Effect of Equipment Age on Reliability

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Sodexo Health Technology Management

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About the Speakers: Binseng Wang

- Binseng Wang is a vice-president with Sodexo HTM, an independent medical equipment service organization located in the USA.
- Previously, Dr. Wang was Director, Quality & Regulatory Affairs for Greenwood Marketing LLC, Vice President, Quality & Regulatory Affairs, for Sundance Enterprises, Aramark Healthcare Technologies, and MEDIQ/PRN. He also worked as a Visiting Scientist at NIH, Adjunct Professor at the Milwaukee School of Engineering, and Associate Professor at Univ. of Campinas, Brazil.
- He is a fellow of ACCE and AIMBE. He received the 2010 AAMI CE Achievement Award, the 2015 ACCE Lifetime Achievement Award and the 2019 AAMI-TRIMEDX Iconoclast award. He was inducted into the Clinical Engineering Hall of Fame by ACCE in 2017 and granted the title of Honorary Life Member by the Int'l Federation of Medical & Biological Eng. (IFMBE) in 2022. He was chair of ACCE International Committee 2018-2023.
- He earned a Doctor of Science degree from MIT and is a Certified Clinical Engineer (CCE).

Binseng Wang, ScD, CCE

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About the Speakers: Torgeir Rui

- Torgeir Rui is a lead data analyst with Sodexo HTM, an independent medical equipment service organization.
- He has held various research and development roles in logistics automation, healthcare, healthcare technology management, electric power, and automotive industries.
- He earned a Sivilingeniør (M.Sc.Eng. equivalent) degree from the Norwegian University of Science and Technology.

Torgeir Rui, SivIng

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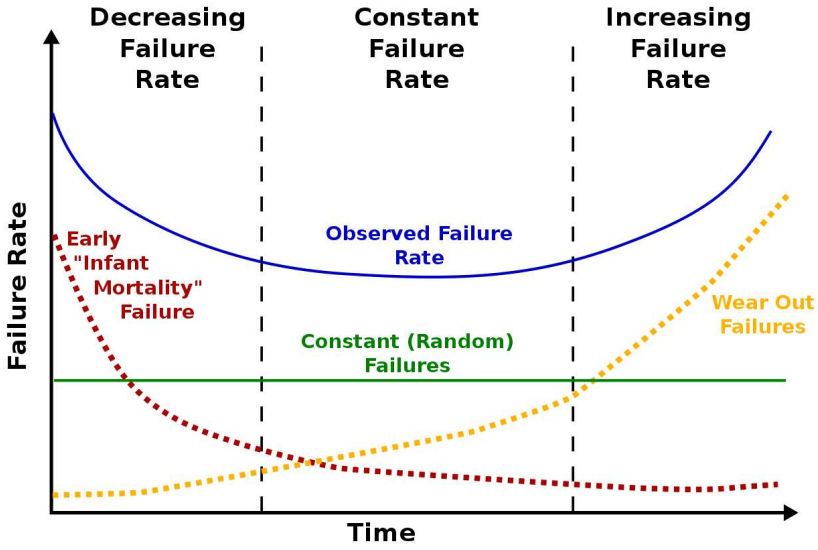
INTRODUCTION - Traditional view

- Industrial maintenance experience showed most equipment exhibit a bathtub-like failure curve composed of:
  - Early failures (“infant mortality”)
  - Constant failures (“random”)
  - Wear out failures (age related)
- AUDIENCE TEST
  - Do you agree this experience applies to medical equipment?
    - If not, why not?
    - If yes, does it apply to all medical equipment?



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INTRODUCTION - Industrial machines vs medical equipment

- Comparison between industrial machines and medical equipment

TECHNICAL ASPECTS	PRODUCTION MACHINE	MEDICAL EQUIPMENT
Mechanical components	Large, heavy, moving	Mostly small, light, small movements
Electrical components	High power, some high voltage	Mostly low power, few high voltage
Electronic components	Solid-state + software controls, limited networking typically within facility	Solid-state + software controls, extensive networking even outside
Cleanliness	Dirty, scraps, oil/grease	Body fluid, infectious material
Mobility	Mostly fixed/installed	Some fixed but many moveable
Utilization	12-24 hours	Few 24x7, most <12h/day, standby
Robustness	Well built for durability	Some robust while others may not

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INTRODUCTION - Implications of age effects on reliability

- If equipment's age does have significant effects on its reliability (and safety for patients and users), we have the obligation to consider
  - Inventory sufficiency & back-ups
  - Maintenance strategy revisions
  - Replacement/retirement planning
- Example: many HDOs and consultants use the AHA's *Estimated Useful Lives of Depreciable Hospital Assets* for replacement planning (indicated with ↑ in Results)

METHODOLOGY

- **Data Source**: Sodexo HTM's MinuteMan (MM) CMMS database with ~520,000 pieces of equipment belonging to >100 hospital clients managed in the last 25+ years. However, only a portion (~87%) of the inventory and service history could be analyzed due to data quality issues.

- **Equipment Age**: year manufactured or purchased
  - Equipment Age When Managed: equipment age at which time we managed it, i.e., performed a service (PM, CM, recall, etc.) or controlled it as an asset, regardless when the coverage started and whether it is still in use or not.
  - #Equipment Managed: number of pieces of equipment at a certain age when they were under our management coverage.

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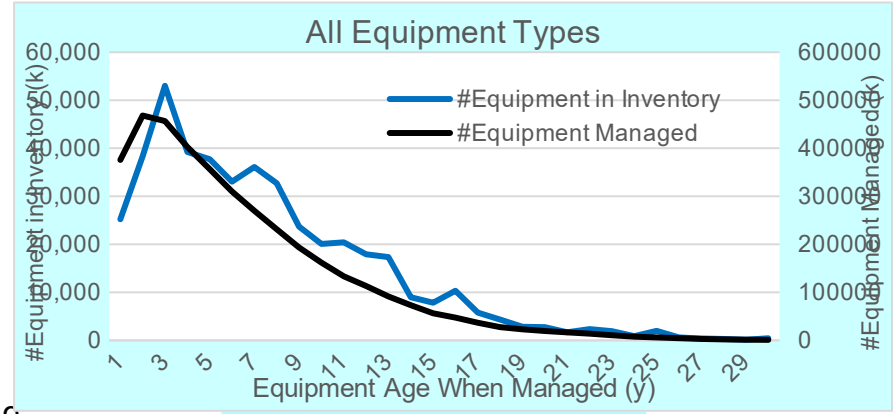
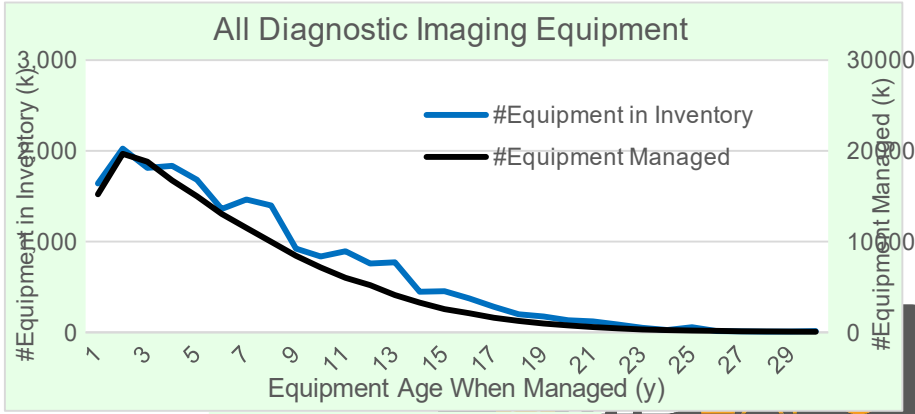
METHODOLOGY (CONT.)

- **CAUTION**: *#Equipment Managed ≠* #equipment within active inventory, either currently or at a particular date. Some equipment may have since been disposed and some were used for several years before or after the *Equipment Age When Managed.* Typically, *#Equipment Serviced >>* Inventory count by age (by a factor of 10), as each piece is counted during all the years it was being managed.



TIC = 448,000; TEM = 3,912,145



TIC = 19,858; TEM = 165,705

METHODOLOGY (CONT.)

