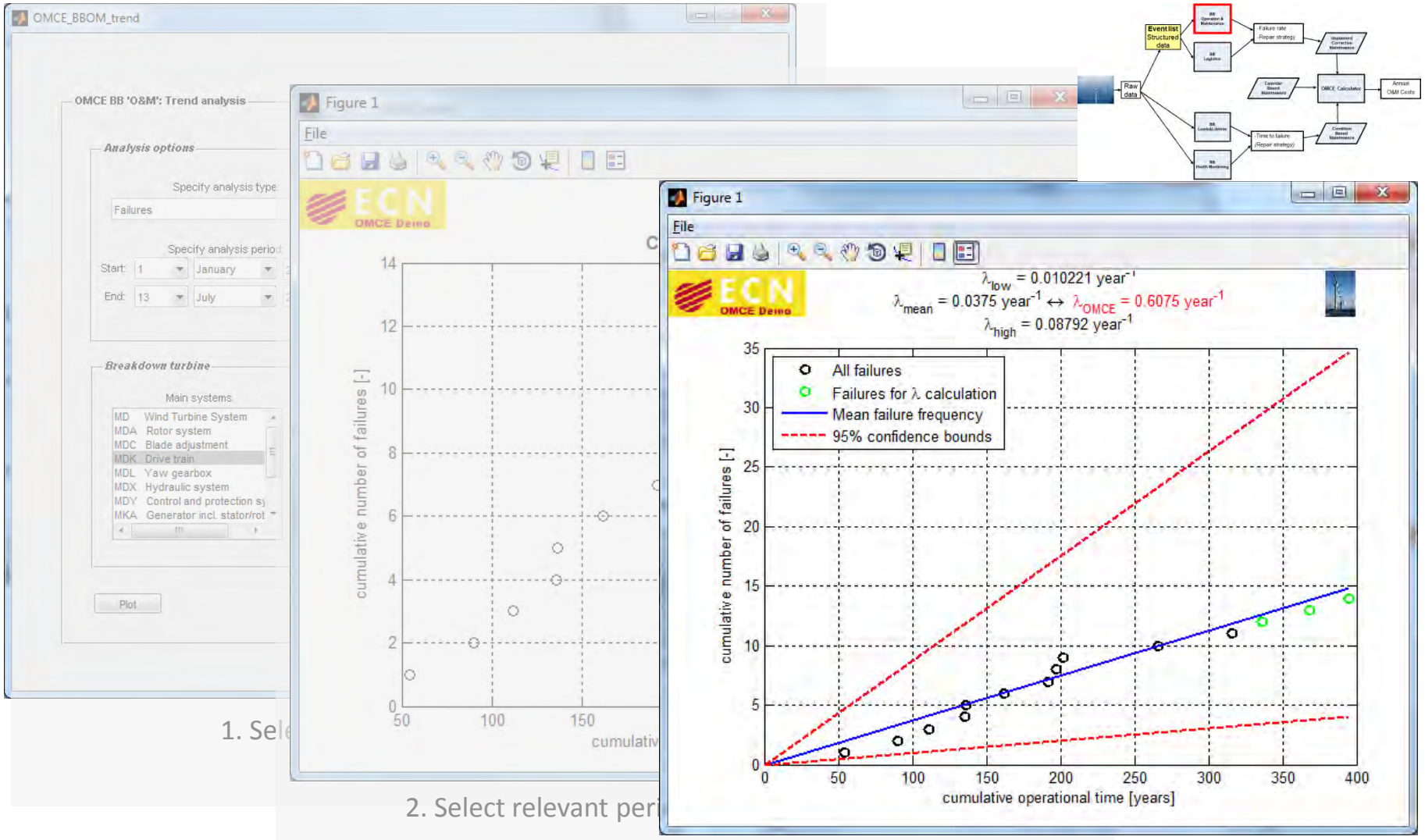


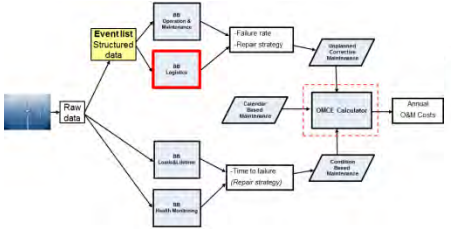


1. Sel

2. Select relevant peri

3. Results

Data analysis:
Building Block 'Logistics'



Goal:

- Quantify costs of repair actions
- Spare parts and stock control

Method:

- Determine effort per Repair Class
- Characterise Equipment
- Characterise Spare Control Strategy

OMCE BB 'Logistics': RPC characterisation

Analysis options

Select main system:

MDK Drive train

Select component:

Select component...

