Fundamentals of Asset Management

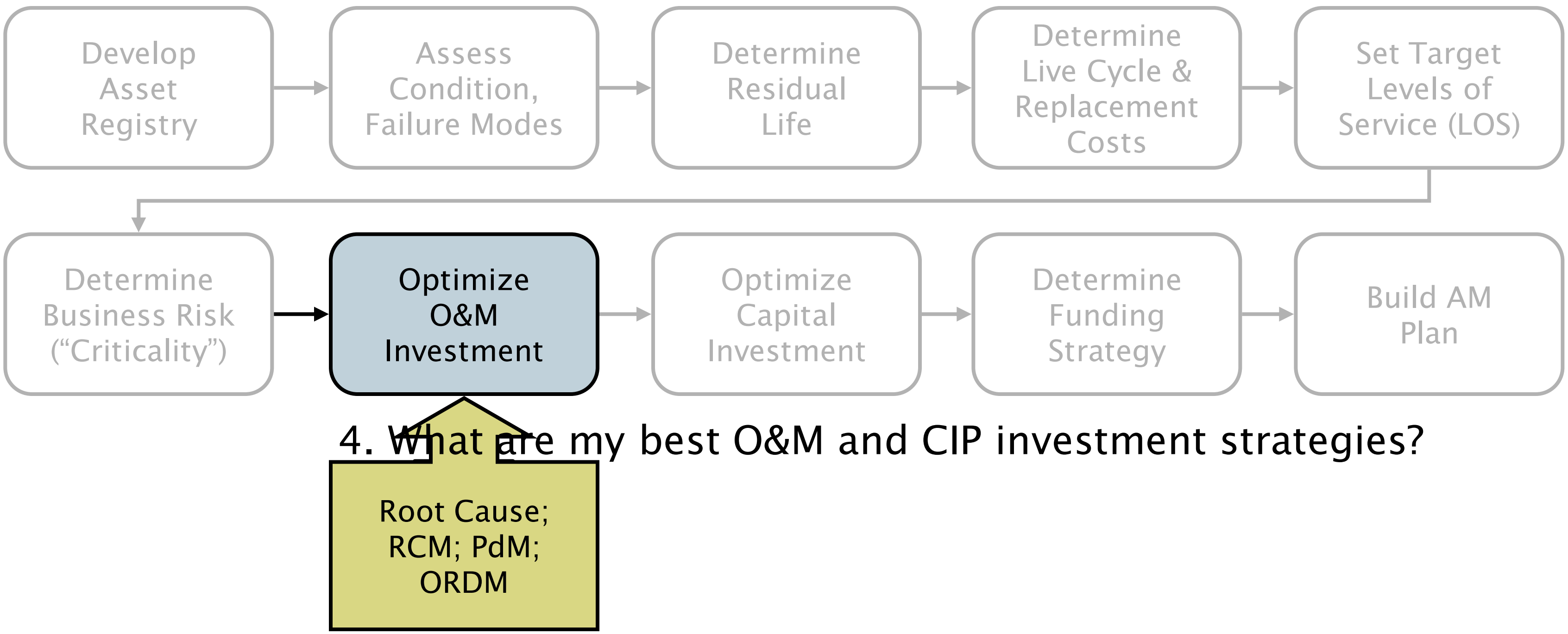
Step 7. Optimize Operations & Maintenance (O&M) Investment

A Hands-On Approach

Fourth of 5 core questions

4. What are my best O&M and CIP investment strategies?
   - What alternative management *options* exist?
   - Which are the *most feasible* for my organization?

AM plan 10-step process

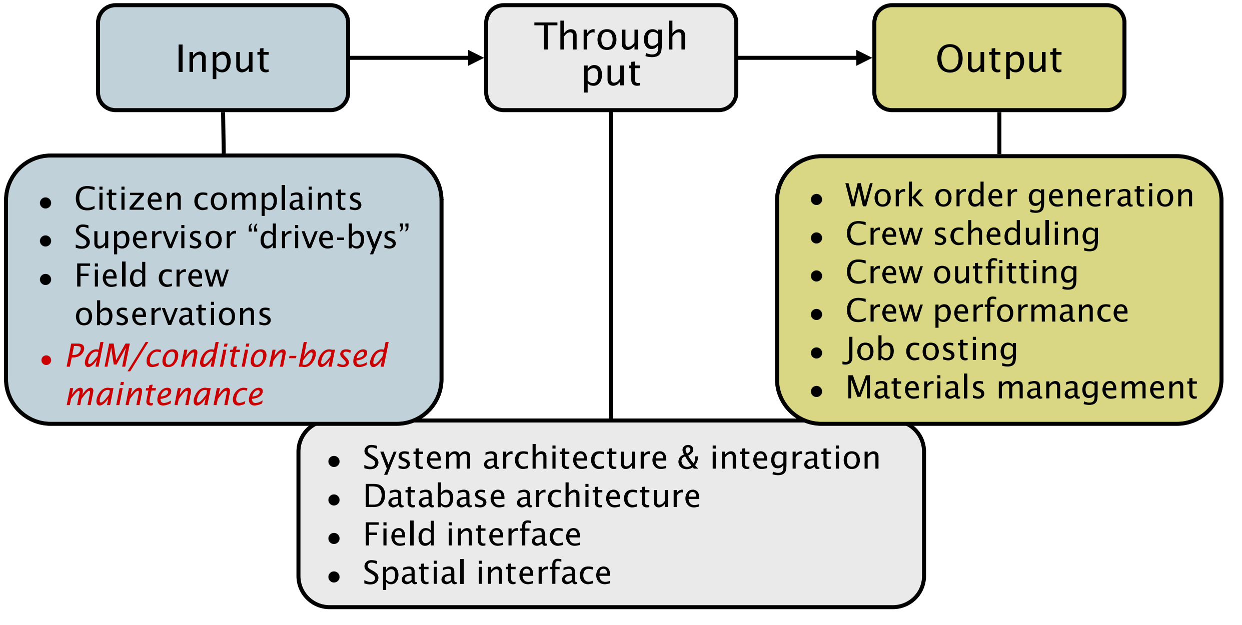


Definition

Maintenance - normal support, periodic and minor in nature, required to sustain performance and functionality of an asset consistent with design, manufacturer, and operational requirements

What triggers a work order?

Computerized Maintenance Management System (CMMS)



Importance Of The Work Order: Asset Level

WORK ORDER

Type: PM or UM

- 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

Tells us planned (PM) or unplanned (UM) maintenance costs

Builds life cycle cost history; ties to warehouse management

Tells us actual direct costs of activity

Tells us the activity used; necessary for activity analysis

Useful in *failure mode analysis*

Necessary for *causal analysis*

Indirect costs on business; impact on customers (*consequence analysis*)

Used in *efficiency analysis*

Data feedback enables substantive analysis

Importance of the work order: Portfolio level

WORK ORDER

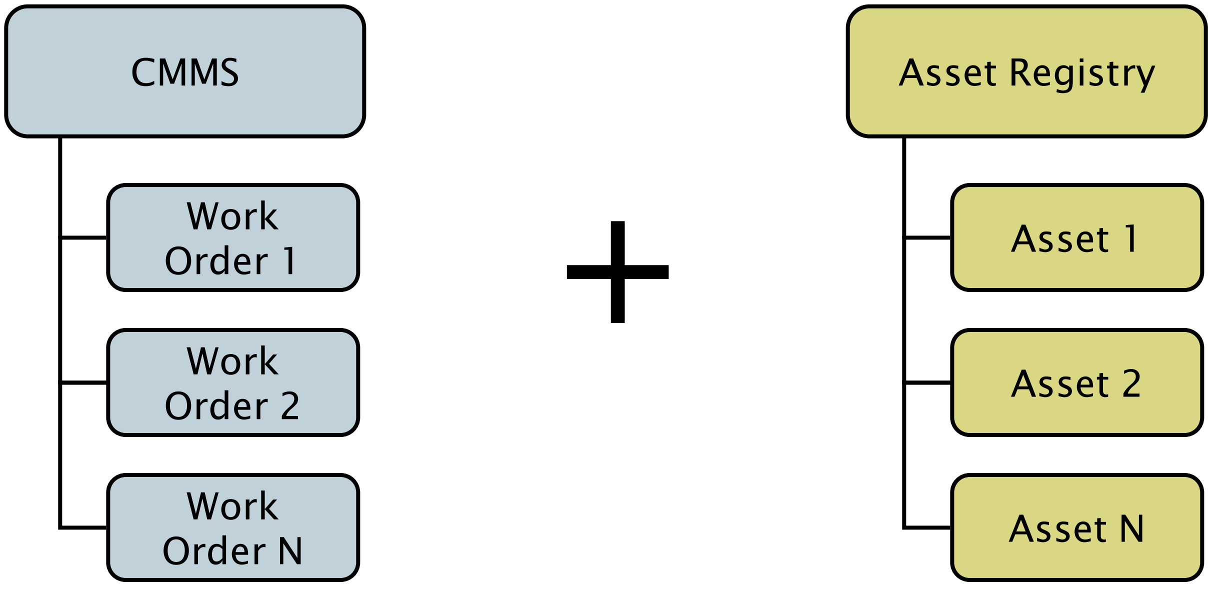
Asset details

- Type
- Category
- Size
- Condition
- Performance history
- Failure modes

Asset-linked costs enable 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?

What Distinguishes EAMS from CMMS?



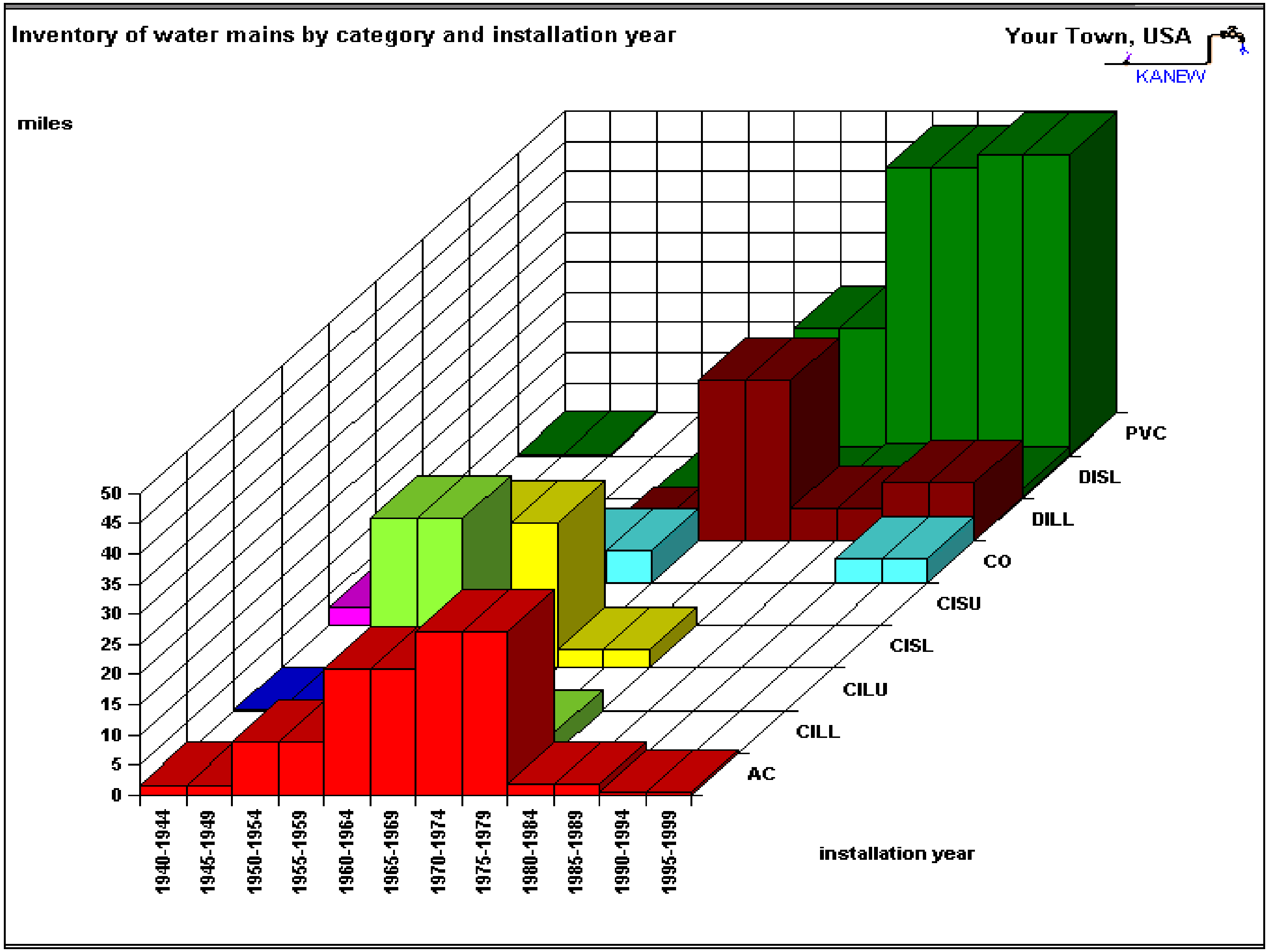
Focus is on the *maintenance work order* and maintenance performance for a defined period

