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TIME RESOURCES OPTIMIZATION FOR AN INVESTMENT PROJECT

The article considers the issues of optimization of time resources for an investment project on the case study of constructing the first integrated gas chemical facility in the Republic of Kazakhstan. A discrete event model is offered as an instrument for this research, it was constructed by means of "Anylogic".

Keywords: *investment project; resources; works; optimization; model; process modelling; Monte Carlo method.*

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ОПТИМІЗАЦІЯ ЧАСОВИХ РЕСУРСІВ ІНВЕСТИЦІЙНОГО ПРОЕКТУ

У статті розглянуто питання оптимізації часових ресурсів інвестиційного проекту на прикладі проекту будівництва першого інтегрованого газохімічного комплексу у Республіці Казахстан. Інструментом дослідження запропоновано дискретно-подієву (процесну) модель, реалізовану через систему "Anylogic".

Ключові слова: *інвестиційний проект; ресурси; роботи; оптимізація; модель; процесне моделювання; метод Монте-Карло.*

Рис. 9. Табл. 2. Літ. 11.

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ОПТИМИЗАЦИЯ ВРЕМЕННЫХ РЕСУРСОВ ИНВЕСТИЦИОННОГО ПРОЕКТА

В статье рассмотрены вопросы оптимизации временных ресурсов инвестиционного проекта на примере проекта строительства первого интегрированного газохимического комплекса в Республике Казахстан. В качестве инструмента исследования предложена дискретно-событийная (процессная) модель, реализованная в системе "Anylogic".

Ключевые слова: *инвестиционный проект; ресурсы; работы; оптимизация; модель; процессное моделирование; метод Монте-Карло.*

Problem statement

One-sided development of Kazakhstan's oil & gas sector, oriented solely on mining and further export, has lead to nearly total absence of the national gas chemical production. Associated oil gas is a valuable raw material, however, it is either burnt right on oil fields, or after preliminary preparation is being used for internal needs, at best.

For further industrial innovative development of the Republic of Kazakhstan creating oil & gas chemical facilities of the world advanced level is of major importance. For organization of such joint productions investment projects are to be developed which would be one of the corner stones of Kazakhstan's economic competitiveness. One of such investment projects is the construction of the first integrated gas chemical facility in the Atyrau region. One of the key tasks at development of this project is to estimate the duration of this construction and how to optimize it, since this project includes quite a number of interrelated stages.

Literature review

The first works on creation of the efficient calendar plans were written in the USA in the 1950s. As a result of these first attempts Walker and Kelly (1961) created

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a simple and rational method for describing a project, later called Critical Path Method (CPM). At the same time a special project was developed for the US Navy for the analysis and evaluation of their programs, called Program Evaluation and Review Technique, or PERT. The major difference between these two methods is that in the former one the duration of works, included into a project, were considered already determinated, while in the latter one their duration was estimated in terms of probability.

In the USSR the development of methods for assessment and optimization of project resources dates back to 1959, right after the first American publication on networks methods (CPM and PERT). The first works on this matter in the USSR belonged to Razu, Zukhovitskiy and Radchik (1965).

The beginning of the 1970s saw the development of brand new network models, much more flexible and powerful than the counterparts abroad. At the same time methods for constructing the alternative network models were developed further, for example, by such Soviet (later Russian) scientists headed by Pospelov (1976). In the 1980s basing on the concept of program target approach such instruments were developed as network matrices, information technological models and matriced for distribution of managerial tasks. A significant contribution to the development and practical implementation of such organizational toolkit in management was done by Bryanskiy & Ovsyannikov (1983).

Among Kazakhstani studies on the efficiency estimation of innovative (investment) project we would mention the works by Abdygapparova (2003) and Seytkazieva (1998).

Currently, the most popular research on calendar planning and resource planning are focused on software development by means of various methods of network planning and management. One of the most popular and wide spread are the Microsoft Project by Microsoft Corp., USA; the Open Plan by Welcom Corp., USA; Primavera by Primavera Systems, Inc., USA. In Kazakhstan quite well-known is also the software toolkit Project Expert by Pro-Invest-IT (Russia).

The analysis of the abovementioned software has demonstrated that the majority of them use only solely the methods of project analysis.

Their common drawback is the complexity of introducing changes for a particular task, which might be different from a typical one. Other common drawbacks include high prices for further consulting and support.

