Managing Delays in Construction Projects Aiming at Cost Overrun Minimization

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Abstract. The effects of the delay in construction contract execution are always negative for every party being involved. Cancelling the delays of the time schedule means the use of more production means that it was planned. It creates an additional cost. If the delays of the schedule are not cancelled, the contractor suffers from the cost increase. The penalties arisen from not keeping the milestones or the completion date are expected too. There is a trade-off: cancelling delays spending additional money now (during the contract execution) or executing a delayed contract till its end awaiting for its final settlement (showing the cost increase) and possible penalties. There is no one, correct answer how to manage a delayed construction project. There is a natural unwillingness to spend money over the budget. Nevertheless, the delayed completion date can cause much higher contractor’s expenses, than cancelling delays during the contract execution. The decisions made by the project manager depend on various factors discussed in the paper. A delay concerning the single task increases the cost of its execution at a different level. The same, the level of influence of delaying a single task, influences the completion date with varied strength. These influences depend on the location of the task in a net model – the base of a schedule. The tasks located on the critical path – defined in the Critical Path Method – should be of the special care. However, delays on not critical tasks can also break the budget and the planned completion date. The nature of delay is important as well. Lowered productivity of a workers’ brigade can make the execution of the task longer, the same as forced breaks in their efficient work. The reaction of a site manager to such causes of delay should be different, as the origin of the delays is different. The impact of the delay noticed on the single task is discussed in the paper and possible reaction (varied on the type of a delay and a task location too) are proposed. The proposed solutions aim at cost minimizing considering the total expenses spent by a contractor and possible penalties in case of the delayed completion date of a construction contract.

1. Introduction
There is each company definite need to make a profit. It allows to develop but – what is even more important – it allows a company to survive the time of a crisis [1]. There are two bi-directional, simultaneous pursuits: to maximise revenues and to minimise cost of economic activities in the construction industry. Once, the offer for executing of construction contract is placed and accepted, revenues are determined on a certain level that cannot be modified much. The effort of a contractor’s project manager concentrates on keeping the cost and time of the contract execution within as-planned boundaries, what usually leads to achieving the assumed profit. However, these two parameters (time
and cost) are interrelated with reference to the contract and the single scheduled task as well [2], [3], [4]. The often case is when a client sets time limit for construction works execution in the enquiry. The contractors assume the usage of the production means on minimum level but allowing for not exceeding the assumed completion date of the contract, and – at the same time – achieving minimum cost of the work execution. If speeding up the works is necessary, than it requires additional cost to be spent (e.g. for a higher number of works or machine units). Widely applied Webb’s earned value method [5] also confirm this statement. Extending the time of a specific work execution is the cause of its cost increase. There are two main reasons of an increase in time of a given work: forced brakes in the work execution, or lower than assumed productivity (defined as volume of work per time unit). The cause of delay can arise from both of the aforementioned (see figure 1).

![Figure 1](image1.png)

**Figure 1.** Completing a constant volume of work (grey area) a) as planned, b) with lowered productivity, c) with forced brakes, d) with lowered productivity and forced brakes

In every case (b, c, d – where delay is noticed) the cost of executing a certain volume of work is higher than planned as the machinery and the workers are paid for a longer time. The cost of construction materials – the third component of direct costs – remains unchanged. A construction site generates indirect costs too (e.g. hiring office and social containers, lighting the site, security the site). The longer construction works last, the higher total indirect cost are generated. If a delayed task is on the critical path (defined in Critical Path Method – CPM [2], [3]) it extends the time of the contract execution directly, thus, causing the increase in the indirect cost. As the indirect costs are assigned to the same set of tasks, the indirect cost is higher for each task. The influence of a delay (noticed on a single task) on different time of cost is shown in figure 2.
There is one more issue referring to the net model and CPM. The relatively small net model can be analysed in detail and can be prepared carefully, considering all dependencies between planned tasks to execute. When the net model and – based on it – the time schedule is prepared for a big project, such a detailed analysis is prepared less often (despite the fact that it is more needed then). Even if planners’ effort is high and near all dependencies are considered, the form of the time schedule does not show all connections between scheduled tasks (to provide readability of the document). The technological connection between two tasks, previously unconnected, discovered during the work execution, can change the location of the critical path. The example is shown in figure 3.