Focus is on an *asset's performance* over its life cycle and on aggregate performance of asset groups

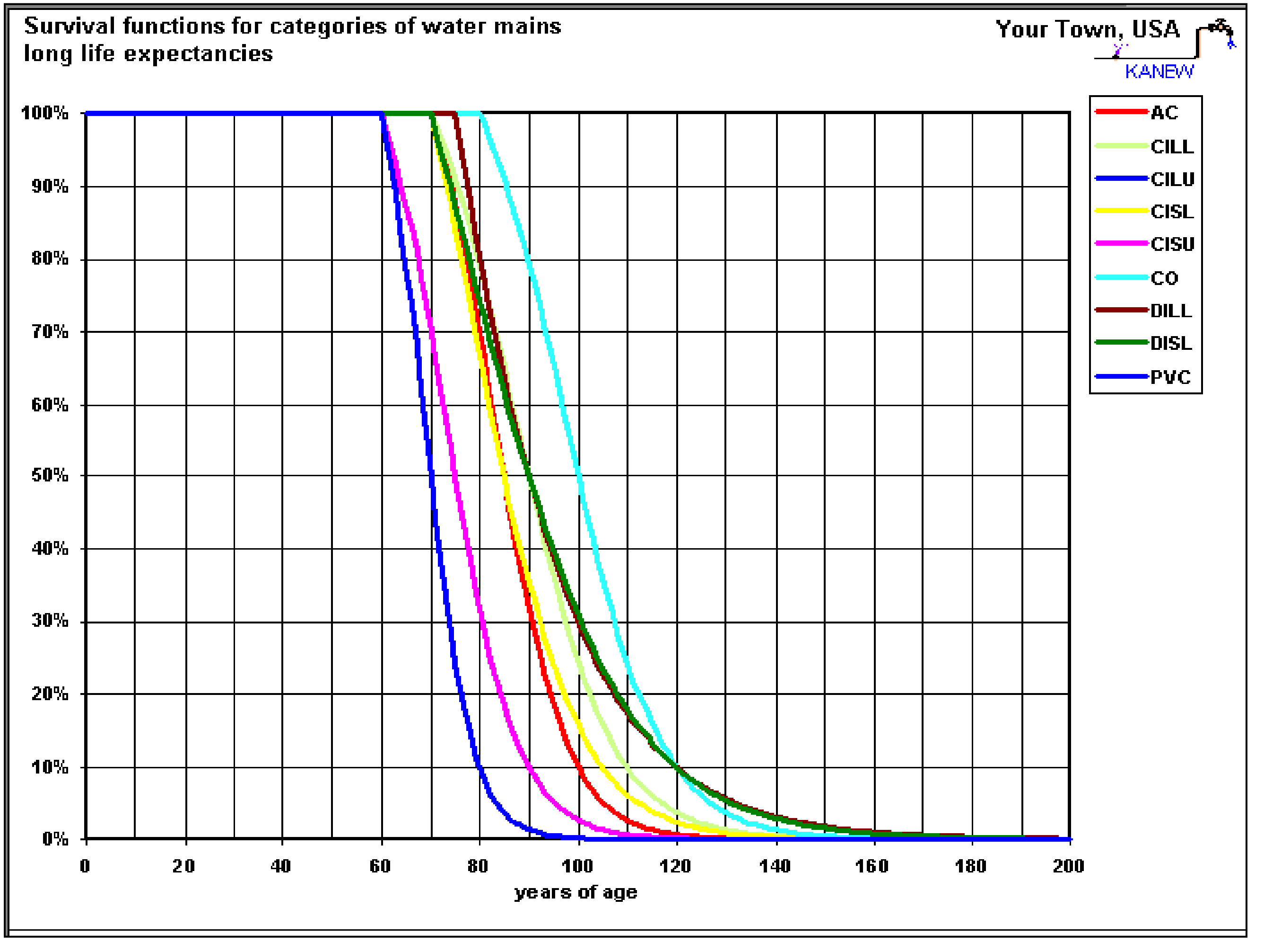
Bottom-line maintenance “KPIs” from an AM perspective

Metric	*Definition*	*Target*
Availability	The portion of time that a plant or major system is available for producing output of the required quality and quantity	95 – 99%
% Failure analysis	The portion of equipment downtime events that undergo a thorough analysis of failure modes, effects, and root causes	85 – 100%
% Planned work	The portion of corrective maintenance work hours that are planned and scheduled in advance (not unplanned breakdowns)	85 – 95%
% Overtime	The portion of maintenance work hours that are performed at an overtime rate	5 – 8%
Relative maintenance cost	Annual maintenance spending as a percentage of asset replacement value of the plant being maintained	1.5 – 2.5%
Technician productivity	The percent of work hours spent on productive activities versus nonproductive (rework, waiting for parts, etc)	70 – 85%
% Rework	The portion of maintenance work that has to be redone due to poor installation, shoddy workmanship or incorrect diagnosis	2 - 5%