- **Equipment Reliability**:
  - Individual equipment type: number of PM and CM workorders performed in each *Equipment Age When Managed* divided by the *#Equipment Managed* in that age period, for a certain equipment type. Each equipment type may have multiple brands and models.
  - Multiple equipment types: average of individual equipment type averaged PMs and CMs in each *Equipment Age When Managed,* for multiple equipment types (e.g., imaging, biomed, etc.)
- Outliers, typically caused by low fractional #Equipment Managed, were excluded.

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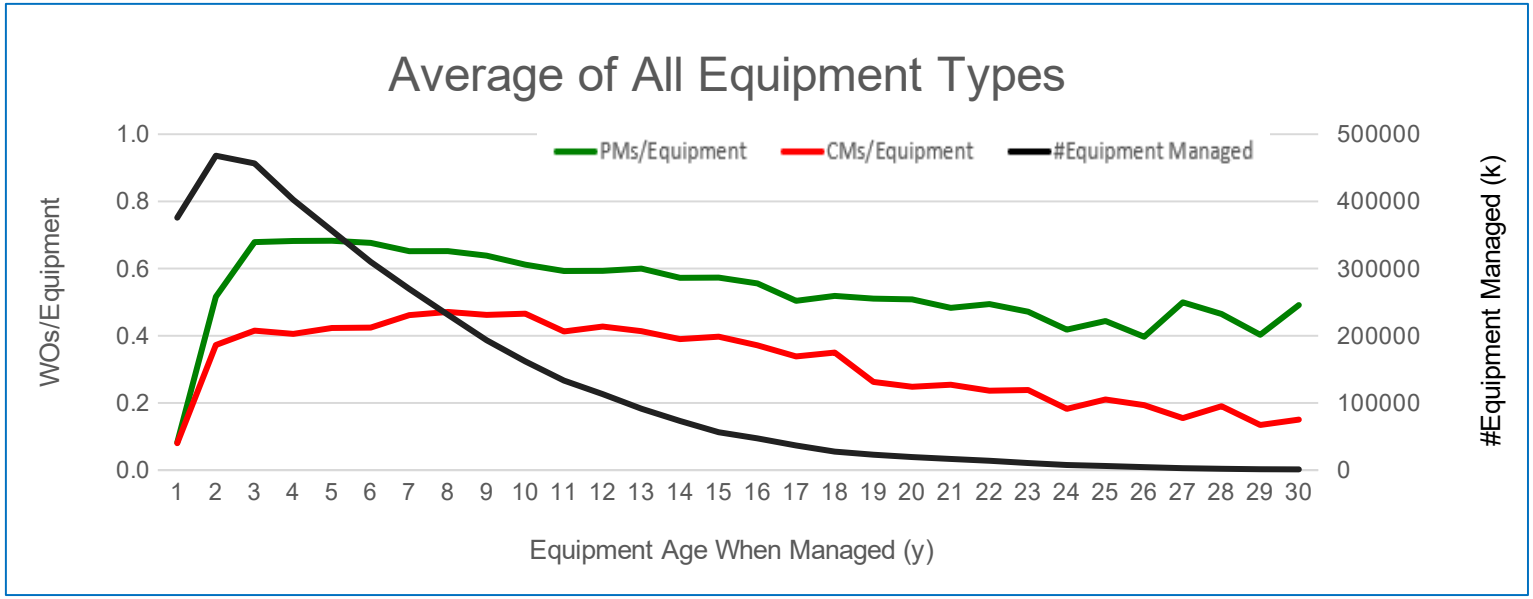
RESULTS - All Equipment Types



- Surprise! CM seems almost independent of age, even decreasing >15y! Equipment becoming more reliable as it ages?!
- But "devil is in the details"

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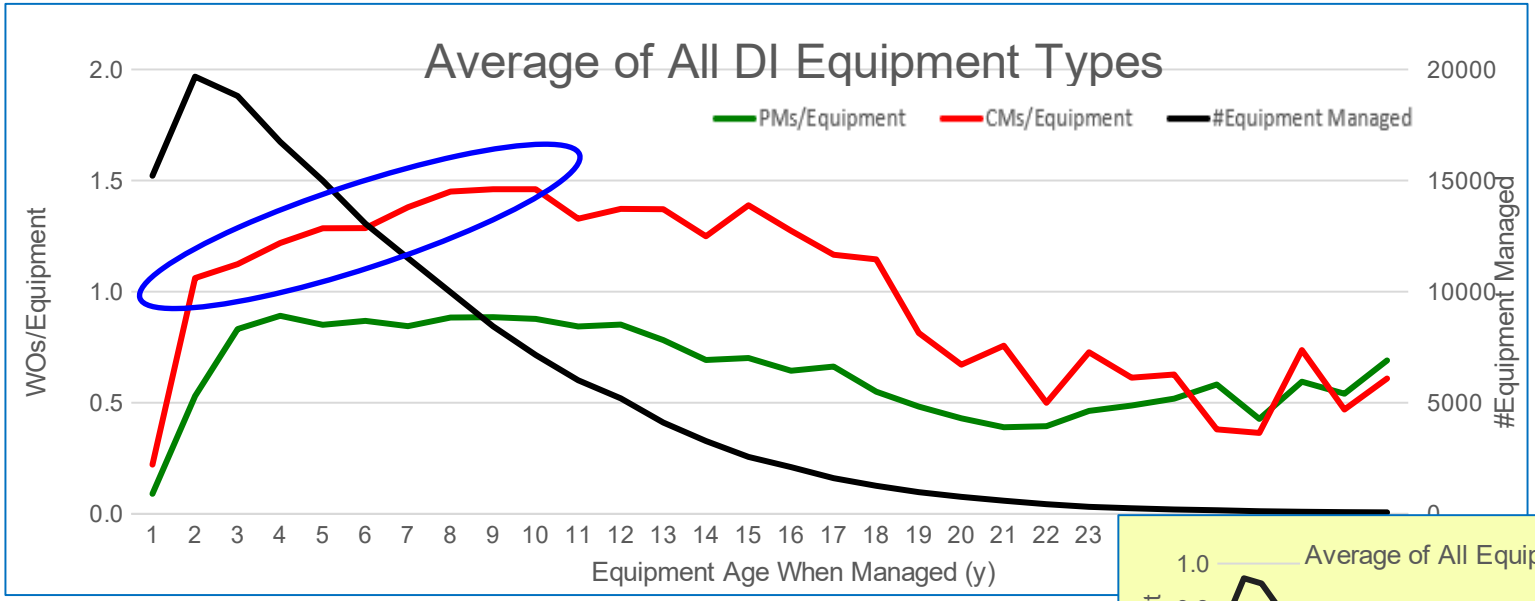
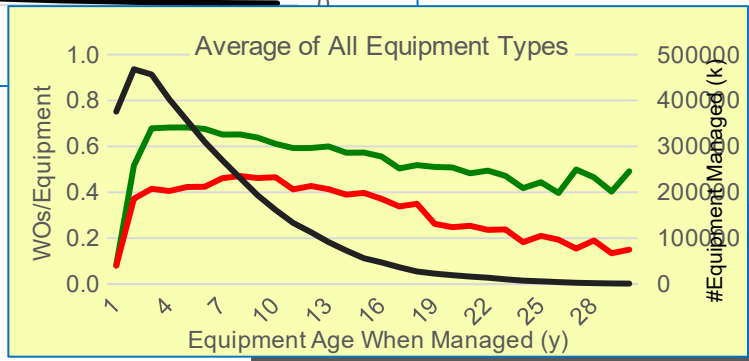
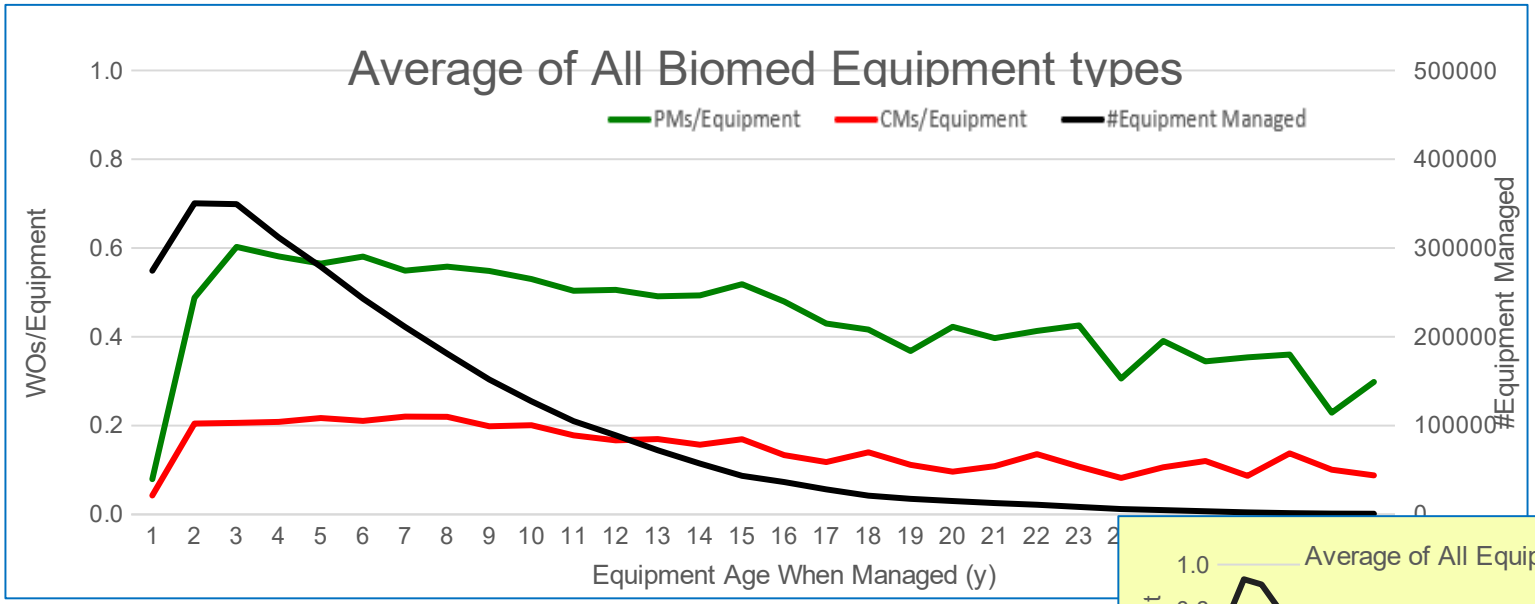
RESULTS - Diagnostic Imaging (DI)

