Optimisation of coordination's selection by innovation and investment projects

Ilana Ter-Saakova*

Baltic International Academy, 4 Lomonosova Str., LV-1019, Riga, Latvia

**Corresponding author's e-mail: ilana@alida.lv*

Abstract

The steady onward progress of engineering developments, together with increasing competition, implies the need for the development of implementation for novelties and innovations. This involves a huge number of innovative projects emerging, thus consecutively defining the formation of investment criteria

Keywords: innovations investments project intensity probability model function

1 Introduction

The increasing competition in the goods and services market and the ongoing development of facilities require continuous improvement of the development and integration of innovations in various fields of science and technology. This results in the formation of a large number of innovative projects that cause, in turn, the need for appropriate funding, and therefore require the formation of investment projects.

This is especially evident in the preparation of investment plans in various industries intended for the development of a particular region. In this case, the investment appropriation requests exceed the financial capacity almost without exception.

2 Research

The ongoing development and the need for innovation development and integration set the problem of the comprehensive selection of innovative projects and their adequate funding at the expense of potential investment projects. In order to solve it, let us consider the following setting set up of the problem.

A set of innovative projects is formed {M}, each with sufficient definiteness of the result and measurability of their characteristics.

There is also a set of investment projects {N} (M ⊂ N) based on the above-mentioned investment projects.

There are time constraints on the implementation of innovation and investment projects, as well as cost and resource constraints on the project financing for the entire period and within its individual intervals.

One needs to select the best project versions, order them by preference in accordance with the given resource constraints and adopted criteria.

Let us introduce the following notation

X_{ik} is the i-th innovation project with k-th execution intensity;

Y_{lj} is the l-th investment project with j-th intensity version;

$X_{ik} \in (X)$; $Y_{lj} \in (Y)$; (X) and (Y) are a set of Boolean variables.

$X_{ik} = 1$ mean that the i-th innovation project with k-th intensity is selected.

By project intensity we shall mean the project organisation version coordinated with the project executors and characterised by cost, duration, and expected completion.

In the course of project preparation, the probability of execution P_{ik} is possible and as well as non-execution possible $P_{ik} = 1 - P_{ik}$.

Within the project $X_{ik} = 1$ income B^L can be obtained with L-th efficiency criterion, where L=1, A is a possible number of criteria.

Losses B^{-L} within the project are also possible.

In view of this notation, the problem of the coordinated selection of innovation and investment projects can be presented as a mathematical optimisation problem.

It is necessary to find the following:

$$\sum_{i=1}^{L} \sum_{k=1}^{K} (P_i k B^L X_i k Y_i n - (1 - P_i k) B^{(-L)} X_i k Y_{in}) \to \max . \quad (1)$$

Since the cost and time resources are constrained, the equation (1) should be solved under the following constraints:

$$\sum_{i=1}^{L} \sum_{k=1}^{K} (C_{ik} X_{ik} + C_{in} Y_{in}) \le C_{\max} , \quad (2)$$

$$\sum_{i=1}^{L} \sum_{k=1}^{K} (T_{ik} X_{ik} + T_{in} Y_{in}) \le T_{\max} . \quad (3)$$

The duration of a particular i-th project can be divided into a number of discrete intervals, and as a rule can be equal to a month, a quarter or a year. In the case of the definition of each project by the univariate model network, the project parametric analysis procedure can be used for the given financial resources C and time T in a certain range.

When selecting projects we shall recognise that the result of the i-th innovative project must be equal to a similar investment project in content and characteristics.

The well-known approaches to solving vector optimisation problems can be used to find the optimal solution of the expression (1) on the selection of the best set of projects. The well-known approaches to solving vector optimisation problems can be used for the projects. Boolean integer programming can be used to find the numerical solution. Upon finding the solution, it is required to determine an optimal subset of projects to be developed, the start and end dates of each of them, as well as the best version of the set of projects being formed in terms of the general optimality test.

The cost and the reliability of the project are functions of the project time. Determining the correlations between these parameters is an actual scientific and practical problem, since, as is known, the cost (C) and the duration (T) of the project are an important subject in the coordination of interests between the customer and the project developer under the relevant requirements on the project reliability.

