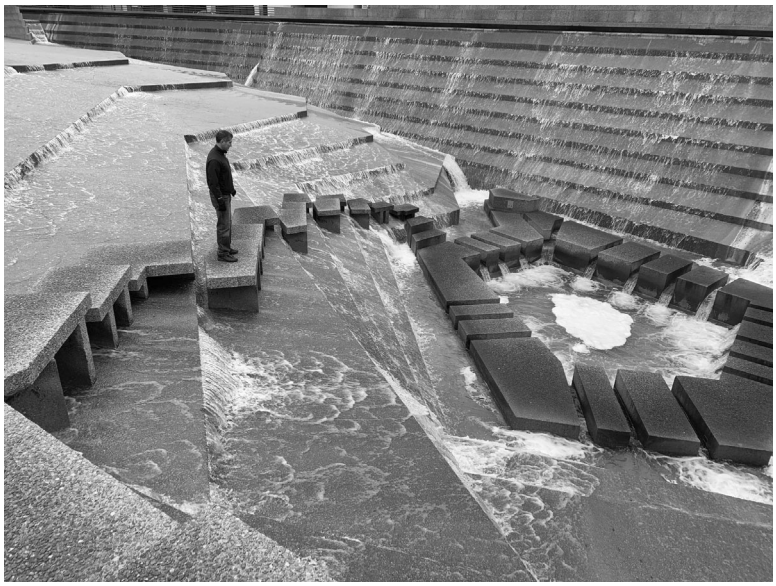
AIA Continuing Education Provider

UNIVERSITY of VIRGINIA

Preventive/Predictive Maintenance Systems

APPA Institute
for Facilities Management

Chris Smeds
Technology Officer
U.Va. Facilities Management
smeds@virginia.edu



Today we will cover…

Philosophy of Preventive Maintenance	Case Study: PM Culture Case Study: The impact of planning work at UVA. Case study: How many people does it take to change a light bulb at UVA?
Break	Preventive Maintenance Systems in Facilities Management

Credit(s) earned on completion of this course will be reported to American Institute of Architects (AIA) Continuing Education Session (CES) for AIA members.

Certificates of Completion for both AIA members and non-AIA members are available upon request.

This course is registered with AIA CES for continuing professional education. As such, it does not include content that may be deemed or construed to be an approval or endorsement by the AIA of any material of construction or any method or manner of handling, using, distributing, or dealing in any material or product.

Questions related to specific materials, methods, and services will be addressed at the conclusion of this presentation.

AIA Continuing Education Provider

Course Description

532: Preventative/Predictive Maintenance Systems

A comprehensive maintenance program relies on an effective approach to preventive and predictive maintenance. This session will address the key elements in establishing a preventive maintenance program and explore the challenges and benefits of sustaining the program.

Faculty Member: Chris Smeds

AIA Continuing Education Provider

Learning Objectives

AIA Continuing Education Provider

1. Learn the effective approach to preventive and predictive maintenance
2. Discuss the key elements in establishing a preventive maintenance program
3. Discuss the explore the challenges and benefits of sustaining the program
4. Discuss what a comprehensive maintenance program relies on

Have a question or comment?

Feel free to ask or share during the presentation

This is ***your*** session…

We all do preventive maintenance – 1.0

We all do preventive maintenance – 2.0

2005 Texas City refinery explosion

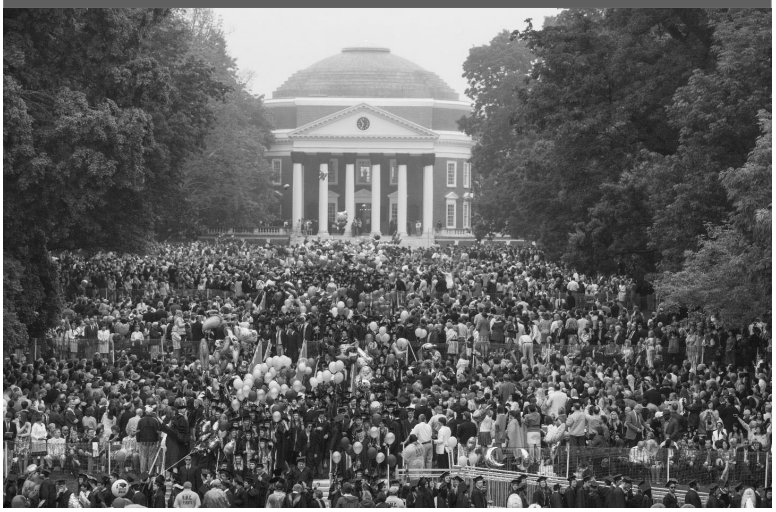
2005 Texas City refinery explosion

- 15 workers killed
- 170 workers injured
- The pressure wave was so powerful it shattered windows off site up to ¾ miles away
- An area estimated at 200,000 square feet was burned

- "Technical failings included … **a lack of preventive maintenance on safety critical systems…**"

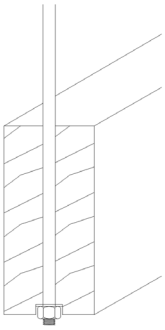
  (Report by Chemical Safety and Hazard Investigation Board)

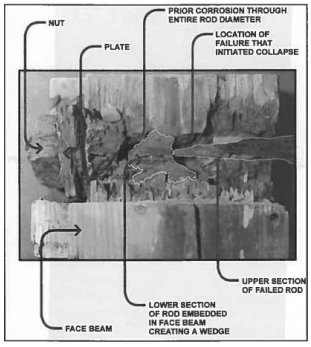
1997 University of Virginia balcony collapse



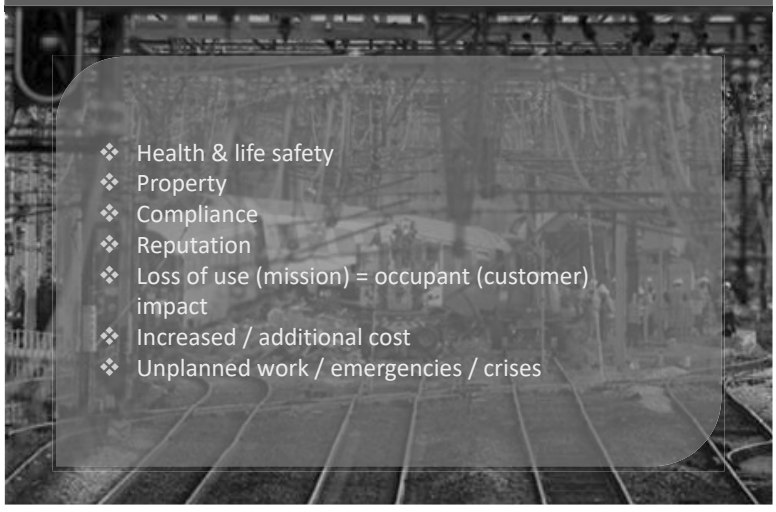
1997 University of Virginia balcony collapse

1997 University of Virginia balcony collapse





What is the cost of a maintenance failure?

