NORTHROP GRUMMAN

DEFINING THE FUTURE

Estimating Support Labor for a Production Program

ISPA / SCEA Joint Conference
June 24-27, 2008

Jeff Platten PMP, CCE/A
Systems Project Engineer
Northrop Grumman Corporation

Cleared for Public Release, Control No. 08-033, dtd. 4-9-08

Estimating Support Labor for a Production Program

Biography

- Jeff Platten is a Systems Project Engineer with Northrop Grumman Corp.
- BS in Statistics from the University of Minnesota – IT
- 15 years experience as an Industrial Engineer
  - Time Study / Standards Development
  - Formerly Certified in Several Courses of Methods Time Measurement
- 18 years experience as an Estimator, Affordability Analyst and Project Engineer
- SCEA Certified Cost Estimator / Analyst
- Project Management Professional from the Project Management Institute
- Recently completed Six Sigma Black Belt training from UCLA

e-mail jeffrey.platten@ngc.com

Estimating Support Labor for a Production Program

Abstract

Common methods for estimating support labor are:
Percent to Touch Labor, Fixed / Variable, Semi-Variable, and Improvement Curves.

The problem with improvement curves is that rate variation may require an adjustment.

The problem with the other methods is that they do not significantly address variation due to program maturity.

Variation in support labor due to program maturity is usually different than the variation in touch labor due to program maturity. In other words, support labor does not follow the same improvement slope as touch labor.

Support Labor costs to a production program are a function of two things:

1. Experience (or Maturity)
   - As a program matures, you typically need less support
2. Production Quantity (or Rate)
   - Higher production rates require more support (but typically a lower proportion)
   - Lower production rates require less support (but typically a higher proportion)

This model uses Experience and an adjusted formula for Production Quantity as the two predictor variables to predict the dependent variable which is the support labor hours per year.

- Experience is a number which is as a combination of years and cum quantity.
- Production Quantity is adjusted to get a number that represents the "Degree of Difficulty" in producing that quantity.

Regression analysis was performed of support labor hours against the two predictor variables and achieved high correlation. The resultant formula looks like this:

$$\text{Support Hours} = a - b \cdot (\text{Year} \cdot \text{Cum Quantity})^{0.5} + c \cdot \text{Qty}^{(1 / \text{Year}^{0.5})}$$

This formula is used in estimating similar production programs with adjustments for programmatic differences.

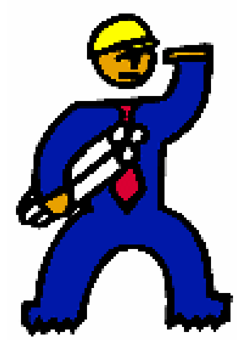
The methodology is applicable to almost any industry, from aerospace to zippers.

This paper describes how to set up your historical data, perform regression analysis, and calibrate the model to create an estimate for your production program.

Estimating Support Labor for a Production Program

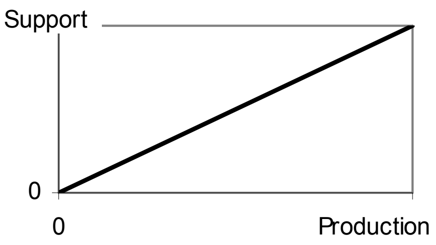
- What Is Support Labor ?
  People Who Perform Necessary Work, But Not Directly Hands On Product
  - Manufacturing Support
    - The People Who Move Stuff
    - The People Who Plan the Work
    - The People Who Figure Out Processes and Improvements
    - The People Who Figure Out Time Standards
    - The People Who Ensure Quality
  - Tooling Support
    - The People Who Maintain the Equipment
  - Material Support
    - The People Who Order Stuff and Keep Track of Stuff
  - Engineering Support
    - The People Who Make Changes
    - The People Who Resolve Problems
  - Business / Program Management Support
    - Bean Counters



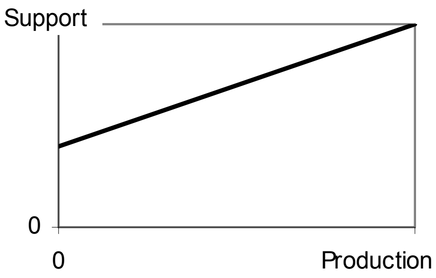




Estimating Support Labor for a Production Program

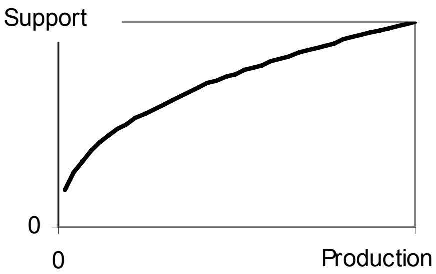
- Common Ways to Estimate Support Labor
  - Percent (Ratio) to Factory Touch Labor