When the task T3 (in figure 3) is delayed by 4 days, it will change the critical path too. It can be found in the literature (e.g. [6], [7]) that delays in construction contracts can be compensable or non-compensable. A compensable delay mean a delay caused by a client, when they agree to cover the cost arisen from their mistake or a late action. It is often accompanied by an allowance for an extension of the contract duration. The recognition of the delay as compensable or non-compensable by a project manager is crucial for the decisions being undertaken.

Managing delays of a construction contract requires then gathering at least the following information:
- if a delay can be compensated,
- if a delay concerns the task on the critical path,
- if a delay is caused by insufficient productivity, or forced breaks,
if the critical path may be changed by any delayed task or by any undisclosed before technological connections of the delayed task to the other scheduled tasks. The character of all above mentioned issues is organisational, non-financial, concerning time management (if the non-financial side of a compensation is analysed). As a construction site should generate a profit the financial side of the decision to be taken should be recognized and evaluated.

2. Managing delays

2.1 Contractor’s expenditures in case of delay

Possible contractor’s expenses in case of delay can be divided into two groups: expenses already made and expenses to be made (or to be covered) – the effect of the decision undertaken as a reaction to the delay noticed. Expenses already made (when the delay is noticed) are as follows:
- additional labour cost,
- additional cost of machinery

as these production means were involved for the time longer than planned. This part of additional expenses is important for the final calculation of the profitability of a construction contract but it cannot be considered in any further manager’s decisions – the additional cost was already spent and none of decisions can lower it. There is much more expenses to made as a result of the decision made after the delay is noticed – they can be named “post expenses”. The list below presents most of them, but not all of them are necessary to cover in every case of the delay. The possible post expenses can be as follows:
- the cost of bringing productivity to the assumed level,
- the cost of speeding-up remaining works to be executed,
- the increase of indirect costs (arisen from the extension of the contract duration),
- the contract penalties in case of not keeping the milestone or the completion date of construction.

Independently from the causes of a delay (low productivity, forced brakes or both of them), bringing the productivity to the assumed level requires the engagement of higher number of production means. It equals to additional cost. The same effect can be observed when it is decided to speed-up the works (to cancel the delay noticed). It is necessary to evaluate the increase of the indirect costs and the value of penalties, even if it is decided to execute the remaining part of a construction contract without any action on the delay.

2.2 Minimum expenses finding

Which set of activities should be chosen as a reaction to the noticed delay, can be determined by the lowest sum of expenses decreased by possible financial compensation as shown in the formula.

\[
\text{min} E_f = \text{min} \left( C_b + C_s + I_C + P - C_m \right) \quad \text{for} \quad 1 < i < n
\]

where:

- \( E_f \) the total financial effect of the decision
- \( C_b \) the cost of bringing productivity to the planned level
- \( C_s \) the cost of speeding-up remaining works
- \( P \) the contract penalties to be covered
- \( C_m \) the value of financial compensation (allowed by a client)
- \( n \) the number of possible variants of actions to the delay noticed

It is to state that depending on the \( i \)-variant of actions chosen, the part of the components of the sum can be equal to 0. The total financial effect \( E_f \) will usually have the positive value, but it represent the increase of expenses, so its minimum is searched.

2.3 Decision making

Based on the phenomena presented in the introduction, there are 16 possible sets of circumstances when a delay in execution can be noticed. They are illustrated in figure 4. As the effects of manager’s
decisions can cause expenses varying much in different variants (from figure 4), managing a delay cannot be analysed as an stable set of the rules.

![Delayed task]

**Figure 4.** 16 variants (V1 to V16) of circumstances accompanying the delay of a task; where “Low P” is low productivity, “Forced B” are forced breaks, “C-CP” means “critical path may be changed”, “F-fC” means “critical path is free from any changes”.

