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MONTE CARLO SIMULATION AND AGILE METHODS IN PROJECT RISK MANAGEMENT

Prof. Dr. Tysiak Wolfgang, University of Applied Sciences, Dortmund, Germany

Abstract

There are various methodologies in project management that are collectively known as 'agile' (like 'scrum' or DSDM), as they promote the values of the 'agile manifesto' and they are consistent with the principles mentioned there. One main idea is that new challenges require an adaptive, not anticipatory, project management. But if you follow this guideline consequently to the final end, risk management seems to be no longer needed in an adaptive and iterative process. In other words: You ignore risks until they manifest into issues!

We want to show in this contribution that it still makes sense to perform risk management even in connection with agile approaches. And especially Monte Carlo simulation should be mentioned here as an appropriate tool to use.

Key words: *project management, risk management, agile methods, scrum, Monte Carlo simulation*
JEL codes: G32, C53, O22

Introduction and Background

Although we can suppose that even the construction of the pyramids in Egypt must have had some kind of project management, modern project management came into being in the middle of the last century. Project management societies were founded (USA/Project Management Institute (PMI) in 1969, UK/Association for Project Management (APM) in 1972, Germany/Deutsche Gesellschaft für Projektmanagement (GPM) in 1979) in different countries and during the second half of the 20th century we could perceive a huge development in methods, tools, approaches, and models. The number of textbooks increased dramatically, some organizations established their own standards (like PMBOK, Prince2 etc.), and the topic 'project management' was omnipresent. On the other hand in some sense it evoked an impression that it became overloaded, inflated, inflexible, and too complex.

Since the focus of this paper is risk management in projects, let us look especially into that a little in detail:

- In the **late 50's** PERT was introduced into project management (c.f. Kerzner (2009), Taylor (2010)), developed by the United States Navy together with the OR department of Booz, Allen, and Hamilton. The purpose of this development has been to support the deployment of the Polaris-Submarine weapon system (c.f. Fazar (1959)). PERT on the other hand is based on the Critical Path Method (CPM) that was invented by DuPont (c.f. Kelley/Walker (1959)). CPM assumes deterministic durations of the different activities, but in PERT we choose beta distributions for the durations, usually estimated by so-called three-point estimates (optimistic, most probable, and pessimistic durations). In that way, PERT was the very first – but tiny – step into the right direction. Later on, this PERT approach was varied to GERT (graphical evaluation and review technique) and SCERT (synergistic contingency evaluation and review technique).

- In the **early 90's** there was a shift in the perception of risk: Risk was no longer seen as something that only leads to negative effects, but synonymous to "uncertainty". Therefore, risks can be seen bad or good: a threat or an opportunity.

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- In the **first decade** of the third millennium there was an increasing interest in risk management in projects. For example, the number of members of the RiskSIG (risk management special interest group, founded in 1986) of the APM grew between 2004 and 2011 from 350 to 2,700 (c.f. Campbell (2012)).

- **Nowadays** risk management in projects has become one of the 10 knowledge areas of PMBOK (Project Management Body of Knowledge, PMI (2013)) and covers 6 of the almost 50 processes. Like the whole discipline 'project management', risk management in projects tends to become overloaded, more complex, and more difficult to handle.

Agile Methods

In the light of that development in project management a group of 17 participants of a conference in Utah in the year 2001 discussed, compiled, and signed a manifest that later on became famous as the '**Manifesto for Agile Software Development**' (c.f. Augustine (2005)).

"We are uncovering better ways of developing software by doing it and helping others do it.

Through this work we have come to value:

- **Individuals and interactions** over processes and tools
- **Working software** over comprehensive documentation
- **Customer collaboration** over contract negotiation
- **Responding to change** over following a plan

That is, while there is value in the items on the right, we value the items on the left more".

Remarkable is the fact that the signatories mentioned in the postscript that they do not want to move into extremes, but want to focus more on the flexible aspect of processes. Afterwards several agile project management approaches were generated; one of the most popular of them seems to be the so-called "scrum" approach (c.f. McKenna (2016), Maximini (2015)). This approach is characterized by several presets (e.g. the different roles of the product owner, the team, and the scrum master) and especially a clearly defined time management.

