

This tutorial will go into the details of how PROBE Methods are evaluated for best fit based on the individual's historical data.

## Lecture Topics

Using PROBE to make size and time estimates

Overview of PROBE Methods A & B

Method selection criteria for "size" and "time" in methods A & B

A review of

- PROBE Size Estimating Template

- Derived Measures

PROBE Historical Data

PROBE Charts

We will provide a refresher for the class and go over the PSP Size Estimating Template in the student tool.

It may be a good idea to have the students bring up their student tool.

Engaging the class to look at their tool will also help keep the focus on the tutorial and eliminate internet surfing and email correspondence during the lecture.



## Using PROBE

PROBE is used to make continuously improving Size and Time estimates by

- collecting historical data
- calculating regression parameters on historical data
- adjusting the estimates for trends

PROBE methods A & B are introduced this week.

What differentiates methods A & B from method C, introduced in PSP Fundamentals, is that methods A & B use **linear regression** on your historical data to calculate the projected size and time estimates.

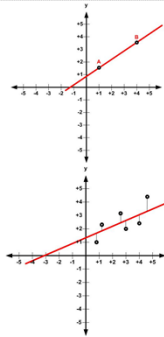


## Minimum Data for Using Regression

The regression line represents the best fit (or smallest possible distance from the regression line to the data points).

When we have only 2 data points, the regression line goes right through them for a perfect fit, but it is not meaningful.

For the regression line to act as the predictor, we need more data points (at least 3).

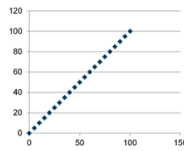


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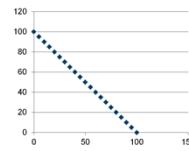


## Correlation

Correlation ( $r$ ) (a.k.a. Correlation Coefficient): Degree to which two sets of data are linearly related.



Positive Relationship ( $r = +1$ )



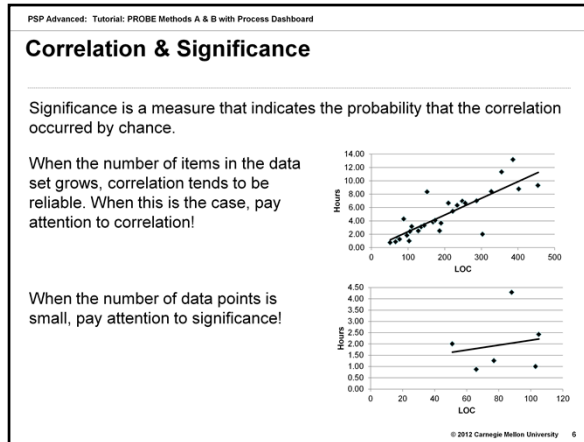
Negative Relationship ( $r = -1$ )

Correlation squared ( $r^2$ ): Descriptive measure between zero and one, indicating how good one term is at predicting another.

An  $r^2$  of 1 is considered a perfect fit!

To use methods A & B, an  $r^2$  of 0.5 or higher is required.





Note, there is always the possibility that a high correlation was the result of chance (just a random event) and there is not a real cause and effect relationship between the two data sets. Significance is measure of that probability.

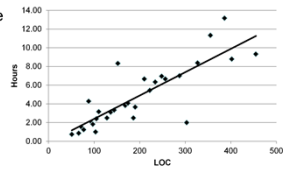
The point here is that when you have only a small number of data points in the regression and you get a good correlation, you should also check the significance measure to determine if the relation is likely due to chance and is not a true cause/effect relationship.

The students will implement the significance calculation in assignment on day 3 of this course.



