Generalized Analysis of Value Behavior over Time as a Project Performance Predictor

By Bob Prieto

As projects have grown more complex our performance analysis frameworks have remained largely unchanged even as newer more powerful tools have become available to manage and manipulate large volumes of data. Newer analytical tools provide deeper insights into existing data sets especially from a statistical point of view but we continue to use traditional project metrics to assess project performance on both a retrospective as well as prospective basis.

Whether our measure of project achievement is cost, schedule, physical % complete, risk or manhours we look at a relatively common set of "achievement" metrics that include absolute values (datum); changes in those values (progress) and their rate of change (progress rate). In limited instances we consider changes in the rate of progress (ramp rate) but do not more broadly analyze this throughout the project.

Higher order performance measures that look at disruption and overall efficiency of delivery are not typically considered.

The analog for each of these achievement metrics can be seen in the following table.

Generalized Analysis of Value Behavior over Time

Derivative	Spatial		Achievement	
	Point	**x**	**Datum**	
0	**Distance**	**dx**	**Progress**	**Δ datum (dd)**
1	**Velocity**	**dx/dt**	**Progress Rate**	**Δ progress (dp/dt)**
2	**Acceleration**	**dv/dt**	**Ramp Rate**	**Δ progress rate (dpr/dt)**
3	**Jerk**	**da/dt**	**Disruption**	**Δ ramp rate (drr/dt)**
4	**Snap**	**dj/dt**	**Efficiency**	**Δ disruption (ddis/dt)**

In this paper we will consider some potential index type metrics to help evaluate the level of potential "disruption" that exist in a project plan or is subsequently realized. In addition we will look at how the various "disruptions" combine to impact the overall efficiency of the project. These indices correspond to third and fourth order derivatives, jerk and snap, in a spatial context and are subjects of one or more patents pending.

Conceptual Framework

Complex construction projects are susceptible to potential disruption from many different sources including site based safety events, late or incomplete information, poorly conceived or executed work processes, out of sequence work, unrecognized interferences and a host of external factors which lie outside a project team's control. Throwing up one's hands in dismay is not an acceptable management strategy and thus we must ensure that we have the best possible plan and approach when we start and gain the insights necessary to control or limit many of these potential sources of project disruption.

The conceptual framework envisioned, seeks to provide a tool to assess the potential disruption or execution inefficiencies present in a project plan, allowing project teams to identify particularly troubling time frames and take steps to improve activity transitions, startup and completion in particular.

Within an ongoing project context the conceptual framework should provide insight into disruption durations and severity, and while not addressed here, provide insights in closely coupled, multi-project programs.

Comparable insights are not well developed today.

The conceptual framework for construction of these indices falls within the realm of optimization theory. Optimization theory is the more modern term for operations research. Optimization theory includes the calculus of variations, control theory, convex optimization theory, decision theory, game theory, linear programming, Markov chains, network analysis, optimization theory, queuing systems, etc. (1)

In the simplest terms it is about making a system or project as effective or functional as possible.

Let's look at one example where the use of third and fourth order derivatives comes into play. Consider the skilled movement of a hand. It is smooth and graceful and can be described as minimizing jerk, a third order derivative in a spatial context. This minimization of jerk allows us to predict the qualitative and quantitative features of the hand movement. (2)

In general, when considering higher order derivatives, relative values are better portrayed by utilizing the minimum squared derivative (MSD) principles. This implies that the higher order derivatives will have low absolute values. In the example of skilled hand movement above the squared jerk actually provides a better measure of relative smoothness of the trajectory of movement.

While one may consider MSD for any order derivative, it has been found that 3rd and 4th order MSD principles performed better than other orders. These correspond to minimum jerk and minimum snap (snap is the time derivative of jerk).

