IOP Conference Series: Materials Science and Engineering

PAPER • **OPEN ACCESS**

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To cite this article: Sergey Yashin *et al* 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **497** 012063

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Three-dimensional method of assessing R&D projects using real put options

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Abstract. Despite a good number of scientific developments in innovation, most studies suggest that the most effective innovation project should be only selected for a group of economic indicators related to investment. In practice, it is necessary to create a method for assessing the effectiveness of innovative projects based on the use of economic, innovative, socio-economic, environmental-economic and other indicators. For that end, this article proposes a set of tools for the formation of a set of multi-dimensional integral indicators to bring them to a comparable form, develops a graphical method of forming a group of effective innovative projects based on the Pareto principle, develops a three-dimensional method for assessing the effectiveness of projects based on the principle of "prospects / costs / innovation" complementing the Pareto principle with the risk assessment of innovative projects, which can be carried out using a real put option to abandon a project in the future.

1. Introduction

In modern economic conditions, a corporate innovation policy involves the formation of a portfolio of innovative projects and the selection of the most effective one out of them. However, the complexity of the selection for the implementation of an innovative solution includes the need to take into account many conflicting indicators [1]. This gives rise to the need for a comprehensive analysis of the effectiveness of implicating innovations related to the implementation of innovative projects in the economic turnover of a business enterprise, for determining not only the economic efficiency of scientific and technical developments, but also social, environmental and other performance indicators of projects. As can be seen from the above, an important task includes the formation of methods for assessing the effectiveness of innovative projects, allowing to take into account all aspects related to their implementation [2-5].

Despite a certain community of methods for assessing the effectiveness of investment and innovation projects, the latter have a number of specific features, which are due to the following factors: a wider range of participants, the mandatory comparative analysis of project performance indicators, the assessment multicriteriality, and the fundamental novelty of the object of implementation. In addition, the selection of a set of the most profitable innovative projects should be supplemented with a project risk assessment, which can be carried out using a real put option to abandon a project in the future. This is the research objective of this paper.

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2. Three-dimensional method for performance evaluation of R&D projects

2.1. Tools for the formation of a set of multi-dimensional integral indicators

In a comprehensive review of a task at hand, all areas of evaluation can be reduced to five types of project effectiveness, each of which characterizes its own aspect of the implementation of an innovation project. Thus, the evaluation of an innovative project involves the determination of the level of its effectiveness by a set of integrated indicators characterizing the economic, innovative, social, environmental and other aspects of investment (table 1).

Table 1. Matrix of multi-criteria evaluation of innovative projects.

IP performance indicators	Project				Basic indicator	Significance coefficient
	No. 1	No. 2	No. 3	*N*		
1	2	3	4	5	6	7
1. Economic indicators						
1. Net present value (NPV), RUB	q_{111}	q_{211}	q_{311}	q_{N11}	$X_{11\max}$	C_{11}
	X_{111}	X_{211}	X_{311}	X_{N11}		
2. Internal rate of return (IRR)	q_{112}	q_{212}	q_{312}	q_{N12}	$X_{12\max}$	C_{12}
	X_{112}	X_{212}	X_{312}	X_{N12}		
3. Discounted pay-back period (DPBP)	q_{113}	q_{213}	q_{313}	q_{N13}	$X_{13\max}$	C_{13}
	X_{113}	X_{213}	X_{313}	X_{N13}		
4. Profitability index (PI)	q_{114}	q_{214}	q_{314}	q_{N14}	$X_{14\max}$	C_{14}
	X_{114}	X_{214}	X_{314}	X_{N14}		
5. Accounting rate of return (ARR)	q_{115}	q_{215}	q_{315}	q_{N15}	$X_{15\max}$	C_{15}
	X_{115}	X_{215}	X_{315}	X_{N15}		
Overall indicator for the group (Q_{i1})	Q_{11}	Q_{21}	Q_{31}	Q_{N1}	–	–
2. Technical-economic indicators						
1. Project intellectual demand (*R*)	q_{121}	q_{221}	q_{321}	q_{N21}	$X_{21\max}$	C_{21}
	X_{121}	X_{221}	X_{321}	X_{N21}		
2. Project patent security (*P*)	q_{122}	q_{222}	q_{322}	q_{N22}	$X_{22\max}$	C_{22}
	X_{122}	X_{222}	X_{322}	X_{N22}		
3. Patent salability (*Ps*)	q_{123}	q_{223}	q_{323}	q_{N23}	$X_{23\max}$	C_{23}
	X_{123}	X_{223}	X_{323}	X_{N23}		
4. Equipment reliability improvement (E_R), RUB	q_{124}	q_{224}	q_{324}	q_{N24}	$X_{24\max}$	C_{24}
	X_{124}	X_{224}	X_{324}	X_{N24}		
Overall indicator for the group (Q_{i2})	Q_{12}	Q_{22}	Q_{32}	Q_{N2}	–	–
3. Indicators of IP implementation impact on enterprise economic development						
1. Growth of enterprise market size after project	q_{131}	q_{231}	q_{331}	q_{N31}	$X_{31\max}$	C_{31}
implementation (R_G^M)	X_{131}	X_{231}	X_{331}	X_{N31}		

