PO.ID 111

Return on Investment Modeling to Support Cost Avoidance Business Cases for Wind Farm O&M

Roozbeh Bakhshi, Peter Sandborn, Xin Lei and Amir Kashani-Pour
CALCE, Department of Mechanical Engineering, University of Maryland

Abstract

Accurate life-cycle costing is a key enabler for wind farm operation and maintenance (O&M) optimization. Research has shown that maintenance is not optimized and that significant opportunities exist for reducing the total cost for maintenance and production losses, especially for large wind farms. This paper describes a stochastic life-cycle cost model and an associated return on investment (ROI) model that can be used to assess wind farm O&M management alternatives and technologies.

While formulating the ROI associated with investing money in a financial instrument is simple, the calculation of an ROI associated with a future cost avoidance that results from the implementation of a particular technology or process, or from a particular system management approach is not simple. In this paper we develop a simulation-based analysis for determining the ROIs for activities relevant to wind farm O&M. While there are analyses that forecast the ROI of wind turbines and the energy ROI (EROI), these high-level analyses are not applicable to the cost avoidance ROI calculations associated with technology or methodology adoption.

Introduction

This project has developed a stochastic modeling capability for detailed life-cycle cost analysis and associated return on investment (ROI) analysis that can be used to assess offshore wind farm O&M management alternatives and technology insertion.

- Technology providers need business cases that demonstrate the economic value of their technology
- These are "cost avoidance" (not cost savings) business cases, which are not simple and requires the calculation of accurate ROIs
- While many life-cycle cost models have been developed, existing models generally do not have the capability to calculate the stochastic ROIs needed to produce business cases
- Existing life-cycle cost models also do not include critical legacy system effects.
  - Aging supply chain (obsolete parts, counterfeit parts, degrading in storage etc.)
  - Wear out of key subsystems
  - Loss of critical human skills, etc.

Life-Cycle Simulation

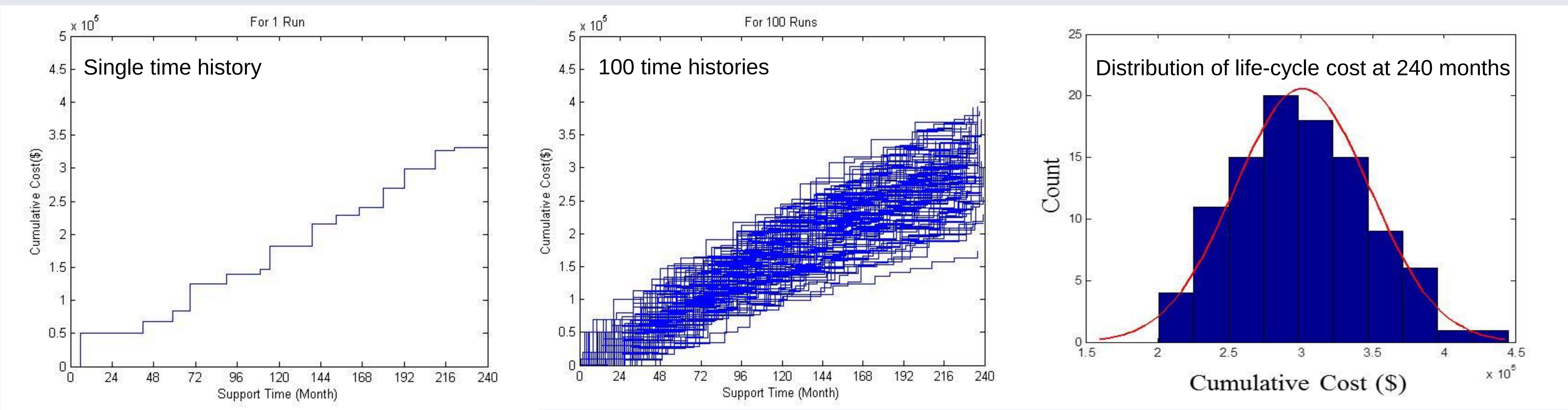
Stochastic discrete-event simulation based life-cycle cost model that samples time (or cycles) from failure distributions

