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A Second Generation Upgrade to Anderlohr's Retrograde Method for Broken Learning

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Outline

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- Review of Retrograde Method for Broken Learning
- Review of the most Common Solution
- Introduction of the 2nd Generation Upgrade
- Peripheral Topics
  - Potential issues with the technique
  - Potential Application of the technique

About the Author

- Tommie (Troy) Miller
- Education
  - SAS/Analytics Certificate, Texas A&M
  - M.Stat, Econometrics, University of Utah
  - B.S. Applied Mathematics with Econ Emphasis, Weber State University
- Certifications
  - PMP
  - CCEA
- Experience:
  - Cost Estimation (Operations Research): 17 years
  - Tecolote Research Inc.
    - Air Force ICBM Directorate
    - NASA Constellation Program
    - Navy SSP

Background

- Task: Develop LCCE for a component upgrade
- RDT&E to be performed by the acquisition team
- Production
  - LRIP performed by acquisition team (2 buys)
  - FRP performed by sustainment team (multiple buys)
- Important Assumptions
  - Bona fide need
    - Production Rate X unit per year
    - Production Requirement X/10 units per year (i.e. limited deployment capacity)
  - The contractor used for LRIP may be distinct from that of FRP (i.e. cannot be assumed to be the contractor)
  - Corollary Assumptions
    - There will be production gaps
    - The cost improvement rates experienced in LRIP may not manifest in FRP

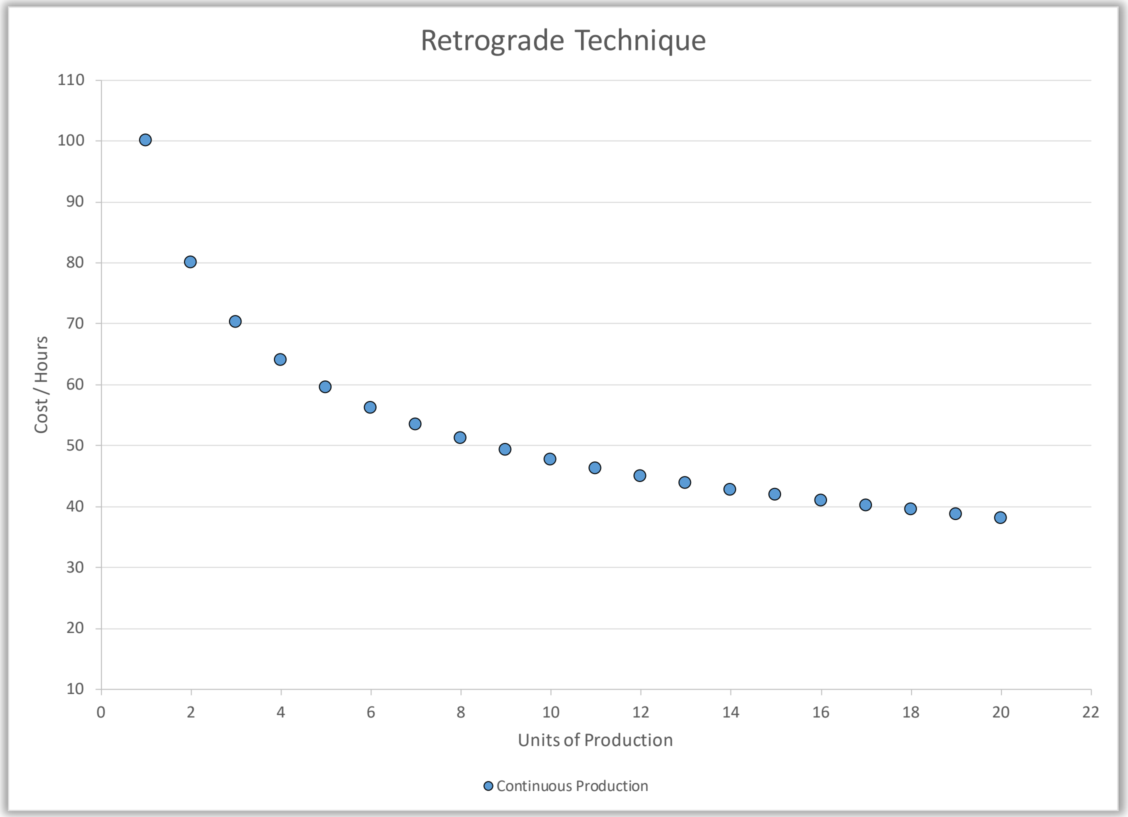
Background (cont'd)

- Initial Methodology
  - Estimated the learning rate based on historical programs
  - Employed retrograde method to model the lost learning
  - Anderlohr's method to estimate the level of lost learning
    - *Personnel Learning*
    - *Supervisory Learning*
    - *Continuity of Productivity*
    - *Methods*
    - *Special Tooling*
    - *Example:*