Consideration of Representative Achievement Curves

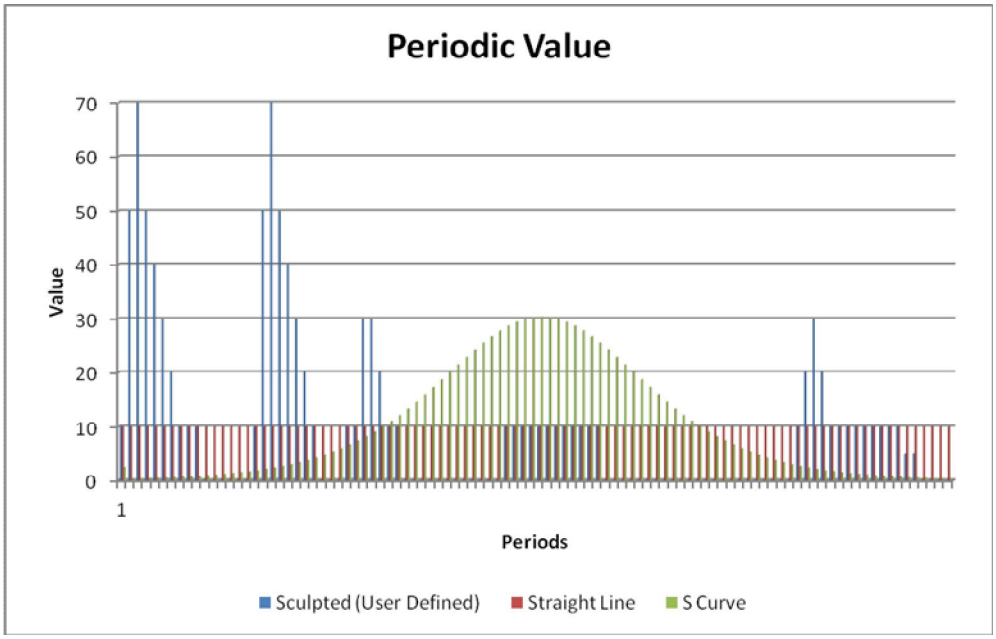
The development of project plans results in a planned set of achievement curves. These may correspond to manhours worked in a given period; installation rates; expenditure rates or earned value. Inherent in these achievement curves are assumptions around the efficiency with which certain activities are carried out and importantly the efficiency with which we can transition these activities (start:stop; ramp-up:ramp-down). Inefficient transitions lead to disruptions that have broader ripple effects and impact overall project outcome.

In order to evaluate the impacts of different achievement plans, three typical achievement models were constructed. These corresponded to:

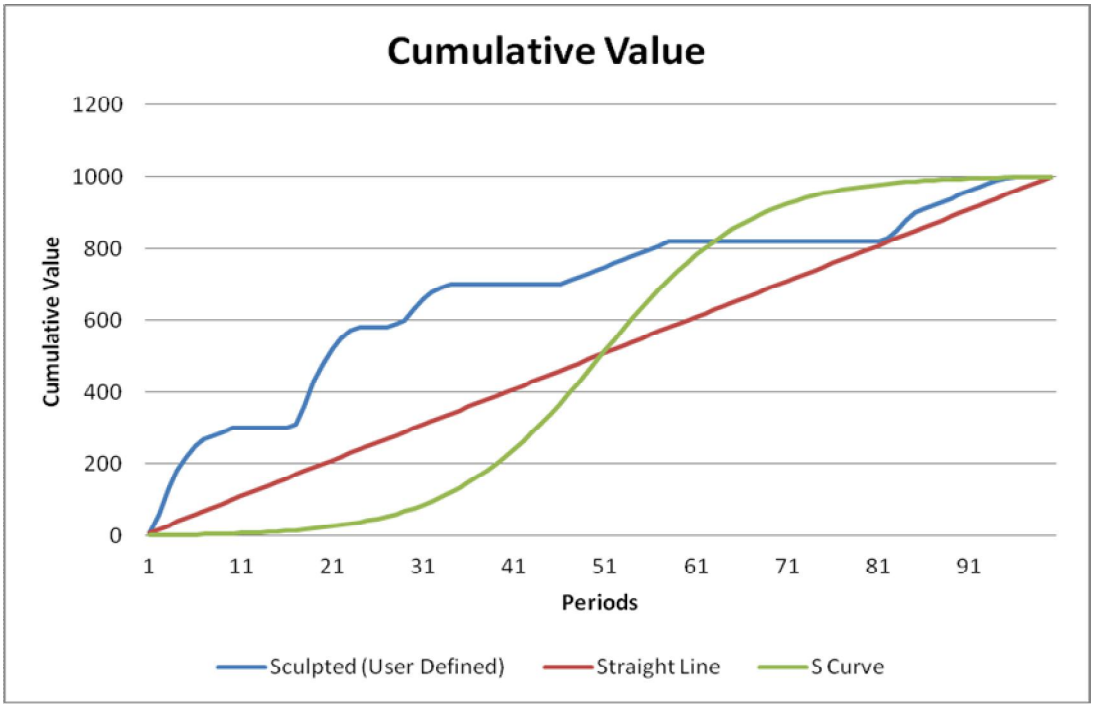
- Straight line achievement
- S-curve achievement
- Sculpted or user defined achievement

Each resulted in 1000 units of achievement over 100 time periods. The achievement parameter and time period were kept dimensionless but it is important that time periods do not become so long as to lose a view on the variations in progress that would occur in such a long time period.

The following figures illustrate both the periodic achievement as well as the cumulative achievement under each model.



In the periodic value we can see the disruptive start and stop nature of achievement in the sculpted model while the straight line shows a sudden start and stop with no variation in periodic progress throughout. The S-curve model provides a gradual ramp up (versus abrupt full out start) and gradual ramp down (versus sudden abrupt stop).