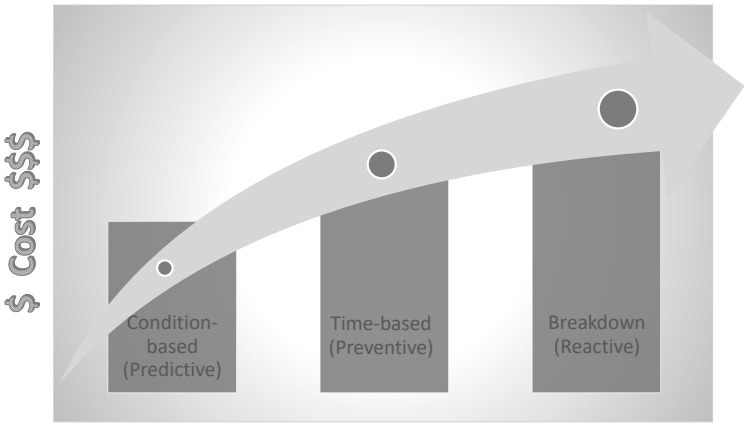


- Health & life safety
- Property
- Compliance
- Reputation
- Loss of use (mission) = occupant (customer) impact
- Increased / additional cost
- Unplanned work / emergencies / crises

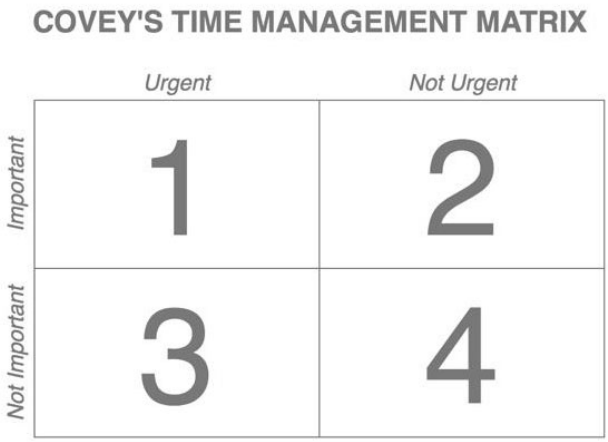
Options for a maintenance program

- No maintenance
- Reactive maintenance (RM, CM, DM)
- Preventive maintenance (PM)
  - Interval; time-based
  - Cycle time (e.g. # of revolutions; number of activations)
- Predictive maintenance (PdM)

The cost of maintenance



How do you prioritize maintenance?



How do you prioritize maintenance?

	URGENT	NOT URGENT
IMPORTANT	I ACTIVITIES: Crises, pressing problems, deadline-driven projects	II ACTIVITIES: Exercise, long-range planning, preparation, preventive maintenance, relationship building, personal growth activities, some leisure
NOT IMPORTANT	III ACTIVITIES: Interruptions, some calls, some mail, some reports, some meetings	IV ACTIVITIES: Trivia, busy work, some mail, some calls, time wasters, some pleasant activities

APPA's Maintenance Levels of Service include PM

Level	1	2	3	4	5
Description	Showpiece Facility	Comprehensive Stewardship	Managed Care	Reactive Management	Crisis Response
Customer Service & Response Time	Able to respond to virtually any type of service, immediate response.	Response to most service needs, including non-maintenance activities, is typically in a week or less.	Services available only by reducing maintenance, with response times of one month or less.	Services available only by reducing maintenance, with response times of one year or less.	Services not available unless directed from top administration, none provided except emergencies
Customer Satisfaction	Proud of facilities, have a high level of trust for the facilities organization.	Satisfied with facilities related services, usually complimentary of facilities staff.	Accustomed to basic level of facilities care. Generally able to perform mission duties. Lack of pride in physical environment.	Generally critical of cost, responsiveness, and quality of facilities services.	Consistent customer ridicule, mistrust of facilities services.
vs. Corrective Maintenance	100%	75-100%	50-75%	25-50%	<25%
Maintenance Mix	All recommend preventive maintenance (PM) is scheduled and performed on time. Emergencies (e.g. storms or power outages) are very infrequent and are handled efficiently.	A well-developed PM program: most required PM is done at a frequency slightly less than per defined schedule. Occasional emergencies caused by pump failures, cooling system failures etc.	Reactive maintenance predominates due to systems failing to perform, especially during harsh seasonal peaks. The high number of emergencies causes reports to upper administration.	Worn-out systems require staff to be scheduled to react to systems that are performing poorly or not at all. PM work possible consists of simple tasks and is done inconsistently.	No PM performed due to more pressing problems. Reactive maintenance is a necessity due to worn-out systems. Good emergency response because of skills gained in reacting to frequent system failures.
Aesthetics, Interior	Like-new finishes.	Clean/crisp finishes.	Average finishes.	Dingy finishes.	Neglected finishes.
Aesthetics, Exterior	Windows, doors, trim, exterior walls are like new.	Watertight, good appearance of exterior cleaners.	Minor leaks and blemishes, average exterior appearance.	Somewhat drafty and leaky, rough-looking exterior, extra painting necessary.	Inoperable windows, leaky windows, unpainted, cracked panes, significant air and water penetration, poor appearance overall.
Aesthetics, Lighting	Bright and clean, attractive lighting.	Bright and clean, attractive lighting.	Small percentage of lights out, generally well lit and clean.	Numerous lights out, some missing diffusers, secondary areas dark.	Dark, lots of shadows, bulbs and diffusers missing, cave-like, damaged, hardware missing.
Service Efficiency	Maintenance activities appear highly organized and focused. Service and maintenance calls are responded to immediately.	Maintenance activities appear organized with direction. Service and maintenance calls are responded to in a timely manner.	Maintenance activities appear to be somewhat organized, but remain people-dependant. Service and maintenance calls are variable and sporadic, without apparent cause.	Maintenance activities appear somewhat chaotic and are people-dependant. Service and maintenance call are typically not responded to in a timely manner.	Maintenance activities appear chaotic and without direction. Equipment and building components are routinely broken and inoperable. Service and maintenance calls are never responded to in a timely manner.
Building Systems' Reliability	Breakdown maintenance is rare and limited to vandalism and abuse repairs.	Breakdown maintenance is limited to system components short of mean time between failures (MTBF).	Building and systems components periodically or often fail.	Many systems are unreliable. Constant need for repair. Backlog of repair needs exceeds resources.	Many systems are non-functional. Repair instituted only for life safety issues.
Facility Maintenance Operating Budget as % of CRV	>4.0	3.5-4.0	3.0-3.5	2.5-3.0	<2.5
Campus Average FCI	<0.05	0.05-0.15	0.15-0.29	0.30-0.49	>0.50