Category	Weight	Percent Lost	Weighted Loss
Personnel	25%	75%	18.8%
Supervisory	20%	20%	4.0%
Continuity of Production	20%	50%	10.0%
Tooling	15%	25%	3.8%
Methods	20%	50%	10.0%
Total Loss of Learning Factor	100%		46.5%

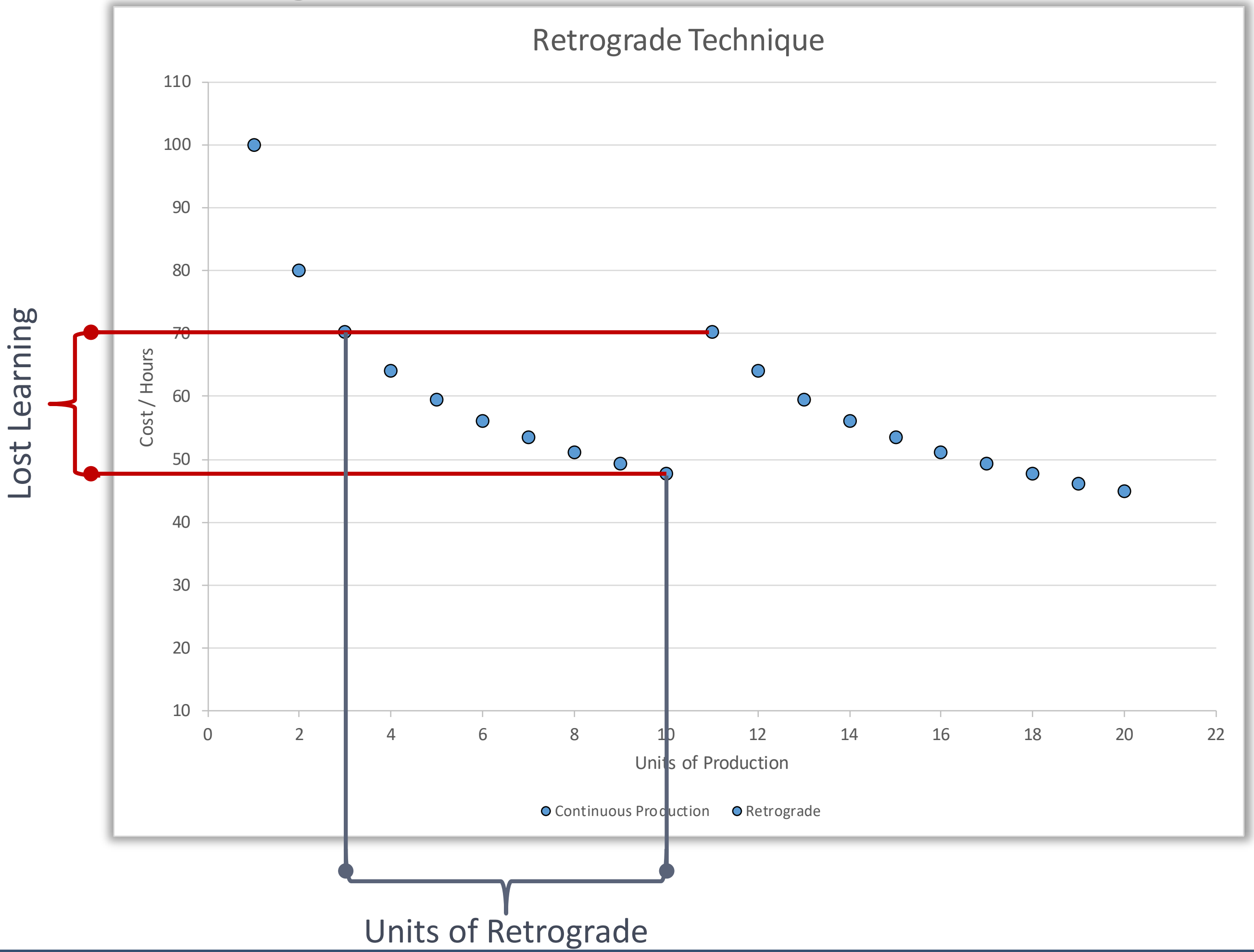
Review of Retrograde Technique

- Learning Curve Equation
  - $UC = AX^b$
  - Where
    - A = Theoretical First Unit (TFU)
    - X = The number of the production unit in question
    - b = Ln(slope)/Ln(2)
- Problem Illustration
  - TFU = 100 hours
  - Learning Slope = 80%
  - Production Break at the 10th unit



Review of Retrograde Technique (cont'd)

- Illustration: Retrograde Solution
  - Incorporating 45% loss of gained efficiencies yields an equivalent of 7 units of retrograde



Review of Retrograde Technique (cont'd)

