Optimization of Investment Costs in Construction by Planning the Time for Implementing Activities

Dragomir Stefanov, PhD
Chief Assistant at "Real Estate Property" Department
University of National and World Economy
Bulgaria

Abstract

Investment projects for construction or reconstruction of buildings and facilities are often characterized by a high volume of investment costs, numerous different construction and erection activities and tasks, as well as long periods of implementation. Observations show that, in general, in Bulgaria insufficient attention is paid to the timing of implementation of the activities as well as to the necessary financial, material and human resources. This leads to a number of negative effects for investors and end-users, such as delays in implementation, increased investment costs, and more. This article describes an author's model for optimizing investment costs in construction projects by deploying non-critical activities in the process with a certain time advance before the latest possible time for the implementation thereof. Thus the low risk of delay project implementation and optimization of the present value of the investment cost are combined. The goal of the model is to accurately determine the duration of this time advance depending on the size of the risk of delay in executing the individual activity, the investment spending for its performance, and the additional cost per unit time delay of the investment process as a whole.

Keywords: investment and construction project; optimization of investment costs; Gantt chart; non-critical activities.

JEL: **D92**

1. Introduction

One of the main steps in the process of investment planning is the forecasting of the time for implementation of the individual activities, as well as of the project as a whole. This is so because the time, through the risk and uncertainty of the investment decisions taken, influences the determination of all changes in the final results and impacts the magnitude of the cash flows. Starting from the theory of the decreasing value of money over time we can derive the relationship that the shortening of the period for the development and operation of an investment project will increase its effectiveness, other conditions being equal. This rule is valid assuming that the economic effects of the activity as a whole are retained as a nominal value despite the optimization of the duration of the project. The time during which the investments have an impact on the welfare of the investor or through which the impact of capital investment is manifested, is most - often called *a period of economic life of the project* (Georgiev 1999). Without its establishment, none of the dynamic methods for economic evaluation of investment projects can be applied. i.e., in practice it is not possible to make a precise analysis of its economic efficiency. Hence, the comparison and ranking of alternative investments is also made on the basis of this period, even when its duration is established on the basis of indirect signs (expert assessments, similar projects, etc.)

The economic life of an investment and construction project usually covers two relatively distinct phases. The first one - *the investment period* - is characterized by the investment of funds (investment costs) for the design, construction and commissioning of the construction site. The second phase is actually the *period of normal operation (operation)* of the site and should have yielded positive effects for the investor (rental income, sales revenue, etc.). Its duration depends on a number of factors such as the physical fitness and technological feasibility of the main fixed assets, the horizons of the forecast economic parameters, etc. In general, the investor's goal is to reduce the duration of the investment period and increase the lifetime of the object. The purpose of this article is to direct the attention to the first phase of the economic life of the projects by developing one of the leading models of its optimization.

2. Network models of time planning

Planning of investment projects for construction and reconstruction of buildings and facilities most often involves a complex set of interrelated activities and tasks. This requires the engagement of many contractors and the implementation of an effective coordination between them, as well as the provision of the necessary funding under the conditions of the restrictions set by the investor.

In addition, planning should answer the question of how to implement the project in the shortest possible time without affecting the quality and value of the work. Practice in Bulgaria shows that there are serious shortcomings in the process of time planning for the development and implementation of investment projects. A confirmation of this is the fact that over 60% of the projects for housing are not finalized within the time provided by the investor. The bad organization and coordination between contractors, the lack of detailed investment project and poor execution of tasks are the major reasons for that. One of the most popular methods to solve this problem is the *network models or timetables* for planning and control in the management of various projects. It is typical for them to divide the entire process, in which the project will be carried out, into separate single activities (tasks) and to determine the time for implementation of each of them. Then the different types of interdependencies and constraints between such separate tasks are defined. Such dependencies of a purely technological nature are the relations of subordination between activities that are four types (Aleksandrova 2001):

- "start-to-end" subordination relationships requiring the first activity to end in order to begin the second one;
- "start-to-start" subordination relationships, where the second activity can start only if the first one has started;
- "end-to-start" relations of subordination, where the first activity cannot be completed unless the second one has begun;
- "end-to-end" subordination relationships requiring the second activity to be completed in order to complete the first one.

