Observation of Production Rate Effect in Historical Costs of Weapon Systems

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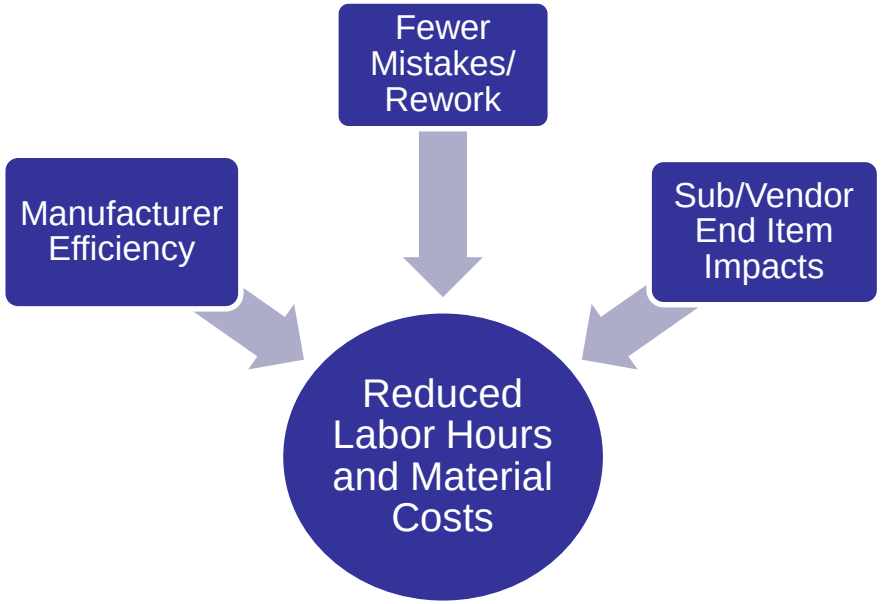
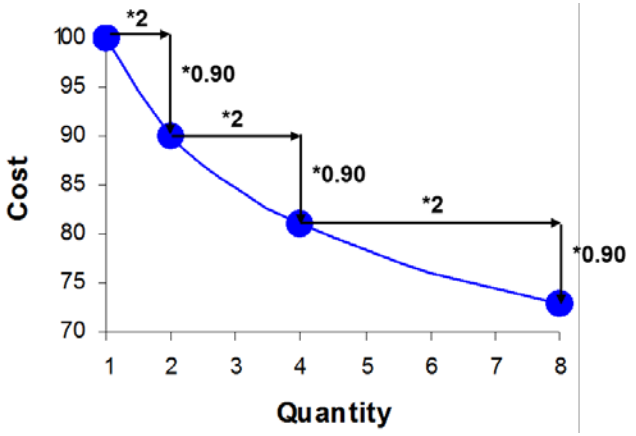
- Background
- PRE Defined
- Data Sources
- Analysis
- Sample Programs
- Results
- Conclusions

- Most cost analysts are familiar with production rate effect's (PRE) "older brother", the learning curve:

$$y = Ax^b$$

- Learning curves capture the decrease in costs associated with the continuous production of an unchanging system
- Impacts both labor and material costs of prime contractors





Source: CEBoK Module 7

- PRE functions similar to learning curves in that it exists in logarithmic space and is a reduction of lot average unit cost (AUC) with the doubling of lot quantity
- PRE differs from learning curves in that it:
  - Lacks “memory”
  - Only applies to material costs
- Modeled as an extension of the unit learning curve formula, as first proposed by RAND in 1974:

$$y = Ax^b q^r$$

q: lot quantity
r: PRE slope
$\ln(rate\ effect)/\ln 2$

At a simplified level, PRE results from the amortization of fixed costs over a larger base.

- PRE only impacts direct, recurring material costs
- Unsuitable data sources for PRE analysis include:
  - Program budgets
  - Proposal costs
  - Negotiated contract prices
  - Stepladder pricing data
- Key distinctions need to be made between
  - Price and cost
  - Planned and actual

- Primary sources for historical actuals
  - Priced Bills of Material (PBOMs)
  - Contractor Cost Data Reports (CCDRs)

- Collected directly from contractors
  - Unaltered data pulled directly from a contractor's accounting system
  - May require reference tables to interpret unique data fields
- Typically provide costs at the individual purchased part level
  - Individual nuts and bolts required for assembly
  - Full end-item components or subassemblies purchased directly from a vendor or subcontractor
- PBOMs for a single lot can be thousands of lines long and have dozens of columns

