

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

**Please make a copy of your student database,
as you will be exploring the tool and experimenting with the options**

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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.

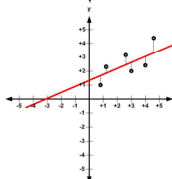
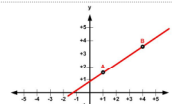


Minimum Data for Using Regression

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.

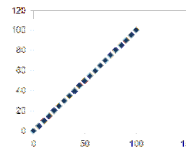
For the regression line to act as the predictor, we need more data points (at least 3).



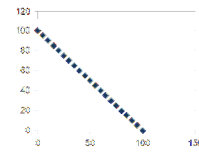
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Correlation

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.

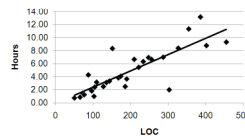
An r^2 of 1 is considered a perfect fit!

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

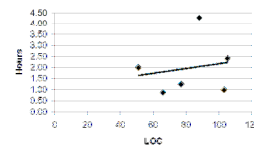
Correlation & Significance

Significance is a measure that indicates the probability that the correlation occurred by chance.

When the number of items in the data set grows, correlation tends to be reliable. When this is the case, pay attention to correlation!



When the number of data points is small, pay attention to significance!



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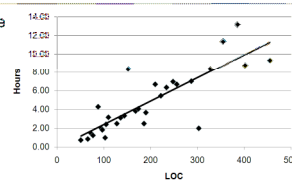
Note, there is always the possibility that a high correlation was the result of chance (just a random event) and there is not a real cause and effect relationship between the two data sets. Significance is measure of that probability.

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:

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

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

β_0 is a constant bias in the size, e.g., overhead LOC and/or constant estimating bias
 β_1 is the factor for the ratio of under-estimates and over-estimates

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

β_0 is a constant bias in the estimated time, e.g., overhead time and/or constant estimating bias
 β_1 is the average additional time to develop one line of code

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



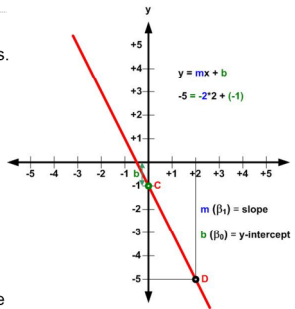
What do negative β_0 and β_1 mean?

The y-intercept (β_0) represents overhead and constant estimating bias.

While overhead can only be positive, constant estimating bias can be negative due to a strong bias towards over-estimating.

Only small, relative to the final estimate, negative values of β_0 are acceptable.

Negative slope (β_1) means that as the proxy size estimate increases, the size and/or effort decreases! This should not be true, thus **negative values for β_1 are not acceptable.**



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It's important to note that negative values of beta0 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 beta0.

Note that the absolute value of B0 is used in the PROBE method selection scripts. A small negative B0 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 β_0 is less than about 25% of the expected size of the new program.
- β_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 β_0 is less than about 25% of the expected size of the new program.
- β_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.

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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 ($r^2 \geq 0.50$).
- β_0 should be near 0 (substantially smaller than the expected development time for the new program).
- β_1 should be within 50% of $1/(\text{historical productivity})$

If method A cannot be used, check method B.

- You have three or more data points (**plan A&M** and **actual time**) that correlate ($r^2 \geq 0.50$).
- β_0 should be near 0 (substantially smaller than the expected development time for the new program).
- β_1 should be within 50% of $1/(\text{historical productivity})$

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

If you have no historical data, use method D.

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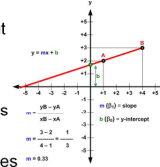
Where do the Size guidelines come from?

Rule for Size β_0

- Having the overhead and constant bias (β_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 β_0 should be less than about 25% of the expected size of the finished product.

Rule for Size β_1

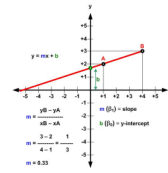
- Normally, the slope (β_1) should be near 1.0. Values between 0.5 and 2.0 are acceptable.
- A value of less than 0.5 or greater than 2.0 indicates a large proportional over or under bias and should not be used unless your instructor agrees.



Where do the Time guidelines come from? - 1

Rule for **Time** β_0

- Having the overhead and constant bias (β_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 β_0 should be significantly smaller than the estimated development time.



Where do the Time guidelines come from? - 2

Rule for *Time* β_1

- "Time" β_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 β_1 is not between 1 and 3 minutes per LOC (within 50%), the correction applied is too great and should not be used.



