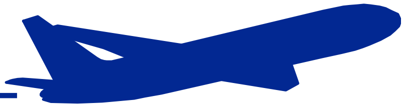
Application – Obsolescence Analysis for Different Types of Equipment

Facility Condition Assessment, Facility Condition Index

NEXTOR

Previous Work

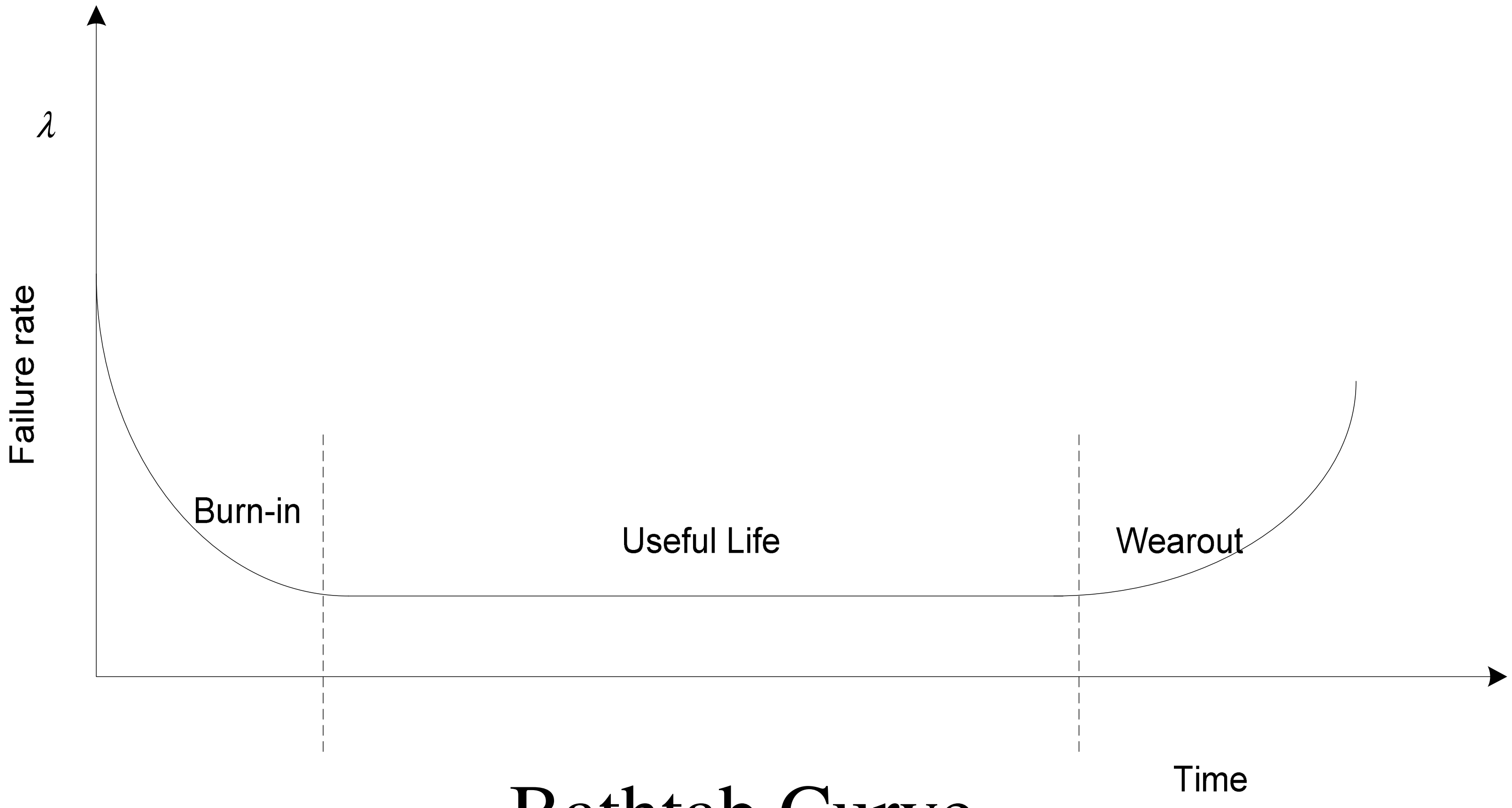


Methodology

Markov Decision Processes

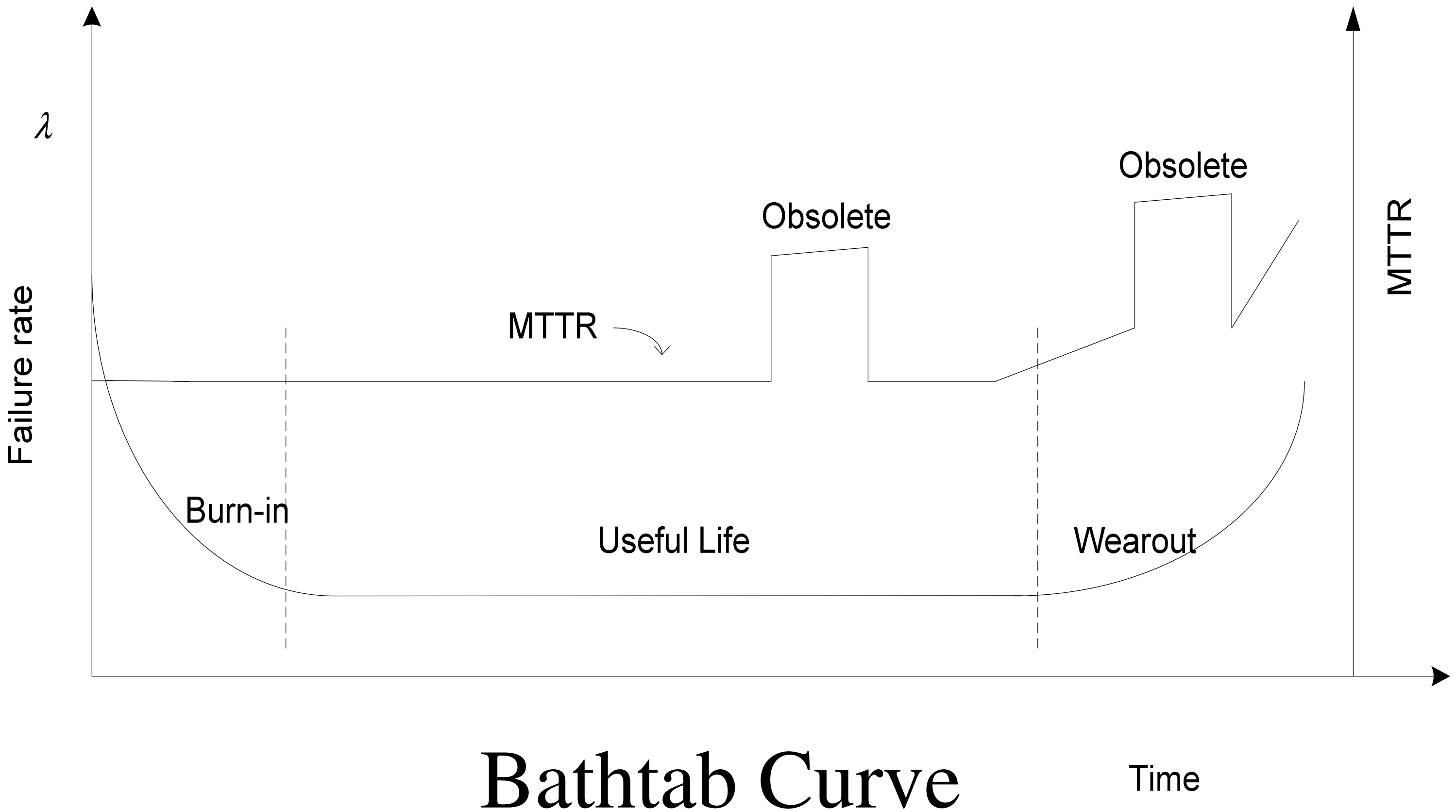
Decision	Cost State (probability)	Expected cost due to caused traffic delays Cd	Maintenance Cost Cm	Total Cost Ct = Cd + Cm
1. Leave ASR as it is	0 = good as new 1 = operable – minor deterioration 2 = operable – major deterioration 3 = inoperable	$ 0 $ 1 000,000 (for example) $ 6 000,000 $ 20,000,000	$ 0 $ 0 $ 0 $ 0	$ 0 $ 1 000,000 $ 6 000,000 $ 20,000,000
2. Maintenance	0 = good as new 1 = operable – minor deterioration 2 = operable – major deterioration 3 = inoperable	If scheduled, $0; otherwise $X2 If scheduled, $0; otherwise $Y2 If scheduled, $0; otherwise $Z1 If scheduled, $M2; otherwise $N2	If scheduled $A2, otherwise $B2 If scheduled $C2, otherwise $D2 If scheduled $E2, otherwise $F2 If scheduled $G2, otherwise $ H2	Cd + Cm
3. Replace	0 = good as new 1 = operable – minor deterioration 2 = operable – major deterioration 3 = inoperable	If scheduled, $0; otherwise $X3 If scheduled, $0; otherwise $Y3 If scheduled, $0; otherwise $Z3 If scheduled, $M3; otherwise $N3	If scheduled $A3, otherwise $B3 If scheduled $C3, otherwise $D3 If scheduled $E3, otherwise $F3 If scheduled $G3, otherwise $ H3	Cd + Cm
4. Upgrade	0 = good as new 1 = operable – minor deterioration 2 = operable – major deterioration 3 = inoperable	If scheduled, $0; otherwise $X4 If scheduled, $0; otherwise $Y4 If scheduled, $0; otherwise $Z4 If scheduled, $M4; otherwise $N4	If scheduled $A4, otherwise $B4 If scheduled $C4, otherwise $D4 If scheduled $E4, otherwise $F4 If scheduled $G4, otherwise $ H4	Cd + Cm