The cumulative value figure illustrates the classical S-curve shape as well as straight line and highly sculpted cumulative achievements. An infinite variety of S-curves are possible with the shapes being flatter or steeper; more or less developed earlier or later in the time frame; or skewed sooner or later in the time range. The particular example illustrated includes no skew.

Construction and Selection of Higher Order Indices

Various indices may be calculated on both an instantaneous and cumulative basis for each achievement model. Specifically, the progress in each period was tabulated and corresponds to the Periodic Value Figure above. Based on these a time series of values corresponding to the "instantaneous" change in the rate of progress (first derivative) were tabulated and a ramp up rate (the rate at which the rate of progress is changing or second derivative) was comparably tabulated.

Disruption (third derivative or jerk) and efficiency (fourth derivative or snap) were similarly tabulated.

For purposes of constructing meaningful indices the effects of disruption were considered on a periodic basis utilizing both absolute values as well as MSD values (squared jerk). A similar approach was utilized for efficiency (fourth derivative or snap) with both absolute values as well as MSD values (squared snap) considered. Lower values represented better performance, reflecting less variance from the trend.

Tables 1, 2, and 3 included at the end present the results of these calculations. Attention should be paid to start up, ramp-up, and ramp-down transitions in particular. The S-curve time period 1 value includes all prior activities reflecting the "infinite" tails associated with such curves.

In evaluating different potential approaches a singular set of values related to disruption and efficiency were deemed to be more useful than a time series. The selected values corresponded to:

- Cumulative disruption (sum of the absolute disruption values for all time periods)
- Cumulative efficiency (sum of the absolute efficiency values for all time periods)
- MSD Disruption Index (sum of the squares of the periodic disruption values for all time periods)
- MSD Efficiency Index (sum of the squares of the periodic efficiency values for all time periods)

The calculated values for the three selected models are shown in the following table.

Third and Fourth Order Measures of Project Plan and Performance

	Cumulative Disruption Index	Cumulative Efficiency Index		MSD Disruption Index	MSD Efficiency Index
Straight	**40**	**80**		**600**	**2000**
S Curve	**19**	**37**		**108**	**380**
Sculpted	**780**	**1360**		**19950**	**55300**

Lower is Better

Conclusion

Better understanding, measuring and quantifying the relative effects of disruption in today's more complex project environments is increasingly important. Third and fourth order derivatives represent a tool for contrasting alternative execution models as well as assessing the impacts of actual performance against plan.

Time series modeling of these higher order derivatives illustrate how the effects of disruption are felt over an extended time frame and offer the potential to influence workface planning as well as broader project planning.

Through use over time, determination of acceptable disruption levels will be defined for different project execution strategies, allowing us to establish performance linked ranges for each of the recommended indices. Sensitivity to selected time period (hourly, daily, weekly, monthly) requires further research. Similarly the significance of start-up "disruption" and prior period values incorporated into the first time period of the S-curve model must be judged.

References

(1) Weisstein, Eric W. "Optimization Theory." From MathWorld--A Wolfram Web Resource. http://mathworld.wolfram.com/OptimizationTheory.html

(2) Hogan N (1984a) Adaptive control of mechanical impedance by coactivation of antagonist muscles. IEEE Trans.Automatic.Control AC-29: 681-690