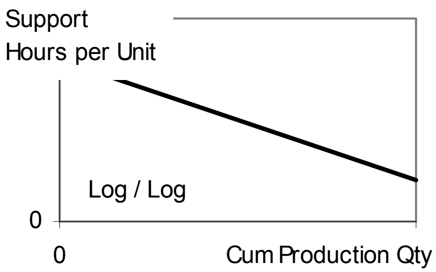
  - A Function of Fixed and Variable



  - A Semi-Variable (Power) Function



  - Improvement Curve

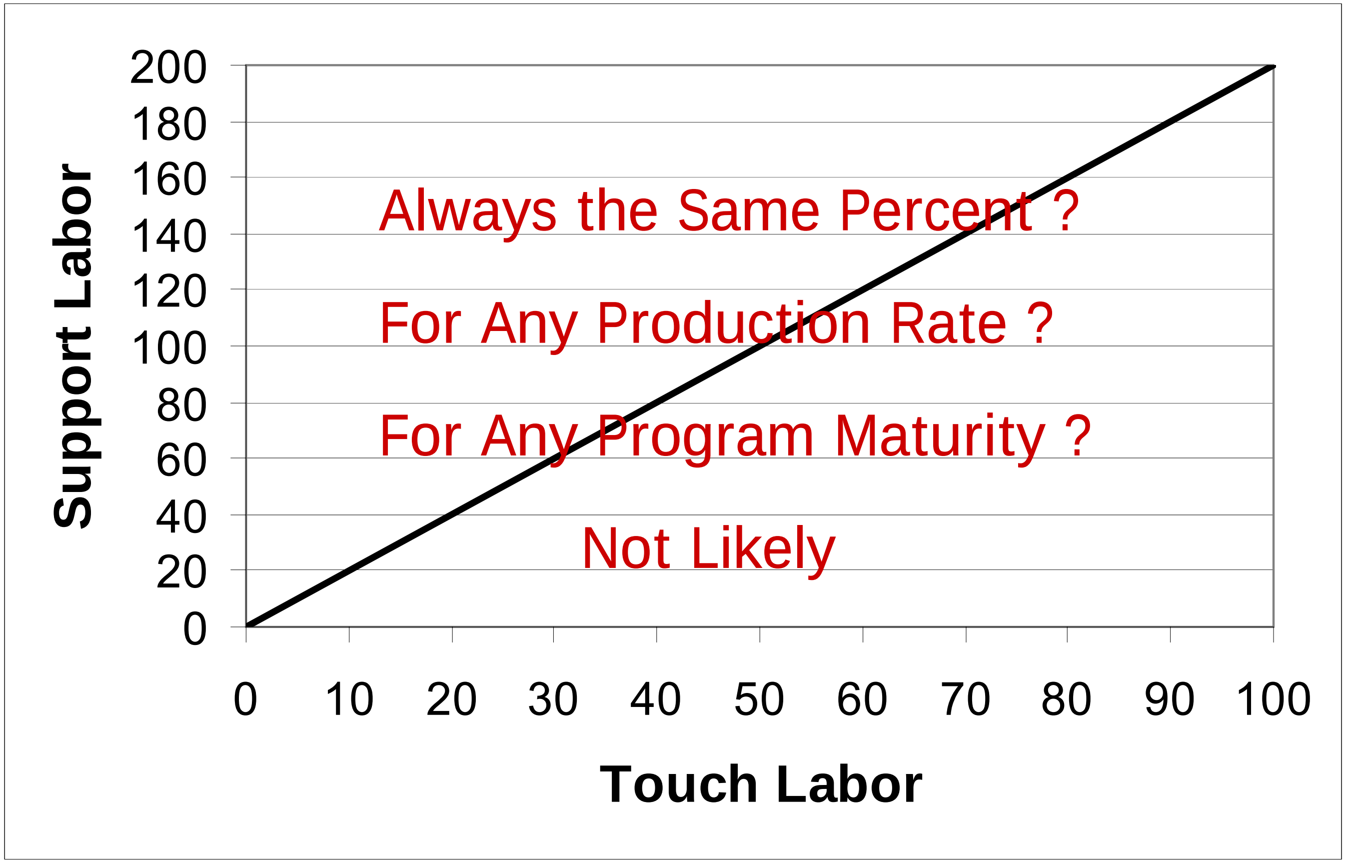


Cleared for Public Release, Control No. 08-033, dtd. 4-9-08

Estimating Support Labor for a Production Program

Is Support Labor Just a Percent (Ratio) to Factory Touch Labor ?

- **Y = bX**
  - Where b is the Slope (the Percent)
  - and X is Touch Labor

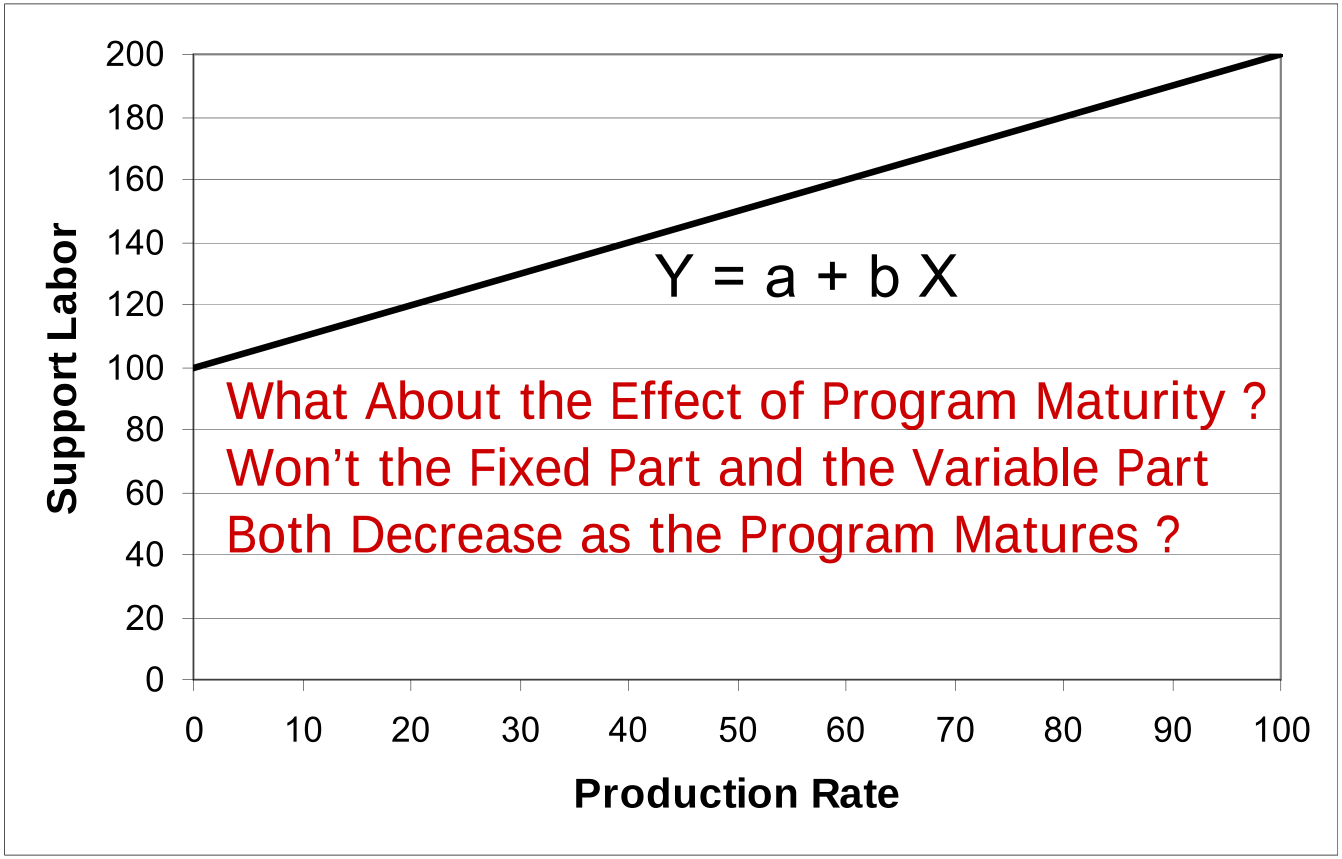


Cleared for Public Release, Control No. 08-033, dtd. 4-9-08

Estimating Support Labor for a Production Program

Is Support Labor Just a Function of Fixed and Variable ?

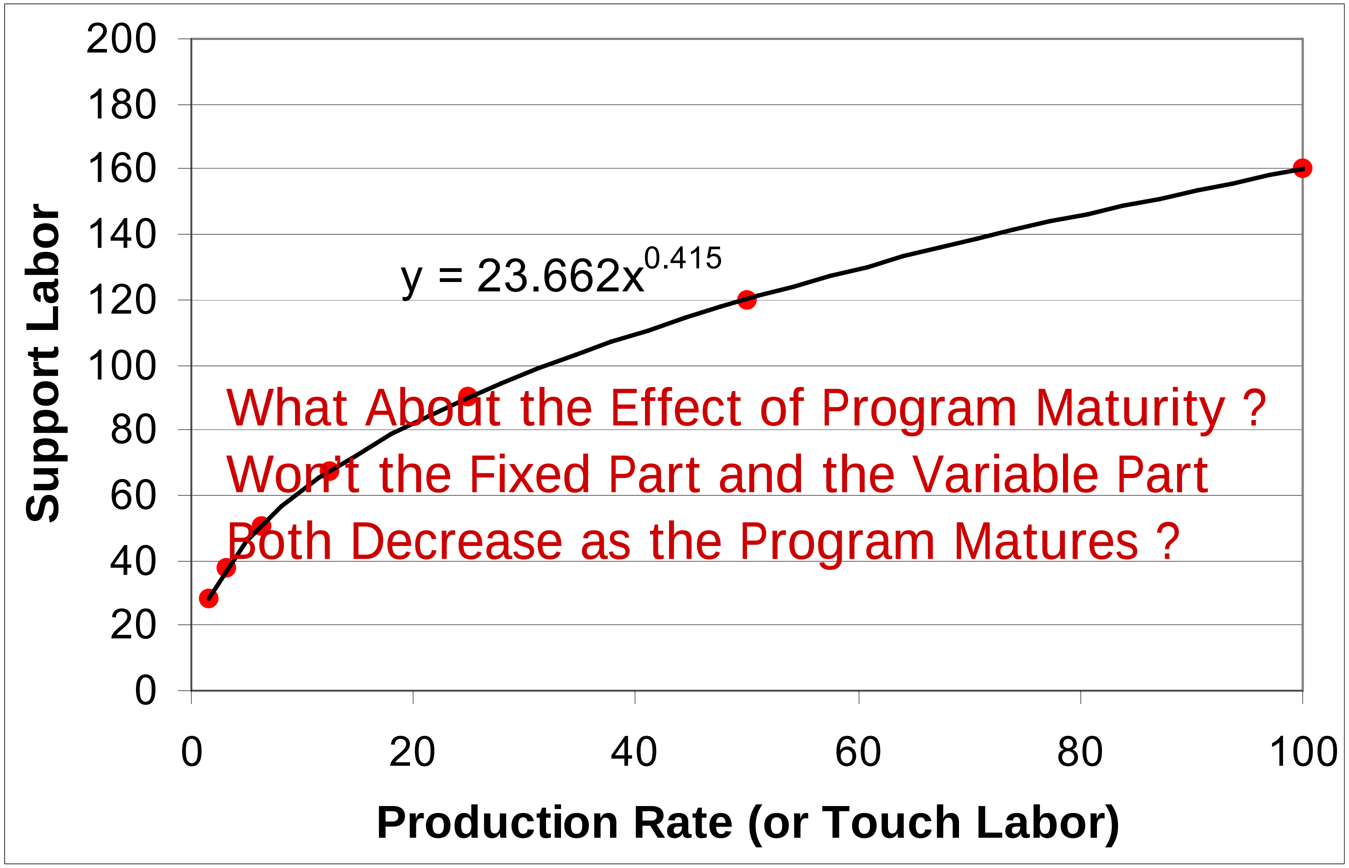
- **Y = a + bX**
  - Where a is the Fixed Part (the Y Intercept)
  - and bX is the Variable Part, Where b is the Slope (Variable Amount per Unit) and X is the Production Rate