Select FTC:

Large parts failure < 30 MT

Select action:

Replacement (hoisting)

Specify analysis period:

Start: 1 January 2000

End: 16 July 2012

Results

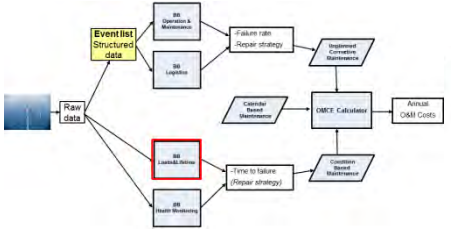
Show graphs

Number of records: 5

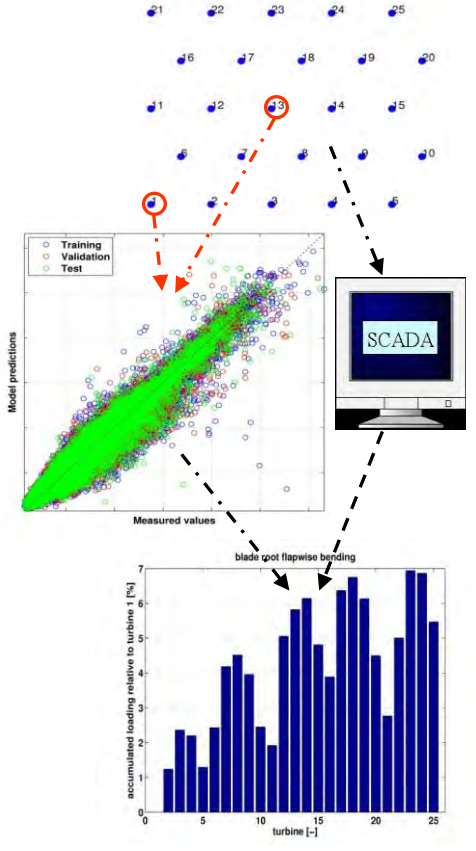
	Avg	Std	Min	Max
Time to organise [h]	0.0534	0.1195	0	0.26
Duration [h]	3.1867	0.7142	2.3364	3.78
Crew size [-]	4.6000	0.8944	4	

	Name	[%]	Name	[%]	Name
Equipment 1	Large access ves...	40	Helicopter	40	RIB (access/short)
Equipment 2					
Equipment 3	Crane ship (100MT)	60	Jack-up barge (10...	40	

Data analysis:
Building Block 'Loads&Lifetime'



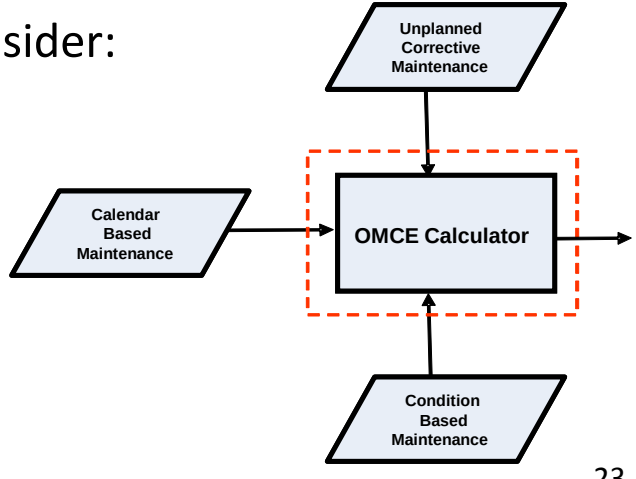
- Goal:
  - Keep track of load accumulation at all turbines in an offshore wind farm
- Method (ECN's Fleet leader concept):
  - Only few turbines at strategic locations equipped with mechanical load measurements *(Innovative Optical Sensors)*
  - Relations between load indicators and SCADA parameters
  - Combine these relations with SCADA data at all turbines to obtain load accumulation for the entire wind farm



Cost Modelling: OMCE-Calculator

*Specifications based on long term experiences with **ECN O&M Tool***
> 20 licenses world wide; > 50% of European wind farms since 2005