## Adjusting estimates with linear regression

PROBE methods A & B calculate the trend line with linear regression:



In PROBE " $y = mx + b$ " equates to:

$$y \text{ (adjusted estimate)} = b \text{ } (\beta_0) + m \text{ } (\beta_1) * x \text{ (Estimated Proxy Size)}$$

(P)rojected Added and Modified Size =  $\beta_0 + \beta_1 * \text{Estimated Proxy Size}$

$\beta_0$  is a constant bias in the size, e.g., overhead LOC and/or constant estimating bias  
 $\beta_1$  is the factor for the ratio of under-estimates and over-estimates

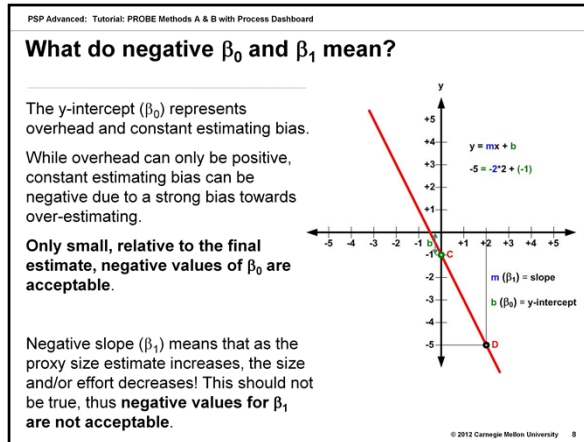
Estimated Development Time =  $\beta_0 + \beta_1 * \text{Estimated Proxy Size}$

$\beta_0$  is a constant bias in the estimated time, e.g., overhead time and/or constant estimating bias  
 $\beta_1$  is the average additional time to develop one line of code

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Note that beta0 is not strictly overhead (LOC or time), it also accounts for a consistent constant estimating bias.





It's important to note that negative values of  $\beta_0$  are valid. They can arise due to a constant estimating bias to overestimate. The regression compensates for this tendency to overestimate by a constant amount with a negative  $\beta_0$ .

Note that the absolute value of  $\beta_0$  is used in the PROBE method selection scripts. A small negative  $\beta_0$  is acceptable because it will not make the estimate unreasonable. The script guidelines work well enough for planning purposes.





## PROBE Methods A & B Overview

PROBE Method A is the most preferred method.

Method A requires a minimum of 3 data points and uses:

- "E"stimated Proxy Size and Actual A&M for "size" estimation.
- "E"stimated Proxy Size and Actual development time for "time" estimation.

If the correlation and regression parameter values are within the selection criteria Method A is used.

PROBE Method B is the next preferred method in the hierarchy.

Method B requires a minimum of 3 data points and uses:

- Planned A&M (planned program size) and Actual A&M (actual program size) for "size" estimation.
- Planned A&M (planned program size) and Actual Development Time for "time" estimation.

If the correlation and regression parameter values are within the selection criteria Method B is used.

When PROBE Methods A or B do not fit the selection criteria, use

Method C if you have some historical data

- Method C uses averaging and does not look at correlation

Method D if you have no historical data

- Method D uses "engineer's best guess!"



## Rules for Method Selection regarding Size

Check if method A can be used.

- You have three or more data points (*estimated E* and *actual A&M*) that correlate ( $r^2 \geq 0.50$ ).
- The absolute value of  $\beta_0$  is less than about 25% of the expected size of the new program
- $\beta_1$  is between 0.5 and 2.

If method A cannot be used, check method B.

- You have three or more data points (*plan A&M* and *actual A&M*) that correlate ( $r^2 \geq 0.50$ ).
- The absolute value of  $\beta_0$  is less than about 25% of the expected size of the new program.
- $\beta_1$  is between 0.5 and 2.

If method B cannot be used and you have historical data, use method C.

If you have no historical data, use method D.



## Rules for Method Selection regarding Time

Check if method A can be used.

- You have three or more data points (*estimated E* and *actual time*) that correlate ( $r^2 \geq 0.50$ ).
- $\beta_0$  should be near 0 (substantially smaller than the expected development time for the new program).
- $\beta_1$  should be within 50% of 1/(historical productivity)

If method A cannot be used, check method B.