Other types of dependence between tasks arise from the forms and sources of financing the investment, the characteristics of human resources, and the seasonality of certain activities. After identifying the individual activities, the duration and the interdependencies thereof, comes the placement of them over time. For this purpose a specific symbolism and various graphical tools are used to graphically represent the entire project and to help for the ease of interpretation. Thus the subject of management gets a more complete picture of the volume, sequence and relations between the activities of the studied project. Most simplified network model is to prepare a map of the processes and their consecutive time course which is called *a flowchart.* Another graphical model is the *hour chart*, which, in addition to the technological sequence of activities, specifies also their time duration. In the 50s of the twentieth century, American economists Morgan Walker and James Kelly developed a network model that uses only arrows and dots (nodes) and relatively easily allows you to determine which activities are *critical* and which are *non-critical* (Aleksandrova 2001).

Critical are those works the implementation delay of which will extend the total length of the project as a whole. It is to them that the investors' attention is most often targeted in the implementation of current control and of the efforts to optimize the investment costs. The sequence of all critical activities forms the *critical path* and its duration determines the minimum necessary period for completion of the project. Therefore, the method is known by the name of *"Critical Path Method*" (CPM). Every critical activity can and should begin immediately after the previous one, because they are technologically bound. The CPM model is commonly used, especially in construction, for succeeding in the provision of the necessary coordination and control over operations and at the same time is extremely easy to interpret. On the other hand, the method does not take into account the timing of non-critical activities, thus neglecting the possibilities for optimization of investment costs in the implementation thereof. This problem is somewhat overcome by using *Gantt charts*[1]. They are horizontal strip diagrams where each line depicts a strip with a single operation, and the horizontal axis is plotted in days, weeks, decades or months. The longer the activity is, the longer the tape marking the activity. An important advantage is the ability to switch from technological time for work implementation to calendar time. Thus, practically without any problem, the investor can establish, as of certain date, which operations will be completed according to the plan, which will be in the process of being implemented and which have not yet begun. In this way, the financial, material, and human resources necessary for the smooth running of the activity can be reasonably foreseen, which is particularly useful in the parallel realization of many works. Moreover, by comparing the actual state of the process with the plan, it is easy to see in which operations there is a delay in performance and where there is an advance of time.

3.Approaches to place in time the non-critical activities

When developing a Gantt-type mesh table, the issue of time-based deployment of non-critical activities needs to be addressed. By definition, the time period of completing such activities is shorter than the period between the earliest possible start and the latest possible completion thereof. In this sense, different approaches are possible, with the general rule not to disturb the duration of the process as a whole.

[1] Named after the American engineer and scientist Henry L. Gantt, used for the first time in 1917

Under the first approach, it is planned that all non-critical operations begin at the earliest possible time, i.e. immediately after the technologically preceding critical work. Under this option, the risk of delaying the implementation period for various reasons is the smallest. The second approach provides that the start of the "floating" in time operations is at the latest possible moment, i.e., to finish according to the plan just before the start of the next critical work. Based on the theory of the decreasing value of money over time and the hypothesis that the payments for the execution of the individual works are carried out in parallel with the implementation thereof, this is the approach that minimizes the present values of the investment costs. In an effort to combine the advantages of both models in this article, the author recommends using an approach where non - critical activities begin with a certain *time advance* before the latest possible time. Thus it is possible to combine a lower level of risk of delays in construction and optimization of investment costs. The purpose of the model is to determine the duration of this time advance with accuracy. Here we start from the realistic assumption that postponing the launch of a non-critical activity at any given time leads to a reduction in the present value of the cost of its execution while increasing the risk of prolonging the entire investment process due to a delay in the deadline for completing the task. Assuming that any delay can be given a value depending on its duration (in view of the constant costs of staffing, machinery and equipment, missed benefits of project delay as a whole, etc.), we can conclude that mathematically it is possible to find out the moment (the point), at which the refusal of further reduction of the present value of the investment costs becomes equal to the amount of costs for covering the risk of delay. It is the optimal point at which the implementation of the analyzed non-critical activities should have been executed under the plan.