### 2.3.1. Compensable delay

As it is the most favorable case for a contractor, the manager should firstly examine, if the noticed delay is caused by a client i.e. should be compensated by this party. When the delay concerns the task lying on the critical path, the compensation should comprise financial means and the time allowance. As a result of making the contract execution longer, the increase in indirect costs should be covered by a client too. Agreed time extension should not rise the risk of charging penalties over the initial one. The situation described reflects variants V2 and V4. In V4, forced breaks – the reason of the delay noticed – were probably caused by a client. The additional cost for longer than planned use of production means (spent before the compensating decision, not considered in formula (1)) is fully covered. Contractor’s revenue and expenses are increased by the same amount ($E_f = 0$). In V2 circumstances (simultaneous forced breaks caused by a client and contractor’s lowered productivity), to avoid future delays caused by lowered productivity (and costs arisen from this), the contractor’s manager should motivate the staff more or change it (what is usually additional costs and time incurring). When unexpected technological connections are discovered (when the delay is noticed) – variants V1 and V3 – the contractor’s position is worse. It can be much more difficult to prove (to a client) that the extension of a contract duration should be higher than arisen directly from the compensated delay. The manager’s effort put to bringing back planned productivity should be higher (in V1). As a client usually compensate the time in 1:1 ratio (referred to the delay value) and discovered unexpected technological connections influence the critical path more than the delay itself, penalties are expected. Then, speeding-up the works should be considered as one of the possible solution. The formula (1) can be applied: cost of speeding-up the works vs value of penalties should be compared, and the decision based of $\min E_f$ criterion should be worked out.

When a client agrees to compensate the delay not lying on the critical path (V5 to V8), it means that only additional cost may be compensated to the contractor. But even then, the compensation negotiation will be difficult for a contractor. A client can argue that if the forced breaks had been long enough, the production means affected by the breaks, could have been used to execute other works. This argument is true in many cases. So, even the delay can be classified as a compensable, the cost increase arisen from this is rarely covered. Any higher expenses caused by lowered productivity (V5, V6) or caused by an unexpected change of the critical path (when new technological connections are disclosed (V5, V7), will be covered by a contractor. The possible ways of improving productivity should be worked out and increase in expenses related to each way evaluated to find $\min E_f$. The general sequence of a project manager actions to the delay noticed is shown in figure 5.

### 2.3.2. Non-compensable delay

Variants V9 to V16 affect more financial result of a construction project as no compensation is possible. Each delay generates additional expenses and can cause an extension of the total time of a project execution (the reason of next expenses and penalties to be covered by a contractor). The set of analysis and further actions in V9 and V13 should be similar. Even if a certain delay is not on the critical path (V13), it can affect it in two ways. When the total float (defined in CPM) is consumed, the task becomes critical or unexpected technological connections are discovered.
**Figure 5.** The sequence of a project managers’ actions to the delay noticed

So, the manager’s reaction to them should be identical. To avoid penalties, any time savings should be searched in the further part of a project (not executed yet). It is obvious that the tasks lying on the critical path should be shortened (in order to keep the project completion date unchanged), so the criterion of minimum cost increase should be applied in searching the best tasks (from the critical path) to shorten. This can be optimized e.g. by a particle swarm method [8] or linear programming [9], [10]. However, the decision about shortening should be undertaken as one in a set, when min\(E_f\) criterion is considered. The cost of bringing productivity to the planned one should be considered too in V9 and V13, as well as, in V10 and V14. Taking into account that in V15 and V13 the extension of not critical task can easily influence the location and length of the critical path, the cost of this influence should be considered when min\(E_f\) is searched. The stress to the organizational matters should be put especially for variants V11, V12 and V15, V16, where it can protect from any further additional contractor’s expenses. Every time the delay occurs, the contractor’s additional expenses appear. It highly reasonable to prepare plans to lower them and to choose the method providing min\(E_f\).