Common PBOM Data Fields	
Part Number	Quantity
Part Description	Unit Price/Total Price
Order Number	WBS Element
Vendor	Purchase Date

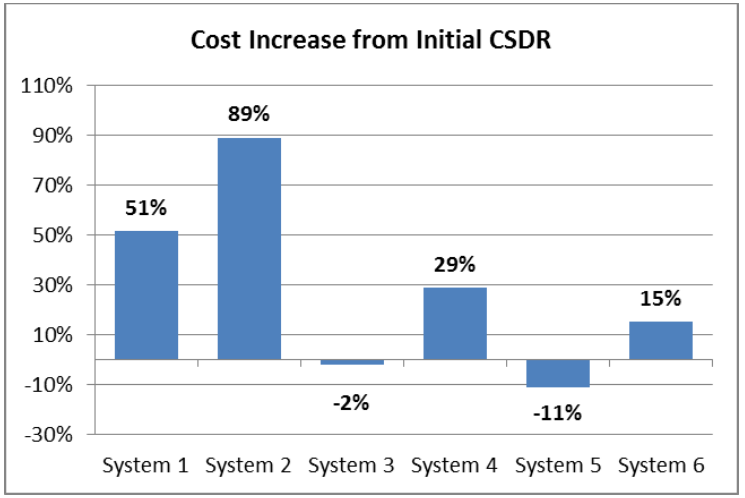
May be prudent to focus on top cost drivers.

- Most often collected in support of a Milestone C or later cost estimate when production lots have already been completed
- Primary limitation is difficulty in obtaining and a high resource requirement to analyze

- Available through the Defense Cost and Resource Center (DCARC)
  - Typically reported by contract, life cycle phase, and lot for production data
  - Should pursue Final reports for analysis
- Primary report types for PRE analysis
  - 1921 Cost Data Summary Reports (CDSR)

    → Reports quantity and total cost by WBS element, broken out into recurring and nonrecurring costs
  - 1921-1 Functional Cost Hour Reports (FCHR)

    → Reports the above for each WBS element broken out by major cost components
    - Engineering labor hours/costs
    - Manufacturing labor hours/costs
    - Material costs
    - Subcontractor costs
    - Etc.



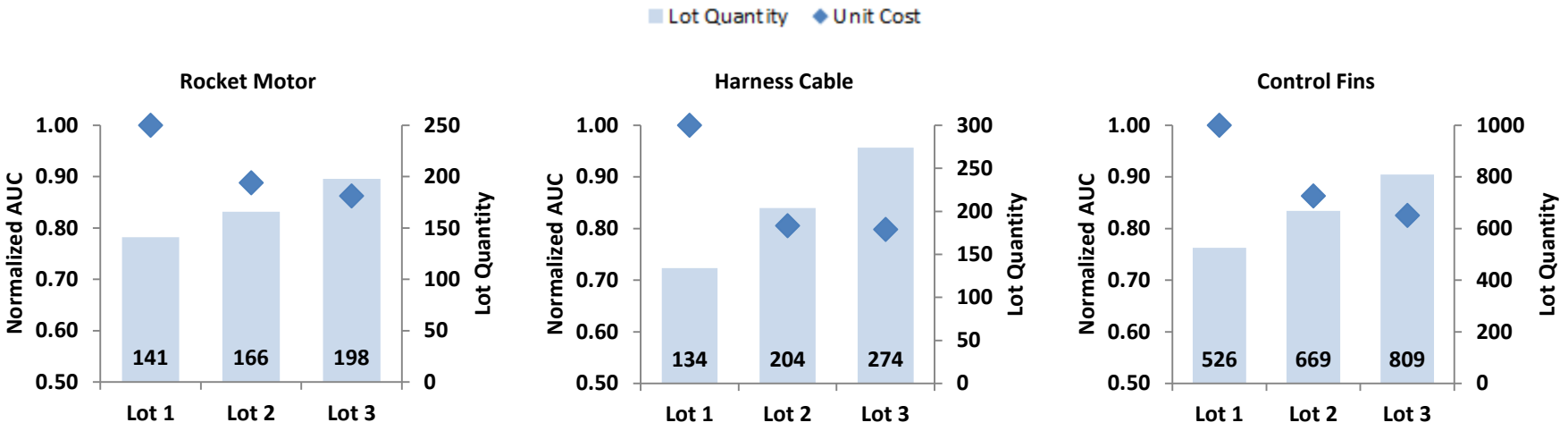
- Primary limitations are reporting lag and lack of availability outside of ACAT 1 programs

