WHY ARE PROJECTS ALWAYS LATE?

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ABSTRACT
Did you know that most of the project schedule and budget estimates that are done today have less than a 50% chance of making their promise date? This paper will explain why. We will discuss making better promises of project completion time, and ways of improving schedules and cost estimates.

In this paper we will discuss the probability of making schedule promise dates and budgets. We will keep it fairly simple in terms of the statistics used but we will use some statistics to prove that what we have to say about schedule and budget promises today needs to be changed considerably. It is however important that we keep statistics handy as a tool because we are talking about project budgets and schedules and that discussion involves evaluating the uncertainties involved and that, of course, involves evaluating the probability.

What we eventually want to do is develop a closer relationship between what we promise our stakeholders and what really happens. We can begin by changing the promise itself. Most project promises for delivery or budgets are stated in terms of a single value. We should begin by stating these in terms of a range of values and their likelihood of actually occurring.

In terms of budgets this would mean that there would be a possible range of values for which the project will actually be completed. The high end of the budget range represents the worst-case situation and the low end the best-case. In the case of schedules it will be a bit more difficult because we not only have to have a range of values for the completion of the project but we have to have a way of applying it to the proper tasks in the schedule.

1 INTRODUCTION
This paper is aimed at those of us that have difficulty getting our projects to be completed by the promise date and for the budget that we had set at the beginning of the project. When we talk of completing our projects on time and for the stated budget we mean that we do this for the work required in the original scope of the project. If the scope changes, the budget and schedule will usually have to be adjusted and should be.

Many times the project schedule and budget are set for a stated project scope and never adjusted for changes in scope that the customer asks for and our management agrees to. Some of the time the company sees it is in their best interest to allow customer driven changes in project scope to be add without increasing the project schedule or budget. Many times there is just no more budget available for the project.

Is it really fair or just for the project manager to be required to meet the new and added scope of the project without additional funding for the budget or time for the schedule? Frequently the project manager can pull a rabbit out of a hat and make the project with added scope still finish on time and for the original budget.

When projects are managed this way, is the project manager a magician or a villain? It would seem that there could be no good outcome from projects with expanded scope being done on time and on budget. If the budget was based on bad or overly generous estimates then the project manager is no
hero. If the quality of the project was compromised and testing and evaluation of the project were shortened to save time or money then the project manager is no hero either.

Often the project manager has a poor understanding of the real facts of how schedules and budgets are really determined and just follows the development of budgets and schedules the way that they have been done in the past and the way that he or she has always done them as well.

2 PROBABILITY OF MEETING PROMISE DATES AND BUDGETS

A probability distribution associates the probability of any possible value of a project parameter occurring when the project is actually done. In the area of budgets we are generally interested in the probability of a certain money value being spent at the end of the project. In the case of schedules we are interested in the likelihood of the project being completed on the promise date. So, we have various budget values or schedule dates along the horizontal axis and probability along the vertical axes. Probability is usually measured in terms of the percent of likelihood that a given value will occur.

Since budgets and schedules begin with estimates and estimates are our best approximation of how much money and how much time it is going to take to complete the project, it would be naïve of us to think of budgets and schedules without associating them with probability.

We have to look no further than the normal distribution to see what the problem is. The normal distribution, shown approximately in Figure 1, is discussed here but the same idea is true for most of the distributions that make any sense at all for managing projects. There is much discussion in scheduling literature about the various kinds of probability distributions that can be used. Much of the discussion is in support of using the Beta distribution. For schedules and budgets there is good rationale for using a probability distribution that is skewed to the left.

This skewing of the probability distribution shown in Figure 2 is logical because when we are discussing schedules it is quite possible for us to be very late in our schedule but difficult for us to be early. The same is true in budgeting, it is difficult to bring the project to completion under budget but quite easy to make it over budget.

Any probability distribution will have some sort of peak. If it did not it would be telling us that there was a continual increase in probability of ever increasing budget or schedule values. This would make managing a project or even making any kind of estimate impossible. So, it is reasonable to say that whatever distribution we use will have a minimum value rising to a most likely value and then falling off to some minimum value again.

Because of the central limit theorem as we take a series of tasks that would be done in sequence and recognize that each of them has a skewed probability distribution, we will see that as more tasks are added together the probability distribution approaches a normal distribution.

