Q4 What Are My “Minimum Life-Cycle Cost” CIP And O&M Strategies”?

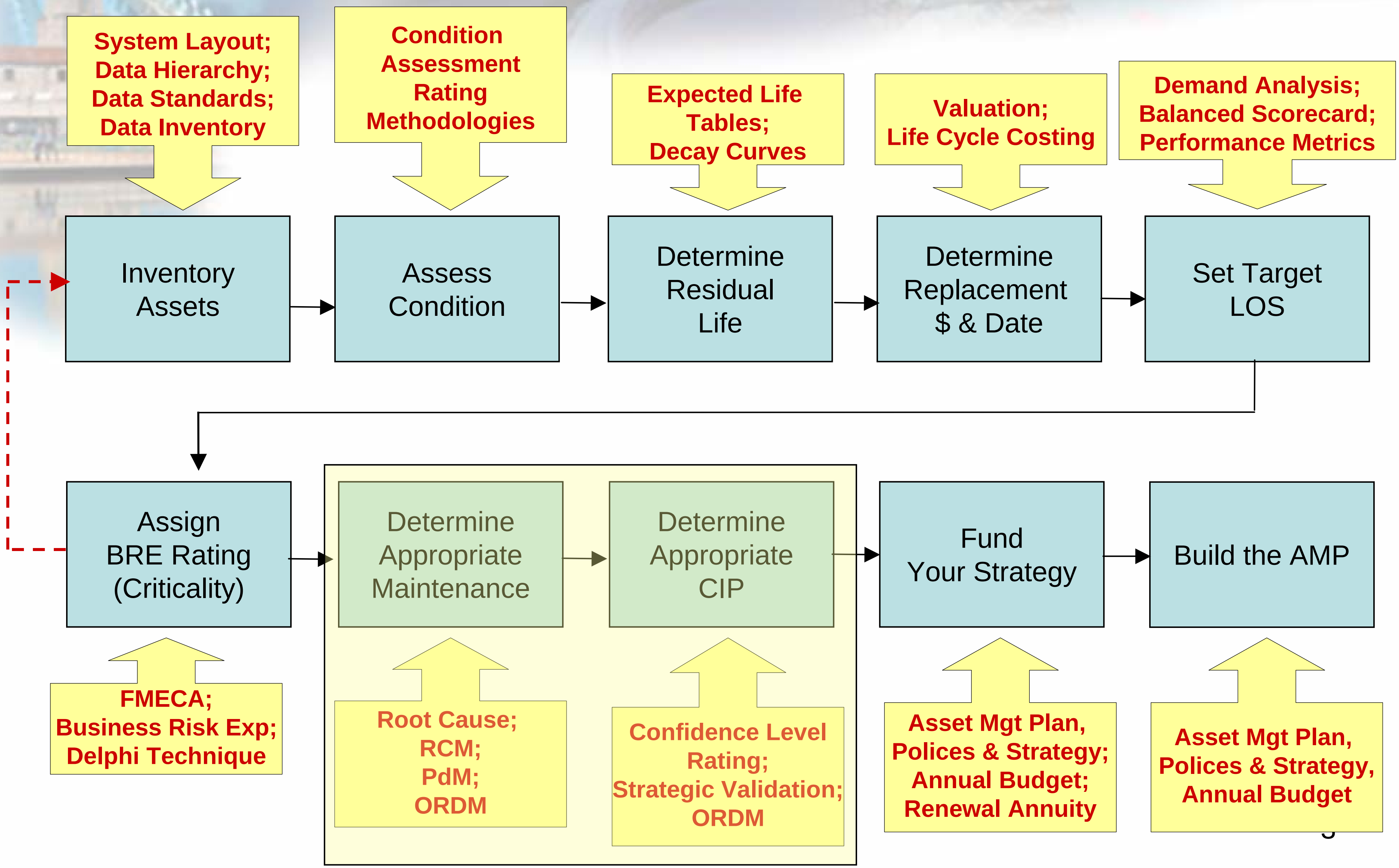
AMPLE

Asset Management Program Learning Environment

Recapping Our Progress

- *We have our asset register …*
- *We have assessed condition…*
- *We understand residual life and the approximate probability of failure...(estimated)*
- *We understand criticality and have a rating for the Business Risk Exposure (BRE)...*
- *Now we need to predict the future costs of the facility…*
- *What do we need to spend to meet our LOS performance?*

Core AAM Program Process Tools



AAM Focuses on Three Fundamental Management Decisions:

- What are my work crews doing, where are they doing it – *and why*?
- What CIP projects should be done and when?
- When to repair, when to refurbish and when to replace?

These decisions typically account for *at least 80%* of a Utility's annual expenditures!

The Asset Decision Framework

<u>The Big Picture</u>

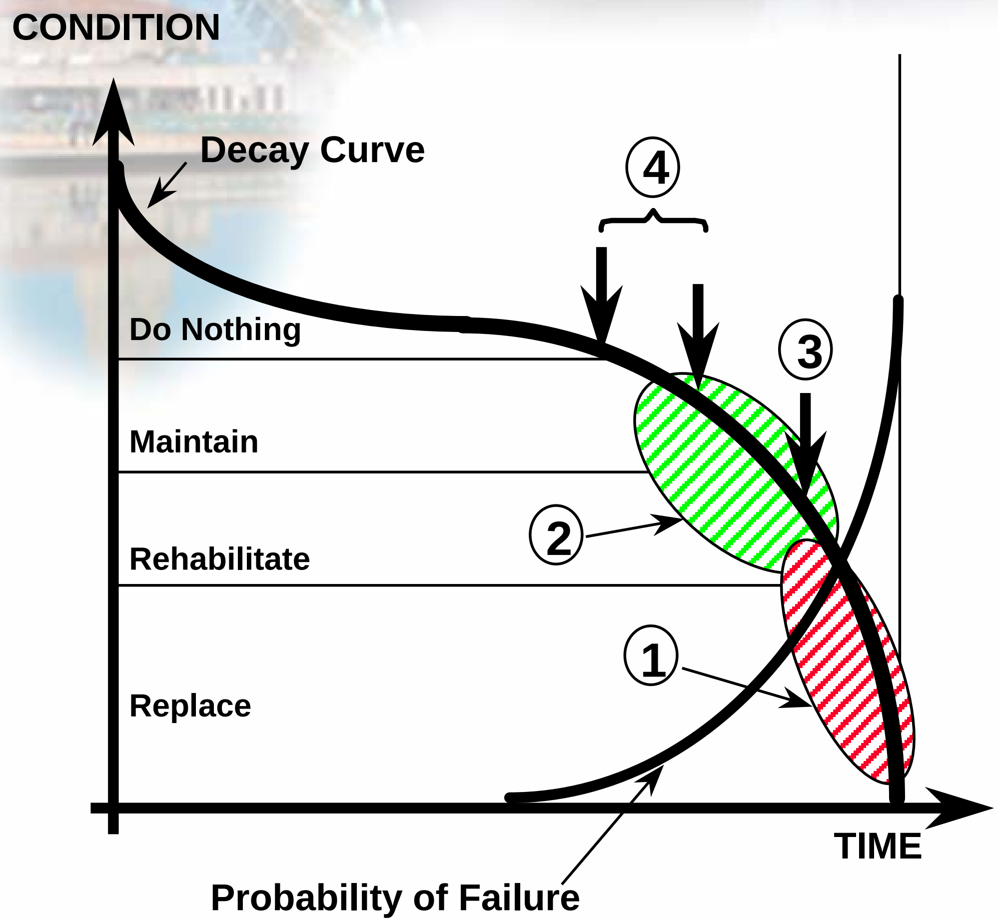
- “Whole portfolio” perspective
  - Trends
  - “Macro forces”
- Policy framework
- Budget arena

<u>The Micro View</u>

- Event-based
- Specific asset focus
- Case-by-case decision points

Repair? Renew? Replace?Augment?