3. **Discussions**

As it is shown in figure 4, the circumstances accompanying the delay occurrence can vary significantly. The time-cost trade-off is an immanent part of a delayed construction project [11], [12]. There are really rare cases, where the additional expenses derived from delays are fully covered by a client’s compensation. If they are not covered, a project manager is faced with a bundle of cost rising problems. Finding technological and organizational solutions for a delayed contract execution, it is necessary to evaluate their costs. The problem is which expenses are lower, when the execution remains delayed or when the chosen plan for reducing delays is introduced. The choice should be done based on the formula (1) i.e. the set of actions providing minimum additional expenses is to be chosen. To help the manager which actions should be considered (and their cost should be calculated), the below table 1 was created.
Table 1. Recommended actions to delay noticed in different circumstances.

| Type of manager’s action                                | Variant (described in figure 4) where the action is recommended |
|--------------------------------------------------------|----------------------------------------------------------------|
| Bringing the productivity of production means to the planned level | V1*, V2, V5*, V6, V9*, V10, V13*, V14                                |
| Reorganizing a part of the works to avoid forced breaks  | V11*, V12, V15*, V16                                                  |
| Considering speeding-up remaining part of the works     | V9*, V10*, V11*, V12*, V13, V15                                     |
| Resolving unexpected technological connections discovered| V1, V3, V5, V7, V9*, V11*, V13*, V15*                               |

* The recommendation is very strong.

In every case the increase in expenses should be calculated for each element of formula (1) – even to realise that a given element is equal to 0. The same concerns the value of possible penalties and compensated value.

There is an assumption that has not been mentioned yet: penalties are charged even if the completion date of a construction contract is delayed for one day. The real case is different. Private companies (clients) are more likely to charge penalties than public clients, as their decisions are more of business nature (based on expected financial results). Each client has its own, specific threshold that trigger charging penalties to a contractor (some days of delay in a completion date or a month). The experience of a whole contractor’s company should be used (not a project manager’s only) to evaluate the client’s threshold. Then, evaluation of \( \min E_f \), and the decisions arisen from it, should consider the aforementioned issue.

Another important factor that influences project managers’ decisions is the fact that the penalties, as well as, the increase in indirect costs occur after the end of a construction contract. During the contract’s execution, its completion dates its not certain, as there are a lot of causes that may delay it [13], [14] more than the delay just discovered (occurring further). That is one of the main reasons (despite the natural unwillingness to spent additional cost), why the managers’ response to the delay noticed is usually done late, when the influence of some delayed tasks on the time schedule has a cumulative character.

A lot of analysis and proposed models can be found aiming at proofing the schedule from delays. Goldratt ideas [15] are being developed [16], [17]. Constrained, by the renewable resources, schedules are being optimized [18], [19], [20]. Schedules constrained by non-renewable resources [21] are optimized with the aim to increase efficiency of those resources user – a contractor. Effectiveness of scheduling, where the level of utilization of the resources is measured, can be assessed [22]. The less breaks in any machine work (slack times), the more efficient the schedule is. The other side of efficiency of the resources usage during a construction project execution is that the more the schedule is efficient, the more it is exposed to disturbances caused by a delay noticed on a single task. As there is no other way of development than increasing efficiency of operations, a project manager’s decision should be characterised by similar “efficiency” i.e. be made on time, based on analysis, lead to additional expenses minimisation. The execution of such schedule-strained construction projects simply requires that.

4. Conclusions
The proposed, general sequence of the project manager’s actions is aimed at minimising additional expenses appearing while even single task is delayed. The lack of reaction to the delay noticed increase
different types of cost and makes penalties charged. These negative influences of a delay can be limited if the proper set of actions is undertaken. Proper – means reaching the minimum of additional expenses. Circumstances accompanying a delay are varied. A delay can be caused by contractor’s employees or by a client’s decisions. A delay can have different origins (lowered productivity or forced breaks). A delayed task can lay on a critical path or can have a time float (defined in CPM). Noticing the delays is often accompanied by disclosing technological connections between tasks of the schedule (not explicit before). So, the circumstances where construction process faces a delay can vary significantly. That is why, the proposed set of manager’s actions is analysed for each variant of circumstances. Every time, the proposed analysis should be followed by calculating the total increase of contractor’s expenses (including penalties) and the decision, which set of action is to be executed, should be based on min\(E_f\) criterion. This is pure financial approach. It can be widened by considering the issue of a brand building. However, the decision about not exceeding the completion date of a contract for any price – as all company’s decision concerning a brand building – should be taken at the highest management level, not solely by a project manager (but he should consider it in his decisions).

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