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APPLICATION OF COST-TIME INVESTMENT SIMULATION IN PROJECT OPTIMIZATION

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ABSTRACT
Projects are one of the basic means by which a company achieves its competitive advantage and successful business operations. Project oriented companies very rarely use cost-time profile tools in their project evaluation activities. Money savings and reduced cost-time investments are extremely important in the crisis time and contribute to the effectiveness of the company. Among all success criteria, factors and frameworks, costs and time remain the most important ones. They are also extremely interdependent, especially in the field of project scheduling.
In the paper we deal with a case study of a selected simple project. We test the impact of non-critical activities execution time periods to project's cost-time investment. Using slack for delay of such activities brings essential total improvements. The results show that the differences are significant, bringing a potential for project optimization.
Keywords: project, slack time, cost-time investment

1. INTRODUCTION
Project management has become one of the most popular tools for worldwide organisations to improve internal operations and respond rapidly to external opportunities [1]. The project duration is set by the project critical path, where the focus is on critical activities. But non-critical activities also play a vital role in project success as their start and finish times directly influence the capital invested in the project. We have simulated different scenarios of project schedules based on non-critical activities delay and applied Cost-Time Profile concept. We present how focus on Cost-Time Investment could influence our decision on project scheduling process.
Project is a sequence of unique, complex and connected activities that have one goal or purpose and that must be completed by a specific time, within budget, and according to specification [2]. Projects and their activities are constrained by limitations on budget and personnel availability [3].
If the project fulfils the performance, time and costs criteria, it is said to be efficient, and we have to find an appropriate balance between them [4]. Project success may even be extended further to include the accomplishment of more strategic objectives and benefits, including impacts on markets and competitors, business development or expansion, and ability to react to future opportunities or challenges [5].

2. COST-TIME PROFILE IN PROJECT MANAGEMENT
A Cost-Time Profile (CTP) is a graph that depicts the accumulated costs that have been expended during the execution of a project at every time unit during the process. This way of presenting the

information follows the use of resources through time, from the moment the execution begins until the company recovers those invested resources through the sale of the product. The area under the CTP is called the Cost-Time Investment (*CTI*), because it presents how much money has been tied up in the manufacturing process and for how long before being recovered through sales [6]. Fig. 1 gives a simple illustration of a CTP.

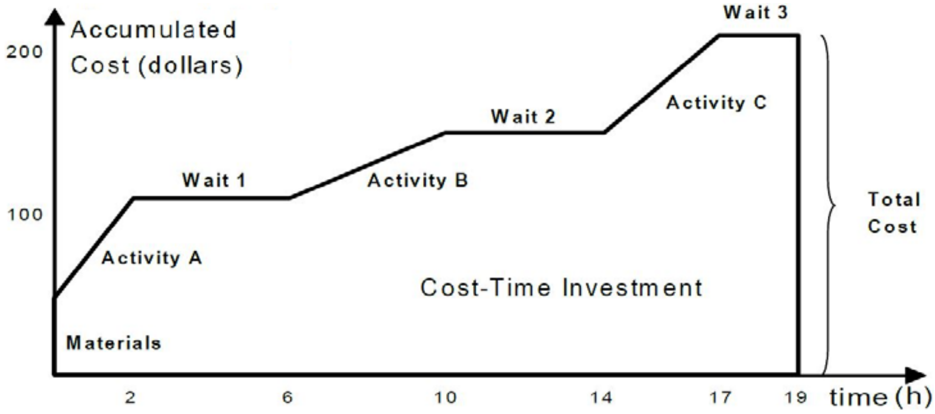

Figure 1. Example of Cost-Time Profile and Cost-Time Investment [7].

There are several important parts on a CTP. Activities are the parts that actively add cost. They are represented by positive slope lines. Some activities require materials to be performed. The assumption is that the materials arrive right at the beginning of the activity and all at once, therefore they are represented by a vertical line (instantaneous accumulation of cost). Waits are moments when nothing that adds cost is actively happening. Total cost is the height of the curve at the end of the project. It represents the total accumulated cost of the project. However, this total cost does not reflect the effect of time on the investment. *CTI* is the area under the CTP curve, and it represents how much money and for how long has it been invested in the project [8].