Determining Lowest-Cost Action



Benefit Based Priorities

Priority order

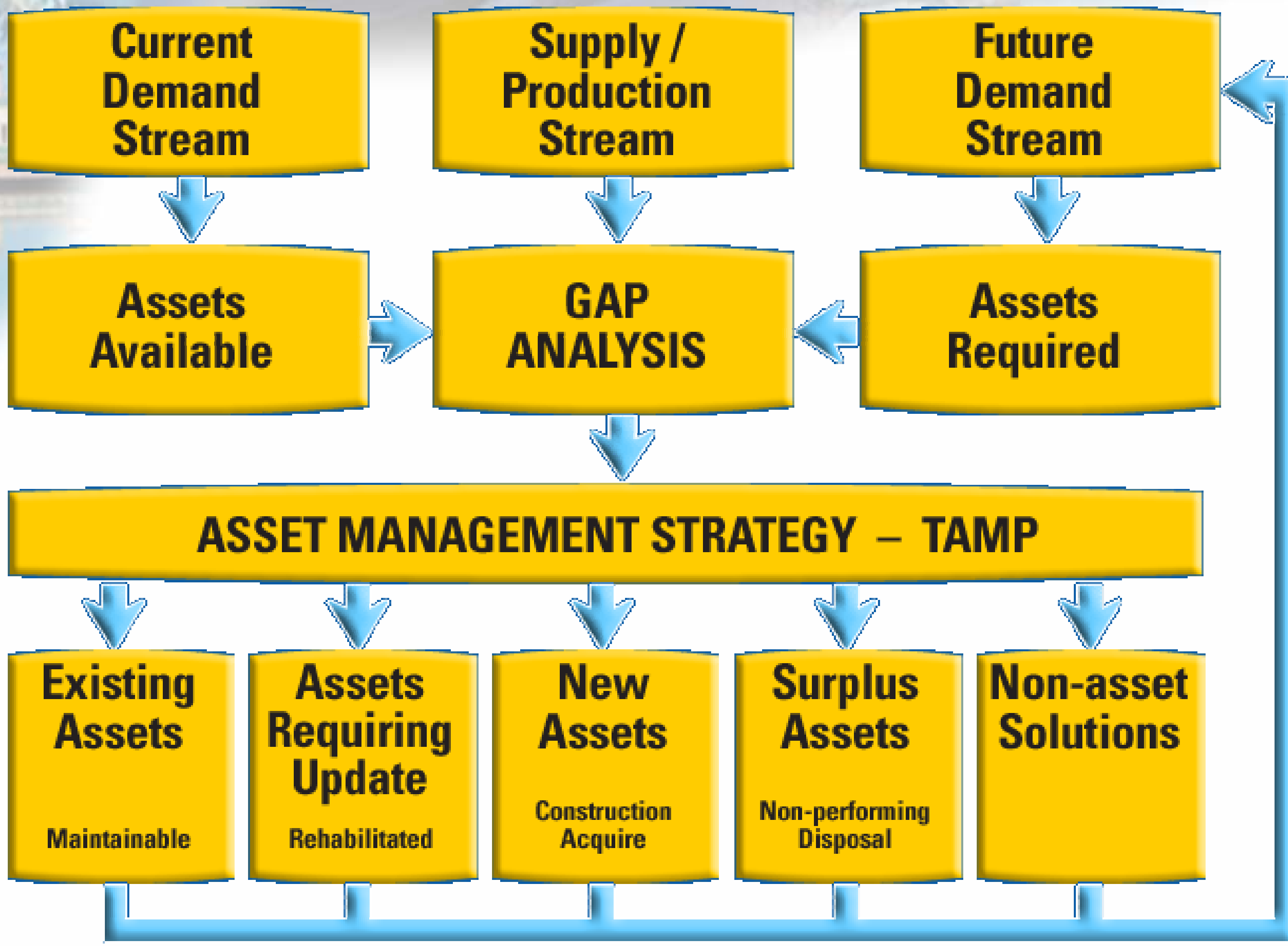
1 Assets with a high probability or history of failure (reliability).

2 Assets with a high business risk cost (consequence).

3 Assets where rehabilitation intervention is beneficial.

4 Assets where more appropriate maintenance is beneficial (eg. with high unplanned maintenance).

Infrastructure Assets — Strategic Planning



So, What do we mean by "…minimum life cycle cost strategies?"

- The fundamental asset management options available to the management team include:
  - Do nothing ("Zero-based' strategy)
  - Status quo
  - Repair
    - "Run-to-failure"
    - Preventive-based
    - Condition (predictive)-based
  - Refurbish/Rehabilitate
  - Replace
  - Decommission/non-asset-based
- Which *strategy* for each asset?
- Combinations over life cycle

What Do We Mean By "Alternative Treatment Options?"

Maintenance Options

Maint Option 1

Maint Option 2

Maint Option 3

Refurbish Options

Renewal Option 1

Renewal Option 2

Renewal Option 3

Replacement Options

Replace Option 1

Replace Option 2

Non-Asset Options

Non-Asset Option 1

Our "Decision Rule"

Maintenance Option 1..N

Renewal Option 1..N

Replacement Option 1..N

	Year	Year	Year	Year	Year
Direct Costs					
Indirect Costs					
Total Costs					
PV Total Costs					

"Search for the Alternative Treatment with the lowest ***average annual*** PV."

Putting it all together – “ORDM”

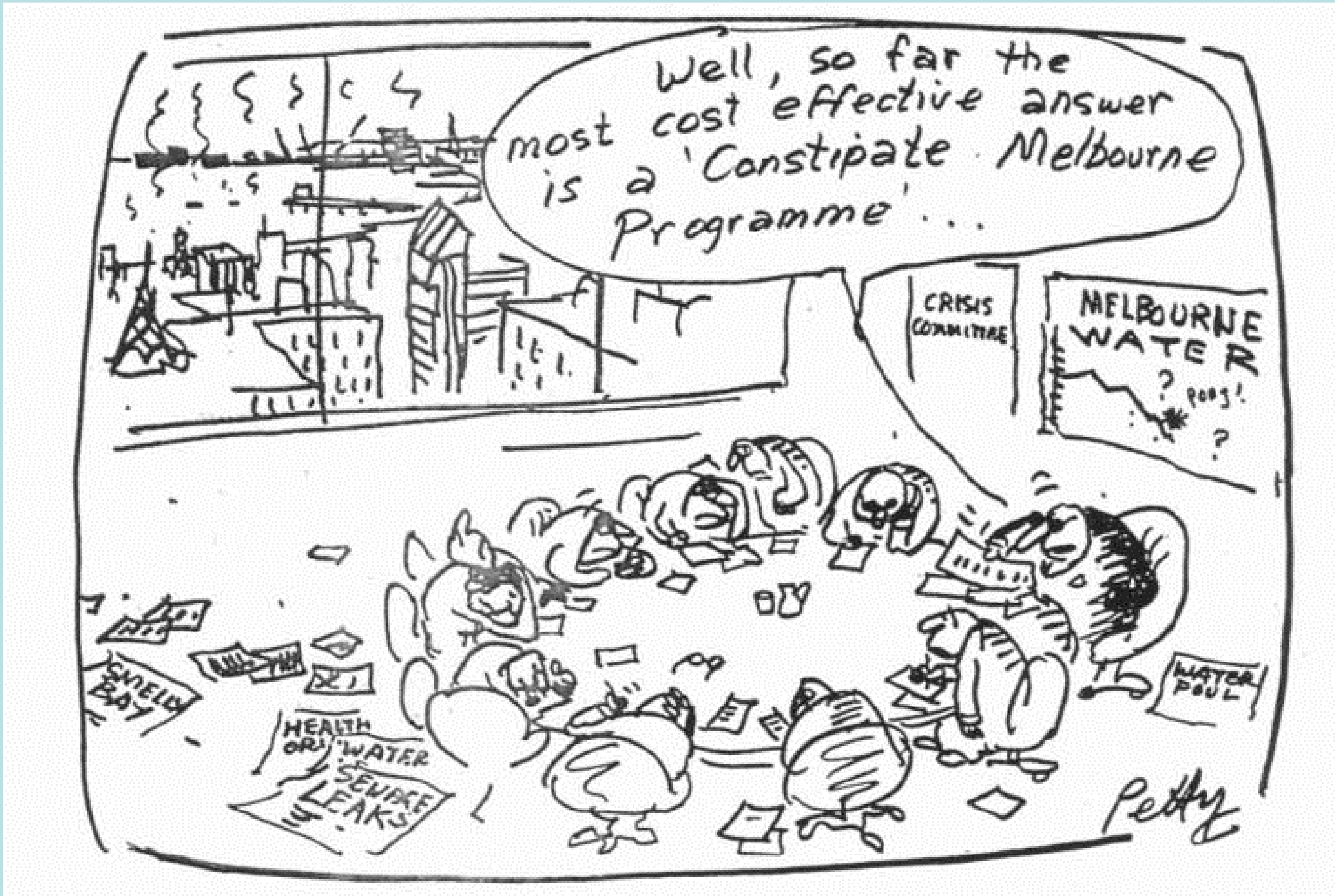
- “ORDM” – Optimal Renewal/Replacement Decision-making
- Treatment (management) options:
  - Continued maintenance
  - Renewal
  - Replacement
  - Non-asset solutions
- Decision rule: seek “treatment” option with lowest cost (“lowest present value of average annual economic costs)

