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METHODICAL SUPPORT FOR THE REFLEXIVE MANAGEMENT OF COMPANY BUSINESS PROCESSES BASED ON THE THEORY OF RELIABILITY OF HIERARCHICALLY BRANCHED SYSTEMS

МЕТОДИЧНЕ ЗАБЕЗПЕЧЕННЯ РЕФЛЕКСИВНОГО УПРАВЛІННЯ БІЗНЕС-ПРОЦЕСАМИ ПІДПРИЄМСТВ НА ЗАСАДАХ ТЕОРІЇ НАДІЙНОСТІ ІЄРАРХІЧНО РОЗГАЛУЖЕНИХ СИСТЕМ

Oleksandra B. Mrykhina, Doctor of Economic Sciences, Professor
Lviv Polytechnic National University, Lviv, Ukraine
ORCID: 0000-0002-0567-2995
Email: o.mrykhina@gmail.com

Oleksandra V. Farat, Doctor of Economic Sciences, Professor
Lviv Polytechnic National University, Lviv, Ukraine
ORCID: 0000-0002-2192-4136

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Мрихіна О.Б., Фарат О.В. Методичне забезпечення рефлексивного управління бізнес-процесами підприємств на засадах теорії надійності ієрархічно розгалужених систем. Науково-методична стаття.
У статті розроблено методичне забезпечення рефлексивного управління бізнес-процесами підприємств. Обгрунтовано, що рефлексивне управління бізнес-процесами доцільно розглядати як ієрархічно розгалужену структуру. Розроблено модель оцінювання ефективності рефлексивного управління, зокрема для бізнес-процесу розроблення та підготовки технології до трансферу. Модель апробовано на технологічних підприємствах Львівської області. Для її обгрунтування використано теорію надійності ієрархічно розгалужених систем, які дають змогу: підвищити рівень точності показника готовності технології до трансферу; за допомогою рекурентних виразів встановлювати характер взаємодії елементів; розробляти часові та інші параметри для оцінювання рівня готовності технологій у межах наведеної системи; обгрунтовувати сценарії рефлексивного управління бізнес-процесами підприємств.
Ключові слова: управління, бізнес-процес, рефлексивний підхід, теорія надійності ієрархічно розгалужених систем

Mrykhina O.B., Farat O.V. Methodical Support for the Reflexive Management of Company Business Processes Based on the Theory of Reliability of Hierarchically Branched Systems. Scientific and methodical article.
The article develops methodological support for the reflexive management of business processes in companies. It is argued that reflective management of business processes should be considered as a hierarchically branched structure. A model for evaluating the effectiveness of reflective management, in particular for the business process of developing and preparing technology for transfer, has been developed. The model was tested on technological enterprises of the Lviv region. The theory of reliability of hierarchically branched systems is used for its substantiation, which allows: to increase the level of accuracy of the indicator of technology readiness for transfer; to determine the nature of interaction of elements using recursive expressions; to develop time and other parameters for assessment of the level of technology readiness within the given system; to substantiate scenarios of reflexive management of business processes of enterprises.
Keywords: management, business process, reflexive approach, theory of reliability of hierarchically branched systems

In today's rapidly changing and increasingly complex market environment, effective management of business processes is becoming a key factor in the success of organisations. The ability of companies to adapt in the global technological world and to respond flexibly to new challenges depends largely on the quality of their management processes. One of the modern concepts in this area is reflective management, which is based on a deep understanding not only of the external environment but also of the internal aspects of the company's activities, in particular the relationships between the participants in the business processes, their motivation, values and expectations. Reflective management is particularly important for innovative technology companies, as it facilitates their market agility and ensures a systematic approach to the generation and commercialisation of new technologies. Such companies are constantly faced with the need to respond quickly to consumer demands and to mitigate risks. Therefore, reflective management is a tool that allows them to effectively analyse feedback, make informed decisions and adjust development strategies.

In practice, companies apply reflective management to their technology development business processes according to their level of technology readiness. Depending on the level of technology readiness, specific methods of the reflective approach are used within the business process of technology implementation. For example, at higher levels of readiness, a technology will typically require more frequent and deeper reflection, as this will determine the effectiveness of its transfer and commercialisation. However, to successfully implement reflective business process management, organisations often lack adequate methodological support. Existing methodologies often do not take into account the specificities of each stage of technology readiness, which complicates tactical and strategic decision making and reduces the effectiveness of management actions. This is particularly critical at higher levels of technology readiness, when an organisation needs not only to integrate all the components of its development into the business process, but also to ensure a successful market launch. The lack of methodological support therefore complicates the reflection process, slows down the adaptation to market conditions and reduces the competitiveness of the company.