- You have three or more data points (*plan A&M* and *actual time*) that correlate ( $r^2 \geq 0.50$ ).
- $\beta_0$  should be near 0 (substantially smaller than the expected development time for the new program).
- $\beta_1$  should be within 50% of 1/(historical productivity)

If method B cannot be used and you have historical data, use method C.

If you have no historical data, use method D.



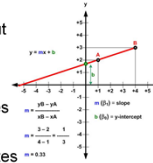
## Where do the Size guidelines come from?

### Rule for **Size** $\beta_0$

- Having the overhead and constant bias ( $\beta_0$ ) almost as big as the finished product would not make sense. It would mean estimated proxy size has little influence on the estimate size.
- The absolute value of  $\beta_0$  should be less than about 25% of the expected size of the finished product.

### Rule for **Size** $\beta_1$

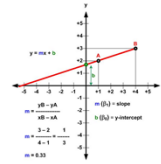
- Normally, the slope ( $\beta_1$ ) should be near 1.0. Values between 0.5 and 2.0 are acceptable.
- A value of less than 0.5 or greater than 2.0 indicates a large proportional over or under bias and should not be used unless your instructor agrees.



## Where do the Time guidelines come from? - 1

### Rule for *Time* $\beta_0$

- Having the overhead and constant bias ( $\beta_0$ ) almost as large as the final estimated time would not make sense. It would mean estimated proxy size has little influence on the estimated time.
- The absolute value of  $\beta_0$  should be significantly smaller than the estimated development time.



## Where do the Time guidelines come from? - 2

### Rule for *Time* $\beta_1$

- "Time"  $\beta_1$  needs to be within 50% of (1/Historical Productivity)

### Example:

How long would it take to code one LOC if historical average productivity is at 30 LOC per hour?

$$\begin{array}{rcl} 30 \text{ LOC} & & 1 \text{ hr} \\ 1 \text{ LOC} & & x \text{ hrs} \\ \hline 30x = 1 & \rightarrow & x = 1/30 = 2 \text{ minutes per LOC} \end{array}$$

For this example, if  $\beta_1$  is not between 1 and 3 minutes per LOC (within 50%), the correction applied is too great and should not be used.



## PROBE Wizard

The rules and guidelines for PROBE method selection can be complex. In the Process Dashboard, the PROBE Wizard automates the evaluation of these rules to reduce the likelihood of planning errors.

The PROBE Wizard uses Estimated Proxy Size as an input to its calculations. So before you can use the PROBE Wizard, you must produce an Estimated Proxy Size.

You produce an Estimated Proxy Size by completing the upper portion of the PSP Size Estimating Template.



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## PSP Size Estimating Template

This is the upper part of the PSP Size Estimating Template where the detailed size estimating is performed.

We are interested in:

**Added Size =**  
**Base Additions + Part Additions**

**Estimated Proxy Size =**  
**Base Additions + Part Additions**  
**+ Modifications**

No effort is spent in development on inclusion of **Reused** parts so they are not included in **A** or **E**.

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This slide is a refresher to get everyone's understanding on the same page.

We are interested in two derived measures:  $A = BA + PA$  and  $E = BA + PA + M$ .

It is a good idea to remove any confusion about "base" and "reused" here, if there is any!

Also remind the students that if most of the newly added parts are of medium size it is indicative of a good conceptual design, not too detailed where many parts are too small, and not too high level where many parts are too large.





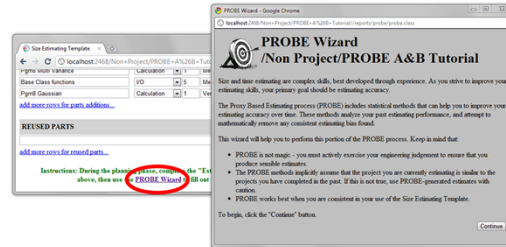
### Follow Along ...