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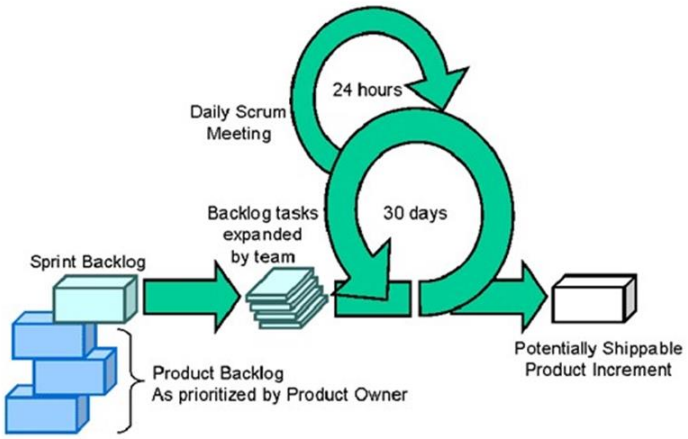

source: adapted from Schwaber/Beedle (2008)

Fig. 1. **The scrum framework**

The whole workload of the project is broken down into work packages for the next 'sprint'. Such a sprint usually covers a period of 8 to 30 days. And within this period there is a daily 'scum' meeting. By this the main idea is the adaptive and iterative line of action. The whole team is able to permanently react to things that occur over time and therefore this approach is very flexible.

But it is quite irritating to find statements like the following on the internet:

- "This has led many to believe that **risk management is irrelevant in an iterative model.** Some follow the approach of ignoring risks until they manifest into issues; they then manage them through the natural sprint progression."
- "Risk management is an important part of both PMBOK/PMI and Prince2. Most agilists on the contrary find separate formal **risk management in agile practices unnecessary**, as agile inherently addresses risks and mitigates them continuously."
- "One can debate the need for spending additional amount of time in firming up schedules when **agile has the inherent flexibility** about keeping timeline fixed while ensuring only high priority items get delivered."

Obviously some people have not read (or forgotten) the last sentence of the 'agile manifest' and strongly believe that this iterative, adaptive approach substitutes an elaborated planning and especially risk management.

Comparison to Machine/Job Scheduling

In some sense this reminds those of us, who witnessed, followed, or tracked the development in production and operations management, that a similar process happened there. In the beginning the dominating perception was that everything can be analysed and planned and that it depends mostly on the available computer performance to calculate the optimal

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schedule for the execution of a set of orders. The aim was to get via MRP (manufacturing resource planning) a totally integrated CIM (computer integrated manufacturing) in which each order is **pushed** through the production system. But because of the increasing complexity, the high fragility in relation to any disturbance ("butterfly effect"), and the handling of uncertain events, another development took place, mostly initiated in the Asian countries. In this approach orders were not pushed through the system, but rather **pulled**. This approach was characterized by terms like Kanban, just-in-time, and lean management. In some sense you can interpret the development as if you "overshoot the mark" and have to move back. But in the end you come to the conclusion that each situation needs its own individual approach and there is not one unique approach that always fits best. You have to decide this again and again and adjust your specific 'hybrid' approach to your specific environment.

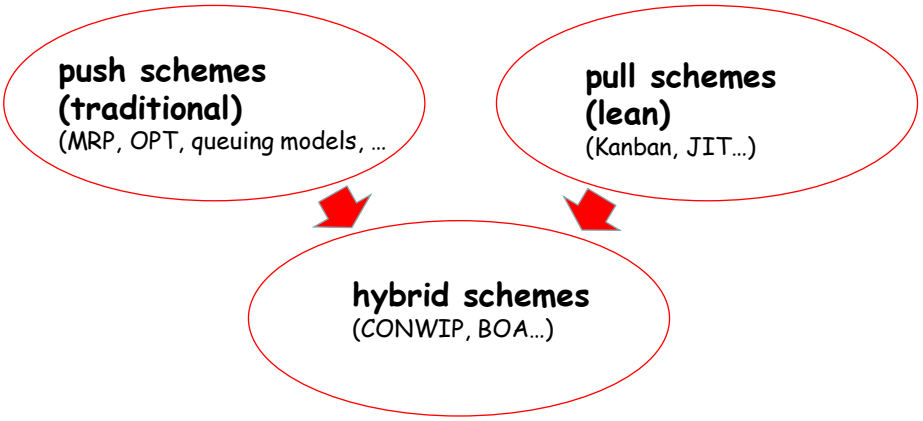

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Fig. 2. **Development in production and operations management**

But since these experiences have already been made in operations management, we can try to learn from them in project management.