Estimating Support Labor for a Production Program

Is Support Labor a Semi-Variable (Power) Function ?

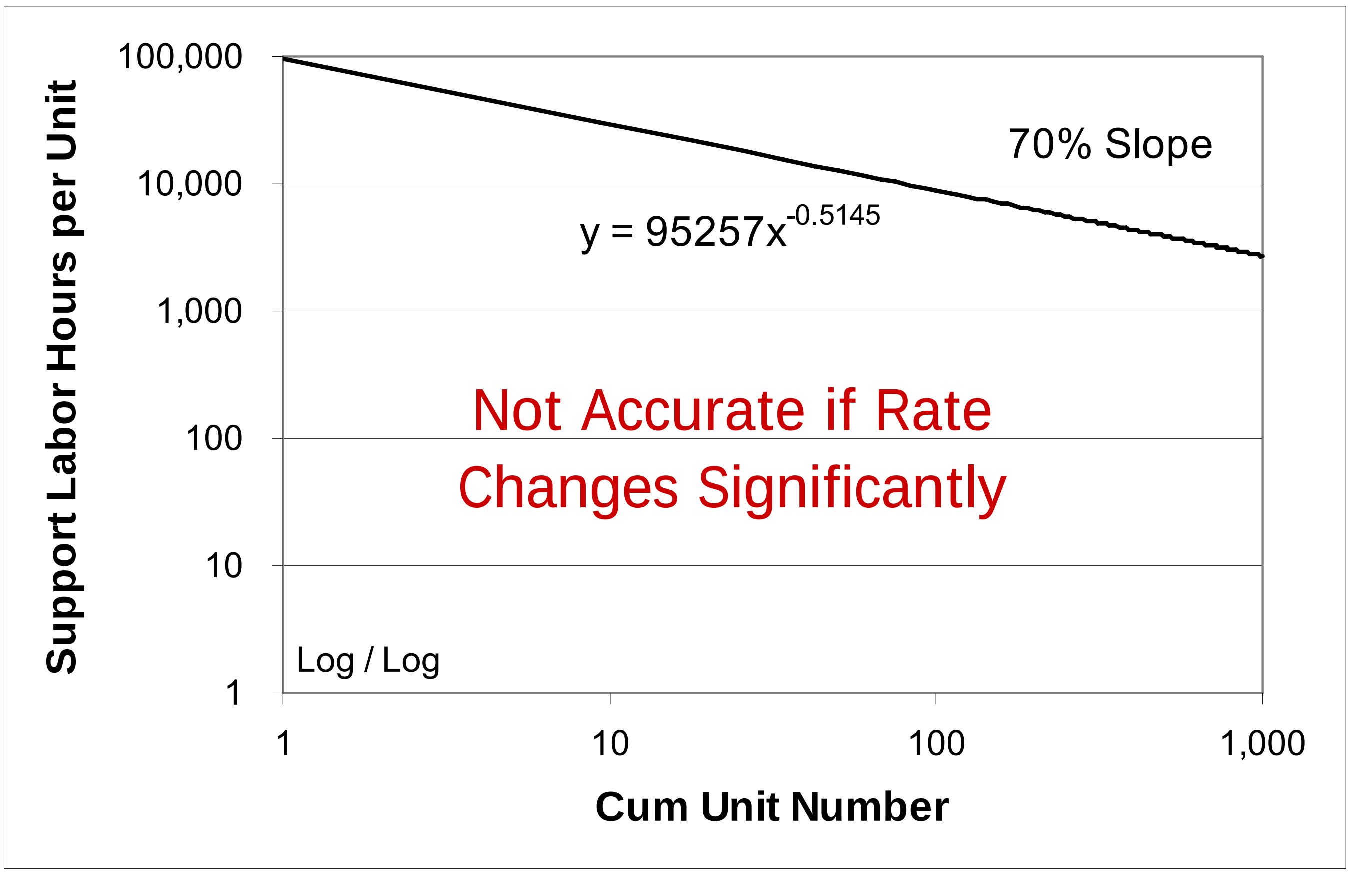
- i.e. When the Production Rate is Halved, Support Can Be Reduced by 25%
- **Y = aX^b**
  - a is the "Fixed" Part (the Value When Production Rate is 1)
  - b is the "Logarithmic Slope"



Estimating Support Labor for a Production Program

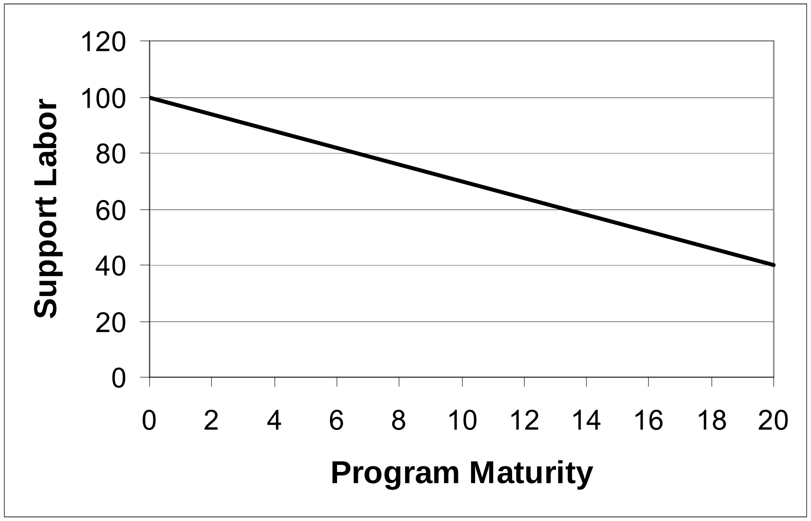
Does Support Labor Follow an Improvement Curve ?