Table 1 - S Curve

Time	Progress	Progress Rate	Ramp Rate	Disruption	Efficiency	Absolute Periodic Disruption	Cumulative Disruption Index	Absolute Periodic Efficiency	Cumulative Efficiency Index	MSD Disruption	MSD Efficiency
0	0	0	0	0							
1	2.48	2.48	2.48	2.48	-2.48	2.48	2.48	2.48	2.48	6.14	6.14
2	0.32	-2.16	-4.64	-7.12	9.60	7.12	9.60	9.60	12.08	50.66	92.09
3	0.36	0.04	2.20	6.84	-13.96	6.84	16.44	13.96	26.03	46.79	194.82
4	0.41	0.05	0.01	-2.20	9.04	2.20	18.63	9.04	35.07	4.82	81.65
5	0.46	0.05	0.01	0.00	-2.20	0.00	18.63	2.20	37.27	0.00	4.82
6	0.52	0.06	0.01	0.00	0.00	0.00	18.63	0.00	37.27	0.00	0.00
7	0.58	0.07	0.01	0.00	0.00	0.00	18.63	0.00	37.27	0.00	0.00
8	0.66	0.07	0.01	0.00	0.00	0.00	18.64	0.00	37.27	0.00	0.00
9	0.74	0.08	0.01	0.00	0.00	0.00	18.64	0.00	37.27	0.00	0.00
10	0.83	0.09	0.01	0.00	0.00	0.00	18.64	0.00	37.27	0.00	0.00
11	0.94	0.11	0.01	0.00	0.00	0.00	18.64	0.00	37.27	0.00	0.00
12	1.06	0.12	0.01	0.00	0.00	0.00	18.64	0.00	37.27	0.00	0.00
13	1.19	0.13	0.01	0.00	0.00	0.00	18.64	0.00	37.27	0.00	0.00
14	1.34	0.15	0.02	0.00	0.00	0.00	18.64	0.00	37.27	0.00	0.00
15	1.51	0.17	0.02	0.00	0.00	0.00	18.65	0.00	37.27	0.00	0.00
16	1.70	0.19	0.02	0.00	0.00	0.00	18.65	0.00	37.27	0.00	0.00
17	1.91	0.21	0.02	0.00	0.00	0.00	18.65	0.00	37.27	0.00	0.00
18	2.15	0.24	0.03	0.00	0.00	0.00	18.65	0.00	37.27	0.00	0.00
19	2.41	0.27	0.03	0.00	0.00	0.00	18.66	0.00	37.27	0.00	0.00
20	2.71	0.30	0.03	0.00	0.00	0.00	18.66	0.00	37.27	0.00	0.00
21	3.04	0.33	0.03	0.00	0.00	0.00	18.66	0.00	37.27	0.00	0.00
22	3.41	0.37	0.04	0.00	0.00	0.00	18.67	0.00	37.27	0.00	0.00
23	3.82	0.41	0.04	0.00	0.00	0.00	18.67	0.00	37.27	0.00	0.00
24	4.28	0.46	0.05	0.00	0.00	0.00	18.67	0.00	37.27	0.00	0.00
25	4.78	0.51	0.05	0.00	0.00	0.00	18.68	0.00	37.27	0.00	0.00
26	5.34	0.56	0.05	0.00	0.00	0.00	18.68	0.00	37.27	0.00	0.00
27	5.96	0.62	0.06	0.00	0.00	0.00	18.68	0.00	37.27	0.00	0.00
28	6.64	0.68	0.06	0.00	0.00	0.00	18.69	0.00	37.27	0.00	0.00

29	7.38	0.74	0.07	0.00	0.00	0.00	18.69	0.00	37.27	0.00	0.00
30	8.20	0.81	0.07	0.00	0.00	0.00	18.70	0.00	37.27	0.00	0.00
31	9.08	0.89	0.07	0.00	0.00	0.00	18.70	0.00	37.27	0.00	0.00
32	10.04	0.96	0.07	0.00	0.00	0.00	18.70	0.00	37.27	0.00	0.00
33	11.07	1.03	0.07	0.00	0.00	0.00	18.70	0.00	37.27	0.00	0.00
34	12.18	1.11	0.07	0.00	0.00	0.00	18.70	0.00	37.27	0.00	0.00
35	13.36	1.18	0.07	0.00	0.00	0.00	18.70	0.00	37.28	0.00	0.00
36	14.60	1.24	0.07	0.00	0.00	0.00	18.71	0.00	37.28	0.00	0.00
37	15.91	1.30	0.06	-0.01	0.00	0.01	18.72	0.00	37.28	0.00	0.00
38	17.26	1.35	0.05	-0.01	0.00	0.01	18.73	0.00	37.28	0.00	0.00
39	18.65	1.39	0.04	-0.01	0.00	0.01	18.74	0.00	37.29	0.00	0.00
40	20.06	1.41	0.02	-0.02	0.00	0.02	18.75	0.00	37.29	0.00	0.00
41	21.47	1.41	0.00	-0.02	0.00	0.02	18.77	0.00	37.29	0.00	0.00
42	22.87	1.39	-0.02	-0.02	0.00	0.02	18.79	0.00	37.29	0.00	0.00
43	24.22	1.35	-0.04	-0.02	0.00	0.02	18.82	0.00	37.30	0.00	0.00
44	25.50	1.28	-0.07	-0.03	0.00	0.03	18.85	0.00	37.30	0.00	0.00
45	26.69	1.18	-0.10	-0.03	0.00	0.03	18.87	0.00	37.30	0.00	0.00
46	27.74	1.06	-0.12	-0.03	0.00	0.03	18.90	0.00	37.30	0.00	0.00
47	28.65	0.91	-0.15	-0.03	0.00	0.03	18.93	0.00	37.30	0.00	0.00
48	29.39	0.73	-0.17	-0.02	0.00	0.02	18.95	0.00	37.30	0.00	0.00
49	29.93	0.54	-0.19	-0.02	0.00	0.02	18.97	0.00	37.31	0.00	0.00
50	30.26	0.33	-0.21	-0.02	0.00	0.02	18.99	0.00	37.31	0.00	0.00
51	30.37	0.11	-0.22	-0.01	-0.01	0.01	18.99	0.01	37.32	0.00	0.00
52	30.26	-0.11	-0.22	0.00	-0.01	0.00	19.00	0.01	37.32	0.00	0.00
53	29.93	-0.33	-0.22	0.00	-0.01	0.00	19.00	0.01	37.33	0.00	0.00
54	29.39	-0.54	-0.21	0.01	-0.01	0.01	19.01	0.01	37.34	0.00	0.00
55	28.65	-0.73	-0.19	0.02	-0.01	0.02	19.03	0.01	37.34	0.00	0.00
56	27.74	-0.91	-0.17	0.02	0.00	0.02	19.05	0.00	37.35	0.00	0.00
57	26.69	-1.06	-0.15	0.02	0.00	0.02	19.07	0.00	37.35	0.00	0.00
58	25.50	-1.18	-0.12	0.03	0.00	0.03	19.10	0.00	37.35	0.00	0.00
59	24.22	-1.28	-0.10	0.03	0.00	0.03	19.12	0.00	37.35	0.00	0.00
60	22.87	-1.35	-0.07	0.03	0.00	0.03	19.15	0.00	37.35	0.00	0.00
61	21.47	-1.39	-0.04	0.03	0.00	0.03	19.18	0.00	37.36	0.00	0.00
62	20.06	-1.41	-0.02	0.02	0.00	0.02	19.20	0.00	37.36	0.00	0.00
63	18.65	-1.41	0.00	0.02	0.00	0.02	19.22	0.00	37.36	0.00	0.00