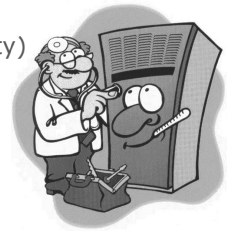
What is preventive maintenance?

A planned and controlled program of continuous inspections and corrective actions taken to ensure peak efficiency and minimize deterioration.

A procedure of inspecting, testing, and reconditioning a system at regular intervals according to specific instructions, intended to prevent failures in service or to retard deterioration.

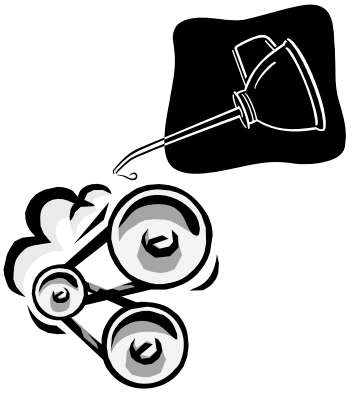
What are the objectives of preventive maintenance?

- Reduce frequency of unscheduled breakdowns and downtime of critical equipment and systems
- Extend service life of equipment
- Reduce energy consumption (sustainability)
- Improve safety
- Compliance
- Improve overall appearance of facilities
- Reduce overall maintenance costs
- Reduce occupant impact, improve service level
- Liability
- Improve service level



What are typical PM activities?

- Inspection
- Cleaning
- Adjustment
- Lubrication
- Replacing parts
- Analysis and testing
- Minor repairs



Does a preventive maintenance program prevent failures?

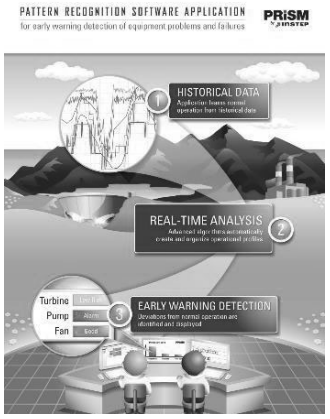
- Is more maintenance better?
  - "70% failures are self-induced" ??
- Is time-based better?
- Is cycle frequency better?
- Is 0% failure ideal?
- Is 100% PM completion ideal?
  - World class: > 95% PM completion
  - Reality: 60% (20-30% properly done)!
  - What is your PM completion %?

Predictive technologies

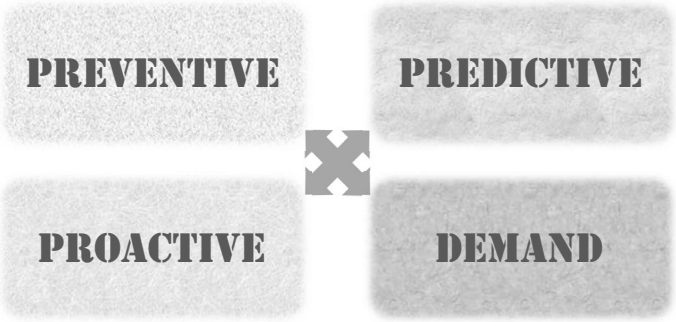
Inspections
- Visual
- Noise
- Thermal
- Vibration
- Fluid analysis
- Performance analysis (flow across a filter)

Monitoring
- Automated BAS system monitoring

Data-based
- Real-time data from building systems
- Fault Detection and Diagnosis (FDD)
- Trending & Modeling (e.g. flow, InStep Prism)



Reliability Centered Maintenance / Culture



Case study:

"The best service is no service."

UVA McCormick Rd. Zone

Air filter's impact on customer service – not just a bunch of hot air!

Case study:

The impact of planning work at UVA

Meet the Coordinators:

Mike Jessee – North Grounds

Eric Luedeking – West Grounds

Jerry Schwartz – Newcomb

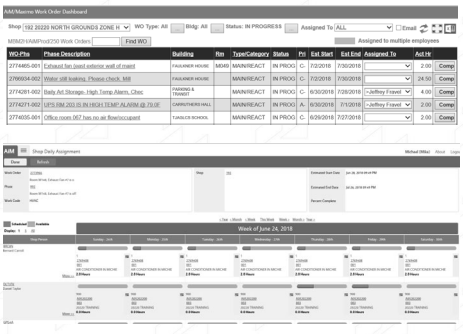
Paige Herndon – Fire & Life Safety

John Quinn – Central Grounds

Jason Falls - McCormick

The Maintenance Coordinator Initiative

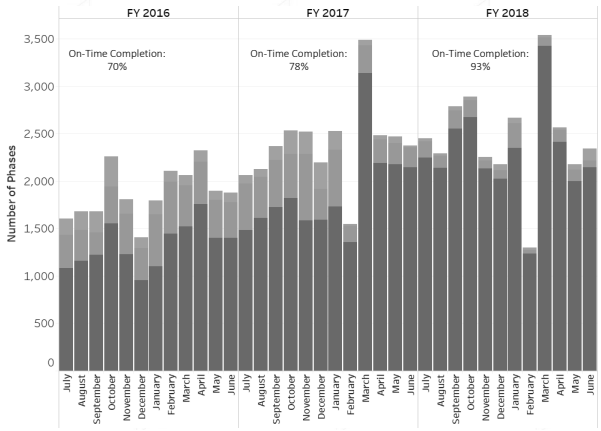
Improve 'wrench time' through planning & scheduling:



PM Completion Rates
- improved in coordinator maintenance shops

31%

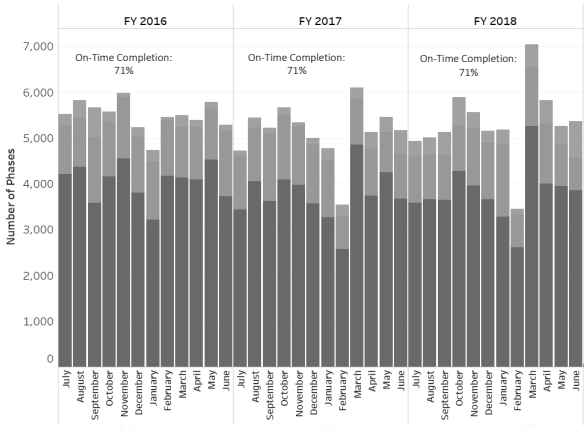
Increase in # of PM phases FY16 to FY18



PM Completion Rates – all other non-coordinator shops combined

3%

Decrease in # of PM phases FY16 to FY18



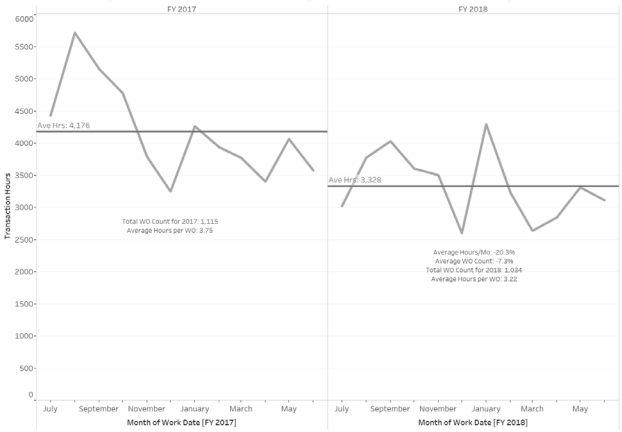
Reactive Work – decreases in coordinator maintenance shops from FY17-18

7%

Decrease in # of WOs

20%

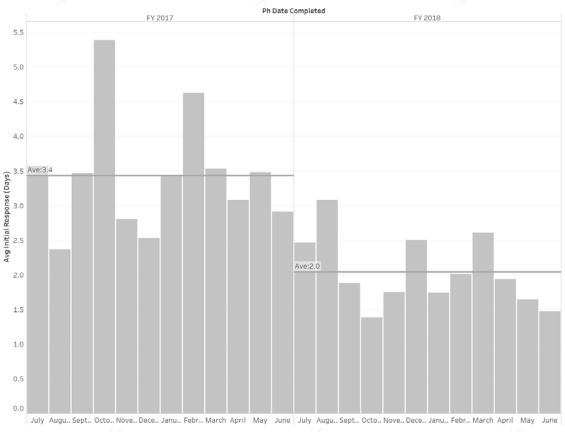
Decrease in labor hrs charged per month



Initial Response Time – to reactive WOs in coordinator maintenance shops improve in 2018

41%

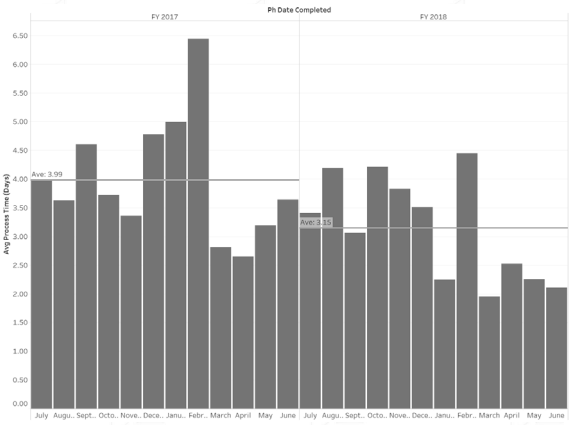
Improvement in time taken to begin work on a reactive WO



Reactive Process Time – work is being completed more quickly once started in coordinator maintenance shops

21%

Improvement in time spent on reactive work



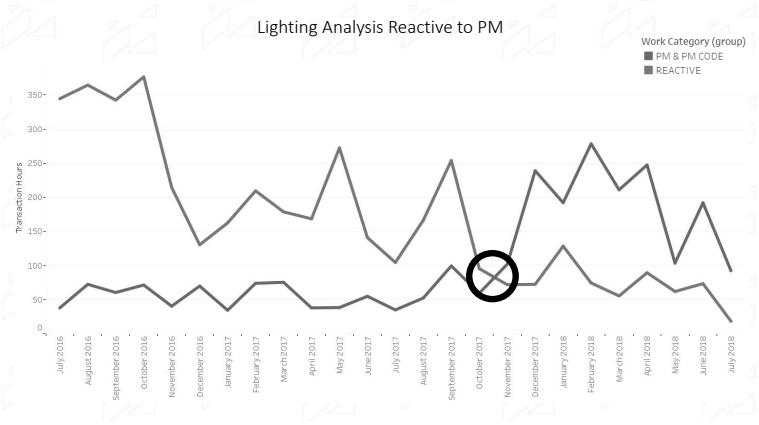
Case study:

How many people does it take to change a light bulb at UVA?