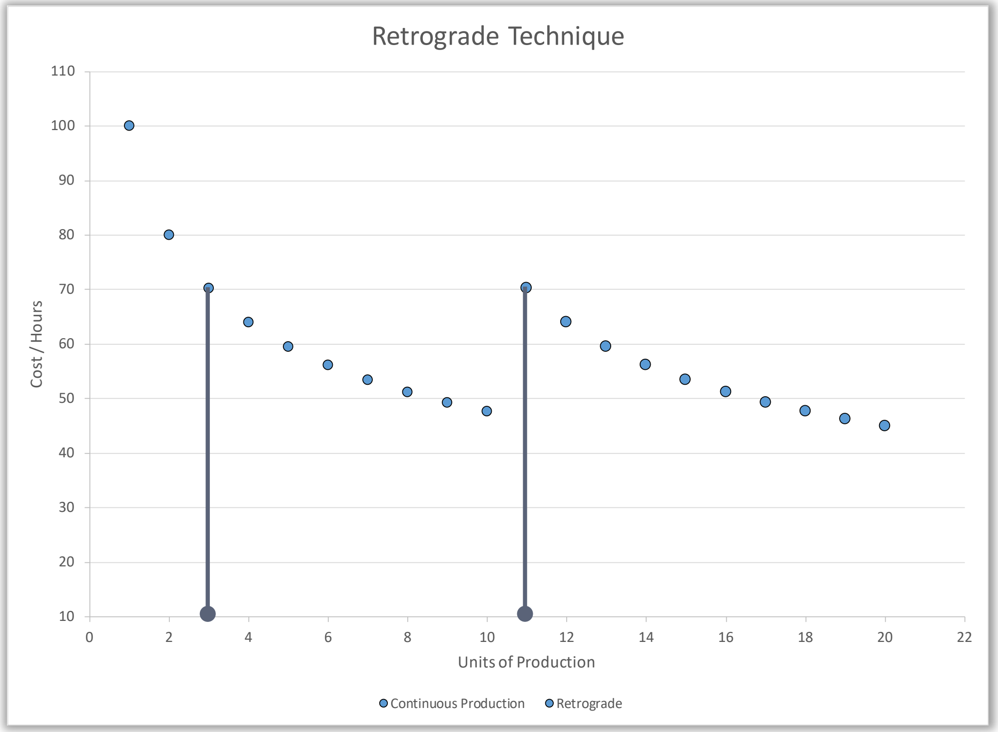
Illustration: The math

- Efficiencies gained: $UC_1 - UC_{10} = 100 - 47.7 \approx 52.4$
- Lost Efficiency (from Anderlohr's technique): $0.465 * 52.4 \approx 24$
- Hours for the 11th unit would have been 46, but now they equal:

  $46 + 24 = 70 \approx UC_3$
- The number of retrograde units = 7

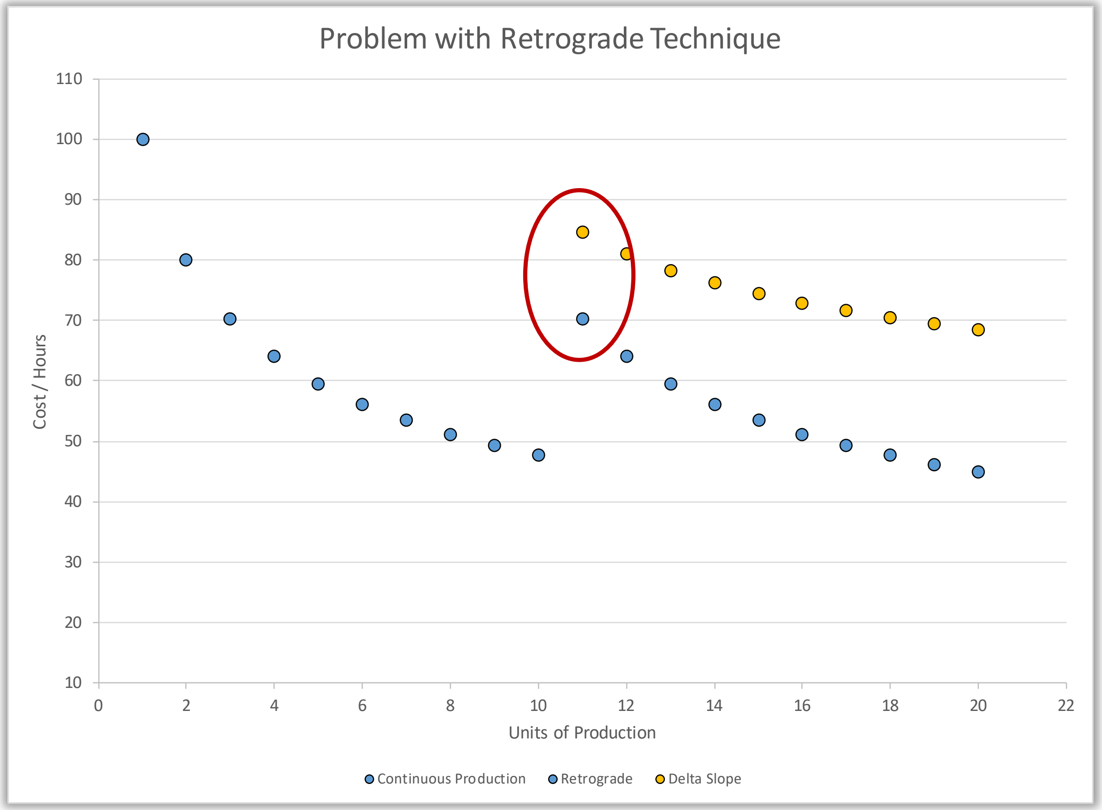
Equation of Curve after the break

- $UC_{1,X} = UC_{0,(X-K)}$; $X \geq F$
  - UC = Unit Cost
  - X = X^{th} production Unit
  - K = Units of Retrograde + 1
  - F = First Unit after Break
- $UC_{1,11} = UC_{0,(11-8)} = UC_{0,3}$



Problem Illustration

- When the post-break slope (b_1) does not equal the pre-break slope (b_0)
  - $UC_{1,11} = A_0(X - K)^{b0}$
    - $A_0(X\text{-}K)^{b0}$ = 100 * 3^ (ln(.80)/ln(2)) = 70.2, given original slope
    - $A_0\,(X\text{-}K)^{b1}$ = 100 * 3^ (ln(.90)/ln(2)) = 84.6, given the new slope