64	17.26	-1.39	0.02	0.02	0.00	0.02	19.24	0.00	37.36	0.00	0.00
65	15.91	-1.35	0.04	0.02	0.00	0.02	19.26	0.00	37.37	0.00	0.00
66	14.60	-1.30	0.05	0.01	0.00	0.01	19.27	0.00	37.37	0.00	0.00
67	13.36	-1.24	0.06	0.01	0.00	0.01	19.28	0.00	37.37	0.00	0.00
68	12.18	-1.18	0.07	0.01	0.00	0.01	19.29	0.00	37.38	0.00	0.00
69	11.07	-1.11	0.07	0.00	0.00	0.00	19.29	0.00	37.38	0.00	0.00
70	10.04	-1.03	0.07	0.00	0.00	0.00	19.29	0.00	37.38	0.00	0.00
71	9.08	-0.96	0.07	0.00	0.00	0.00	19.29	0.00	37.38	0.00	0.00
72	8.20	-0.89	0.07	0.00	0.00	0.00	19.30	0.00	37.38	0.00	0.00
73	7.38	-0.81	0.07	0.00	0.00	0.00	19.30	0.00	37.38	0.00	0.00
74	6.64	-0.74	0.07	0.00	0.00	0.00	19.30	0.00	37.38	0.00	0.00
75	5.96	-0.68	0.07	0.00	0.00	0.00	19.30	0.00	37.39	0.00	0.00
76	5.34	-0.62	0.06	0.00	0.00	0.00	19.31	0.00	37.39	0.00	0.00
77	4.78	-0.56	0.06	0.00	0.00	0.00	19.31	0.00	37.39	0.00	0.00
78	4.28	-0.51	0.05	0.00	0.00	0.00	19.31	0.00	37.39	0.00	0.00
79	3.82	-0.46	0.05	0.00	0.00	0.00	19.32	0.00	37.39	0.00	0.00
80	3.41	-0.41	0.05	0.00	0.00	0.00	19.32	0.00	37.39	0.00	0.00
81	3.04	-0.37	0.04	0.00	0.00	0.00	19.33	0.00	37.39	0.00	0.00
82	2.71	-0.33	0.04	0.00	0.00	0.00	19.33	0.00	37.39	0.00	0.00
83	2.41	-0.30	0.03	0.00	0.00	0.00	19.33	0.00	37.39	0.00	0.00
84	2.15	-0.27	0.03	0.00	0.00	0.00	19.34	0.00	37.39	0.00	0.00
85	1.91	-0.24	0.03	0.00	0.00	0.00	19.34	0.00	37.39	0.00	0.00
86	1.70	-0.21	0.03	0.00	0.00	0.00	19.34	0.00	37.39	0.00	0.00
87	1.51	-0.19	0.02	0.00	0.00	0.00	19.35	0.00	37.39	0.00	0.00
88	1.34	-0.17	0.02	0.00	0.00	0.00	19.35	0.00	37.39	0.00	0.00
89	1.19	-0.15	0.02	0.00	0.00	0.00	19.35	0.00	37.39	0.00	0.00
90	1.06	-0.13	0.02	0.00	0.00	0.00	19.35	0.00	37.39	0.00	0.00
91	0.94	-0.12	0.01	0.00	0.00	0.00	19.35	0.00	37.39	0.00	0.00
92	0.83	-0.11	0.01	0.00	0.00	0.00	19.36	0.00	37.39	0.00	0.00
93	0.74	-0.09	0.01	0.00	0.00	0.00	19.36	0.00	37.39	0.00	0.00
94	0.66	-0.08	0.01	0.00	0.00	0.00	19.36	0.00	37.39	0.00	0.00
95	0.58	-0.07	0.01	0.00	0.00	0.00	19.36	0.00	37.39	0.00	0.00
96	0.52	-0.07	0.01	0.00	0.00	0.00	19.36	0.00	37.39	0.00	0.00
97	0.46	-0.06	0.01	0.00	0.00	0.00	19.36	0.00	37.39	0.00	0.00
98	0.41	-0.05	0.01	0.00	0.00	0.00	19.36	0.00	37.39	0.00	0.00