- Hours per Unit Continually Improve at a Logarithmically Decreasing Rate
- **Y = aX^b** Where Y is Hours per Unit, X is the Cum Unit Number
  - a is the T1 Value (the Hours for the First Production Unit)
  - b is Log (Slope) / Log (2), The Slope = 10 ^ (b • Log(2))



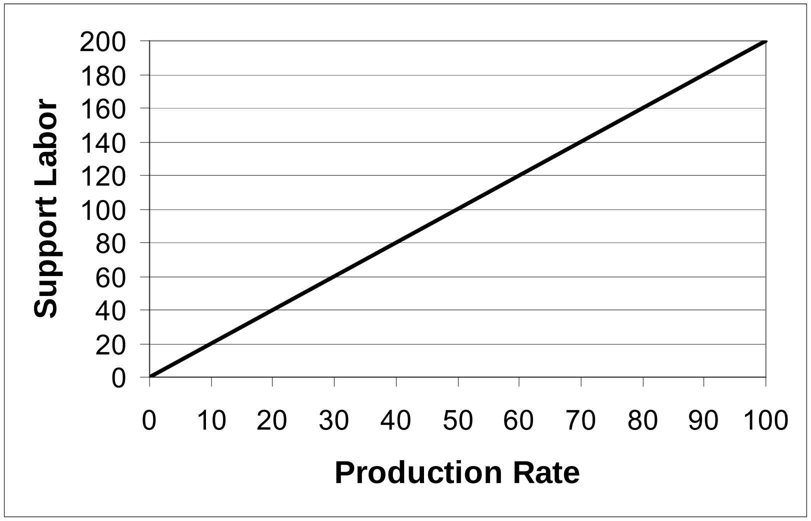
Estimating Support Labor for a Production Program

- Support Labor Is a Function of Two Things:
  1. Experience (or Maturity)
     - As a Program Matures, You Typically Need Less Support



Think of This as the "Fixed" Part, or the Minimum Support Required (At Near-Zero Production Rate)

  2. Production Quantity (or Rate)
     - Higher Production Rates Typically Require More Support
     - Lower Production Rates Typically Require Less Support

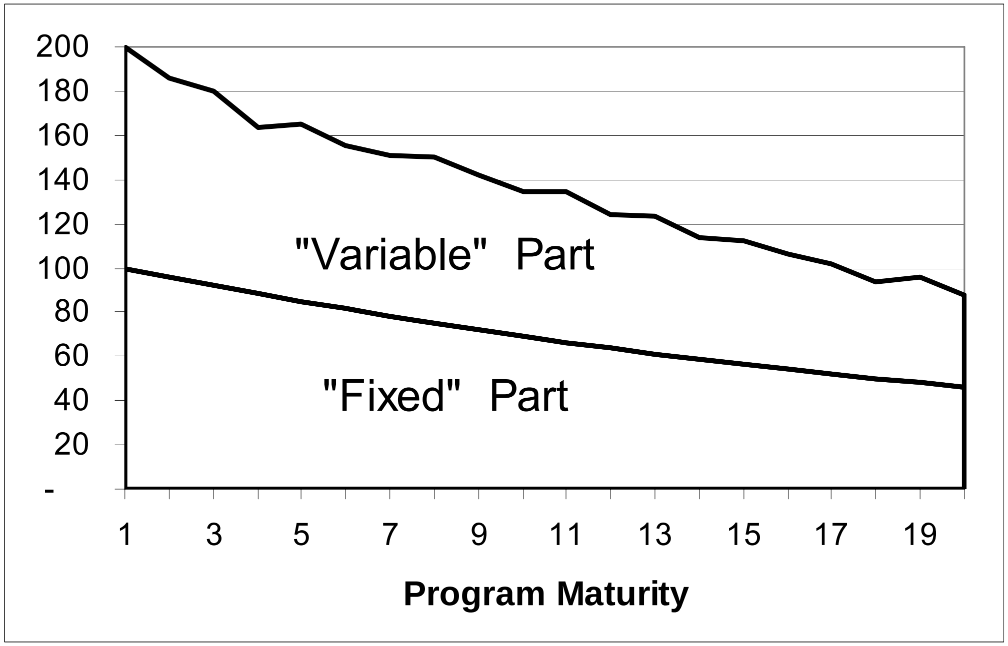


Think of This as the "Variable" Part, or the Additional Support Required Due to Production Rate

But This Is Still Too Simplistic.

Estimating Support Labor for a Production Program

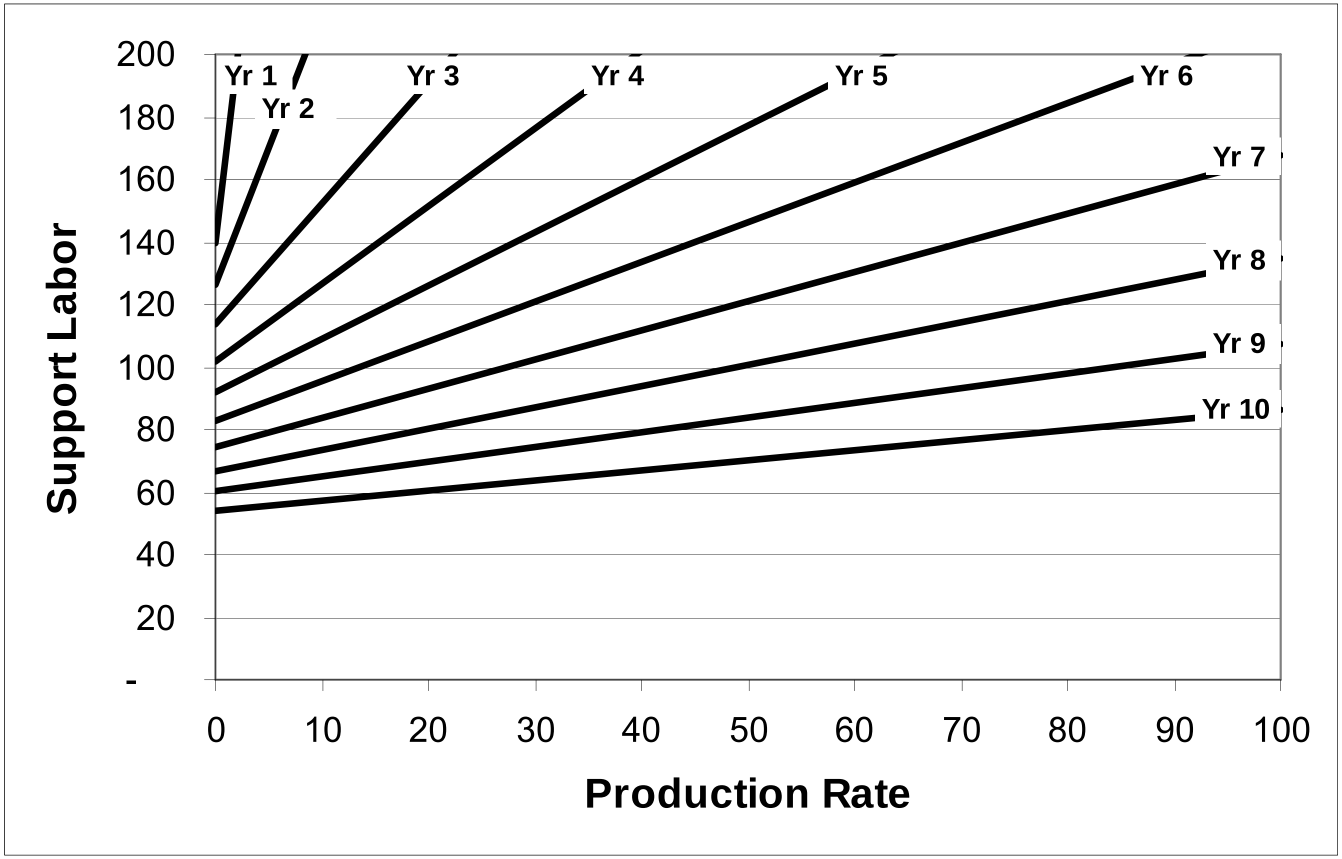
- Support Labor Has a "Fixed" Component and a "Variable" Component
  - But the Fixed Part Is Not Really Fixed - It Declines as the Program Matures
  - The Variable Part Is Dependent on the Production Rate and Program Maturity
    - Because It's Not Just the Production Rate That Drives the Variable Part
    - It's the Production Rate Relative to the Maturity of the Program, or You Might Say It's "The Degree of Difficulty" in Producing the Rate
    - It's More Difficult to Produce a Small Number of Units in the Early Years of Production Than It Is to Produce a Large Number of Units In a Mature Program



Cleared for Public Release, Control No. 08-033, dtd. 4-9-08

Estimating Support Labor for a Production Program

- We Could Develop a Series of Equations for Each Year
- Fixed / Variable Methodology With Ever Decreasing Intercepts and Slopes