Central Grounds Zone Maintenance Analysis

Lighting Frequency Analysis for Central Grounds

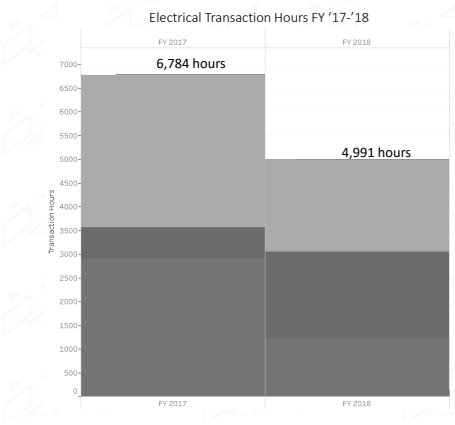
Building	Total Hours	Reactive Hours	Percentage Reactive	Original Frequency	New Frequency
RANDALL HALL	16	2.5	15.63%		Bi-Monthly
GARRETT HALL	99.5	14.5	14.57%	Monthly	Bi-Monthly
VARSITY HALL	4	2	50.00%	Semi-Annual	Quarterly
ROBERTSON HALL	641	8	1.25%	Semi-Weekly	Monthly



Reactive to Proactive

- Reduced the total amount of hours spent maintaining assets
- Improved customer service

35%
less hours spent
on electric assets



Case study take-aways: keys to a successful PM program:

It starts with culture change

Staff your PM program

Use your data

Tell your story

It pays to plan!

Preventive Maintenance Systems in Facilities Organizations

Preventive Maintenance Systems

- Various types of PM systems
  - People-based
  - Paper-based
  - Excel-based
  - CAFM/CMMS/IWMS

- What are you doing?
  - What works well? What doesn't work so well? What do you wish it did?

A Preventive Maintenance System begins with assets

- Accurate inventory
- Initial inventory
  - Physical inventory
  - Construction drawings
  - Commissioning process
  - BIM / COBIE model

- Updating inventory
  - How do you keep your asset inventory up-to-date?
  - Update on PM?
  - Update on service call?
  - Periodic update?

Asset terminology

Asset Terminology

•3Com ADT Advance Technologies Aerco Amerex Corporation American-Standard A.O. Smith Armstrong Babcock & Wilcox Baltimore Aircoil Bell & Gossett Brands Bryan Boilers Bussman Canon Inc Carrier Caterpillar Central Sprinkler Corp Cleaver Brooks Clow Canada Compaq Cook Craftsman Cutler-Hammer Data Aire Dayton Dell Digital Domestic Dor-O-Matic Drew Electrical Elkay Energy Labs Engineered Air Epson Ericsson Fedders Filtrine Fisher Flygt Ford Frigidaire Fulton Furniture GE General Motors General Refrigeration GF Morin Greenheck Hayward Herman Miller Hewlett Packard Hobart HON Honeywell Hoover Hubbell IBM Ice-O-Matic InFocus Corporation Ingersoll-Rand International Environmental ITT Johnson Controls Kenmore Kidde KitchenAid Krups Liebert Lifefitness Mail Mas MarRad McQuay Motorola Myers Nailor NEC Netgear Nortel Office Supplies Palm Panasonic Peerless Electric Penn Ventilator Polycom Port-A-Cool Powerex Ramsey Rehau Reliance Rheem Rittling Rockwell Sanyo Sealy Seating Unlimited Sentech Sharp Skil Sony SteamEye Steelcase Sun Microsystems Taskmaster Trane Tranter Universal Boiler Works Inc. US Electric Motor Viking Watts Western Safety Westinghouse Whirlpool Xerox York Zenith Unavailable Sears Grainger Kohler

Common Asset Attributes

- Spec ID
- Reference ID
- Serial Number
- Condition
- Criticality
- Brand Name
- Model Number

CSI MasterFormat Number

Local Name

Criticality Codes

Score	Effect	Criticality Comment
1	None	No reason to expect failure to have any effect on safety, health, environment, or mission.
2	Very Low	Minor disruption to facility function. Repair to failure can be accomplished during trouble call.
3	Low	Minor disruption to facility function. Repair to failure may be longer than trouble call but does not delay mission.
4	Low to Moderate	Moderate disruption to facility function. Some portion of mission may need to be reworked or process delayed.
5	Moderate	Moderate disruption to facility function. 100% of mission may need to be reworked or process delayed.
6	Moderate to High	Moderate disruption to facility function. Some portion of mission is lost. Moderate delay in restoring function.
7	High	High disruption to facility function. Some portion of mission is lost. Significant delay in restoring function.
8	Very High	High disruption to facility function. All of mission is lost. Significant delay in restoring function.
9	Hazard	Potential safety, health, or environmental issue. Failure will occur with warning.
10	Hazard	Potential safety, health, or environmental issue. Failure will occur without warning.

Asset inventory basics – common asset attributes

- Asset ID
  - Smart numbers?
  - Sharpie? Barcode? RFID? QR Codes?
- Hierarchy
  - Uniformat
  - Systems
    - Note classification doesn't necessarily tell you which system an asset is part of
- Location
  - Building, Room, Floor
  - Geocoding
  - Locating on floor plans, CAD drawing, GIS

Asset inventory basics - Uniformat

Figure 1 - ASTM UNIFORMAT II Classification of Building Elements (E1557-97)

Level 1 Major Group Elements	Level 2 Group Elements	Level 3 Individual Elements
A. SUBSTRUCTURE	A10 Foundations	A1010 Standard Foundations A1020 Special Foundations A1030 Slab on Grade
	A20 Basement Construction	A2010 Basement Excavation A2020 Basement Walls
B. SHELL	B10 Superstructure	B1010 Floor Construction B1020 Roof Construction
	B20 Exterior Closure	B2010 Exterior Walls B2020 Exterior Windows Exterior Doors
	B30 Roofing	B3010 Roof Coverings B3020 Roof Openings
C. INTERIORS	C10 Interior Construction	C1010 Partitions C1020 Interior Doors C1030 Specialties
	C20 Staircases	C2010 Stair Construction C2020 Stair Finishes
	C30 Interior Finishes	C3010 Wall Finishes C3020 Floor Finishes C3030 Ceiling Finishes
D. SERVICES	D10 Conveying Systems	D1010 Elevators D1020 Escalators & Moving Walks D1030 Material Handling Systems
	D20 Plumbing	D2010 Plumbing Fixtures D2020 Domestic Water Distribution D2030 Sanitary Waste D2040 Rain Water Drainage D2050 Special Plumbing Systems
	D30 HVAC	D3010 Energy Supply D3020 Heat Generating Systems