1	2	3	4	5	6	7
2. Increments of enterprise assets (R_G^A)	q_{132}	q_{232}	q_{332}	q_{N32}	$X_{32\max}$	C_{32}
	X_{132}	X_{232}	X_{332}	X_{N32}		
3. Increment in net profit (R_G^{NI})	q_{133}	q_{233}	q_{333}	q_{N33}	$X_{33\max}$	C_{33}
	X_{133}	X_{233}	X_{333}	X_{N33}		
4. Increment in sales revenue (R_G^{NS})	q_{134}	q_{234}	q_{334}	q_{N34}	$X_{34\max}$	C_{34}
	X_{134}	X_{234}	X_{334}	X_{N34}		
Overall indicator for the group (Q_{i3})	Q_{13}	Q_{23}	Q_{33}	Q_{N3}	–	–
4. Socio-economic indicators						
1. Reduction of accident effects ($E_{\downarrow\mathrm{AE}}$), RUB	q_{141}	q_{241}	q_{341}	q_{N41}	$X_{41\max}$	C_{41}
	X_{141}	X_{241}	X_{341}	X_{N41}		
2. Expansion in number of jobs (N_{NJ}), pcs	q_{142}	q_{242}	q_{342}	q_{N42}	$X_{42\max}$	C_{42}
	X_{142}	X_{242}	X_{342}	X_{N42}		
3. Employee salary increase ($\overline{S}$), RUB	q_{143}	q_{243}	q_{343}	q_{N43}	$X_{43\max}$	C_{43}
	X_{143}	X_{243}	X_{343}	X_{N43}		
Overall indicator for the group (Q_{i4})	Q_{14}	Q_{24}	Q_{34}	Q_{N4}	–	–
5. Eco-economic indicators						
1. Reduction of environmental emissions (ΔV_E)	q_{151}	q_{251}	q_{351}	q_{N51}	$X_{51\max}$	C_{51}
	X_{151}	X_{251}	X_{351}	X_{N51}		
2. Noise reduction (ΔL_N), dB	q_{152}	q_{252}	q_{352}	q_{N52}	$X_{52\max}$	C_{52}
	X_{152}	X_{252}	X_{352}	X_{N52}		
3. Reduction of SHF and ionizing radiations (ΔL_I), W	q_{153}	q_{253}	q_{353}	q_{N53}	$X_{53\max}$	C_{53}
	X_{153}	X_{253}	X_{353}	X_{N53}		
Overall indicator for the group (Q_{i5})	Q_{15}	Q_{25}	Q_{35}	Q_{N5}	–	–
Overall indicator for the project (Q_i)	Q_1	Q_2	Q_3	Q_N	–	–

The relative estimate of the *k*-th indicator in the *j*-th efficiency group of the *i*-th project q_{ijk} is defined in two ways:

– if there is a direct relation between the effectiveness of the *i*-th project and the value of the *k*-th indicator in the *j*-th efficiency group, the calculation of q_{ijk} is carried out according to formula

$$q_{ijk} = \frac{X_{ijk} - X_{jk\min}}{X_{jk\max} - X_{jk\min}}; \quad (1)$$

– if there is an inverse relation between the effectiveness of the *i*-th project and the value of the *k*-th indicator in the *j*-th efficiency group, the calculation of q_{ijk} is carried out according to formula

$$q_{ijk} = \frac{X_{jk\max} - X_{ijk}}{X_{jk\max} - X_{jk\min}}, \quad (2)$$

where X_{ijk} – value of the *k*-th indicator in the *j*-th efficiency group for the *i*-th project.