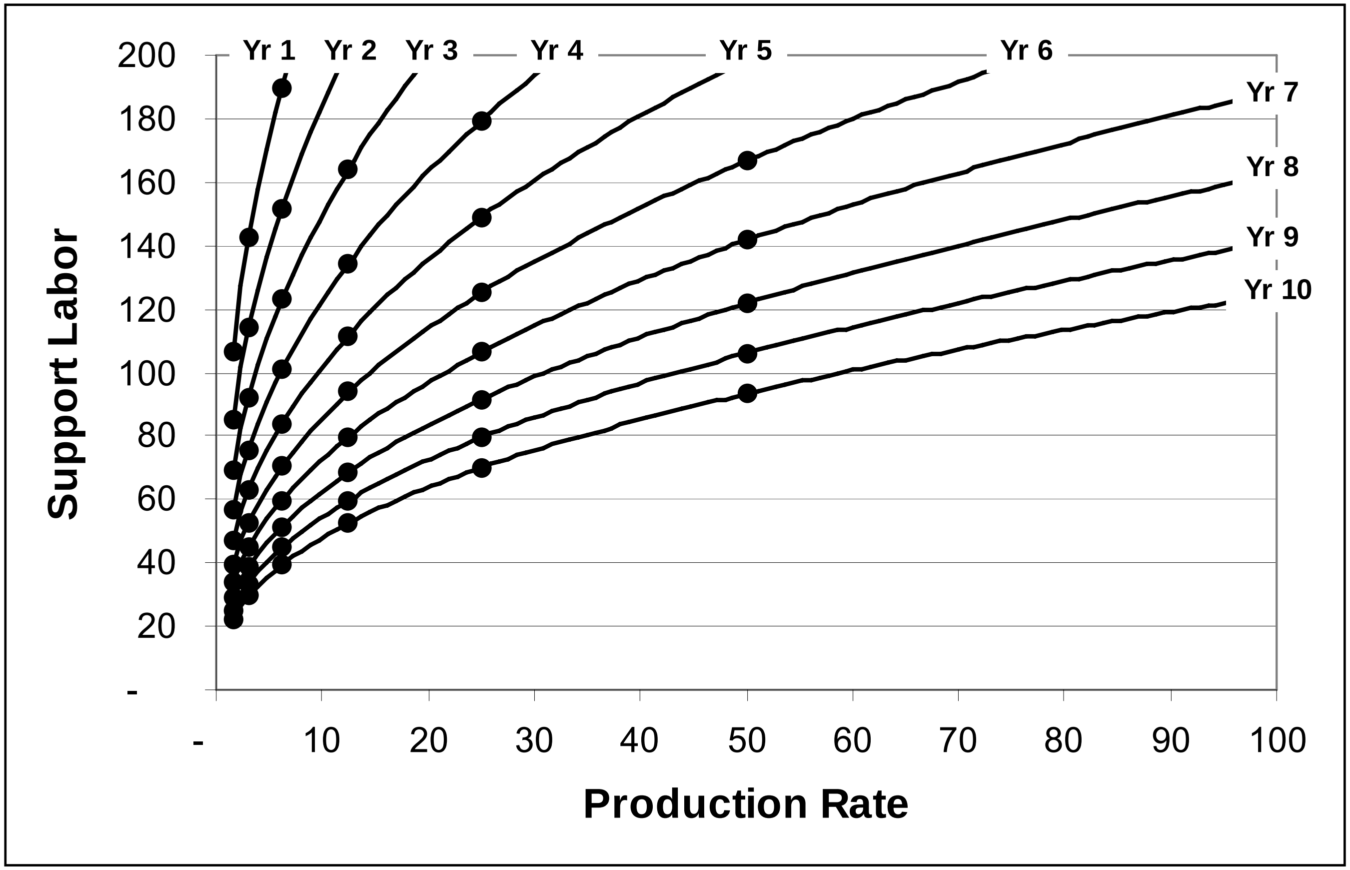


This Would Not Be Practical.

It Would Be Difficult to Calculate the Formulas for All Those Lines.

Estimating Support Labor for a Production Program

- We Could Develop a Series of Equations for Each Year
- Semi-Variable Methodology With Ever Decreasing “Intercepts” and Slopes



This Would Not Be Practical.

It Would Be Difficult to Calculate the Formulas for All Those Lines.

Estimating Support Labor for a Production Program

Regression Model Development

- 2 Predictor Variables Chosen
  - 1st Predictor Variable: **Experience** (or Program Maturity) =
    ("Year" x "Cum Quantity") **^ 0.5**
  - 2nd Predictor Variable: "**Degree of Difficulty**" of the Production Rate =
    "Quantity" **^ (1 / Year ^ 0.5)**
- Perform Regression Analysis to Predict The Dependent Variable Which Is the Support Labor Hours Per Year
- Definitions
  - "Year" Is a Value of 1 for the First Year of Production and Goes Up 1 Per Year to the End of Production
  - "Cum Quantity" Is the Total Number of Units That Have Been Produced (to the Midpoint of Each Year)
  - "Quantity" Is The Annual Production Quantity

Estimating Support Labor for a Production Program

Sample Historical Data

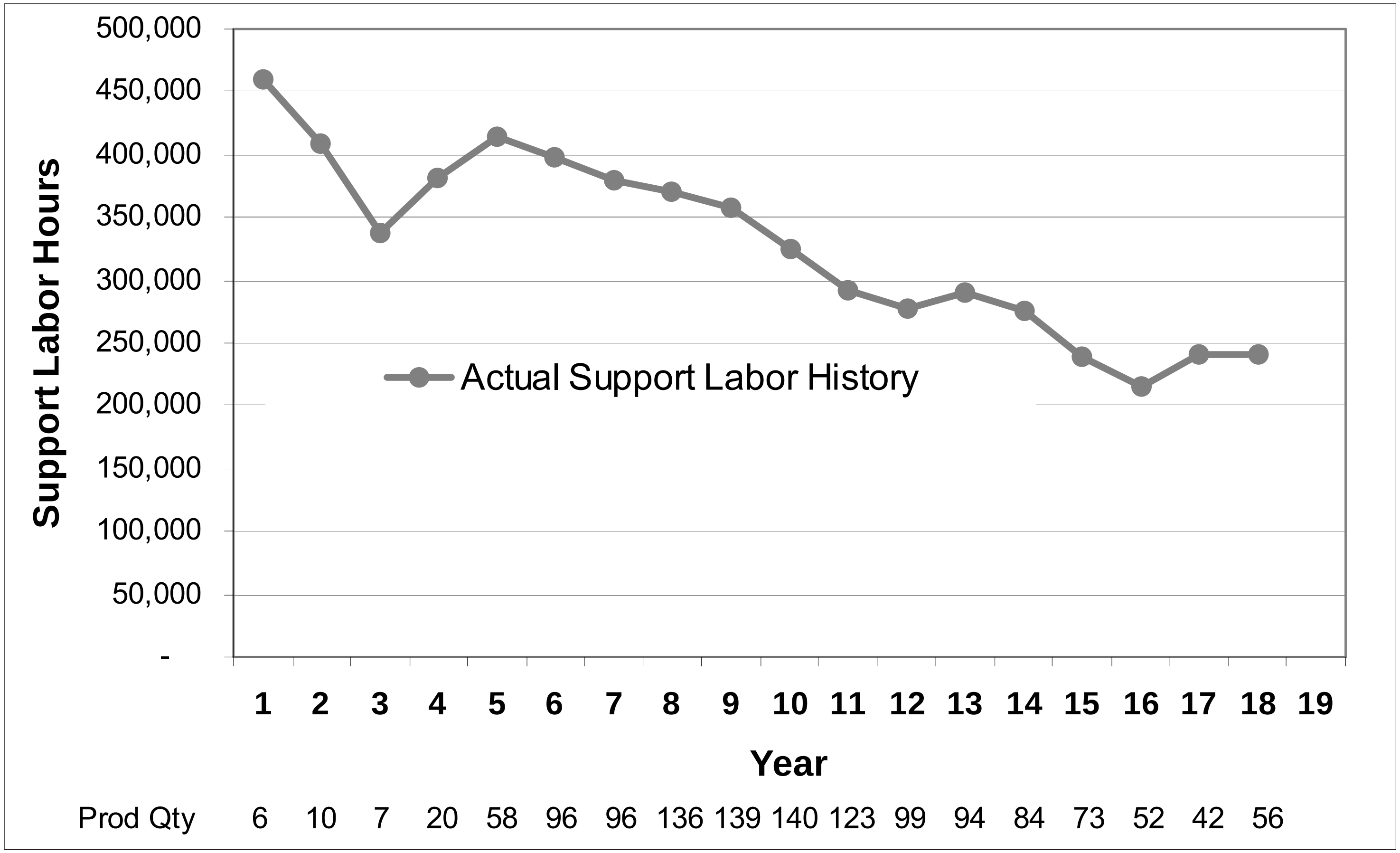
First Predictor Variable → SQRT (Yr·Midpt)
Second Predictor Variable → $1/Yr^{0.5}$ Qty^
Dependent Variable → Support Hours