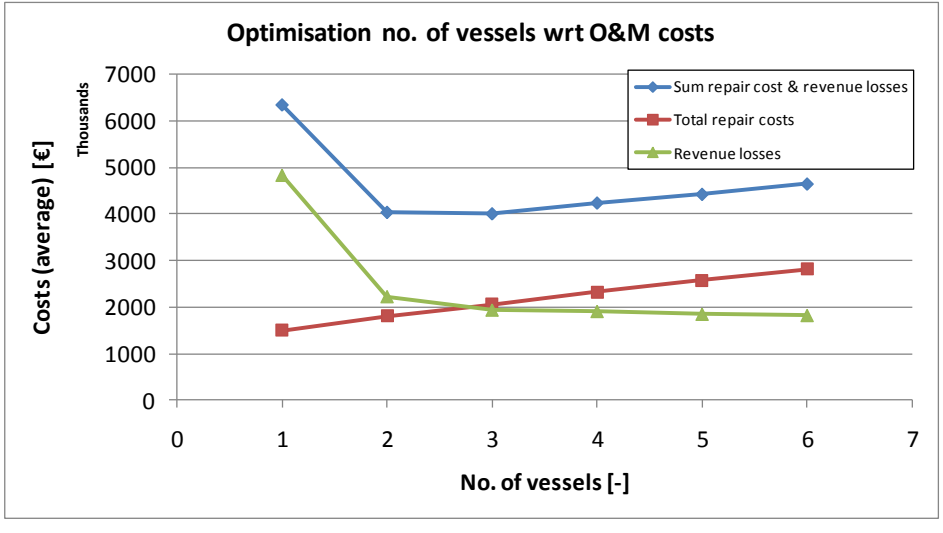
- Designed for operational phase of wind farm
- User-friendly input to define 3 types of maintenance and their priorities
- Time domain simulation allows to better consider:
  - vessel optimisation
  - clustering of maintenance actions
  - stock control
  - combine preventive and corrective
  - condition based maintenance
  - revenue losses



Cost Modelling: OMCE-Calculator

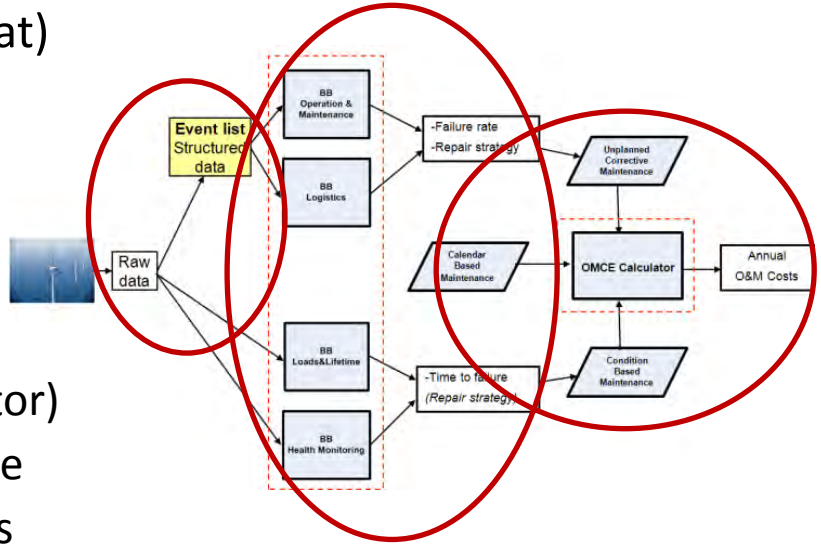
Example of scenario study

- Project defined for an imaginary wind farm: 50 turbines
- Average failure rate of: $\lambda_t = 5\, year^{-1}$ distributed over components and FTC's
- **Goal: Investigate relation nr. of access vessels and availability and costs**
- Conclusion: 2 or 3 vessels is optimal



Conclusions

- Operators/OEM's should structure data collection process (e.g. Event List format)
- Apply data analysis tools (e.g. Building Blocks) to generate:
  - input for cost modelling
  - general insight in farm behaviour
- Cost modelling tools (e.g. OMCE-Calculator) can be applied to determine (near-)future O&M effort and perform scenario studies
- Further development of OMCE foreseen in FLOW project with ECN and RWE



Thank you for your attention

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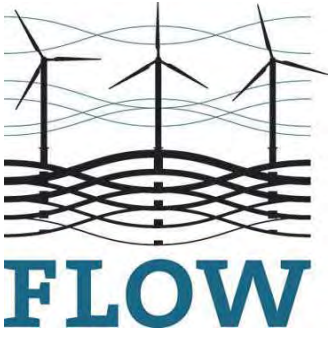

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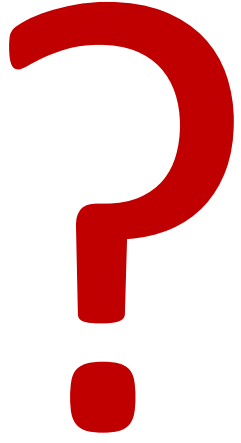
"If we knew what it was we were doing, it would not be called research, would it?"

Albert Einstein

Questions



End of presentation