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Is something missing from Project Risk Management? – Correlation matters.

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Abstract. In this paper, we show that correlations between the durations of project activities can change the project's total variance and some risk sensitivity indexes such as the Cruciality (CrI) and SSI (schedule sensitivity index). These results are relevant in project risk management as correlations may change risk response strategies, and monitoring efforts should focus on other activities. We performed Monte Carlo simulations using different network topologies with different characteristics.

Keywords: Project Risk Management, Sensitivity Index, Cruciality, Risk Strategy, MCSimulRisk

1 Introduction

The Scheduled Risk Analysis (SRA) [1] is a methodology widely used in project risk management. Essentially, the objective is to find those activities whose duration variability contributes the most to the total project duration risk. Project managers should then focus their monitoring efforts on these activities, taking corrective actions when necessary.

To this aim, scholars have proposed several sensitivity measures, the most used by researchers [2]: Criticality (CI, the probability of the activity to fall on the critical path), Significance Index (SI, it measures the significance of individual activities on the project duration), Cruciality (CrI, the correlation between the duration of an activity and the total project activity; measures the relative importance of the activity) and Schedule Sensitivity Index (SSI, multiplies the criticality by the quotient between the standard deviations of the activity and the project, thus obtaining a probability-impact measure).

In practice, project managers should focus on the activities with higher sensitivity and establish some "*threshold*" numbers to take corrective actions. In a simulation study with 4100 fictitious project networks, Vanhoucke [3] shows that Criticality (CrI) and the Schedule Sensitivity Index (SSI) perform better than the others in terms of the success of corrective actions during project tracking.

The methodology seems easy to implement, and many risk analysis software programs include a Monte Carlo simulation that helps compute the sensitivity indexes.

But is something missing? SRA literature has not considered the influence of interactions between activities (e.g., correlations) on the values of sensitivity variables.

In this paper, we show that if there is a correlation between the duration of some of the project's activities, the sensitivity indexes of activities change widely. Therefore, the activities project managers should focus on for monitoring can be completely different from project variables without correlations.

In particular, our research shows that correlations change activity cruciality, SSI, total project variance, and, under some circumstances, criticality. Having verified this phenomenon with different project networks, we wondered what factors might influence the magnitude of such changes. To this end, we simulated scenarios with varying network topologies and correlations between different activities.

The arguments of this paper can modify the practice of risk analysis in projects. Project managers should consider the effect of correlations among the duration of activities in both the planning and executing phases, as risk monitoring strategies may change. Furthermore, the impact of correlations can be used proactively, trying to eliminate possible correlations or even force them according to the project objectives.

The rest of the paper is structured as follows: Section 2 explains why the duration of project activities may be correlated. Section 3 shows the simulation results for different project network topologies to see how the network influences sensitivity indexes. We finish with the most relevant conclusions, limitations, and ongoing research.

2 Correlations in actual projects and SRA.

The literature has not sufficiently considered the existence of a correlation between project activity durations. Most scheduling methods, such as CPM, PERT, risk management, and simulation methods, consider the probability of distributions between activity durations independent.

However, in many projects, project durations might not be independent; therefore, their durations can be correlated. Among other reasons [4]:

- There are external risks affecting several activities in a project, like seasonal risks and meteorological conditions [5], etc.
- Learning Effect. Experience and knowledge gained in one activity can make teams more efficient in other activities requiring similar skills [6]
- Project changes requested by the customer or other stakeholders can affect several project activities.
- Negative correlations. For example, the more time spent on design work, the less time is needed in the manufacturing phase.
- Etc.

Some researchers, like [7] suggested that the interrelationship between activities should not be underestimated, especially in large projects. However, they highlighted the difficulty of incorporating them into the models using the available software packages. This is not the case today.

The few papers that have addressed the correlation between activities, such as [8] or [9], found that such correlations do not affect the project's expected duration. Probably for this reason, there has not been a proliferation of papers relating correlations and SRA. Our study also shows that correlations do not affect the total project duration. However, this is not the case for total project variance or sensitivity indexes such as cruciality or SSI, thus affecting the strategies to be deployed to manage risk.

3 Simulations and results.

We used the educational simulation software MCSimulRisk to carry out the experiments [10]. This tool allows the project's Monte Carlo simulation and provides numerical and graphical data for the total project duration and the different sensitivity indicators we use. We have run 25,000 iterations in each simulation.

We have also used the RANGEN project network generator [11], which provides artificial project networks with different network topology characteristics defined by network parameters. We will focus on the serial/parallel indicator (SP takes the extreme values of 0 when all activities are in parallel, and 1 when all the activities are in series) and total flow indicator that measures network density and the possibility of shifting activity within its structure (TF=0 for a 100% dense network) [12].