- State variables change only at a discrete set of points in time (i.e., at "events")
- Event = an occurrence to the system at an instant in time that may change the state of the system (successive changes are separated by finite amounts of time)
- Timeline = the sequence of events and their calendar times
- Stochastic = having a probability of occurrence
- Stationary process

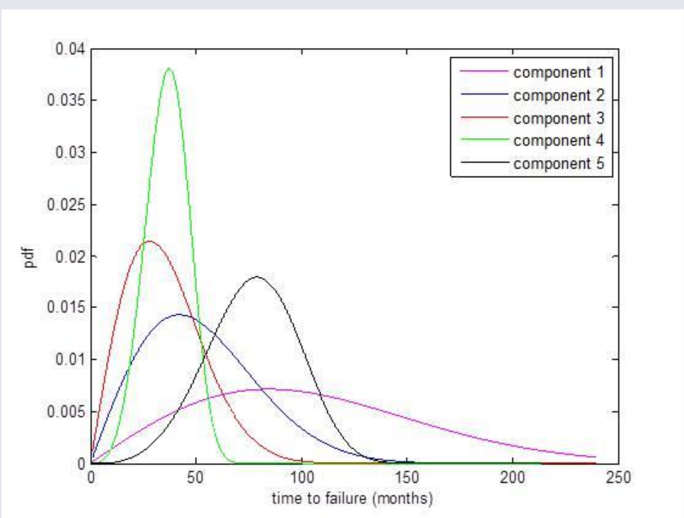
The output of the simulation is the total life-cycle cost of the system and the return on investment for implementation of technologies and methodologies

- The analysis is done over a long period of time
- Highly dependent on time value of money
- The sequence of the events is important

Discrete Event Simulator Illustration



Example Inputs:
- 5 components in one wind turbine
- Each maintenance event costs $10,000 (present value)
- Failures occurring within 2 month windows are resolved together
- WACC = 7%



Life-Cycle Cost Model

$$LCC = C_{inv} + C_{CM} + C_{PM} + C_{PL} + C_{rem}$$

$$C_{CM} = C_{US} + C_{MC} \qquad C_{PM} = C_{PHM} + C_S$$

$$C_{US} = kC_M + C_{sp} \qquad C_{MC} = kC_M + C_R$$

- C_{inv} = investment cost
- C_{CM} = corrective maintenance cost
- C_{PM} = preventive maintenance cost
- C_{PL} = production loss cost
- C_{rem} = remainder (salvage) value
- C_{US} = unscheduled service cost
- C_{MC} = replacement of major components cost
- C_{PHM} = PHM implementation cost
- C_S = scheduled service cost
- k = labor hours
- C_M = labor cost
- C_{sp} = spare parts cost
- C_R = components cost

WACC

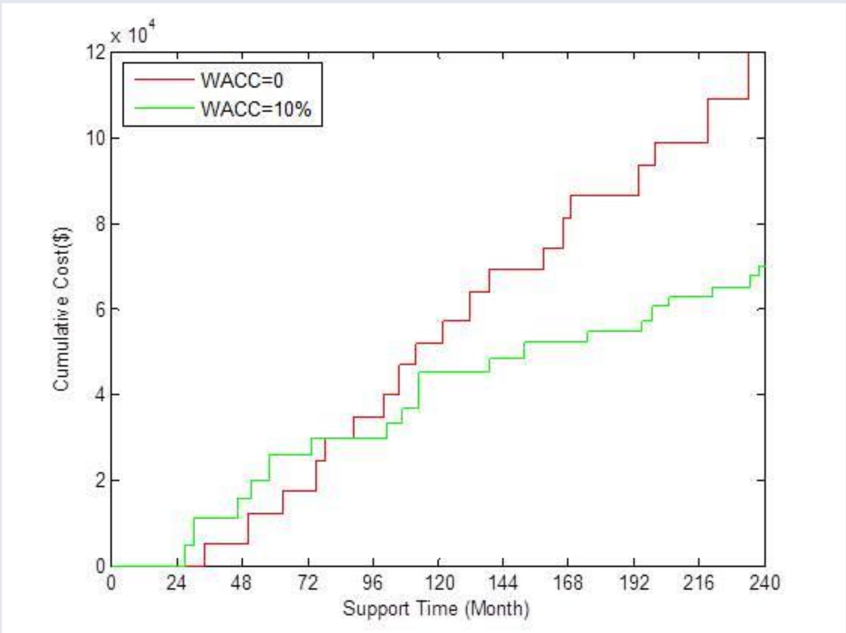
- The money required to finance a project could be raised different ways (e.g., debt finance, equity). Each of these components has a different required rate of return and the weighted average of various components is called weighted average cost of capital or WACC