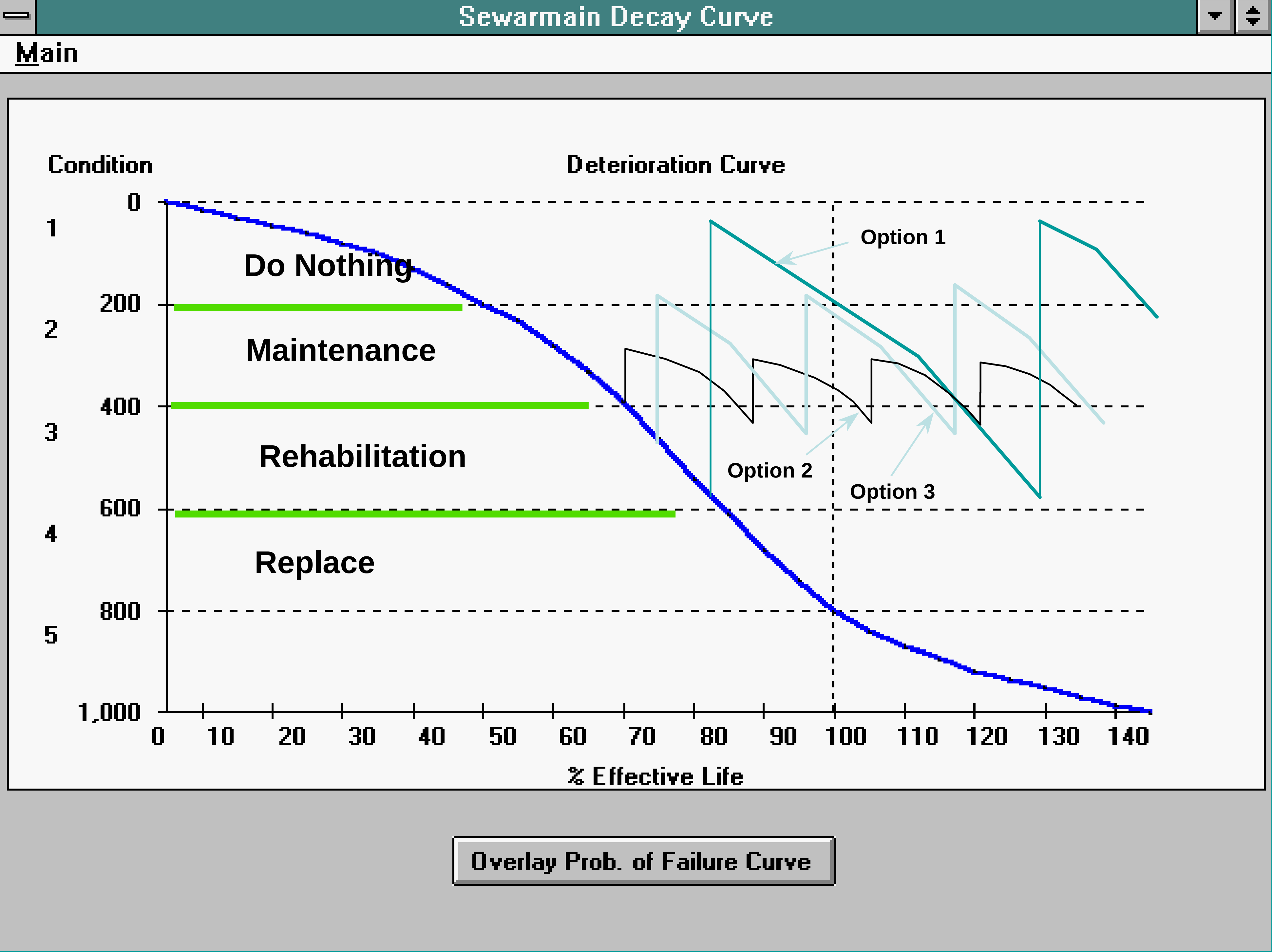
Articulating “Costs”*

- **Direct Costs to the Government Organization**
  - Repair and return to service costs
  - Service outage mitigation costs
  - Utility emergency response costs
  - Public safety costs
  - Admin & legal costs of damage settlements
  - (Lost product costs)
- **Direct Customer Costs**
  - Property damage costs (including restoration of business)
  - Service outage costs
  - Service outage mitigation and substitution costs
  - Access impairment and travel delay costs
  - Health damages
- **Community Costs**
  - Health/safety/welfare
    - Disease and illness mitigation
    - Emotional strain/welfare
  - Environmental impact
    - Pollution, erosion, sedimentation
    - Destruction of/damage to habitat
  - “Attractability” (tourist, economic)

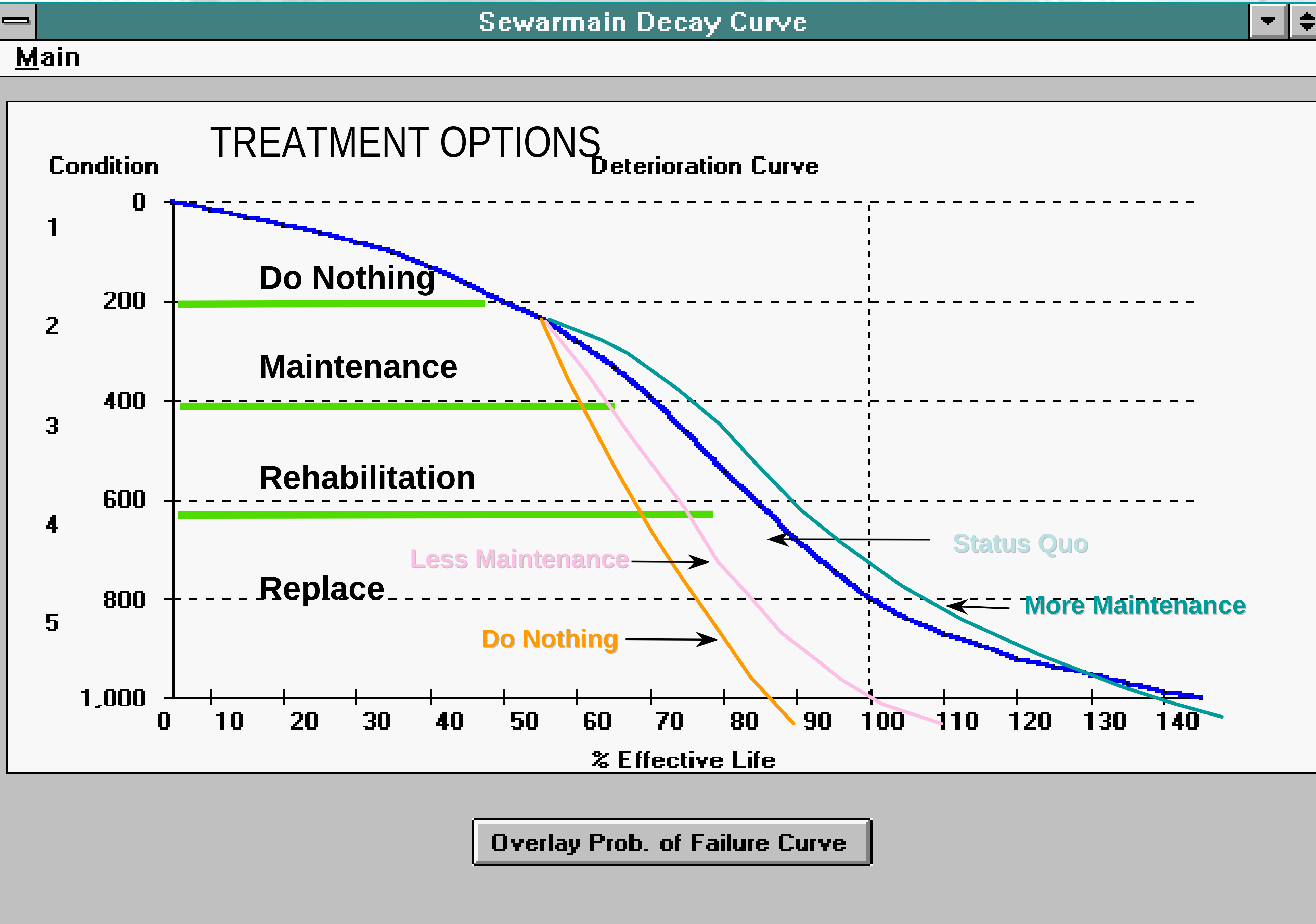
Optimal Renewal Decision Making — Options

