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

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Outline

- About the Author
- Background
- 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:

<table>
<thead>
<tr>
<th>Category</th>
<th>Weight</th>
<th>Percent Lost</th>
<th>Weighted Loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>Personnel</td>
<td>25%</td>
<td>75%</td>
<td>18.8%</td>
</tr>
<tr>
<td>Supervisory</td>
<td>20%</td>
<td>20%</td>
<td>4.0%</td>
</tr>
<tr>
<td>Continuity of Production</td>
<td>20%</td>
<td>50%</td>
<td>10.0%</td>
</tr>
<tr>
<td>Tooling</td>
<td>15%</td>
<td>25%</td>
<td>3.8%</td>
</tr>
<tr>
<td>Methods</td>
<td>20%</td>
<td>50%</td>
<td>10.0%</td>
</tr>
<tr>
<td>Total Loss of Learning Factor</td>
<td>100%</td>
<td></td>
<td>46.5%</td>
</tr>
</tbody>
</table>
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
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): $0.465 \times 52.4 \approx 24$
- 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 ($b_0$)
  - $UC_{1,11} = A_0(X - K)^{b_0}$
    - $A_0(X-K)^{b_0} = 100 * 3^{\ln(.80)/\ln(2)} = 70.2$, given original slope
    - $A_0(X-K)^{b_1} = 100 * 3^{\ln(.90)/\ln(2)} = 84.6$, 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:
  - \( A_1 F^{b_1} = A_0 (F - K)^{b_0} \)
  - \( A_1 = A_0 (F - K)^{b_0} / F^{b_1} \)

- The Post-Break equation becomes:
  - \( UC_{1,X} = [A_0 (F - K)^{b_0} / F^{b_1}]X^{b_1}; \ X \geq F \)
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

Potential Problem with the Common Solution

![Graph showing potential problem with the common solution](image-url)
Second Generation Upgrade: Problem Statement

- Using the common solution, the rate of change at the first unit after the production break, does not equal the rate of change 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 straightforward**
  - $UC'_0, F – K = A_0 b_0 (F – K)^{(b_0 - 1)}$
  - $UC'_1, F = A_1 b_1 F^{(b_1 - 1)}$

- **Expanding the equations for the first condition yields**
  - $A_1 F^{b_1} = A_0 (F – K)^{b_0}$

- **Expanding the equations for the second condition yields**
  - $A_1 b_1 F^{(b_1 – 1)} = A_0 b_0 (F – K)^{(b_0 – 1)}$

- **This gives us 2 equations and 2 unknowns. Solving them yields**
  - $A_1 = A_0 (F – K)^{b_0} / F^{(b_0 * F / (F – K))}$
  - $b_1 = b_0 F / (F – K)$
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
  - \( b_1 = b_0 \frac{F}{F - K} \)
- Since \( F > 0 \) and \( K > 0 \) it necessarily follows that \( \frac{F}{F - K} \geq 1 \)
- 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
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.