Example: Pitfall Traps because of Blinders

To illustrate the necessity of planning and the danger of a purely adaptive approach, we adopt one of the examples that have been created in the context of the discussion in production and operations management and that are now known as "*Graham's anomalies*" (Graham (1968)). For the sake of simplicity, a deterministic case has been chosen, in the sense that no uncertainties of the parameters are assumed.

Suppose that we have a project that contains seven activities with the necessary (deterministic) durations and the predecessor relations given in fig. 3.

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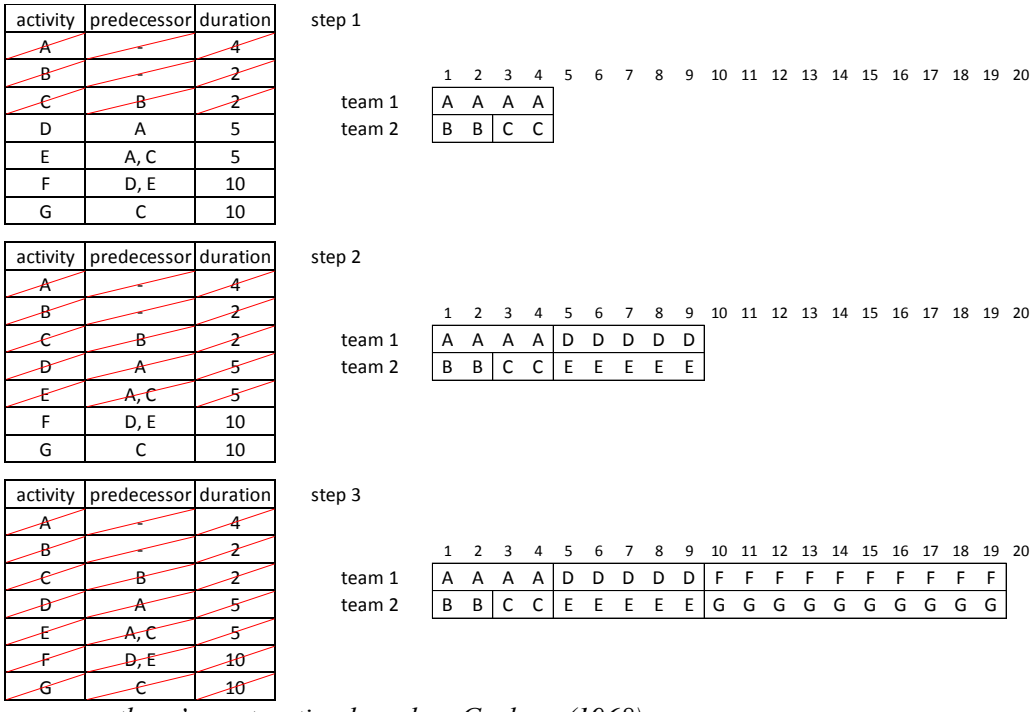
activity	predecessor	duration
A	-	4
B	-	2
C	B	2
D	A	5
E	A, C	5
F	D, E	10
G	C	10

source: authors' construction based on Graham (1968)

Fig. 3. **The first example project**



source: authors' construction based on Graham (1968)

Fig. 4. **The first example with the adaptive approach**

To handle this project we deploy two teams that are able to perform each activity, but only one activity per team at the same time. If these teams behave in an adaptive way, which means that each team consistently takes over the next available task, we get the schedule given in fig. 4 with a total duration of the whole project of 19 units.

If we now succeed in improving the project in that way that we can shorten the duration of each activity by 1 unit, we get the project that is shown in fig. 5.

