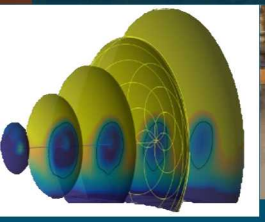
This paper describes objective technical results and analysis. Any subjective views or opinions that might be expressed in the paper do not necessarily represent the views of the U.S. Department of Energy or the United States Government.

SAND2018-12198C

Optimizing Functionality and Increasing Profitability through Blade Design: The Blade Lifetime Value Model

2018 Blade O&M USA, October 10th, 2018



PRESENTED BY

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SAND2018-9430 PE

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Outline

- Blade Lifetime Value Model
  - Goal
  - Use Cases
  - Structure
- Feedback

BLVM Goal

Develop a techno-economic model of a wind turbine blade that incorporates the full life-cycle

- Design
- Manufacturing
- Operation
- Retirement.

Enable analysis of how proposed innovations affect the total lifetime cost of a blade vs. the total lifetime revenue generated.

BLVM Project Plan

Objective 1: Model Definition (Identify use cases, goals)

Objective 2: Model Requirements (code, compatibility)

Objective 3: Develop Preliminary Model (minimum functional model)

Objective 4: Assess Model (Verify with example use case)

Objective 5: Document Model (User guide, theory)

Potential Use Cases

Leading edge erosion

Impacts of leading edge erosion have been evaluated

Potential mitigation methods

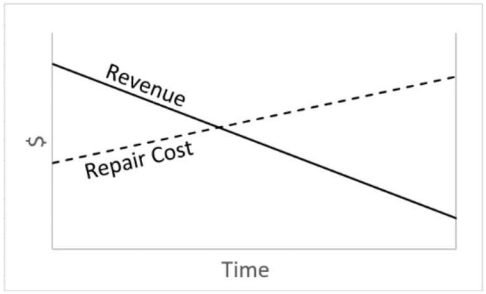
Characterization of local design conditions and the resulting impacts on erosion have not been sufficiently studied or classified in a standardized way.

Cost/energy capture trade off of turbine operation, mitigation technologies, and design could be evaluated.

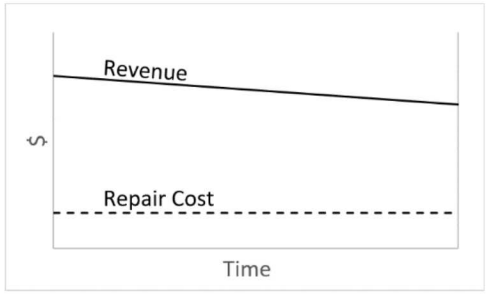
Potential Use Cases: Leading Edge Erosion

Post-Commission Field Installation

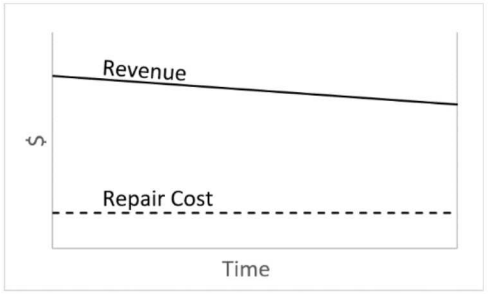
Operation



Field Installation



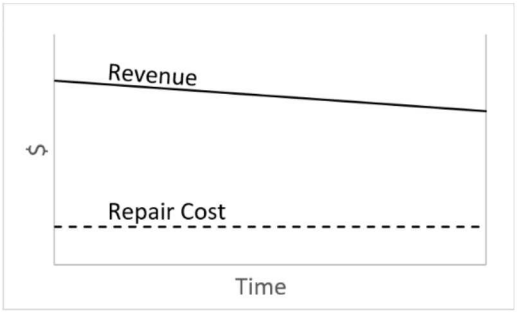
Field Replacement

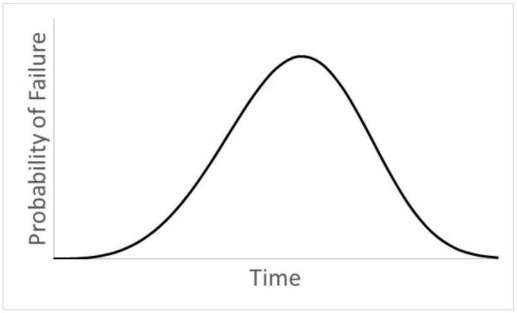


Potential Use Cases: Leading Edge Erosion

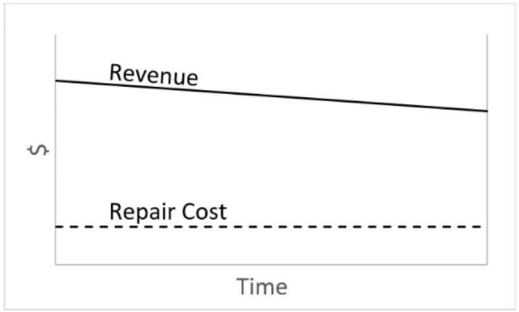
Factory Installation

Initial Cost





Field Replacement



Wind Plant Controls

Analysis of wind plant control concepts (wake steering, induction control, blade actuators) require both power and loads