Asset inventory basics – Common asset attributes, cont…

- Serial Number
- Condition
- Criticality
- Brand Name
- Model Number

Criticality Codes

Score	Effect	Criticality Comment
1	None	No reason to expect failure to have any effect on safety, health, environment, or mission.
2	Very Low	Minor disruption to facility function. Repair to failure can be accomplished during trouble call.
3	Low	Minor disruption to facility function. Repair to failure may be longer than trouble call but does not delay mission.
4	Low to Moderate	Moderate disruption to facility function. Some portion of mission may need to be reworked or process delayed.
5	Moderate	Moderate disruption to facility function. 100% of mission may need to be reworked or process delayed.
6	Moderate to High	Moderate disruption to facility function. Some portion of mission is lost. Moderate delay in restoring function.
7	High	High disruption to facility function. Some portion of mission is lost. Significant delay in restoring function.
8	Very High	High disruption to facility function. All of mission is lost. Significant delay in restoring function.
9	Hazard	Potential safety, health, or environmental issue. Failure will occur with warning.
10	Hazard	Potential safety, health, or environmental issue. Failure will occur without warning.

Asset inventory basics – Common asset attributes, cont…

Asset Specific Attributes (varies by asset type)

- Description
- Amps
- Voltage
- KVA
- GPM
- Belt Size
- BTUH
- **RPM**
- **Filter Size**
- **Ton**
- **HP**
- **Gal**
- **CFM**
- **Max P**

Asset inventory basics – Common asset attributes, cont…

Asset Specific Attributes (varies by asset type)

- Description
- Amps
- Voltage
- KVA
- GPM
- Belt Size
- BTUH

RPM
Filter Size
Ton
HP
Gal
CFM
Max P

A Preventive Maintenance System begins with assets

Additional data to consider

- Confined Space
- Lock Out-Tag Out
- Photo URL
- Service/Parts Manuals
- Special Maintenance Instructions
- Maintenance notes/log
- Asset Retirement Explanation
- Links to locations served

What maintenance is required for your assets?

- Regulatory compliance requirements
- Risk assessment | failure mode analysis

- OEM manual
- RS Means
- GSA PM guidelines (available on web)
- Others (e.g. Whitestone, trade publications)

- Maintenance staff (tribal knowledge)
- Equipment history

Preventive Maintenance Job Plans

- Tasks
  - Checkpoints
- Labor hours
- Materials

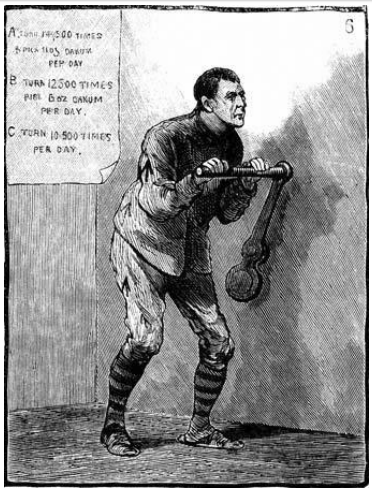
- Frequency
  - Weekly, monthly, quarterly, semi-annual, annual?
- Sequence

Sample PM tasks

PREVENTIVE MAINTENANCE COMPONENTS		LH	W	M	Q	S	A
DUPLEX AIR COMPRESSOR							
1.	Replace compressor oil	.341			✓	✓	✓
2.	Perform operation check of compressor system and adjust as required	.221			✓	✓	✓
3.	Check motor operation for excessive vibration, noise and overheating	.042			✓	✓	✓
4.	Lubricate motor	.047			✓	✓	✓
5.	Check operation of pressure release valve	.030			✓	✓	✓
6.	Check tension, condition, and alignment of V-belts; adjust as needed.	.030			✓	✓	✓
7.	Drain moisture from air storage tank and check low pressure cut-in.	.046			✓	✓	✓
8.	Clean air intake filter on compressor.	.177			✓	✓	✓
9.	Clean oil and water tap.	.177			✓	✓	✓
10.	Clean exterior of compressor, motor and surrounding area.	.066			✓	✓	✓
11.	Fill out maintenance, checklist and report deficiencies.	.022			✓	✓	✓
	Total Labor-Hours / period				**1.19**	**1.19**	**1.19**
	Total Labor-Hours / year				**2.39**	**1.19**	**1.19**
	Total Annual Hours						4.79

Excerpted from R.S. Means Facility Maintenance and Repair Costs Manual.

PM Work Order Generation



PM Work Ordes

UVA Facilities Management — **PM Work Order Print 2238961**

Description: EMERG LIGHTS/EXIT SIGNS QUARTERLY (NORTH GROUNDS RECREATION CTR)	**Property:** 5561 (NORTH GROUNDS RECREATION **Status:** OPEN **Date Created:** Dec 18, 2014, 5:08 PM **Created By:** JNT6H
Type/Cat: MAINTENANCE / PM **Contact:** JOEY TOMBS - FM-PREVENTIVE-MAINT@VIRGINIA.EDU - 243-1458	**Project:**

(FM-North Zone Maintenance 151) SHOP 151

PHASE: 001	**Location:**	**Phase Priority:**	PM-2
		Work Code:	ELECTRICAL
Description: EMERGENCY LIGHTS/EXIT SIGNS - EMERGENCY LIGHTS/ EXIT SIGNS (NORTH GROUNDS RECREATION CTR)		**Status:**	IN PROGRESS
		Status Date:	Dec 18, 2014, 5:08 PM
		Status By:	JNT6H
		Week:	1
		Est. Start:	Dec 29, 2014
		Est. End:	Jan 26, 2015
		Actual End:	
Created: Dec 18, 2014, 5:08 PM by JNT6H		**FM Route:**	

SHOP ASSIGNMENT: 151 (FM-North Zone Maintenance 151)

Shop Person:	WAL4T (William Layne)	**Primary:**	
Assigned By:	WAL4T	**Assigned Date:** Dec 23, 2014	**Certified:**

Asset Tag: 100023 — **Asset Priority:** 0
Description: EMERGENCY LIGHTS/EXIT SIGNS — **Asset Group:** D5005-250 (EMERGENCY LIGHTS AND EXIT SIGNS)
Manufacturer — **Asset Type:** SYSTEM
Model: — **Serial No:**

SERVICE ORDR. DEVELOP CORRECTIVE MAINTENANCE (IP) WORK ORDER FOR LIGHT DISCREPANCIES FOUND. PLEASE INCLUDE THE EQUIPMENT NUMBER ON THE CORRECTIVE MAINTENANCE WORK ORDER.

