@RISK for the Highway Contractor

The highway industry is one of the premier stalwarts of the construction world. For years there have been stories of great success and growth as the market expanded and the need for military, business and private transportation provided opportunity that seemed endless. Today that industry seems far removed as funding is limited and has to compete with other interests. There are those who have skilled personnel that seem to make good choices most of the time and have managed to succeed more frequently than others. However, can they pass these skills to the next generation and then the next or maybe just to the next project?

One answer is to incorporate the skills into expert systems that define and even quantify the steps and choices that have to be made in pursuing and executing projects. There was a day when the tools to facilitate this transfer were slide rules, pencil and paper. As automation began to grow the computer became an essential and today the immediate access to information seems to demand that technology is the key to success. Even a two year old wants to play with the iPhone to look at videos and call anyone on speed dial. What then is the expert system? Is it simply to teach how to access and distribute information or does it require the ability to understand what you see and share. @RISK is a tool that uses technology while at the same time offering a greater understanding of what is being shared. Offering not only the opportunity of knowing what to expect but, also the probability of that and other reasonable expectations.

To acquire an in-depth understanding of business performance it is beneficial to measure activities as a process. By doing this results can be determined to be stable, capable and predictable. Designing a Core Business Experience Capital (CBEC) database to effectively capture data that is both useful and practical is the key to success. The right level of detail and summary will depend on the business and how decisions are made. Too much detail may be impractical and create more variance than is useful. Too little detail may make comparisons vague with more questions than answers. If the right level is achieved information can be captured and modeled in such a way to accelerate the performance of new employees ahead of their years of experience (Expert System).

This is where @RISK simulations become the tool of choice. Many companies capture data, calculate numeric and weighted averages, and look for highs and lows. But, if they stop there they will never know how frequently to expect one result compared to another and for certain will not understand the impact of multiple activities interacting to a final outcome.

Scheduling is one area where interaction sometimes works differently than might be expected. Consider a project with 5 activities on a path where each has to finish before the other can start. Each has an expected duration of 10 days based on most likely past history. The schedule shows the project to finish in 50 days. The project is completed in 55 and everyone is shocked except the person who understands process measures and simulation. The expected outcome is really related to the distribution shape of each of the 5 activities. Most schedule and cost activities can perform a little better than the most likely some of the time but, if things really go bad the performance can be much worse at other times. This creates a skewed process distribution to the higher number of days to be expected. What is found with multiple iterations in a network is that the real expectation should be the sum of the means which are skewed by the poor performance durations. This also creates opportunity to identify causes and try to avoid poor performance which leads to process improvement.

Consider this example; a market product can be completed in 30 days. But, more often than any other single result it usually takes 35 days. In fact some experiences have even taken 60 days. What should be scheduled for the next product and what should be proposed to the customer? If the decision is 35 days there will probably be frequent disappointment and if the decision is 30 days (just to get the work) then disaster is not far away. Take a look at Sample A (column Sample 1):