CTP does not consider indirect costs because it is truly hard to assign these costs directly to activities or to product parts. In project management, it is reasonable to assume that all resources, people and equipment that take part in the project are directly and completely assignable to the project.

3. CASE STUDY

The presented research focuses on investigation of the applicability of the *CTI* criterion at project implementation phase. For that purpose, we have used a simple case of a project with 8 activities and tested different scenarios. With the *CTI* simulation, the comparison and appropriate conclusions with some specific guidelines are enabled. Basic information about the project is presented in Table 1.

Table 1. Project information.

Activity	**Estimated duration** (h)	**Predecessors**
A	40	–
B	62	–
C	55	–
D	90	A
E	30	A, B
F	75	C
G	40	D, E
H	30	F, G
∑	422	

Activities A, B and C can begin immediately. All other activities have one or more predecessors, which must be completed to enable their start. For constructing the activity network we have applied Activity-on-Arrow (AOA) logic (the arrow represents the activity). Network analysis has been done with the Critical Path Method (CPM). The results are given in Fig. 2.

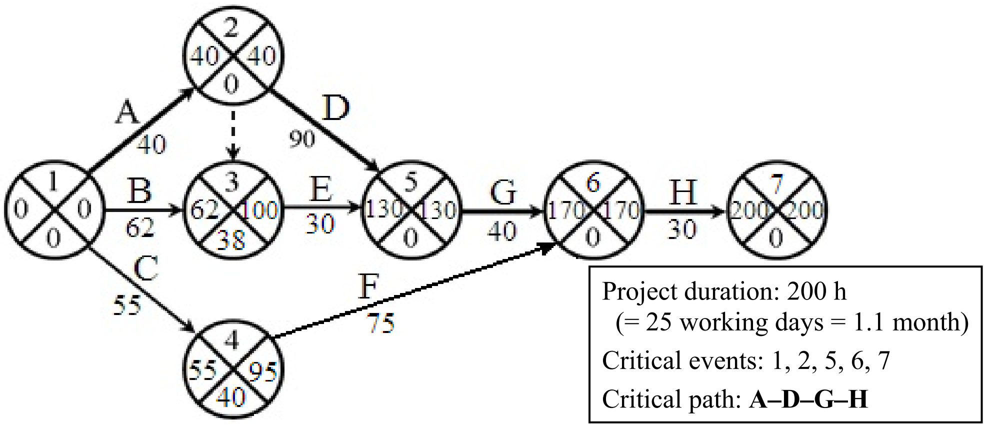

Figure 2. Project network diagram for given project data.

As a result we got 4 critical activities and 4 non-critical activities (which represent 53 % of total project activities time). All non-critical activities have some slack (each 39 hours on average, which means 20 % of project duration); each activity may be delayed from its early start without delaying the finish of the project. To study the impact of possible delay of non-critical activities on the *CTI* we have simulated three scenarios:

- non-critical activities are performed as soon as possible (case 1),
- non-critical activities start in the middle of the early start and the late start time interval (case 2),
- non-critical activities are performed as late as possible (case 3).

Activity periods for non-critical activities and for all three cases are collected in Table 2.

Table 2: Non-critical activities' intervals (scheduled starting and finishing times).

Activity	Case 1		Case 2		Case 3	
	Start (h)	**Finish** (h)	**Start** (h)	**Finish** (h)	**Start** (h)	**Finish** (h)
B	0	62	19	81	38	100
C	0	55	20	75	40	95
E	62	92	81	111	100	130
F	55	130	75	150	95	170

Other important project data and necessary simplifications, constraints or presumptions are: number of working days per year is 250; annual cost of capital rate is 10 %; materials and tools are purchased using the JIT principle; materials and tools cost, for B – totally 6000 EUR, for D – totally 12000 EUR; hourly rates (in EUR) for the whole group of employees (between 1 and 10 persons in a group) engaged for the activities, A: 45, B: 175, C: 28, D: 16, E: 38, F: 50, G: 50, H: 35; other cost components, possible to be used in the software (maintenance cost, resources' price, resources' life, overhead rate, profit rate etc.) are neglected and taken as zero; all costs are entered in 10^2 EUR (for better visibility in graphic presentation, see Fig. 3).