NON-ASSET OPTIONS…

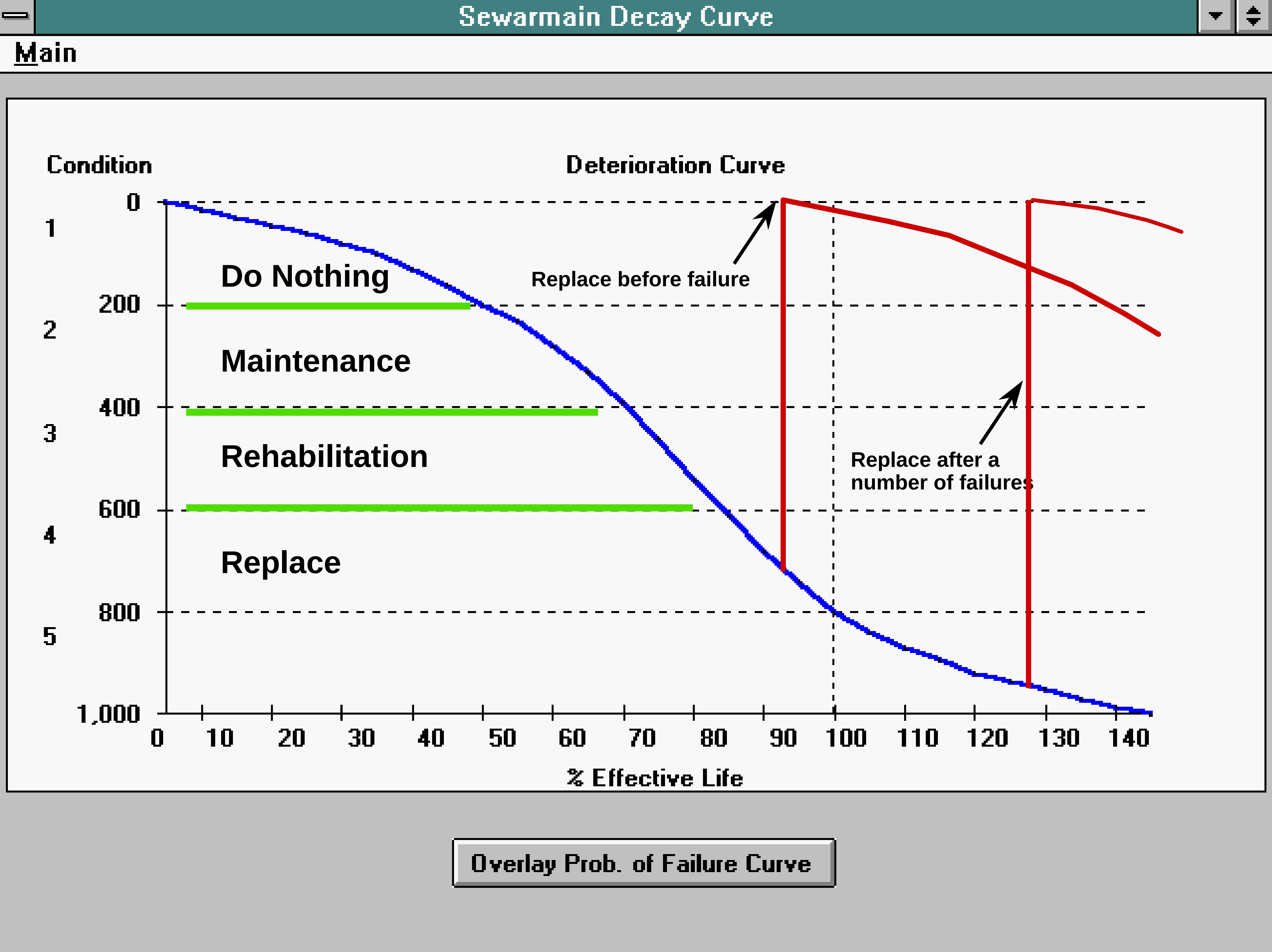




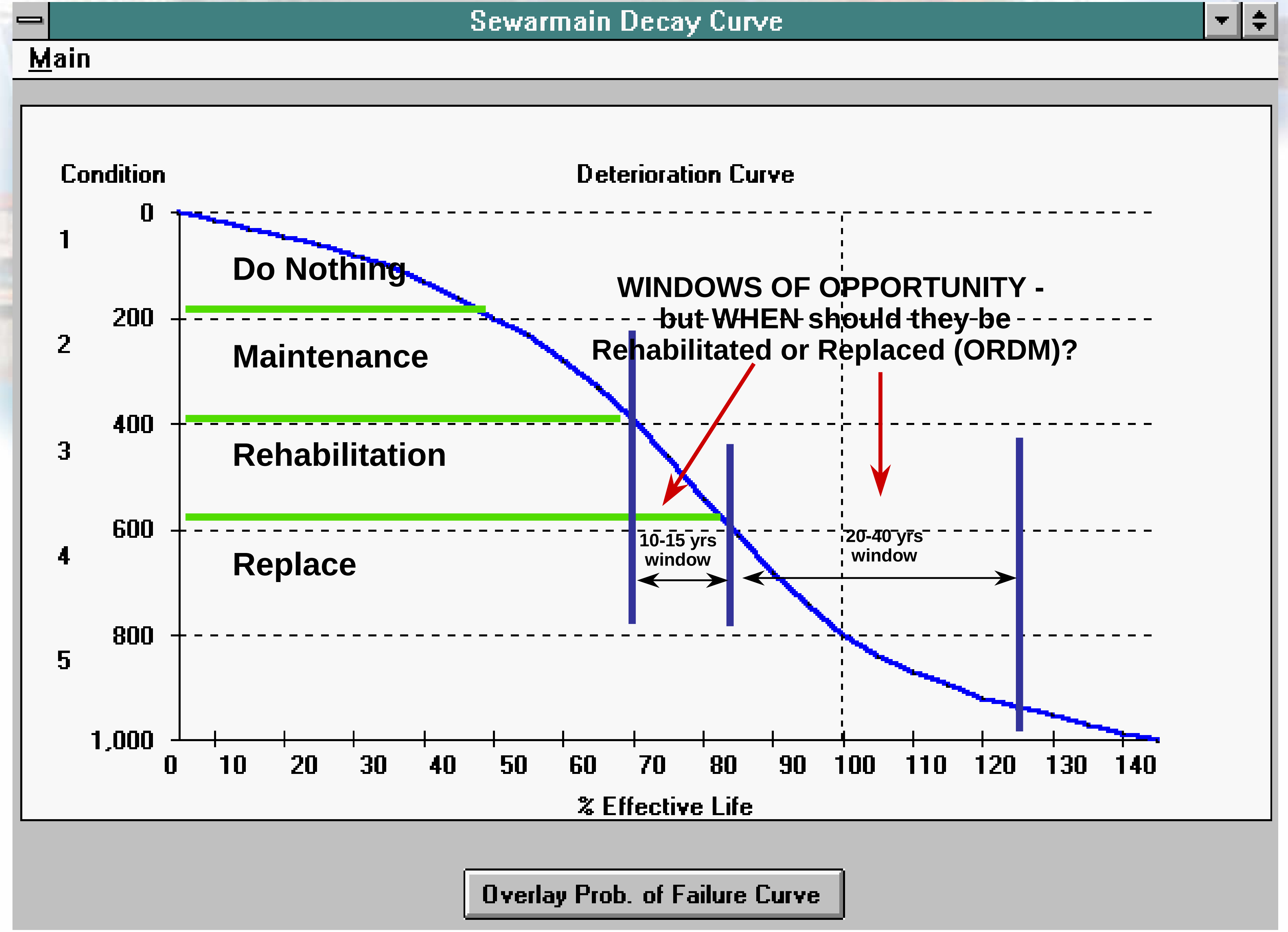
Sewarmain Decay Curve
Main
Condition
Deterioration Curve
0
1
200
2
400
3
600
4
800
5
1,000
Do Nothing
Maintenance
Rehabilitation
Replace
Option 1
Option 2
Option 3
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
% Effective Life
Overlay Prob. of Failure Curve



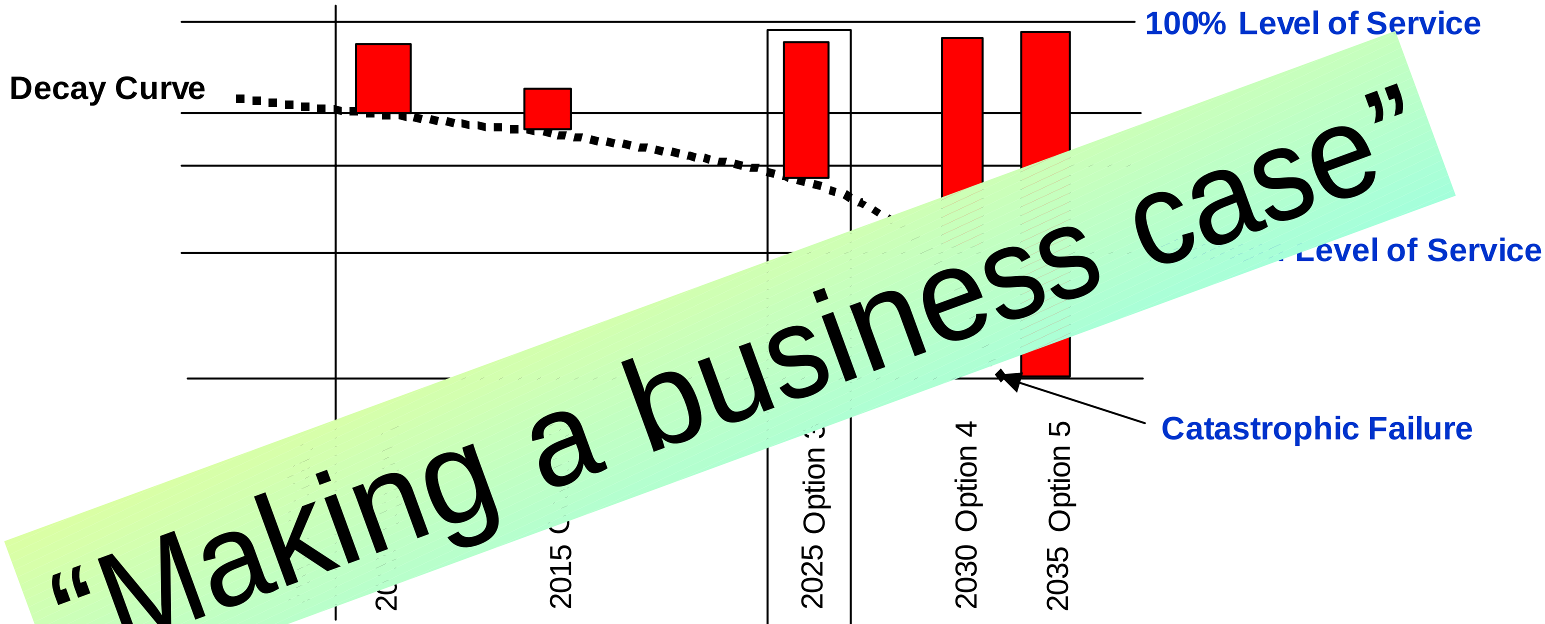
Sewarmain Decay Curve
Main
TREATMENT OPTIONS
Condition
Deterioration Curve
0
1
200
2
400
3
600
4
800
5
1,000
Do Nothing
Maintenance
Rehabilitation
Replace
Less Maintenance
Do Nothing
Status Quo
More Maintenance
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
% Effective Life
Overlay Prob. of Failure Curve



Sewarmain Decay Curve
Main
Condition
Deterioration Curve
0
1
200
2
400
3
600
4
800
5
1,000
Do Nothing
Maintenance
Rehabilitation
Replace
Replace before failure
Replace after a
number of failures
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
% Effective Life
Overlay Prob. of Failure Curve


Sewarmain Decay Curve
Main
Condition
Deterioration Curve
0
1
200
2
400
3
600
4
800
5
1,000
Do Nothing
Maintenance
Rehabilitation
Replace
WINDOWS OF OPPORTUNITY -
but WHEN should they be
Rehabilitated or Replaced (ORDM)?
10-15 yrs
window
20-40 yrs
window
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140
% Effective Life
Overlay Prob. of Failure Curve

Optimal Replacement Decision Theory



Treatm ions	M	M	RH	RP	RP
Direct Cost	270	72	360	610	630
Indirect Cost	0	10	20	40	130
Benefit	200	75	480	780	320
Benefit/Cost Ratio	0.7	0.9	1.3	1.2	0.42
Option Ranking	4	3	1	2	5

HANSEN CORPORATION

Importance Of The Work Order

WORK ORDER

ASSET DETAILS

- TYPE
- CATEGORY
- SIZE
- CONDITION
- PERFORMANCE HISTORY

ASSET LINKED COSTS ALLOW SIGNIFICANT ANALYSIS:

1. What type of sewer suffers the greatest number of blockages caused by tree roots?

2. How many failures are experienced by water mains of different ages in different ground conditions?

Importance Of The Work Order

WORK ORDER

TYPE
P.M.
U.M.

