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MONTE CARLO SIMULATION RELATED TO RISK COSTS

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Abstract

If there are uncertainties in a project, let it be in quality, durations, or costs, you have to estimate probability distributions. By this, the entire planning process becomes more complex, but on the other hand, offers even more insights into the risk structure of the project. Whereas most often Monte Carlo simulation in risk management in projects is mainly related to risks in the durations of the individual tasks and therefore finally, of course, related to the duration of the entire project (c.f. Tysiak, (2014a)), this contribution is focused on risks in the costs of the tasks. By way of an example possible applications, the flexibility, and the productivity of such an approach are shown. Additionally, it becomes obvious that this Monte Carlo approach only needs little efforts, because it can easily be implemented by means of Excel.

Key words: *project management, risk management, Monte Carlo simulation, Excel*

JEL codes: G32, C53, O22

Introduction and Background

Everybody, who is familiar with project management, knows that risk management is an integral component in this subject that usually contains the following cyclic phases (c.f. PMI (2017), Kerzner (2017), Schelle et al. (2006)): (1) risk management planning, (2) risk identification, (3) qualitative risk analysis, (4) quantitative risk analysis, (5) risk response planning, (6) risk monitoring and control. Especially in the steps (3) and (4), the knowledge of some analytical/statistical methods might be useful, because you have to deal with uncertainties and insecurities and therefore with densities and distributions. These uncertainties usually have to be used in two aspects, because a risk is commonly characterized by the probability of occurrence and - if it occurs - by a distribution of the possible impacts. These impacts can be measured in various dimensions, such as time (duration), costs, quality, etc.

In Tysiak (2014a) we introduced the example shown in fig. 1. As it is standard in PERT (c.f. Taylor (2010)), we assumed beta distributions for the durations of the individual tasks (the abbreviations OD, MD, and PD stand for the parameters optimistic duration, most probable duration, and pessimistic duration of the individual distribution). In Tysiak (2014b) and later in Tysiak (2017) we performed Monte Carlo simulations to generate the resulting final distribution of the entire project. We could also identify the critical field (given in fig. 2), generated the distributions of the individual buffers, performed sensitivity analyses, studied the changes in all these densities throughout the lifetime of the project, examined correlations - and we performed a lot of similar other things. But in all these analyses the focus has been mainly on risks in time. This might be because of the historical development in the deterministic approach in project management: One of the dominant tools in the beginning was the critical path analysis, then followed by PERT (program evaluation and review technique), the first attempt to introduce uncertainties – all these techniques were time related.

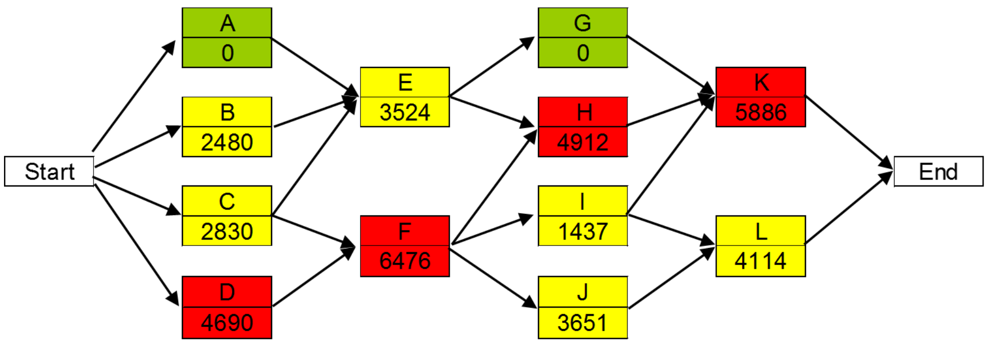
In this current contribution, we want to shift the focus from risks exclusively in time and introduce additional risks in costs. The word “additionally” is used here, to make sure that this should not be seen as an alternative way of integrating risks into a project, but more as a complementary approach.