For the calculations and simulation of cost-time profiles and *CTI* we used **C**ost **T**ime **P**rofiler software, developed in 2006 at Virginia Tech (in the Center for High Performance Manufacturing).

3.1. Case 1

Non-critical activities start at earliest possible start times. The *CTI* is calculated for all activities and for all considered costs (6379780 €·h). Project total cost: 41570 EUR (the same in all studied cases).

3.2. Case 2

Non-critical activities start at time, which is delayed for 50 % of slack (after the earliest possible start time). $CTI = 5932170$ €·h.

3.3. Case 3

Non-critical activities start at latest possible start times giving the smallest $CTI = 5484560$ €·h.

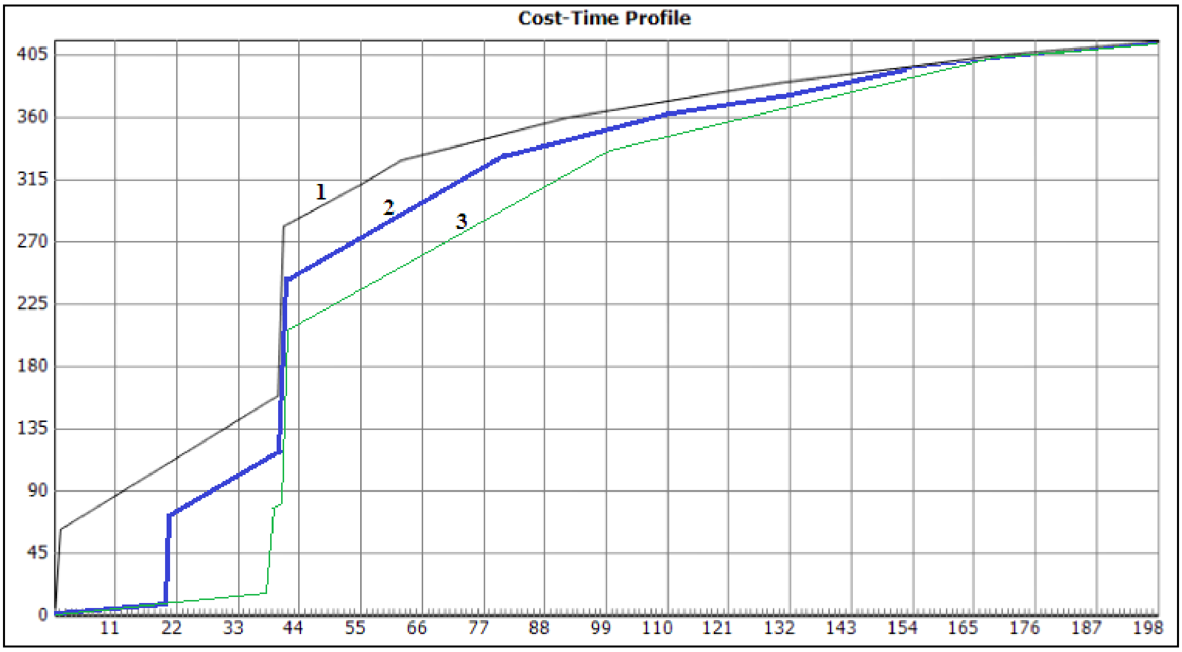

Figure 3. Project cost-time profile / investment presentation for the cases 1, 2, and 3.

The influence of performing times of non-critical activities (always our planning decision) on the *CTI* value is the following:

$$\frac{CTI_1}{CTI_2} = 107.5\,\% \qquad \frac{CTI_1}{CTI_3} = 116.3\,\% \qquad \ldots (1)$$

The difference of more than 16 % between the best and the worst result should not be overlooked. Even at very simple projects we must tend to the implementation of JIT principles regarding the scheduling of all non-critical activities. Such actions also contribute to the lean project philosophy.
Optimal CTI_3 means that we invest (locked-up capital) in the time of 25 days on average 219382 EUR daily. In the most unfavourable case 1 we have on average 255191 EUR invested.

4. CONCLUSION

In the paper we have dealt with a simple project to test the impact of non-critical activities execution time periods to project's cost-time investment. Using slack for delay of such activities brings essential improvements, but we must be aware of all potential, associated risks and uncertainty.
Our future work in the field of cost-time profiles will include more complex projects and detailed observation of all cost components.

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