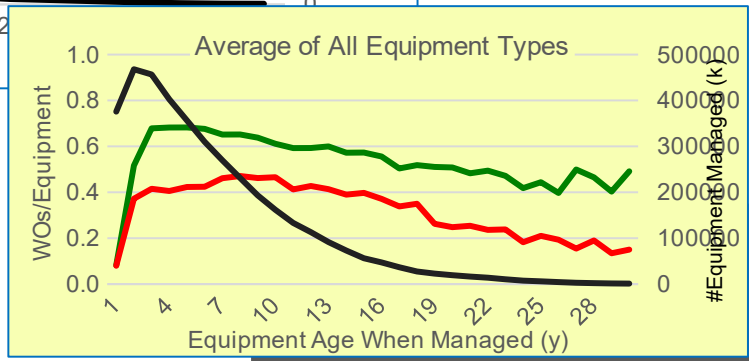




- Much higher CMs than biomed (no surprise)
- Clear age effect <10y & CMs decrease >18y?!

RESULTS - General Biomedical Equipment





- Much lower CMs than DI
- No clear age effect & CMs decrease >10-14y??

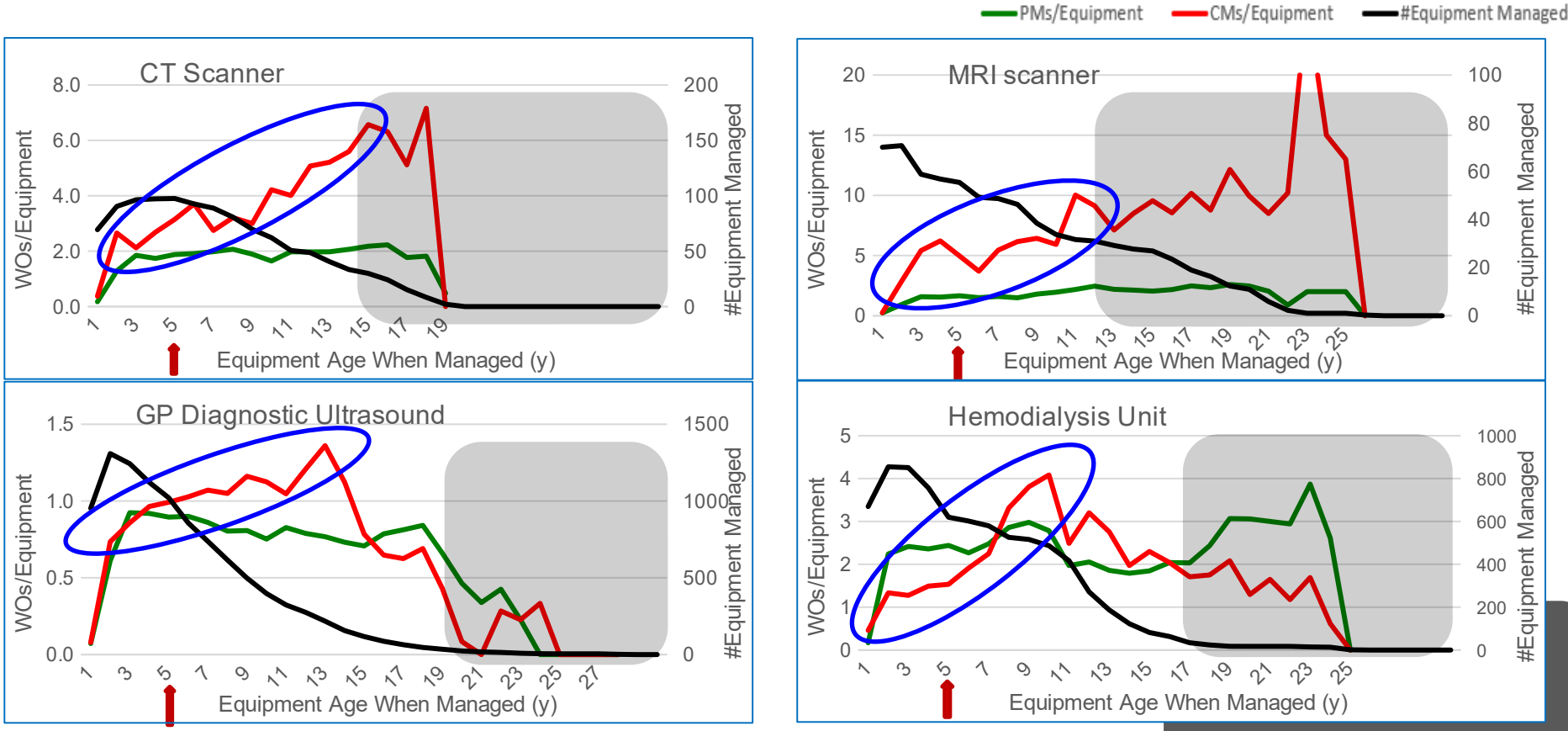
Test Your Age Effect IQ!

Which of the following equipment types exhibits the classical age-related wear-out pattern?

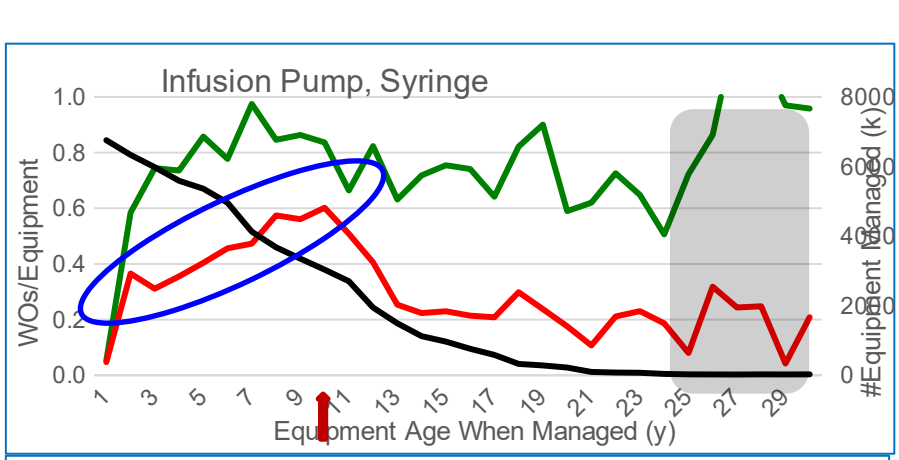
EQUIPMENT TYPE
Anesthesia machine
CT scanner
Defib/monitor w/pacemaker
Diagnostic ultrasound, Cardiac
Diagnostic ultrasound, GP
Diagnostic ultrasound, POC
Electric bed
ESU
Hemodialysis machine
Hypo/hyperthermia machine
Infusion pump, feeding
Infusion pump, modular
Infusion pump, multi-channel
Infusion pump, PCA
Infusion pump, single channel