- ESTIMATED
  BILL OF QUANTITIES
- ACTUAL
  - LABOR
  - PLANT
  - MATERIALS
- PROCEDURE FOLLOWED
- FAILURE MODE NOTED
- PRIMARY CAUSE OF
  FAILURE

MEMOS

- IMPACT ON CUSTOMERS
- UNPRODUCTIVE TIME
- OTHER ISSUES

DATA FEEDBACK ALLOWS
SIGNIFICANT ANALYSIS

TELLS US PLANNED (PM) OR
UNPLANNED (UM) MAINTENANCE COSTS

MONITORS PERFORMANCE
REPORTS ON COST OVERRUNS

TELL US ACTUAL DIRECT COSTS
OF ACTIVITY

TELL US THE ACTIVITY USED
NECESSARY FOR ACTIVITY ANALYSIS

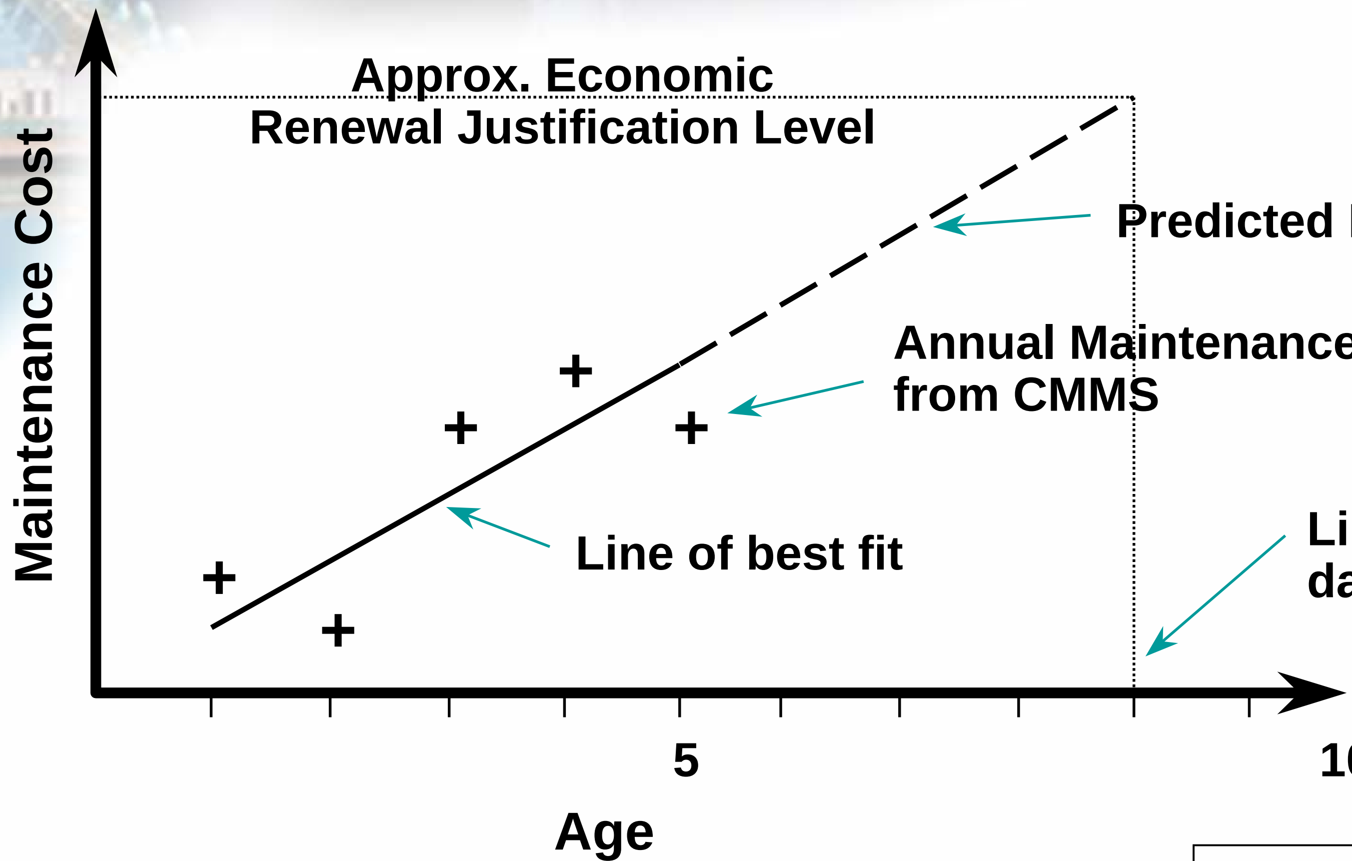
USEFUL IN FAILURE MODE ANALYSIS

NECESSARY FOR CAUSAL ANALYSIS

INDIRECT COSTS ON BUSINESS IMPACT
ON CUSTOMERS EFFECTS ANALYSIS

CAUSE OF COST OVERRUNS OR
POTENTIAL COST REDUCTIONS

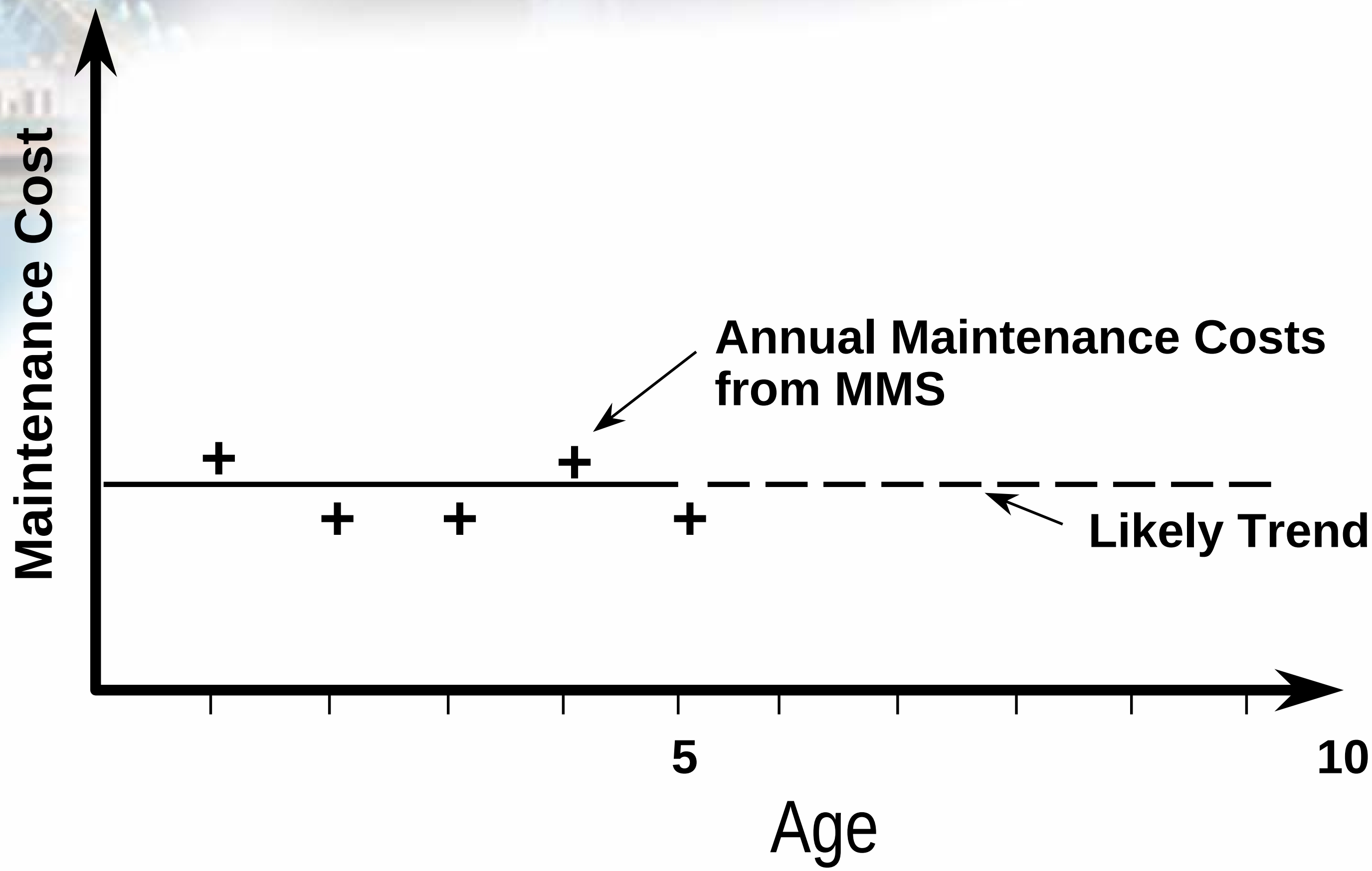
Predicting Maintenance Costs



CMMS – Computer-based Maintenance Management System