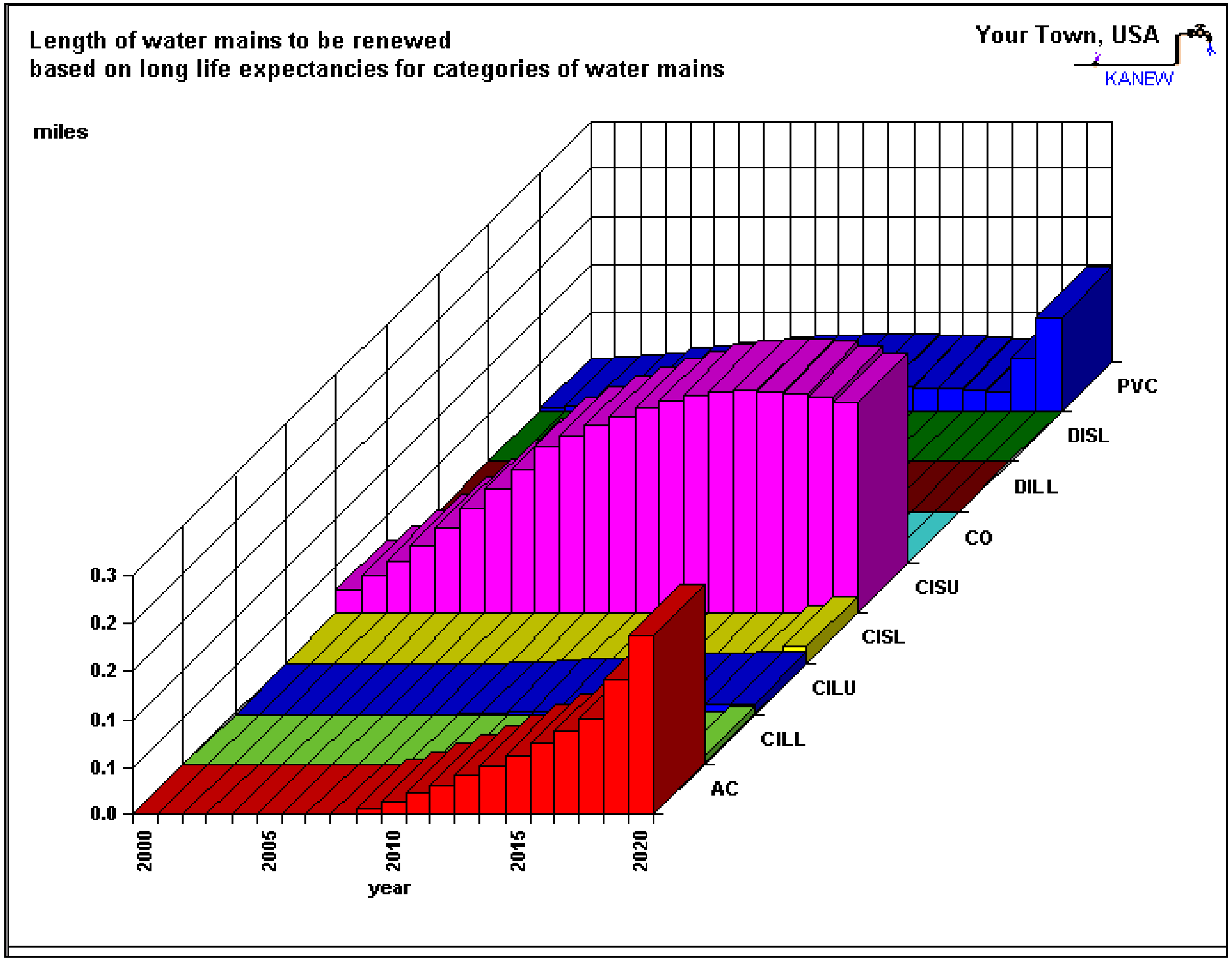
The asset portfolio view - 1



The asset portfolio view - 2



The asset portfolio view - 3

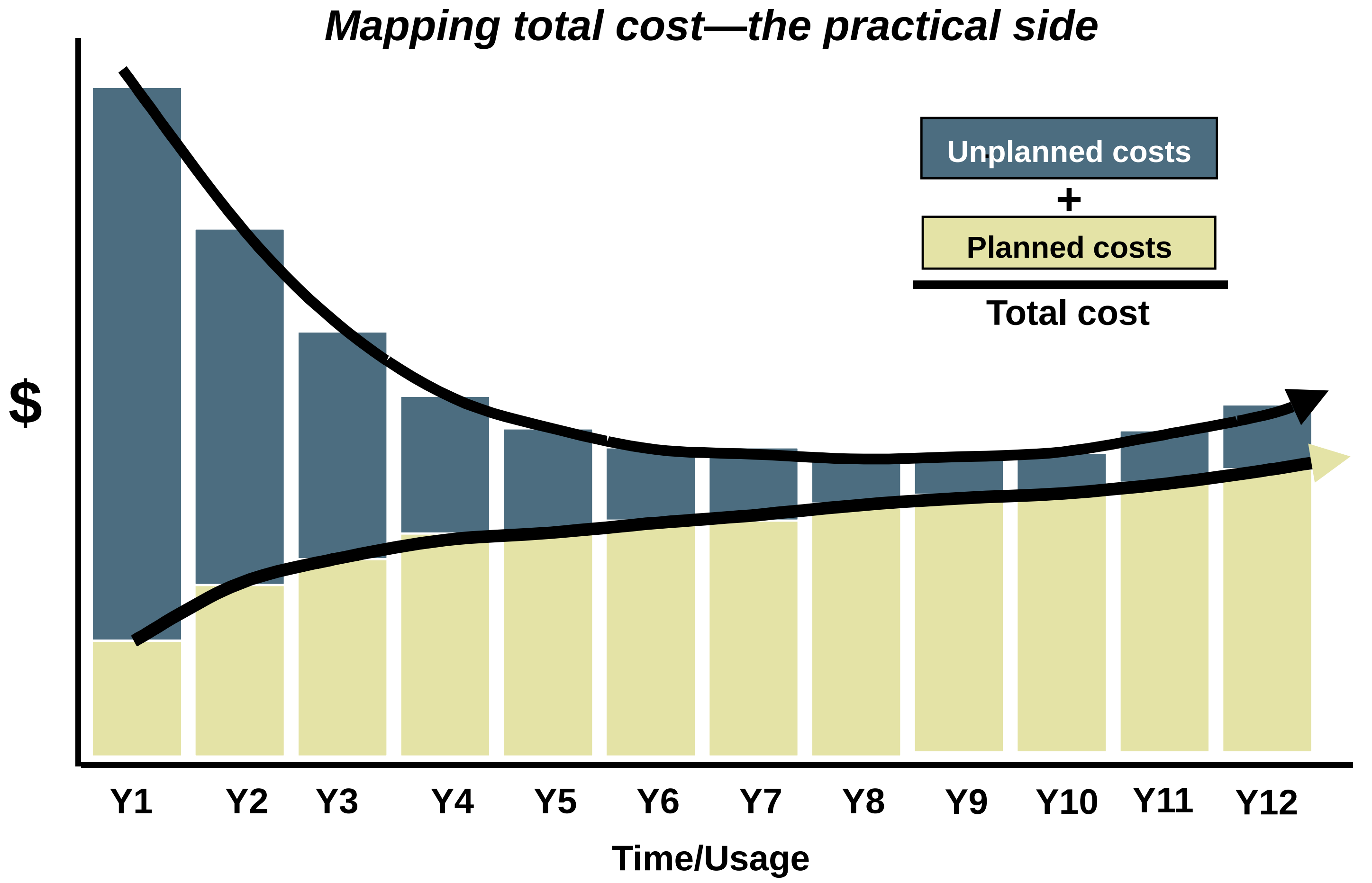


The Cost of Maintenance

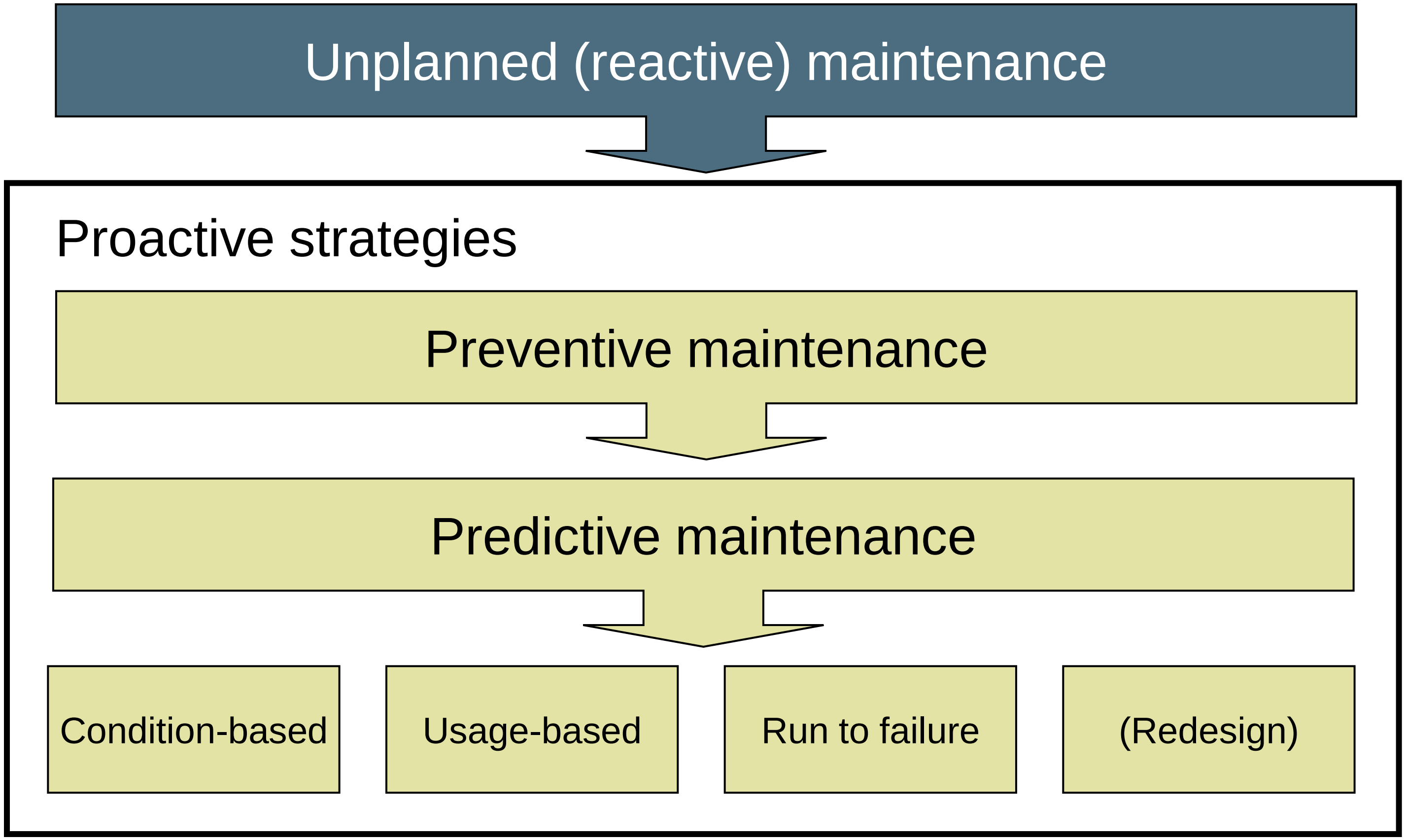
Rule of thumb

Roughly speaking, planned maintenance costs *one-third less* than unplanned maintenance for the same task

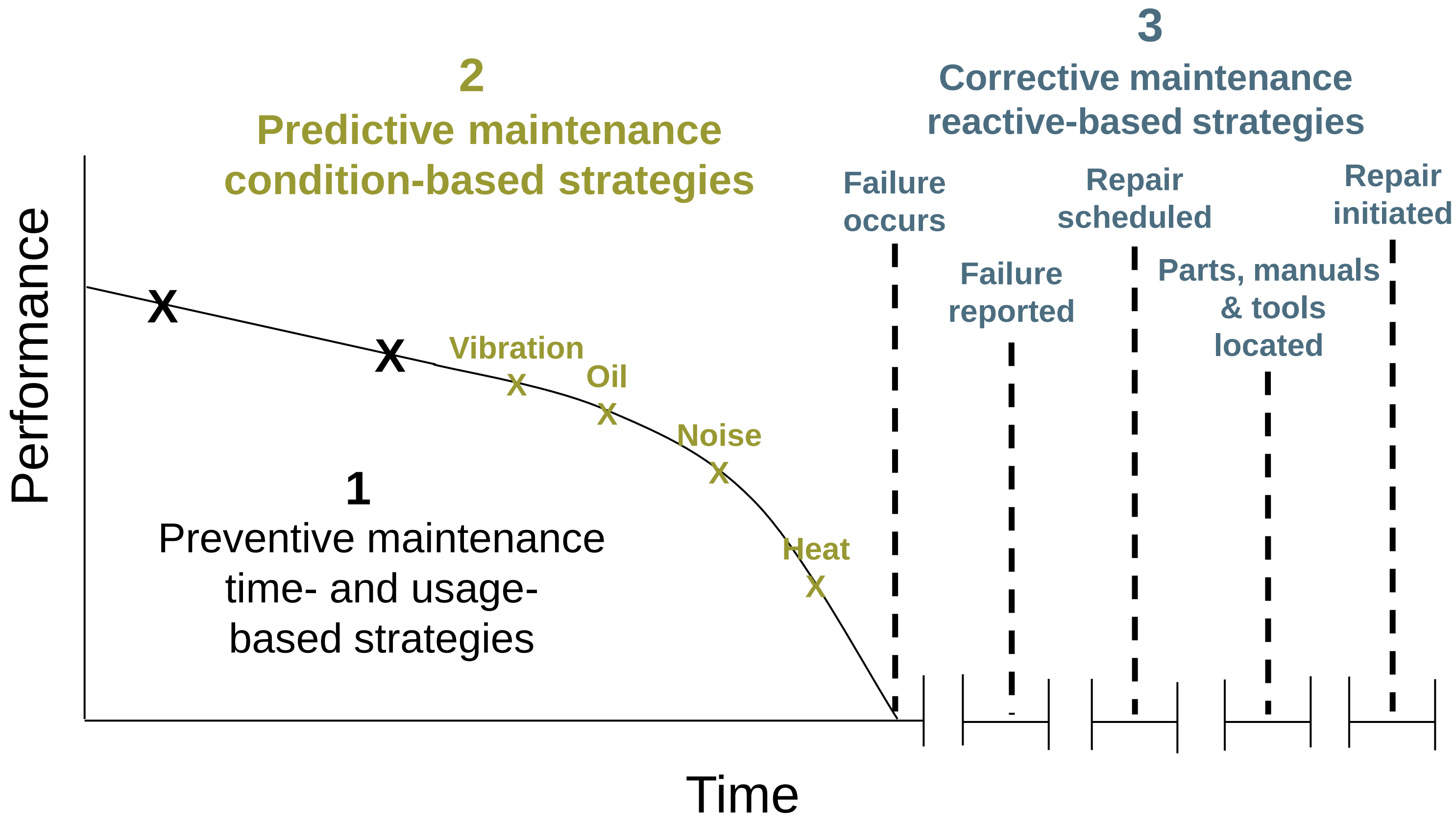
Transition to Planned Maintenance



Evolution of maintenance techniques



Fitting maintenance strategies to failure curve



Cost comparison strategies & tactics—the maintenance toolbox

Core strategies		
Total productive maintenance	Reliability centered maintenance	Zero breakdown maintenance

Operational tactics			
Design reliability analysis	Asset condition assessment	Early equipment management	Maintenance prevention
Accelerated deterioration elimination	Infrastructure, equip-ment, & component standardization	Commodity configuration management	Design for serviceability
Failure lead-time analysis	Demand criticality classification	Location failure analysis	Standardized failure codes