One of the ways to develop the necessary methodological support is to apply the methods of the theory of reliability of hierarchical systems, which allows structuring the processes of reflective management of business processes and increasing their efficiency. In hierarchically branched systems, the key is the interaction between different levels and a clear definition of responsibilities, which allows a systematic approach to reflection and a rapid response to changes.

Integrating the methods of the reliability theory of hierarchically branched systems into the methodological support of reflective business process management will help to create more flexible and adaptive management systems that are able not only to take into account the current state of technology but also to predict its further development. This will realise a proactive approach to business process management, where an organisation can identify potential weaknesses in advance and develop appropriate measures to address them.

Analysis of recent researches and publications

A scientific search for publications on the subject of reflective management of business processes of enterprises has shown its significant representation, but all developments are fragmentary in nature. Considerable attention is paid to the study of business processes of enterprises in different contexts, which can serve to understand the specifics of the application of reflective management. For example, paper [1] presents an approach to understanding the principles of modern business process management, focusing on their unification and complexity. Paper [2] points out the value of contextual factors in business process management. The authors investigated the relationship between the maturity of business process management and its effectiveness, and identified previously unknown differences between two contextual factors (size and industry) in this regard. The development of new concepts and methodologies in this area has been explored by researchers [3-5], and the possibility of applying a reflective approach in different contexts has been investigated by [6-8].

An interesting development from a scientific point of view is that published in [9], where the authors present Business Process Management (BPM) as a certain philosophy that has been supported for many years by a number of concepts: BPM Systems, process modelling, process design, coordination and interoperability, model management, process analysis and new technologies.

Paper [10] presents the results of a study on the mediating role of knowledge exchange between organisational culture, organisational structure, technological infrastructure and process improvement in the context of knowledge management in enterprises. These elements are particularly important to consider in the practice of reflective management of business processes in innovative companies.

From a problem perspective, the authors of [11] considered business process management in terms of strategies, practical tasks and structured hierarchical organisational systems in different industries, business functions and disciplines. The researchers showed how reflection manifests itself in studies conducted in different business areas. They have identified certain common denominators that can guide further research and action and provide a basis for future reflection.

Unsolved aspects of the problem

Despite the fact that the problems of reflective business process management have been studied sufficiently thoroughly, the existing developments are of a fragmentary nature. At the same time, the complexity of the modern market's demands for methodological support of reflective business process management is growing faster than the answers to them are being developed. The disadvantages of using most of the proposed methods and approaches are the high degree of subjectivity of the assessments due to the use of expert methods and the predominance of qualitative parameters over quantitative ones. Therefore, there is a significant need to develop methodological support for the reflective management of business processes of enterprises on the basis of economic and mathematical tools, which would provide detailed quantitative assessments of business processes, which would help to substantiate scenarios for their development and the company's strategy in general. In particular, the theory of reliability of hierarchically branched systems can serve as a basis for this.

The aim of the article is to develop a methodological support for the reflexive management of business processes of enterprises (on the basis of the theory of reliability of hierarchically branched systems).

The main part

The complexity of assessing the reflexive management of business processes of technological enterprises lies in the fact that the objects of such processes – technologies contain intellectual property rights (IPR), which are one of the most difficult tasks of modern economy to analyse. Such analysis is multifactorial. Therefore, it is advisable to use the development of scientists [12], where a reflexive model of business process management in the system of innovation technology transfer is formed, as a basis for methodological support of the assessment of the reflexive management of business processes. This will make it possible to substantiate reflexive measures for the business process by the stages of technology readiness in the model [12], in particular using the methods of the theory of reliability of hierarchically branched systems, which will contribute to higher accuracy of the results. From this perspective, we will consider the reflexive management of the business process of technology development in the context of the stages of its readiness for transfer and commercialisation.

Given that the model [12] is a multilevel system, it is necessary to understand the nature of the processes in it and to take into account destabilising and enabling factors in the process of reflective technology assessment. Therefore, an important and urgent task is to create a method of reflective management of the business process of developing and preparing technology for transfer that not only allows a reasonable conclusion to be drawn about the level of technology readiness, but also shows the nature of the interaction between the components of the assessment model on the basis of reflection.