A more flexible tool for network project analysis is the simulation process modelling by means of Anylogic. This instrument enables the developers to take into account each particular aspect of a modeled system with various levels of detalization.

The analysis of the tasks solved by means of Anylogic has demonstrated that prior to this study there were no, to the best of our knowledge, works on network projects and process modeling within Anylogic (Karpov, 2009).

The objective goal of this research is the optimization of time factors of an investment project by means of multivariant calculations within Anylogic, taking the case study of a construction project of the first integrated gas chemical facility in the Atyrau region.

The first stage in our research will be the construction of technological configuration of production, as presented in Figure 1.

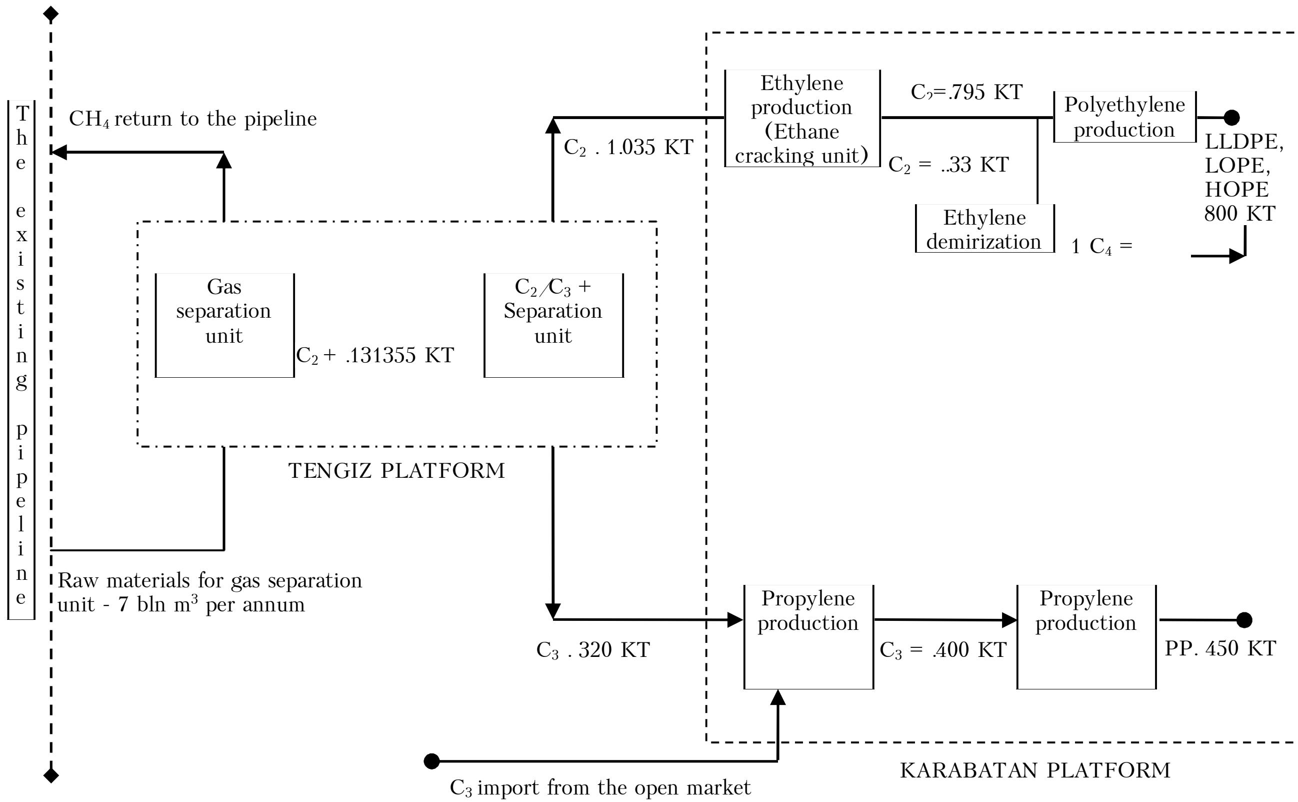

Figure 1. **The preliminary technological flowchart of a project,** *developed by the author*

As we can see from Figure 1, for a gas separation plant it is suggested to convert the dry gas, coming from the existing pipeline into 3 major products, that are commercial gas (methane), ethane and propane.

Ethane and propane would be transported separately via the pipelines of the gas chemical facility to technological units. Commercial gas is to be pumped back to the main pipeline.