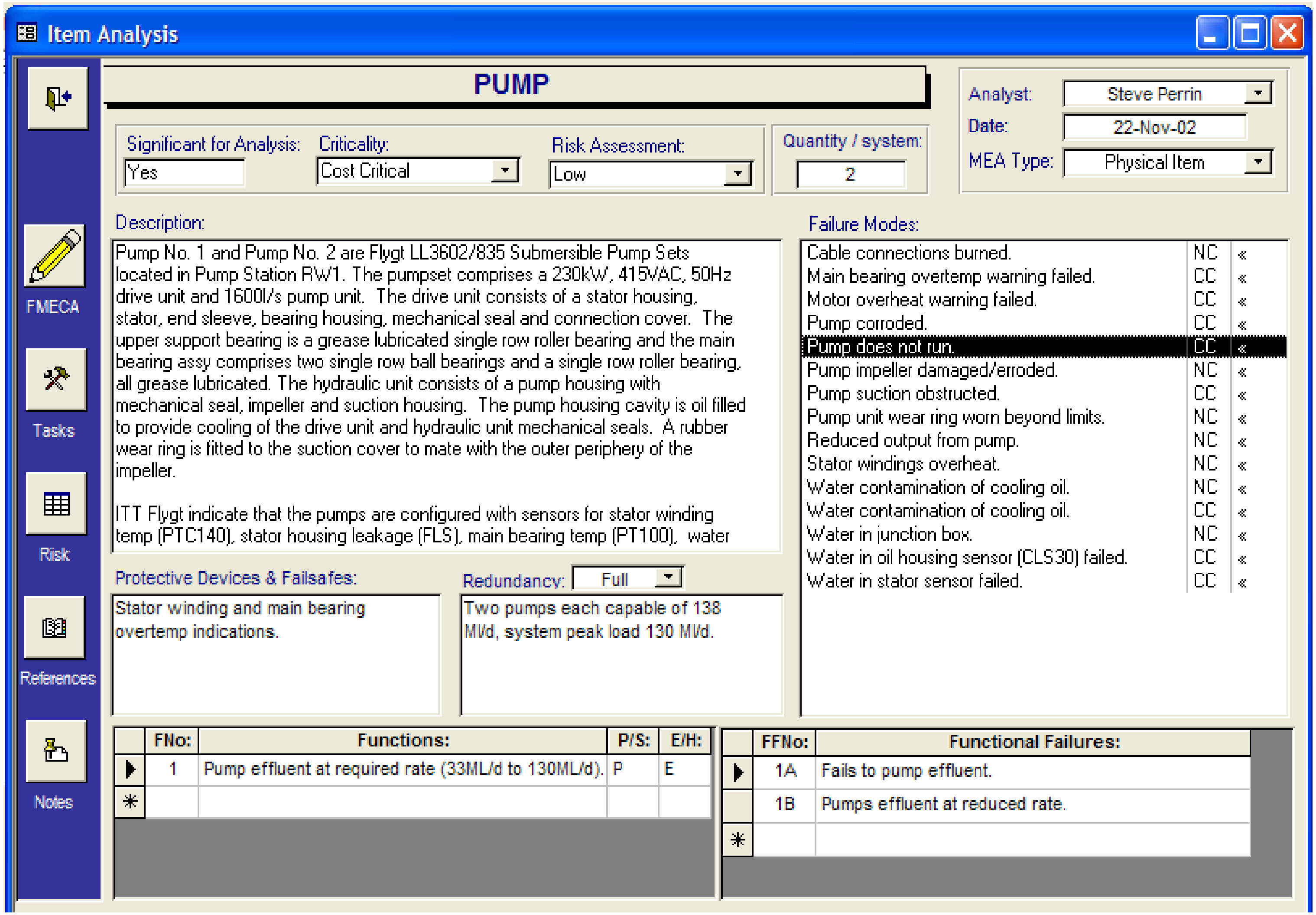
Reliability-centered maintenance—the seven fundamental questions

1. What are the functions and associated performance standards of the asset in its present operating context?
2. In what ways does it fail to fulfill its functions?
3. What causes each functional failure?
4. What happens *mechanically* when each failure occurs?
5. In what way does each failure matter?
6. What can be done to predict or prevent each failure?
7. What should be done if a suitable proactive task cannot be found?

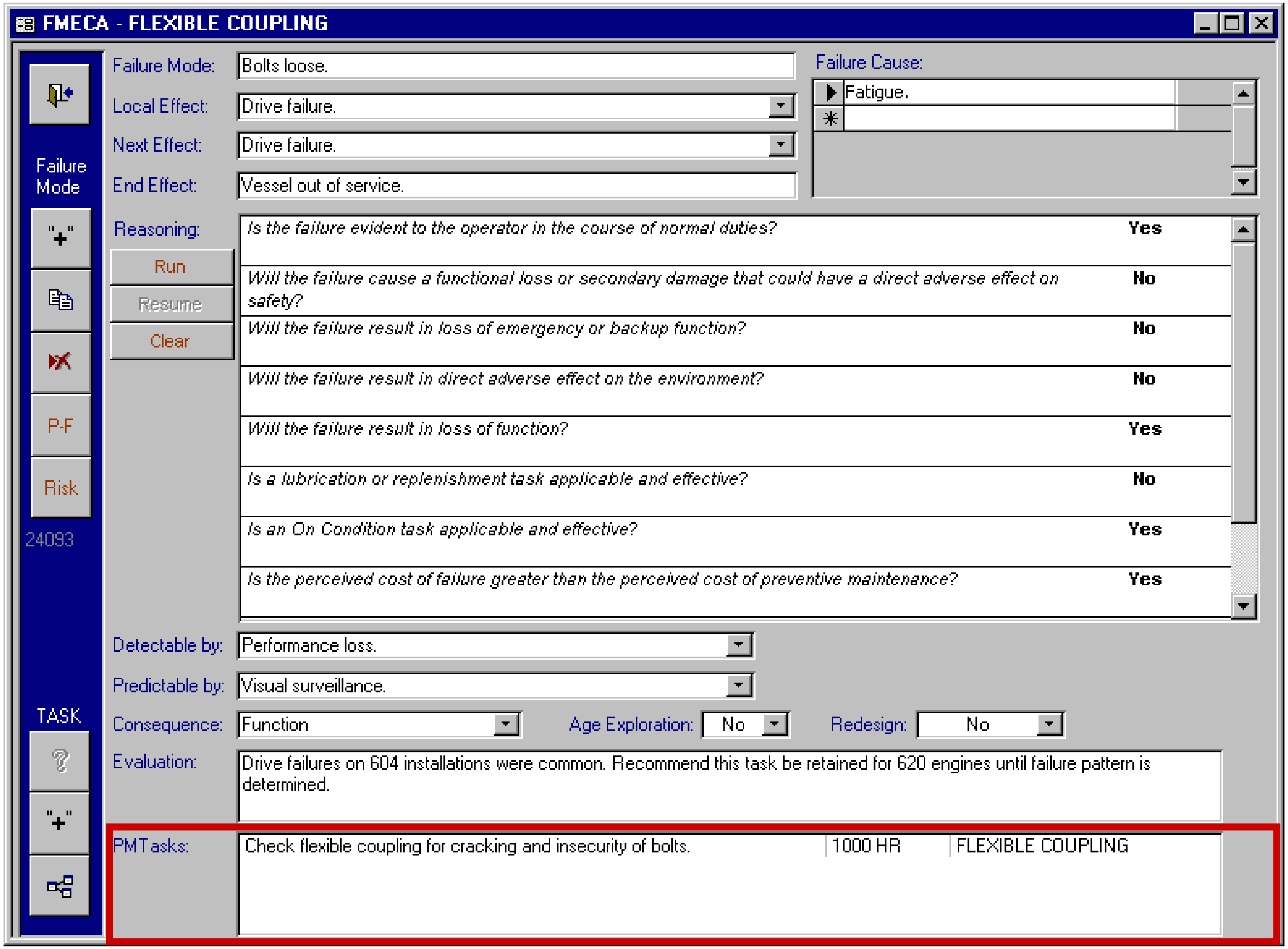
Techniques

- Function and performance standards
- Functional failures
- Failure modes
- Failure effects
- Failure consequences
- Proactive tasks