For our discussion it is reasonable to use the normal distribution as an illustration but one should recognize that the Beta, Triangular, Binomial and many other distributions could be used if they more closely represent the real probability distribution of the project.

2.1 Using and misusing the “Most Likely” date and budget

What is most likely done in predicting project completion schedules and budgets is that the most likely date or budget value is used. In the case of normal and other symmetric distributions this will also be the average or mean value of the distribution as well. In the case of the skewed distribution as shown above in Figure 2, the mean value will be to the right of the most likely value. The most likely value of the distribution is the peak of the curve and has the value on the horizontal axis that has the highest value for the probability.
If the project manager uses the most likely value in the distribution to promise delivery or budget value to the customer there is going to be a 50% chance that the project will be done earlier than this date or for less than the most likely budget. Of course there is also a 50% chance that the project will be done after the most likely date and for more than the most likely budget amount.

Would it not be a foolish project manager that would promise a customer a completion date for a project that only had a 50% chance of actually occurring? What causes this? Briefly, let me say a few words about variability. In the world of Quality Management we consider common causes and assignable causes for variability. Common causes are the normal things that go on in any project that cause variation between plans and reality. Assignable causes are the things that should not happen, normally don’t happen and need corrective action when they do. What we need to do is to adjust our budgets and schedules so that we more closely predict what will really happen in the project when these common and assignable causes take place.

2.2 Standard Deviation and Delivery confidence
There is a convenient way of looking at the amount of adjustment needed for schedules and budgets. This adjustment is through the use of the standard deviation. Simply, the standard deviation is the amount of spread there is in the probability distribution. As can be seen in Figure 3, small standard deviation means that there is small range for most of the values around the peak of the probability distribution and a large standard deviation means that there is a large range for most of the values.

If we consider the middle of the distribution, the most likely value is the peak point. The probability of exactly that value is quite small. In fact it is only one value in the entire possible range of values possible. What we need is a range of values. Once we have a range of values, we can determine the probability of the actual value falling somewhere in that range. For convenience, it is easy to use units of standard deviation. For any normal distribution, one standard deviation on either side of the mean value is going to equal the range of values that will have a 68.3% probability of having the actual value between the high and low. If we want to consider 2 standard deviations from the mean then there is a 95.5% probability that the actual value will be between the high and the low. If we use 3 standard deviations we will have the probability that many quality management people consider for their control charts and acceptance criteria at 99.9%. It is only convenient to use the standard deviation. It is not necessary since any range or percentage could be used.

2.3 What probability of completion do we really want to promise?
In the case of project budgets and schedules it is pretty reasonable to use two standard deviations. Most of us would be happy to be able to predict the project completion date range within 4.5%. At three standard deviations, the range of values becomes so large that although it has a 99.9% probability of including the actual value, the value is just too large to be helpful.

If what most of us are promising our management and our customers is the most likely budget and the most likely completion date for the project then we are accepting a chance of 50% that the project will be completed after that most likely date and over the most likely budget. Would it not be smarter to promise the customer and our management dates and budgets that have a 95% probability of actually occurring? We should promise two standard deviations from the most likely date and budget in our estimates.

3 WHERE DO WE GET THE DATA?
In order to apply any of this we need to have good data going in. Unless we can be sure that our estimates for budget and schedule are accurate, there is no point of building a more confident system of predicting the results of our projects.
3.1 Honesty in Estimating
It is essential that we have honesty in estimating. One way we can do this is by allowing the people that must perform to the estimates the right to make them. Project estimates that are made by people other than the ones who must perform to them will never succeed but estimates made by the person that must perform to those estimates are likely to have ownership of them and succeed. We must therefore instil confidence in those that are making the estimates. This may require some training and knowledge of good estimating practices but the time and effort training the members of the project team will have long term benefits far in excess of the costs involved.

3.2 No padding allowed
One of the situations that will reduce the reliability of our estimates is to pad and remove cost and time from them. An estimate is submitted to a manager and the manager arbitrarily removes cost or time from it. The estimator, on the next submission simply adds in more than the last time to compensate for the amount the manager is expected to remove. The manager, realizing this, simply takes out more than the last time. If this continues, larger and larger estimates, with less and less accuracy are submitted to larger and larger reductions. In the course of this the estimates become less and less accurate because the estimator feels that there is no point wasting time doing a good estimate because the manager does not believe anything that is submitted, so a good estimate or a bad estimate will be treated equally and it is a lot easier to make a bad estimate than a good one.

