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The True Risk of Complex Projects: Teachings from Statistical Theory

In this paper we draw on the knowledge of risk theory to explain why the risk of Complex Projects is significantly different from the risk of Simple projects. The interdependency of contributors, which is the mark of complexity, leads to mathematical properties of the resulting risk which is often overlooked by decision makers: higher probability of large failures, and a high influence of correlation.

Teachings from statistical theory: probability of the outcome of simple versus complex systems

In statistical theory, the two extremes of systems simplicity and complexity lead to significantly different statistical distributions. Complexity is related to the interdependency between the different elements of the system under consideration. The more a system is complex, the more interdependent are all the different elements.

For simple systems where all the different elements are fully independent, the limit value theorem states that the overall statistical distribution of their sum tends to be a *normal distribution* (also called Gaussian or "bell curve"). An interesting property here is that even if some elements show a non-symmetrical (skewed) probabilistic distribution, the resulting sum tends to be much more symmetrical.

In complex systems, the probability to have a significant event far away from the average is much greater

Complex systems tend to behave very differently and the resulting risk is generally a *power law curve* (also called Pareto curve). It is a distribution where typically, events that are 10 times less frequent are 10^n times more severe, where n is a parameter. For example, for earthquakes magnitude, n≈3. It works the same for popularity: the category of elements that are 10 times less frequent are 10^n times more in number or size: for the distribution of family names, n≈1,9; for the hits on webpages, n≈2.4, for the population of US cities, n≈2.3 [1]. It is a phenomenon that can be observed in a large variety of man-made or natural situations. The famous 'long tail' (Zipf law) which represents the distribution of popularity of any product, the probability/impact of earthquakes or the famous 80/20 rule of prioritization, are all based on this power law distribution for complex systems. The power law distribution tends to represent a lot of real-life situations, as long as they correspond to a complex system with a lot of interaction.

The actual risk of project management for complex projects has been constantly undervalued in traditional quantitative methods

Actually, without knowing much about the system other than it is a complex system with a lot of interdependent elements, we know the outcome probability distribution is a power law curve. This powerful insight will be used in this paper.

What are the main differences in the resulting probability distribution?

The main difference in the resulting distribution is that the tail of the power law distribution is much wider than the tail of the normal distribution. In other words, in complex systems, the probability to have a significant event far away from the average is much greater. On the contrary, the normal distribution leads to very, very low probabilities quickly when one moves away from the average by a few standard deviations. Not so with the power law distribution!.

For example, the probability of an event distant from the median (P50) value more than 3 times the standard deviation is less than 0.1% for a normal distribution – and still about 2% for a power law (exponent 2.5).

This observation has a lot of consequences, and fits much better real life observations. Unfortunately, because normal distributions are much easier to handle mathematically, and are more intuitive, they are used in a number of instances where they do not represent reality. This has resulted in a lot of criticism with regard to the traditional equations derived from power law assumptions supporting various financial products, for example, or representing the fluctuations of markets ([2], [3]). It is even more the case in the field of project management, where the few quantitative risk approaches have all been based on assumptions of independence of the different factors at play in a project.

Hence, the actual risk of project management has been constantly undervalued in traditional quantitative methods, which is confirmed by actual observations: while Monte-Carlo based quantitative methods for project risk give a variability of the project cost in the range of ±5% or maybe at most ±10%, we can observe at the same time a significant number of complex projects with variances far above these numbers, reaching sometimes 2 or 3 times the estimated cost with a measurable probability (as they do visibly happen in all industries, and every few years in project companies).

How different distributions affect the risk of the aggregate of several projects

We have now established that mathematically, the outcome of complex projects need to be represented by a power law distribution, with a much higher probability of significant deviation from the mean values. Let's suppose that the outcome of a project we consider is its cost.

Let's consider a number of similar projects. If we consider that their outcome is fully independent (which is not the case in actual project organizations, more on that in the next paragraph, but we'll use this simplification here as a first approach), there will be sometimes outcomes better than average, and sometimes outcomes worse than average.

For simple projects which have a normal distribution, good and not so good outcomes cancel out nicely, and the final distribution ends up to be narrower in relative terms: the addition of several projects is a good way to average out outcomes and diminish the overall risk to the organization. The probability of loss making for the aggregation of projects becomes very small. This is the usual justification of project-based organization – the aggregation of many projects makes a relatively predictable overall performance.

The reality of complex projects is that really disastrous projects occur far more often than predicted by common knowledge. The consequences of this mathematically demonstrated situation are far reaching.

The traditional economic protection offered by aggregation of project risk at the organization level does not really work when it comes to complex projects.

For complex projects that follow the power law distribution, it is not so much the case, because not so good outcomes are generally much worse than good outcomes; the addition of all these projects produce a distribution that is skewed toward worse outcomes. The probability of the aggregation of these projects to be loss making is still very high, in the same order of magnitude than for a single project, because it is driven by this relatively rare occurrence of a project that is really very bad.

As an illustration, some research simulations have been done by PVD with representative distributions for project outcomes, with projects considered to be independent. For normal distributions, even if the probability for one project to be loss making is 15% (after utilization of contingencies etc), the probability of the sum of 6 of these projects to be loss making was only 0.5%. For power law distributions, if the probability for one project to be loss making is 15%, the probability of the sum of 6 of these projects to be loss making was still 12%!! (and while the probability that one single project's loss exceeded the project average revenue by more than 25% was 5%, the probability that the aggregate exceeded the total revenue by more than 25% was still 1.5%!). This is because there is a high probability that one of these projects will be very significantly loss-making, erasing all the gains from the other projects.

The reality is much worse: correlation

In reality, the situation is even worse, because in a particular organization or industry, the different projects are somewhat correlated. They are correlated through the use of common processes, policies, people or equipment; because they happen in similar locations, etc. The amount of correlation varies; we will discuss here the general effect of correlation.

Even with weak correlation coefficients, the effect of correlation is to increase the spread of the aggregate of the projects, and thus, increase the overall risk to the organization or branch. This effect remains limited in the case of normal distributions, but can become quite dramatic in the case of power law distributions: correlation increases the probability of freak events appearing simultaneously on several projects, and that has a significant impact on the overall risk level of the aggregate.

Summary

The reality of complex projects is that really disastrous projects occur far more often than predicted by common knowledge. It can be represented statistically by a power law. The consequences of this mathematically demonstrated situation are far reaching: it shows that the traditional economic protection offered by aggregation of project risk at the organization level does not really work when it comes to complex projects. A series of papers will evaluate the consequences for the organizations and for risk management policies.

References:

[1] Power laws, Pareto distributions and Zipf's law, paper retrieved at http://www-personal.umich.edu/~mejn/courses/2006/cmplxsys899/powerlaws.pdf

[2] The Failure of Risk Management: Why it is broken and how to fix it, Douglas Hubbard, 2009

[3] The Misbehaviour of Markets: a Fractal View of Financial Turbulence, Benoit Mandelbrot, Richard Hudson