To calculate the significance coefficients of the *k*-th indicator in the *j*-th efficiency group (C_{jk}) in Table 1, the following approach should be used. In a context of uncertainty, when the performance indicators can be ranked by priority only at a qualitative level, the significance coefficients of these indicators are calculated on the basis of Fishborn's estimates [6] according to formula

$$C_j = \frac{2(y - j + 1)}{y(y + 1)}, \quad (3)$$

where *y* – number of reviewed categories of innovation project performance indicators;

j – number of the relevant category.

The overall performance indicator of the *i*-th project Q_l is defined as a sum of non-dimensional relative estimates of all indicators q_{ijk} measured using significance coefficients C_{jk} according to the following formula:

$$Q_i = \sum_{j=1}^{5} Q_{ij} = \sum_{j=1}^{5} \sum_{k=1}^{M} q_{ijk} C_{jk}, \quad (4)$$

where Q_{ij} – overall indicator of the *j*-th efficiency group of the *i*-th project;

q_{ijk} – relative estimate of the *k*-th indicator of the *j*-th efficiency group of the *i*-th project;

$i = \overline{1, N}$ – innovation project order number;

N – number of innovation projects being compared;

$j = \overline{1,5}$ – efficiency group number;

$k = \overline{1, M}$ – number of the indicator in the *j*-th efficiency group;

C_{jk} – significance coefficient of the *k*-th indicator in the *j*-th efficiency group.

2.2. Method of graphical determination of a group of effective projects based on the Pareto principle

This method involves the determination of a subset of effective and a subset of non-effective innovative projects by the graphical method based on the Pareto principle. This makes use of the overall indicator Q_l and the relative value of original expenses for the project implementation $C_{\text{rel}.i} = \frac{C_i}{C_{\max}}$, where C_i is the value of original expenses for the *i*-th project, RUB, $C_{\max}$ is the maximum value of original expenses among the projects being compared, RUB (Figure 1).

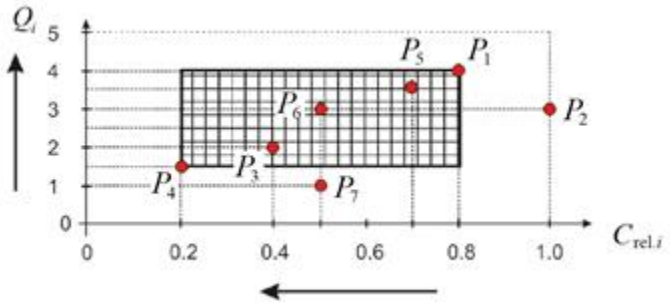


Figure 1. Method of graphical determination of subsets of "effective" and "non-effective" innovative projects.

The set of effective projects in the example shown in figure 1 includes projects P_1, P_3, P_4, P_5, P_6 determined on the basis of an analysis using the Pareto principle.

2.3. Three-dimensional PCI (prospects / costs / innovation) method

The Pareto principle presented above should be supplemented with a project risk assessment, which can be carried out using a real put option to abandon a project in the future. When it comes to voluntary reasons for terminating a project, we have to do with a situation of *exercising a real option to abandon the project* [4, 7-10].

The cost of a real put option (Put) reflects the prospects of an innovative project, taking into account the risk of abandoning its implementation. Thus, adding the designated risk component to the two-dimensional, i.e. in-plane, Pareto principle, we obtain a three-dimensional method in space that allows us to assess in more detail the effectiveness of the innovative project. Let us designate this method as PCI (prospects / costs / innovation) method. In other words, projects are first compared in a horizontal plane by the metrics of innovation (c) and costs ($C_{\text{rel}.i}$), and after selecting a set of projects according to the Pareto principle, the remaining projects are compared using the prospects metric, i.e. the real put option value (Put).

Using model [11], the expression for the real put option value of each project can be written as

$$\text{Put} = \sum_{t=1}^{n-1} L_t \, p \left(\frac{1-p}{1+r_f} \right)^t , \tag{5}$$

where L_t – project disposal value in the year t (RUB);
p – annual average probability of abandoning the project;
r_f – risk-free rate as adjusted for Russia's sovereign risk (%);
n – project term (years).