Model will capture impacts to non-standard rotor operation in terms of cost vs. increased energy capture.

Potential Use Cases

Merchant / spot market analysis

Increasing percent of installed wind capacity sells power on the wholesale or spot market

Incorporating market pricing into value model could highlight important operational opportunities

- Not operating a wind plant during a low-level jet event at night because the value of electricity on the spot market could be lower than the potential damage to the rotor.
- Uprating during times with higher power prices

Blade icing

Icing events can have significant cost impacts to wind plants due to

- Revenue loss during downtime
- Potential damage to blades depending on the operational strategies

Relative effectiveness of icing event prediction (sensors and/or forecasts), prevention, and turbine operating states can be evaluated

SHM assessment

Addition of structural health monitoring systems including sensors and analysis software could be a net benefit in terms of cost, but requires an analysis framework that can account for maintenance costs/savings.

Design Standards & Certification

IEC 61400-5 draft standard has new safety factor guidance to allow more flexibility in turbine blade design and manufacturing

Framework is needed to assess the potential benefit of meeting the new certification requirements

Preliminary Requirements

- Integration with other analysis tools
  - NREL WISDEM
  - Sandia NuMAD
  - OpenFAST
- Public/Open Source models/data
- Validation plan
- Documentation
- Adaptable to HPC platforms
- Dynamic model
- Probabilistic model (flaw size, erosion rates, etc) that accommodates varying amount of data

Module Structure

Parameter Configuration Input File(s)

- Parameter inputs to initiate models
- Option parameters for models to select fidelity
- Model selection if multiple
- Defaults
- Distribution parameters

Module Fidelity

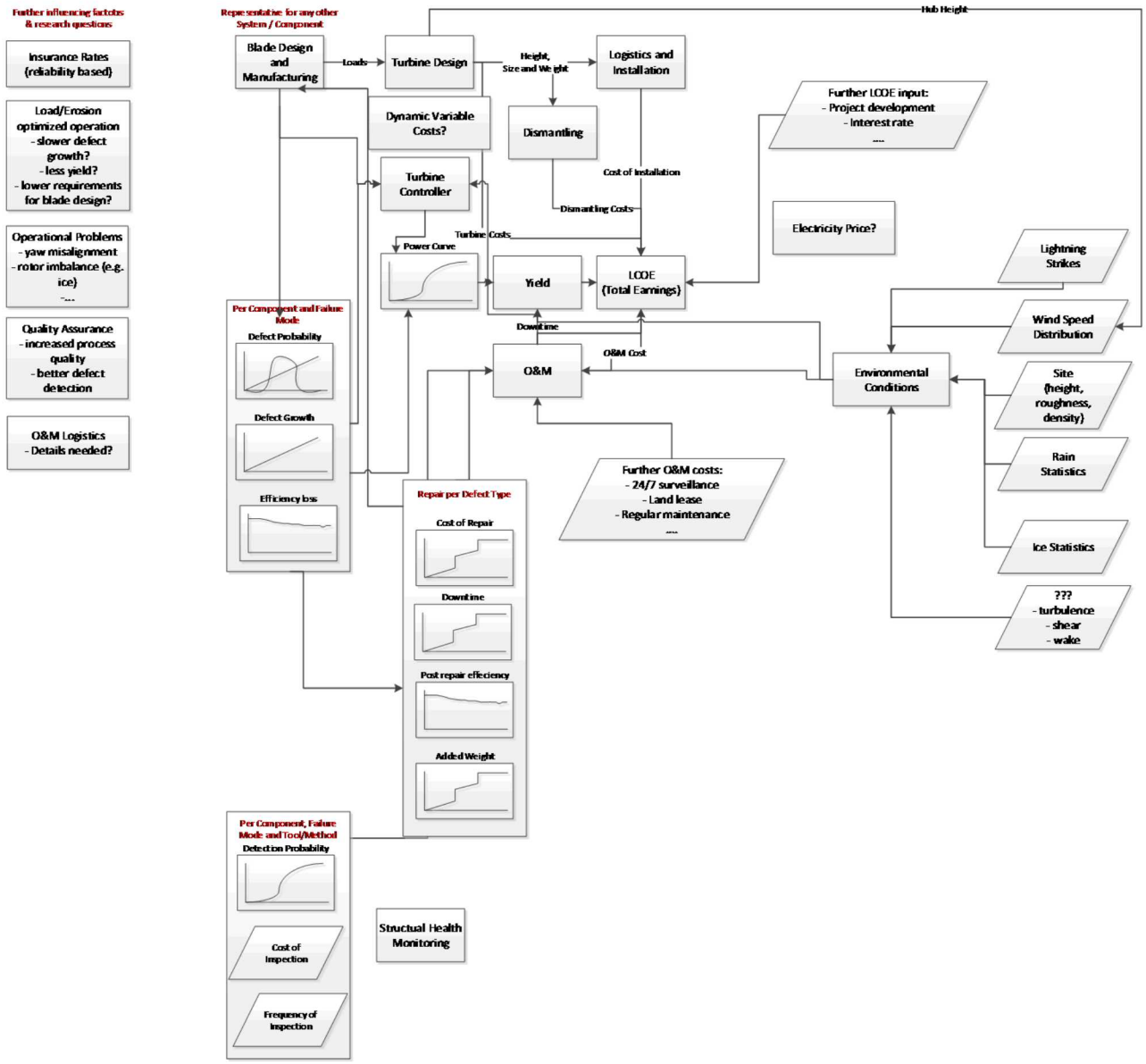
Low Fidelity (minimum functional model)