1. Download the PROBE Methods A & B Sample DB for Dashboard.zip data backup file.
2. In your Process Dashboard, choose "C → Tools → Open Dataset." Open the ZIP file you just downloaded.
3. A second Process Dashboard window will open, showing the name of the ZIP file in the title bar.
4. This second window is showing example data from the ZIP file. Use this second window to follow along with this tutorial.



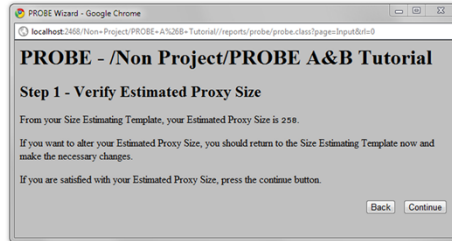
## Launching the PROBE Wizard

After the conceptual design has been entered into the upper portion of the PSP Size Estimating Template, you can click the hyperlink to launch the PROBE Wizard.



## Verify Estimated Proxy Size

The first step of the PROBE Wizard is to review the Estimated Proxy Size that you have produced.



## Review Historical Data - 1

Next, the PROBE Wizard will display a list of the historical data that will be used for the calculations.

Review this list for

- Completeness
- Known outliers

PROBE Wizard - Google Chrome

localhost:4000/Non-Project/PROBE-4/2020-7/actual/verify-probe-probe-check-page.html#taskid=

### PROBE - /Non Project/PROBE A&B Tutorial

#### Step 2 - Verify Historical Data

The PROBE calculations will be based upon the following set of historical data:

Project/Task	Estimated Proxy Size	Planned Added & Modified Size	Actual Added & Modified Size	Estimated Hours	Actual Hours	Exclude?
Historical Data Program 1		5	4.5	3.13		
Historical Data Program 2	400	282	3.33	8.05		
Historical Data Program 3	76.9	126	1.08	2.82		
Historical Data Program 4	89.2	161	2.3	1.93		
Historical Data Program 5	166	62	3.02	3.67		
Historical Data Program 5b	59.9	140	3.9	0.62		
Historical Data Program 6	66.2	156	1.85	2.7		
Historical Data Program 7	106	116	2.42	3.03		

(Advanced: If you find that one or more of the projects in the list above is an "outlier" you may exclude it from the PROBE calculations by checking the appropriate box in the "Exclude" column. Check you really understand what you are doing. It is best to leave all the boxes unchecked.)

If all the information above is correct, press the continue button.

Back Continue



## Review Historical Data - 2

The PROBE Wizard will look through your past projects to create this list of historical data.

Only projects that have been marked complete will be included in the list. If a recently finished project is not on the list, open its Project Plan Summary form and make certain it has been marked complete.

Also, review the data in the Actual Size column. If data is missing or "#VALUE!", you forgot to enter the actual size for a recently completed project. You can open the Project Plan Summary for that project to fix the problem.

If you do not resolve these problems, the missing/incomplete data will be excluded from the PROBE calculations.



### Review Historical Data - 3

A past project could be an outlier if something unusual occurred during its development. For example:

- The requirements changed
- The project characteristics are different than the other historical data points (e.g. new development vs legacy changes)

If you are aware of any problems such as these on past projects, you can mark individual data points as outliers.

A poor estimate is not a valid reason to mark a data point as an outlier.

**Follow Along:** JD knows that his instructor altered the requirements for Program 5 after he discovered a limitation in a platform library that he could not work around. *Check the box* to mark Program 5 as an outlier.



## Select PROBE Method for Size - 1

Next, the PROBE Wizard will:

- Perform calculations for PROBE Method A, B, and C for size
- Eliminate methods that cannot be used because they violate the selection criteria (e.g. bad  $\beta_0$  or  $\beta_1$ )
- Sort the available options, placing the most viable options at the top of the list
- Display the choices for your consideration.

Use your engineering judgment to evaluate the options, then select the one that you feel produces the most realistic estimate for the project.