To this end, a number of steps were taken, the first of which was a statistical survey of Ukrainian technology companies in 2024. The purpose of this study was to identify problems in the area of technology transfer and commercialisation by domestic developers. The study was conducted on the basis of a questionnaire by the initiative group of the Lviv National Polytechnic University. The essence of the survey was to assess the probability of technology readiness according to the specified stages by components on a 100-point scale, reflecting a probability scale from 0 to 1. The information base of the study is based on the results of a survey of 22 participants (technology companies) of various types of economic activity in the Lviv region on the effectiveness of technology selection and evaluation at a particular stage of the above model components.

The experts involved made an assessment, noting the acceptability (deviation) of each indicator (in %). The choice of the scale in relative elements was due to the fact that in the analysed industries technologies are assessed by different indicators and even more by different scales of physical units. It should be noted that the assessment was carried out in five components. The analysis of the independence of indicators for each of the stages of these components was carried out separately in the group for each component. The summary results of the survey on these issues are presented in Table 1.

Table 1. Summary results of the survey of Ukrainian technology companies*

Experts	Components	Stages								
		Consumer value of the technology								
1	100	92	93	92	94	92	96	94	98	97
2	96	93	94	98	93	93	95	96	96	97
3	98	92	94	95	94	93	97	96	99	100
…	…	…	…	…	…	…	…	…	…	…
22	98	92	94	94	95	96	98	97	98	97
		Competitiveness of the technology								
1	97	93	92	94	93	95	94	97	98	98
2	97	92	93	93	95	94	97	98	96	97
3	96	91	93	93	94	94	96	98	96	100
…	…	…	…	…	…	…	…	…	…	…
22	100	92	90	94	93	94	95	97	96	98
		Technology readiness of the technology								
1	98	91	92	94	93	95	98	97	97	99
2	99	93	92	94	95	93	96	97	95	96
3	96	91	91	92	93	94	92	99	94	98
…	…	…	…	…	…	…	…	…	…	…
22	98	94	93	94	92	94	96	94	98	97
		The cost of the technology								
1	97	93	92	93	93	94	96	97	98	96
2	97	91	93	92	95	93	95	95	95	99
3	98	93	96	92	93	96	95	98	97	99
…	…	…	…	…	…	…	…	…	…	…
22	99	94	91	93	93	97	98	98	96	98
		The riskiness of the technology								
1	97	92	93	93	94	95	97	97	99	96
2	96	91	92	94	93	95	96	97	97	98
3	98	95	91	93	97	95	96	98	98	99
…	…	…	…	…	…	…	…	…	…	…
22	97	94	95	94	95	95	96	96	95	98

Source: authors' own elaboration

In all calculations, the significance level is α = 0.05; the error is 1 point; the variance does not exceed 4. Under these conditions, the required sample size is n=12,06 representatives of business entities involved in the survey. We will conduct an initial study of the sample by calculating the following indicators: $\overline{P}_i$ – is the average of the scores for the i-th indicator of the technology training component; σ_i^2 – is an unbiased estimate of the variance of the i-th indicator of the technology training component; σ_i – is the standard deviation of the i-th indicator of the evaluation of the technology training component; D_i – is the variance value of the i-th indicator of technology training component assessment; $(\overline{P}_i - \Delta_i; \overline{P}_i + \Delta_i)$ – confidence interval for estimating the i-th indicator of the technology training component with probability 0,95.

The calculated indicators of the study components of the business process evaluation of technology preparation for transfer and their corresponding stages are presented in Table 2.

Table 2. Results of statistical analysis of indicators for assessing the business process of preparing technology for transfer