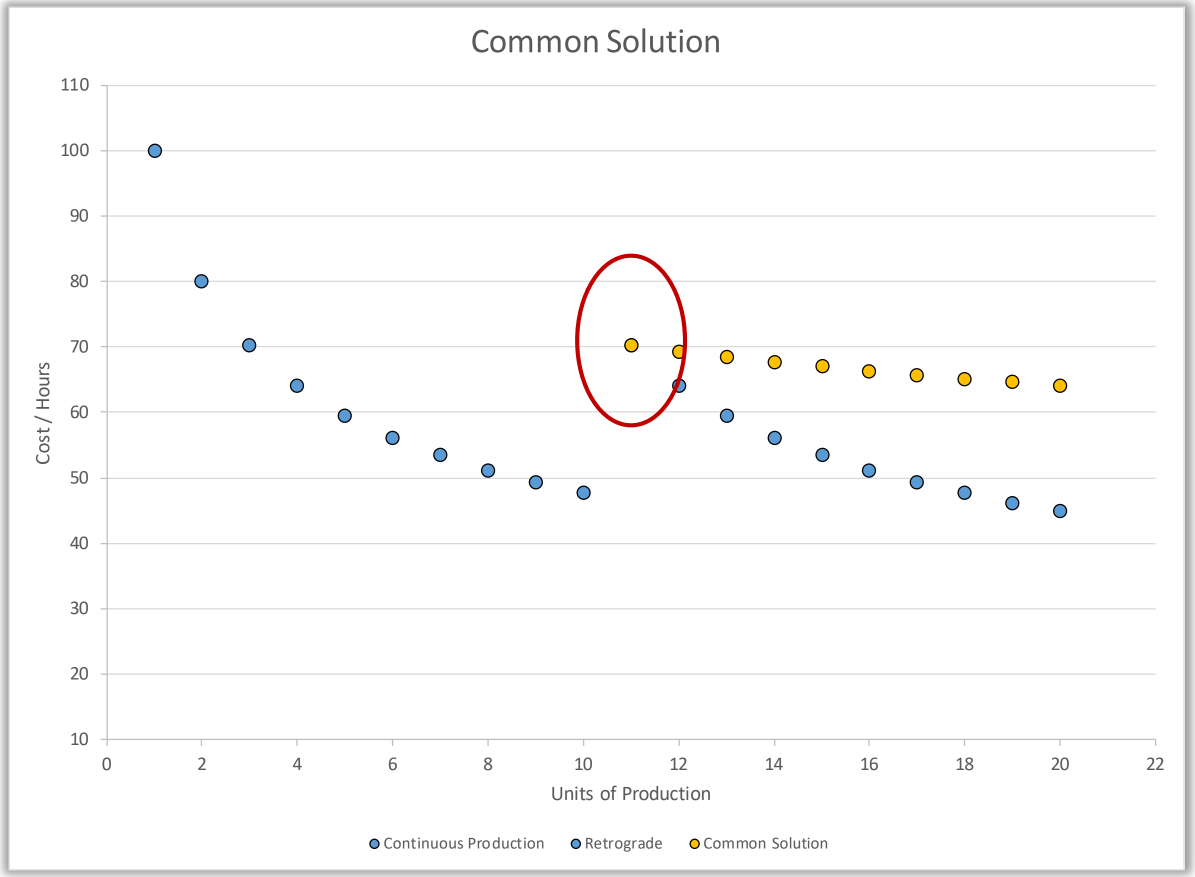


Common Solution

- By changing the learning slope after the break, we must necessarily relax the condition $UC_{1,X} = UC_{0,(X-K)}$ for $X \geq F$
- We recognize that the important condition is that the proper level of learning is lost. So we treat the pre and post-break curves as distinct equations and set the initial condition
  - $UC_{1,F} = UC_{0,F-K}$
- With only one unknown (A_1) we can solve the equation
  - $A_1F^{b1} = A_0(F-K)^{b0}$
  - $A_1 = A_0(F-K)^{b0} / F^{b1}$
- The Post-Break equation becomes
  - $UC_{1,X} = [A_0(F-K)^{b0} / F^{b1}]X^{b1}; X \geq F$

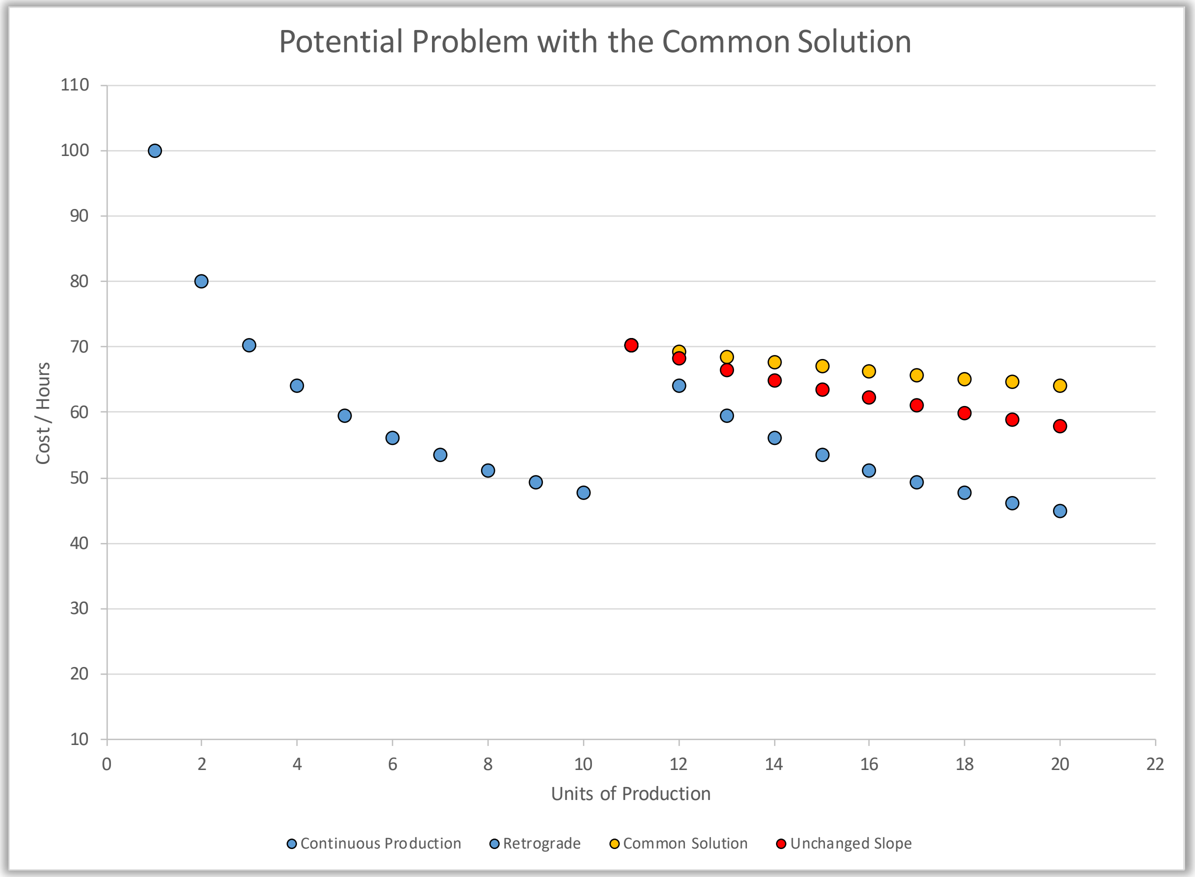
Common Solution (cont'd)

- As expected the amount of lost learning is calculated correctly and the post-break slope follows the new learning slope