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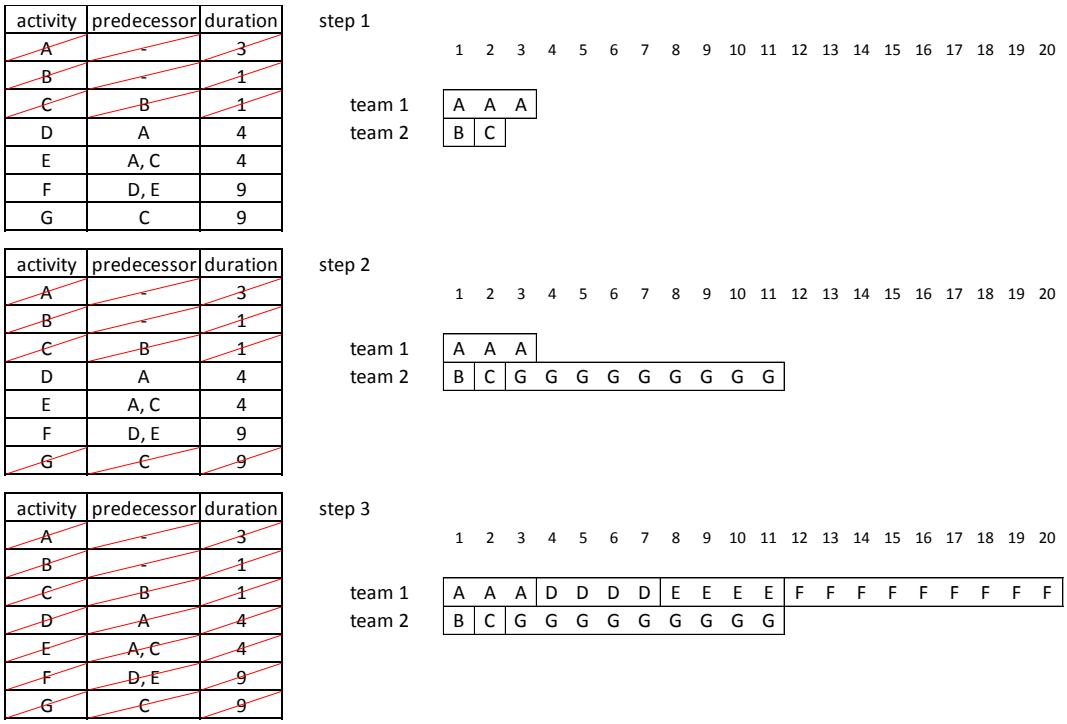
activity	predecessor	duration
A	-	4
B	-	2
C	B	2
D	A	5
E	A, C	5
F	D, E	10
G	C	10
	Σ	38

activity	predecessor	duration
A	-	3
B	-	1
C	B	1
D	A	4
E	A, C	4
F	D, E	9
G	C	9
	Σ	31

source: authors' construction based on Graham (1968)

Fig. 5. **Modification of the first example**

Solving this modified project in exactly the same adaptive way, now leads to the schedule given in fig. 6. It can be seen that although the total workload decreased from 38 units to 31 units (c.f. fig. 5) the duration of the project increased from 19 units to 20 units. On the other hand one would have expected that having a workload of 31 units and 2 available teams, it would be possible to execute the project within 16 units. And indeed: This is possible! To achieve this, one team needs some idle time in the beginning in order that everything fits at the end (fig. 7). But unfortunately the adaptive approach is not able to handle this.



source: authors' construction based on Graham (1968)

Fig. 6. **Solving the modified example with the adaptive approach**

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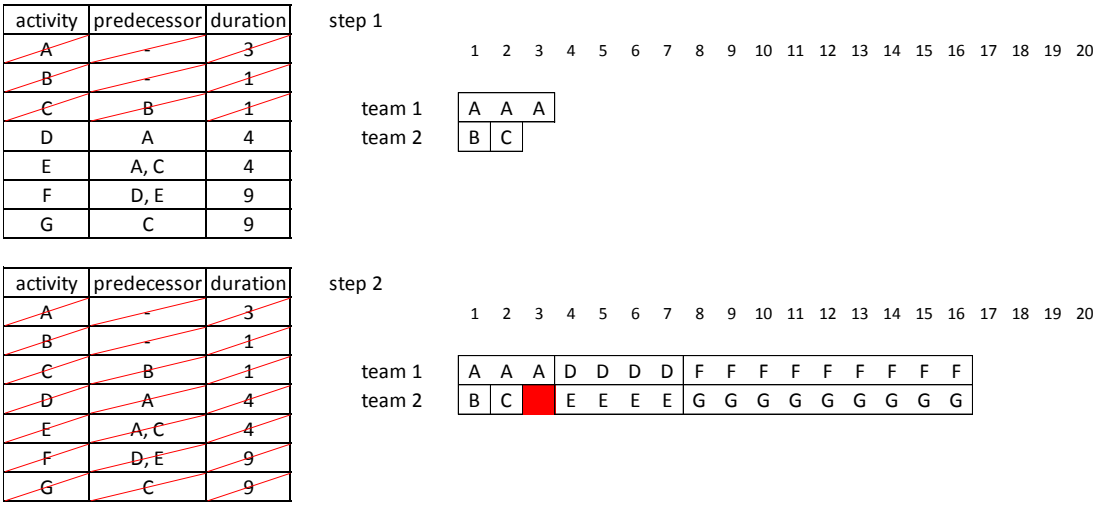

source: authors' construction based on Graham (1968)