Obsolescence Analysis



Bathtab Curve

Obsolescence Analysis



Bathtab Curve

Traditional Elements of Obsolescence

An “obsolescence” event occurs if:

- There is a lack of technician training (“basic obsolescence”)

  The equipment could be in either the useful life phase or the wearout phase. The absence of appropriately trained technicians increases MTTRs making it economically unjustifiable to keep such assets in the system.

- There is a lack of spare parts (“basic obsolescence”).

  Inability to obtain spare parts increases MTTRs and reduces assets’ AVAILABILITY ($A = MTBO / (MTBO + MTTR)$). If spare parts are not attainable, an asset will become obsolete even if its failure rate is in the useful life phase.

- functionality of a piece of equipment cannot be changed (“functional obsolescence”).

  Automation tools (Host computer or ARTS) have aged and are no longer able to “absorb” additional functions required to modernize these tool.

Traditional Elements of Obsolescence

Cost Issues:

☐ operation and maintenance costs exceed the FAA’s designated budget

☐ maintenance cost exceeds replacement cost

How do we determine the economic service life of equipment as a function of obsolescence?

New Thinking

Classification of different methodologies as a function of:

- ☐ obsolescence definitions
- ☐ types of equipment analyzed

New Thinking

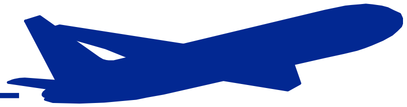
Obsolescence as a function of market competitiveness:

- A facility becomes obsolete when a manufacturer stops offering its parts in the market.
- Solving an obsolescence replacement problem requires a forecast of both existing equipment performance and future technology properties.

New Thinking

Traditional solutions to an obsolescence replacement problem emphasize cost/service trade-offs.

They assume either a constant market technology or a constant rate of change in technology – neither of which accurately reflect reality.



New Thinking

Technology is improving: old systems are phased out and eventually replaced by newer models.

When making decisions on whether to keep a piece of equipment or replace it with a new-technology (currently available on the market), we should take into consideration that it might be better to keep the old equipment and wait until it is replaced with an even newer and more advanced technology.

Accordingly, technology changes stochastically: costs associated with technology can vary with time; occurrence of technology has a probabilistic nature.

New Thinking

We must consider the following variables as uncertain:

- ☐ the time at which the new technology becomes available
- ☐ the cost of the new technology

These are important issues when making maintenance decisions.

Proposed Methodology

Optimization Technique:

Methodology to obtain optimal solutions by working backward from the end of a problem to the beginning, by breaking up a larger problem into a series of smaller, more tractable problems.

Dynamic Programming (DP) is often used to solve network, inventory, and resource allocation problems.

DP is used as a central methodology to find the optimal replacing.

Methodology Summary

We must consider uncertainty of future technology in modeling equipment replacement decisions.

The proposed model adopts a dynamic programming method to find the optimal hold-or-replace decision at specific points in time with the objective to keep equipment operation costs as low as possible.

Formulation 1

Objective:

Maximize expected net value over the infinite horizon. Determine the optimal action in the first period of the infinite planning horizon.

Forecast horizon: the minimum number of periods of forecasted information required to guarantee that the initial decision is optimal, regardless of forecasts in later periods.

Applicable to equipment whose obsolescence is market driven.

Notation

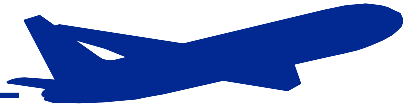
(i, l) state at some point in time, t

i index of technology used by the firm

l index of the latest technology available on the market;

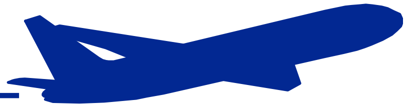
0 : technology currently in use
1 : better technology available on the market
2 : exactly one advanced technology that may appear in the future (second generation).