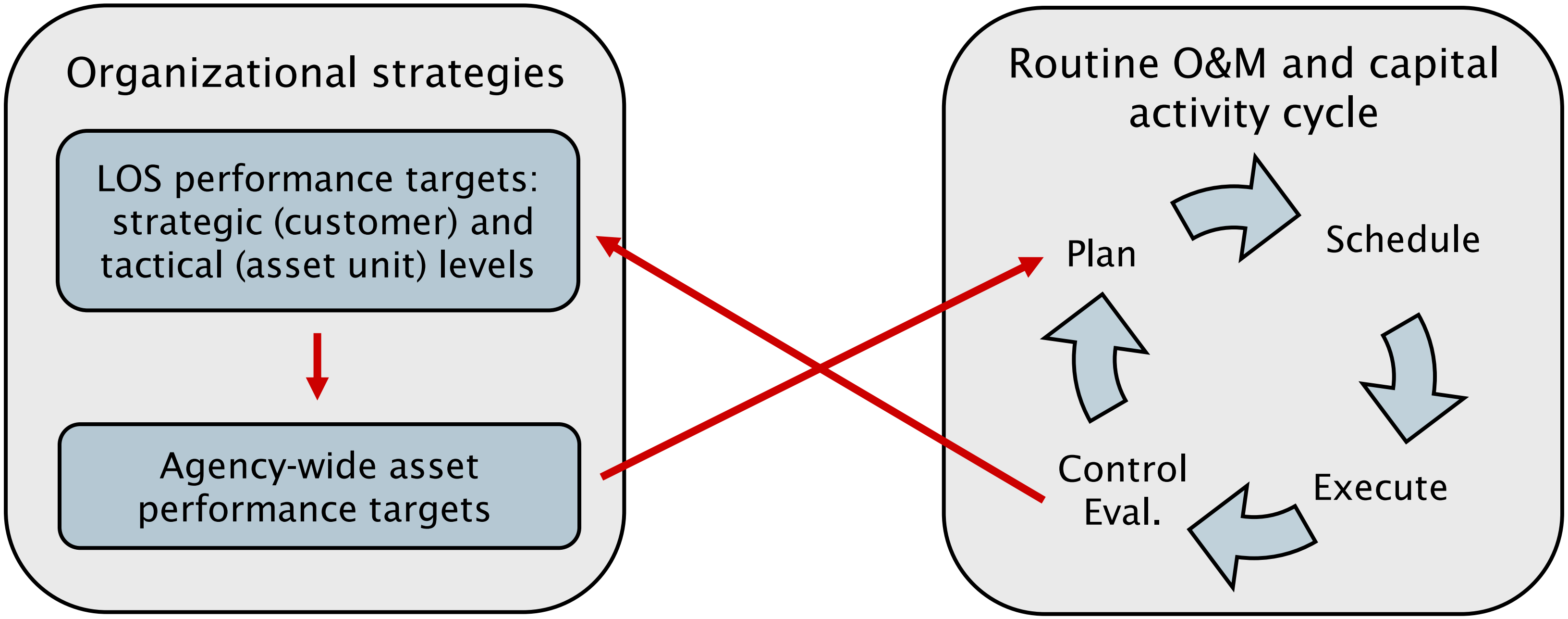
Intervention action—RCM



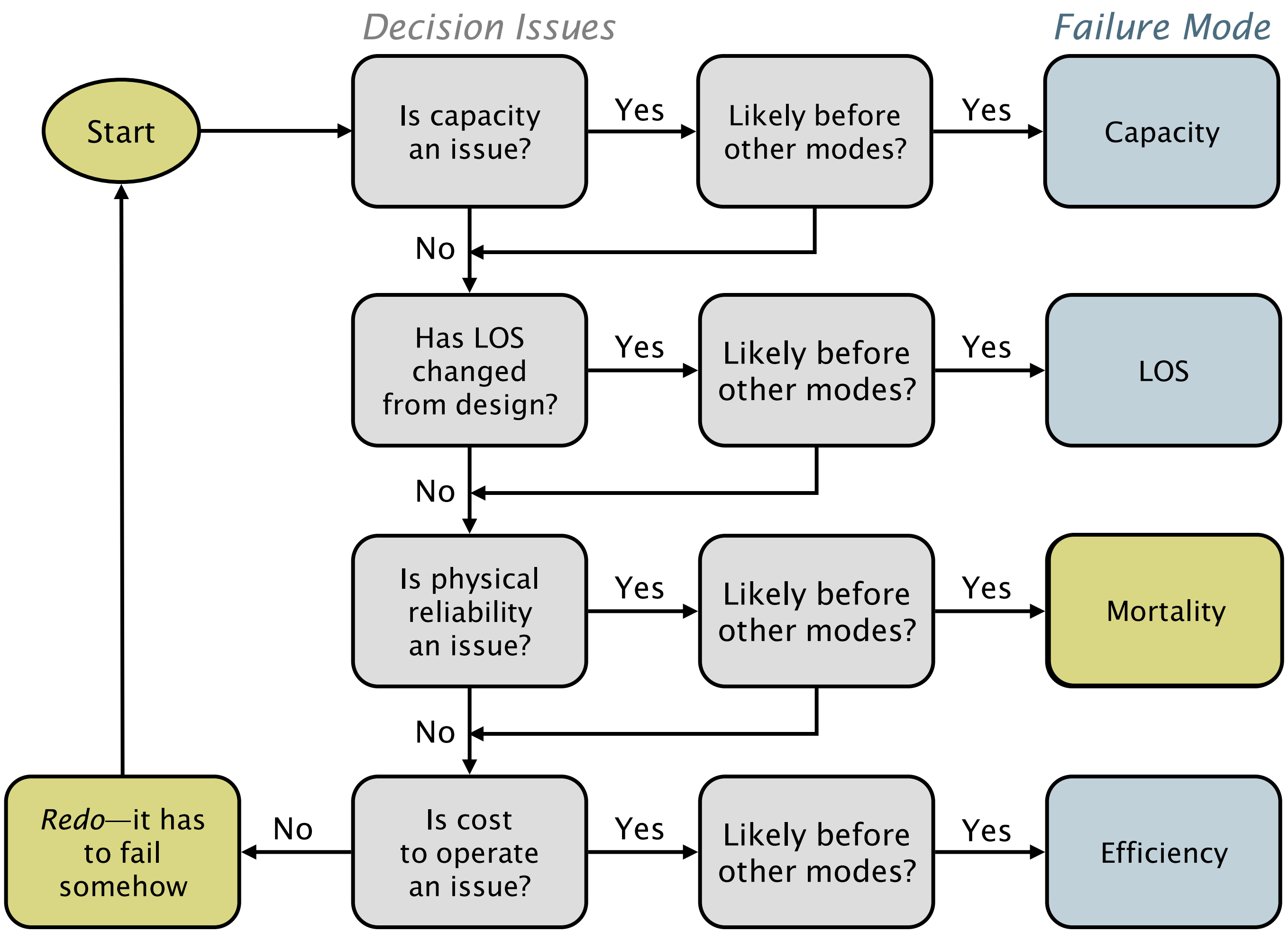
Intervention action—RCM, cont.



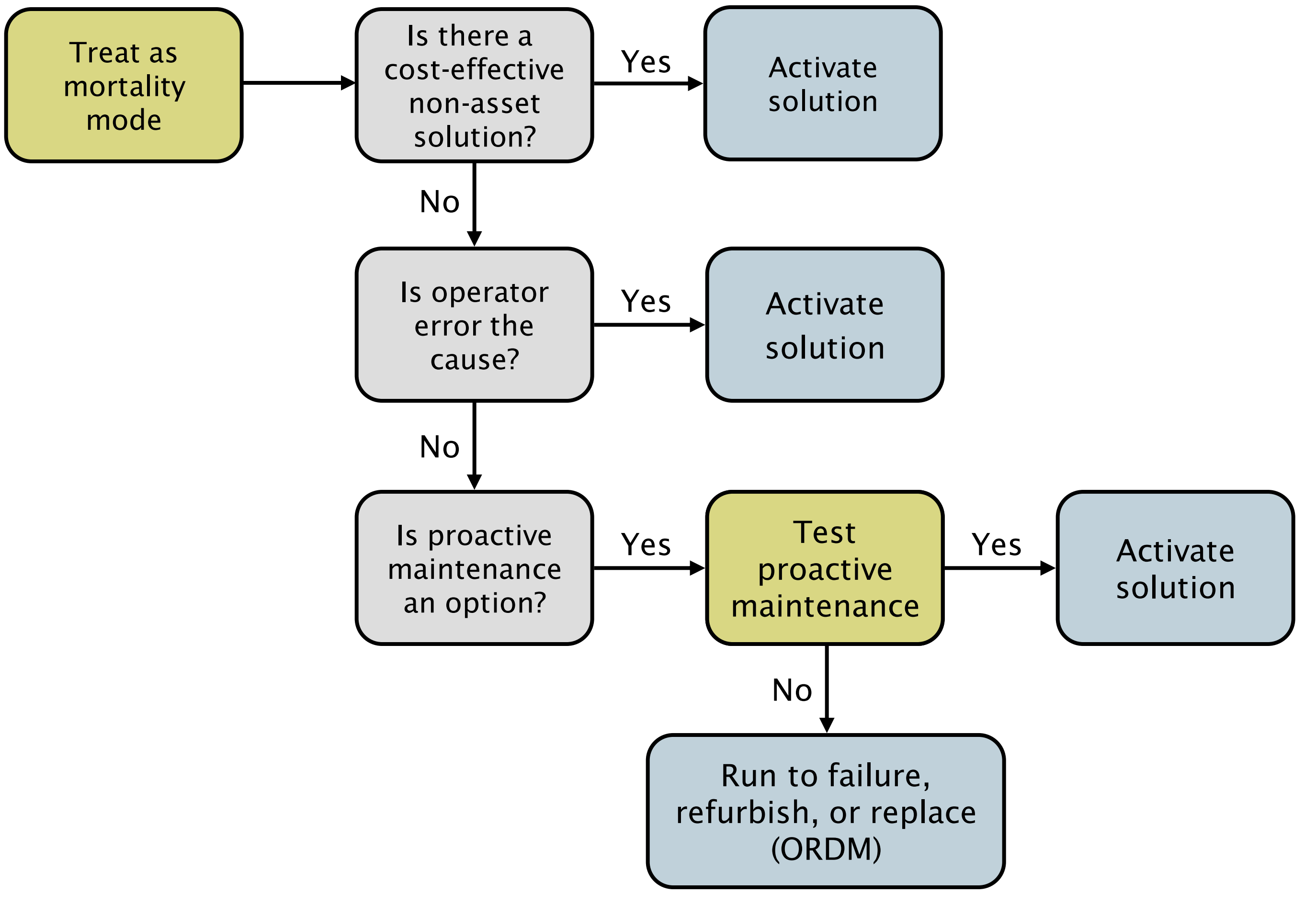
Alignment of routine O&M activities with organizational strategies



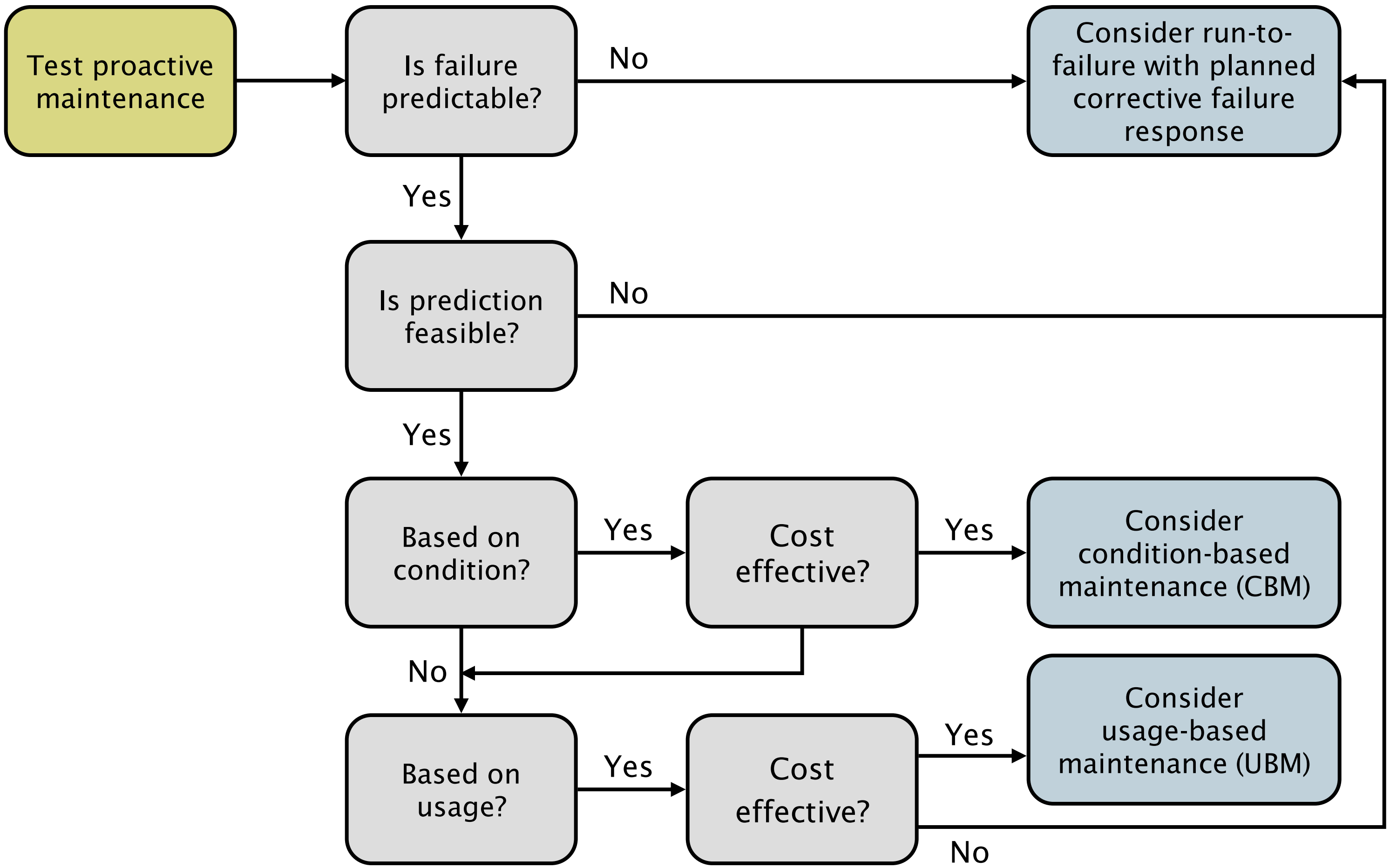
Using failure modes to determine probability of failure



