A Probabilistic Method for Predicting Code Growth - 2018 Update

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Outline

• Software Cost Estimating Process
• What is code growth?
• Existing Methodology - DSLOC Estimate Growth Model v7 (DEGM7)
• New Methodology - DSLOC Estimate Growth Model v8 (DEGM8)
  • Equations and Explanations
    • Technical Baseline Estimates (TBE)
    • Baseline Growth Amounts
      • Orthogonal Distance Regression (ODR)
  • Maturity
  • SRDR Filtering
  • Outputs
• Conclusion
• Contact Information
• References
• Backup
  • Variable Definition
  • Methodology Based on Specific Operating Environments
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**r2-v2 SEF Process Flow:**

Creating New CDERs for the Library

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**r2-v2 SEF Process Flow Diagram:**

1. **CARD**
   - Size\textsubscript{New} (DSLOC)
   - Size\textsubscript{Mod} (DSLOC)
   - Size\textsubscript{Unmod} (DSLOC)
   - Maturity (0%-100%)

2. Historical Data
3. **DSLOC Growth Model**
4. **Rework Model**
   - Effective Size (ESLOC)

5. **ACEIT**
6. **Excel**

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**Acquisition GR&As & System Description**

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**Cost Analyst**

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**Selected CDER(s)**

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**Joint CDER Model**

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**Duration**

---

**Cost**

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**Effort**

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**Historical Data**

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**Joint CDER Calibrate**

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**Cost Analyst**

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**ACEIT**

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**Presented at the 2018 ICEAA Professional Development & Training Workshop - www.iceaaonline.com**
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What is code growth?

• Code growth is the difference between actual Delivered Source Lines of Code (DSLOC) of a completed software development project and its previously estimated DSLOC amount.

  Actual DSLOC > Estimated DSLOC → Growth
  Actual DSLOC < Estimated DSLOC → Growth (Shrink)

• Reasons for Code Growth:
  • The customers didn’t know what they wanted at the start of the program
  • The mission/requirements (REQTS) changed (requirements volatility)
  • The vendor finished early so the customer thought up a few things to add
  • Software regulations have changed
  • Optimistic (e.g. overestimate of unmodified DSLOC)
  • Poor DSLOC TBE
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Existing Growth Methodology

DSLOC Estimate Growth Model v7 (DEGM7)

- What we are currently using:
  - Step 1: Baseline Growth (w/ uncertainty) applied to Technical Baseline
    - Based on DSLOC Estimate Growth Methodology (Ross, v07) using 2011 SRDR data
    - Factored Based Model
  - Step 2: Total growth discounted based on maturity
    - Barry Boehm’s “Cone of Uncertainty”
    - Unchanged for DEGM8
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New Growth Methodology
DSLOC Estimate Growth Model v8 (DEGM8)

• This model represents a significant update and modernization of the DSLOC Estimate Growth Model version 7 (DEGM7) (Ross, 2011) in that:
  • It is based on additional data from the 2015 SRDR database.
  • It is based on a better method of regressing the historical data.
  • It recognizes non-linear relationships between size and growth.
  • It introduces error on the independent variable (DSLOC)
  • It decomposes the version 7 notion of Pre-existing reused software into Modified software and Unmodified software.
  • It recognizes correlation between New, Modified, and Unmodified growth.
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The DEGM8 equations for applying growth and uncertainty to TBE New, Modified, and Unmodified DSLOC are shown in Figure 1

\[ S_{DGANew} = S_{DNew} + e^{-(\text{Decay})(\text{Maturity})} \left( \tilde{b}_{GN} \varepsilon_{GN} \left( \frac{S_{DNew}}{K_N} \right)^{aGN} K_N - S_{DNew} \right) \]

\[ S_{DGAMod} = S_{DMod} + e^{-(\text{Decay})(\text{Maturity})} \left( \tilde{b}_{GM} \varepsilon_{GM} \left( \frac{S_{DMod}}{K_M} \right)^{aGM} K_M - S_{DMod} \right) \]

\[ S_{DGAUmod} = S_{DUmod} + e^{-(\text{Decay})(\text{Maturity})} \left( \tilde{b}_{GU} \varepsilon_{GU} \left( \frac{S_{DUmod}}{K_U} \right)^{aGU} K_U - S_{DUmod} \right) \]

Figure 1  DEGM8 equations yield the sum of the appropriate TBE DSLOC value and its calculated DSLOC growth amount. The calculated DSLOC Growth amount is the product of the baseline DSLOC growth amount (zero maturity) and the calculated estimate maturity adjustment factor.