The first part of the analysis is focused on the investment costs. By means of the concept of money value over time it can be determined what the present value of the investment cost will be for the performance of the analyzed activity which is not on the critical path in the network scheduling. It is assumed that the actual payment occurs after completion of the planned work, but not earlier than the agreed deadline for its completion. In practice, in delaying a payment, the free financial resources can be directed to alternative investments (such as a bank deposit) and bring income. Given that borrowed funds are used (which is a common assumption in construction), deferment in time of a due payment leads to a reduction of the value of the appropriate remuneration to the lender (interest). It is possible part of the investment cost due to be paid before the completion of the specific work in the form of an advance payment or lease installment, in which case it is appropriate that the prepaid amount is deducted from the cost amount that will be discounted. The following formula is used:

$$PV = \frac{I_t}{(1+r)^t} \tag{1}$$

where:
PV - the present value of the future payment;
I_t - the agreed value of the investment cost;
r - Interest rate for the accrual period;
t - Number of interest accrual periods.
$PV = \frac{I_t}{(1+r)^t}$ - Discount factor.

It should be noted here that for the analysis to be correct, it is necessary to work with one and the same time units in all calculations and in the elaboration of the network scheduling itself, as well as in the setting of the deadlines for the implementation of the individual works. Such units can be: day, week or month depending on the specificity of the investment object, and for the purposes of this analysis we will measure the time in days. From here it logically follows that interest rate on bank "overnight" deposits/credits is assumed for **r**, and **t** is the number of days.
Given the extremely small values of **r**, respectively the near-zero values when raised to a degree, we can simplify the analysis by revising the formula (1) into the following form:

$$\begin{aligned} PV &= \frac{I_t}{(1+r)^t} = I_t * (1+r)^{-t} \\ &= I_t * (1^{-t} - t * 1^{t-1} * r - t * 1^{t-2} * r^2 - \cdots - t * 1 * r^{t-1} + r^{-t}) = \\ &= I_t * (1 - t * r - t * r^2 - \cdots - t * r^{t-1} + r^{-t}) \approx I_t * (1 - t * r) \end{aligned} \tag{2}$$

Thus in practice, in the calculation of the present value we use as an approach the principle of simple interest accrual on the amounts and not the compound one, and the differences in the results of the two approaches are negligible small

values which do not distort the assessment[2]. However, this assumption allows us to represent the present value as a linear function of the two parameters - the investment cost and the interest rate.
Based on formula (2) we can conclude that the size of the reduction achieved in the volume of the investment costs, resulting from the delay in the execution of a certain activity in time, is represented by the increasing function $\mathbf{I_t * r * t}$, where the marginal daily reduction is $\mathbf{I_t * r}$. The second key moment in this analysis is the assessment of the risk of delay in the implementation of activities. Formally, there is a risk of completion of work before the agreed deadline too, but due to the fact that in our investment activity this happens rather as an exception, an assumption is made that the payment of outstanding remuneration is made no earlier than planned (see above).This eliminates the possibility of an earlier payment commitment and hence an increase in the present value of the investment cost over the estimated amount[3]. At the same time, the earlier completion of a non-critical activity has no impact in any way on the investment process as a whole and in essence should not be seen as a risk.

In the economic theory, it is generally accepted to measure the risk of a phenomenon by using the statistical dissipation parameter of the results of its manifestation – standard deviation **(σ)**. The larger the range of possible deviations of the actual values of the basic parameter (in this case the period for the activity) from the expected (planned) ones, the greater the risk. This dispersion is established through the standard deviation, which is calculated as the square root of the sum of the square differences between the expected and average values of the analyzed parameter (to eliminate the negative meanings), weighed with the corresponding probability for each of the possible results (Petrov 1997). The following formula is used:

$$\sigma = \sqrt[2]{\sum_{i=1}^{n}(T_i - \bar{T})^2 * P_i} \qquad \sum_{i=1}^{n} P_i = 1 \tag{3}$$

where:
$\boldsymbol{T_i}$ - expected duration in days for the completion of the activity at the i[th] state of the project;
$\boldsymbol{T}$ - average weighed duration in days;
$\boldsymbol{P_i}$ - the probability of occurrence of the i[th] state of the project.