Year	Annual Quantity	Midpoint Cum Unit	SQRT (Yr·Midpt)	$1/Yr^{0.5}$ Qty^	Support Hours
1	6	3.5	1.87	6.00	460,000
2	10	11.5	4.80	5.09	408,000
3	7	20.0	7.75	3.08	338,000
4	20	33.5	11.58	4.47	381,000
5	58	72.5	19.04	6.15	415,000
6	96	149.5	29.95	6.45	397,000
7	96	245.5	41.45	5.61	379,000
8	136	361.5	53.78	5.68	370,000
9	139	499.0	67.01	5.18	358,000
10	140	638.5	79.91	4.77	324,000
11	123	770.0	92.03	4.27	292,000
12	99	881.0	102.82	3.77	277,000
13	94	977.5	112.73	3.53	290,000
14	84	1,066.5	122.19	3.27	276,000
15	73	1,145.0	131.05	3.03	239,000
16	52	1,207.5	139.00	2.69	215,000
17	42	1,254.5	146.04	2.48	240,000
18	56	1,303.5	153.18	2.58	240,000

Note: Last Few Years (19 and Up) Prior to Program Termination Are Not Included

Estimating Support Labor for a Production Program

Sample Historical Data



Cleared for Public Release, Control No. 08-033, dtd. 4-9-08

Estimating Support Labor for a Production Program

Regression Results

REGRESSION SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.9780612
R Square	0.9566037
Adjusted R Square	0.9508175
Standard Error	16007.123
Observations	18

Good Regression Statistics
Your Results May Vary

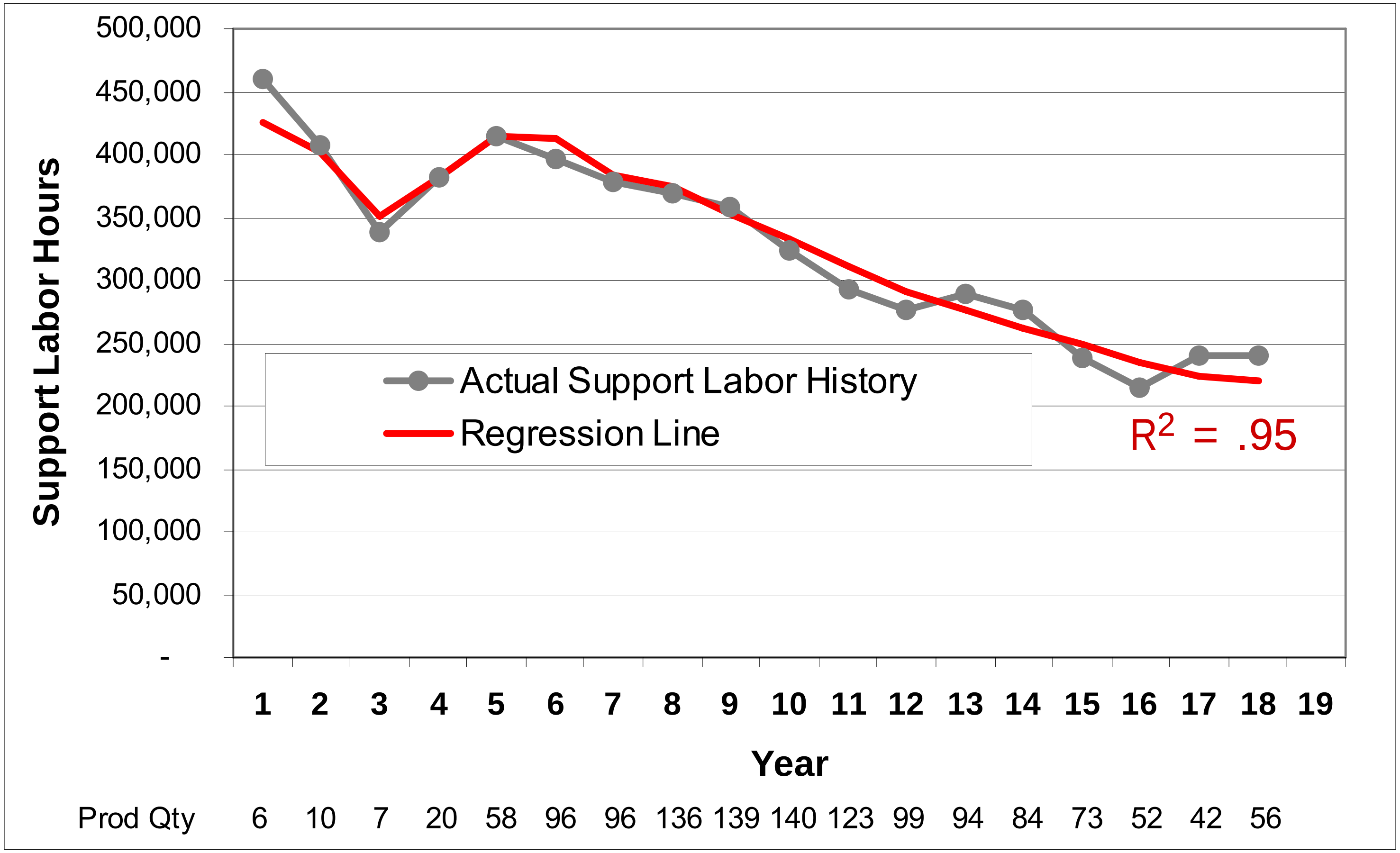
ANOVA	df	SS	MS	F	Significance F
Regression	2	8.5.E+10	4.2E+10	165.326	6.038E-11
Residual	15	3.8.E+09	2.6E+08		
Total	17	8.9.E+10			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%
Intercept	284,201.0	26,349	10.7862	1.8E-08	228040.38	340361.58
X_1 Variable	(813.96)	111	-7.32623	2.5E-06	-1050.771	-577.1529
X_2 Variable	23,754.1	4,467	5.31712	8.6E-05	14231.876	33276.244

Hours = 284,201 - 814 • (Year • Cum Qty) ^ 0.5 + 23,754 • Quantity ^ (1 / Year ^ 0.5)

Estimating Support Labor for a Production Program

Goodness of Fit
Historical Data vs. Regression Line



Regression Line:

$$\text{Hours} = 284{,}201 - 814 \bullet (\text{Year} \bullet \text{Cum Qty})^{\wedge\, 0.5} + 23{,}754 \bullet \text{Quantity}^{\wedge\, (1 / \text{Year} \,\wedge\, 0.5)}$$

Estimating Support Labor for a Production Program

$$\text{Hours} = 284{,}201 - 814 \cdot (\text{Year} \cdot \text{Cum Qty})^{0.5} + 23{,}754 \cdot \text{Quantity}^{(1/\text{Year}^{0.5})}$$