99	0.36	-0.05	0.01	0.00	0.00	0.00	19.36	0.00	37.39	0.00	0.00
100	0.32	-0.04	0.01	0.00	0.00	0.00	19.36	0.00	37.39	0.00	0.00

Table 2 - Straight Progress

Time	Progress	Progress Rate	Ramp Rate	Disruption	Efficiency	Absolute Periodic Disruption	Cumulative Disruption Index	Absolute Periodic Efficiency	Cumulative Efficiency Index	MSD Disruption	MSD Efficiency
0	0	0	0	0							
1	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	100	100
2	10.00	0.00	-10.00	-20.00	-30.00	20.00	30.00	30.00	40.00	400	900
3	10.00	0.00	0.00	10.00	30.00	10.00	40.00	30.00	70.00	100	900
4	10.00	0.00	0.00	0.00	-10.00	0.00	40.00	10.00	80.00	0	100
5	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0
6	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0
7	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0
8	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0
9	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0
10	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0
11	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0
12	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0
13	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0
14	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0
15	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0
16	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0
17	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0
18	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0
19	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0
20	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0
21	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0
22	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0
23	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0
24	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0

25	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0
26	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0
27	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0
28	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0
29	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0
30	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0
31	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0
32	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0
33	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0
34	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0
35	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0
36	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0
37	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0
38	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0
39	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0
40	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0
41	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0
42	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0
43	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0
44	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0
45	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0
46	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0
47	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0
48	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0
49	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0
50	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0
51	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0
52	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0
53	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0
54	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0
55	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0
56	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0
57	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0
58	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0
59	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0

60	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0
61	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0
62	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0
63	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0
64	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0
65	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0
66	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0
67	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0
68	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0
69	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0
70	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0
71	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0
72	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0
73	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0
74	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0
75	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0
76	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0
77	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0
78	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0
79	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0
80	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0
81	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0
82	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0
83	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0
84	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0
85	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0
86	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0
87	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0
88	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0
89	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0
90	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0
91	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0
92	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0
93	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0
94	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0

95	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0
96	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0
97	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0
98	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0
99	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0
100	10.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	80.00	0	0

Table 3 - Sculpted Progress

Time	Progress	Progress Rate	Ramp Rate	Disruption	Efficiency	Absolute Periodic Disruption	Cumulative Disruption Index	Absolute Periodic Efficiency	Cumulative Efficiency Index	MSD Disruption	MSD Efficiency
0	0	0	0	0							
1	10.00	10.00	10.00	10.00	10.00	10.00	10	10	10	100	100
2	50.00	40.00	30.00	20.00	10.00	20.00	30	10	20	400	100
3	70.00	20.00	-20.00	-50.00	-70.00	50.00	80	70	90	2500	4900
4	50.00	-20.00	-40.00	-20.00	30.00	20.00	100	30	120	400	900
5	40.00	-10.00	10.00	50.00	70.00	50.00	150	70	190	2500	4900
6	30.00	-10.00	0.00	-10.00	-60.00	10.00	160	60	250	100	3600
7	20.00	-10.00	0.00	0.00	10.00	0.00	160	10	260	0	100
8	10.00	-10.00	0.00	0.00	0.00	0.00	160	0	260	0	0
9	10.00	0.00	10.00	10.00	10.00	10.00	170	10	270	100	100
10	10.00	0.00	0.00	-10.00	-20.00	10.00	180	20	290	100	400
11	0.00	-10.00	-10.00	-10.00	0.00	10.00	190	0	290	100	0
12	0.00	0.00	10.00	20.00	30.00	20.00	210	30	320	400	900
13	0.00	0.00	0.00	-10.00	-30.00	10.00	220	30	350	100	900
14	0.00	0.00	0.00	0.00	10.00	0.00	220	10	360	0	100
15	0.00	0.00	0.00	0.00	0.00	0.00	220	0	360	0	0
16	0.00	0.00	0.00	0.00	0.00	0.00	220	0	360	0	0
17	10.00	10.00	10.00	10.00	10.00	10.00	230	10	370	100	100
18	50.00	40.00	30.00	20.00	10.00	20.00	250	10	380	400	100
19	70.00	20.00	-20.00	-50.00	-70.00	50.00	300	70	450	2500	4900
20	50.00	-20.00	-40.00	-20.00	30.00	20.00	320	30	480	400	900
21	40.00	-10.00	10.00	50.00	70.00	50.00	370	70	550	2500	4900