The standard deviation can be used to compare the magnitude of the risk of delay in the implementation of uniform types of activities (excavation, foundations, concrete works, installation of windows, masonry, etc.), for which there are certain standards of continuity. In addition, using the standard deviation, it can be ascertained with what percentage of certainty the value of the parameter will be within defined limits[4]. For example, with a probability of 68.27%, the value of the parameter will be in the range of $\boldsymbol{\bar{T} \pm \sigma}$, with a probability of 95.45% it will be in the range of $\boldsymbol{\bar{T} \pm 2\sigma}$, and with a probability of 99.73% it will be in the range of $\boldsymbol{\bar{T} \pm 3\sigma}$.

If we assume that through appropriate calculations, depending on the specifics of investment project, it is possible to establish the size of the additional investment costs that we will have to make for each day of delay of the execution of the entire project, then these costs can be noted as **d (**from **d**elay). Most easily this value can be determined for projects where there is a fixed amount for penalty payable by the investor for each day of completion delay. Another realistic financial measure of this delay is the amount of daily fixed costs for the resources (material, human and financial) involved in the project. It is also possible to use an approach where the size of the minimum additional costs needed to accelerate the work on some of the subsequent critical project activities is used to measure **d** with a unit time, in order to make up for the delay in the implementation of the analyzed activity.

From this point of view, the graphical increase of the risk of delay, respectively the potential increase of the investment costs, can be represented by a linear function with the standard deviation **σ** (depending on the degree of risk-phobia of the investor **2σ** or **3σ** can be used also too) and the calculated daily cost of construction delay **d** as parameters. Of course, for a greater correctness of the analysis it is necessary to take into account that the additional costs in delayed project implementation are the result of delayed implementation of the observed non-critical activities and the size **d** thereof must be adjusted by the marginal reduction of the present value of the cost for the implementation of the activity, namely $\mathbf{I_t * r}$, e.g., the actual amount of additional costs per day will be $\mathbf{d - I_t * r}$.

[2] For example, at an annual rate of 7, 2 %, or a daily rate of 0.02% respectively and a number of periods of 50, a deviation in the results according to both approaches is achieved within 0.005%, and for 100 days - 0.02 %.
[3] In practice, this time limitation of payment does not affect either the logic of the model or the results of its implementation, but only leads to the limitation of the length of the time period investigated.
[4] Provided that research parameter is with approximately normal distribution of the results.

Fig. 1 is a graphical model for optimization of the investment costs for the construction of buildings and facilities by deploying over time the non-critical activities during a certain time advance before the latest possible moment.