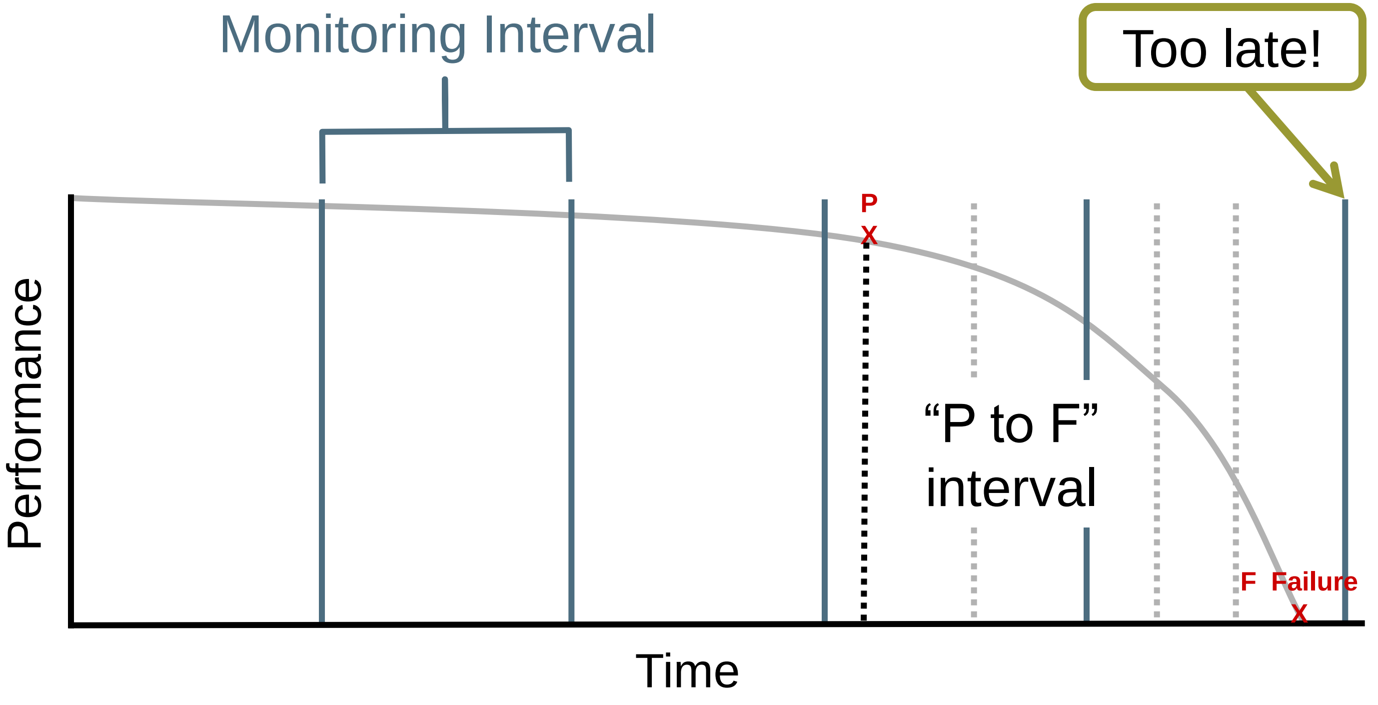
Tactical-level failure modes



Mortality failure mode: Determining appropriate maintenance tactics

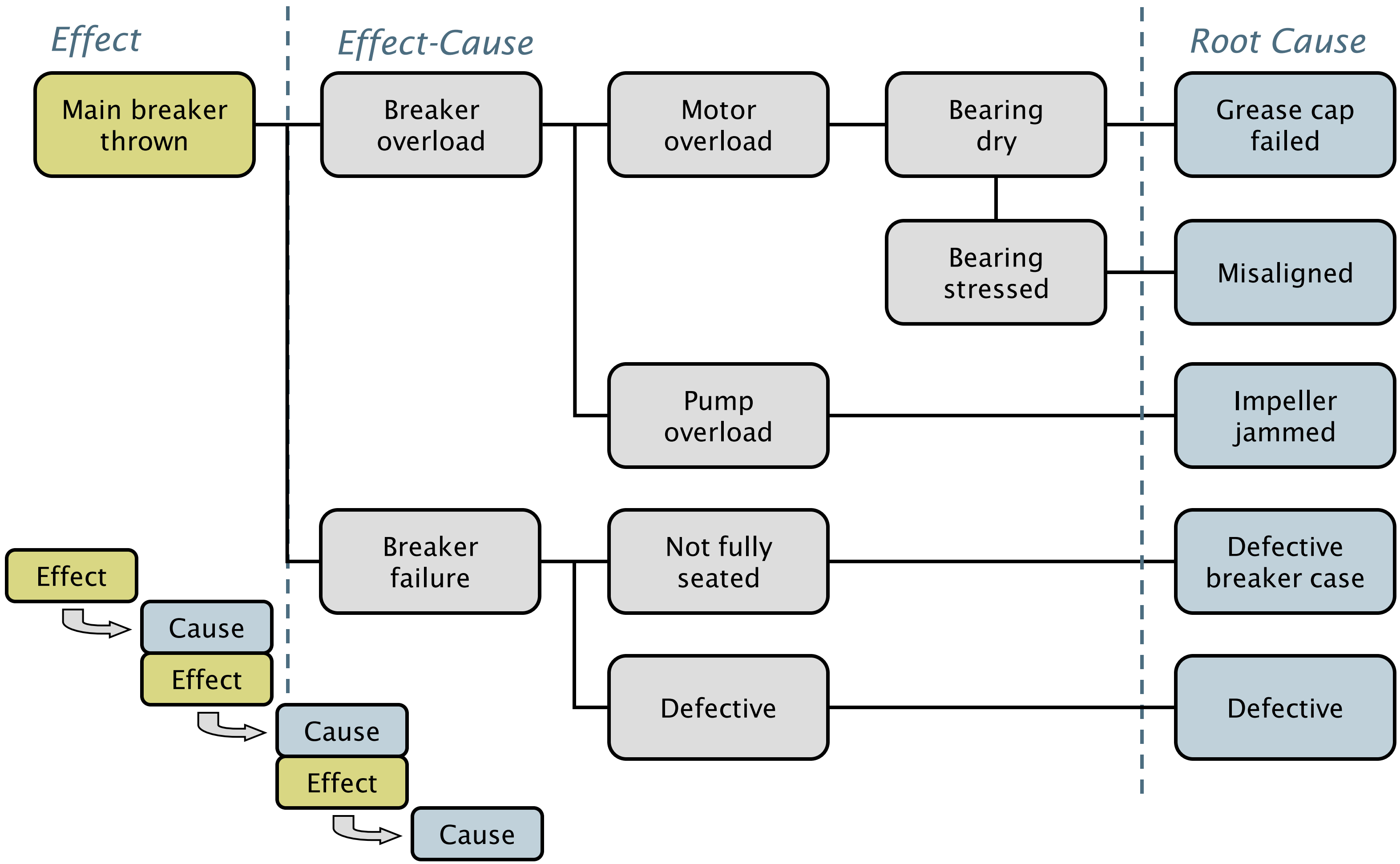


Predictive maintenance and the monitoring interval

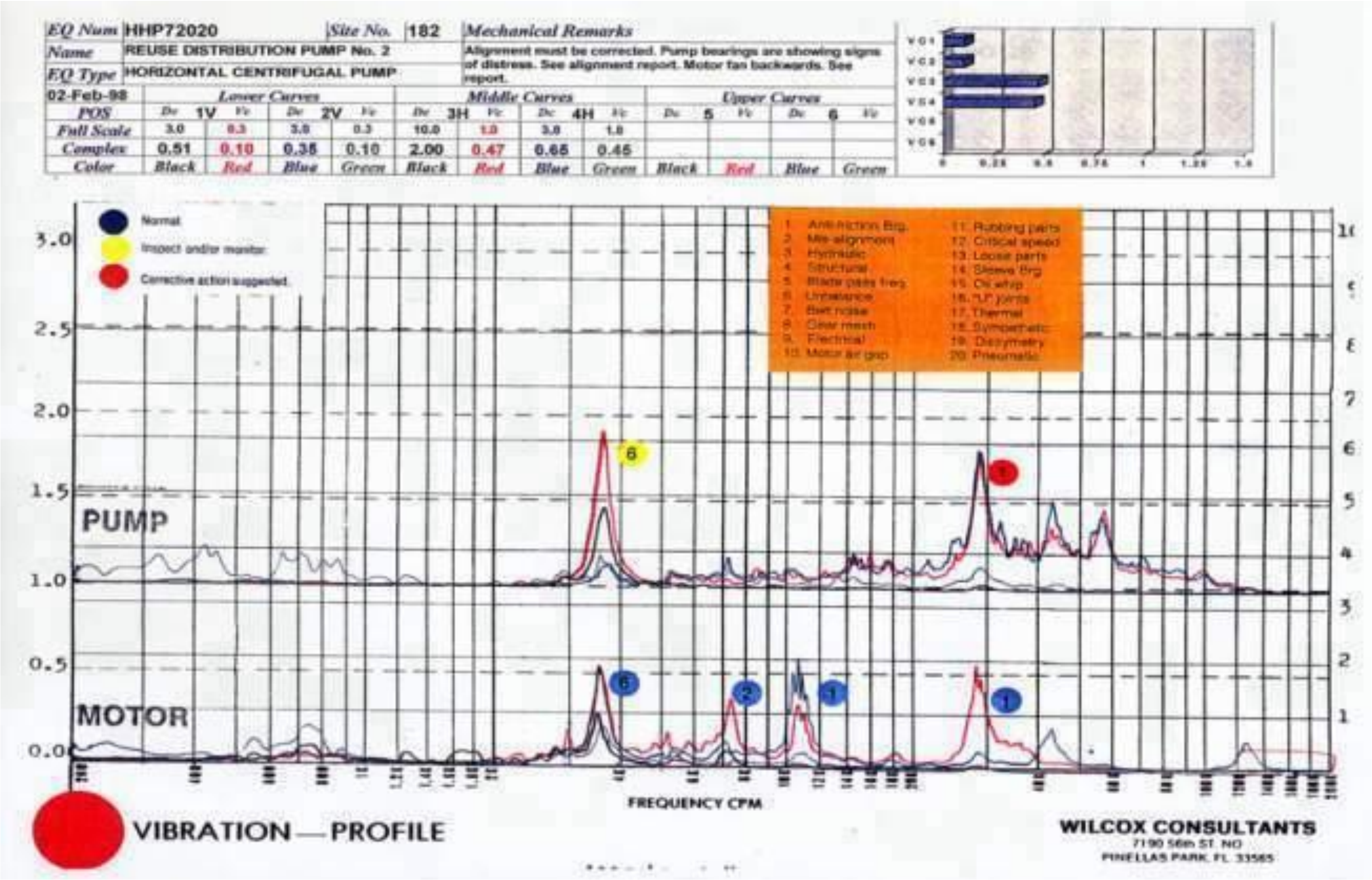


Can the progression of the failure be detected? Is there typically enough time to respond? Does consequence exceed cost of cure?