3.3 Lowest level of detail. Why more detail?
One of the other nice things that the mathematics of statistics does for us is to give us a way of adding the standard deviation. If we had several items, such as the expected cost of 5 tasks and their standard deviation, we would have to add them together by first adding the averages. When it came to adding the standard deviations we would have to first square them, add them together and then take the square root of the total.

For example suppose we had five tasks that had an estimated cost of $20 each and a standard deviation of $2. We would first add the average cost of each for a total of $100. The standard deviation would be $2 squared or $4 each for a total of $20. Then we would take the square root of the total to get the standard deviation for the total cost of the five tasks. This would give us $4.47.

Notice that when we find the standard deviation for a sum of tasks, the magnitude, not the actual number, for the standard deviation gets smaller than the standard deviation of the individual items. This is because as we increase the number of items in an estimate there is a greater and greater probability that an increasingly equal number of over estimates and under estimates will cancel each other out. This is convergence. It is a bit like flipping a coin a large number of times. The more times we flip a coin, the closer we come to having a total of 50% heads and 50% tails.

Using this logic, the more individual items we have in our estimate, the smaller the standard deviation of the total estimated value will be.

3.4 Range of values
There is yet another way to improve our estimating process. We can ask our estimators to give us a range of values instead of the single value that we are probably getting from them today. If an estimator tells us that something costs between $39 to $43 to manufacture, doesn’t that give us much more information than telling us that it costs $41. Consider the difference in knowledge about the estimate when we also consider an estimate for the same part as being between $27 and $55.

In the first situation we have a worst-case estimate of $43 and in the second a worst-case of $55. Suppose we can sell the part for $48. In the first case we have a possible profit of $5 per unit and in the second a worst case of $7 loss. Both have the same most likely cost of $41 as does the single
valued estimate. In the single valued estimate there is no way to tell how much the range of values could be.

3.5 Using PERT for Cost
If we consider the estimating calculations used for PERT schedules, we can also apply them to our budget estimates. In PERT we estimated the duration of a task by taking the weighted average of the optimistic, the pessimistic and the most likely:

\[
\text{Optimistic} + 4 \times \text{Most Likely} + \text{Pessimistic}
\]

\[
\frac{6}{6}
\]

This is approximately equal to the expected value of the estimate.

In PERT we also calculate the standard deviation as well by the simple calculation:

\[
\text{Pessimistic} - \text{Optimistic}
\]

\[
\frac{6}{6}
\]

This is approximately equal to the standard deviation of the estimate.

The interesting thing about this estimating technique is that it is essentially free. This always gets everyone’s attention. The additional cost of preparing estimates this way does not add to the total cost of preparing estimates. This is because anyone preparing an estimate will have to consider the optimistic, pessimistic and most likely value anyway in order to properly consider the possibilities that might go on during the actual performance of the work.

Since, when we total the individual estimates we end up with a total cost plus the standard deviation of the total. It now becomes a simple matter to take a look at the range of values that gives us a 95% probability of having the actual cost be somewhere within the range of the estimate. This gives us another important piece of information. It tells us what we must do to improve the range of values of the estimate. To get the range of values for the estimate smaller we simply increase the number of items in the details that are estimated. As the number of individual items increases the standard deviation will decrease in magnitude and the range of values in the total will get smaller.

3.6 Summary
To summarize our discussion of estimates. If we ask our estimators to do our estimates we must give them the self-confidence to carry out the task. This is fundamental to good project management practices for any assignment. We can do this by giving training where necessary and not arbitrarily changing the estimates. It is perfectly all right to question any estimates but the estimating of the values should be left to the individual making the estimate.

Having the estimator make an estimate in terms of a possible range of values would be a good improvement over what is normally done in a single value estimate. An even greater improvement would be to use a three-valued estimate of independently estimating the optimistic, pessimistic and most likely. The three-value estimate gives us the standard deviation of the estimate and also gives us a way to sum up the details into a higher level estimate and calculate the standard deviation of the total as well. This also gives us an indicator as to how much further into detail we should go to achieve the range of values and probability for our estimate.
4 WHAT DO WE DO WITH THE DATA?