LOCATION: NORTH WING, MAIN FLOOR

EMERGENCY LIGHTS

QUANTITY	LOCATION	MANUFACTURER
(1)	WOMEN'S ROOM	HUBBELL
(1)	MEN'S ROOM	HUBBELL
(2)	MULTIPURPOSE ROOM 2	TELEDYNE
(2)	MULTIPURPOSE ROOM 1	TELEDYNE
(9)	GYMNASIUM	HUBBELL
(1)	GYMNASIUM-MAIN ENTRANCE (RIGHT SIDE)	HUBBELL
(1)	GYMNASIUM-MAIN ENTRANCE (LEFT SIDE)	HUBBELL
(4)	MAIN LOBBY	LITHONIA
(1)	MECHANICAL ROOM	DUAL-LITE
(12)	WEIGHT TRAINING AREA	PMC LIGHTING
(1)	VENDING AREA	HUBBELL

EXIT LIGHTS

QUANTITY	LOCATION	MANUFACTURER
(1)	EMERGENCY DOOR BY WOMEN'S ROOM	HAVILITE
(2)	MULTIPURPOSE ROOM 2	TELEDYNE
(2)	MULTIPURPOSE ROOM 1	TELEDYNE/LITHONIA
(9)	GYMNASIUM	HUBBELL
(4)	MAIN LOBBY	HAVILITE
(1)	MAIN ENTRANCE VESTIBULE	HAVILITE

Jan 8, 2015, 4:29 PM — UVA Facilities Management Work Order **2238961** — Page: 1

Handling PM Work Orders

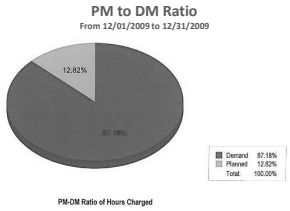
- What is the normal work flow of PM work orders?
  - How are PM work orders distributed?
  - Planning & Scheduling?
- Things to consider:
  - How do you handle completion? (e.g. status change? Labor hours applied?)
  - How do you handle deficiencies found during PM?
  - How do you handle deferred PM?

PM – Reactive Maintenance Link

- Service calls (reactive work) vs. PM work orders
- Asset ID on service calls
  - We want to answer the question: Is preventive maintenance impacting service calls?
- Failure codes / types

Using the data from your PM program – what do you measure?

- Reporting / KPIs / dashboards
  - Percentage of PM work orders completed
  - Estimated vs. actual hours
  - Overdue PM
  - Deferred PM
  - Building system reliability
  - PM vs. corrective work
  - PM vs. major maintenance and repair
  - Cost reports



Unintentionally incentivizing the wrong behaviors

- **Response time to service calls**: Institutions track this metric to help improve customer service. However, publicly posting this metric sends the signal to staff that responding to service calls is more critical than scheduled work. As a result, staff prioritize service calls over preventive maintenance tasks.
- **Preventive maintenance completion rates**: This metric is intended to encourage staff to complete all of their assigned preventive work orders. However, asking staff to focus on this metric can lead to artificially high completion rates. Some institutions report staff close out tasks that are not fully resolved.
- **Time to close work orders**: This metric aims to minimize the number of open work orders and maximize the volume of work completed across all staff. However, staff often close work orders before they are finished and open new ones, duplicating the work to reduce their time to close.
- **Cost per work order**: The purpose of tracking cost per work order is to minimize costs. But asking staff to manage this metric often leads to staff completing only the cheapest fixes and re-logging more expensive work for later.

Recommended operational metrics

Metric	Definition	Directionality
Number of Service Calls	Number of customer-initiated work orders	↓
Compliance Completion Rate	Percentage of required preventive maintenance tasks completed	↑
Maintenance Mix (PM/RM)	Ratio of preventive maintenance to reactive maintenance tasks completed	↑
Rework	Number of work orders submitted as a result of an error in recently performed maintenance	↓
Follow Up Work Orders per 100 PM Checks	Number of follow up work orders for repairs submitted during 100 preventive maintenance checks	↓
Work Order Queue (Backlog) per Employee	Number of open preventive maintenance work orders in an employee's queue	↓

Source: Educational Advisor Board (EAB), Facility Forum

Recommended strategic metrics

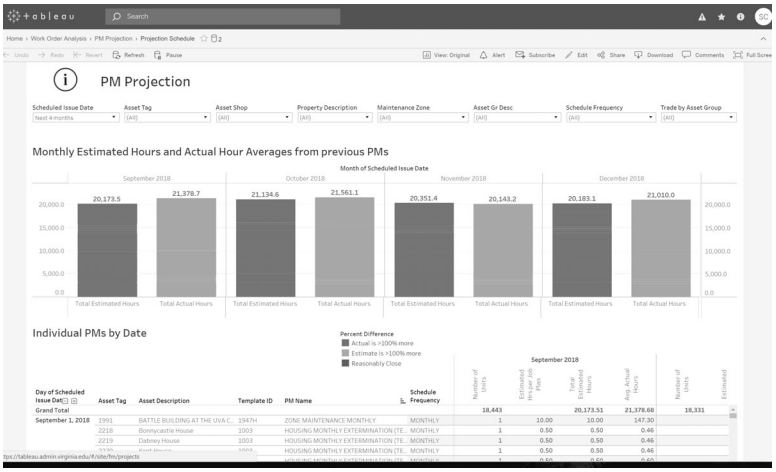
Metric	Definition	Directionality
Number of Preventable Service Calls	Number of customer-initiated work orders that could have been prevented through performing scheduled preventive maintenance	↓
System Runtime/Downtime	Number of days running without failure or time and extent of system shutdown	↑ / ↓
Proactive Maintenance	Number of work orders submitted by staff for issues observed in the field	↑
Failure Code	Indicator of why an asset failed to facilitate better maintenance interventions	N/A
Normalized Investment	Money spent on new equipment due to inadequate preventive maintenance	↓
Customer Satisfaction	Customer responses on work order satisfaction questionnaires	↑