№	Stages	$\overline{P}_i$	σ_i^2	D_i	s_i	ν_i	Δ_i	$\overline{P}_i - \Delta_i$	$\overline{P}_i + \Delta_i$
1.		98,61984	1,144539	0,945065	1,08477	0,923763	0,927618	98,19743	99,63927
1.1	1	92,292744	1,3119827	0,9622994	1,1287640	0,929875	0,5394768	91,98712	92,799876
1.2	2	92,0578498	1,0909282	0,799188	1,0987787	0,0098389	0,4999873	91,762071	92,9987105
1.3	3	93,061738	0,9894362	0,6008352	0,9467567	0,0873004	0,4210946	91,665103	93,982093
1.4	4	93,858173	0,87778714	0,6223921	0,9247859	0,0666783	0,3909851	93,476168	94,2876654
1.5	5	94,778923	1,0922345	0,8438766	1,02244569	0,013345	0,4586252	94,398217	95,220091
1.6	6	96,0461789	1,2245789	0,8234978	1,1234987	0,0113333	0,4944568	95,59813	96,237848
1.7	7	97,0234589	1,142349	0,835928	1,0719738	0,0177786	0,4703324	96,523481	97,467337
1.8	8	97,1783793	1,8293927	1,0437467	1,34564564	0,01546512	0,5787686	96,534356	97,689678
1.9	9	97,5780003	1,29797979	0,843636356	1,10436363	0,0346346	0,4864533	97,3767867	98,376867
2		98,0456456	1,0957687	0,3989991	1,0345896	0,01996123	0,4098766	97,63888	98,57823
2.1	1	92,064577	0,9635636	0,73892489	0,9564646	0,0189842	0,487123333	91,65908885	92,50923498
2.2	2	92,0467474	1,14825888	0,7320048	1,06456457	0,0787299	0,47887234	91,57787643	92049175
2.3	3	92,96746756	1,8868588	0,73124014	1,06454747	0,01999876	0,498765	92,5873455	93,45667
2.4	4	93,96756675	1,04575777	0,73340280	1,02564574	0787112222	0,8982340	93,578643	94,4892310
2.5	5	94,5934789	0,8634599	0,73409844	0,92787879	0877654001	0,90838666	94,178765	94,989789
2.6	6	95,6999604	1,4333333	0,98927378	1,1779999	0,0676754	0,528987	95,1987900	96,1892340
2.7	7	96,7937200	0,69487583	0,62414884	0,85677888	0,6654399	0,3690889	96,345629	97,19345
2.8	8	97,00029	1,1456456	0,81491889	1,0446588	05656439	0,78797537	96,565435	97,4093456
2.9	9	98,93748	1,296346376	0,713124727	1,13245678	0,878665	0,4987534	97,7387865	98,99876
3.		97,5795697	0,69689000	0,634295888	0,87893235	0,065542	0,36983457	97,578723	98,292345
3.1	1	92,04674567	1,343895	0,239589259	1,16897955	0,01988532	0,5984566	91,53982340	92,598768
3.2	2	92,3824677	0,5454892	0,634928399	0,756799	0,0233499	0,32888899	92,077783	92,701240
3.3	3	92,899474	1,0234956	0,8359293	1,06789041	0,0999876	0,4490877	92,4188893	93,3067123
3.4	4	93,5767694	0,9949520	0,23542899	0,97892345	0,0866421	0,499999	93,488892	94,389432
3.5	5	94,85495948	1,4459288	1,03948293	1,19886420	0,0187765	0,5285234	94,35562	95,31239356
3.6	6	95,76934777	1,69439998	1,013534535	1,30982467	0,01009866	0,5787654	95,1911134	96,3782340
3.7	7	97,144536	1,6283429	0,97678993	1,288631290	0,07761999	0,59654	96,5894791	97,7678456
3.8	8	97,0023440	1,8429845	1,039494858	1,3467189	0,01887245	0,590834999	96,458627	97,689889
3.9	9	98, 099877	0,799900	0,55679222	0,8875198	0,087629	0,39085000	97,689234	98,3934458
4.		97,10009699	1,54534666	0,9545345	1,2724591	0,01762997	0,54846667	96,68900024	97,68987
4.1	1	92,148987	0,866899	0,69898977	0,9789098	0,08989777	0,3299765	91,7900988	92,5908751
4.2	2	92,0345098	0,9467999	0,76894	0,99854346	0,0167893	0,799900	91,57897765	92,45789
4.3	3	93,0929406	1,17892333	0,2345791	1,092455678	0,99000001	0,47889889	92,67999884	93,523455
4.4	4	93,9672096	0,7899099	0,6123456	0,56778999	0,005799541	0,3789003	93,5456784	94,500987
4.5	5	95,1789231	1,268851234	0,90998672	1,12677854	0,07899345	0,4989990	94,809344	95,567902
4.6	6	95,8094518	1,126667789	0,782405	1,06998765	0,01355588	0,46567893	95,78909764	96,3567926
4.7	7	97,1672905	0,92122344	0,68567300	0,989345	0,098753456	0,452905629	96,7890344	97,5690234
4.8	8	96,6782300	0,9494567	0,78678345	0,9899345	0,01900886	0,4217949	96,78904345	97,0823409
4.9	9	97,888890	1,6924078	0,88998344	1,0088890	0,0998765	0,6890345	97,9002000	98,2446964
5.		95,6345678	1,24888999	0,9980005	1,125693	0,08900765	0,4689004	95,089965	96,1098765
5.1	1	92,1782300	0,7782345	0,588889977	0,82345987	0,08954325	0,6789345	91,7098765	92,9833445
5.2	2	92,099877	0,69000877	0,47616788	0,709926784	0,00641909	0,3897904	91,69882456	92,1233987
5.3	3	92,89722233	1,789045	0,8798996	1,1678230	0,56789233	0,49567893	92,31999009	93,3459055
5.4	4	94,489978	1,46789045	0,978834566	1,27893451	0,01788888	0,53456788	93,0045777	95,0590842
5.5	5	94,98933445	1,39678900	0,97034867	1,178924498	0,01098034	0,517890234	94,3730923	94,88776555
5.6	6	95,68888999	1,3378992	0,95903556	1,178934525	0,01908	0,57896543	95,1609569	96,17329
5.7	7	97,0898553	0,99990887	0,648903489	0,97899323	0,01793570	0,4234556	96,4566788	97,434556
5.8	8	96,99086543	1,426722998	0,8689499	1,1789234	0,01239649	0,89006532	96,398578	97,399877
5.9	9	98,1444556	1,22239561	0,8578934	1,19087623	0,017829	0,489034556	97,6667890	98,699877