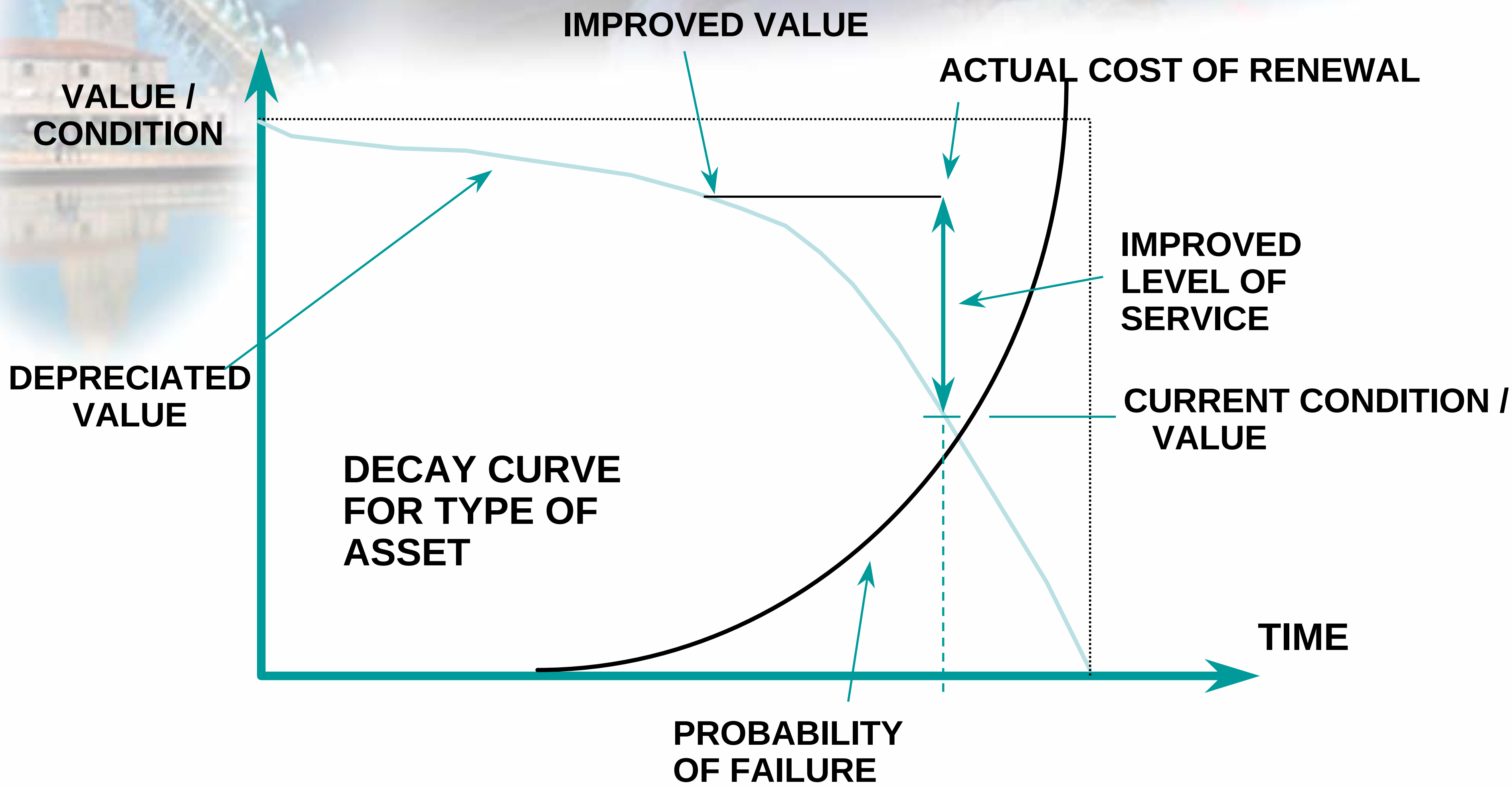
Increasing Costs Scenario (Bath tub tail curve)

Predicting Maintenance Costs



Stable Maintenance Scenario
(Bottom of bath tub curve)

Linking Condition & Probability Of Failure



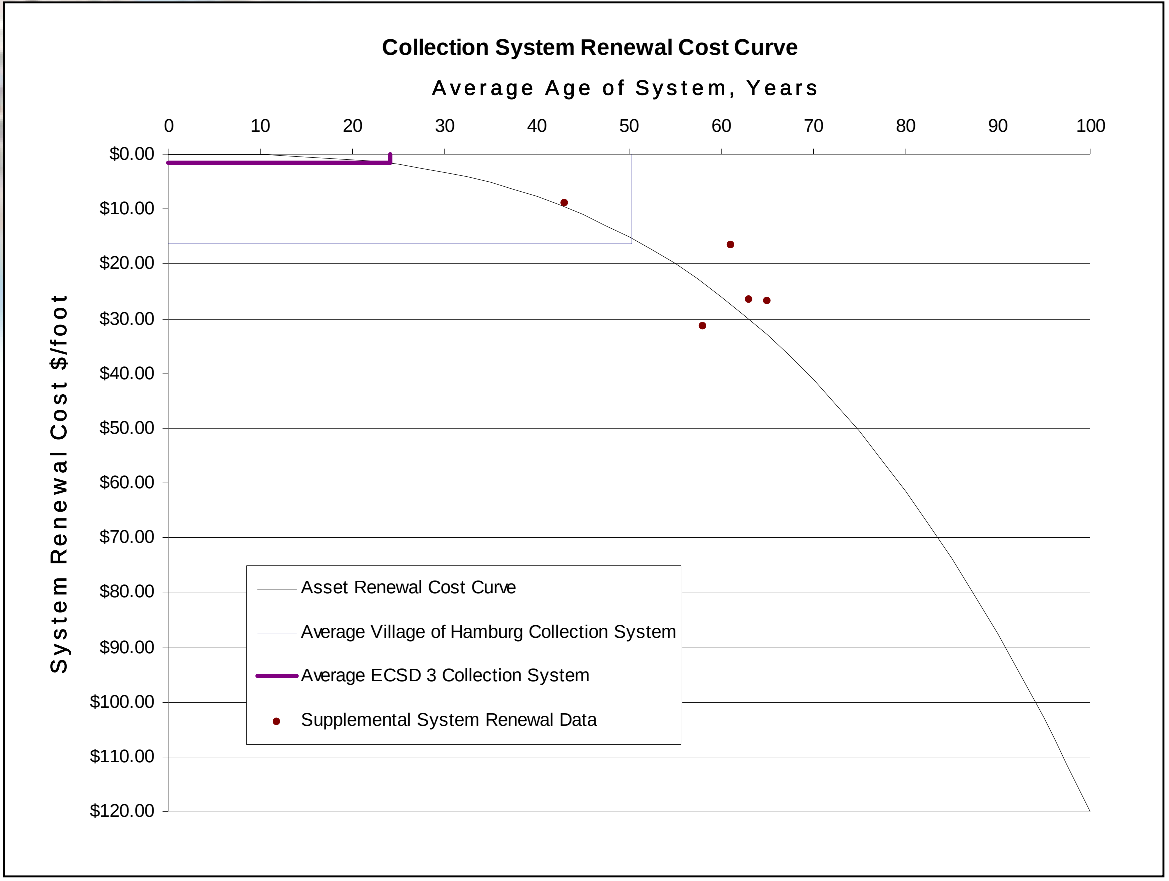
Linking Condition & Probability Of Failure

Effective Lives (Years)

Asset Type	**Effective Lives**	**Condition Rating / Residual Life** 1	2	3	4	5
Civil	75	75	60	45	30	15
Pressure Pipework	60	60	48	36	24	12
Sewers	100	100	80	60	40	20
Pumps	40	40	32	24	16	8
Motors	35	35	28	21	14	7
Electrical	30	30	24	18	12	6
Controls	25	25	20	15	10	5
Building Assets	60	60	48	36	24	12

As condition deteriorates, residual life falls (not necessarily linear)

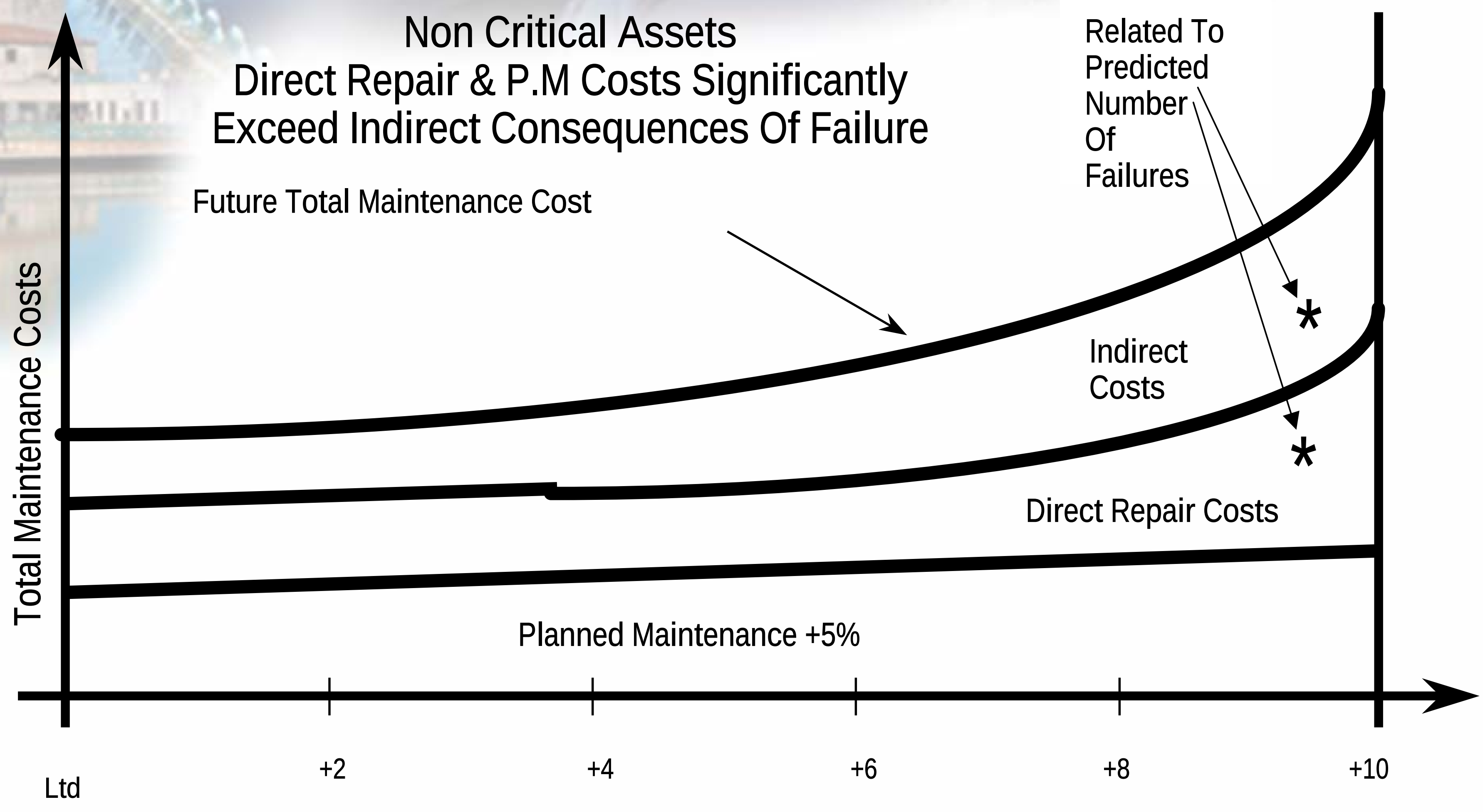
Linking Condition, Age & Probability Of Failure