Source: Educational Advisor Board (EAB), Facility Forum

Sample PM completion report

	Category	Shop	Shop Description	Manager	LABOR COMPLETE	CLOSED	CANCELED	IN PROGRESS	TOTAL	PERCENT COMPLETE	NO LABOR
2	PM CODE	110	HOUSING MAINTENANCE AREA 1	JEFFREY LEAKE	35	0	0	0	35	100%	0
3	PM CODE	111	HOUSING MAINTENANCE AREA 2	DOUG DEMUTH	23	0	0	0	23	95%	1
4	PM CODE	141	FM ARTS PRECINCT ZONE 141	TONY MARUSAK	25	0	0	0	25	100%	0
5	PM CODE	151	FM-North Zone Maintenance 151	GARY WOOD	13	0	0	0	13	100%	0
6	PM CODE	156	FM-SW McCormick Zone Maintenance 156	de Bary, Edmond J JR. (Ed	1	0	0	0	1	100%	0
7	PM CODE	161	FM-Newcomb Zone Maintenance 161	Fitzgerald, Mark W (Spark	4	0	0	0	4	100%	0
8	PM CODE	166	FM-CENTRAL GROUNDS ZONE ELECTRICAL/PLUMBING 166	Spencer, Donald Randolph	12	1	0	0	13	76%	3
9	PM CODE	167	FM-CENTRAL GROUNDS ZONE CARPENTRY 167	SPENCER, DONALD RANDOLPH	9	0	0	0	9	100%	0
10	PM CODE	171	FM-Maintenance-Carpentry 171	Toney, John L	5	0	0	0	5	20%	4
11	PM CODE	176	FM-Maintenance-Plumbing176	Bryant, Howard Lee (Lee)	53	2	0	2	57	96%	0
12	PM CODE	177	FM-Maintenance-Electrical 177	Russell, Wayne A	1	0	0	1	2	50%	0
13	PM CODE	182	FM-FIRE PROTECTION	Spears, James E Jr	41	0	0	0	41	100%	0
14	PM CODE	183	FM-FIRE PROTECTION	Johnson, Forrest V	27	0	0	0	27	100%	0
15	PM CODE	184	FM-FIRE PROTECTION	Farmer, Ronald Eugene	119	0	0	0	119	100%	0
16	PM CODE	187	FM-ELEVATOR (HSPP)	RICHARD, MICHAEL	141	0	0	0	141	100%	0
17	PM CODE	188	FM ELEVATOR (ACADEMIC)	DOWELL, JAMES	163	0	0	0	163	100%	0
18	PM CODE	192	FM-HVAC 192	Henry, Roger L	0	0	0	1	1	0%	0
19	PM CODE	210	FM SAFETY PROGRAM	LAURA DUCKWORTH	24	0	0	5	29	82%	0
20	PM CODE	772	FM BUILDING SERVICES 772	DEBORAH PALMER	32	0	0	2	34	94%	0
21	PM CODE	776	FM-Bldg Services 776	WANDA LUCAS	6	0	0	0	6	100%	0
22	PM CODE	777	FM-Bldg Services 777	CHARLES WHITE	3	0	0	0	3	100%	0
23	PM CODE	778	FM-Bldg Services 778	GOUGH, PHYLLIS ELAINE	2	0	0	0	2	100%	0
24	PM CODE	785	FM-HSPP Bldg Services 785	Fitzgerald, Michael Troy	11	0	0	0	11	100%	0
25	PM CODE	791	FM-Bldg Services 791	KEITH LEWIS	15	0	0	0	15	100%	0
26	PM CODE	792	FM-Bldg Services 792	FINDLEY, GERALYN A	2	0	0	0	2	100%	0
27	PM CODE	793	FM-Bldg Services 793	RICHARDSON, RANDALL	8	0	0	0	8	100%	0
28	PM CODE	796	FM-Bldg Services 796	Snead, Wanda M	3	0	0	0	3	100%	0
29	PM CODE	797	FM-Bldg Services 797	KEY, JAMES (KEV)	3	0	0	0	3	100%	0
30	PM CODE	798	FM-Bldg Services 798	Sayre, James Edward	2	0	0	0	2	100%	0
31					**783**	**3**	**0**	**11**	**797**	**98%**	**8** TOT
32											
33	Category	Shop	Shop Description	Manager	LABOR COMPLETE	CLOSED	CANCELED	IN PROGRESS	TOTAL	PERCENT COMPLETE	NO LABOR
34	PM	110	HOUSING MAINTENANCE AREA 1	JEFFREY LEAKE	153	0	0	0	153	98%	2
4C	PM	111	HOUSING MAINTENANCE AREA 2	DOUG DEMUTH	303	0	0	1	304	99%	2
36	PM	120	HOUSING LOCK SHOP (ACCESS)	TROY MILLER	236	0	0	0	236	100%	0

Sample PM projection



Using the data in your PM program

- Planning & scheduling work
  - Scheduling downtimes – **reducing customer impact!!**
  - Scheduling labor
  - Forecasting labor costs and resources required
  - Forecasting material costs and resources required
  - Program cost forecasting

Using the data in your PM program (more advanced)

- Kitting
  - Link to inventory
  - Link to purchasing & JIT delivery
- Routing
- Data analysis
  - Relationship of service calls to PM
  - Recurring failures on assets
  - Ad-hoc data reporting (e.g. budget adjustments)
  - Others?

Using the data in your PM program (advanced)

- Real time monitoring
- Predictive modeling & trend analysis
- Real time modeling & predictive fault detection

Prerequisites for a successful PM program

- Strong management support
- Acceptance from the front line
- Include continuous training
- Implement in phases
- Once implemented, do not neglect
- Establish ownership: either front line or Program manager

Additional best practices

- Begin with an understanding of your risk and service level goals
- Start with critical/code compliant assets and assets with high failure rates/maintenance costs
- Be proactive and look for ways to utilize predictive technologies
- Automate whenever possible
- Engage front-line staff
- Use your data!

Questions and/or comments?

Thank you

UNIVERSITY of VIRGINIA

Chris Smeds
Technology Officer
U.Va. Facilities Management

smeds@virginia.edu
(434) 982-4796 office

http://www.fm.virginia.edu/

This concludes The American Institute of Architects Continuing Education Systems Course

AIA Continuing Education Provider