- Use the Equation to Estimate Other Production Programs by Plugging in the Projected Production Quantities and Years
- Adjustments You May Want to Make for Your Particular Application
  - Note: This Model Was Developed in an Aerospace Environment, But the Theory is Applicable to Many Industries
  - If Applying This to Larger Scale Production (Rivets, for Example) it is Recommended That You Express the Quantity and Cum Quantity in Hundreds or Thousands or Millions or Whatever Gets You a Value Such That Quantity Values Are No More Than 2-digit Numbers And Cum Quantity Values Are No More Than 3-digit Numbers
  - You May Want to Use Months Instead of Years
  - Try Modifying The Exponents In the Predictor Variables (From 0.3 To 0.7) and See if it Improves Regression Results
  - Make Adjustments For Program Differences
  - Additional Reductions for Last Few Years of Production (Going Out of Business Mode)

Estimating Support Labor for a Production Program

- Adjustments for Program Differences
  - There Will Be Differences Between the Program You Are Estimating and the Historic Program/Programs Which Was/Were Used In the Regression Analysis
  - Examples of Program Differences
    - Weight of the Product
      - Try Using an Advantage Formula (Typically 80% Curve): Weight Factor = $(\text{Weight}_{New} / \text{Weight}_{Old})^{-0.322} \cdot (\text{Weight}_{New} / \text{Weight}_{Old})$
    - Complexity of the Product
      - Try Counting Parts, Manufacturing Steps, Standard Hours, Etc. and Use an Advantage Formula: $(\text{Parts}_{New} / \text{Parts}_{Old})^{-0.322} \cdot (\text{Parts}_{New} / \text{Parts}_{Old})$
    - Difference In Materials
    - Difference In Manufacturing Processes
    - Technology Improvements
      - If the Historical Data Is From a Program Before Computer Aided Design Came Into Fashion, Improvement of ~ 1 Percent Per Year Difference
    - Organization Changes
    - Prime Contractor or Subcontractor
    - Manned Vehicle or Unmanned Vehicle
    - Special Access Program or No Special Security

Estimating Support Labor for a Production Program

- Adjustments for Program Differences
  - Comprehensive Program Adjustment Factor Is the Product of All the Individual Factors, or $\Pi f = f_0 \bullet f_1 \bullet . . . \bullet f_n$
  - Example: If It Is Determined That 3 Factors Are Significant:
    - The Weight Adjustment Factor = (10,000 / 8,450) ^ -0.322 • (10,000 / 8,450) = 1.12
    - The Complexity Adjustment Factor = 1.05
    - The Technology Adjustment Factor = 0.75
    - Then the Comprehensive Program Adjustment Factor Is: $\Pi f = 1.12 \bullet 1.05 \bullet 0.75 = 0.882$
    - So, to Estimate the Support Hours for a New Program: Multiply 0.882 Times the Formula Derived From the Regression

Hours = 0.882 • [284,201 - 814 • (Year • Cum Qty) ^ 0.5 + 23,754 • Quantity ^ (1 / Year ^ 0.5)]

Estimating Support Labor for a Production Program

- Correlating to Actual Data
  - Once You Get a Year or so of Actual Data on the New Production Program, You May Not Need to Estimate the Program Adjustment Factor
  - The Factor Will Just Be the Ratio of the Actual Hours to the Predicted Hours (Without the Program Adjustment Factor)

- Example:
  - Year 1 Actuals Come in at 340,000 Hours and 5 Units Were Produced
  - The Predicted Hours (Without The Program Adjustment Factor) =
  - Predicted Hours = 284,201 - 814 • (1 • 3) ^ 0.5 + 23,754 • 5 ^ (1 / 1 ^ 0.5)
    = 401,561
  - So the New Program Adjustment Factor, Based On Actuals Is: 340,000 / 401,561 = 0.847
  - So the Estimate For Future Years Becomes:

Hours = <u>0.847</u> • [284,201 - 814 • (Year • Cum Qty) ^ 0.5 + 23,754 • Quantity ^ (1 / Year ^ 0.5)]

Estimating Support Labor for a Production Program

Sample Estimate - Correlated to First Year Performance

First Predictor Variable → SQRT (Yr·Midpt)
Second Predictor Variable → 1/Yr^0.5 Qty^
Program Adjustment → Program Adjustment Factor
Dependent Variable → Estimated Support Hours

Year	Annual Quantity	Midpoint Cum Unit	SQRT (Yr·Midpt)	$1/Yr^{0.5}$ Qty^	Program Adjustment Factor	Estimated Support Hours
1	5	3.0	1.73	5.00		340,000 actual
2	7	9.0	4.24	3.96	0.847	317,445
3	17	21.0	7.94	5.13	0.847	338,527
4	28	43.5	13.19	5.29	0.847	338,087
5	37	76.0	19.49	5.03	0.847	328,423
6	40	114.5	26.21	4.51	0.847	313,358
7	45	157.0	33.15	4.22	0.847	302,678
8	45	202.0	40.20	3.84	0.847	290,292
9	40	244.5	46.91	3.42	0.847	277,184
10	42	285.5	53.43	3.26	0.847	269,484
11	45	329.0	60.16	3.15	0.847	262,641
12	46	374.5	67.04	3.02	0.847	255,259
13	48	421.5	74.02	2.93	0.847	248,555
14	54	472.5	81.33	2.90	0.847	243,071
15	45	522.0	88.49	2.67	0.847	233,472
16	41	565.0	95.08	2.53	0.847	226,077
17	31	601.0	101.08	2.30	0.847	217,301
18	35	634.0	106.83	2.31	0.847	213,577
19	35	669.0	112.74	2.26	0.847	208,470

Estimating Support Labor for a Production Program

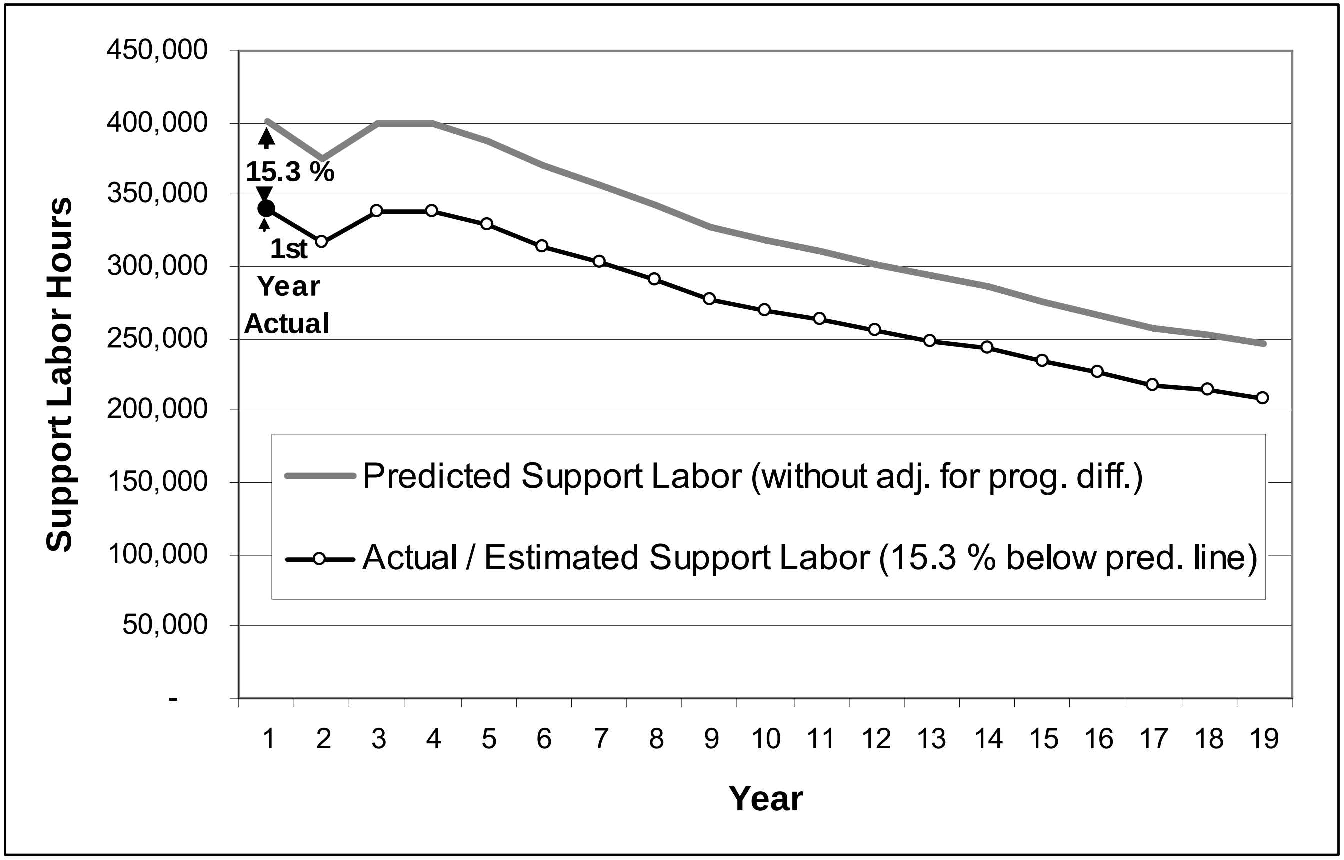
Estimated Support Labor Hours vs Regression Line