Variable Definition in backup
The DEGM8 accepts, as input, Technical Baseline Estimate (TBE) amounts for
New ($S_{D\text{New}}$), Modified ($S_{D\text{Mod}}$), and Unmodified DSLOC ($S_{D\text{Umod}}$).

They are rendered at various times during the program; Based on some combination of engineering analysis, relevant past program experience, and expert judgment.

These estimates represent the technical team’s best guess as to what the final outcome New, Modified, and Unmodified DSLOC values will be when the system is delivered and accepted.
DEGM8 Growth Equations
Baseline Growth Amounts (DSLOC)

- DEGM8 introduces a new regression technique (ODR)
  - Baseline Growth Equation is now a power function rather than a factor
  - Historically, DoD SW intensive programs experience significant growth; this technique allows us to model error on the initial SLOC input
- $\tilde{b}_G, a_G, \varepsilon_G \rightarrow$ calculated as part of the regression technique
- $S_D, K \rightarrow$ Inputs into Baseline Growth Equation
**Orthogonal Distance Regression (ODR)**

- **What is ODR?**
  - A process for finding a “best fit” line (an estimator) through a multi-dimension set of data points (observations) by minimizing the sum of the squared orthogonal (shortest) distances between each data point and that line.

**Ordinary Least Squares (OLS)**
Minimizes the *vertical* distance between each data point and the regression line.

**Orthogonal Distance Regression (ODR)**
Minimizes the *Orthogonal* distance between each data point and the regression line.
Why is ODR better than Ordinary Least Squares (OLS) regression and its variants?

- Works in situations where there are more than two dimensions (measures) without making assumptions about which measure is dependent and which are independent (example: Space Flight Software)
- Accounts the existence of measurement error in all dimensions; not just in the “dependent” variable
Singular Value Decomposition (SVD) for DEGM8 Equation Coefficients

To find the system of equations that define an ODR best fit line we center the data set by using the data set centroid and then applying the SVD.

Transform & center the data

\[
M = \begin{bmatrix}
\ln(S_{DNEst_1}) - C_{ln(p)_{SDNEst}} & \ln(S_{DNAct_1}) - C_{ln(p)_{SDNAct}} \\
\ln(S_{DNEst_2}) - C_{ln(p)_{SDNEst}} & \ln(S_{DNAct_2}) - C_{ln(p)_{SDNAct}} \\
\vdots & \vdots \\
\ln(S_{DNEst_N}) - C_{ln(p)_{SDNEst}} & \ln(S_{DNAct_N}) - C_{ln(p)_{SDNAct}}
\end{bmatrix}
\]

Perform SVD

\[
SVD(M) = \{U, \Sigma, V^T\} \quad | \quad M = U\Sigma V^T
\]

Define ODR coefficients using Direction Vector, \(a\)

\[
M = U \begin{bmatrix}
\Sigma_{1,1} & 0 \\
0 & \Sigma_{2,2}
\end{bmatrix} \begin{bmatrix}
V_{1,1} & V_{1,2} \\
V_{2,1} & V_{2,2}
\end{bmatrix}^T
\]

\[
= U \begin{bmatrix}
\Sigma_{1,1} & 0 \\
0 & \Sigma_{2,2}
\end{bmatrix} \begin{bmatrix}
a_{SDNEst} \\
a_{SDNAct}
\end{bmatrix} \begin{bmatrix}
V_{1,1} & V_{1,2} \\
V_{2,1} & V_{2,2}
\end{bmatrix}^T
\]

The resulting ODR best fit line is specified by a known point on the line (the data set centroid) and a direction vector (the column of the singular vector matrix that is associated with the largest singular value in the singular value matrix).

\[
S_{DGANewBL} = b_{GN} S_{DNew} a_{GN}
\]

Note: Please see paper for details on SVD and transformation of SVD results to ODR line.
DEGM8 Growth Equations

Maturity Adjustment Factor

- Maturity Adjustment Factor = $e^{-(\text{Decay})(\text{Maturity})} = e^{-(3.466)(\text{Maturity})}$

- **Growth Decay:** Based on Boehm’s (1981 pp. 310-311) Cone of Uncertainty. Given the limited amount of granular, periodic, and relevant historical DSLOC estimate data available, we used Boehm’s (1981 pp. 310-311) Cone of Uncertainty as the DEGM8’s default position.
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The baseline (default) instance of the DEGM8 equation parameter values for New, Modified, and Unmodified DSLOC is based on a subset of 2015 Software Resources Data Report (SRDR) data collected and archived by the U.S. Department of Defense’s Defense Cost and Resource Center (DCARC).