Every project's range of characteristic parameters values (k range members) embodies its final result properties, its cost value C_k at k^{th} intensity variance and duration T_k, as its implementation time.

Being aware that, under a market economy, both the project cost (C) and time (T) are subject for agreement between the client and the contractor, immediately after the concluding of the contract, the project task supervisor proceeds to the elaboration of project implementation network model, seeking to provide the operative management of the works for the whole implementation period, accounting for possible interfering impacts that, in general, bear a random character. In the case the initiated project is defined with a univariance network model, each project work stage correlates to a monotonous decreasing time-dependent cost function $C = C(T)$, whose type and the existence interval [T_{min}, T_{max}] can be found. Under the precondition of an a-priori accurate and reliable project implementation assessment, the dependence $C(T)$ forms a convex function (Figure 1).

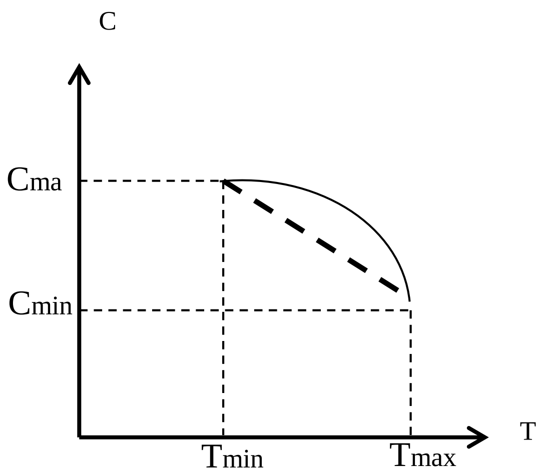

FIGURE 1 Time-dependent cost function $C = C(T)$

Let us consider the generalized reliable project implementation assessment characteristic P, i.e. the probability of the project's successful completion within scheduled delays as a T-dependent function. According to the leading experts in the field, this characteristic is revealed as a monotonous increasing one, while the T-dependent, has a concave shape (Figure 2); here, the project reliable implementation parameter slightly decreases when there exists an insignificant differrence between T and T_{max}, and, when the T value is further diminished, the P parameter goes down more abruptly.

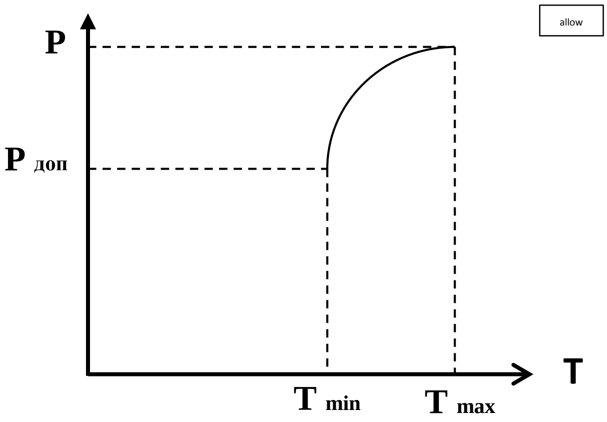

FIGURE 2 Time-dependent project reliable implementation assessment characteristic

On one hand, the T_{max} is determined with the maximum allowed (Client side) project development delay and, on the another, with sufficiently high project implementation reliability degree characteristic for the specified allowed delay (as assessed by the Contractor's experts).

The T_{min}, value is determined with the criterion that the probability of the project's successful implementation for every $T\epsilon\left[T_{min},\ T_{max}\right]$ should never be less that the liming allowed value $P_{allow} < P\left(T_{min}\right)$ and, consecutively $P = P\ (T) > P_{allow}$ within interval $T\epsilon\left[T_{min},\ T_{max}\right]$.

Determining the T_{min} value, other considerations include: availability of client finances, degree of the client's motivation to speed up receiving the results of the final project.

Taking into account the dependence of $P= P\ (T)$, we can determine $M(C)$ mathematical expectation as the project cost function $f(T)$:

$$f\left(T\right)\ =\ C\left(T\right)\ \times\ P\left(T\right). \tag{4}$$

To proceed with the first approximation, according to Figure1, we choose a linear dependency:

$$C\ =\ C\left(T\right)=\ -KT+R\,, \tag{5}$$

where

$$K>0, R\ >0,\ \left(-KT\ +\ R\right)\ >0\,.$$

And, examining Figure 2, we observe $P'\left(T\right)>0$ and $P''\left(T\right)<0$, which means that the $P(T)$ function is positive, monotonously increasing and convex.