Ethane after being transported from the gas separation plant via the pipeline will be further piped to the ethane cracking unit. If it turns out that the cracking facility is inactive, ethane going from the gas separation unit will be blended with commercial gas.

The propane from the gas separation unit would go to the place called Karabatan as a raw material for the propane dehydrogenation facility. If this facility can not be activated in the process, propane would fill bullet tanks in which it can be stored for up to 5 days. In case the propane dehydrogenation facility stays inactive for a longer period, the offload would be suspended, and the propane in its vapour phase would be blended with commercial gas.

This would enable the operations of all other units within a gas chemical facility (the ethane cracking unit and the polyethylene production unit) in the regular mode.

For the technological support for production, the construction of infrastructure objects is treated as a separate project, the results of which make the grounds for further operation of the key project which is realized in 2 stages: the first stage is the establishment of production facilities for polypropylene production, working capacity 500 ths t per annum; and the second stage – the establishment of polyethylene production, working capacity 800 ths t per annum.

In this article let us consider the application of process modelling for time optimization of the first stage in such a project. Narrowing this particular study to the first stage only does not decrease the generalization opportunities of the suggested modelling technique, the same time optimization can be also applied to the whole investment project.

To finish a project on time, it is needed to control the time of finishing each part of the work within it. The key peculiarity here lies in the interrelation between works. Some operations depend on other operations and can not be started until the previous part of works has been done. At this, we need to note that the time of finishing one part of work may be random.

Thus, the significant difference of the CRM method realized by means of simulation modelling in Anylogic, from the traditional methods of network modelling lies in the multiple selection of time for works performance basing on the rule of works duration differentiation.

The parameters for such differentiation are determined basing on the statistical data and expert estimations.

As a result of reconsideration of the list of works for the first stage of the project (the polypropylene production) a table is constructed to show the connection between different types of works and the averaged time needed for their performance (see Table 1).

Table 1. **List of works for the first stage of the project,** *developed by the author*

Work	Description of the nature of works	The preceding works	Time needed for works, in months
A	Organization of project financing	-	5
B	Determining the source for raw materials and laboratory tests	-	6
C	Projecting the major production facilities	A	4
D	Selecting the contractors for supple and construction works	A	3
E	Preparing documents for licensing and expert evaluation	A	1
F	Expert evaluation	E	4
G	Construction works on major facilities (polypropylene production, Stage 1)	D, F	14
H	Signing the contracts with the suppliers of raw materials. Installation works on construction for Stage 1	C	12
I	Pilot operation on the constructed unit	G, H	2

Basing on Table 1 let us present graphically the first stage of the project (Figure 2).

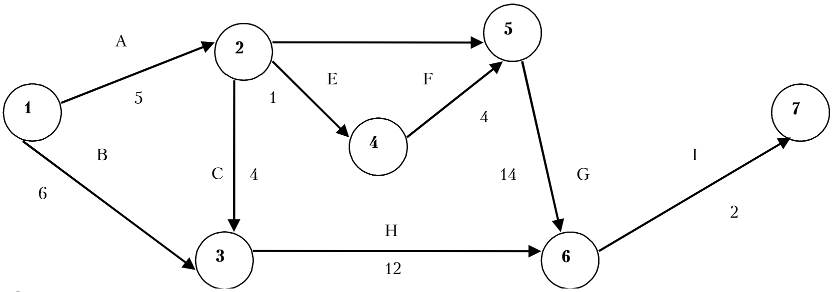

Figure 2. **The network chart of the first stage of the project,** *developed by the author*

The network chart depicts the topology of the network. Each node in the graph presents the event of the work start or works ending within the list of work to be performed during the first stage of the project. The edges of the graph show the directions of moves. The duration of the works is described by the resources. In this way the task is formalized by means of discrete event simulation. The model for simulation of all the processes within the first stage of the project by means of Anylogic is presented in Figure 3.

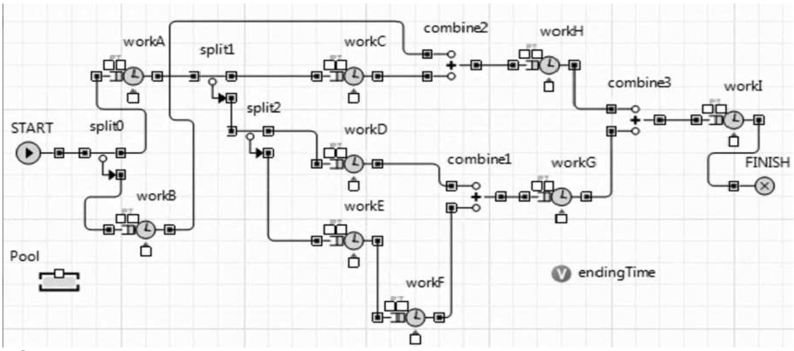

Figure 3. **The discrete event model of the first stage of the project,** *developed by the author*

The process is described by means of objects within the Anylogic library.