## Select PROBE Method for Size - 2

PROBE Wizard - Google Chrome  
localhost:3668/Non-Project/PROBE-a/b/208-Tutorial/reports/probe/probe.class?page=Size&Size=2

### PROBE - /Non Project/PROBE A&B Tutorial

#### Step 3 - Size

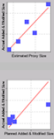
To create your final size estimate, use your engineering judgement to choose from the following PROBE methods:

☒ 321 ± 64.2 LOC

Your best option for estimating size could be PROBE Method A. Your regression parameters are within bounds ( $Beta0 = 25.7 \text{ LOC}$ ,  $Beta1 = 1.15$ ). In addition, the historical data points have an excellent correlation ( $r^2 = 0.83$ ). This correlation appears to be significant ( $p = 3.15\%$ ).

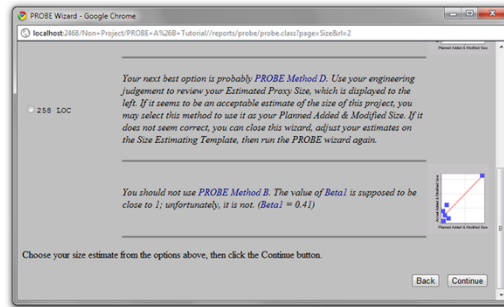
☐ 295 LOC

Your next best option is probably PROBE Method C. The slope of the line is within bounds ( $Beta1 = 1.14$ ).





## Select PROBE Method for Size - 3



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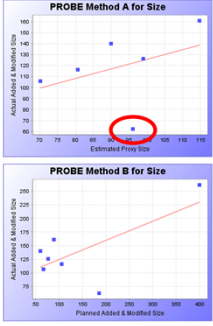
### Viewing Charts of Historical Data

Chart thumbnails are displayed next to the various PROBE methods. Click on a thumbnail to open a larger chart.

The charts are useful for quick, visual verification of correlation and also for identification of outliers.

A data point may look like an **outlier** when there are not enough data points. Wait to accumulate enough data points to make a sound judgment call on an **outlier**.

If you determine that a point is an outlier, click the Back button to return to the "review historical data" step.



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Note that based on an individual's perception a visually drawn regression line may or may not be accurate!

On this example explain that when the data point circled in red is marked as an outlier we get a pretty good regression, but this would be the wrong approach as there are too few data points to make a sound judgment call!

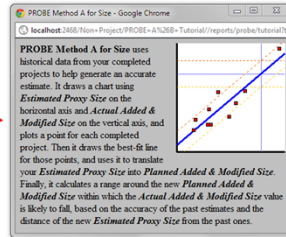
Note: Student tool does not draw a **regression line**. It is best to go back to PROBE Size Estimating Template and look at the calculated correlation value and regression parameters!



## PROBE Glossary Terms

The PROBE Wizard includes a glossary to help with the definitions of various terms. When you see a word or phrase written in dark blue letters, you can click on the word for an explanation of its meaning.

Your best option for estimating size could be **PROBE Method A**. Regression parameters are **intercepts (Beta0) = 25.7 LOC**, **Beta1 = 1.15**. In addition, the historical data points have an excellent correlation ( $r^2 = 0.83$ ). This correlation appears to be significant ( $p = 3.15\%$ ).




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### PROBE Method A Selection Criteria for Size - 1

The PROBE Wizard automatically checks the selection criteria rules on our behalf. But for this tutorial, let's review these rules.

321 ± 64.2 LOC

Your best option for estimating size could be PROBE Method A. Your regression parameters are within bounds ( $Beta0 = 25.7$  LOC,  $Beta1 = 1.15$ ). In addition, the historical data points have an excellent correlation ( $r^2 = 0.83$ ). This correlation appears to be significant ( $p = 3.15\%$ ).



Size selection criteria (Step-1)

- Is the correlation ( $r^2$ ) equal to or greater than +0.50?
- In this example  $r^2$  meets the requirement (0.83)

**Reminder:**  
Method A uses "E"stimated Proxy Size and Actual A&M for "size", and  
"E"stimated Proxy Size and Actual development time for "time" estimation.