Filter criteria:
- SI: TRUE – the observation must represent a Computer Software Configuration Item (CSCI)-like Software Item (SI) (i.e., not a collection, summary, or roll-up of multiple CSCIs).
- Nonphysical: TRUE – the observation’s DSLOC values must not be measured in units of straight physical lines of code (i.e., they must be measured in logical lines of code (language statements) or non-comment physical lines of code).
- GFValid: TRUE – the observation must contain DSLOC values to calculate New, Modified, and/or Unmodified DSLOC growth factors that are all inside three geometric standard deviations from their respective population (entire database) geometric mean (see Table 2 on the next slide).

Database exhibit some CSCI’s with unrealistic growth; they are obvious outliers in the database.
- 1 Example showed a CSCI with >100x’s growth.
- Filtering out data at +/- 3 Geometric SD’s is an attempt to unbiasedly remove those outliers.
Table 2: Statistical outlier filtering comparison; regression JCDER349 with 3 geometric standard deviation statistical outlier filtering was chosen as the basis for the DEGM8.

<table>
<thead>
<tr>
<th>Statistical Outlier Filtering:</th>
<th>New DSLOC</th>
<th>Modified DSLOC</th>
<th>Unmodified DSLOC</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>JCDER345</td>
<td>JCDER349</td>
<td>JCDER346</td>
</tr>
<tr>
<td></td>
<td>None</td>
<td>3 GeoSigma</td>
<td>2 GeoSigma</td>
</tr>
<tr>
<td></td>
<td>302</td>
<td>225</td>
<td>213</td>
</tr>
<tr>
<td></td>
<td>0.7947</td>
<td>1.2084</td>
<td>1.1137</td>
</tr>
<tr>
<td>Geometric (log space) mean of b:</td>
<td>3.4527</td>
<td>1.7360</td>
<td>1.4867</td>
</tr>
<tr>
<td></td>
<td>19.1832</td>
<td>1.8493</td>
<td>1.3418</td>
</tr>
<tr>
<td>Standard deviation of b:</td>
<td>5.49</td>
<td>1.07</td>
<td>0.90</td>
</tr>
<tr>
<td>Coefficient of Variation (CV) b:</td>
<td>1.3968</td>
<td>1.3665</td>
<td>1.2819</td>
</tr>
<tr>
<td>Arithmetic (unit space) mean of t:</td>
<td>3.2795</td>
<td>1.2238</td>
<td>0.9590</td>
</tr>
<tr>
<td>Standard deviation of t:</td>
<td>1.69</td>
<td>0.50</td>
<td>0.75</td>
</tr>
<tr>
<td>Mean Magnitude of the Relative Error:</td>
<td>61%</td>
<td>44%</td>
<td>39%</td>
</tr>
<tr>
<td>Implied Growth Factor at data set arithmetic mean baseline DSLOC:</td>
<td>96% at 74,958 DSLOC</td>
<td>53% at 56,443 DSLOC</td>
<td>49% at 60,213 DSLOC</td>
</tr>
<tr>
<td></td>
<td>31% at 45,547 DSLOC</td>
<td>11% at 22,934 DSLOC</td>
<td>10% at 23,216 DSLOC</td>
</tr>
<tr>
<td>Implied Growth Factor at data set geometric mean baseline DSLOC:</td>
<td>80% at 25,635 DSLOC</td>
<td>50% at 23,038 DSLOC</td>
<td>45% at 23,672 DSLOC</td>
</tr>
<tr>
<td></td>
<td>33% at 9,161 DSLOC</td>
<td>22% at 7,756 DSLOC</td>
<td>17% at 7,808 DSLOC</td>
</tr>
</tbody>
</table>

Default Method based on filtering out +/- 3 Geometric SD
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Output (Default: All Paired Data – Filtered)
ODR Equation

<table>
<thead>
<tr>
<th>Coefficient</th>
<th>New</th>
<th>Modified</th>
<th>Unmodified</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a_G)</td>
<td>1.021</td>
<td>0.913</td>
<td>1.044</td>
</tr>
<tr>
<td>(b_G)</td>
<td>1.208</td>
<td>2.651</td>
<td>0.6199</td>
</tr>
</tbody>
</table>