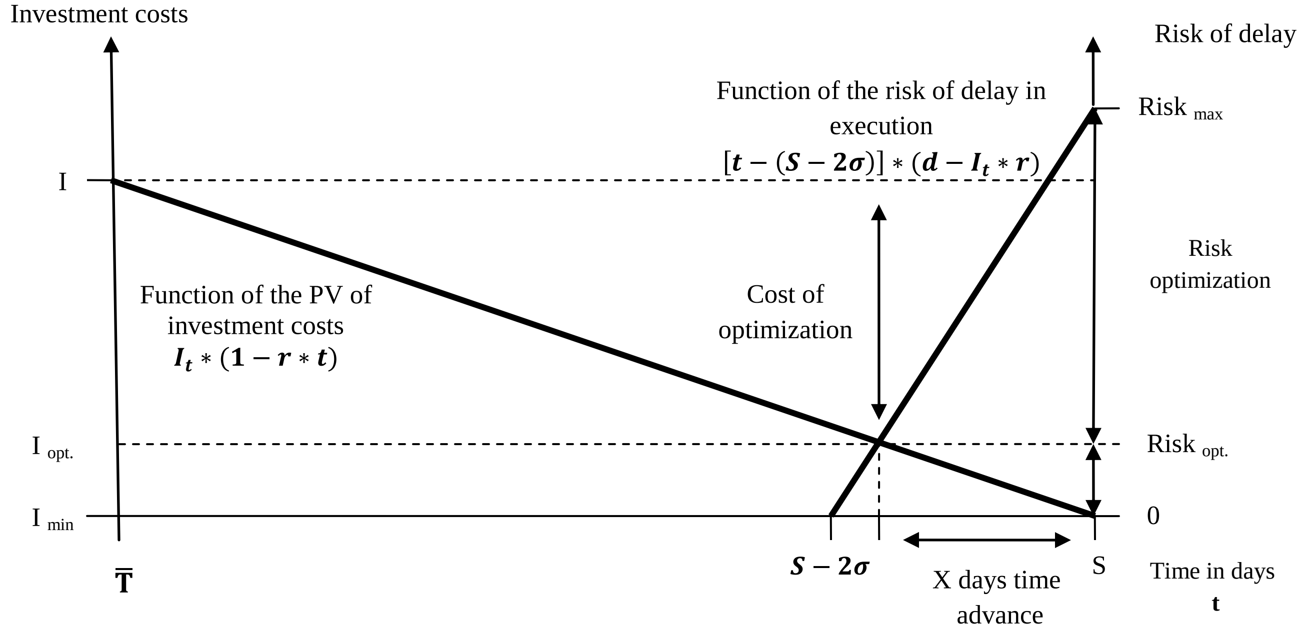

Fig. 1 Model for Optimizing Investment Costs by Planning Time to Implement Non-Critical Construction Activities

The length is presented of time between the earliest possible completion of the analyzed non-critical activity under the plan ($\overline{\mathbf{T}}$) and the time at which the next critical activity **(S)** is to begin. In other words, **S** is the number of days between the end of the preceding critical activity and the beginning of the subsequent one, in which time the analyzed activity should be performed. By definition, $S > \overline{T}$ and that is why we call these non-critical activities "*floating in time*". The decreasing function of the present value of the investment costs for the realization of the latter takes its maximum **I** at the beginning of the period under consideration $\overline{\mathbf{T}}$. It's the approach with the earliest possible start of implementation, and the earliest payment of due costs, respectively. The function reaches its minimum at the end of the period **S** (the approach with the latest possible start), and is described by approximately straight line (formula 2).

Valued function of risk of delays in the implementation of the non-critical activities takes a zero value so far $S-2\sigma$[5] **-** until then virtually there is no risk of slowing down the whole process, as there is an advance of time until the next critical activity greater than **2σ** days. It is quite logical that the risk function is increasing, reaching its maximum at the end of the reviewed period **S** (this is the approach with the latest possible start, and with the greatest risk of delay, respectively). The function is represented by the following straight line:

$$f(\text{risk}) = [t-(S-2\sigma)]*(d-I_t*r) \qquad (4)$$

where:

$[t-(S-2\sigma)]$ - counts the time in days;

$(d-I_t*r)$ **-** takes into account the amount of additional investment costs for each day of delay in the performance of the activity.

The intersection of these two functions, described in straight lines, shows us the time advance in days (**X**), where both optimization of investment costs and the incumbent risk of delay are simultaneously optimized. The economic interpretation of this model is as follows: a part of the additional potential savings in investment costs for late commencement of operations is sacrificed against a significant reduction of the value of potential costs of realizing the risk of delay. The mathematical length of the time advance **X** can be determined by solving the following equation:

$$I_t*r*X = [(S-X)-(S-2\sigma)]*(d-I_t*r) \qquad (5)$$

The left side of the equation represents the left size of the forgone extra saving of investment costs by the investor due to the start of work with a time advance of **X** days before at latest possible moment.

[5] In this case, it is assumed that the degree of risk phobia (wish to avoid risk) of the investor corresponds to the range 2σ, i.e., a probability of 95.45% of all possible options for the duration of the implementation of the task under consideration is sufficient for the investor.

These missed savings are calculated by multiplying the daily reduction of the present value of the investment cost $\mathbf{I_t * r}$ by the number of days of the early start of the implementation **X**.