- Top Line: Predicted Support Labor without adjustment for program differences

Hours = 284,201 - 814 • (Year • Cum Qty) ^ 0.5 + 23,754 • Quantity ^ (1 / Year ^ 0.5)

- Bottom Line: Actual Support Labor for the 1st year and Estimated Support Labor for the remainder of the program (15.3 % below the predicted line based on 1st year performance)

Hours = 0.847 • [284,201 - 814 • (Year • Cum Qty) ^ 0.5 + 23,754 • Quantity ^ (1 / Year ^ 0.5)]



Cleared for Public Release, Control No. 08-033, dtd. 4-9-08

Estimating Support Labor for a Production Program

- Additional Continuous Improvement Adjustment
  - Take a More Aggressive Approach if Expected Improvements or Pressures to Reduce Are Greater Than What The Historical Data Would Have Predicted
    - Process Improvements
    - Technology Improvements
    - Competitive Pressures
  - Estimate a Line Which Continually Improves Against the Predicted Line
  - Additional 1 Percent Per Year or More
  - For example, If the Gap Between the Predicted Line and the Estimate Is 15.3% In The First Year, You May Be Able to Achieve 16.3% In the Second Year, 17.3% In the Third Year and So On.

Estimating Support Labor for a Production Program

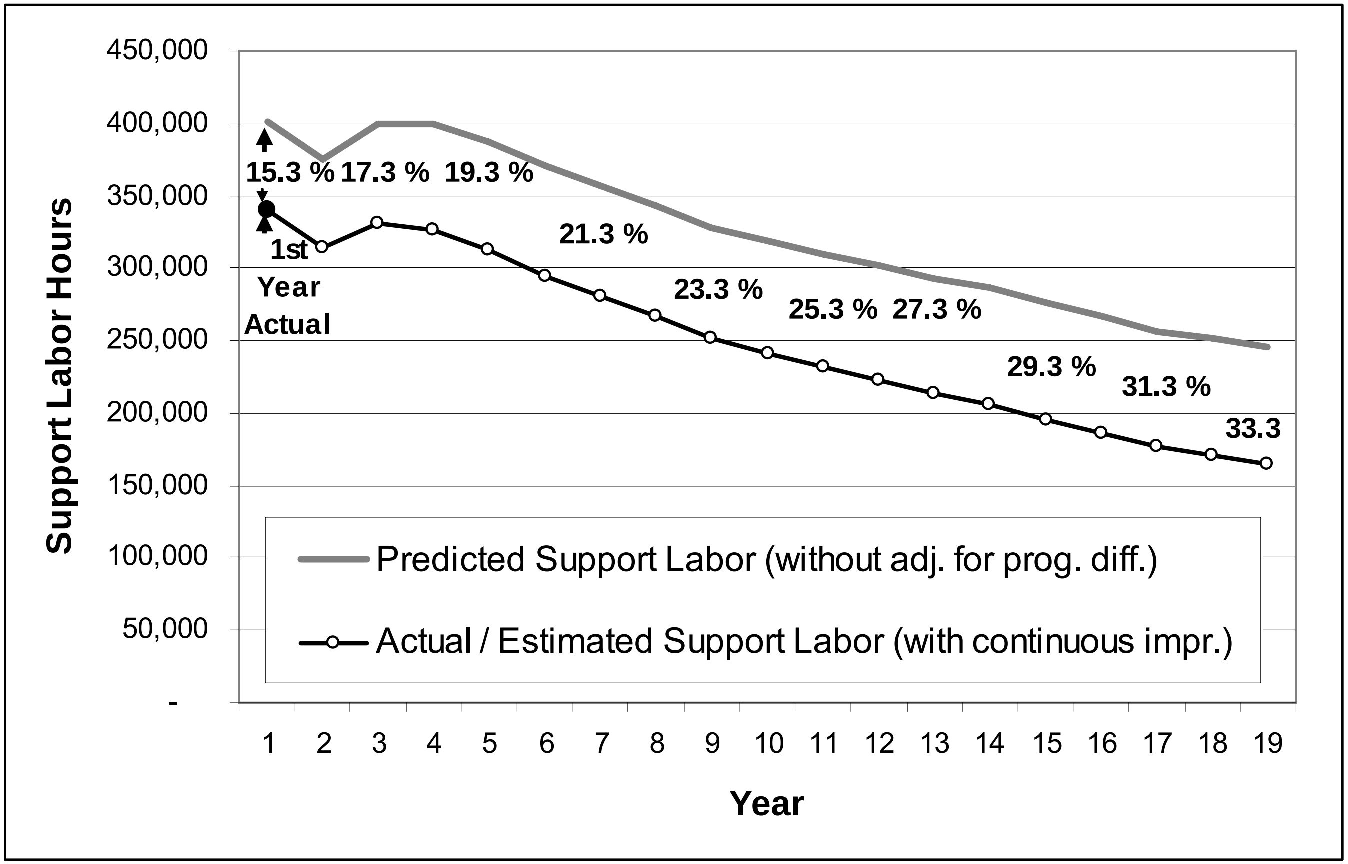
Estimated Support Labor With Continuous Improvement

- Top Line: Predicted Support Labor without adjustment for program differences

Hours = 284,201 - 814 • (Year • Cum Qty) ^ 0.5 + 23,754 • Quantity ^ (1 / Year ^ 0.5)

- Bottom Line: Actual Support Labor for the 1st year and Estimated Support Labor for the remainder of the program with continuous improvement (of 1% per year)

Hours = [0.847 - 0.01 • (Year - 1)] • [284,201 - 814 • (Year • Cum Qty) ^ 0.5 + 23,754 • Quantity ^ (1 / Year ^ 0.5)]



Estimating Support Labor for a Production Program

- Conclusion / Summary
  - Support Labor Is Not Just :
    - A Percentage of Touch Labor
    - A Function of Fixed and Variable
    - A Semi-Variable (Power) Function
    - An Improvement Curve
  - The Outlined Methodology Was Developed in an Aerospace Environment, But Is Applicable to Many Industries
  - Provided an Example on How to Set Up Historical Data
  - Formulas Can Be Changed to Suit Your Particular Industry
    - Change the Exponents for the Predictor Variables to Improve Correlation
  - Perform Regression of Support Labor History Against Predictor Variables to Obtain an Equation
    - 1st Predictor Variable Represents Experience (or Program Maturity)
    - 2nd Predictor Variable Represents Degree of Difficulty of the Production Rate
  - Make Adjustments for Program Differences
  - Consider Making Adjustments for Additional Continuous Improvement
  - When Actuals Start to Come In, Calibrate to Actual Performance and Track the Trend vs. the Predicted Line
  - Make Additional Reductions for Last Few Years of Production (Going Out of Business)

Questions ?