A Problem with the Solution

- $UC_{1,X} \neq UC_{0,(X-K)}$ for X > F when the slope remains unchanged



Second Generation Upgrade: Problem Statement

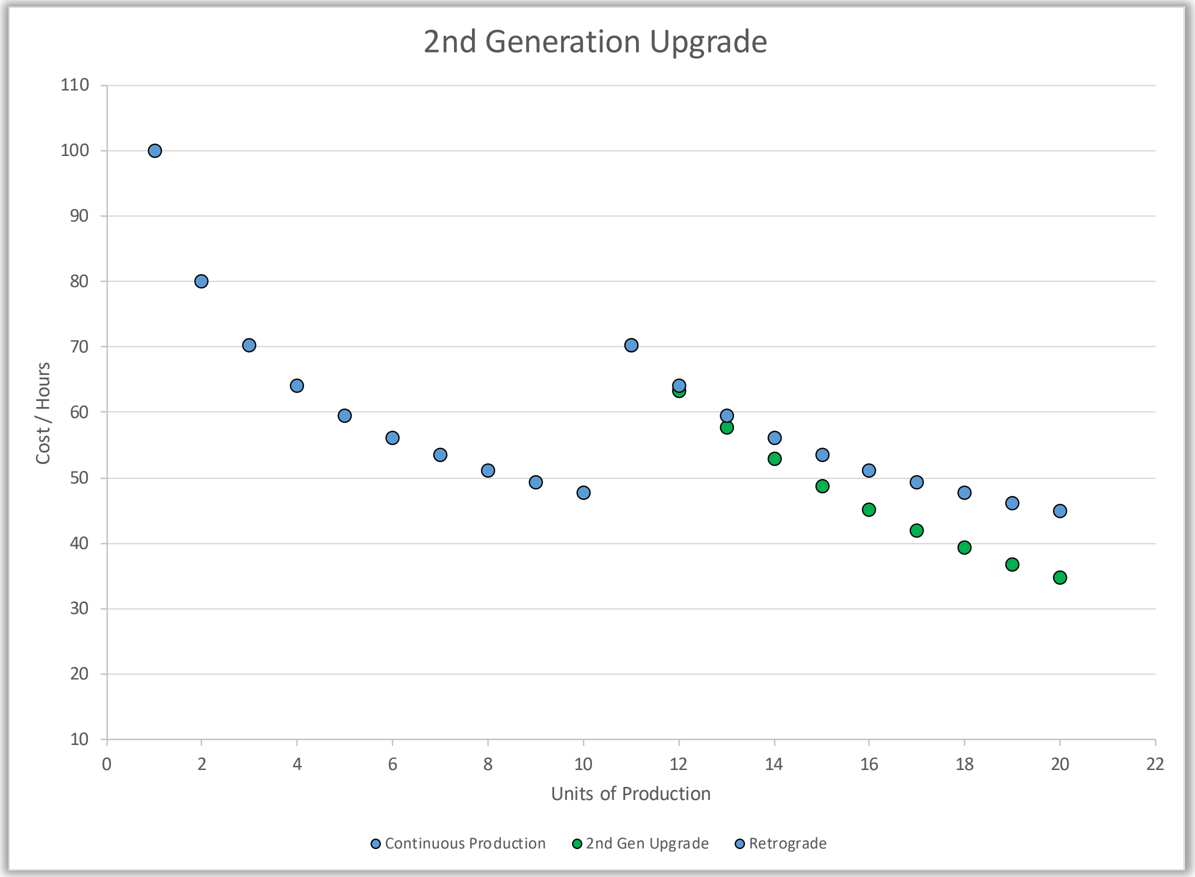
- Using the common solution, <u>the rate of change</u> at the first unit after the production break, does not equal <u>the rate of change</u> at the equivalent unit prior to the production break when the learning slope remains unchanged
  - $UC'_{0,\,F-K} \neq UC'_{1,\,F}$

Second Generation Upgrade

- Conditions for the Second Generation Upgrade
  - $UC_{0,\, F-K} = UC_{1,\, F}$
  - $UC'_{0,\, F-K} = UC'_{1,\, F}$
- Finding the derivatives of UC_0 and UC_1 are straight forward
  - $UC'_{0,\, F-K} = A_0\, b_0\, (F-K)^{(b0-1)}$
  - $UC'_{1,\, F} = A_1\, b_1\, F^{(b1-1)}$
- Expanding the equations for the first condition yields
  - $A_1F^{b1} = A_0(F-K)^{b0}$
- Expanding the equations for the second condition yields
  - $A_1\, b_1\, F^{(b1-1)} = A_0\, b_0\, (F-K)^{(b0-1)}$
- This gives us 2 equations and 2 unknowns. Solving them yields
  - $A_1 = A_0\, (F-K)^{b0} \,/\, F^{(b0 * F/(F-K))}$
  - $b_1 = b_0\, F \,/\, (F-K)$

Second Generation Upgrade (cont'd)