Each project usually contains several risk dimensions at the same time and above that, they are strongly dependent/correlated to each other: If a risk occurs, it might lead to additional work that will prolong the duration of this task as well as increase its expenditure. Sometimes there will be a clear cause and effect relationships, whereas sometimes there are only experiences that can be measured by correlations. However, in the end, we will see, that these two dimensions have a couple of fruitful mutual coherences.

Activity	Predecessors	OD	MD	PD
A	-	2	3	4
B	-	3	6	9
C	-	2	5	10
D	-	4	6	9
E	A, B, C	3	7	10
F	C, D	2	7	9
G	E	2	3	4
H	E, F	3	6	8
I	F	3	5	9
J	F	2	7	10
K	G, H, I	2	6	8
L	I, J	3	5	8

source: Tysiak (2014a)

Fig. 1. **The main example**



source: Tysiak (2014a)

Fig. 2. **The critical field (number of times that a node is critical)**

Risks in Costs

Let us assume that the project team analysed the costs of the individual tasks of our given project and they agreed on the data given in fig. 3. Therefore, together with the data from fig. 1, the table in fig. 3 can be seen as part of the risk register.

In this table, the terms "triangle" and "beta" denote the triangular and the beta distributions with the three parameters optimistic duration, most probable duration, and pessimistic duration, whereas the term "normal" refers to the normal distribution with the two parameters mean and standard deviation.

task	risk-free costs	probability to occur	distribution of impact	addional condition/remark
A	1000		A1: normal(0,300)	there is a correlation of +0.3 between A1 and D1
B	2000	0.1	B1: normal(300,50)	
C	800	0.2	C1: triangle(100,200,500)	
D	1500		D1: normal(0,100)	there is a correlation of +0.3 between A1 and D1
		0.1	E1: beta(1500,1800,2300)	
E	700	0.2	E2: triangle(300,500,1000)	
		0.3	E3: normal(500, 50)	if C1 occured, the parameters in E3 change to (200,20)
F	800			
G	1200			
H	1500	0.05/0.2	H1: triangle(600,800,1400)	if the impact of E1 is higher than 2000, then the probability of occurance is 0.05, otherwise 0.2
I	1000		I1: normal(0,100)	there is a correlation of -0.3 between I1 and L1
J	1500	0.2	J1: normal(-500,100)	this is a chance!!
K	2000	depends on time	K1: normal(1000,300)	risk occurs if the start of task K is later than 20
L	1000		L1: normal(0, 150)	there is a correlation of -0.3 between I1 and L1

source: author's own construction

Fig. 3. **The cost situation**

Let us try to categorize the information presented in fig. 3 in different groups:

1. Risk-free tasks

There are tasks that are assumed to be totally risk-free (like F and G). The only evaluations we get in the corresponding lines of the table are the risk-free (fixed) costs in the second column. This might be the case if tasks are totally outsourced and therefore all the possible risks that may occur in relation to these tasks are transferred to a third party via contracts.

2. Tasks with remaining fuzzy uncertainties

Some other tasks (like A, D, I, and L) have supplementary to the risk-free costs some uncertainties in the task costs. These uncertainties mean that there are still some fuzzy variations possible because we only have estimates. Additionally, there might be estimated correlations between these uncertainties.

3. Risks that may appear with an assumed probability of occurrence

As we already mentioned, risks in general have the two dimensions that they may occur or may not occur with some (estimated) probability and on the other hand that they will have an uncertain impact, if they occur (like B, C, E1, and E2). Even in this case, correlations between the densities of the impacts are possible.

4. Conditional risks

Quite often we are able to find conditions that may influence the probability that a risk occurs or affect the distribution of the impacts (like E3, H, and K). These risk drivers may have external origin or may be internal events that might occur during the execution of the project. Particularly we find here a lot of relationships to the time performance of the project (like in K).