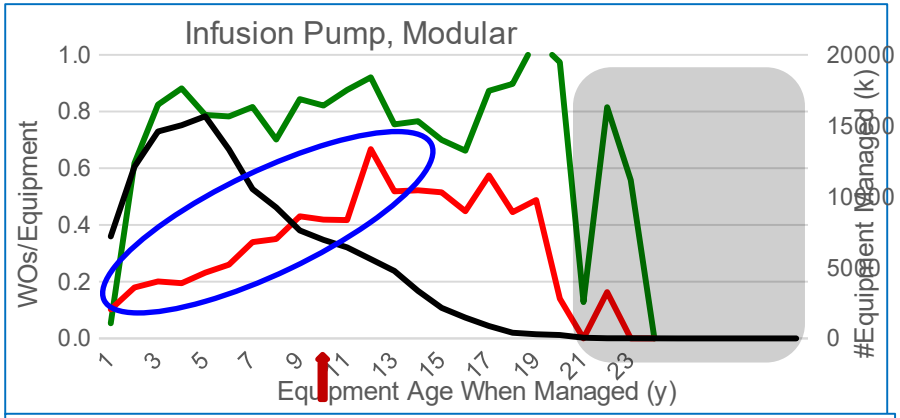
EQUIPMENT TYPE
Infusion pump, syringe
Laser, CO2
Laser, holmium YAG
Laser, photo diode
Mobile X-ray
MRI scanner
Neonatal incubator
Pt monitor, multi-parameter
Steam sterilizer, medium
Stretcher, mobile
Telemetry receivers
Telemetry transmitter
Ventilators (w/compressors)
Ventilators (w/o compressors)
Waste management system

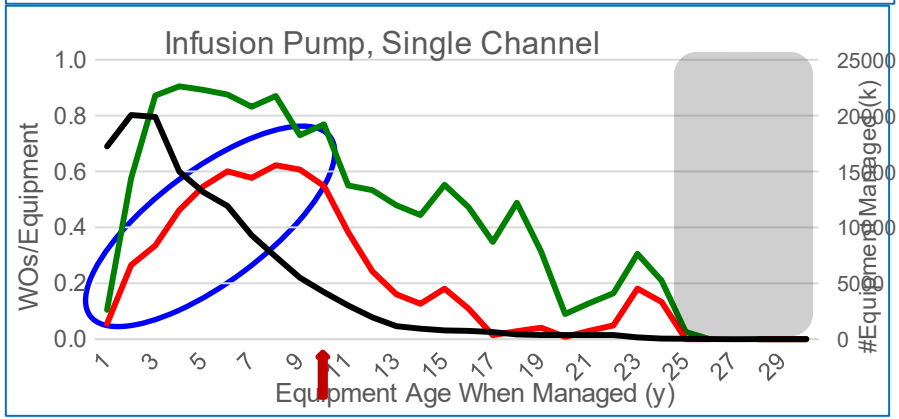
RESULTS – Clear Wear Out

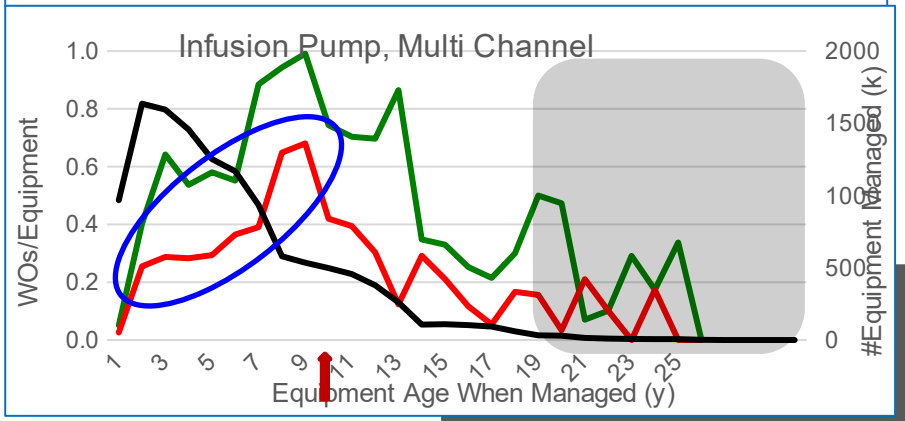


RESULTS – Clear Wear Out (cont. 1)