Follow Along ...

- Download the PROBE methods A & B.mdb database and import it into a copy of your PSP Student Workbook.



PSP Advanced: Tutorial: PROBE Methods A & B

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 Added & Modified =
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 $E = BA + PA + M$.

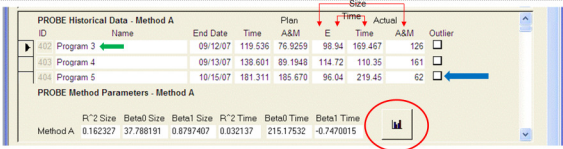
It is a good idea to remove any confusion about "base" and "reused" here, if there is any!

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.



PSP Advanced: Tutorial: PROBE Methods A & B

PROBE Method A



ID	Name	End Date	Time	Plan A&M	E Time	Actual A&M	Outlier
402	Program 3	09/12/07	119.536	76.9259	98.94	169.467	<input type="checkbox"/>
403	Program 4	09/13/07	138.601	89.1948	114.72	110.35	<input type="checkbox"/>
404	Program 5	10/15/07	181.311	185.670	96.04	219.45	<input type="checkbox"/>

PROBE Method Parameters - Method A						
	R ² Size	Beta0 Size	Beta1 Size	R ² Time	Beta0 Time	Beta1 Time
Method A	0.162327	37.788191	0.8797407	0.032137	215.17532	-0.7470015

Method A uses:

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

PROxy Based Estimation started with the 3rd programming assignment!

Outliers are best visible on the chart. They should be marked as such after careful evaluation.

We will visit Method A's chart next by clicking on the **Chart** button.

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

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.

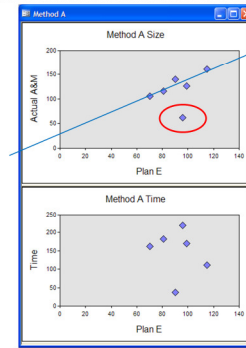
Method A's historical data starts with Program-3 where they started proxy based estimating.

PROBE Method A Size & Time Charts

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**.



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!

PSP Advanced: Tutorial: PROBE Methods A & B

PROBE Method A - Outlier

PROBE Historical Data - Method A				Plan		Actual		
ID	Name	End Date	Time	A&M	E	Time	A&M	Outlier
403	Program 4	09/13/07	138.601	89.1948	114.72	110.35	161	<input type="checkbox"/>
404	Program 5	10/15/07	181.311	185.670	96.04	219.45	62	<input checked="" type="checkbox"/> Before
405	Program 6	10/16/07	111.825	66.2187	70.15	162.15	106	<input type="checkbox"/>

PROBE Method Parameters - Method A

R ² Size	Beta0 Size	Beta1 Size	R ² Time	Beta0 Time	Beta1 Time
Method A: 0.162327	37.788191	0.8797407	0.032137	215.17532	-0.7470015

PROBE Historical Data - Method A				Plan		Actual		
ID	Name	End Date	Time	A&M	E	Time	A&M	Outlier
403	Program 4	09/13/07	138.601	89.1948	114.72	110.35	161	<input type="checkbox"/>
404	Program 5	10/15/07	181.311	185.670	96.04	219.45	62	<input checked="" type="checkbox"/> After
405	Program 6	10/16/07	111.825	66.2187	70.15	162.15	106	<input type="checkbox"/>

PROBE Method Parameters - Method A

R ² Size	Beta0 Size	Beta1 Size	R ² Time	Beta0 Time	Beta1 Time
Method A: 0.829723	25.691613	1.1454832	0.095584	230.43022	-1.0821272

In your student tool, mark a program as an outlier and see how PROBE reacts to it with new calculation. Review displayed data.

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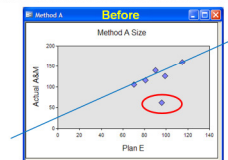
Explain that this is the “advanced” course and the students should feel pretty comfortable exploring the options on the tool and get familiar with them.

Note: **Correlation changed drastically in this example!**

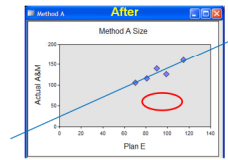


PROBE Method A Size Charts with(out) Outlier

The before chart was built based on all the data.



Once one or more data points get marked as outliers they no longer appear on the charts and they are also excluded from the calculations!