**Baseline Growth (New DSLOC)**

\[ b_{GN} \varepsilon_{GN} \left( \frac{S_{DNew}}{K_N} \right)^{a_{GN}} K_N - S_{DNew} \rightarrow 1.208 \varepsilon_{GN} \left( \frac{S_{DNew}}{K_N} \right)^{1.021} K_N - S_{DNew} \]

**Baseline Growth (Mod DSLOC)**

\[ b_{GM} \varepsilon_{GM} \left( \frac{S_{DMod}}{K_M} \right)^{a_{GM}} K_M - S_{DMod} \rightarrow 2.651 \varepsilon_{GM} \left( \frac{S_{DMod}}{K_M} \right)^{0.913} K_M - S_{DMod} \]

**Baseline Growth (Unmod DSLOC)**

\[ b_{GU} \varepsilon_{GU} \left( \frac{S_{DUmod}}{K_U} \right)^{a_{GU}} K_U - S_{DUmod} \rightarrow 0.6199 \varepsilon_{GU} \left( \frac{S_{DUmod}}{K_U} \right)^{1.044} K_U - S_{DUmod} \]
Output (Default: All Paired Data – Filtered)
Cumulative Distribution Function (CDF)

- $\varepsilon_{GN}$, $\varepsilon_{GM}$, $\varepsilon_{GU}$

<table>
<thead>
<tr>
<th>Percentile</th>
<th>JCDER349_e_GN_CDF</th>
<th>JCDER349_e_GM_CDF</th>
<th>JCDER349_e_GU_CDF</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>0.22780002</td>
<td>0.19797695</td>
<td>0.31476088</td>
</tr>
<tr>
<td>10</td>
<td>0.29379456</td>
<td>0.26905482</td>
<td>0.52151790</td>
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<tr>
<td>15</td>
<td>0.42005378</td>
<td>0.37202772</td>
<td>0.69719375</td>
</tr>
<tr>
<td>20</td>
<td>0.51067177</td>
<td>0.44448984</td>
<td>0.80244290</td>
</tr>
<tr>
<td>25</td>
<td>0.58960123</td>
<td>0.58049465</td>
<td>0.87663594</td>
</tr>
<tr>
<td>30</td>
<td>0.72495221</td>
<td>0.74853580</td>
<td>0.93359197</td>
</tr>
<tr>
<td>35</td>
<td>0.86357696</td>
<td>0.88755418</td>
<td>0.95855498</td>
</tr>
<tr>
<td>40</td>
<td>0.94805461</td>
<td>0.96684746</td>
<td>0.97517640</td>
</tr>
<tr>
<td>45</td>
<td>1.07607675</td>
<td>1.04115081</td>
<td>0.99675890</td>
</tr>
<tr>
<td>50</td>
<td>1.13572756</td>
<td>1.12987711</td>
<td>1.01372680</td>
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<tr>
<td>55</td>
<td>1.21842846</td>
<td>1.17893913</td>
<td>1.02592816</td>
</tr>
<tr>
<td>60</td>
<td>1.33350780</td>
<td>1.20158562</td>
<td>1.04526460</td>
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<td>65</td>
<td>1.44006179</td>
<td>1.29116776</td>
<td>1.09504214</td>
</tr>
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<td>70</td>
<td>1.48139681</td>
<td>1.37838414</td>
<td>1.13383614</td>
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<tr>
<td>75</td>
<td>1.51552892</td>
<td>1.51895071</td>
<td>1.16555251</td>
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<td>80</td>
<td>1.63383151</td>
<td>1.67307957</td>
<td>1.26139028</td>
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<td>85</td>
<td>1.86949605</td>
<td>2.17763327</td>
<td>1.39181571</td>
</tr>
<tr>
<td>90</td>
<td>2.68118931</td>
<td>4.02790186</td>
<td>1.77923586</td>
</tr>
<tr>
<td>95</td>
<td>3.85981488</td>
<td>5.56055883</td>
<td>2.52099764</td>
</tr>
<tr>
<td>100</td>
<td>8.80095370</td>
<td>8.68058303</td>
<td>6.98289033</td>
</tr>
</tbody>
</table>

CDFs above are abbreviated for this presentation

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Correlation between DSLOC type
- New & Modified: 0.00257
- New & Unmodified: 0.302
- Modified & Unmodified: 0.0745

For this particular subset, correlation between growth is weak and will have little impact on result.