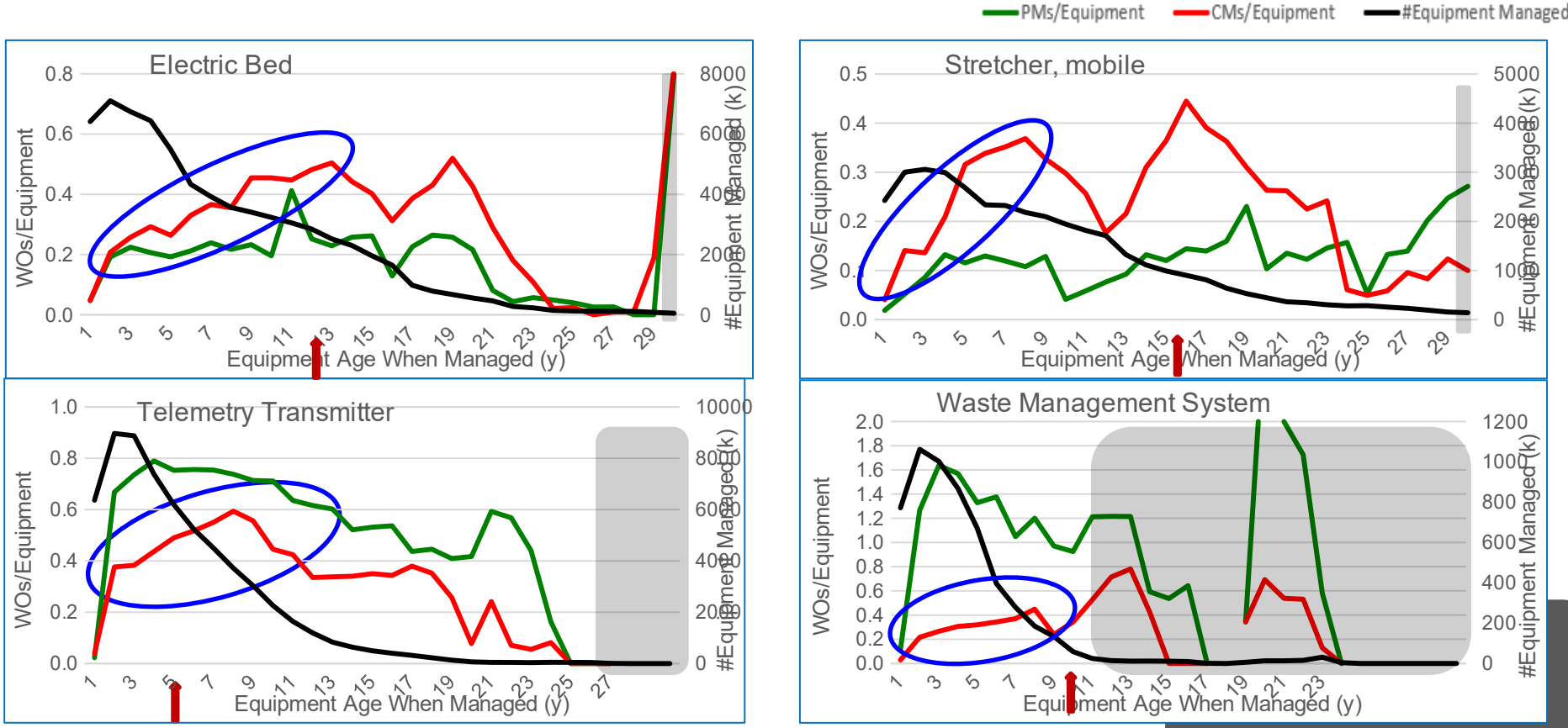




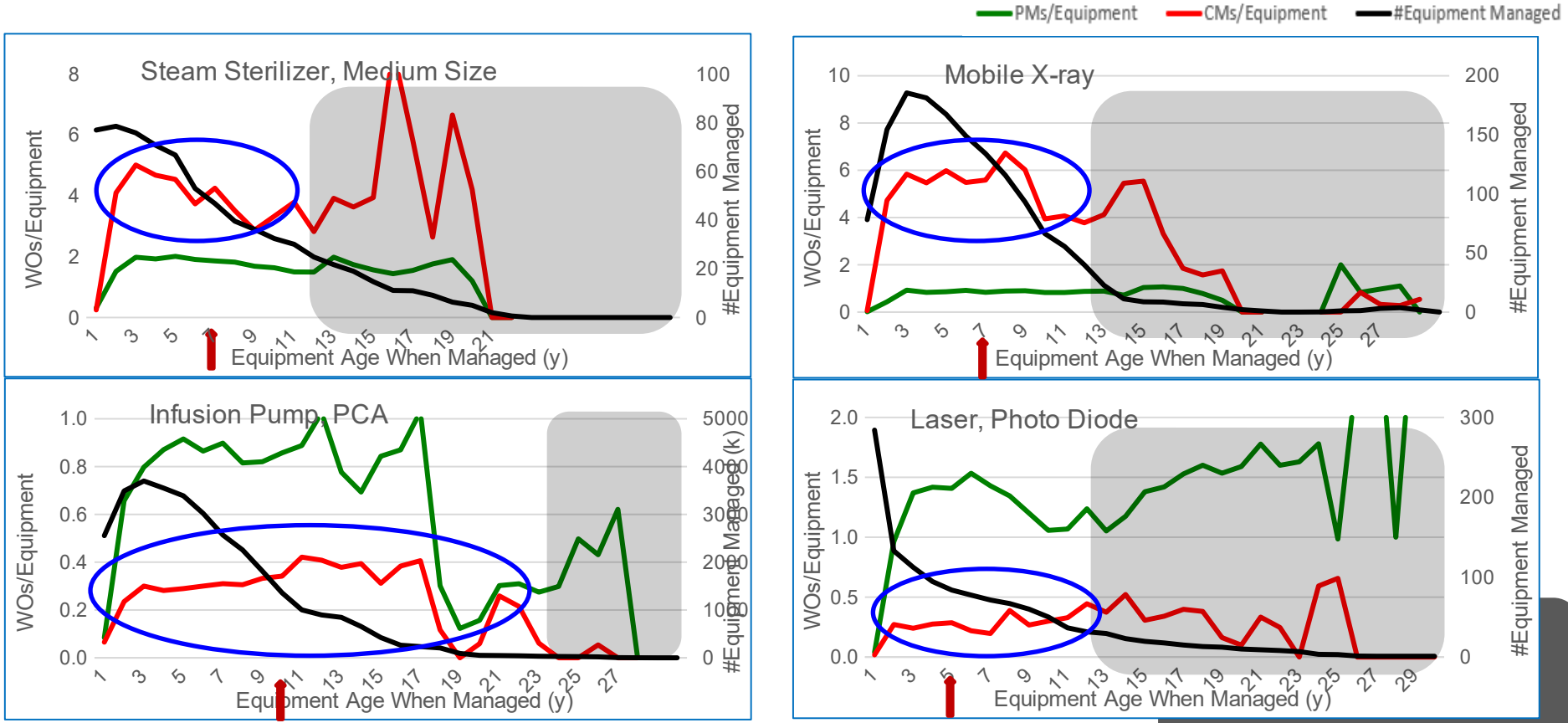




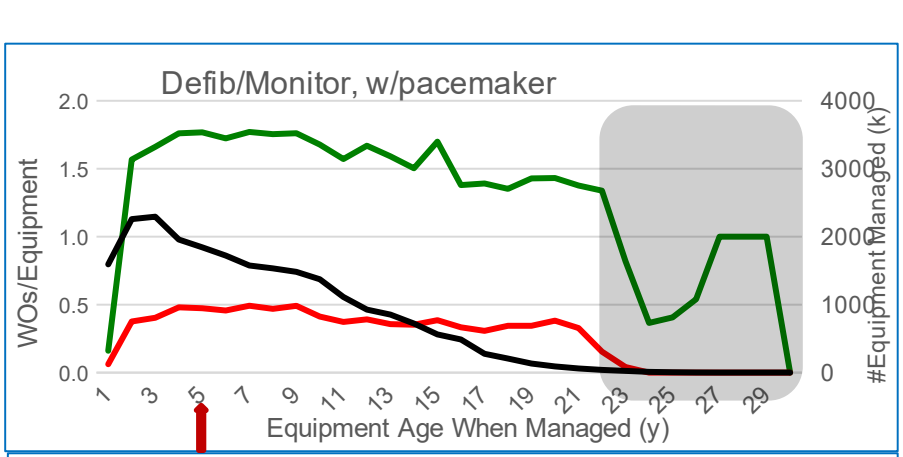
RESULTS – Clear Wear Out (cont. 2)