Start (object "Source" is often used as a starting point in the flow of applications). In the model presented the object is titled "Start" and it serves for establishing the beginning of works under the project.

Finish (the object "Sink" as a rule is used as the ending point in the applications flow). In the model presented this object under the title "Finish" serves to end the modelling and determine the time of the projects works in their variety of realizations.

Within the project Work A, ...Work I are realized by means of the object "Service" which covers the predetermined amount of the resources of a given type. In the model presented these are time resources which are predetermined: in the first variant – by the average time needed for works performance, see Table 1; in the second variant – by random deviation of the works beginning and also by the average time left to end works; and in the third variant – by random deviation from the average time of the corresponding works' performance.

Split0, Split1, Split2 (the Split object for each incoming application is creating a given number of new copy applications for sending them further through the port "Outcopy". The whole procedure is performed in zero time). In the model this object is used for organization of generation of one and the same preceding work for various further works.

Pool (the object "ResourcePool" predetermines the set of resources which could be captured by the applications by means of the objects "Seize", "Release" and "Service"). In the model this object predetermines time resources of the projects for Work A ... Work I. Resources are generated as individual objects.

Combine1, Combine2, Combine3 (the object "Combine" waits for the arrival of two applications to the ports in1 and in2, random order, and then creates a new application, then directing it to the outcoming port). In the model these objects are applied in the case when the works require finishing several preceding works.

The objects are joined together via ports which are the visual interface elements. As the result of modeling a Gannt chart is constructed automatically. The structure of such Gannt chart is presented in Figure 4.

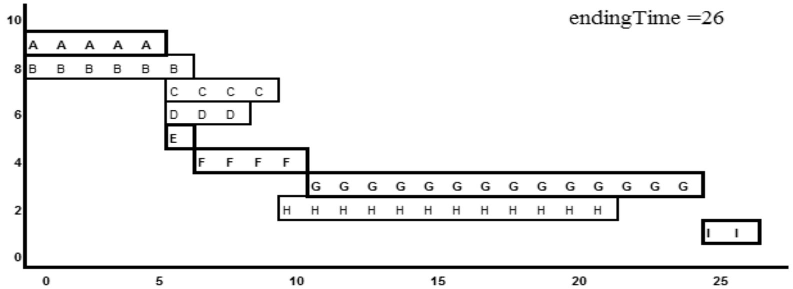

Figure 4. **The Gannt chart, variant 1,** *developed by the author*

The chart shows that the total duration of the first stage of the project is 26 months, the same duration is shown by the variable endingTime which is derived from the model presentation. The critical path is comprised of the works A, E, F, G, I (in Figure 4 these works are in bold). All other works are not considered to be critical. Reducing the duration of any of these works will not influence the time of the project ending. However, changing the duration of any of the critical works will impact the total duration of the project. Critical works do not have time allowance, their reserve on that is equal to zero. Looking at the forward and return pass on the Gannt chart we can determine the early beginning and the early ending, late beginnings and late endings of events and thus calculate time reserves (Table 2).

Table 2. **Calculating the reserves for project works,** *developed by the author*

Work	Time reserve	Early beginning	Early ending	Late beginning	Late ending	Reserve
A	5	0	5	0	5	0
B	6	0	6	6	12	6
C	4	5	9	8	12	3
D	3	5	8	7	10	2
E	1	5	6	5	6	0
F	4	6	10	6	10	0
G	14	10	24	10	24	0
H	12	9	21	12	24	3
I	2	24	26	24	26	0

Let us introduce the parameter of duration into the model, this new parameter will determine the duration of the works D. Then the sensitivity analysis is carried out for it, and Figure 5 presents the analysis of the works duration at increasing time reserves for these works by 2 months.

project duration										
0	1	2	3	4	5	6	7	8	9	10
26	26	26	26	26	26	27	28	29	30	31,5

Figure 5. **The analysis of the time reserves exceeded, works D,** *developed by the author*

In Figure 5 it is clearly visible that the exceeding time reserves by 2 months would increase the total duration of the project.