Upon differentiation of the project cost mathematical expectation

$f\left(T\right)=C\left(T\right) \text{x}\ P\left(T\right)$ f(T) we obtain:

$$f'\left(T\right)=\left(-KT+R\right)\times P'\left(T\right)-KP'\left(T\right). \tag{6}$$

The necessary precondition satisfying the $f(T)$ monotonously decreases within all intervals [T_{min}, T_{max}] refers to the $f'(T)<0$, criterion, that is:

$$\left(-KT\ +\ R\right)\times\ P'\left(T\right)<KR\left(T\right), T\epsilon\left[T_{min},\ T_{max}\right]. \tag{7}$$

Consecutively, both K and P assigned values should satisfy conditions (7), either definition of region T should be positioned to the right of the maximum of the *f(T)* function.

The *f(T)* function is convex regardless of which *K* and *P* values are assigned, as always, the conditions are satisfied above, and this will be $f''=(-KT + R) *P''(T) - 2KP'(T)< 0$. Respectively, the time-dependent cost function will appear as shown in Figure1.

During the discussion and definition of the project's implementation conditions, we must consider the variety of variance from the viewpoint of the final result criteria. The implementation conditions are established with the final product parameters (features) limit values. It is certain that these features should reflect not only the technical, but also the economical characteristics.

The provided interval of whole values of every parameter variance, range within relevant limits, and is divided into non-crossing subpopulations (either subpopulations with essentially insignificant crossing areas) arranged by the increase in the level of consumer-demanded parameter quality, we can find the L index represents the number of project implementation variances, every one individually complying with the integrity of requirements to the final result. These criteria for innovative projects can be formulated as parameter values of the final scientific technical product required to satisfy, within the evolved subpopulation limits in respect of every above-considered characteristic.

Every project implementation variance correlates, as aforementioned, with the values: $(T_{max} C_{min})$, $(T_{min} C_{max})$, and $C = C (T)$ function, found within these intervals.

In such a way, the target project can correlate with the family $\{C = C (T)\}$

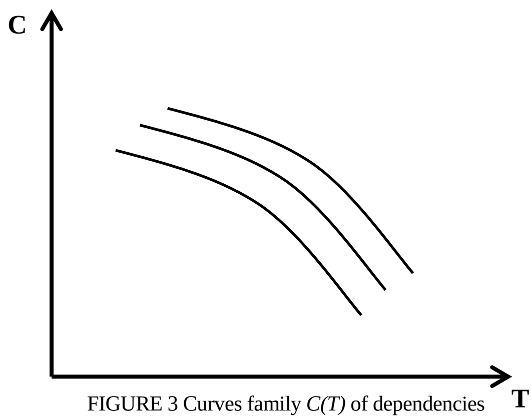

FIGURE 3 Curves family *C(T)* of dependencies

Both the innovative project cost and its implementation delay (beginning from the scientific research and experimental design development), are significantly influenced by the decisions taken at the earliest stages of development. Several foreign experts estimate the situation as follows: as early as the completion of the project draft, 75% of such new project costs are defined, nevertheless namely this specific stage costs amount nearly 5% of the project's total cost. Thus, at the stage of conceptual design embodiment and pre-production prototype manufacturing, the real possibility to reduce the newly designed product cost is shortened to about 20%, and during the serial production stage (general expenses reaching the maximum), this possibility never exceeds 5%.

3 Results

These ciphers evidently show that time and money saving during the early development stage of the innovative project obligatorily involves the resulting innovative product increased cost.

Such an approach serves as a stimulus, not only for the project's accelerated implementation, but also to achieve the highest possible characteristics of the final scientific and engineering product.