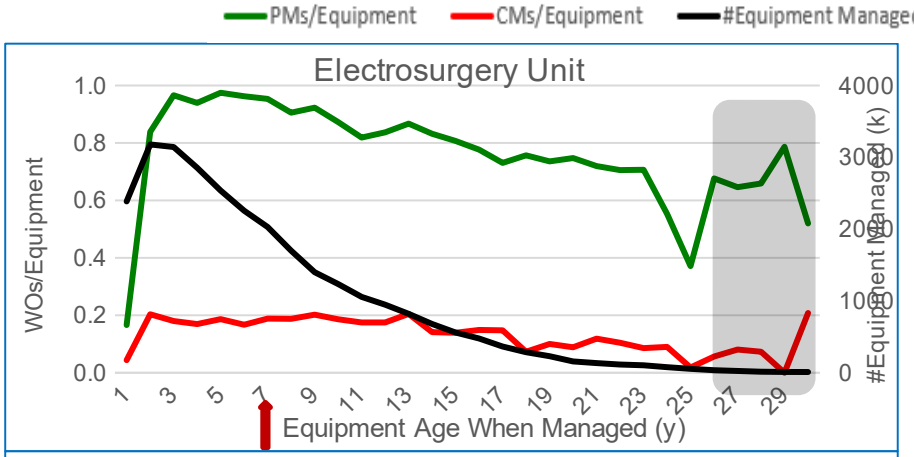


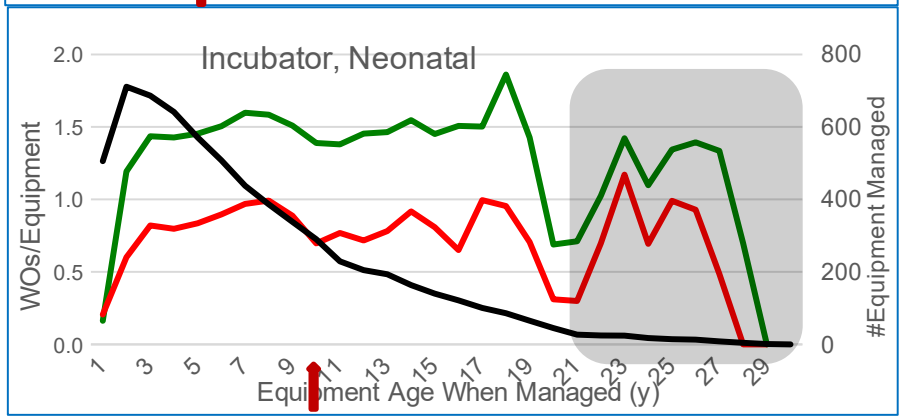
RESULTS – Unclear Wear Out

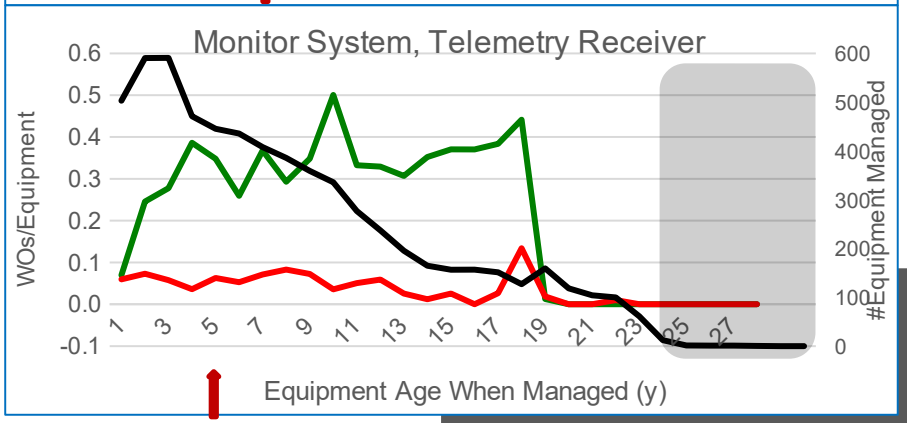


RESULTS – No Clear Wear Out

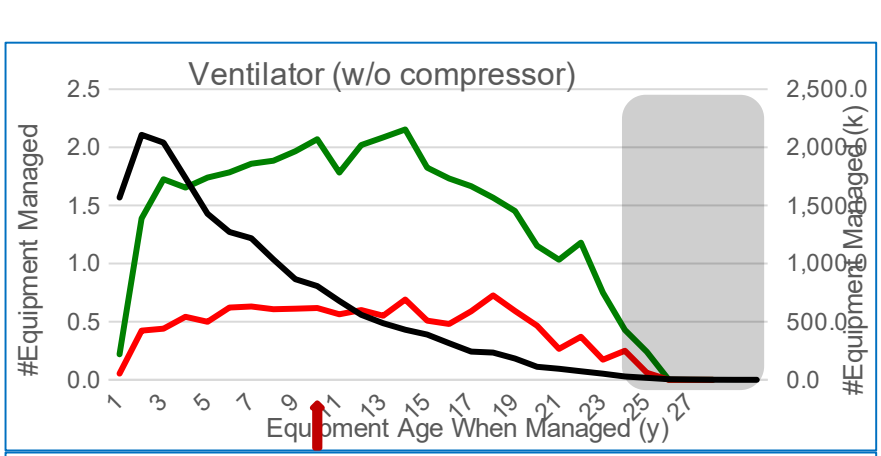


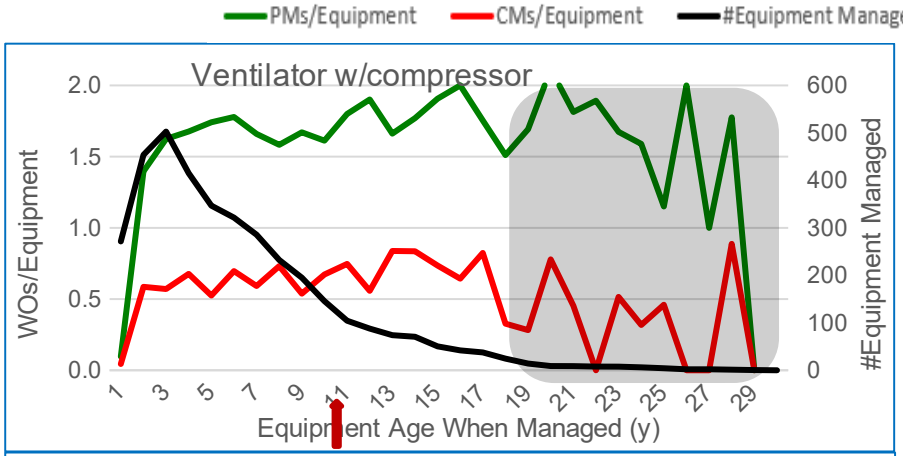


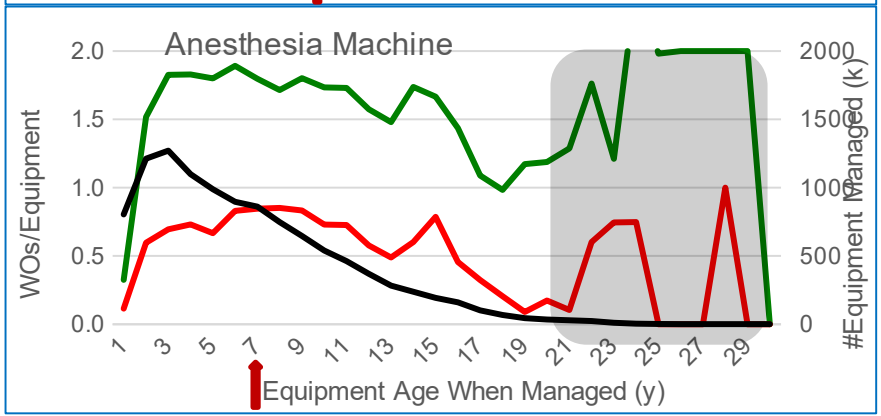


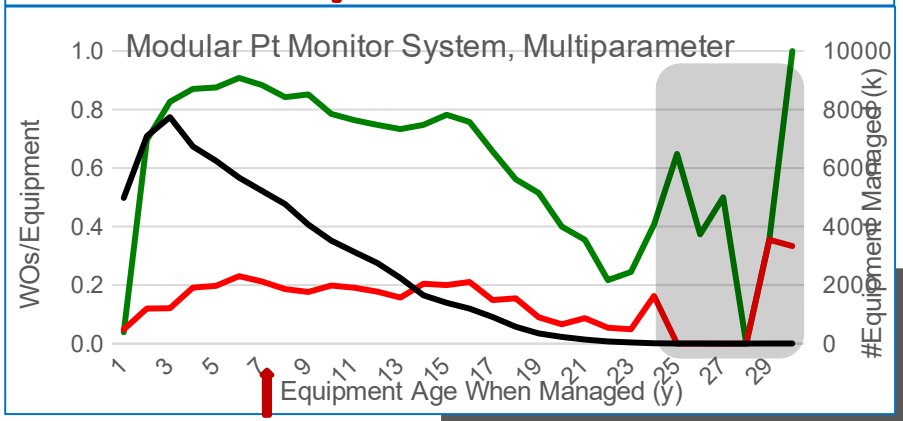


RESULTS – No Clear Wear Out (cont. 1)