					Sample A							
	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Sample 8	Sample 9	Sample 10		Total
	41.67	41.67	41.67	41.67	41.67	41.67	41.67	41.67	41.67	41.67		416.67
Name												
Minimum	30.37	30.37	30.37	30.37	30.37	30.37	30.37	30.37	30.37	30.37		365.83
Maximum	59.34	59.34	59.34	59.34	59.34	59.34	59.34	59.34	59.34	59.34		493.36
Mean	41.67	41.67	41.67	41.67	41.67	41.67	41.67	41.67	41.67	41.67		416.67
Std Deviation	6.56	6.56	6.56	6.56	6.56	6.56	6.56	6.56	6.56	6.56		20.94
Mode	35.12	35.12	35.12	35.12	35.12	35.12	35.12	35.12	35.12	35.12		411.90
5% Perc	32.74	32.74	32.74	32.74	32.74	32.74	32.74	32.74	32.74	32.74		382.55
10% Perc	33.86	33.86	33.86	33.86	33.86	33.86	33.86	33.86	33.86	33.86		388.70
15% Perc	34.74	34.74	34.74	34.74	34.74	34.74	34.74	34.74	34.74	34.74		394.91
20% Perc	35.50	35.50	35.50	35.50	35.50	35.50	35.50	35.50	35.50	35.50		398.74
25% Perc	36.28	36.28	36.28	36.28	36.28	36.28	36.28	36.28	36.28	36.28		402.37
30% Perc	37.08	37.08	37.08	37.08	37.08	37.08	37.08	37.08	37.08	37.08		405.04
35% Perc	37.91	37.91	37.91	37.91	37.91	37.91	37.91	37.91	37.91	37.91		407.94
40% Perc	38.77	38.77	38.77	38.77	38.77	38.77	38.77	38.77	38.77	38.77		411.15
45% Perc	39.67	39.67	39.67	39.67	39.67	39.67	39.67	39.67	39.67	39.67		413.63
50% Perc	40.62	40.62	40.62	40.62	40.62	40.62	40.62	40.62	40.62	40.62		415.88
55% Perc	41.62	41.62	41.62	41.62	41.62	41.62	41.62	41.62	41.62	41.62		418.35
60% Perc	42.67	42.67	42.67	42.67	42.67	42.67	42.67	42.67	42.67	42.67		421.35
65% Perc	43.78	43.78	43.78	43.78	43.78	43.78	43.78	43.78	43.78	43.78		423.95
70% Perc	44.98	44.98	44.98	44.98	44.98	44.98	44.98	44.98	44.98	44.98		427.21
75% Perc	46.30	46.30	46.30	46.30	46.30	46.30	46.30	46.30	46.30	46.30		430.51
80% Perc	47.75	47.75	47.75	47.75	47.75	47.75	47.75	47.75	47.75	47.75		433.88
85% Perc	49.37	49.37	49.37	49.37	49.37	49.37	49.37	49.37	49.37	49.37		438.96
90% Perc	51.31	51.31	51.31	51.31	51.31	51.31	51.31	51.31	51.31	51.31		444.52
95% Perc	53.82	53.82	53.82	53.82	53.82	53.82	53.82	53.82	53.82	53.82		452.44

This sample is based on a triangular distribution where 35 days is the most likely (mode), 30 days is the fastest and 60 days is the slowest. It reveals that even for a single occurrence there is less than a 20% chance to complete in 35 days and less than a 5% chance to complete in 30 days.

The picture gets even more dramatic if the capacity is one at a time (start to finish) cycles and the customer requires 10 products. If the decision is to complete the 10 products in the combined most likely duration of 350 days (10 x 35), there is less than a 5% chance that this will be successful.

The reason for this drama is that although there is less than a 20% chance for 35 days in a single occurrence, the reality is that with multiple occurrences it becomes far less likely that all will occur in the low range or high range at the same time. In fact there becomes a central tendency where both the lows and highs occur less frequently in the combined total and actually begin to form a more symmetrical shape nearer to the mean or expected value of 42 days.

Please note, that a triangular distribution creates a more dramatic picture than most curved distributions. However, in all skewed distribution cases the expected results will gravitate to the mean or expected value. Therefore, any business where making schedule is critical to success should consider applying @RISK simulations to gain reality insights for decisions.

Estimating is another business function that gains insight using @RISK simulation. In the highway estimating world depending on the complexity of the job, there can be many issues to affect the outcome. Traffic, phasing, access, weather, skills, acceleration, and on and on all create the opportunity for people to express their expert opinions and ideas. The question is how have these things been measured to quantify the impact on productivity, cost and schedule? The persons mentioned earlier that seem to frequently make good choices and succeed more than others get the most attention. They are able to talk about how much work they placed in a day and how many people were on the crew. Usually stories that don't match the final results on the completed project cost report for a given activity but, due to their past successes the estimate decisions are greatly influenced by their comments. How can you determine that they are right for the current choice? More importantly if their choice is always used can you quantify how often it will succeed and how often it will fail in pursuit of multiple projects strategic goals? After all, despite these issues that affect the outcome even a project consists of multiple activities like; mobilizing, preparing right of way, dirt, subgrade, concrete, steel, etc.