Fig. 7. **Optimal solution of the modified example**

Monte Carlo Simulation and Risk Management

After having illustrated that a planning and especially risk planning process is quite useful - if not necessary – let us view, which kind of risk management might fit into an agile oriented process. Since agile oriented processes possess its special timing, the used tools have to be easily applicable with little effort in the sense that they can be used during a sprint or even within a scrum meeting, without the consultation of external specialists or the use of specific software. Therefore we favour Monte Carlo simulation, since it creates a plain output in form of distributions instead of non-transparent indices that need interpretation. Additionally these simulations have to be performed with a tool that is well-known to most of us and that can be handled by most – if not all – of the team members. Excel belongs to this kind of tools.

Let us try to give an impression of possible applications with the following more complex example project (fig. 8). Here the durations of the individual activities are assumed to be uncertain and given by three-point estimates (optimistic (OD), most probable (MD), and pessimistic durations (PD)).

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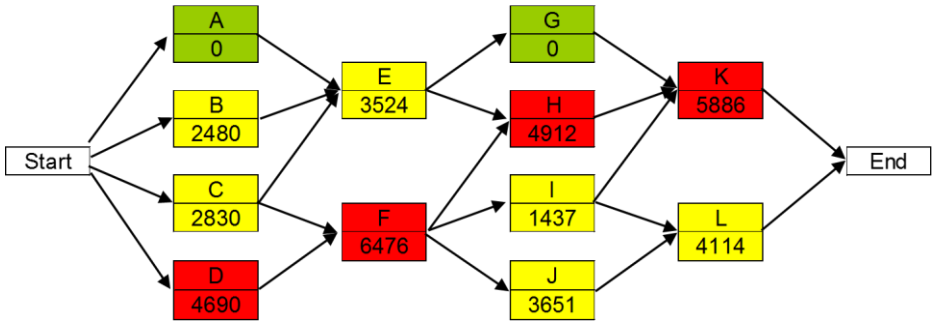
Activity	Predecessors	D	D	D
A	-			
B	-			
C	-			0
D	-			
E	A, B, C			0
F	C, D			
G	E			
H	E, F			
I	F			
J	F			0
K	G, H, I			
L	I, J			

source: Tysiak (2015)

Fig. 8. **A fictitious project plan**

With a little experience it takes approximately in the range of about one hour to create a Monte Carlo simulation model with Excel for this project. This effort might of course increase if the project becomes larger or more complex (e.g. if there are a lot of incorporated conditions or correlations (c.f. Tysiak/Sereseanu (2010), Tysiak/Tietz (2016)), but it remains manageable within a reasonable time. You also have to keep in mind that this generation of the model has to be done only once in the beginning. In this example we have chosen beta distribution for the expansion of the three-point estimates, which is quite easy because of the built-in functions of Excel. The employment of the model is of course as easy as any use of Excel sheets: You simply change parameters and notice the changes.

The first instance that can be shown with the model is the probability of an activity to be critical. Therefore we create 10,000 simulations (which only takes seconds) and calculate how often an activity belongs to the critical path (c.f. fig. 8).



source: Tysiak/Tietz (2016)

Fig. 8. **The critical field (number of times (out of 10,000) that a node is critical)**

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Similar to the above given example with the two teams, we could be interested which activities overlap in time, so that they have to be executed (at least partly) simultaneously. In fig. 9 the probabilities of an overlap in time and the average lengths of these overlaps are given.