Cause and effect diagram—what to monitor



Condition-based maintenance: Vibration analysis



Power evaluation

Sample County - Waste Water Utilities Systems

Sewage Lift Stations - Electrical Report - Data as Recorded, June, 1998

	Voltage Line to Line			Amperage			Voltage Drops			Power Data				Horsepower and Load Percent		
Equip. Number	A to B	B to C	C to A	A	B	C	A	B	C	KVA	KVAR	KW	PF	Calc.	Rated	Percent
20LS-RSP-002	244.0	243.0	244.0	24.2	23.7	24.3	0.09	0.08	0.09	9.7	6.9	6.8	90.0	9.1	15.00	60.7
ABLS-RSP-001	474.0	473.0	475.0	24.1	25.1	25.7				17.5	2.8	17.2	98.7	23.1	25.00	92.4
ABLS-RSP-002	474.0	474.0	475.0	27.5	26.7	29.1				18.8	3.2	18.5	98.6	24.8	25.00	99.2
ABLS-RSP-003	474.0	475.0	475.0	25.4	25.8	29.5				17.8	2.9	17.6	98.7	23.6	25.00	94.4
BELS-RSP-001	239.0	240.0	242.0	59.8	52.6	65.7	0.19	0.19	0.18	23.9	12.7	20.3	84.9	27.2	25.00	108.8
BELS-RSP-002	240.0	242.0	240.0	50.5	51.3	55.4	0.16	0.16	0.18	21.5	13.6	16.7	77.6	22.4	25.00	89.6
BGLS-RSP-001	242.0	241.0	242.0	8.5	8.6	8.8	0.30	0.30	0.36	3.6	2.4	2.7	74.5	3.6	3.00	120.0
BGLS-RSP-002	242.0	241.0	242.0	9.4	9.3	9.6	0.24	0.18	0.17	3.9	2.1	3.3	84.2	4.4	3.00	146.7
BLLS-RSP-001	479.0	475.0	468.0	3.9	3.8	3.9	0.08	0.08	0.07	3.0	2.0	2.3	75.3	3.1	2.00	155.0
BLLS-RSP-002	482.0	483.0	485.0	4.0	3.9	4.0	0.08	0.06	0.13	3.1	2.1	2.3	73.9	3.1	2.00	155.0
CMLS-RSP-001	457.0	456.0	456.0	6.6	6.6	7.2	0.40	0.40	0.42	5.1	3.6	3.7	71.3	5.0	7.50	66.7
CMLS-RSP-002	457.0	458.0	458.0	6.0	6.0	6.1	0.27	0.27	0.63	4.7	3.8	2.7	58.0	3.6	7.50	48.0
DWLS-RSP-001	486.0	485.0	486.0	22.1	22.9	24.0	0.14	0.21	0.14	19.0	10.9	15.6	82.0	20.9	20.00	104.5
DWLS-RSP-002	485.0	486.0	485.0	21.3	22.0	22.8	0.16	0.14	0.15	18.3	10.7	14.8	81.1	19.8	20.00	99.0
FDLS-RSP-001	239.0	239.0	239.0	21.1	22.1	22.8	0.21	0.25	0.20	9.0	6.6	6.1	68.2	8.2	10.00	82.0
FDLS-RSP-002	240.0	239.0	240.0	23.9	24.0	25.6	0.26	0.26	0.31	10.0	7.0	7.1	70.9	9.5	10.00	95.0
FRLS-RSP-001	212.0	213.0	215.0	4.9	5.4	5.9	0.23	0.22	0.26	2.0	1.5	1.3	66.5	1.7	2.00	85.0
FRLS-RSP-002	212.0	213.0	215.0	5.2	5.6	6.1	0.25	0.25	0.27	2.1	1.5	1.4	70.0	1.9	2.00	95.0
FSLS-RSP-001	239.0	240.0	240.0	33.7	36.8	42.7	0.14	0.14	0.13	14.8	10.3	10.6	71.7	14.2	15.00	94.7
FSLS-RSP-002	239.0	239.0	240.0	31.4	34.7	39.8	0.17	0.18	0.19	13.9	10.7	8.9	63.9	11.9	15.00	79.3
H5LS-RSP-001	244.0	242.0	242.0	8.2	8.8	9.5	0.62	0.79	0.73	3.8	2.5	2.9	74.7	3.9	3.00	130.0
H5LS-RSP-002	242.0	242.0	241.0	10.2	9.5	10.0	0.49	0.81	0.60	4.1	2.9	2.9	70.8	3.9	3.00	130.0
HCLS-RSP-001	242.0	242.0	243.0	28.4	27.1	26.0	0.12	0.10	0.12	11.2	9.0	6.7	59.3	9.0	15.00	60.0
HCLS-RSP-002	243.0	242.0	243.0	28.3	26.9	25.6	0.12	0.11	0.12	11.2	8.6	7.1	63.6	9.5	15.00	63.3
HKLS-RSP-001	241.0	241.0	242.0	60.3	60.1	38.2	0.45	0.30	0.72	27.1	20.6	17.7	65.1	23.7	40.00	59.3
HKLS-RSP-002	240.0	241.0	241.0	62.4	63.2	65.0	0.23	0.36	0.66	26.6	15.9	21.3	80.2	28.6	40.00	71.5
HSLS-RSP-001	208.0	206.0	208.0	240.3	26.2	28.1	0.19	0.19	0.28	9.0	5.8	6.9	76.5	9.2	10.00	92.0
HSLS-RSP-002	208.0	206.0	208.0	24.1	26.4	27.7	0.17	0.19	0.20	9.0	5.7	6.7	77.4	9.0	10.00	90.0
JHLS-RSP-001	244.0	243.0	243.0	50.9	52.4	51.6	0.21	0.65	0.19	21.4	15.4	14.9	69.6	20.0		
JHLS-RSP-002	245.0	244.0	245.0	44.1	42.9	45.1	0.36	0.54	0.32	18.4	12.7	13.4	72.7	18.0		
MWLS-RSP-001	241.0	240.0	241.0	11.0	11.6	12.4	0.19	0.13	0.14	4.7	2.5	4.0	84.8	5.4	7.50	72.0

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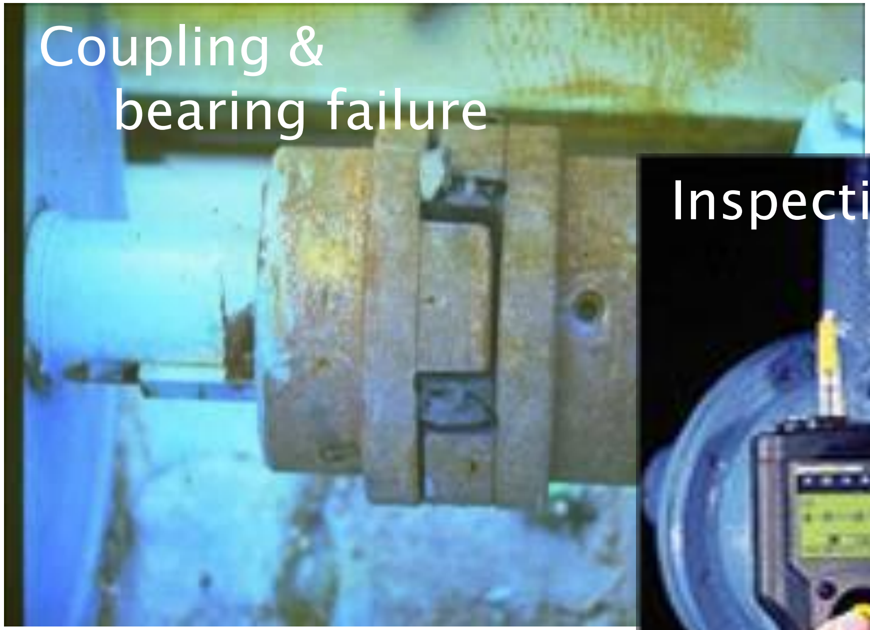
Page 1

Most condition indicators are not visible to the unaided eye

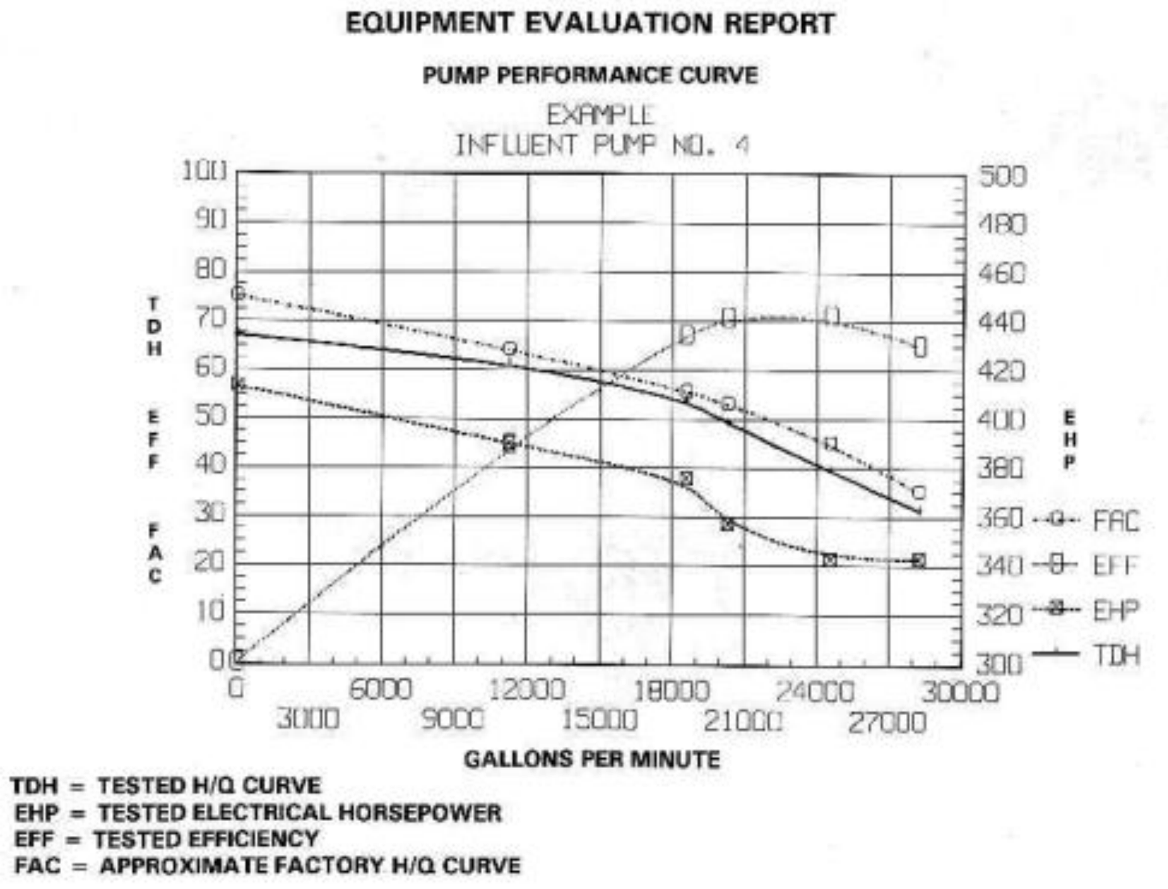
Visual inspection

Infrared view

Alignment of inspection and correction data



Baseline machine performance tests



Baseline at handover sets life cycle benchmark. Conforms to factory test curves?