CBEC database modeling applied to @RISK simulations is an outstanding way to answer this question. As long as processes remain stable with consistent capabilities their multiple outcomes are very predictable. Over a period of years I applied direct labor, simulation models in a range estimating process to highway proposals for mostly TXDOT bids. The successful bids were constructed and the outcomes measured at completion. The actual direct labor cost experienced was $125,000,000. The traditional estimating process budgeted $100,000,000 and the range estimating model calculation predicted $120,000,000 (19% more accurate). Please, note two things, 1. The range estimating was done at bid time and had some influence on the budget. Otherwise, the budget would have probably been less. 2. The range estimating was an automated calculation which with a little estimator judgment would have had the opportunity to be even more precise.

Silpform concrete paving is a good example of modeling for process alignment issues between estimating and actual construction. Labor productivity is significantly affected by issues such as; length of run, width and thickness, days per month, hours per day, material delivery, size of crew and reliability of equipment. With all of these and more the decision is generally made based on a standard crew, a generic days per month, a job level hours per day and the deciding (subjective) factor of cubic yards (CY) per day. Reality later, after comments and choices are forgotten comes to life on a cost report in dollars and manhours per CY. If the choices are consistently reasonable then the estimating and actual construction processes will be aligned for multiple projects and cumulative strategic business goals will be achieved. Unfortunately, in a competitive market this is one way that anxious contractors try to buy jobs by letting desires and egos exceed reality.

Sample B illustrates the impact of this type of decision making and how modeling can at least influence choices with quantified risk and opportunity ranges. In Sample B the estimating and review process arrives at a decision that they can slipform 20,000 CY of concrete paving at an average rate of 700 CY/day with a 15 man crew working 10 hours/day. This calculates to 0.21 manhours/CY and $126,000. It is within the range of experience and has been achieved or exceeded 3 of 10 times. Using an @RISK distribution from Job History it has a 25-30% probability of success and may be reasonable for the uncertainty conditions on this specific project. However, if all proposals in a stable process receive the same optimism then 3 of 10 will succeed and 7 of 10 will fail. Depending on the magnitude of the processes not being in alignment this will result in reduced margins or even out of pocket losses. Measuring and modeling enhance the opportunity to orchestrate favorable outcomes in achieving strategic business goals. @RISK simulations can help sustain competitive advantage with best practices ahead of industry practices to continuously learn from experience.

Sample B

Highway XYZ Slipform Concrete Paving					
Job History		Estimate			
Job Number	Actual wh/cy sorted	cy	wh	$/wh	$
Job 8	0.40	20,000	8,000	$30.00	$240,000
Job 4	0.36	20,000	7,200	$30.00	$216,000
Job 9	0.32	20,000	6,400	$30.00	$192,000
Job 2	0.31	20,000	6,200	$30.00	$186,000
Job 10	0.28	20,000	5,600	$30.00	$168,000
Job 5	0.28	20,000	5,600	$30.00	$168,000
Job 1	0.22	20,000	4,400	$30.00	$132,000
Job 7	0.21	20,000	4,200	$30.00	$126,000
Job 6	0.20	20,000	4,000	$30.00	$120,000
Job 3	0.19	20,000	3,800	$30.00	$114,000
Average	0.28	20,000	5,540	$30.00	$166,200
Estimate	0.21	20,000	4,200	$30.00	$126,000
@RISK expected					$160,980

Name	@RISK	Estimate
Minimum	$108,820	
Maximum	$548,125	
Mean	$161,020	
Std Deviatio	$52,442	
Mode	$109,045	
5% Perc	$111,457	
10% Perc	$114,234	
15% Perc	$117,208	
20% Perc	$120,396	
25% Perc	$123,755	
30% Perc	$127,326	$126,000
35% Perc	$131,231	
40% Perc	$135,435	
45% Perc	$139,922	
50% Perc	$144,943	
55% Perc	$150,383	
60% Perc	$156,564	
65% Perc	$163,478	
70% Perc	$171,569	
75% Perc	$181,059	
80% Perc	$192,667	
85% Perc	$207,789	
90% Perc	$228,563	
95% Perc	$264,774	

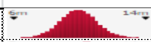
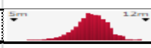
Another example is related to business development in the competitive bidding market. Suppose there are 3 competitors in the market that consistently bid above and below each other and have profiles that are symmetrical and average the same above and below at a 1.0 ratio to your profile (your bid $ / competitor bid $). The expectation might be since each of the competitors has a 50% chance of being above or below you that you would expect to be the low bidder 50% of the time. And, if you were bidding against them one at a time that is a reasonable expectation. However, when all four bid at the same time and the low bid is successful the distribution of the low bid is less than the 1.0 ratio profile (your bid $ / low competitor bid $) since it is not likely that all four would bid above average. Not only will the low bid not average 1.0 but, its distribution will be skewed to the low side since any time the low bid does come out above the 1.0 ratio it will probably not be much higher. Conversely, any competitor bidding in the low range of their profile has a much greater chance of being the low bidder.