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Note that the correlation should be a positive number. If there is a negative correlation for example, between size and time, then it would mean that it takes less time to write larger programs!



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### PROBE Method A Selection Criteria for Size - 2

Your best option for estimating size could be **PROBE Method A**. Your regression parameters are within bounds ( $\text{Beta}_0 = 25.7 \text{ LOC}$ ,  $\text{Beta}_1 = 1.15$ ). In addition, the historical data points have an excellent correlation ( $r = 0.83$ ). This correlation appears to be significant ( $p = 3.15\%$ ).

321 ± 64.2 LOC

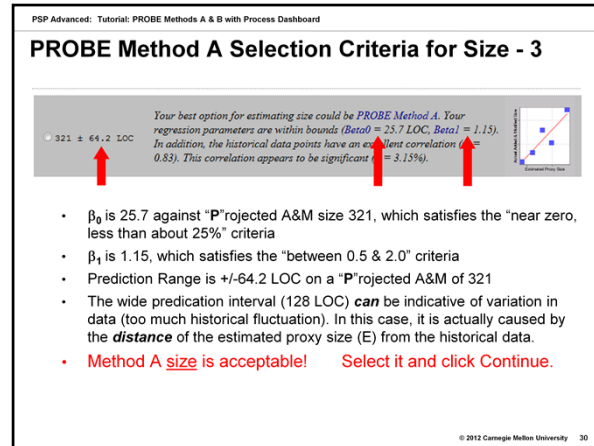
Size selection criteria (Step-2)

- Absolute value of  $\beta_0$  should be near 0, less than about 25% of the expected size of the new program.  $\beta_0$  represents overhead and/or constant estimating bias, so it should not be more than about 25% of projected A & M size!
- $\beta_1$  represents proportional estimating bias and proportional overhead. It should be between 0.5 and 2.0

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$\beta_1$  represents proportional estimating bias and is used to correct the estimated LOC. If we are correcting it by more than 100% as is the case with 2.0, then we should not be using these regression parameters as the tool thinks that the finished product will be two times the size of our estimate. In contrast if we are reducing our estimated LOC by more than 50% as is the case with 0.5, then again we should not be using these regression parameters as the tool thinks we are being overly cautious.





Method A fits the selection criteria, so it should be selected.

A couple things to note about the prediction interval

- It is not part of the selection criteria for the method choice.
- The magnitude of the prediction interval is mainly affected by 2 items
  - the variation of the historical data about the regression line
  - The "distance" of the new estimated proxy size (E) from the historical data
- The larger either of these is, the larger the prediction interval is
- In this example, the variation of the historical data about the regression line is "small" – see the earlier charts. But the "distance" of the new estimated proxy size from the historical data is "large". So although the historical data has little fluctuation, because the new estimated proxy size (e) is well outside the range of the existing data, the prediction interval is large.

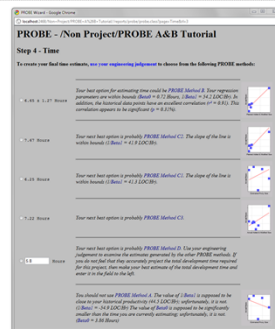


## PROBE Method A Selection for Time - 1

Next, the Wizard will present the PROBE methods for Time.

Once again, the wizard evaluates selection criteria, eliminates unacceptable options, and sorts the most viable options first.


For this tutorial, let's review its assessment of PROBE method A for Time.