Notation



K_i	action ‘keep technology *i*’
R_j	action ‘replace the current technology with technology *j*’
r_{it}	expected one-period-revenue generated by technology *i* in period *t*
c_{it}	expected capital cost of purchasing technology *i* in period *t*

Notation



s_{it}	expected salvage value received from selling technology i in period t;
p_t	probability of appearance of technology 2 in period t given that it has not appeared in period t-1 or earlier
β	one period discount factor
$f_t^T(i,l)$	maximum expected discounted revenue of being in state (i, l) in period t, if an optimal policy is followed from period t through some time horizon T ($T \geq t$)
$L(i,l) \equiv f_T^T(i,l)$	boundary condition
$\pi_t^T(i,l)$	optimal action in state (i, l) in period t of the T horizon

Numerical Examples:

We are looking for solution to $\pi_0(0,1)$, i.e. the optimal action in the first time period facing technology state (0, 1).

Let

$$r_{2t} = 175,\ c_{2t} = 200,\ s_{1t} = 75 \ and \ s_{0t} = 35 \ for\ \forall t; T = 4 \ and \ \beta = 0.9$$

$$r_{00} = 50, \quad r_{01} = 60, \quad r_{02} = 45, \quad r_{03} = 50, \quad r_{04} = 65,$$

$$r_{10} = 100, \quad r_{11} = 100, \quad r_{12} = 95, \quad r_{13} = 90, \quad r_{14} = 75,$$

$$c_{10} = 125, \quad c_{11} = 175, \quad c_{12} = 100, \quad c_{13} = 100, \quad c_{14} = 200.$$

Numerical Examples:

Example 1:

Let $p_1 = 0.1,\ p_2 = 0.2,\ p_3 = 0.3,\ p_4 = 0.6$

be the technological forecasts.

Solution:

$\pi_0(0,1)$ is R_1 and the forecast horizon is 3

(replace the current technology with technology 1)

Formulation 2

Objective:

Minimize expected discounted present cost over the infinite horizon. Determine the optimal action during the first period of the infinite planning horizon.

Forecast horizon: the minimum number of periods of forecasted information required to guarantee that the initial decision is optimal, regardless of forecasts in later periods.

Applicable to equipment whose obsolescence is primarily age-dependent.

Notation:

$S = \{0,1,\ldots,m\}$ the finite state space, where 0 represents the best state (i.e. a brand new machine) and m represents the worst state

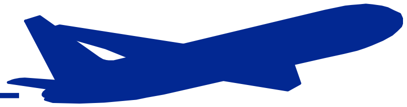
p_{ij} the probability of being in state j at the beginning of the next period if the machine is in state i at the beginning of current period (i.e. machine deteriorates according to a Markov chain with transition matrix $P = [p_{ij}]$), and $\sum_{j=0}^{m} p_{ij} = 1 \ for \ \forall i$

c_i one-period operating cost of a machine in state i

R cost of replacing a machine

$f_t(i)$ optimal expected net cost at time period t with state i if an optimal policy is followed after this time, when new technology hasn't appeared yet

Notation:



$g(i)$	the optimal value function given that the new technology has appeared
β	one-period discount factor
k	action ‘keep’
r	action ‘replace’
q_t	the probability of the new technology appearing during time period *t* given that it has not already appeared, and a sequence of values designates a technological forecast

Notation:

h	the expected net present cost of the new technology over the infinite horizon
$\pi_0(i)$	optimal action to take given an initial state i

Numerical Example:

Assumptions:

- number of states is 4
- one period discount factor is 0.9
- replacement cost *R* is 40
- infinite horizon cost after replacing with the new technology (*h*) is 225
- operating costs *c*=[10,20,25,29,32]
- Markov deterioration matrix

  P for the old technology

$$P = \begin{bmatrix} 0.3 & 0.7 & 0 & 0 & 0 \\ 0 & 0.3 & 0.7 & 0 & 0 \\ 0 & 0 & 0.3 & 0.7 & 0 \\ 0 & 0 & 0 & 0.3 & 0.7 \\ 0 & 0 & 0 & 0 & 1 \end{bmatrix}$$

Numerical Example:

Results:

$\pi_0(i)$: optimal action given an initial state *i*

- for states 0, 1 and 2, the optimal decision is to keep the existing machine for an additional period.
- for states 3 and 4 it is better to replace it with a new one.