Source: authors' own elaboration

The value of the quantile t_{tab} according to Student's table for the components of the assessment of the business process of technology transfer was $t_{tabl}(n – 1, \alpha/2) = t_{tabl}(48; 0{,}025) = 2{,}01063481$.

It is worth noting that the confidence intervals for all components of the assessment of the business process of technology transfer are largely high and close to each other. The largest variation was observed in the assessment of the cost component of technology. This is due to the fact that respondents have different views on the importance of a particular component of the assessment.

The statement that the estimates of the model components are not random was tested on the hypothesis of homogeneity of the average values of the obtained sample sets for each pair of model components. It can be assumed without reservation that the sample means have a normal distribution. In order to prove the homogeneity of the components of the assessment of the business process of preparing technology for transfer, it is sufficient to prove that the null hypothesis is satisfied $H_0 : \bar{Y}_i = \bar{Y}_j$ The competing hypothesis is as follows $H_0 : \bar{Y}_i \neq \bar{Y}_j$, so the critical region is bilateral. In this case, a random variable can be used to evaluate the hypothesis

$$Z(Y_i, Y_j) = \left|\bar{Y}_i - \bar{Y}_j\right| \Big/ \sqrt{\frac{D(Y_i)}{n_{Y_i}} + \frac{D(Y_j)}{n_{Y_j}}}.$$

If $Z(Y_i, Y_j) < Z_{crit}$, then the null hypothesis is accepted, otherwise it is rejected, where the critical value $Z_{crit} = 1{,}645$ is found from the equation $\Phi(Z_{crit}) = (1 - 2\alpha)/2 = 0{,}495$, where $\Phi(Z_{crit})$ is the Laplace function. The calculated values of the pairwise interactions between the i-th and j-th components of the assessment of the business process of preparing technology for transfer are presented in Table 3.

Table 3. Calculated values of pairwise interactions $Z(Y_i, Y_j)$

i \ *j*	Consumer value of the technology	Competitiveness of the technology	Technology readiness of the technology	The cost of the technology	The riskiness of the technology
Consumer value of the technology		19,320	23,456	48,556	96,84
Competitiveness of the technology	17,230		7,689	31,578	8,356
Technology readiness of the technology	25,745	6,356		24,002	80,122
The cost of the technology	43,821	31,869	24,009		47,092
The riskiness of the technology	97,945	84,578	82,446	48,934	

Source: authors' own elaboration

As can be seen from Table 3, for all pairwise comparisons, the inequality $Z(Y_i, Y_j) > Z_{crit}$, which means that the respondents clearly distinguish the role of these components of the business process of technology transfer.

Calculation of probabilistic estimates of the completed stages of the main components of the business process of technology transfer preparation based on probabilistic readiness values (P_1) or deviation of the stages (q_1) is shown in Table 4, which is an indicative scoreboard of the hierarchically branched system for assessing the business process of preparing technology for transfer.

The next step is to develop tools to interpret the results. The evolution of many processes in nature is tree-like and branched. Therefore, mathematical models for studying the probabilistic and temporal characteristics of branched systems can be used to study such processes. In particular, these are complex systems with a hierarchical structure.