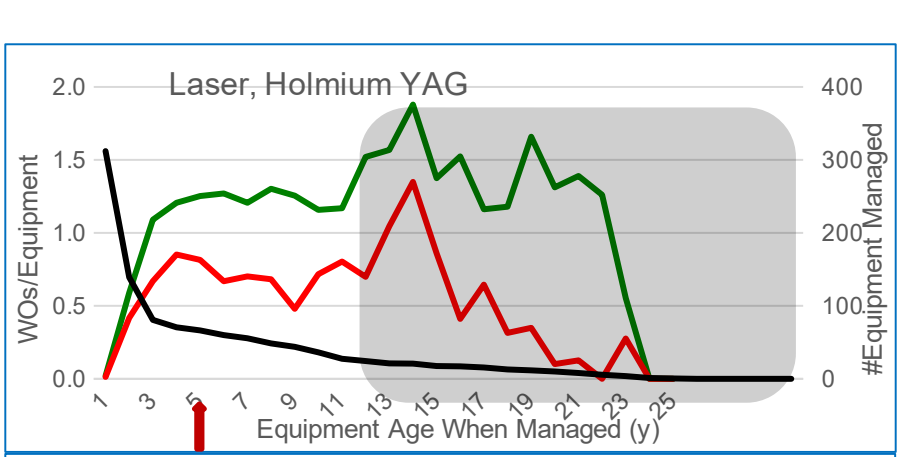


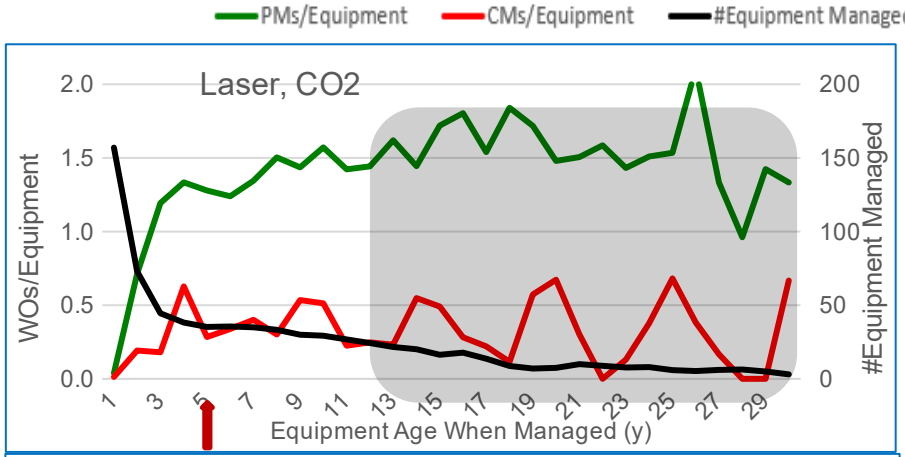


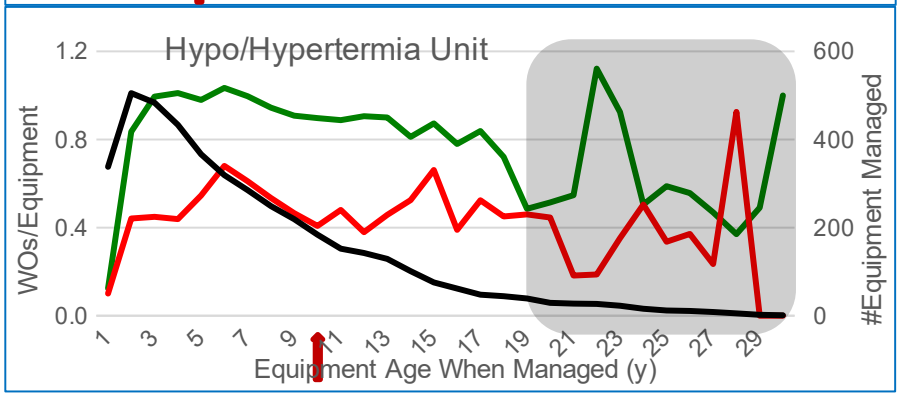


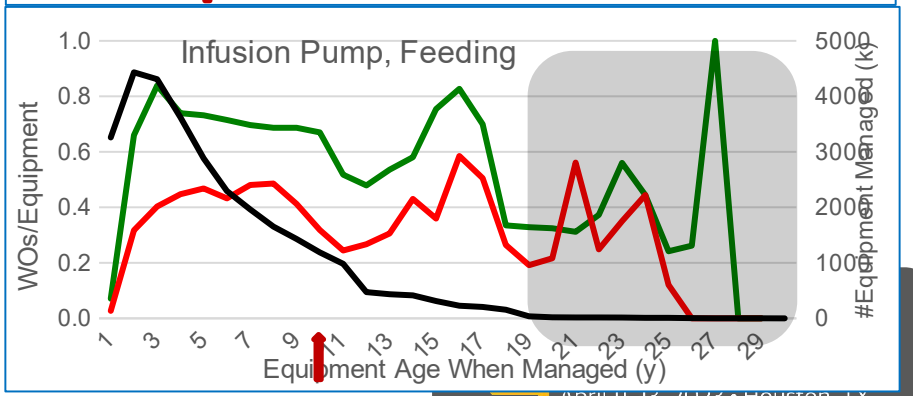


RESULTS – No Clear Wear Out (cont. 2)

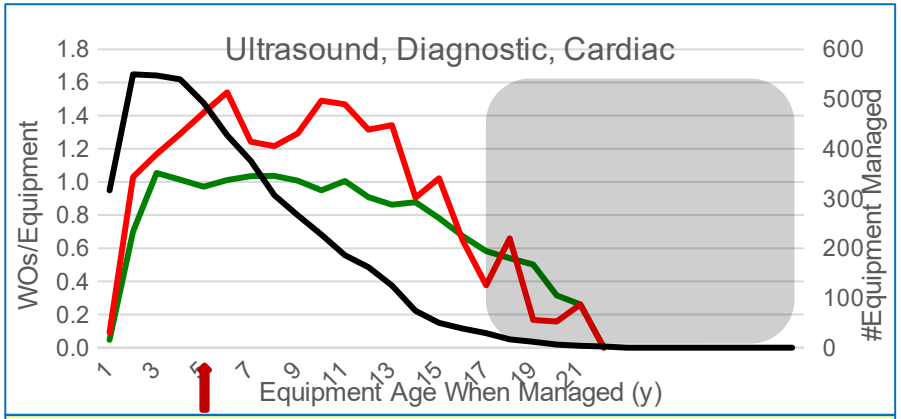


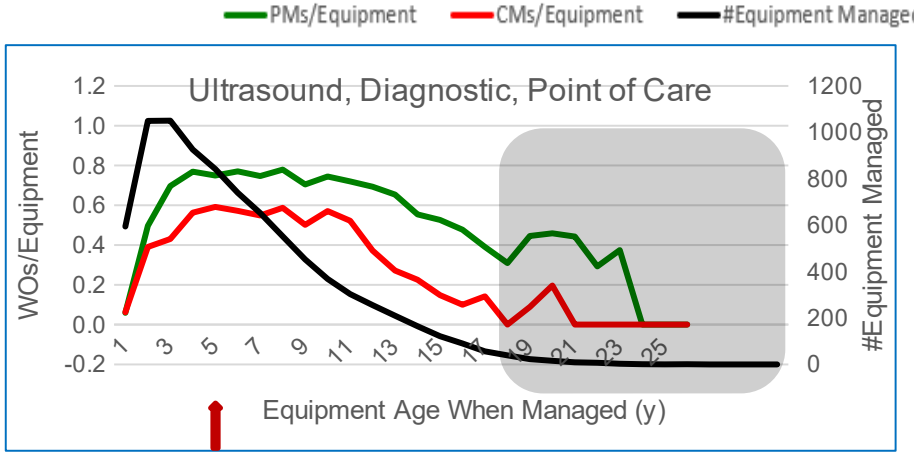


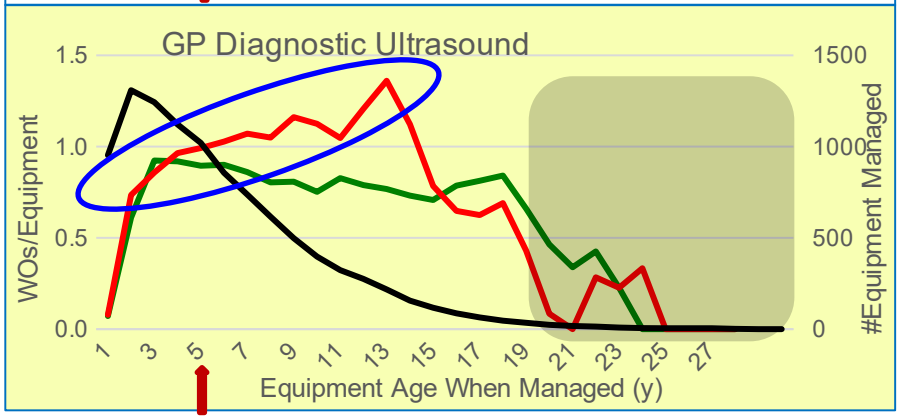




RESULTS – Diagnostic Ultrasound







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DISCUSSION - Primary causes of wear out: Weight & Power?

EQUIPMENT TYPE	WEIGHT	POWER/ VOLTAGE	WEAR OUT DETECTED?
CT scanner	heavy	high	yes
MRI scanner	heavy	high	yes
Mobile X-ray	medium	high	unclear
Steam sterilizer, medium	medium	high	unclear
Diagnostic ultrasound, GP	medium	medium	yes
Electric bed	medium	medium	yes
Hemodialysis machine	medium	medium	yes
Stretcher, mobile	medium	medium	yes
Waste management system	medium	medium	yes
Anesthesia machine	medium	medium	no
Hypo/hyperthermia machine	medium	medium	no
Ventilators (w/compressors)	medium	medium	no
Ventilators (w/o compressors)	medium	medium	no
Laser, CO2	medium	medium	no
Diagnostic ultrasound, Cardiac	medium	medium	no

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DISCUSSION - Primary causes of wear out: Weight & Power? (cont.)

EQUIPMENT TYPE	WEIGHT	POWER/ VOLTAGE	WEAR OUT DETECTED?
Neonatal incubator	medium	low	no
Defib/monitor w/pacemaker	light	medium	no
Laser, holmium YAG	light	medium	no
Diagnostic ultrasound, POC	light	medium	no
Infusion pump, multi-channel	light	low	yes
Infusion pump, single channel	light	low	yes
Infusion pump, modular	light	low	yes
Infusion pump, PCA	light	low	unclear
Infusion pump, syringe	light	low	yes
Telemetry transmitter	light	low	yes
Infusion pump, feeding	light	low	no
Laser, photo diode	light	low	unclear
Pt monitor, multi-parameter	light	low	no
Telemetry receivers	light	low	no
ESU	light	low	no

DISCUSSION – Primary causes of wear out: Utilization and Sturdiness?