5. Chances

Everybody should keep in mind that in risk management according to the different definitions of "risk" (c.f. PMI (2017)), we might also have risks with a positive impact (like J). In our daily life, we tend to call these kind of risks "chances", but in risk management, we subsume them under risks.

To get an impression, to what the assumptions collected in fig. 3 lead to, we performed a Monte Carlo simulation (c.f. Garlick (2007), Rubinstein/Kroese (2016)). As a simulation tool, we used Excel, because it offers a lot of advantages. In Excel, it is not only easy to model all the conditions given in fig. 3, but it is also very simple to generate random numbers that follow a predefined distribution, let it be normal, beta, or triangular etc. (c.f. Tysiak/Sereseanu (2010), Tysiak (2018)). The entire simulation can be generated by only using cell formulas, there is no need for any visual basic programming.

The resulting density of the total costs of the project is given in fig. 4. The mean is μ = 15,690 with a standard deviation of σ = 995. But in risk management other parameters are more important, e.g. the quantiles. The 95% quantile is the value that is exceeded with a probability of only 5%, and respectively the 99% quantile is the value that divides the lower 99% percent range from the upper 1% area. In our example, we get a value of 17,530 for the 95% quantile, which means that with a probability of 95% the total costs will be less than this value. The 99% quantile is 18,460.

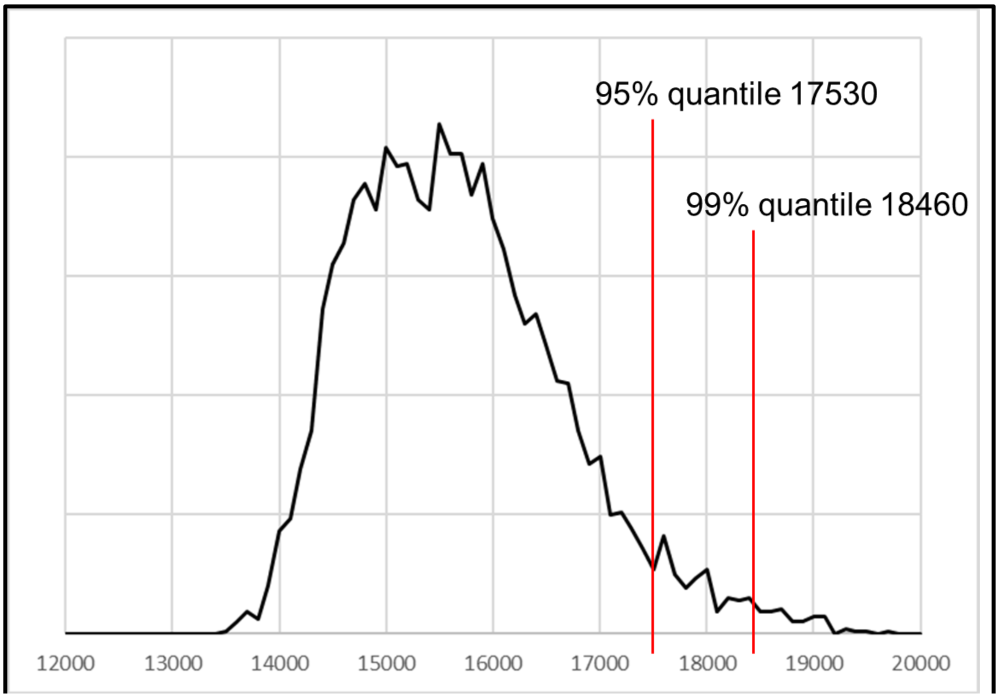


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Fig. 4. **The distribution of costs of the entire project**

Development of Costs During the Lifetime of the Project

Fig. 4 shows the distribution of the total costs as a simulation with the initial assumptions/estimates given in fig. 3. But all the individual risks are associated with tasks. Therefore, we can also interpret the costs as time related. If a project team has already created such a Monte Carlo simulation model right at the beginning of the project, it can be used throughout the whole lifetime of the project as a controlling tool. The only thing that has to be done, is to update the values, especially, of course, the realizations of risks that have occurred or that are no longer existent. A possible development over time is shown in fig. 5. We assumed that every 5 periods the model is updated and the remaining lifetime of the project is simulated. As it can be seen, the standard deviation decreases from almost 995 in the beginning to 310 short before the end of the project.