Sample C

Low Bid Simulation

Four Contractors with a 1.0 profile in the market

Cont A (you)	Cont B	Cont C	Cont D		Low Bid
1.00	1.00	1.00	1.00		
$10,000,000	$10,000,000	$10,000,000	$10,000,000		$10,000,000

Name	Graph	Min	Mean	Max	5%	95%
Cont B		$6,763,327	$9,999,974	$13,434,990	$8,353,542	$11,642,730
Cont C		$5,959,451	$9,999,245	$13,319,650	$8,350,359	$11,644,440
Cont D		$6,806,365	$9,999,759	$13,241,050	$8,351,996	$11,644,440
Low Bid		$5,959,451	$9,162,136	$11,598,550	$7,870,391	$10,318,070

Name	Low Bid
Minimum	$6,390,891
Maximum	$11,023,790
Mean	$9,149,972
Std Deviatio	$743,910
Mode	$9,350,163
5% Perc	$7,861,840
10% Perc	$8,168,372
15% Perc	$8,365,038
20% Perc	$8,535,144
25% Perc	$8,660,162
30% Perc	$8,784,247
35% Perc	$8,897,496
40% Perc	$9,005,078
45% Perc	$9,089,822
50% Perc	$9,199,126
55% Perc	$9,281,229
60% Perc	$9,372,795
65% Perc	$9,463,676
70% Perc	$9,549,017
75% Perc	$9,642,028
80% Perc	$9,772,206
85% Perc	$9,920,540
90% Perc	$10,089,550
95% Perc	$10,324,540

In the year 2000 I created bid strategy models using @RISK simulation designed to point to the bids required to achieve a strategic frequency of low bid success. One of the models was designed for 50% success which in a perfect world should result in a 1.0 ratio to low bid. After 12 years of bidding the profile ratio was 1.01 (45% capable). During strong market years the profile was as low as 0.98 (61% capable) in weak cycles as high as 1.04 (30% capable). Please note, that 50% bid success is not being recommended as a good strategic target. If all contractors used this strategy it would not be long before the market would erode and new players would have to take over. One of the most brilliant persons I ever knew to practice bid strategy would not usually use the low bid in his model. He preferred the second bid as a target to be $1 below the second bidder. Another way to do that using @RISK simulation might be to target 20-30% market share. Whatever the market share strategy is this modeling can certainly reduce the amounts left on the table and increase the proportion of available profit better than contractors randomly diving to be low bidder.

The potential for more complete understanding of processes and modeling applications in the highway industry is exciting and can add great value. Here are a few other @RISK applications to consider:

- Project Control projections based on % complete factored range estimating models
- Design-build parametric modeling using range estimating models
- Contingency modeling for materials, subcontracts, supplies and indirect cost
- Time/Cost integration modeling based on Core Business Experience Capital (CBEC)
- More detailed Bid Strategy at the activity and grouping level
- Value engineering comparisons at a consistent level of probability of success

The highway industry is steeped with tradition and stories regarding successes where tactical approaches to a specific project reaped exceptional rewards. Sometimes these approaches lead to new processes and even new inventions that can be repeated on other projects. Those stories will be quantified and documented in the CBEC database for others to learn from most effectively if they are measured as a process and determined to be a process shift. At which point the @RISK estimating model should be redefined and based on the new data. This is one way that the highway industry becomes a learning environment using quantified results to share and promote best practices. Statistics begin to be perceived as reality with the understanding that strategic modeling does not precisely predict the next individual activity or project result but, does reasonably predict the results of multiple activities and projects in a stable process. Also, consistent applications to process improvement and value engineering create effective choices based on quantified evidence. The end result is strategic plans are achieved and corporate goals are consistently met.

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