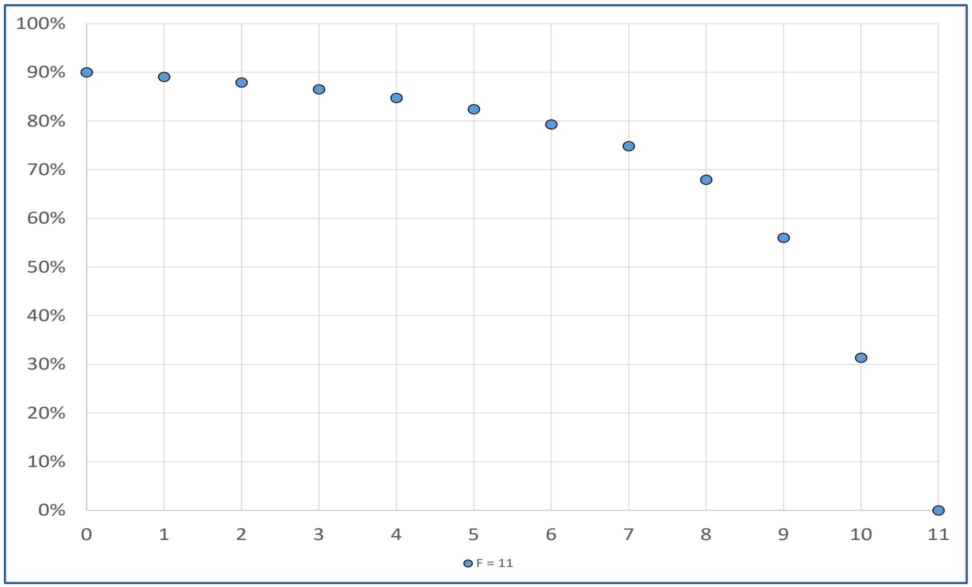
- This upgrade offers a more aggressive learning slope relative to the retrograde solution



Peripheral Topics

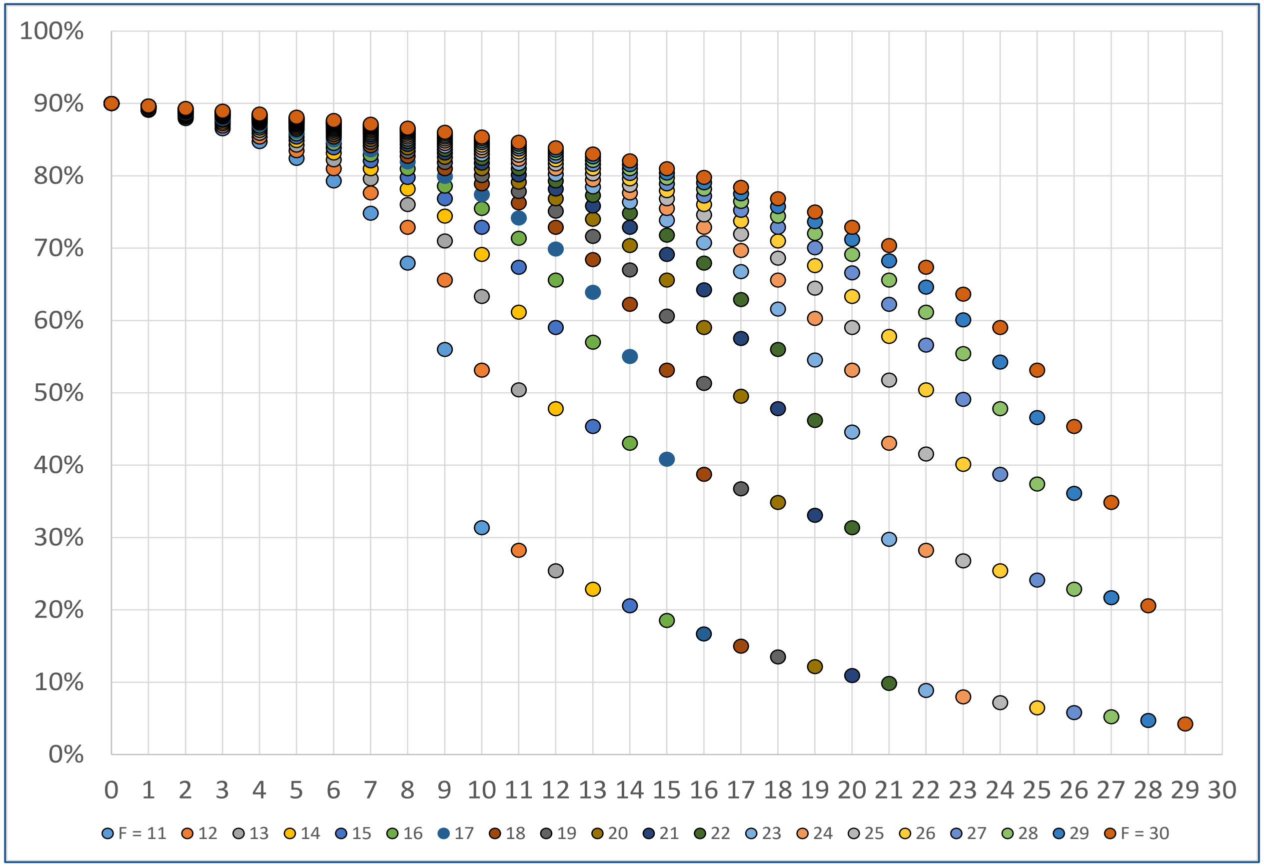
Challenges to the Technique

- From the solution we calculate
  - $b_1 = b_0 F / (F - K)$
- Since $F > 0$ and $K > 0$ it necessarily follows that $F/(F - K) \geq 1$
- Since $b_0 \leq 0$, $b_1 \leq b_0$ (i.e. b_1 is more negative than b_0)
- This means that the slope of the post-break curve is at least as aggressive than the slope of the pre-break curve