- Input parameters
- Algorithm(s)
- Internal parameters
- Output parameters

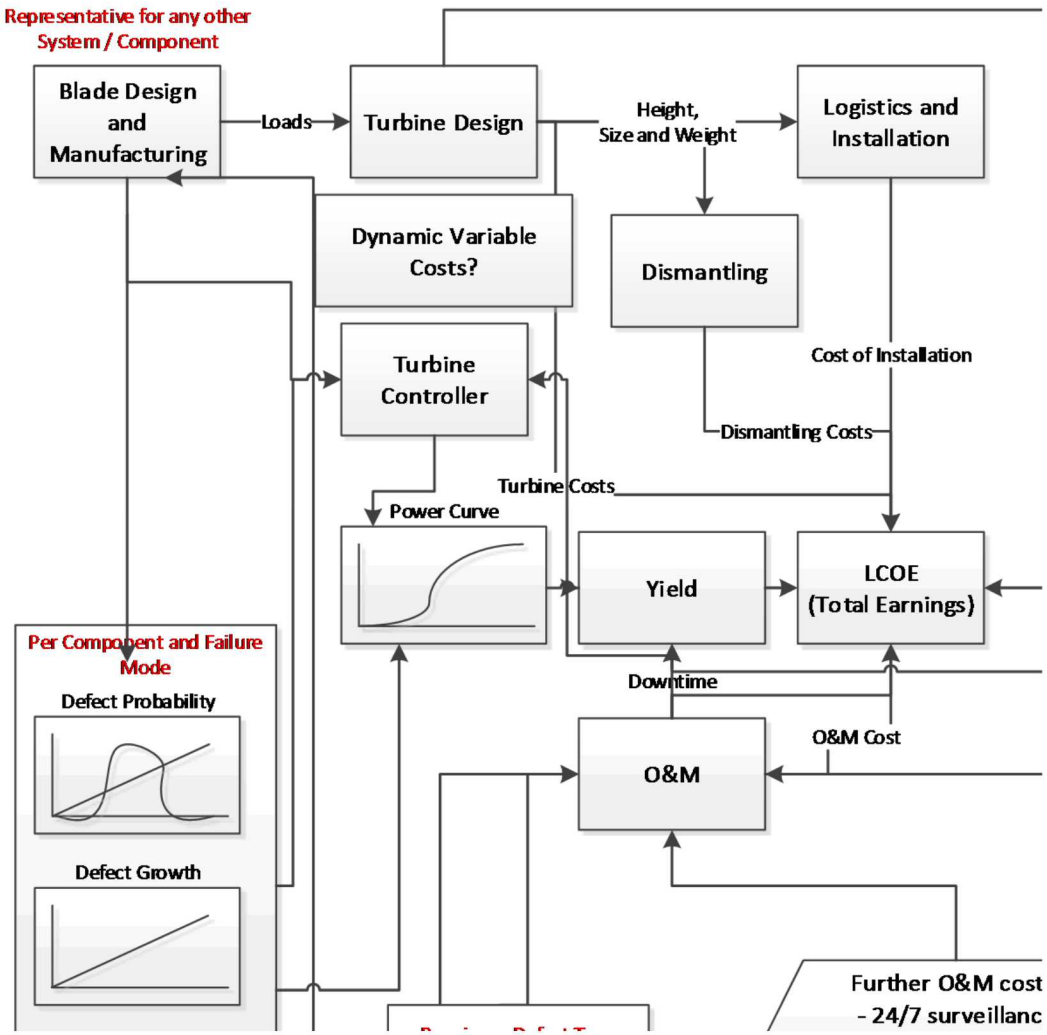
High Fidelity (options for higher fidelity)