EQUIPMENT TYPE	WEIGHT	POWER/ VOLTAGE	WEAR OUT DETECTED?	UTILIZATION	ROBUSTNESS - STURDINESS
Infusion pump, multi-channel	light	low	yes	high	low
Infusion pump, single channel	light	low	yes	high	low
Diagnostic ultrasound, GP	medium	medium	yes	high	medium
CT scanner	heavy	high	yes	high	high
Electric bed	medium	medium	yes	high	high
Hemodialysis machine	medium	medium	yes	high	high
MRI scanner	heavy	high	yes	high	high
Stretcher, mobile	medium	medium	yes	high	high
Waste management system	medium	medium	yes	high	high
Infusion pump, modular	light	low	yes	medium	low
Infusion pump, PCA	light	low	unclear	medium	low
Infusion pump, syringe	light	low	yes	medium	low
Telemetry transmitter	light	low	yes	medium	low
Infusion pump, feeding	light	low	no	medium	medium
Laser, photo diode	light	low	unclear	medium	medium

DISCUSSION – Primary causes of wear out: Utilization and Sturdiness? (cont.)

EQUIPMENT TYPE	WEIGHT	POWER/ VOLTAGE	WEAR OUT DETECTED?	UTILIZATION	ROBUSTNESS - STURDINESS
Pt monitor, multi-parameter	light	low	no	medium	medium
Telemetry receivers	light	low	no	medium	medium
Anesthesia machine	medium	medium	no	medium	high
Diagnostic ultrasound, POC	light	medium	no	medium	high
ESU	light	low	no	medium	high
Hypo/hyperthermia machine	medium	medium	no	medium	high
Mobile X-ray	medium	high	unclear	medium	high
Neonatal incubator	medium	low	no	medium	high
Steam sterilizer, medium	medium	high	unclear	medium	high
Ventilators (w/compressors)	medium	medium	no	medium	high
Ventilators (w/o compressors)	medium	medium	no	medium	high
Diagnostic ultrasound, Cardiac	medium	medium	no	low	medium
Defib/monitor w/pacemaker	light	medium	no	low	high
Laser, CO2	medium	medium	no	low	high
Laser, holmium YAG	light	medium	no	low	high

DISCUSSION – Utilization and Sturdiness >> Weight & Power

EQUIPMENT TYPE	WEIGHT	POWER/ VOLTAGE	WEAR OUT DETECTED?	UTILIZATION	STURDINESS	AHA Est Useful Life (y)
Infusion pump, multi-channel	light	low	yes	high	low	10
Infusion pump, single channel	light	low	yes	high	low	10
Diagnostic ultrasound, GP	medium	medium	yes	high	medium	5
CT scanner	heavy	high	yes	high	high	5
Electric bed	medium	medium	yes	high	high	12
Hemodialysis machine	medium	medium	yes	high	high	5
MRI scanner	heavy	high	yes	high	high	5
Stretcher, mobile	medium	medium	yes	high	high	15
Waste management system	medium	medium	yes	high	high	10
Infusion pump, modular	light	low	yes	medium	low	10
Infusion pump, syringe	light	low	yes	medium	low	10
Telemetry transmitter	light	low	yes	medium	low	5
Infusion pump, PCA	light	low	unclear	medium	low	10
Laser, photo diode	light	low	unclear	medium	medium	5
Mobile X-ray	medium	high	unclear	medium	high	7
Steam sterilizer, medium	medium	high	unclear	medium	high	7
Infusion pump, feeding	light	low	no	medium	medium	10
Pt monitor, multi-parameter	light	low	no	medium	medium	7
Telemetry receivers	light	low	no	medium	medium	5
Anesthesia machine	medium	medium	no	medium	high	7
Diagnostic ultrasound, POC	light	medium	no	medium	high	5
ESU	light	low	no	medium	high	7
Hypo/hyperthermia machine	medium	medium	no	medium	high	10
Neonatal incubator	medium	low	no	medium	high	10
Ventilators (w/compressors)	medium	medium	no	medium	high	10
Ventilators (w/o compressors)	medium	medium	no	medium	high	10
Diagnostic ultrasound, Cardiac	medium	medium	no	low	medium	5
Defib/monitor w/pacemaker	light	medium	no	low	high	5
Laser, CO2	medium	medium	no	low	high	5
Laser, holmium YAG	light	medium	no	low	high	5

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DISCUSSION – Factors with Impact on Wear Out

- While weight and power/voltage may be significant, utilization and sturdiness are clearly more influential than the former ones
- Unfortunately, failure causes were NOT identified in the older workorders, so it is not possible to differentiate “natural” wear out from “abnormal” wear out, i.e., accessories, batteries, use (accidents, abuse, environmental issues, etc.)
- Equipment grouping by type assumes that all have similar utilization and sturdiness => while directionally correct, may miss important details
- Some likely confounding factors that contributed to the paradox of apparent increased reliability (i.e., reduced CMs) with age detected:
  - Older equipment often is used mostly or only for backups (lack of utilization data)
  - Some old equipment are used only by a few users (“physician preference” items)

DISCUSSION – PMs and CMs

- Sometimes, “small” repairs were performed during PMs without opening a separate CM workorder => inaccurate accounting of CMs
- Higher PM rates in younger equipment may simply reflect changes in accreditation standards and some older equipment has been in storage and, thus, not available for PMs.
- Often equipment is replaced when a **single** catastrophic failure occurred and the repair cost is considered NOT worthwhile (e.g., >30-50% of fair-market value) so no clear end-of-life wear out can be detected.
- PMs do NOT necessarily reduce CMs but the lack of PMs could increase CMs (the “necessary but not sufficient” logic rule).
- Until a direct comparison of PM effectiveness is made between OEM-recommendations and AEM for imaging/radiologic equipment and lasers, we can’t say that one strategy is clearly better than the other, but our results suggest that some imaging devices (e.g., ultrasound and lasers) could be good candidates for AEM (prior limited analyses also didn’t find any significant difference), BUT … ☹

DISCUSSION – Replacement Planning

- Replacement should **NOT** be determined primarily by equipment age but by the combination of
  - Safety (including impact on mission—i.e., collective safety—and not only individual safety)
  - Reliability
  - Supportability
  - Clinical Impact
- As AHA itself admitted in its book, “The estimated service life for each asset as presented in this booklet is to be used primarily as a guide. An organization may consider assigning a longer or shorter life depending on usage, types of facility, and extenuating circumstances affecting the service life of the asset.” [my emphasis in blue]
- In addition, AHA states “The method for determining the depreciable cost is largely dependent on the productive period of the asset. Numerous factors influence this determination… Another contributing factor has to do with technological innovation, which can render an asset obsolete before the end of its estimated useful life.” [my emphasis in blue]
- Our results suggest most equipment can be used far beyond AHA’s estimated service life.

CONCLUSIONS

- **Maintenance strategy** should consider wear out pattern:
  1) **Equipment with clear wear out pattern:**
     - **Identification**: look for equipment types with these characteristics:
       - Medium to high utilization (e.g., beds, hemodialysis)
       - Low sturdiness (e.g., many infusion pumps, telemetry transmitters)
       - Heavy weight (e.g., CT and MRI scanners)
       - High power and/or voltage (e.g., mobile X-ray and CT)
     - **PMs**: focus on parts replacement if possible or predictable ("condition-based maintenance")
     - **Repairs**: plan for increasing labor and cost with age
  2) **Equipment without clear wear out pattern:**
     - **PM Strategy**: AEM with PM frequency and/or tasks reduction, including run-to-failure (RTF)
     - **Repairs**: only as needed and cost effective (fair market value

CONCLUSIONS (cont.)

- “Infant mortality”/”burn in” is seldom seen in medical equipment, although some replacement parts were previously reported to have such issues => no need to include it in maintenance planning
- **Equipment replacement planning:**
  - **Age** should NOT be used as the primary replacement criterion but can be used in conjunction with other parameters, i.e., safety, reliability, supportability and clinical impact
- CAUTION: While analyses of large databases provide quick and solid statistical results, be careful in using them on your local assets. The utilization and equipment sturdiness may be quite different (e.g., defib’s used in ambulances and EDs). So use statistics from large databases as the starting point to look for equipment types with clear wear out patterns in your own inventory.

THANK YOU

- Questions & suggestions are most welcome!
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