22	30.00	-10.00	0.00	-10.00	-60.00	10.00	380	60	610	100	3600
23	20.00	-10.00	0.00	0.00	10.00	0.00	380	10	620	0	100
24	10.00	-10.00	0.00	0.00	0.00	0.00	380	0	620	0	0
25	0.00	-10.00	0.00	0.00	0.00	0.00	380	0	620	0	0
26	0.00	0.00	10.00	10.00	10.00	10.00	390	10	630	100	100
27	0.00	0.00	0.00	-10.00	-20.00	10.00	400	20	650	100	400
28	10.00	10.00	10.00	10.00	20.00	10.00	410	20	670	100	400
29	10.00	0.00	-10.00	-20.00	-30.00	20.00	430	30	700	400	900
30	30.00	20.00	20.00	30.00	50.00	30.00	460	50	750	900	2500
31	30.00	0.00	-20.00	-40.00	-70.00	40.00	500	70	820	1600	4900
32	20.00	-10.00	-10.00	10.00	50.00	10.00	510	50	870	100	2500
33	10.00	-10.00	0.00	10.00	0.00	10.00	520	0	870	100	0
34	10.00	0.00	10.00	10.00	0.00	10.00	530	0	870	100	0
35	0.00	-10.00	-10.00	-20.00	-30.00	20.00	550	30	900	400	900
36	0.00	0.00	10.00	20.00	40.00	20.00	570	40	940	400	1600
37	0.00	0.00	0.00	-10.00	-30.00	10.00	580	30	970	100	900
38	0.00	0.00	0.00	0.00	10.00	0.00	580	10	980	0	100
39	0.00	0.00	0.00	0.00	0.00	0.00	580	0	980	0	0
40	0.00	0.00	0.00	0.00	0.00	0.00	580	0	980	0	0
41	0.00	0.00	0.00	0.00	0.00	0.00	580	0	980	0	0
42	0.00	0.00	0.00	0.00	0.00	0.00	580	0	980	0	0
43	0.00	0.00	0.00	0.00	0.00	0.00	580	0	980	0	0
44	0.00	0.00	0.00	0.00	0.00	0.00	580	0	980	0	0
45	0.00	0.00	0.00	0.00	0.00	0.00	580	0	980	0	0
46	0.00	0.00	0.00	0.00	0.00	0.00	580	0	980	0	0
47	10.00	10.00	10.00	10.00	10.00	10.00	590	10	990	100	100
48	10.00	0.00	-10.00	-20.00	-30.00	20.00	610	30	1020	400	900
49	10.00	0.00	0.00	10.00	30.00	10.00	620	30	1050	100	900
50	10.00	0.00	0.00	0.00	-10.00	0.00	620	10	1060	0	100
51	10.00	0.00	0.00	0.00	0.00	0.00	620	0	1060	0	0
52	10.00	0.00	0.00	0.00	0.00	0.00	620	0	1060	0	0
53	10.00	0.00	0.00	0.00	0.00	0.00	620	0	1060	0	0
54	10.00	0.00	0.00	0.00	0.00	0.00	620	0	1060	0	0
55	10.00	0.00	0.00	0.00	0.00	0.00	620	0	1060	0	0
56	10.00	0.00	0.00	0.00	0.00	0.00	620	0	1060	0	0