$$WACC = R_e \frac{E}{V} + R_d(1 - T_c)\frac{D}{V}$$

- E/V = the proportion of the project that is equity financed
- D/V = the portion of the project that is debt financed
- R_e = the cost of equity (which is usually determined using a capital asset pricing model)
- R_d = the cost debt
- T_c = the corporate tax rate.

- The WACC incorporates the cost of money into the life-cycle cost calculation
- The WACC is also a function of time and must be forecasted into the future

Individual time history costs with varying WACC



ROI

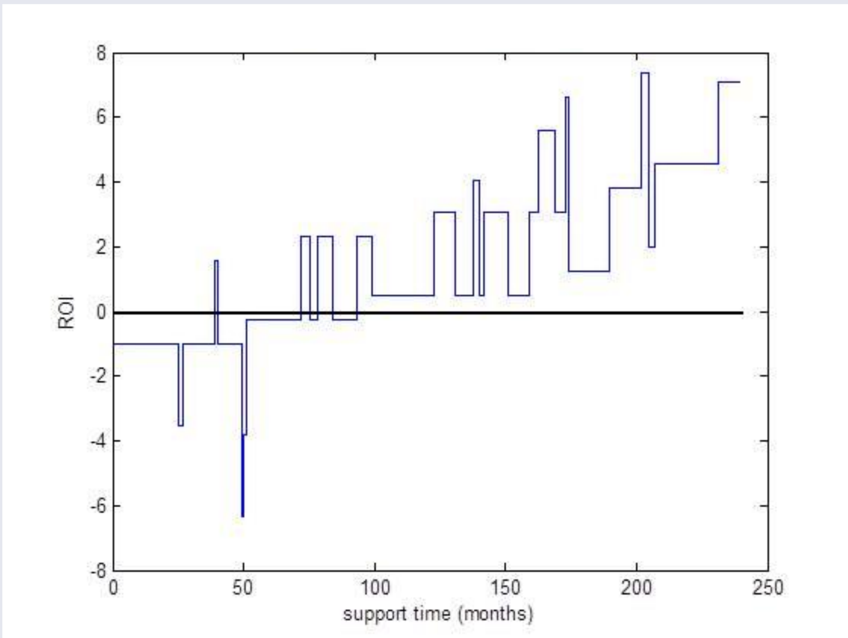
- ROI depends on the timing of events (which are affected by the management approach) because the life-cycle cost depends on the WACC
- ROI is calculated as,

$$ROI = \frac{LCC_{no\,tech} - LCC_{tech}}{C_{tech}}$$

- LCC_{tech} = life-cycle cost after implementing the new technology or approach
- $LCC_{no\ tech}$ = life-cycle cost without the new technology or approach
- C_{tech} = cost of implementing the new technology or management approach

- Management of the analysis is not trivial to implement because of the stochastic nature of the problem, i.e., identical time histories (with different technology or management have to be compared)

Individual time history - ROI



Results

- Example technology/methodology insertion: Prognostic and Heath Management (PHM) for selected subsystems. PHM predicts remaining useful life (RUL) that allows maintenance planning for critical subsystems.
- In the following plots, there is an example of a wind turbine with PHM installed on two of the sub-assemblies. We assume that PHM results are 100% accurate and give a five month lead time (RUL).