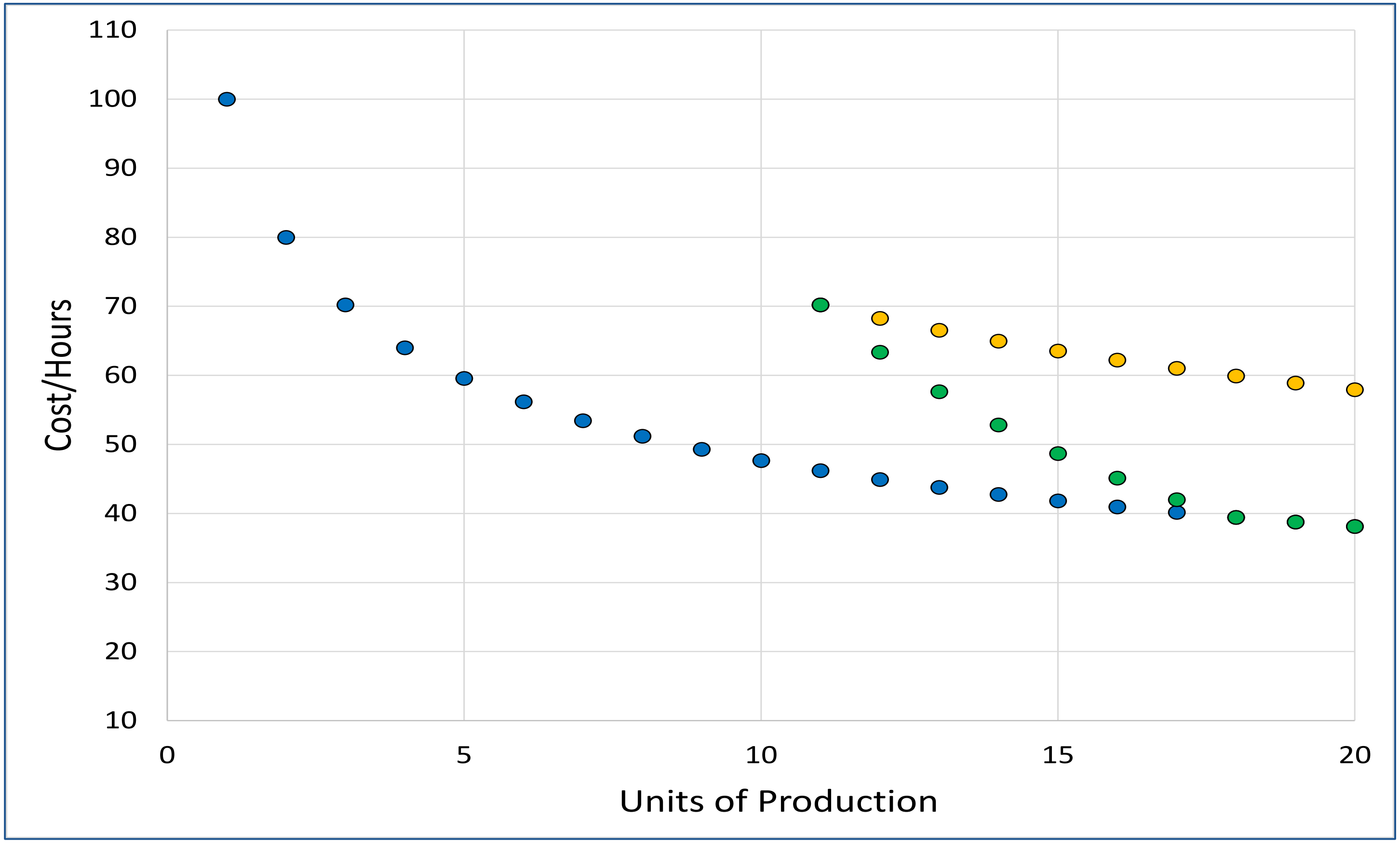
Challenges to the Technique (cont'd)

- The chart illustrates that the steepness of the slope changes mildly for small K, but increases dramatically as K approaches F.



Possible Application

- New plant, or additional production line, the loss of learning is inevitable, but some have argued that the new production line should “catch up” to the original line.



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