On the right side of equity (5) is the value of the potential risk of construction delays. The expression $[(\boldsymbol{S}-\boldsymbol{X}) - \boldsymbol{S}-\boldsymbol{2\sigma}$ shows the maximum expected number of days of delay in the implementation of the analyzed non-critical activities, provided it starts with a time advance of **X** days before the latest possible moment and the maximum expected delay in the implementation of $\mathbf{2\sigma}$ is realized. Here too is the assumption that for the investor the probability of 95.45% of all possible cases is high enough and acceptable for the authenticity of the analysis. The expression $(\boldsymbol{d}-\boldsymbol{I_t} * \boldsymbol{r})$, on its part, measures the additional daily cost of delay of the project as a whole.
Arithmetic conversion of equality (5) leads to the following:

$$\boldsymbol{I_t * r * X = [(S-X)-(S-2\sigma)] * (d - I_t * r) = (2\sigma - X) * (d - I_t * r)}$$

$$\boldsymbol{I_t * r * X = 2\sigma * (d - I_t * r) - X * d + X * I_t * r}$$

$$\boldsymbol{X * d = 2\sigma * (d - I_t * r)}$$

$$\boldsymbol{X = \frac{d - I_t * r}{d} * 2\sigma} \qquad (\mathbf{6})$$

Formula (6) enables the relatively easy and highly accurate determination of the time advance **X** to start carrying out an activity of construction, not lying on the critical path, so as to achieve optimal minimization of investment costs at a level of risk of delay consistent with the degree of risk phobia of the investor. It is evident from formula (6) that the length of time an advance **X** is directly proportional to the size of the daily potential additional cost **d** for delay in the overall schedule for completion of construction, as well as to the standard deviation in the deadline for execution of the respective non-critical activities. The dependence is inversely proportional to the size of the investment cost for carrying out the activity and the current daily interest rate. The two parameters $\mathbf{I_t}$ and **r** are relatively easy to define. The first one is negotiated with the contractor of the specific activity (mostly construction company), and the interest rates on bank loans on a daily basis can be used for the second one. At the other pole are the difficulties in determining the values of the other two unknown parameters. Regarding the additional costs per unit of time (day) of slowdown in the general plan of the investment process **d,** several possible approaches were already mentioned. With respect to the standard deviation **(σ),** the only possible solution is to carry out studies of its values for different types of construction works based on previous experience. At the same time, there is also a subjective element related to the degree of willingness of the investor to take risks, which should be determined by the latter.

4.Conclusion

Most often in practice, because of the low levels of the parameter **r** (daily interest rate), the fractional part in formula (6) takes values close to one. This, in turn, gives leading values of the standard deviation from the duration of the construction work. However, I believe that my model expands the field of investment analysis and questions the generally accepted thesis that only the deployment of critical activities should be monitored, analyzed, and optimized. Using the approach can be extremely useful, especially for large-scale construction projects with large size investment costs. At the same time, it is also applicable when using multifactorial PERT[6] models, where unambiguous assessments are not used for the time of the execution of activities, but probabilistic assessments of the duration thereof. Here the question is asked whether a specific work is to be executed for the shortest time or at the lowest costs, while the model described above can show what the impact will be on parallel performance of works when involving additional resources. Using network planning models enables an investor to significantly improve the organization of activities in investment projects, coordination between the separate executive units and more effective use of resources. Moreover, they are not just an information tool, but also models for dynamic process management and through them an opportunity is provided for more efficient control. Ultimately, all this creates preconditions for optimizing investment costs and project duration.

References

Alexandrova, M. (2001) *Optimization of Investment Selection*. Sofia: Trakia – M.
Georgiev, Iv. (1999) *Fundamentals of Investment*. Sofia: Stopanstvo.
Markowitz, H. (1952) Portfolio Selection. *Journal of Finance 7 (1).*
Petrov, G. (1997) *Fundamentals of Company Finance*. Sofia: Stopanstvo.
Tobin, J. (1958) Liquidity Preference as Behavior towards Risk. *Review of Economic Studies*.

[6] Abbreviation in English - **Program Evaluation Review Technique**. In literature also known as **Program Evaluation Research Task**