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### PROBE Method A Selection Criteria for Time - 2

*You should not use PROBE Method A. The value of  $1/\text{Beta}_1$  is supposed to be close to your historical productivity (44.5 LOC/Hr); unfortunately, it is not. ( $1/\text{Beta}_1 = -54.9 \text{ LOC/Hr}$ ) The value of  $\text{Beta}_0$  is supposed to be significantly smaller than the time you are currently estimating; unfortunately, it is not. ( $\text{Beta}_0 = 3.86 \text{ Hours}$ )*



Time selection criteria (Step-2)

- $\beta_0$  should be near 0 (substantially smaller than the expected development time for the new program).
- $\beta_1$  should be within 50% of  $\left(\frac{1}{\text{Historical Productivity}}\right)$

$$\left(0.5 * \left(\frac{1}{\text{Historical Productivity}}\right)\right) < \beta_1 < \left(\frac{1}{\text{Historical Productivity}}\right) + \left(0.5 * \left(\frac{1}{\text{Historical Productivity}}\right)\right)$$

Reminder:  
Method A uses "E"stimated Proxy Size and Actual A&M for "size", and  
"E"stimated Proxy Size and Actual development time for "time" estimation.

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$\beta_0$  and  $\beta_1$  should be explained here as to what they mean regarding "time". In LOC/Size,  $\beta_0$ , represented overhead such as declarations, setting up development environment and/or constant estimating bias.

In "time"  $\beta_0$  represents time spent that isn't related to size (possibly planning and/or postmortem and/or overhead items) and constant estimating bias.

$\beta_1$  should be within half of  $1/\text{"Historical Productivity"}$ . The rational for this is that since the  $\beta_0$  should be substantially smaller than the expected development time and that the Projected A&M should be somewhere between  $\frac{1}{2}$  and  $2x$  the estimated proxy size,  $\beta_1$ , which is the main determinate of the time estimate, should be within 0.5 and 1.5 the reciprocal of the historical productivity expressed in minutes/LOC.

NOTE, however, this is an academic exercise in this case since  $\beta_1$  is negative, we can immediately conclude that method A is not usable for time!

NOTE: The historical productivity needs to be converted to minutes per LOC instead of Hours per LOC before making the comparison.





### PROBE Method A Selection Criteria for Time - 3

You should not use **PROBE Method A**. The value of  $1/\beta_1$  is supposed to be close to your historical productivity (44.5 LOC/Hr); unfortunately, it is not. ( $1/\beta_1 = -54.9$  LOC/Hr) The value of  $\beta_0$  is supposed to be significantly smaller than the time you are currently estimating; unfortunately, it is not. ( $\beta_0 = 3.86$  Hours)



- $1/\beta_1$  is -54.9 LOC/Hr. A **negative** slope is not acceptable! We can immediately conclude that method A is not usable for time.
- $\beta_0$  is 3.86 hours (against a hypothetical total development "Time" of -48.94), which is totally outside of acceptable parameters
- $\beta_0$  also does NOT satisfy the selection criteria
- If  $\beta_1$  had been positive, how would we check its selection criteria?



## PROBE Method A Selection Criteria for Time - 4

You should not use PROBE Method A. The value of  $1/Beta1$  is supposed to be close to your historical productivity (44.5 LOC/Hr); unfortunately, it is not. ( $1/Beta1 = -54.9 \text{ LOC/Hr}$ ) The value of  $Beta0$  is supposed to be significantly smaller than the one you are currently estimating; unfortunately, it is not. ( $Beta0 = 3.86 \text{ Hours}$ )



If  $\beta_1$  were positive, you would then check if it met the criteria.

reciprocal of productivity =  $(1/44.5) = 0.022 \text{ Hours/LOC}$

$0.022 - (0.022/2) < \beta_1 < 0.022 + (0.022/2)$

$0.011 < \beta_1 < 0.033$

$29.7 < 1/\beta_1 < 89 \text{ LOC/Hour}$

Because it is negative,  $\beta_1$  does not satisfy Method A's selection criteria for Time!

Our next option for time is Method B.

Note that historical productivity is LOC/Hr, so we multiply the result by 60 to get the per minute value!