Considering the assessment of the reflexive management of the business process of preparing technology for transfer as a hierarchically branched structure (there are stages, levels, components and stages, etc.), the developments in the theory of reliability of hierarchically branched systems can be used for the above task. The application of this theory solves a whole range of economic issues related to design and operation, including the organisation of control systems, logistics, inventory management, production support, etc. Prediction of the reliability of branched systems, taking into account their characteristics (level transformation, interactions between subsystems, etc.). In a broad sense, the reliability of a system is its ability to operate without failure for a given period of time. Reliability theory is based on the concept of failure, i.e. an event that leads to a total or partial disruption of the system's performance.

Table 4. Indicative scoreboard of elements of a hierarchically branched system for assessing the business process of preparing technology for transfer on the basis of reflective management

Components	Stages of evaluation								
	1	2	3	4	5	6	7	8	9
Consumer value of the technology	Assessment of key competencies for the technology	Analysis of technology's consumer value attributes	Determining the life cycle of the technology's consumer value	Formation of the product offer	Formation of the price of technology consumption	Justification of the technology's value proposition	Establishing marketing communications with the market	Establi-shing a partnership with a technology transfer entity	Verification, correction of deficiencies and preparation of the technology value proposition assessment report
P1	**92,32**	**92,55**	**93,44**	**93,67**	**94,39**	**96,98**	**97,33**	**97,18**	**97,08**
Competitiveness of the technology	Assessment of the technology market(s)	Assessment of competitors' activities	Formation of a map of strategic management zones	Study of the legislative framework for regulating competition relations	Formation of a competitive market map	Assessing the competitive position of the technology	Assessment of barriers and opportunities for technology market launch	Quantitative analysis of the techno-logy's competitive position	Clarification and adjustment of all indicators of technology competitiveness
P1	**92,45**	**92,90**	**92,02**	**93,57**	**94,55**	**95,90**	**96,55**	**97,05**	**98,89**
Technology readiness of the technology	Formulating a hypothesis to determine the topic of research work	Research and development work	Research and development work	Design preparation for production	Technological preparation of production	Organizational preparation of production	Testing the technology in pilot production	Preparing a prototype for a business proposal	Adjustment and finalization of all technological aspects
P1	**92,05**	**92,66**	**92,89**	**93,98**	**94,34**	**95,03**	**97,89**	**97,78**	**98,88**
The cost of the technology	Economic characteristics of the technology	Estimating the cost of a technology feasibility study	Choosing an approach and method for technology valuation	Valuation of technology development	Assessment of IPRs	Estimating inflation during technology transfer	Consideration of uncertainty factors in technology transfer	Establishing the economic efficiency of the technology project	Refining the results and correcting errors
P1	**92,22**	**92,09**	**93,17**	**93,49**	**95,93**	**95,71**	**97,53**	**96,49**	**97,66**
The riskiness of the technology	Characterization of all types of risks inherent in technology development	Market risk assessment	Assessment of the risk of unsuccessful completion of R&D	Assessing the risk of insufficient resources for technology development	Patent risk assessment	Assessing the risk of technology certification failure	Identifying threats to technology transfer	Assessing the risk of inefficient scaling	Checking and adjusting all types of technology risks
P1	**92,57**	**92,03**	**92,8**	**94,38**	**94,22**	**95,39**	**97,29**	**96,29**	**98,77**

Source: authors' own elaboration

Within the framework of the reliability theory, the reliability parameters of objects are distinguished, taking into account various factors of influence. The study has shown that this theory is suitable for assessing the reflexive management of the business process of preparing technology for transfer, since:

- assessment of the business process of technology preparation for transfer is a system (has input and output elements), isotropic with simple subordination, symmetric with branching;
- assessment of each of the stages by the components of the model [12] reflects a certain level of technology readiness, which requires the determination of probabilistic estimates of technology readiness, can be expressed quantitatively;
- integral estimation of the model's output parameters shows the failure rate and, in economic terms, the generalised level of technology readiness for transfer.

One of the possible basic mathematical tools for predicting the reliability of branched systems is probability theory. In the case of the model analysed, the determination of probabilistic estimates of technology readiness for each of the assessment components makes it possible to predict the technology readiness at a certain level, which at the same time allows the application of reflection methods and the comparison of results.

To solve this problem, it is necessary to consider such categories of reliability of a branched system as product functions, recurrent expressions, and mathematical expectations of a particular event. The product function is used for discrete random variables. A discrete random variable is a random variable whose set of values is equal to the product of the random variable and its probability. Based on the product function, a recurrent expression is developed to calculate the probability distribution of the number of operating output elements. The recurrent expression can be used to determine the probability of trouble-free operation of a given number of output elements in the system. This makes it possible to determine the mathematical expectation, probability distribution and availability factor of such systems.