- Data normalization will be unique for each dataset, but in general there are some standard processes to ensure data consistency prior to beginning analysis
  - Escalation to a constant base year
    - PBOMs are typically reported as a given Then Year (TY)
    - CCDRs are typically summed over several TYs
    - Standard OSD escalation indices by commodity were used for this study
  - Normalization for quantity
    - Ensure consistency of subassembly quantities between lots
    - Calculate lot-representative AUC if varying costs for a subassembly in a single lot
- Other data inconsistencies that required normalization for this study:
  - Foreign currencies
  - Subcontractor cost reporting
  - Accounting inconsistencies

Thorough visual examination of data can be a powerful tool for identifying data inconsistencies or abnormalities.

- Analysis should be based on recurring material AUCs for a number of subsequent production lots
- Perform regression analysis on normalized datasets following the standard form of the PRE equation
- Depending on the data, analysts may perform a regression for PRE in isolation or a multiple regression for PRE and learning curve concurrently
  - If only three lots of data are available, PRE will have to be analyzed in isolation
  - If greater than three lots of data are available, visual inspection of the AUC vs. both lot midpoint and lot quantity should be used to determine if correlation is present between the independent and dependent variables
- For this study, all regression analysis was performed in CO$TAT
- Common statistical tests were used to determine the validity and significance of all results

- Analysis based on PBOMs in support of a Milestone B estimate for a follow-on variant of a missile system
- Data was collected for prior variant due to consistent design of aft section subassemblies
- Prime contractor provided PBOMs for three lots
  - Included many international vendors, requiring normalization to USD
  - PBOM costs were verified as actuals with invoices
  - Analysis was performed at the subassembly level for the rocket motor, harness cable, and control fins

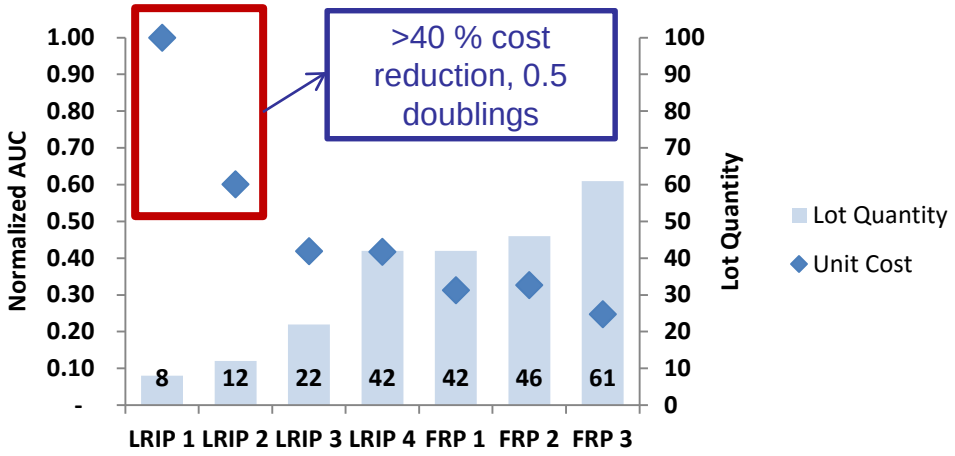


- Results:

Subassembly	PRE Slope	R^2 Adj	T-Stat: Prob Not Zero Ind. Var.	F-Stat: Prob Not Zero Reg	Residual Distribution
Rocket Motor	74.1 %	75.4 %	77.2%	77.2%	Normal
Harness Cable	79.7 %	71.3 %	75.3%	75.3%	Normal
Control Fins	73.0 %	89.6 %	85.3%	85.3%	Normal