The annual average probability p of abandoning the project can be evaluated using the PERT approximate statistical estimate method [8, 12].

3. Empirical results

For individual lines of activities of BIOTA LLC laboratory, the following most promising projects were obtained.

1. Non-ionizing radiation: Project 3 – "BE meter AT-004 and 50 Hz".
2. Vibroacoustics: Project 2 – "VShV-003-M3".
3. Microclimate: Project 3 – "Iva-6N-D".
4. Lighting: Project 1 – "Testo 540".
5. Chemicals: Project 5 – "SK-2-PMZ".

Figure 2 presents a graph, which shows that according to the prospects metric, i.e. the real put option value, the most promising is Project 4, i.e. the Lighting line of activity represented by Testo

540. With a view to business diversification, it is also possible to develop Project 3, i.e. the Microclimate line of activity represented by **Iva-6N-D.**

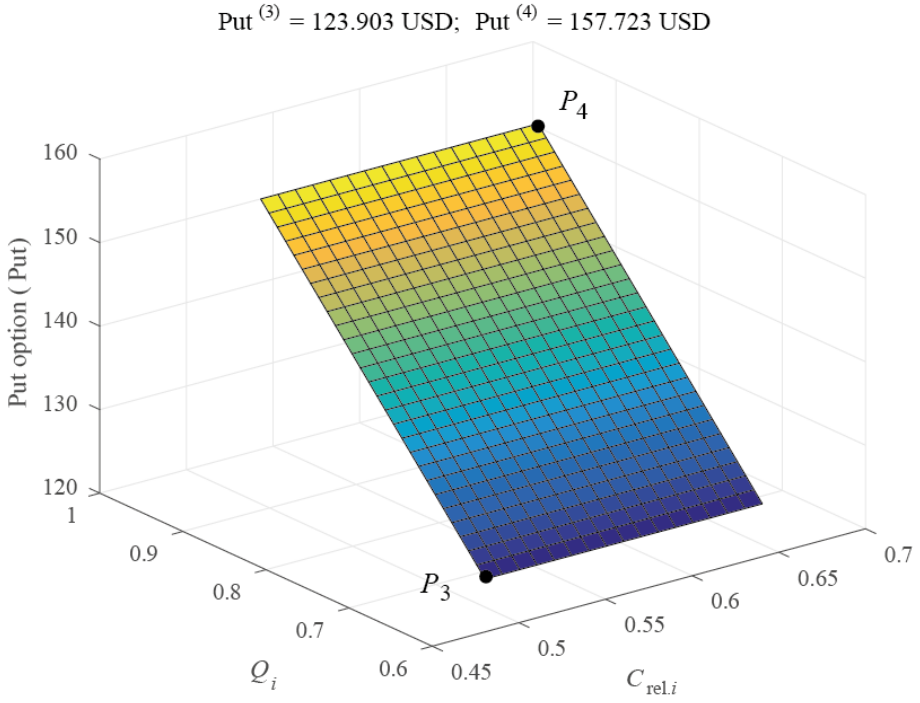


Figure 2. Three-dimensional representation of a project evaluation PCI method.

4. Conclusion

1. On the basis of the research conducted, criteria have been selected and justified to evaluate innovative projects through their comprehensive analysis based on the study of a set of indicators that reflect the main aspects of the effectiveness of innovative projects.

2. The proposed tools for selecting innovative projects by several indicators allow determining the most effective projects for the implementation by the business enterprise according to the proposed five groups of indicators characterizing their implementation by the industrial enterprise.

3. The proposed Pareto principle for the selection of a set of the most profitable innovative projects should be supplemented with a project risk assessment, which can be carried out using a real put option to abandon a project in the future. Here, the moment of the project abandonment refers to any time period of the project, except the last year.

4. For entire BIOTA LLC laboratory, according to the prospects metric, i.e. the real put option value, the most promising is Project 4, i.e. the Lighting line of activity represented by Testo 540. With a view to business diversification, it is also possible to develop Project 3, i.e. the Microclimate line of activity represented by Iva-6N-D.

Themes for future research may include calculation of probabilities of potential project abandonments in future in each and every year separately, which will allow for improving the proposed three-dimensional method.

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