57	10.00	0.00	0.00	0.00	0.00	0.00	620	0	1060	0	0
58	10.00	0.00	0.00	0.00	0.00	0.00	620	0	1060	0	0
59	0.00	-10.00	-10.00	-10.00	-10.00	10.00	630	10	1070	100	100
60	0.00	0.00	10.00	20.00	30.00	20.00	650	30	1100	400	900
61	0.00	0.00	0.00	-10.00	-30.00	10.00	660	30	1130	100	900
62	0.00	0.00	0.00	0.00	10.00	0.00	660	10	1140	0	100
63	0.00	0.00	0.00	0.00	0.00	0.00	660	0	1140	0	0
64	0.00	0.00	0.00	0.00	0.00	0.00	660	0	1140	0	0
65	0.00	0.00	0.00	0.00	0.00	0.00	660	0	1140	0	0
66	0.00	0.00	0.00	0.00	0.00	0.00	660	0	1140	0	0
67	0.00	0.00	0.00	0.00	0.00	0.00	660	0	1140	0	0
68	0.00	0.00	0.00	0.00	0.00	0.00	660	0	1140	0	0
69	0.00	0.00	0.00	0.00	0.00	0.00	660	0	1140	0	0
70	0.00	0.00	0.00	0.00	0.00	0.00	660	0	1140	0	0
71	0.00	0.00	0.00	0.00	0.00	0.00	660	0	1140	0	0
72	0.00	0.00	0.00	0.00	0.00	0.00	660	0	1140	0	0
73	0.00	0.00	0.00	0.00	0.00	0.00	660	0	1140	0	0
74	0.00	0.00	0.00	0.00	0.00	0.00	660	0	1140	0	0
75	0.00	0.00	0.00	0.00	0.00	0.00	660	0	1140	0	0
76	0.00	0.00	0.00	0.00	0.00	0.00	660	0	1140	0	0
77	0.00	0.00	0.00	0.00	0.00	0.00	660	0	1140	0	0
78	0.00	0.00	0.00	0.00	0.00	0.00	660	0	1140	0	0
79	0.00	0.00	0.00	0.00	0.00	0.00	660	0	1140	0	0
80	0.00	0.00	0.00	0.00	0.00	0.00	660	0	1140	0	0
81	0.00	0.00	0.00	0.00	0.00	0.00	660	0	1140	0	0
82	10.00	10.00	10.00	10.00	10.00	10.00	670	10	1150	100	100
83	20.00	10.00	0.00	-10.00	-20.00	10.00	680	20	1170	100	400
84	30.00	10.00	0.00	0.00	10.00	0.00	680	10	1180	0	100
85	20.00	-10.00	-20.00	-20.00	-20.00	20.00	700	20	1200	400	400
86	10.00	-10.00	0.00	20.00	40.00	20.00	720	40	1240	400	1600
87	10.00	0.00	10.00	10.00	-10.00	10.00	730	10	1250	100	100
88	10.00	0.00	0.00	-10.00	-20.00	10.00	740	20	1270	100	400
89	10.00	0.00	0.00	0.00	10.00	0.00	740	10	1280	0	100
90	10.00	0.00	0.00	0.00	0.00	0.00	740	0	1280	0	0
91	10.00	0.00	0.00	0.00	0.00	0.00	740	0	1280	0	0

92	10.00	0.00	0.00	0.00	0.00	0.00	740	0	1280	0	0
93	10.00	0.00	0.00	0.00	0.00	0.00	740	0	1280	0	0
94	10.00	0.00	0.00	0.00	0.00	0.00	740	0	1280	0	0
95	5.00	-5.00	-5.00	-5.00	-5.00	5.00	745	5	1285	25	25
96	5.00	0.00	5.00	10.00	15.00	10.00	755	15	1300	100	225
97	0.00	-5.00	-5.00	-10.00	-20.00	10.00	765	20	1320	100	400
98	0.00	0.00	5.00	10.00	20.00	10.00	775	20	1340	100	400
99	0.00	0.00	0.00	-5.00	-15.00	5.00	780	15	1355	25	225
100	0.00	0.00	0.00	0.00	5.00	0.00	780	5	1360	0	25

About the Author

Bob Prieto

Author

Bob Prieto is a senior vice president of Fluor, one of the largest, publicly traded engineering and construction companies in the world. He is responsible for strategy for the firm's Industrial & Infrastructure group which focuses on the development and delivery of large, complex projects worldwide. The group encompasses three major business lines including Infrastructure, with an emphasis on Public Private Partnerships; Mining; and Manufacturing and Life Sciences. Bob consults with owner's of large engineering & construction capital construction programs across all market sectors in the development of programmatic delivery strategies encompassing planning, engineering, procurement, construction and financing. He is author of "Strategic Program Management" and "The Giga Factor: Program Management in the Engineering and Construction Industry" published by the Construction Management Association of America (CMAA) and "Topics in Strategic Program Management" as well as over 400 other papers and presentations.

Bob's industry involvement includes recent and ongoing roles on the National Infrastructure Advisory Council's Critical Infrastructure Resiliency Workgroup and the National Academy Committee "Toward Sustainable Critical Infrastructure Systems: Framing the Challenges". He is a member of the ASCE Industry Leaders Council, National Academy of Construction and a Fellow of the Construction Management Association of America. Bob served until 2006 as one of three U.S. presidential appointees to the Asia Pacific Economic Cooperation (APEC) Business Advisory Council (ABAC), working with U.S. and Asia-Pacific business leaders to shape the framework for trade and economic growth and had previously served as both as Chairman of the Engineering and Construction Governors of the World Economic Forum and co-chair of the infrastructure task force formed after September 11th by the New York City Chamber of Commerce.

Previously, as a senior industry executive, he established a 20-year record of building and sustaining global revenue and earnings growth. As Chairman at Parsons Brinckerhoff (PB), one of the world's leading engineering companies, Bob shaped business strategy and led its execution. Bob Prieto can be contacted at Bob.Prieto@fluor.com.