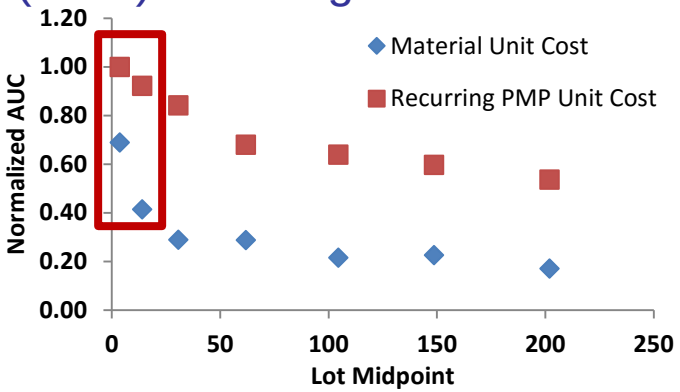
- All three subassemblies demonstrated aggressive PRE slopes → results in large impact on system AUCs
- Fit statistics suggest the regression results were valid and significant
- Results were used to create an uncertainty range for PRE in support of a Milestone B estimate for material costs of production lots for the missile system

- Analysis based on CCDRs for analogous programs in support of Milestone B cost estimate for an electronic warfare (EW) system
- Reports available for production lots LRIP 1-4 and FRP 1-3
- Direct recurring material AUCs were calculated from the 1921-1 reports



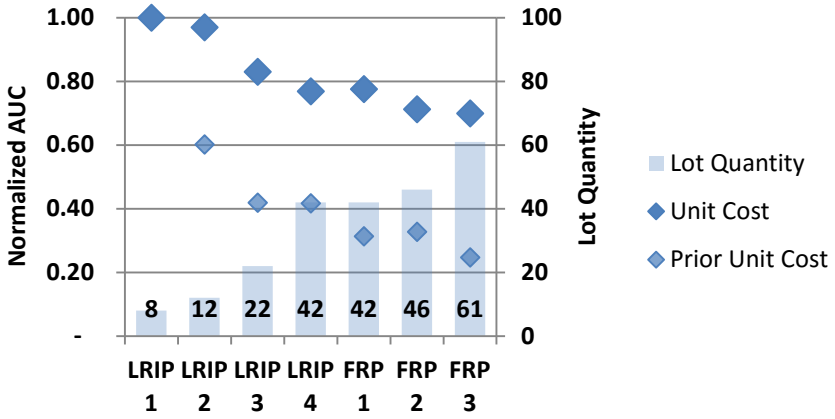
- Regression analysis returned a PRE slope of 92.4 %, along with a learning curve slope of 84.1 %, with an adjusted R^2 of 93.8 %
- However, the relatively large cost decrease between LRIP 1 and LRIP 2 was clearly driving the results

- Upon further inspection, his cost decrease was not present for the total prime mission product (PMP) recurring AUC



- Suggested a reporting variance in material costs between lots
- Examination of 1921-1 reports discovered that significant intra-organizational transfer (IOT) costs were included in the “Other Costs” line for all lots other than LRIP 1
  - IOT costs are items “purchased” from other business units of the contractor’s company
  - Cannot be listed as standard material on the 1921-1 reports due to guidance governing the burdening of IOT costs
  - Functionally the same as material costs from external subcontractors or vendors

- Including the IOT costs as part of the material AUC, the initial decrease between LRIP 1 and LRIP 2 was significantly reduced



- Results:

PRE Slope	LC Slope
92.2 %	97.7 %

- These results were used along with similar analyses on other analogous systems to apply to the material costs being estimated in support of Milestone B for the EW system