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

## PROBE Methods B&C

☒ 6.65 ± 1.27 Hours

*Your best option for estimating time could be PROBE Method B. Your regression parameters are within bounds ( $Beta0 = 0.72$  Hours,  $1/Beta1 = 54.2$  LOC/Hr). In addition, the historical data points have an excellent correlation ( $r^2 = 0.91$ ). This correlation appears to be significant ( $p = 0.313\%$ ).*

☐ 7.67 Hours

*Your next best option is probably PROBE Method C2. The slope of the line is within bounds ( $1/Beta1 = 41.9$  LOC/Hr).*

Method B uses:

- Planned A&M (planned program size) and Actual A&M (actual program size) for "size" estimation.
- Planned A&M (planned program size) and Actual Development Time for "time" estimation.

Method C uses averaging and does not look at correlation

Other than using a different set of data, steps in Method B are identical to Method A.

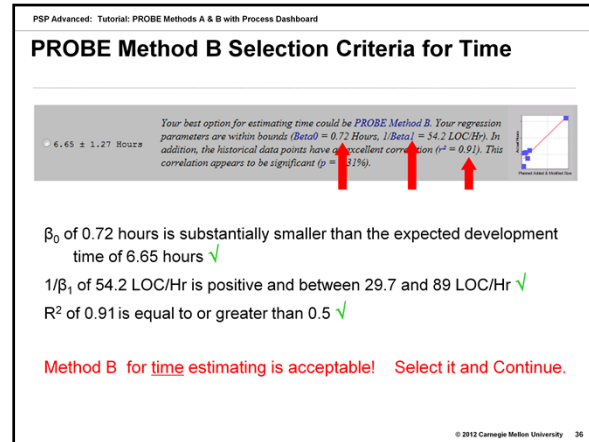
Let's look at PROBE Method B next and see if it provides a better fit!

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We show on the slide where the data is coming from for use in Method B.

Also mention that it is discouraged to mark a data point as an outlier as fluctuation is normal and evaluation should be deferred until substantial amount of data is collected.





In this example, the Time selection criteria was not met by Method A, then we came into Method B and found it to be acceptable

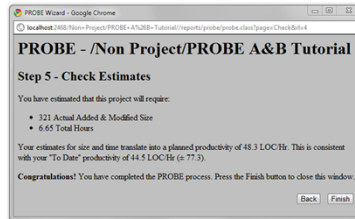


## Final Consistency Check

Our PROBE-adjusted size and time estimates were made independently of each other, using different linear relationships.

As a result, it is possible to produce an overestimate for size and underestimate for time (or vice versa).

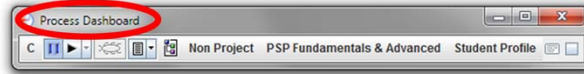
The final page of the wizard compares your newly created estimates to your historical productivity for consistency.



## Ending the “*Follow Along*” Portion of the Tutorial

If you have been following along in the Process Dashboard during this tutorial, you will currently have two Process Dashboard windows open.

1. The main window, which displays “Process Dashboard” in the title bar, is displaying your actual metrics data.



2. The title bar for the second window will be displaying the name of the data backup ZIP file that you created for this tutorial.

Changes in this second window will be **discarded** when the window is closed, so it is important not to record any real data there. To prevent an accidental situation where your metrics are recorded in the wrong window,

**please close that second window now.**





## Messages to Remember

PROBE offers four methods to arrive at size and time estimates

- Method A is the most preferred choice
  - requires a minimum of 3 data points
  - uses "E"stimated Proxy Size and Actual A&M for "size" estimation
  - uses "E"stimated Proxy Size and Actual development time for "time" estimation
  - evaluates correlation along with regression parameters
- Method B uses:
  - requires a minimum of 3 data points
  - Planned A&M (planned program size) and Actual A&M (actual program size) for "size" estimation
  - Planned A&M (planned program size) and Actual Development Time for "time" estimation
  - evaluates correlation along with regression parameters
- Method C uses averaging and does not look at correlation
- Method D uses "engineer's best guess!"