Failure codes

- Use cause-effect diagrams to create codes
- Define codes by class of asset
- Use “drop-down” list

Failure Code

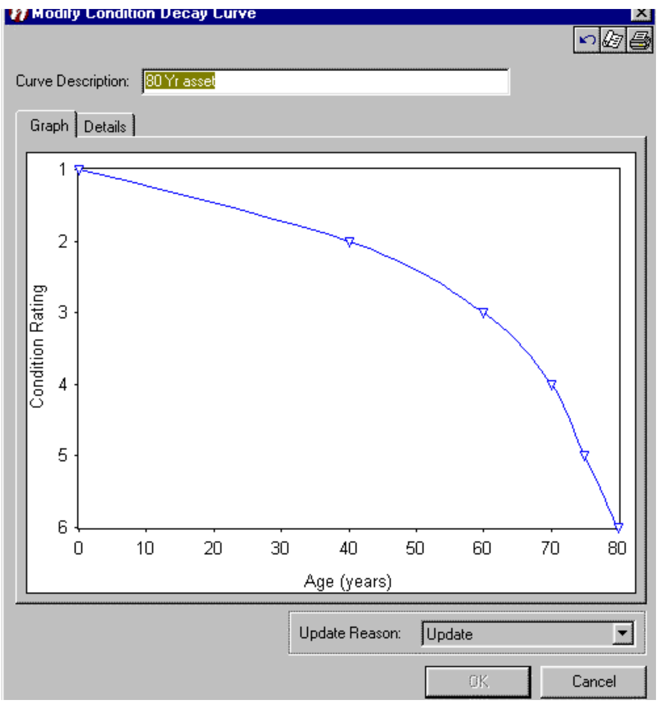
- Coupling failure
- Lube fault
- Misaligned
- Operator error
- Overloaded
- Water damage
- Worn

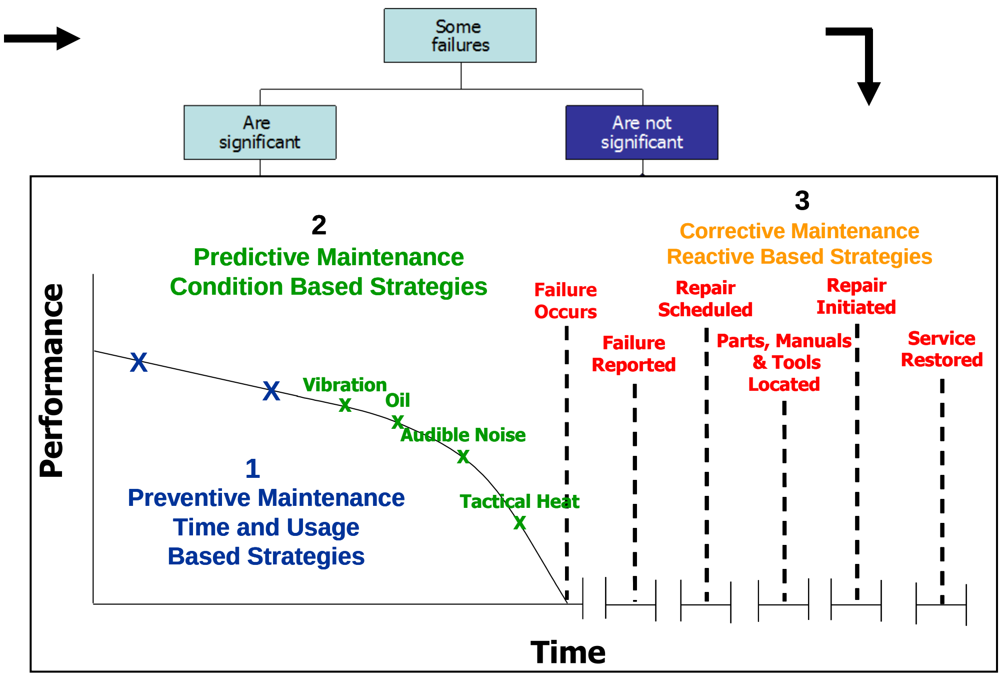
Condition-based maintenance

"Nameplate" Data

+

Vibration Signature	Sonic Signature	Thermal Signature	Electrical Signature	Performance Signature	Oil Residue Signature	Electro-magnetic Signature

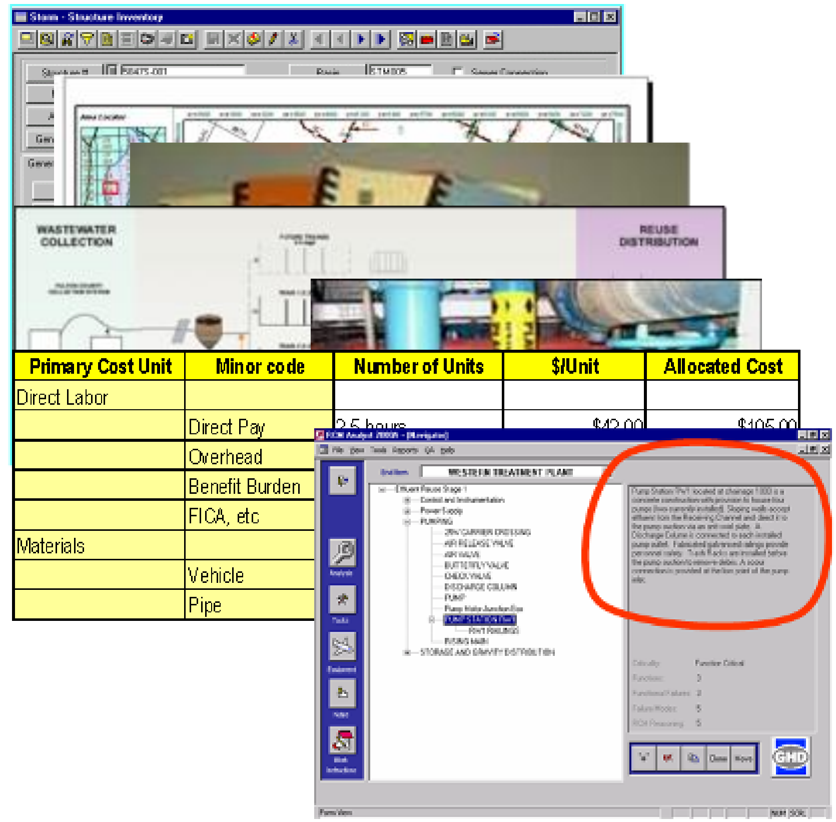




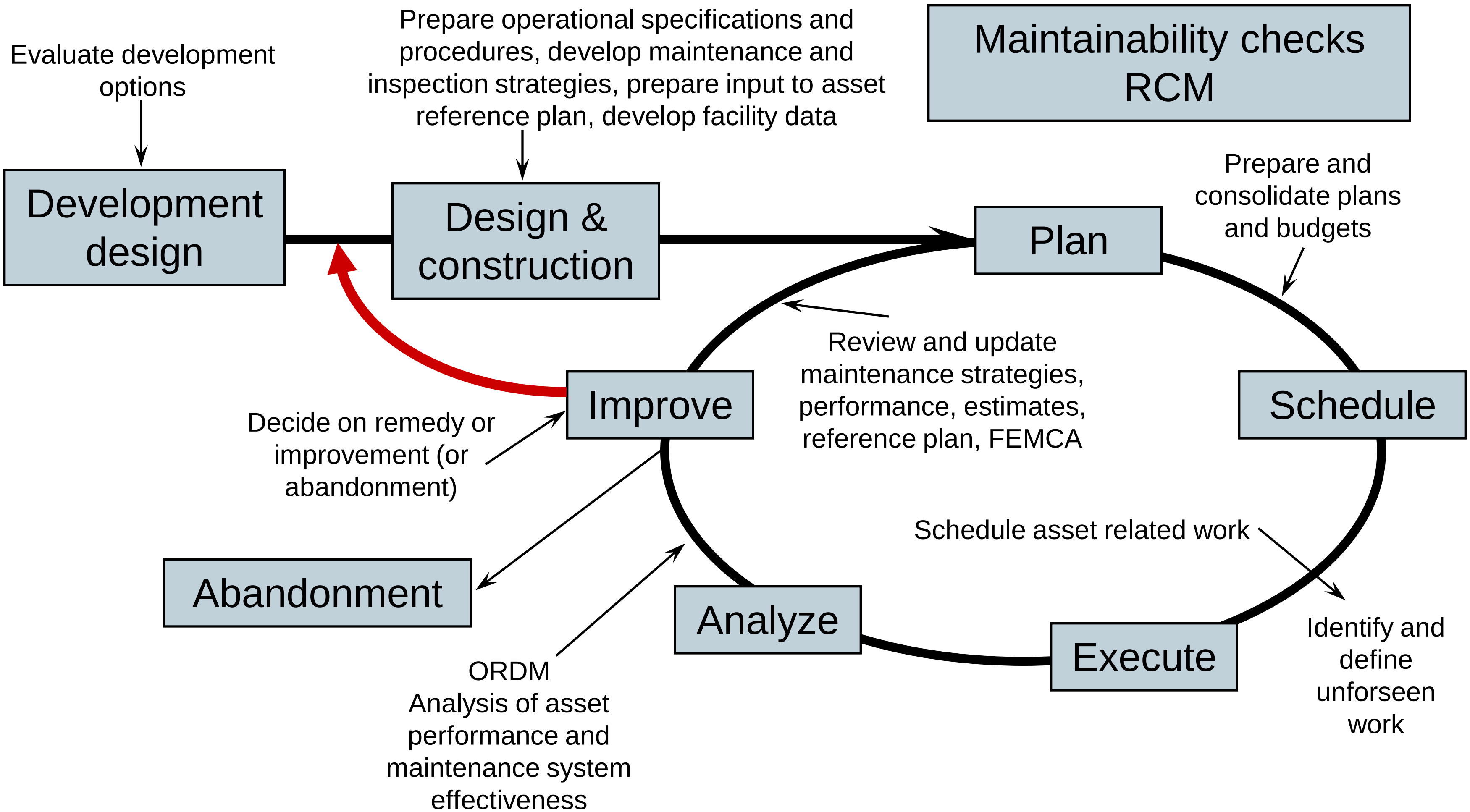
Major components of asset data

Used to *create an asset ID*…

- Physical attributes
- Geo-reference
- O&M manuals
- Drawings and photos
- Life cycle costs
- Knowledge and strategy



Linking maintenance and design



Key points from this session

Given my system, what are my best O&M strategies?

Key Points:·

- Reactive emergency maintenance can be the most expensive type of maintenance and should typically make up no more than 20% to 25% of total maintenance effort
- Preventive and predictive-based pro-active strategies should comprise the bulk of the effort
- Assets, especially dynamic assets, leave discernable clues as to their capacity to perform.
- The most cost effective maintenance strategy for a given asset is determined by the likelihood of failure and the consequence of failure.
- "Run to failure" may well be the most cost-effective maintenance strategy for a given asset, but only when coupled with a carefully developed failure response plan.

Associated Techniques:

- Condition-based monitoring plans and deployment
- Reliability Centered Management
- Root cause analysis
- Asset maintenance strategies (zero breakdown, total productivity, reliability centered maintenance)
- Failure response plans