Condition Decay = $(LTD/EL)^N$

Where:
LTD = Life to Date
EL = Effective Life
And N =:
- Major linear assets = 4
- Architectural passive assets = 3
- Mech/elec/dynamic assets = 4

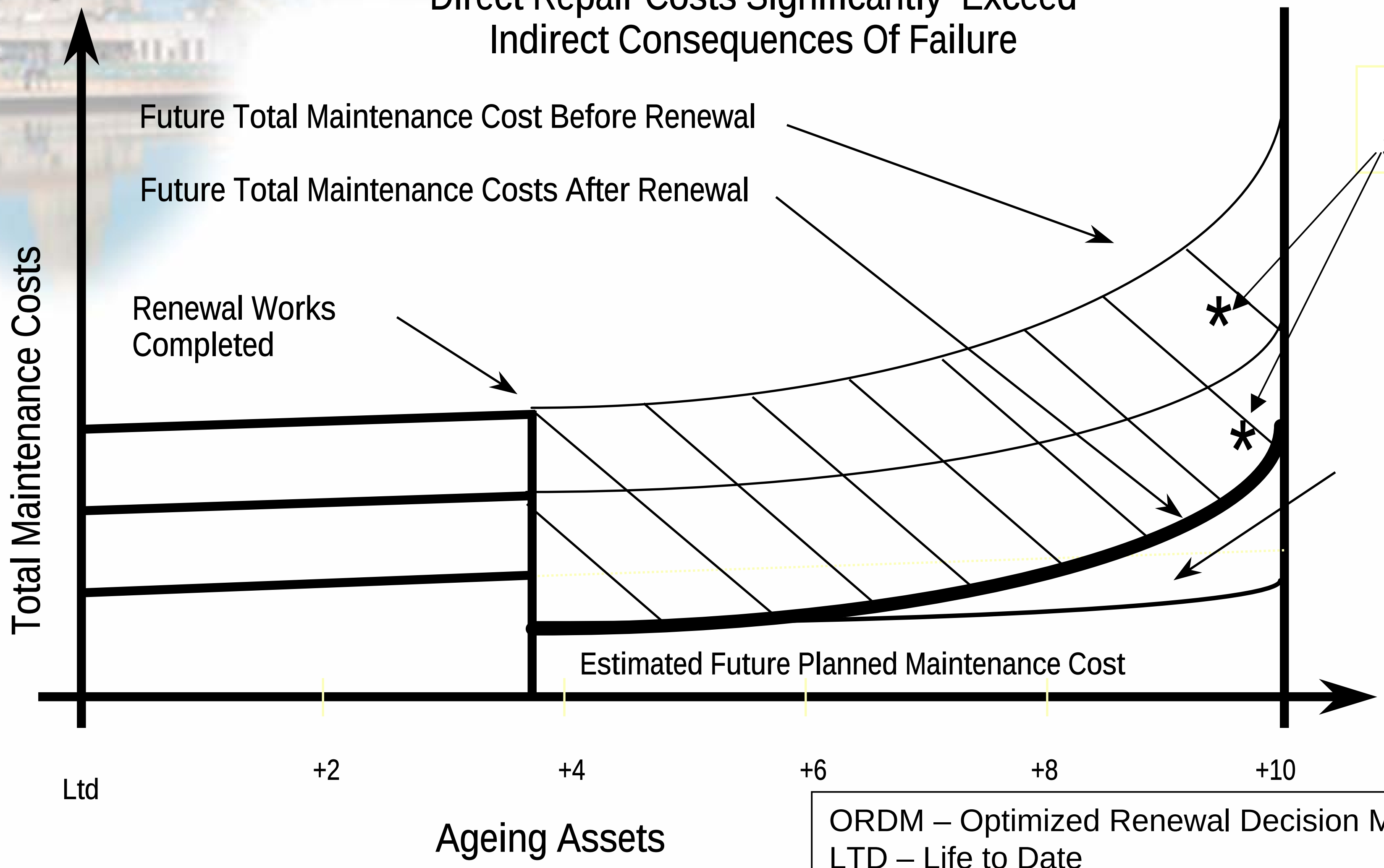
ORDM - Future Costs



LTD – Life to Date

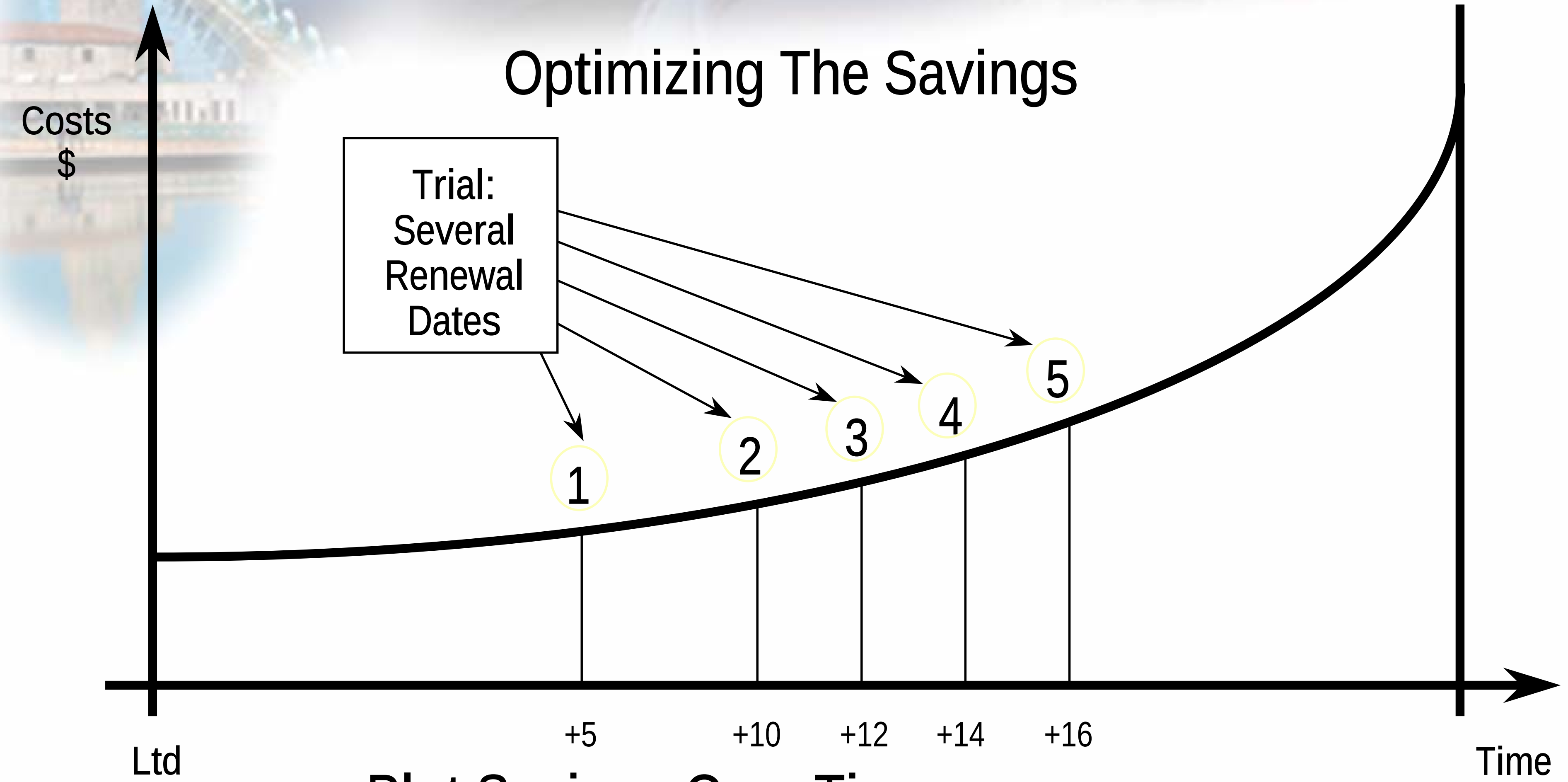
ORDM - Future Costs

Non-Critical Assets
Direct Repair Costs Significantly Exceed
Indirect Consequences Of Failure