E. Goldratt has authored a technique called, “The Critical Chain.” We will explore his ideas and try on some new ones of our own. The basic idea with critical chains is that if we promise our customers delivery of our project using the most likely schedule dates based on the most likely durations of our tasks we have a 50% chance of finishing the project after that date.

In the above discussion we discussed getting proper estimating data. In this section we will try to find the most useful way to use this data. The goals that we are seeking apply equally to scheduling and budgets. The scheduling problem is somewhat more complicated that the budgeting problem.

When we consider the budget of the project we are going to add up all of the cost of all of the tasks to get the total project cost. We will use the standard deviation to help us determine the range of cost values that will have a 95% probability of actually taking place. When we consider schedules we must only consider the things that cause the total duration of the project.

4.1 Critical Chain Adjustments

In Goldratt’s Critical Chain Method he must be very unsure of people’s acceptance of statistics. He first recommends that each of the persons making an estimate make the estimate as accurately as possible and then adjust the estimate to allow for problems to occur. This results in increasing the estimated value by about 50%. Then he says that the manager should take this 50% away and use it to establish time or cost in the area of critical chains.

I don’t believe that a little simple statistics is too much of a difficulty for most people, even Americans who have a notorious problem with statistics.

The problem is that if we were using Goldratt’s 50% suggestion, we would add more than necessary and would possibly lose credibility in our estimating methods. Suppose we have 5 tasks in our schedule that must be done in sequence and each is estimated to have a duration of 10 days and a standard deviation of 3 days. The expected value of the sequence is 50 days and the standard deviation is 6.7 days. ($3^2+3^2+3^2+3^2+3^2 = 45$; square root of 45 = 6.7). Using Goldratt’s adjustment we would insert an additional 25 days (50% of the expected value). If we are willing to accept a 95% probability of the actual value being achieved we would use twice the standard deviation, 13.4 days or by rounding, 14 days.

In fact if you read on with Goldratt he finally comes to terms with this and uses two standard deviations instead of the 50% rule. We will stick to the two standard deviation adjustment since it reflects the uncertainty of the duration while 50% of the expected value does not.

We have discussed several things. It might be a good idea to list the basic assumptions that we will use in the remainder of this article:

Each of the tasks of the project has been estimated and we have an expected value for the duration and a standard deviation for each.

The number of tasks in our project is sufficient for our probability distribution to have an approximately normal distribution. This number is only about 10 tasks. So, it is a safe assumption as well.

5 BUFFERED SCHEDULES

Now that we have a value to apply to our schedules the question is how to do it. Buffering the schedule is basically deliberately adding float to the schedule. We simply take the adjustment to the schedule that we found by adding two standard deviations to the schedule and add it in by creating float in the schedule. The question is: Where should we add it?
5.1 Goldratt’s Critical Chain

In the Critical Chain approach to scheduling, one of the important considerations is that it is important to start all tasks as late as possible rather than as early as possible. The rationale for this is that by starting all the tasks in the schedule as late as possible there is the opportunity for the project team to learn as much as possible about the work of the project before any of it has to be done. The second reason is that it will reduce the amount of work in progress during the project.

5.1.1 Critical Chain or Critical Path

The Critical Chain schedule is created with the idea that there are chains in the schedule and that these chains should be delayed as much as possible. That is that they should be scheduled to begin as late as possible and then adjusted to begin an amount of time before that to allow the creation of a buffer between the end of the chain and the activity on the Critical Chain that depends on it.

This is a little confusing until we realize that a Critical Chain is simply the Critical Path of the project after the resources have been applied. When we normally calculate the Critical Path, according to Goldratt, we are not considering the application of resources to the schedule and are assuming unlimited resources. He goes on to say that once we have applied the resources to the schedule and resolved conflicts of resource availability, the result is that we have something new called the Critical Chain. The Critical Chain is the sequence of events that cannot be delayed without causing the project to be delayed.

In reality this is the Critical Path of a resource-constrained schedule. Suppose we have two tasks in the schedule that, without resource constraints, are scheduled to be done in parallel or at least with some overlap. When we create the resource-constrained schedule, one of them must be rescheduled so that the over commitment of resources is resolved. This essentially creates a dependency between the two tasks and thus creates a new Critical Path.