	B	C	D	E	F	G	H	I	J	K	L
A	1,00	1,00	1,00	0,00	0	0	0	0	0	0	0
B		1,00	1,00	0,66	0,37	0	0	0	0	0	0
C			1,00	0,34	0,29	0	0	0	0	0	0
D				0,43	0,71	0	0	0	0	0	0
E					1,00	1	0,53	0,53	0,53	0	0,00
F						0,47	0,47	1	1	0	0
G							0,95	0,94	0,95	0,00	0,06
H								0,99	1,00	0,78	0,44
I									1	0,22	0,22
J										0,48	0,78
K											0,99

	B	C	D	E	F	G	H	I	J	K	L
A	3,00	2,99	3,00	0	0	0	0	0	0	0	0
B		4,92	5,55	0	0,89	0	0	0	0	0	0
C			5,00	0	0	0	0	0	0	0	0
D				0,97	0	0	0	0	0	0	0
E					5,49	0	0	1,64	1,65	0	0,44
F						1,35	0	0	0	0	0
G							2,49	2,31	2,41	0	0,93
H								4,30	5,03	0	1,50
I									5,11	0	0
J										1,321	0
K											3,95

source: authors' construction

Fig. 9. **Probabilities and lengths of overlap**

As a third illustration of the usage of such a model, we want to point out that you can permanently maintain the model and update the parameters over time and look for the consequences. In fig. 10 the actual values are updated each 5 days and show the change in the distribution of the duration of the whole project. Obviously the standard deviation decreases over time.

These are only three possible applications to show that these models may provide very useful information in a very short and easy way. Each project will of course generate its own desirable or required analyses.

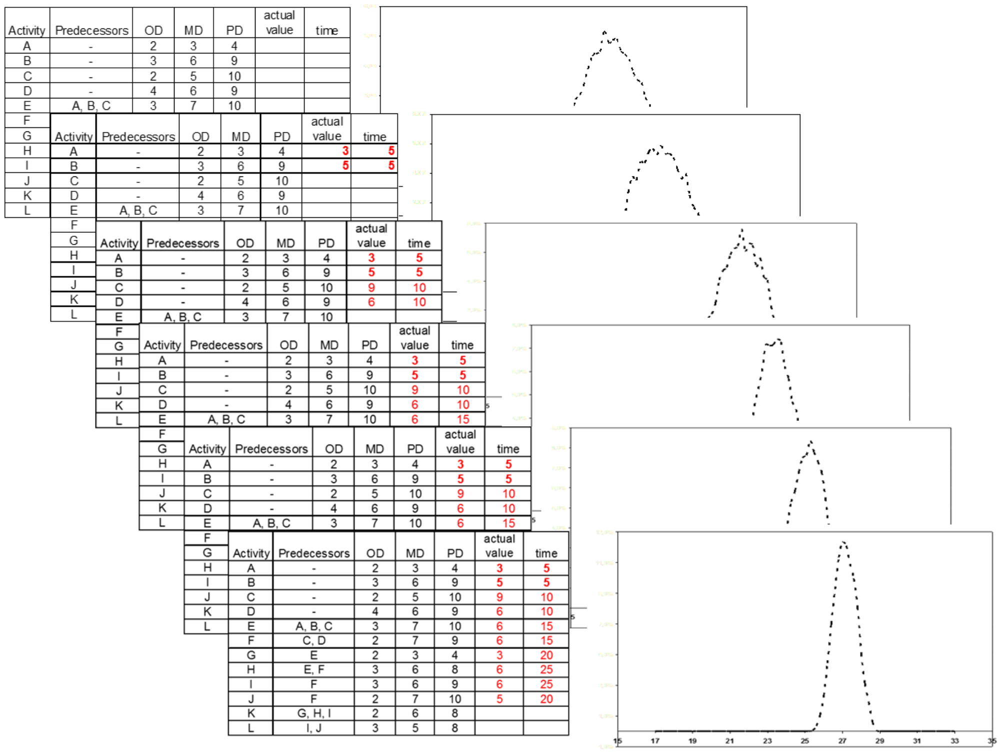

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Fig. 10. **Development over time**

Conclusions

Although sometimes people argue that a sophisticated project planning and especially risk management planning can be substituted by an agile approach, we illustrated that a pure adaptive line of action might be quite dangerous. Therefore, even in agile oriented approaches planning is still useful.

Especially in the context of risk management planning, everybody should be aware that ignoring risks also means the omitting of chances, because uncertainties always cover both tails of the distribution: threats and chances.

Additionally, the fact that one approach moved too far into an extreme direction, should not lead to an attitude to move into the opposite extreme. It normally makes more sense to mitigate the extreme approaches: There are a lot of interesting colours between black and white – we need hybrid models that use a mix of the best tools of all known approaches.

One tool that fits quite well into the agile methodology is the Monte Carlo simulation, especially performed with Excel. It is well-known; most people are familiar with it. It is very flexible; analyses can be done very fast and by the team members themselves.

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