In the process of developing the project's contract conditions (requirements to the newly-created engineering product inclusive) agreeing with the client, the contractor can elaborate a univariance (no alternatives) network model of project implementation. The potential contractors for the works establish every work stage and its respective network model parametric evaluation system. Every i^{th} work within such a network model obtains the following characteristics:

$\overline{R_i}$ - material expenses vector;

$\overline{Q_i}$ - labour expenses vector (staff number by the required specializations;

t_i - work implementation time

These assessment parameters are concurrently elaborated by the potential contractors on the basis of the desired reliability level (probability of successful work completion within t_i period), equal to l ($P_i = l$).

Knowing the project's overall cost (labor inclusive) and the $C = C(T)$ function, the contractors are motivated to assign all mentioned network model's parameters criteria in a manner that the increase in money gained by every contractor per time unit is in direct relation to the increase of labor productivity.

The client's interest in reducing the input of material resources is due to the competition between possible contractors departing from the income distribution after expenses are covered.

When input established assessment criteria for resources (for a given contractor's team) defined are the following: the project implementation overall time *T*, critical works stages, and required time reserves for every j^{th} variance of the network model (Δt_j) and every work (Δt_j).

Provided $T \le T_{max} - \Delta T$, where ΔT – scheduled time reserve to secure the project implementation reliability reserve, the given team can develop the project with a degree of high reliability with respect to complying with scheduled delays. The $\Delta T > 0$ selection is due to the possible inaccuracy of the contractor's estimations. The ΔT is convenient to be linked with the assessment of the established accuracy of the work's parameters. This accuracy being high, we can assume $\Delta T \approx 0$.

Let us consider the case of $T > T_{max} - \Delta T$. Hypothetically, the probability of *P* project successful completion and the same for every separate work in its implementation network model (P_i) is directly proportional to the expected labour input or, a fixed team member, equivalent to the work duration. Therefore, we can conclude that, when works can be fulfilled by a fixed team during T_i time with the probability P_i, then it can be performed during T_i/ P_i time with the probability equal to one unit.

In this case, the function $P_i(T_i)$ can be represented as:

$$P_i = \frac{t_i}{t_i^{(1)}},$$

where $t_i^{(1)}$ – work duration when the fulfilment probability is equal to one.

Admitting the model as the time-dependent function $P_i(T_i)$ is related to a specific character and the peculiarities of some considered work stage. In general, such a dependency model can be expressed with the function of the following kind:

$$P_i = \left(\frac{t_i}{t_i^{(1)}}\right)^n, \tag{8}$$

where the order index "n" depends on the work duration time correlated to the probability of successful completion of the works.

Provided the works successful completion probability increases slower than its length, i.e. if the function $P_i(T_i)$ is monotonously and convexly increasing, then the order index "n" (8) is $n<1$.

To illustrate, we expose the example of $P_i(T_i)$ function type:

$$P_i = \left(\frac{t_i}{t_i^{(1)}}\right)^{\frac{1}{2}}.$$

When the works successful completion probability increases faster than its length, i.e. if he function $P_i(T_i)$ is monotonously and concavely increasing, then the order index "n" (8) is $n>1$.

To illustrate, we expose the example of this case:

$$P_i = \left(\frac{t_i}{t_i^{(1)}}\right)^{\frac{3}{2}}.$$

In general cases, we should consider "reliability for the duration", dependencies differentiating them to be the class of works or type, and for the whole project.

The contractors must specify and give grounds to which $P_i(T_i)$ function types the given work corresponds. In other words, every work type should obtain a substantiated value of "n" order index. Provided, according to the contractors, any of the above-proposed dependencies does not represent an adequate description of some work's character, they are invited to substantiate and propose their own $P_i(T_i)$ function type for agreeing with the client and further feasibility analysis.

We suppose an approximation of the project reliable fulfillment linear dependency onto the duration both for separate works and the whole project. To achieve the project implementation length equal to the maximum allowed value $T_{max} - \Delta T$, it is sufficient to evaluate time for every part of the work for the network model, including the reserves multiplied by the:

$$P = \frac{T_{\max} - \Delta T}{T} \langle 1 \tag{9}$$

Now, we compare the t_i and $(t_i + t_i) \times P$. Provided $t_i \le (t_i + t_i) \times P$, then the fulfillment of these works is also characterized by their completion reliability within the scheduled period, equal to one unit, and the new time reserve shall be found from:

$$t_i(P - l) + Pt_i \ge 0 \tag{10}$$

Let us find the minimum allowed value P_{allow} for the reliable project implementation by a given team and the same parameter for every separate work within the given network model. Supposing $P > P_{allow}$. Now we define works characterized by the reliability index, equal to one unit. From expression (9) we conclude that the initial time reserves of the works should satisfy the condition:

$$\Delta t_i \ge t_i \left(\frac{1}{P_{allow}} - 1\right). \tag{11}$$

For example, when $P_{allow} = 0{,}9$, then

$$t_i \ge 0{,}11 t_i. \tag{12}$$

In other words, when some work time reserve is 11% above the assigned expected completion time, their implementation reliability is equal to one.