When we start to investigate growth by operating environment, there is evidence of stronger correlations.

Interesting to note that negativity correlation may exist.
Output (Default: All Paired Data – Filtered)
Notional Example

- Assume estimating NAV CSCI for Ground System
  - TBEs for New, Modified, and Unmodified software size are 25,000 DSLOC, 50,000 DSLOC, and 100,000 DSLOC respectively
  - 1 CSCI (normalization of the TBEs to the historical data is unnecessary)
  - Assume SLOC estimate rendered at SwRR (20% maturity)
  - Assume based on Boehm’s (1981 pp. 310-311) Cone of Uncertainty
  - Assume methodology based on Default Methodology (All Paired Filtered Data)

❗ Represents mean growth at SwRR for Notional Program
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Conclusions/Way Ahead

• Our latest methodology (DEGM8) is based on a better method of regressing the historical data.
  • It recognizes non-linear relationships between size and growth.
  • Decomposes modified and unmodified software growth methodologies
  • It accounts for correlation between New, Modified, and Unmodified growth.

• Way Ahead
  • Update database with 2017 SRDR
  • Continue Flight Software data collection efforts
  • Rerun the data analysis for additional software operating environments, application domains, and other characteristics of interest.
  • Create a specific growth model for each Joint Cost and Duration Estimating Relationship (JCDER)
Contact Information

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References

**DEGM8 Growth Equations**

**Baseline Growth Amounts (DSLOC)**

- **Input** – Technical Baseline Estimate (TBE) of Unmodified DSLOC
- **Decay** – Decay constant; default is 3.466 based on Boehm’s (1981 pp. 310-311) Cone of Uncertainty
- **Input** – Estimate Maturity Parameter: (SDLCallOccurrence in ATP, Contract Award) = 5%; SyRR = 10%; SwRR = 20%; SwPDR = 40%; SwCDR = 60%; SwTRR = 80%; SwAccept = 100%)
- **Model** – Baseline (SDLCallOccurrence) New DSLOC growth error factor distribution of outcomes with associated attainment probability; approximated by Custom CDF in Appendix A
- **Model** – Baseline (SDLCallOccurrence) Modified DSLOC growth error factor distribution of outcomes with associated attainment probability; approximated by Custom CDF in Appendix A
- **Model** – Baseline Unmodified DSLOC growth error factor distribution of outcomes with associated attainment probability; approximated by Custom CDF in Appendix A
- **Model** – Exponent parameters for New, Modified, and Unmodified DSLOC growth estimating relationships that are calculated by the regression process
- **Model** – Geometric mean (arithmetic mean in log space) scale factor parameters for New, Modified, and Unmodified DSLOC growth estimating relationships that are calculated by the regression process
- **Input** – Software Item (SI) to Computer Software Configuration Item (CSCI) normalization factors for New, Modified, and Unmodified DSLOC

\[ S_{DGAnew} = S_{DSnew} + e^{-(Decay) \cdot (Maturity)} \left( \delta_{GN} \cdot \epsilon_{GN} \left( \frac{S_{DSnew}}{K_N} \right)^{\alpha_{GN}} K_N - S_{DSnew} \right) \]

\[ S_{DGAMod} = S_{DSmod} + e^{-(Decay) \cdot (Maturity)} \left( \delta_{GM} \cdot \epsilon_{GM} \left( \frac{S_{DSmod}}{K_M} \right)^{\alpha_{GM}} K_M - S_{DSmod} \right) \]

\[ S_{DGAtUnmod} = S_{DSUnmod} + e^{-(Decay) \cdot (Maturity)} \left( \delta_{GU} \cdot \epsilon_{GU} \left( \frac{S_{DSUnmod}}{K_U} \right)^{\alpha_{GU}} K_U - S_{DSUnmod} \right) \]

- **Output** – growth-adjusted New DSLOC distribution of outcomes with associated attainment probability
- **Output** – growth-adjusted Modified DSLOC estimate distribution of outcomes with associated attainment probability
- **Output** – growth-adjusted Unmodified DSLOC estimate distribution of outcomes with associated attainment probability

\[ \delta_{GN}, \delta_{GM}, \delta_{GU}, \alpha_{GN}, \alpha_{GM}, \alpha_{GU} \]