A group of scientists in [13] investigated methods for predicting the reliability of branched systems, based on which it was concluded that for systems with simple subordination there are no restrictions on the construction of generative functions when studying reliability characteristics.

Thus, we derive the expressions of the generative function, recurrent and mathematical expectation for the model of evaluation of the business process of preparing technology for transfer on the basis of reflection, using the theory of reliability of hierarchically branched systems. Schematically, the hierarchical system, branched to the first level, is shown in Fig. 1.

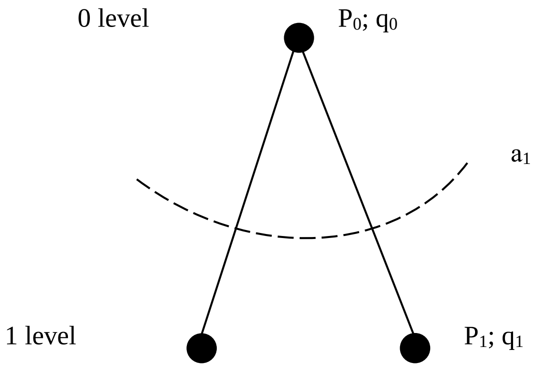

Figure 1. A hierarchical system that branches out to the first level.
Source: compiled by the authors based on [13]

Let's write down the product function of the number of working output elements of this system:

$$S_1(z) = P_0 (P_1 z + q_1)^{a_1} + q_0, \tag{1}$$

where P_0 is the probability of operation and q_0 is the probability of failure of the system elements; z is an arbitrary parameter, a is the branching coefficient.

The element of the first level has the values of these probabilities P_0 and q_0 respectively. The principle of hierarchy is realised here in such a way that the element of the highest level – the zero level – disables the element of the lower, first level in case of failure. Therefore, the operation of the first level element implies the simultaneous operation of the zero level element [13].

The elements of the lowest level of this system are the output elements of the system. As a rule, decomposition is effective for branching from three to six levels. A larger number of levels complicates the assessment with excessive detail. From the point of view of analysing the reliability of hierarchically branched systems, it is advisable to decompose the model of business process evaluation of technology preparation for transfer on the basis of reflection into two levels. The highest level (root) of the hierarchy is the technology under evaluation. The following hierarchical levels of the model are identified:

- zero level of the hierarchy (P_0): obtain the technology and justify its transferability. This level of the hierarchy corresponds to the first level of the model in [12];
- the first level of the hierarchy (P_1): clarify the possibilities of transferring the selected technology (corresponds to the second level of the above model);
- the second level of the hierarchy (P_2): selecting a technology transfer scenario (corresponds to the third level of the above model). This is shown schematically in Fig. 2.

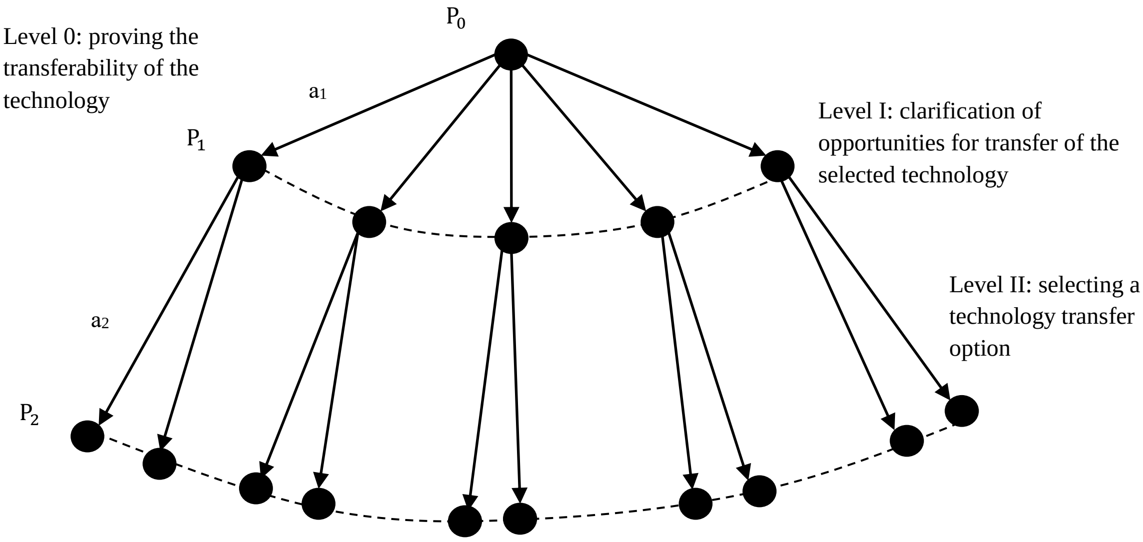

Figure 2. A hierarchically branched model for assessing the business process of preparing technology for transfer based on reflection.
Source: authors' own elaboration