5.1.2 Creating the Critical Chain Schedule

Step 1 – Locate the Critical Path, Figure 4. This is done the way that we calculate the Critical Path normally. We calculate the non-resource constrained schedule by calculating the Early Start and the Early Finish. When all of the schedule dates have been calculated in the forward pass we perform the backward pass to get the Late Finishes and the Late Starts. The Critical Path is the list of tasks that have zero float. For those of you who may not remember, float is the difference between the Early Finish and the Late Finish or, if you prefer, the difference between the Early Start and the Late Start. Either way the Critical Path is the same list of tasks.

Step 2 – Resolve the resource conflicts, Figure 5. We do this by adjusting the schedule of the tasks so that there are no resource conflicts. This is done by not allowing any over commitment of resources.

Step 3 – Identify the Critical Chain. This is really recognizing a new Critical Path. It is still the list of tasks that cannot be delayed without delaying the completion of the schedule. The difference is just that we have now considered a new dependency. In these cases, one task depends on another because of the lack of availability of a resource.

Step 4 – Reschedule all tasks that are not on the Critical Path, these are the feeder chains, to be as late as possible, Figure 6.

Step 5 – Apply Buffer to the feeder chains, Figure 7. Since we scheduled all of the tasks with float in the original schedule to be done as late as possible we have essentially moved the float to the beginning of the sequence of tasks. What this means is that if any of the tasks is late it will now delay the start of any tasks on the critical path that depend on it. We must now move the beginning of the sequence of tasks earlier by the amount of two standard deviations of the sequence. In the Figure, the feeder chains are only one task each, Task B and G. Task B has a standard deviation of
.5 days and task G has a standard deviation of 1 day. Two standard deviations of buffer give us a buffer of 1 day for task B and 2 days for task G.

Step 6 – Apply buffer to the project, Figure 8. This allows us to add five days to the scheduled finish date of the project. This will create five days of float in the project and allow us to reschedule the late finish of the project.

<table>
<thead>
<tr>
<th>Task Number (Resource Constrained Critical Path)</th>
<th>Expected Value of Duration</th>
<th>Standard Deviation</th>
<th>Variance (SD Squared)</th>
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<tr>
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<td>0</td>
<td>0</td>
</tr>
<tr>
<td>C</td>
<td>3</td>
<td>.5</td>
<td>.25</td>
</tr>
<tr>
<td>E</td>
<td>6</td>
<td>1</td>
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<tr>
<td>D</td>
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<td>F</td>
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<td>H</td>
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</tr>
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<td>Total</td>
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<td>Square Root of Total</td>
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</tr>
<tr>
<td>Project Buffer</td>
<td></td>
<td></td>
<td>5</td>
</tr>
</tbody>
</table>

5.1.3 Advantages of the Critical Chain approach
The Critical Chain approach gives us some valuable things. The feeder chains have been rescheduled and buffer has been applied to them. This helps avoid the problem associated with any of the feeder chains delaying the critical path or the Critical Chain of the project. The project itself has had buffer added to it to prevent the items on the Critical Path or the Critical Chain from missing the promise date of the project. Figure 8 shows the completed schedule.

5.2 Other Buffered Schedules
There are other methods to develop buffered schedules. The use of these should be a function of the particular project. In project management, no two projects are the same and the correct tool should be used in the correct situation.

5.2.1 Risk Model
The reason for adding buffer to schedules is really a question for Risk Management. Because risk and uncertainty exist in schedules and budgets all of this is essentially a way of mitigating risk. In the Critical Chain approach to schedules it is assumed that all of the feeder chains and the critical chain have the same level of risk associated with them and it is represented by the standard deviation of the tasks.

Another way to buffer schedules is to apply a proportionate amount of buffer to the risk items that have the largest expected value of risk damage. If a task is in the middle of a feeder chain and it has a high-risk expected value of damage or severity it would make sense to apply buffer directly to that
task. This will create free float for that particular task. This can be done by moving the first task in the feeder chain to start earlier or by scheduling the tasks after the high-risk activity to begin later.