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Tell the students that marking a data point as outlier does not delete the historical data on that program, the PROBE will be blind to that program's data.

PROBE Method A Selection Criteria for Size - 1

PROBE Method Parameters - Method A						
	R ² Size	Beta0 Size	Beta1 Size	R ² Time	Beta0 Time	Beta1 Time
Method A	0.829723	25.681613	1.1464832	0.096584	230.43022	-1.0821272

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 (0.829723)

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

PROBE Method Parameters - Method A						
	R ² Size	Beta0 Size	Beta1 Size	R ² Time	Beta0 Time	Beta1 Time
Method A	0.929723	25.631613	1.1454932	0.095584	230.43022	-1.0821272

Size selection criteria (Step-2)

- Absolute value of β_0 should be near 0, less than about 25% of the expected size of the new program. β_0 represents overhead and/or constant estimating bias, so it should not be more than about 25% of projected A & M size!
- β_1 represents proportional estimating bias and proportional overhead. It should be between 0.5 and 2.0
- Now we will go into PROBE Calculation Worksheet (by scrolling up from this point) to evaluate if the regression parameters satisfy the selection criteria.

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β_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.

PROBE Method A Selection Criteria for Size - 3

	Size	Time
Added Size (A)	255.17	
Estimated Proxy Size (E)	255.17	
PROBE method used (A,B,C,D)	A	A
Correlation (P2)	0.82972114	0.99555399
Regression Parameter (B1)	25.69161399	238.43081712
Regression Parameter (B1)	1.14545209	-1.58212725
Projected A&M (P)	321.421031	
Estimated Total Size (T)	1072.421031	
Estimated Total New Resizable (NR)	sum of T items	218.17
Estimated Total Development Time	Time-DEVELOP	-48.34257143
Prediction Range	Range	64.18723190 411.7209960
Upper Prediction Interval	UPH-R-Range	385.606245 362.783422
Lower Prediction Interval	LPH-R-Range	257.2337812 0
Prediction Interval Percent		70% 70%

- β_0 is 25.69 against "P"rojected A&M size 321.42, which satisfies the "near zero, less than about 25%" criteria
- β_1 is 1.14, which satisfies the "between 0.5 & 2.0" criteria
- Prediction Range is +/-64 LOC on a "P"rojected A&M of 321.42
- The wide predication interval (128 LOC) *can* be indicative of variation in data (too much historical fluctuation). In this case, it is actually caused by the *distance* of the estimated proxy size (E) from the historical data.
- **Method A size is acceptable!**

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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.

PSP Advanced: Tutorial: PROBE Methods A & B

PROBE Method A Selection Criteria for Time - 1

PROBE Method Parameters - Method A						
	R ² Size	Beta0 Size	Beta1 Size	R ² Time	Beta0 Time	Beta1 Time
Method A	0.829723	25.891613	1.1454832	0.095584	230.43022	-1.0821272

Time selection criteria (Step-1)

- Is the correlation (r^2) equal to or greater than +0.50?
- In this example r^2 does NOT meet the requirement (0.096)
- Let's suppose that correlation was good and check the criteria for β_0 and β_1

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 slope (β_1) should be a positive number. For example, if the slope, between size and time, is negative, then it would mean that it takes less time to write larger programs!

In this case, the slope (b_1), is negative so we could immediately conclude that Method A is not usable for time!



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PROBE Method A Selection Criteria for Time - 2

PROBE Method Parameters - Method A						
	R ² Size	Beta0 Size	Beta1 Size	R ² Time	Beta0 Time	Beta1 Time
Method A	0.829723	25.891613	1.1454932	0.095584	230.43022	-1.0821272

Time selection criteria (Step-2)

- β_0 should be near 0 (substantially smaller than the expected development time for the new program).
- β_1 should be within 50% of $\left(\frac{1}{\text{Historical Productivity}} \right)$

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

- Now we will go into PROBE Calculation Worksheet (by scrolling up from this point) to evaluate if the regression parameters satisfy the selection criteria.

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β_0 and β_1 should be explained here as to what they mean regarding “time”. In LOC/Size, β_0 , represented overhead such as declarations, setting up development environment and/or constant estimating bias.

In “time” β_0 represents time spent that isn’t related to size (possibly planning and/or postmortem and/or overhead items) and constant estimating bias.

β_1 should be within half of $1/\text{“Historical Productivity”}$. The rational for this is that since the B0 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, b_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 b_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.