On the branches P_0–P_1 and P_1–P_2 (Fig. 2) the elements of the model (stages of assessing the business process of preparing technology for transfer on the basis of reflection according to [12]) are placed. Given that the main five components of the model are between the zero and the first levels of the hierarchical system, a derivative function is formed to determine the level of technology readiness for transfer. In the classical model, it is assumed that the components of the assessment on the branches $P_0 – P_1$ homogeneous and symmetrical.

So, the expression of the product function is as follows:

$$S_1(z)_{sym}=P_0(P_1z+q_1)^{a_1}+q_0, \quad (2)$$

where P_0, P_1 are the processes of preparing a technology for transfer on the basis of reflection; $q_{0,} q_1$ are the probability of failing to pass the stage of the zero or first level of the model for assessing technology readiness for transfer; a_i is the number of branches at the i-th level of assessment (a_1=5), z is an artificial auxiliary indicator, in some cases it can be interpreted as an indicator of the relative time of bringing a technology to the market ($0 \leq z \leq 1$).

In each case, the assessment of a particular stage is determined individually and only for a specific business process and technology. This is due to their individual characteristics and peculiarities. Some technologies may not require the mandatory passage of some stages, but the complexity of their assessment may outweigh others.

Note that P_0=1, because at the zero level, when a technology is accepted for consideration, we assume that the probability of its successful transfer is 1, and the probability of its failure to be transferred is q_0=0. It is necessary to set the values of each of the elements (stages) on the branches P_0-P_1 so that they sum to 1.

The presented methodological support for the reflective management of business processes is developed on the example of the technology of OSL dosimetry of ionising radiation developed at the Lviv Polytechnic National University. According to the results of calculations using the statistical software package Statistica, the mathematical expectation of technology readiness for transfer is 81,60%. The obtained indicator indicates a sufficiently high level of technology readiness and, consequently, the effectiveness of this business process and, consequently, its reflexive management. According to the proposed model, the most "developed" aspects of the technology are "consumer value" and "competitiveness", while the weakest is "technological readiness", since the technology is still in one of the R&D stages.

Conclusions

In contrast to the known ones, the application of the theory of reliability of hierarchically branched systems within the proposed model for the assessment of the reflexive management of the business process of preparing technology for transfer makes it possible:

- to increase the level of accuracy of the technology readiness indicator;
- to determine, on the basis of recurrent expressions, the nature of interaction of elements, on the basis of which to draw conclusions about the level of technology development and features of its evaluation and transfer;
- to develop time and other parameters for assessing the level of technology readiness within the above system;
- to substantiate scenarios of reflexive management of business processes of enterprises on the basis of methods of the theory of reliability of hierarchically branched systems.

Abstract

The ability of companies to adapt in the global technological world and to respond flexibly to new market challenges depends largely on the quality of their management approaches. Reflective business process management is considered to be one of the modern concepts in this area, but the existing methodological developments for its assessment are fragmentary. Thus, the purpose of the article is to develop a methodological support for the reflective management of business processes in enterprises. It is substantiated that the evaluation of the reflective management of business processes should be considered as a hierarchically branched structure (there are stages, levels, components, stages). Developments in the theory of reliability of hierarchically branched systems can be used for this purpose. A model for evaluating the effectiveness of reflective management of technology preparation for transfer and commercialisation has been developed and tested at technological companies in the Lviv region. In order to substantiate this model, the article uses the methods of the theory of reliability of hierarchically branched systems, which allow: to increase the level of accuracy of the indicator of technology readiness for transfer; to determine the nature of interaction of elements with the help of recurrent expressions, on the basis of which to draw conclusions about the level of technology development and features of its evaluation and transfer; to develop time and other parameters for assessing the level of technology readiness within the system; to substantiate scenarios of reflexive management of business processes of enterprises on the basis of the theory of reliability of hierarchically branched systems.

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