- Estimator equality symbol; the left expression estimates the right expression
- **Input** – Technical Baseline Estimate (TBE) of New DSLOC
- **Input** – Technical Baseline Estimate (TBE) of Modified DSLOC

\[ K_N, K_M, K_U \]
### Output (Default: All Pair Data – Filtered)

**ODR Equation**

<table>
<thead>
<tr>
<th>Percentile</th>
<th>JCDER349_e_GN_CDF</th>
<th>JCDER349_e_GM_CDF</th>
<th>JCDER349_e_GU_CDF</th>
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**JCDER349 (Custom Growth CDFs)**

- **Percentile**
- **JCDER349_e_GN_CDF**
- **JCDER349_e_GM_CDF**
- **JCDER349_e_GU_CDF**

**Correlation**

- **Presented at the 2018 ICEAA Professional Development & Training Workshop - www.iceaaonline.com**

---

**Table: Growth Factor Estimating Relationships Behavior**

<table>
<thead>
<tr>
<th>Growth Factor Estimating Relationships Behavior</th>
<th>New DSLOC Growth</th>
<th>Modified DSLOC Growth</th>
<th>Unmodified DSLOC Growth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Implied Growth Factor at data set mean baseline DSLOC:</td>
<td>50% at 59,443 DSLOC</td>
<td>11% at 22,934 DSLOC</td>
<td>7% at 251,323 DSLOC</td>
</tr>
<tr>
<td>Implied Growth Factor at data set geometric mean baseline DSLOC:</td>
<td>50% at 23,035 DSLOC</td>
<td>22% at 7,756 DSLOC</td>
<td>1% at 70,790 DSLOC</td>
</tr>
</tbody>
</table>
Operating Environment: Fixed Ground

**Joint Cost and Duration Estimating Relationship (JCDER) Data Sheet (continued)**

**DSLOC Estimate Growth Model Version:** Version 8

**Version 8 DSLOC Estimate Growth Model Regression Method:** ODR

**DSLOC Estimate Growth Model Equations and Variables**

**New DSLOC Growth Equation:**

$$S_{DGANew} \equiv \exp(-\text{Decay} \times \text{Maturity}) \times \left[ b_{[GN]} \times \varepsilon_{[GN]} \times \left( \frac{S_{DNew}}{K_{[N]}} \right)^{a_{[GN]} \times K_{[N]} - S_{DNew}} \right] + S_{DNew}$$

**Modified DSLOC Growth Equation:**

$$S_{DGAMod} \equiv \exp(-\text{Decay} \times \text{Maturity}) \times \left[ b_{[GM]} \times \varepsilon_{[GM]} \times \left( \frac{S_{DMod}}{K_{[M]}} \right)^{a_{[GM]} \times K_{[M]} - S_{DMod}} \right] + S_{DMod}$$

**Unmodified DSLOC Growth Equation:**

$$S_{DGAMod} \equiv \exp(-\text{Decay} \times \text{Maturity}) \times \left( \frac{S_{DUmod}}{K_{[U]}} \right)^{a_{[GU]} \times K_{[U]} - S_{DUmod}} + S_{DUmod}$$

where:

- $a_{[GN]} = 1.050$
- $a_{[GM]} = 0.743$
- $a_{[GU]} = 1.275$
- $e \equiv 2.7183$
- $\text{Decay} \equiv 3.466$

**List Statistics**

<table>
<thead>
<tr>
<th>Number of Data Points (observations):</th>
<th>[GN]</th>
<th>[GM]</th>
<th>[GU]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geometric (log space) mean of $b$:</td>
<td>1.001E+00</td>
<td>1.373E+01</td>
<td>4.149E-02</td>
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<tr>
<td>Arithmetic (unit space) mean of $b$:</td>
<td>1.537E+00</td>
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<td>5.440E-02</td>
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<tr>
<td>Standard deviation of $b$:</td>
<td>1.742E+00</td>
<td>1.332E+01</td>
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<tr>
<td>Coefficient of Variation (CV) of $b$:</td>
<td>1.13</td>
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<td>Arithmetic (unit space) mean of $\varepsilon$:</td>
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<tr>
<td>Standard deviation of $\varepsilon$:</td>
<td>1.524E+00</td>
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<tr>
<td>Coefficient of Variation (CV) of $\varepsilon$:</td>
<td>1.03</td>
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<td>Mean Magnitude of the Relative Error:</td>
<td>48%</td>
<td>53%</td>
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**New to Modified DSLOC Correlation:** 1.399E-01