Let us change the constant value of the works duration by making it random and deviating from the average value by the ratio determined by the triangular distribution. Let us introduce into the model the parameters of this triangular distribution: min = 0,95; max = 1,4; mode = 1,1. And into the properties of the object Work1 we enter the formula from Figure 6.

	Service <T extendsEntity>	Application Grade	Entity
Packet	om.xj.anylogic.libraries		
Resource amount D	1		
Time exceeding D	5*triangular(min,max,mode)		
Object ResourcePool D	Pool		

Figure 6. **The properties of the object (works) Work 1,** *developed by the author*

The obtained Gannt chart in the results of the loss on the model of this variant is comparable to Gannt chart of the Variant 1 (see Figure 7).

Comparing the charts, one can see that a random shift of works' beginning in time causes the prolongation of the total duration of the project up to 32 months.

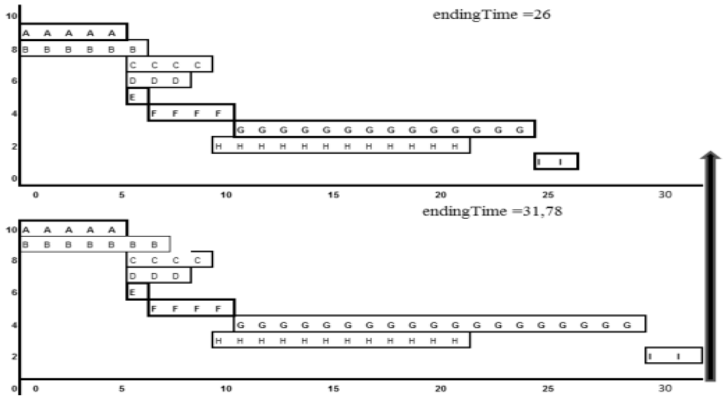

Figure 7. **Comparing the Gannt charts, Variants 1 and 2,** *developed by the author*

Comparing the charts one can easily see that random deviations in the beginning of the works have caused the prolongation of the total duration of the works G, and thus, also the prolongation of the first stage of the project in general.

In the third variant of calculations all works' durations are given as random variables, then the Monte Carlo experiment is performed. Its results allow constructing the distribution histogram (Figure 8) according to the statistics on the project's duration (Figure 9).

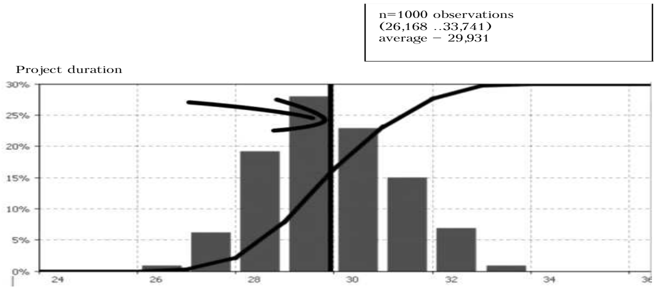

Figure 8. **The histogram of the project duration,** *developed by the author*

Minimum	26,168
Maximum	33,741
Mean square deviation	1,376
Confidence internal for the mean	0,085
Mean	29,931

From	Till	Probability density	Integral distribution
24	25	0	0
25	26	0	0
26	27	9	9
27	28	62	71
28	29	192	263
29	30	280	543
30	31	229	772
31	32	150	922
32	33	69	991
33	34	9	1000
34	35	0	1000

Figure 9. **A fragment of statistics on the project duration (Monte Carlo variant),** *developed by the author*

The Monte Carlo experiment (at random deviations of each work duration) has demonstrated that 1000 measurements resulted in the average duration of the project being equal to 30 months.

Conclusions

By means of Anylogic model we have calculated various scenarios of the project under study. The modelling included calculating the time needed for the project at various assumptions about works duration. Applying the Monte Carlo method the works durations were determined on the basis of the planned average value multiplied by the random coefficient calculated by generation of means of random values distribution. As a result, the minimum and the maximum terms show the time period within which the presented project should be planned.

Thus, on the grounds of the experiments carried out with the model, a new scheme is suggested (Figure 3) by which there is a 99% probability that the planned duration of the first stage of the project, described in this article (see Table 1 for details) would be within 26–34 months. At this the optimal time is suggested as 30 months.

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