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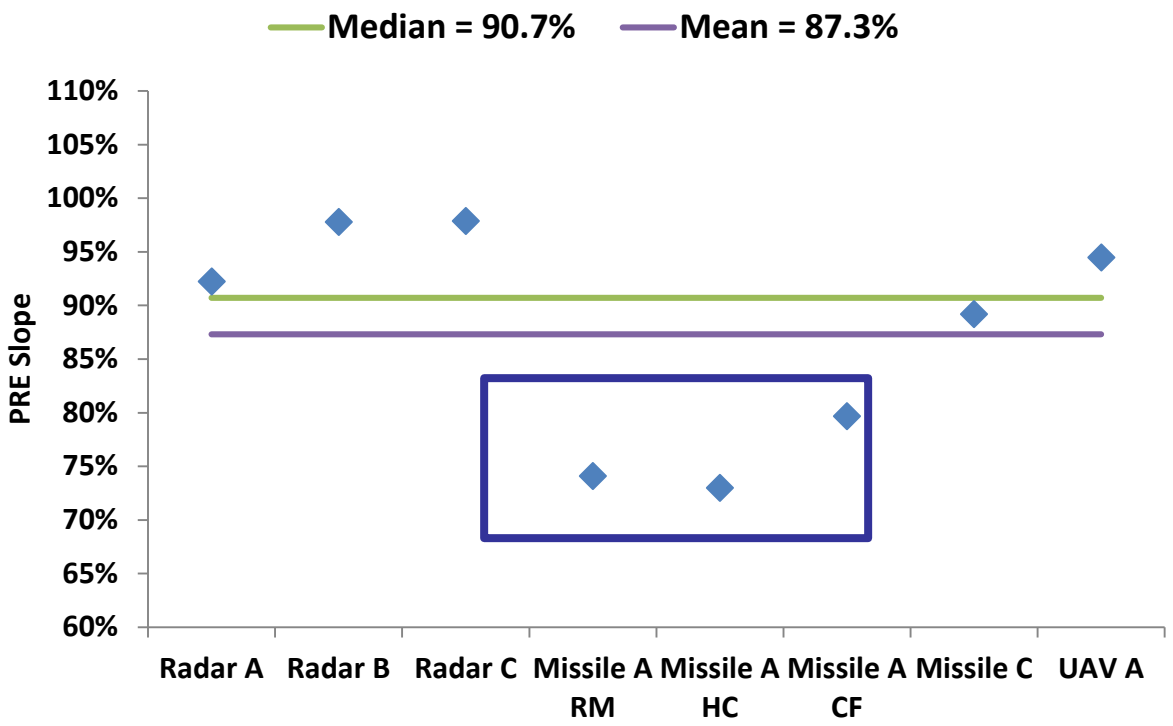
- In addition to the two sample programs, PRE analysis was performed on seven additional systems:

Commodity	Data Source	PRE Slope	Learning Slope	R^2 Adj	T-Stat: Prob Not Zero Ind. Var.	F-Stat: Prob Not Zero Reg	Residual Distribution	
Radar A	CCDR	92.2%	97.7%	94.5%	97.1%	99.9%	Normal	
Radar B	CCDR	97.8%	99.5%	72.1%	93.1%	86.1%	Normal	
Radar C	CCDR	97.9%	95.7%	87.5%	56.5%	97.9%	Normal	
Radar D	CCDR	100.4%	96.0%	46.6%	6.1%	57.8%	Normal	ECP between lots
Missile A RM	PBOM	74.0%		75.4%	77.2%	77.2%	Normal	
Missile A HC	PBOM	73.0%		71.3%	75.3%	75.3%	Normal	
Missile A CF	PBOM	80.0%		89.6%	85.3%	85.3%	Normal	
Missile B	CCDR	89.4%	97.8%	34.6%	95.1%	93.4%	Normal	Poor stats
Missile C	CCDR	88.9%		76.4%	91.8%	91.8%	Normal	
Rocket Launcher A	CCDR	94.5%	98.0%	51.2%	89.7%	95.1%	Normal	Poor stats
UAV A	CCDR	94.5%	88.6%	93.0%	61.2%	99.2%	Normal	



The subassemblies from Missile System A contributed the three lowest (most aggressive) PRE slopes to the set of results.

Two theories as to why Missile System A PRE slopes are relatively low

1. PRE has a greater impact on systems procured in larger quantities

	Missiles	Others
Median PRE Slope	76.9 %	96.2 %
Average Lot Qty	>100	<50

2. PRE has a greater impact on major subassemblies than the system as a whole

	Subassemblies	Systems
Median PRE Slope	74.1 %	94.5 %

- Contractors may negotiate more for higher cost items
- PRE may be minimal or nonexistent for smaller or non-specialized COTS-like parts, reducing the effect of PRE at the total system level
- May suggest an accounting difference between contractors' internal accounting systems and submitted CCDRs

- Analysis has repeatedly confirmed the presence of PRE in historical cost data from DoD weapon and electronic systems
- When estimating material costs for production lots of a DoD system, it is prudent to include PRE along with a learning curve
- Analysts need to be deliberate in application of analysis results
  - If PRE/learning curve analysis is based on direct material cost data, results need to be applied to the direct material cost estimate
  - Since PRE and learning curves are closely tied, analysts need to be cautious about selecting slopes from different data sources and applying together
- This study suggested several lower-level insights into PRE that could be investigated with further analysis
  - Expand data set to include more high-quantity procurements
  - Identify programs for which both PBOMs and CCDRs can be collected for comparison
  - Complete additional analysis at the subassembly level

This presentation would not be possible without the contributions of the following individual, to whom we are grateful

- Ivens Jean
- Liz Goff