- Input parameters
- Algorithm(s)
- Internal parameters
- Output parameters

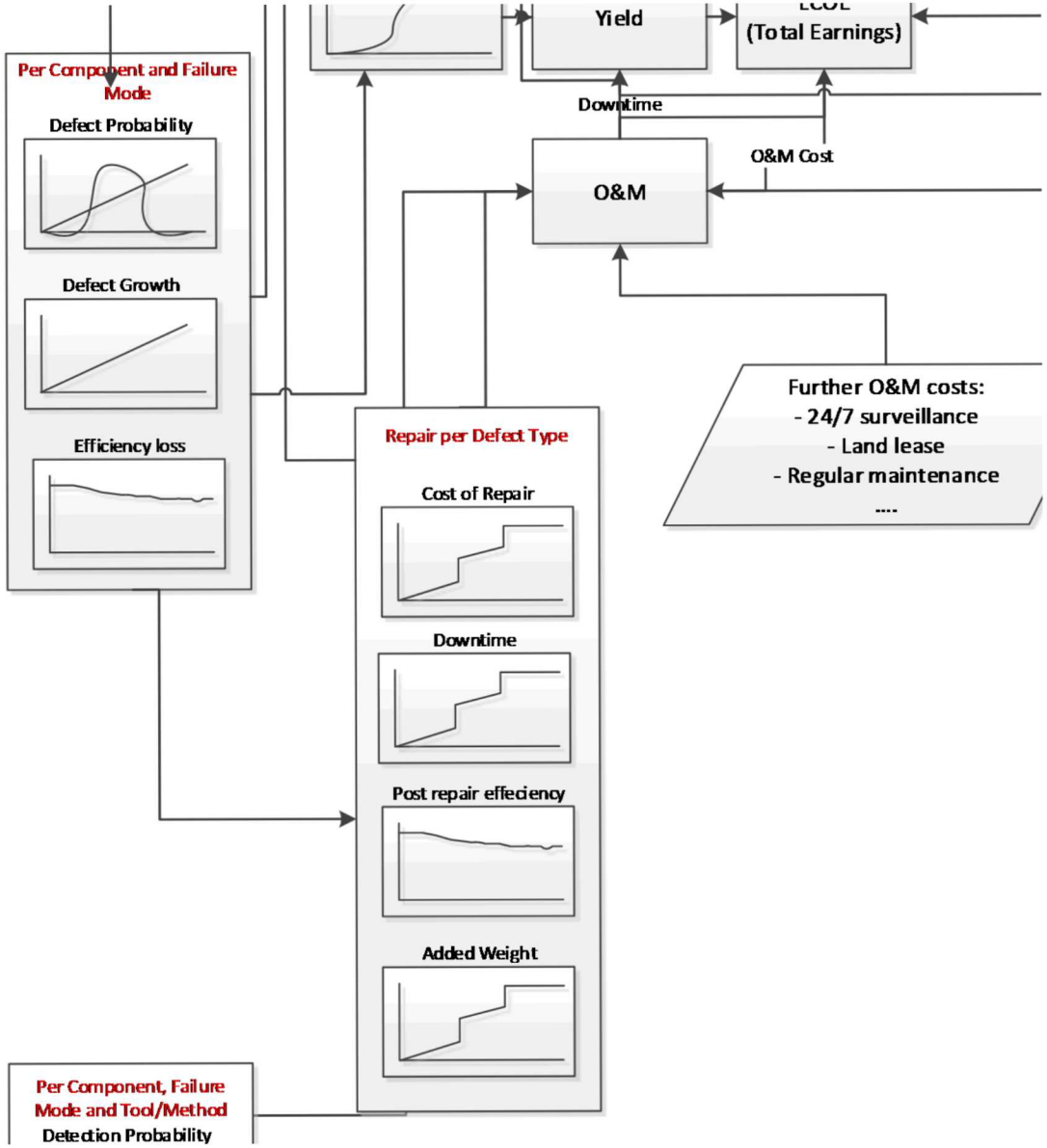
Module Interdependencies



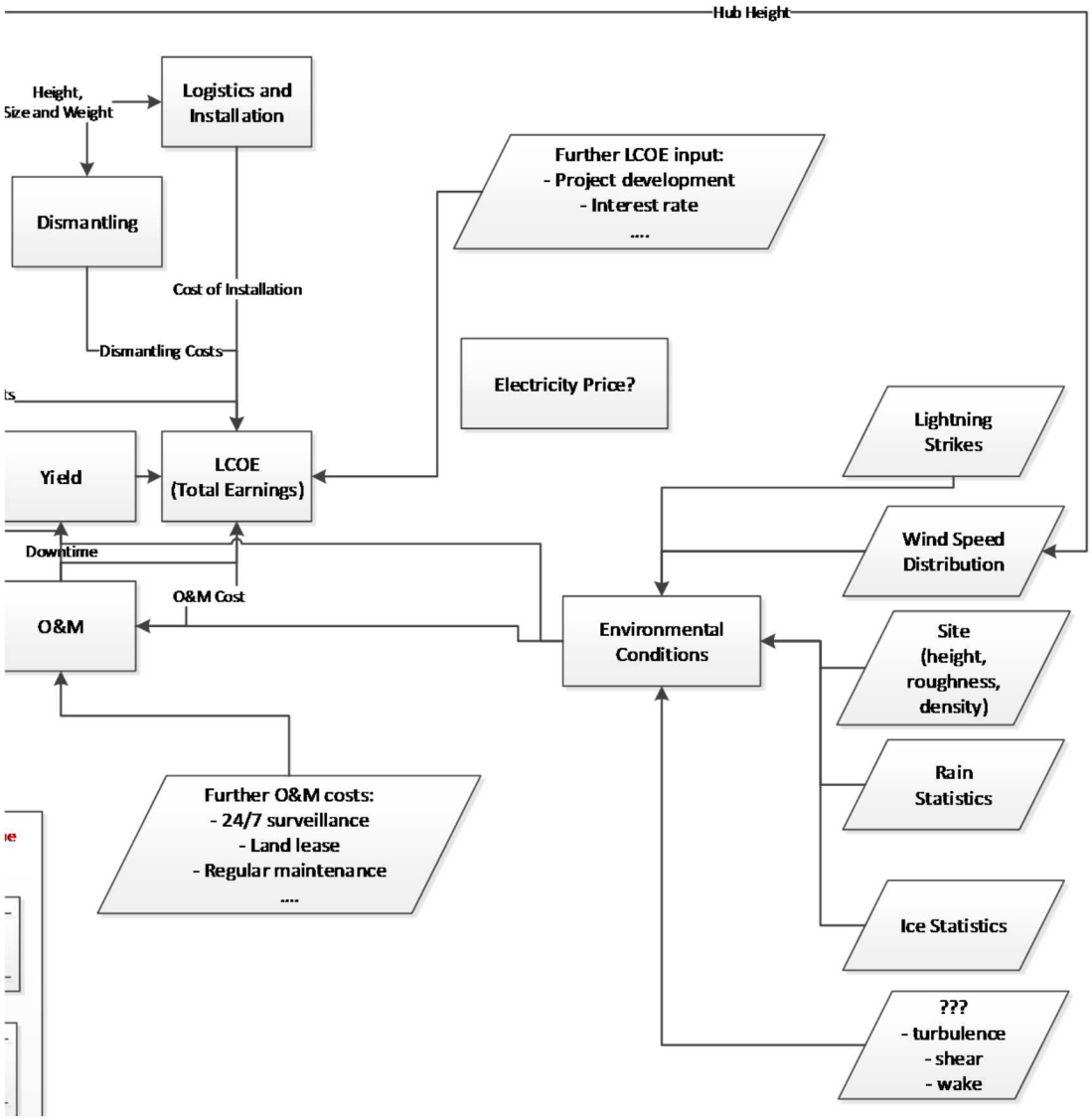
Module Interdependencies



Module Interdependencies



Module Interdependencies



Feedback

- Potential Use Cases for the model and what that implies for model requirements
- Modules / submodules sufficient
- Priorities of important inputs / modules / fidelity
- Most uncertainty
- What information is most valuable to make decisions
- Links between modules
- What frameworks already exist (what is public, commercial, what is proprietary)
- Choice of programming language
- Name and terminology (BLVM, “value”)

Advisory Board Roles

- Participate in project updates
- Provide technical guidance
- Provide data to build/validate models
- Be a beta user

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