All the networks have 8 activities, whose duration has been modeled using triangular distribution functions. The most probable value (MP) is kept as the one provided by the RANGEN application, with min=0.85*MP and max=1.3*MP. Additionally, we have simulated projects changing the MP values provided by RANGEN so that we can enrich the experiments by exploring paths with similar duration. In this way, we can compare project configurations with a "dominant critical path" and projects with paths of similar durations.

Table 1 shows the main results for a set of project networks (named id. A, B, C, etc.) with different SP and TF values (second and third columns). Furthermore, for the same network structure, we change the average durations of the activities to force (and thus analyze) situations in which there is a dominant critical path or several paths with similar durations (A, A1, etc.). We have tested correlations between different activities, both in the same and different paths, and show the values of CI, CrI, and SSI for the activities whose results are the most significant. For simplicity of explanation, we will focus on projects A, A1, H and H1); we have observed similar results in the other cases.

For instance, in project Id. A with a dominant critical path and low SP (0.14 means "near parallel network"), if there is no correlation between activities, the expected project duration is 17.25, and the variance is 1.008. But if there is a correlation between A1 and A4 of 0.8, the value of project variance increases 46.13%, and the cruciality of A1 almost doubles the value without correlation (82 vs. 42). Similar results are obtained with negative correlations but of opposite sign.

Furthermore, the change in variance and CrI is higher when the correlated activities are within the same path than when they are in different paths (Corr type 1 versus 2.).

Table 1. Numerical values corresponding to Project Id A. Correlation type: 0 - No correlation; 1 - Correlation between activities on the same dominant critical path; 2 - Correlation between activities on different pathways.

Id	S/P	TF	Corr. Type	Act. corr	Mean	Variance	CI	CrI	SSI
A	0.14	0.33	0	ρ (Ai;Aj) = 0	17,230	1,008	A1- 50,04	A1- 41,74	A1- 50,04
Dominant critical path							A2 - 50,02	A2 - 50,02	A2 - 50,02
			1	ρ (A1;A4) = 0,8	17,238	1,473	A1- 49,41	A1- 82,56	A1- 30,45
					+0.05%	+46.13%	A2 - 50,62	A2 - 32,72	A2 - 31,30
			1	ρ (A1;A4) = -0,8	17,224	0,542	A1- 50,45	A1- 23,82	A1- 51,32
					-0.03%	-46.23%	A2 - 49,60	A2 - 56,80	A2 - 50,75
			2	ρ (A1;A8) = 0,8	17,226	0,987	A1- 50,00	A1- 41,80	A1- 37,65
					-0.02%	-2.08%	A2 - 50,10	A2 - 42,13	A2 - 37,76
			2	ρ (A1;A8) = -0,8	17,220	0,996	A1- 50,40	A1- 40,46	A1- 37,68
					-0.06%	-1.19%	A2 - 49,68	A2 - 41,52	A2 - 37,10
A1	0.14	0.33	0	ρ (Ai;Aj) = 0	18,767	0,818	A1- 36,84	A1- 45,58	A1- 41,70
Paths of similar durations							A2 - 35,46	A2 - 40,64	A2 - 36,46
			1	ρ (A1;A4) = 0,8	18,872	1,085	A1- 38,04	A1- 60,90	A1- 37,51
					+0.56%	+32.64%	A2 - 34,47	A2 - 33,65	A2 - 30,83
			1	ρ (A1;A4) = -0,8	18,663	0,637	A1- 33,86	A1- 28,43	A1- 43,73
					-0.55%	-22.13%	A2 - 37,75	A2 - 50,37	A2 - 44,42
			2	ρ (A1;A8) = 0,8	18,755	0,866	A1- 37,80	A1- 46,74	A1- 41,84
					-0.06%	+5.87%	A2 - 37,34	A2 - 42,02	A2 - 37,66
			2	ρ (A1;A8) = -0,8	18,789	0,778	A1- 37,28	A1- 42,66	A1- 43,50
					+0.12%	-4.89%	A2 - 34,10	A2 - 40,74	A2 - 36,26
B	0.14	0.67		Dominant critical path			...	...	...
C	0.29	0.3		Dominant critical path			...	...	...
C1	0.29	0.3		Paths of similar durations			...	...	...
D	0.29	0.7		Dominant critical path			...	...	...
E	0.57	0.25		Dominant critical path			...	...	...
E1	0.57	0.25		Paths of similar durations			...	...	...
F	0.57	0.75		Dominant critical path			...	...	...
F1	0.57	0.75		Paths of similar durations			...	...	...
G	0.71	0.4		Dominant critical path					
H	0.71	0.8	0	ρ (Ai;Aj) = 0	34,655	1,991	A1- 100	A1- 53,26	A1- 52,81
Dominant critical path							A4 - 100	A4 - 33,55	A4 - 66,25
			1	ρ (A1;A2) = 0,8	34,668	2,569	A1- 100	A1- 70,34	A1- 46,57
					+0.04%	+29.03%	A4 - 100	A4 - 59,36	A4 - 58,64
			1	ρ (A1;A2) = -0,8	34,65	1,438	A1- 100	A1- 31,36	A1- 62,37
					-0.01%	-27.77%	A4 - 100	A4 - 77,98	A4 - 77,95
			2	ρ (A4;A8) = 0,8	34,644	1,993	A1- 100	A1- 52,59	A1- 52,42
					-0.03%	+0.10%	A4 - 100	A4 - 66,51	A4 - 66,44
			2	ρ (A4;A8) = -0,8	34,654	1,983	A1- 100	A1- 53,35	A1- 53,00
					-0.00%	-0.40%	A4 - 100	A4 - 66,49	A4 - 66,55
H1	0.71	0.8	0	ρ (Ai;Aj) = 0	35,435	2,548	A1- 77,636	A1- 36,77	A1- 36,42
Paths of similar durations							A4 - 61,20	A4 - 37,91	A4 - 36,04
			1	ρ (A1;A2) = 0,8	35,458	2,882	A1- 75,89	A1- 49,12	A1- 33,43
					+0.06%	+13.11%	A4 - 60,36	A4 - 34,87	A4 - 33,30
			1	ρ (A1;A2) = -0,8	35,431	2,273	A1- 79,02	A1- 25,95	A1- 39,41
					-0.01%	-10.79%	A4 - 60,68	A4 - 38,46	A4 - 37,47
			2	ρ (A4;A8) = 0,8	35,163	2,927	A1- 78,09	A1- 35,41	A1- 34,17
					-0.77%	+14.87%	A4 - 63,89	A4 - 75,80	A4 - 35,10
			2	ρ (A4;A8) = -0,8	35,677	2,068	A1- 76,88	A1- 42,34	A1- 40,17
					+0.68%	-18.84%	A4 - 58,57	A4 - 11,82	A4 - 38,20