ORDM – Optimized Renewal Decision Making
LTD – Life to Date

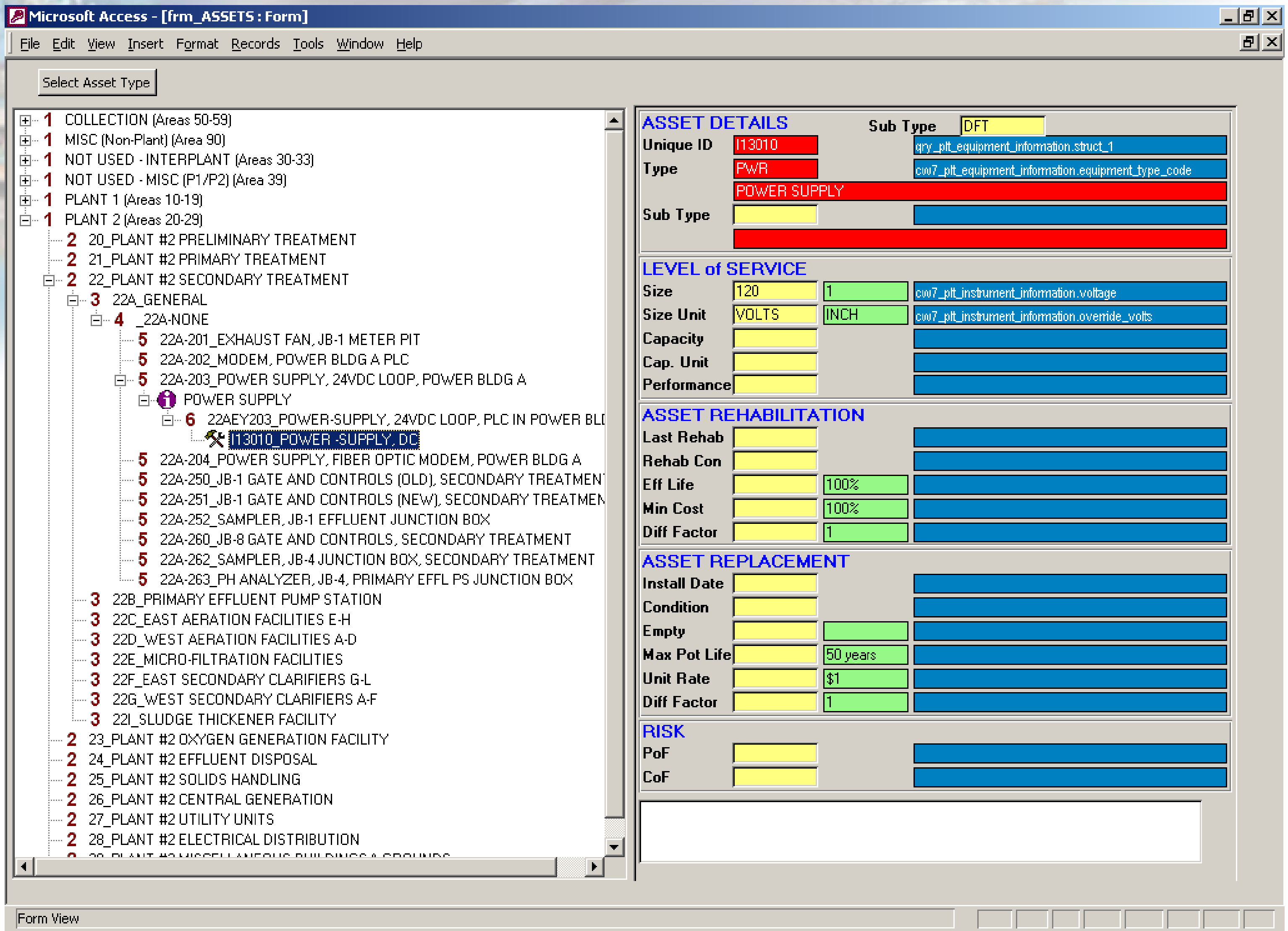
ORDM - Timing The Renewal



Plot Savings Over Time

ORDM – Optimized Renewal Decision Making
LTD – Life to Date

OCSD Hierarchy – Plant Assets



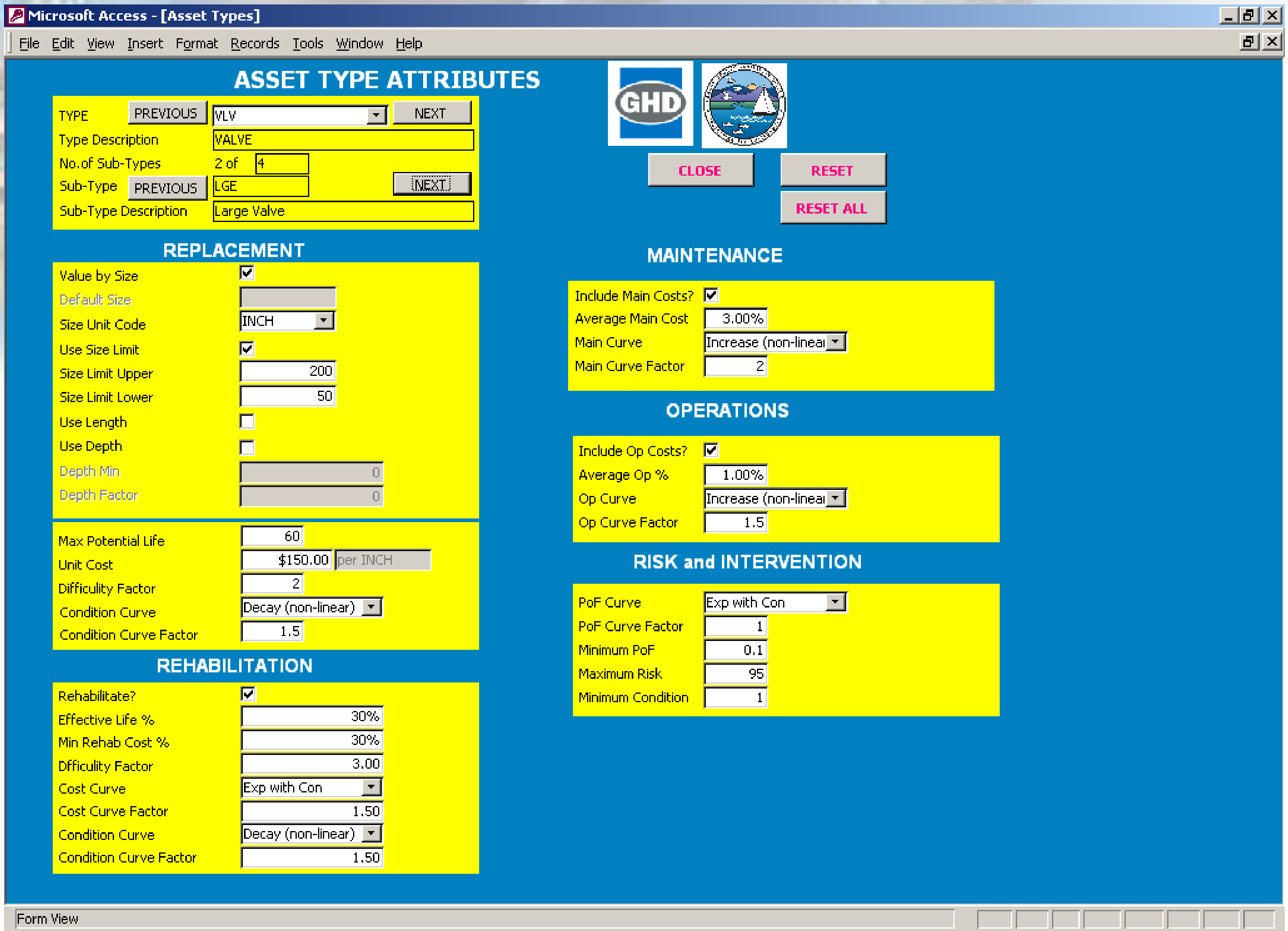
Asset Type Selection

Asset Type Selection

Select All | Unselect All | Apply | Cancel

	TYPE	TYPE DESCRIPTION	SUBTYPE	SUBTYPE DESCRIPTION
☒	AC	AIR CONDITIONING	DFT	DEFAULT SUB-TYPE
☑	AHU	AIR HANDLER UNIT	DFT	DEFAULT SUB-TYPE
☑	ALRM	ALARMS, AUDIO-VISUAL AND SOFTWARE	DFT	DEFAULT SUB-TYPE
☑	ANA	ANALYZER	DFT	DEFAULT SUB-TYPE
☑	APR	ASPIRATOR	DFT	DEFAULT SUB-TYPE
☑	ATMZ	ATOMIZER	DFT	DEFAULT SUB-TYPE
☑	BAT	BATTERIES	DFT	DEFAULT SUB-TYPE
☑	BIC	BICYCLE	DFT	DEFAULT SUB-TYPE
☑	BKR	BREAKER	DFT	DEFAULT SUB-TYPE
☑	BLR	BOILER	DFT	DEFAULT SUB-TYPE
☑	BLTP	BELTPRESS	DFT	DEFAULT SUB-TYPE
☑	BLWR	BLOWER	DFT	DEFAULT SUB-TYPE
☑	BRSC	BARSCREEN	DFT	DEFAULT SUB-TYPE
☑	CAL	CALIBRATOR	DFT	DEFAULT SUB-TYPE
☑	CAP	CAPACITORS	DFT	DEFAULT SUB-TYPE
☑	CAR	CARS	DFT	DEFAULT SUB-TYPE
☑	CART	CART,ELECTRIC	DFT	DEFAULT SUB-TYPE
☑	CEN	CENTRIFUGE	DFT	DEFAULT SUB-TYPE
☑	CFR	CLASSIFIER	DFT	DEFAULT SUB-TYPE
☑	CHIL	CHILLER	DFT	DEFAULT SUB-TYPE
☑	CHR	CHARGER, BATTERY	DFT	DEFAULT SUB-TYPE
☑	CLEAN	CLEANER ULTRASONIC	DFT	DEFAULT SUB-TYPE
☑	CLR	COLLECTOR, CLARIFIER SWEEP UNIT	DFT	DEFAULT SUB-TYPE
☑	CMP	COMPRESSOR	DFT	DEFAULT SUB-TYPE
☑	CND	CONDENSER	DFT	DEFAULT SUB-TYPE
☑	CNVR	CONVEYOR	DFT	DEFAULT SUB-TYPE
☑	COMP	COMPUTER EQUIPMENT	DFT	DEFAULT SUB-TYPE
☑	CON	CONTROLLER	DFT	DEFAULT SUB-TYPE
☑	CRN	CRANES	DFT	DEFAULT SUB-TYPE
☑	CTW	COOLING TOWER (AC)	DFT	DEFAULT SUB-TYPE
☑	CUB	CUBICLE (12KV CONTROLS OR NO BREAKER INSTA	DFT	DEFAULT SUB-TYPE

Asset Type Model



Asset Renewal Decision Model