- β_1 is -1.08. A **negative** slope is not acceptable! We can immediately conclude that method A is not usable for time.
- β_0 is 230.43 against total development "Time" of -48.94, which is totally outside of acceptable parameters
- β_0 also does NOT satisfy the selection criteria
- "Time" is -48.94 minutes, which is meaningless!
- If β_1 was good, how do we check the selection criteria for β_1 ?

PROBE Method A Selection Criteria for Time - 4

	Plan	Actual	To-Date
Productivity	37.0	86.0	52.3

LOC/Hr

- If β_1 were positive, you would then check if it met the criteria.

$$\text{reciprocal of productivity} = (1/52.3) * 60 = 1.14 \text{ min/LOC}$$

$$1.14 - (1.14/2) < \beta_1 < 1.14 + (1.14/2)$$

$$0.57 < \beta_1 < 1.71$$

(From previous slide) β_1 does not satisfy Method A's selection criteria for Time!

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



PROBE Method A Selection Criteria for Time - 5

PROBE Calculation Worksheet		Size	Time
Added Size (A):	A-B+A-B	245.17	
Estimated Proxy Size (E):	E-B+A-B	255.17	
PROBE method used (A,B,C,D):	A	A	B
Correlation (R ²):		0.82972314	0.9953386
Regression Parameter (B0):	Size and Time	85.0916109	238.4082172
Regression Parameter (B1):	Size and Time	1.14548208	-1.88212725
Proposed Add (p):	P-B+M-T	321.421013	
Estimated Total Size (T):	T-B+D-M-R	1072.421013	
Estimated Total New Recusable (NR):	sum of T* beta	215.17	
Estimated Total Development Time:	Time-B+D-T		-48.9425740
Prediction Range:	Range	64.18723190	411.7359880
Upper Prediction Interval:	UPR-Range	385.882845	382.785422
Lower Prediction Interval:	LPR-Range	297.2337812	
Prediction Interval Percent:		70%	70%

- Range is 411.74 minutes against estimated development "Time" of -48.94, which is totally meaningless,
- Upper and Lower prediction intervals therefore are meaningless too.
- Our next option for time is Method B.



PSP Advanced: Tutorial: PROBE Methods A & B

PROBE Methods B&C

ID	Name	End Date	Time	A&M	E	Actual Time	Actual A&M	Outlier
401	Program 2	09/11/07	200	400	0	403.257	262	<input type="checkbox"/>
402	Program 3	09/12/07	119.536	76.9259	98.94	169.467	126	<input type="checkbox"/>
403	Program 4	09/13/07	138.601	89.1948	114.72	110.35	161	<input type="checkbox"/>
404	Program 5	10/15/07	181.311	185.670	96.04	219.45	62	<input type="checkbox"/>

PROBE Method Parameters - Methods B and C

	R ² Size	Beta0 Size	Beta1 Size	R ² Time	Beta0 Time	Beta1 Time
Method C	N/A	0	0.9889326	N/A	0	1.38543737
Method B	0.470499	89.711109	0.3586719	0.90461	41.148897	1.09267135

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 Calculation worksheet next and see if Method B 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.

PROBE Method B Selection Criteria for Time

PROBE Calculation Worksheet		Size	Time
Actual Size (A)	A-B-A+D-A	245.17	
Estimated Proxy Size (E)	E-B-A+D-A	255.17	
PROBE method used (A,B,C,D)	A	0	0
Correlation (R ²)	0.82972314	0.910211199	
Regression Parameter (B0)	Size and Time	25.89181209	+3.20149493
Regression Parameter (B1)	Size and Time	1.145462029	1.107359929
Projected ABB (P)	P-B0-B1*E	321.4219231	
Estimated Total Size (T)	T=A+B-D-M+C	1072.421013	
Estimated Total New Reusable (NR)	sum of P items	210.17	
Estimated Total Development Time:	Time-DB-A+T	329.2539109	
Prediction Range:	Range	64.18723190	70.7012010
Upper Prediction Interval:	Upper-P-Range	305.603245	309.9840447
Lower Prediction Interval:	Lower-P-Range	257.237012	258.4227925
Prediction Interval Percent:		70%	70%

R^2 of 0.91 is equal to or greater than 0.5 ✓

β_1 of 1.11 is positive and between 0.57 and 1.71 ✓

β_0 of 43 is substantially smaller than the expected development time of 329 ✓

Method B for time estimating is acceptable!

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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



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!"