The same patterns are also obtained in simulations A1 (same network SP but paths with similar durations). SSI values are also affected by correlations reaching lower values when there are correlations.

Simulations H and H1 refer to a project network structure closer to “serial”. We also observe increments in project total variance and activity correlations, although the changes' magnitude seems smaller than in the more “parallel” network.

Finally. correlations change not only the Variance, SSI, and Crl values but also the shape of the total project duration probability function (see an example at Figure 1.)

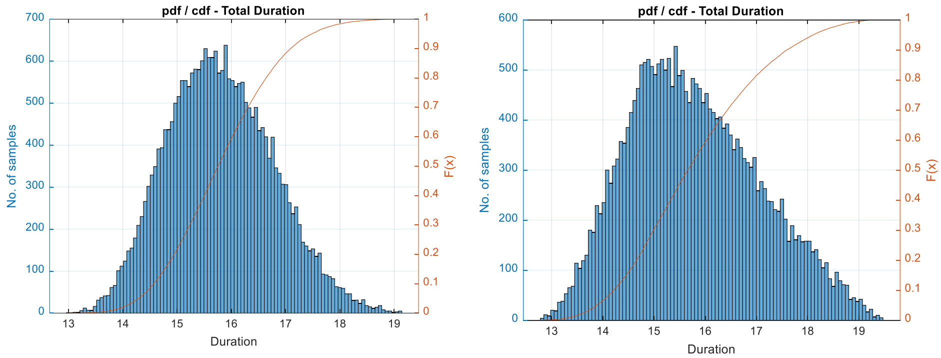

Fig. 1. Distribution function of the total project duration. Case study Id=B. a) No correlation b) Positive correlation ρ (A1;A2) = 0.8

4 Conclusions.

We show that correlations between activity durations can change the value of project total variance and risk sensitivity indexes. Therefore, this research has practical implications for project risk management procedures: As mainstream Schedule Risk Analysis methodologies are based on these indexes, correlations can shift risk monitoring strategies. Project managers should be aware of possible correlations between activities and focus project monitoring on the new activities. Proactive management can also be performed to take advantage of or reduce correlations.

The most affected items were the activities' cruciality and total project variance. In particular, positive (negative) correlations between the durations of 2 activities increase (decrease) the cruciality of the activities involved. The increment is even higher if the activities belong to the same critical path, especially if the critical path is dominant.

The activity values of SSI might change with correlations, but it usually affects all the project activities without changing activity priority for monitoring purposes.

Finally, we confirm previous research ([8], [9]) to observe that correlations do not change the project's expected duration.

Current research has relevant limitations; fortunately. To support our arguments, we have simulated many project networks. A more structured analysis is needed to formalize our arguments. Still, we are also aware of the "explosion" of possible combinations of network topologies, combinations of correlations (including more than 2 activities), etc. Currently, we are designing new simulation "*ceteris paribus*" frameworks to understand the elements affecting sensibility indexes under project activities correlations. Additionally, we are testing the results with actual projects performed in different sectors.

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