**New to Unmodified DSLOC Correlation:** -2.361E-01

**Percentile**

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<tr>
<th>JCDER351_e_GN_CDF</th>
<th>JCDER351_e_GM_CDF</th>
<th>JCDER351_e_GU_CDF</th>
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**JCDER351 (Custom Growth CDFs)**

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<th>r2SEF_JCDER351_e_GM_CDF</th>
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Presented at the 2018 ICEAA Professional Development & Training Workshop - www.iceaaonline.com
Joint Cost and Duration Estimating Relationship (JCDER) Data Sheet (continued)

### DSLOC Estimate Growth Model Version
- **Version 8**

### DSLOC Estimate Growth Model Equations and Variables

<table>
<thead>
<tr>
<th>New DSLOC Growth Equation:</th>
<th>Modified DSLOC Growth Equation:</th>
<th>Unmodified DSLOC Growth Equation:</th>
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</thead>
<tbody>
<tr>
<td>$S[DGAU_{new}] \approx \exp(-[\text{Decay} \times \text{Maturity}]) \times [a[GN] \times e[GN] \times S[DU_{new}]+S[D_{new}]/K[N]] - S[DU_{new}]/S[D_{new}]$</td>
<td>$S[DGAMod] \approx \exp(-[\text{Decay} \times \text{Maturity}]) \times [b[GM] \times e[GM] \times S[DM_{mod}]+S[DM_{mod}]/K[M]] - S[DM_{mod}]/S[DM_{mod}]$</td>
<td>$S[DGAU_{mod}] \approx \exp(-[\text{Decay} \times \text{Maturity}]) \times [b[GU] \times e[GU] \times S[DU_{mod}]+S[DU_{mod}]/K[U]] - S[DU_{mod}]/S[DU_{mod}]$</td>
</tr>
</tbody>
</table>

where:
- $a[GN] = 0.965$
- $a[GM] = 1.023$
- $a[GU] = 1.039$
- $e \approx 2.7183$
- $\text{Decay} \approx 3.466$

### Operating Environment: Mobile Ground

<table>
<thead>
<tr>
<th>Percentile</th>
<th>JCDER501_e_GN_CDF</th>
<th>JCDER501_e_GM_CDF</th>
<th>JCDER501_e_GU_CDF</th>
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### List Statistics
- Number of Data Points (observations):
  - [GN]: 24
  - [GM]: 18
  - [GU]: 13
- Geometric (log space) mean of $\lambda$:
  - $2.483E+00$ (GN)
  - $1.548E+00$ (GM)
  - $6.739E-01$ (GU)
- Arithmetic (unit space) mean of $\lambda$:
  - $3.692E+00$ (GN)
  - $2.727E+00$ (GM)
  - $7.831E-01$ (GU)
- Standard deviation of $\lambda$:
  - $3.937E+00$ (GN)
  - $3.605E+00$ (GM)
  - $4.552E-01$ (GU)
- Coefficient of Variation (CV) of $\lambda$:
  - $1.07$ (GN)
  - $1.32$ (GM)
  - $0.58$ (GU)
- Arithmetic (unit space) mean of $\epsilon$:
  - $1.402E+00$ (GN)
  - $1.443E+00$ (GM)
  - $1.237E+00$ (GU)
- Standard deviation of $\epsilon$:
  - $1.238E+00$ (GN)
  - $9.067E-01$ (GM)
  - $1.097E+00$ (GU)
- Coefficient of Variation (CV) of $\epsilon$:
  - $0.88$ (GN)
  - $0.63$ (GM)
  - $0.89$ (GU)
- Mean Magnitude of the Relative Error:
  - $47\%$ (GN)
  - $55\%$ (GM)
  - $22\%$ (GU)

New to Modified DSLOC Correlation: 3.601E-02
New to Unmodified DSLOC Growth Correlation: 5.369E-02
Operating Environment: Unmanned Space

**Operating Environment:**
- Unmanned Space

**DEGM8SV (Space Vehicle):**
- Lack of Flight Software data in SRDR database
- Performed data collection
  - Insufficient ATP DSLOC estimates
  - Modified DEGM8 to account insufficient data

---

**DEGM8SV (Space Vehicle):**

<table>
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<th>JCDER501_e_GN_CDF</th>
<th>JCDER501_e_GM_CDF</th>
<th>JCDER501_e_GU_CDF</th>
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