This technique has the advantage of avoiding complicated reschedules. Project schedules need to have credibility and it is easy to lose credibility when there are constant reschedules of the project or branches of the project due to risks occurring.

5.2.2 Duration Model
Another way to develop the buffers is by proportioning the project buffer to the individual tasks according to their duration. The rationale is that if a task has a long duration it should be given a larger buffer.

This is essentially a simplistic model. There are many tasks that have high risk and relatively short duration as there are many tasks that have low risk and relatively long durations. This model could be used in situations where risks have been evaluated poorly. Of course this would also bring to question the accuracy of the standard deviation estimates for the tasks then as well.

6 WHAT ABOUT BUDGETS?
We have discussed the schedule and the use of buffer. We must now consider what to do with the equivalent of schedule buffer for the budget. There are two problems with this, one is getting the budget for the project and the other is controlling it once you have it.

6.1 Determining Budget Buffer
We have discussed the use of the PERT calculations in the name of scheduling. Why not use these same calculations for budgets? Our estimators should be thinking about the optimistic, pessimistic and most likely values of the budget for their task as we described above. This will allow us to determine the expected value and the standard deviation for the task as well as the bottoms up estimate for the project or parts of the project.

This determination is rooted in risk management. The driving force behind the pessimistic and optimistic estimates is risk. If the estimator perceives that there is high risk in the task being estimated there will be a large difference between the most likely value and the pessimistic value. If the estimator thinks that there is a good chance that the cost will be lower than expected there will be a large difference in the optimistic value. In any case they will cause an increase in the standard deviation and will also shift the expected value.

The causes for this increase in standard deviation should feed into our risk analysis as a source for identifying risks in the project. There should be a fairly close correlation between the standard deviation of our estimates and the risks associated with them.

When all is said and done our risk management system and our budgets and schedules should have a degree of correlation. In other words the identified risks and their associated evaluation should correspond to our standard deviation for our budgets and schedules.

6.2 Controlling our Budgets
Since we now have recognized the need for adding additional budget to our project budgets we will need a way to manage it.
6.2.1 Contingency Budget
The contingency budget is an amount of budget set aside for the risks that have been identified. Since these risks are identified and have been considered by the project team, the budget should be available to the person or persons doing the task that the risk could occur on. However, as a matter of control, it is tempting for the person responsible for that task to use the risk’s budget to solve other problems. For this reason access to the contingency budget should be limited and require the approval of at least the immediate supervisor of the person responsible for this task.

6.2.2 Management Reserve
The management reserve is the budget that is reserved for risks that were not identified in risk analysis. This budget is determined without knowledge of the specific risks that could occur. It is determined by less reliable means such as analogous estimates. As a matter of control one more level of approval is required to access this budget.

7 SUMMARY
It is important in good project management to allow for risk in projects. It is also important for the project manager to allow for common cause variations in project schedules and budgets and minimize the disruption of their effects on the project.

The reasonable use of adjustments to budgets and schedules is not padding. It is the application of reality in a reasonable way. Managers that react negatively to this process are either inviting disappointment or asking the project managers working on their projects to reduce quality and possibly the unauthorized reduction of the scope of the project.

Goldratt’s Critical Chain concept is really not much of a departure from already recognized project management techniques. It seems to underestimate the abilities of the project manager to deal with some basic mathematics and management skills. A project manager that is not able to deal with these skills should possibly not be managing projects in the modern business world.

There is a unification in project management. Risk management, quality management and all of the other areas of project management are related to the budgeting and scheduling process in a strong way and we must be careful to consider all of the areas of project management.

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Michael is a Project Manager who has been managing projects for the past 30 years. In that time he has managed such diverse projects as those involving many manufacturing systems, electronics assembly, foundry operations, rubber molding, robotics, aerospace manufacturing and automation of manufacturing process and control.

Mike recently led a project to totally rebuild the computer and communications system for Emergency Dispatch for Police, Fire and Emergency Medical for the City of New Orleans.

Mike has been teaching Project Management professionally for the past fifteen years and has taught in many countries throughout the world, authored two books, recently established a branch of his firm in Moscow, Russia and teaches Project Management all over the world.
Fig. 1

Normal distribution

Schedule or Budget possible values

Fig. 2

Skewed Distribution

Schedule or Budget possible values

Fig. 3

Small and Large Standard Deviations