The works not complying with (12) are characterized by the P_i probability of successful completion within the allowed time $(t_{i\,+}t_i) \times P$.

There, from some i^{th} work implementation probability P_i at the assigned linear approximations will be found as:

$$P_i = \frac{t_i + \Delta t_i}{t_i} P. \tag{13}$$

For that, the following condition is required to be satisfied:

$$\frac{(t_i + \Delta t_i)P}{t_i} \le P_i \le 1. \tag{14}$$

From (13) we conclude that the lesser number is some i^{th} work completion time reserve Δt_i respective to t_i, the lower is the lower P_i limit, reaching the minimum value of P_{allow} for the critical stage works. i.e. when $\Delta t_i \to 0$, at $P_{i\,min} = P$ and $P_{i\,max} \to 1$. For example, at $P = P_{allow} = 0{,}9$ and $\Delta t_i = 0{,}05 t_i$, using (13), we find that $P_i = 0{,}945$.

$$\Delta t_i > 0.11 t_i, \tag{15}$$

i.e. for the reserve work time which is 11% above the assigned expected completion time, their implementation reliability is equal to one.

The works not satisfying (15) are characterized by the P_i probability of successful completion within the allowed time

$$(t_i + \Delta t_i)\, P \;\; (t_i + \Delta t_i), \tag{16}$$

$$P_i = \frac{(t_i + \Delta t_i)P}{t_i}.$$

And they comply with the condition:

$$\frac{(t_i + \Delta t_i)P}{t_i} \le P_i \le 1. \quad (17)$$

From (12) we conclude, that the lesser is Δt_i, respective to t_i, then the lower is the lower limit for P_i, reaching its minimum P_{allow} for the critical stage works, i.e. when $\Delta t_i \to 0$, this function is linear at the proportionality coefficient of $\frac{\Delta t_i^t}{t_i}$, at that $P_{i\,min} = P$ and $P_{i\,max} \to 1$.

For example, at $P = P_{allow} = 0{,}9$ and $\Delta t_i = 0{,}05 t_i$ $P_i = 1{,}005 \times 0{,}9 = 0{,}9045$.

4 Conclusions

An expression has been obtained for the project duration defined by the maximum permissible project time with regard to the selected reserve.

The minimum permissible value of the probability P_{add} was defined for the project reliability, as well as the values of the time reserves that ensure that the project reliability is close to one.

An equation has been obtained for solving the problem of the coordinated selection of innovative and investment projects, which optimises the selection of the best set of projects with the given financial and time constraints.

As the cost and the duration of the project are an important subject in the coordination of interests between the customer and the project developer, the obtained dependences of these functions with account of the project reliability can be the basis of the coordination of the parties at the stage of concluding an engineering contract.

References

[1] Schumpeter J A 1982 *Theory of economic development*

[2] Kolobov A, Kochetkov V, Omelchenko I 2007 *Knowledge-intensive industries innovative activity economics*

[3] Nokes S, Major I, Greenwood M, Goodman M 2004 *The Definitive Guide to Project Management: Every executives fast-track to delivering on time and on budget*

[4] Meredith J R, Mantel S J 2011 *Project Management: A Managerial Approach*

[5] Mantel S J, Meredith J R, Shafer S M, Suton M M 2013 *Project Management in Practice*

[6] Kerzner H 2013 *A System Approach to Planning scheduling and controlling*

[7] Yourdon E 2001 *Managing High-Intensity Projects 1st Edition*

Author

Ilana Ter-Saakova, 1975, Riga, Latvia

Current position, grades: Chairman of a Board AS Alida Turs
University studies: PhD BSI
Publications: 4