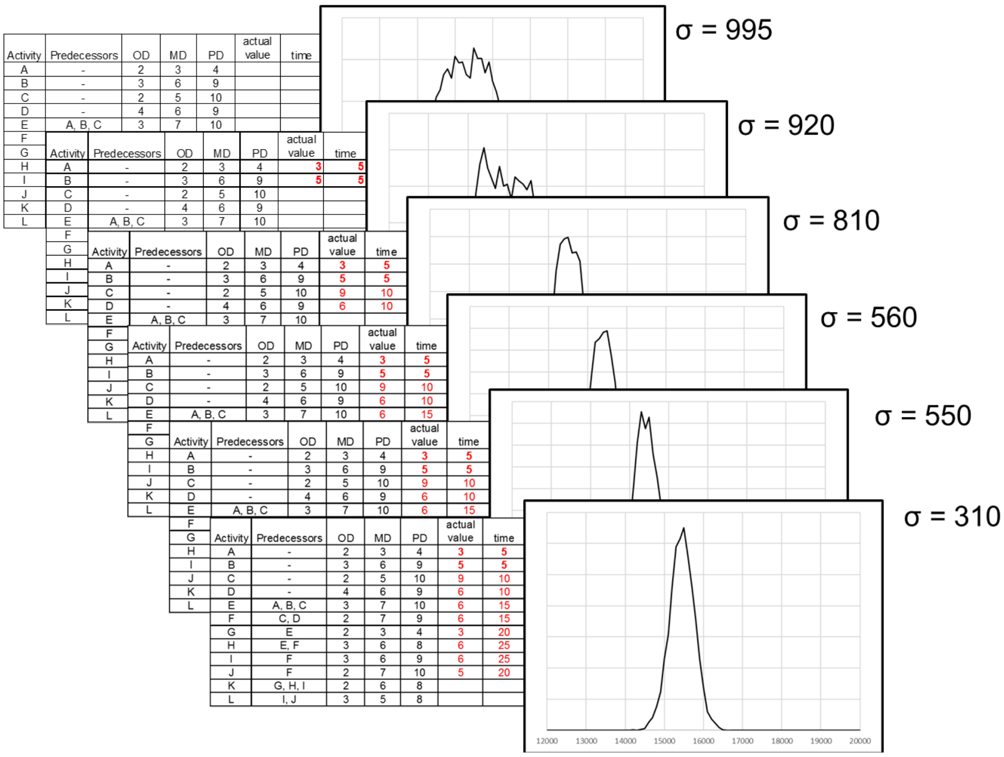

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Fig. 5. **The distribution of costs during the lifetime of the project**

Conclusions

As already seen in a lot of examples, it is quite easy to create Monte Carlo simulation models in risk management in projects. Most of these models focus on risks in time, more or less because of the historical background (like critical path method, PERT, etc.). In this contribution, we showed that it is also quite sensible to use these kinds of models to simulate risks in costs.

Creating the density of the total costs of the project within a sophisticated risk management process offers a better understanding of the whole project. The use of an appropriate tool – and we recommend Excel – implies quite low efforts and therefore the productivity of this approach is very high. All the programming/modelling can be performed by using pure Excel, without any macros or visual basic programs.

Risks might appear in different levels (fuzzy, conditional or unconditional, split into the probability of occurrence and the uncertainty of the impact, etc.). The application of Excel offers the flexibility to implement most of the realistic conditions that you can imagine in projects, let it be internal relationships between the risks within the project or let it be dependent on external risk drivers.

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