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Tracking and predicting solution development in R&D projects using a complex assessment method

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ABSTRACT

One of the key issues in the management of R&D projects is tracking the process of their implementation, and the PR of the development of created solutions. The information about the current progress of the project and the identification of risks in different spheres of its implementation provides the possibility to take appropriate corrective actions on a continuing basis. This article presents a systemic approach and a practical application of a complex assessment of the maturity level of implementation and commercial potential in tracking and predicting the development of innovative technological solutions developed through R&D projects. It presents prediction capabilities for the development of technological solutions based on the analysis of evaluations using the example of tracking research projects conducted within the framework of the Strategic Programme, „Innovative Systems of Technical Support for Sustainable Development". The article proposes directions for further research, which, in the process of predicting the development of solutions, factors in various aspects occurring at the design stage, preparation for the implementation, and commercialization.

KEY WORDS

R&D project, tracking of a R&D project, implementation maturity assessment, commercial potential assessment

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Introduction

The main purpose of R&D projects in the area of advanced technologies is to develop innovative solutions in the form of products or process technologies, intended for implementation and commercialization. The pursuit of maximum application efficiency of the solutions developed within the framework of the projects stems primarily from the constantly increasing market competitiveness. The implementation of innovative R&D projects is usually accompanied by high risk in the technological, economic, and organisational areas. A major source of risk in the process of designing technology solutions is the uncertainty in relation to the development of the concept, the development of the model, and the development and verification of the prototype in real working conditions. Uncertainty in the design of new solutions necessitates, among others, the development of alternative solutions and an analytical search for optimal solutions using multicriterial methods and identification and risk analysis methods.

Seeking to obtain innovative solutions at the highest technical level very often is in conflict with the necessity for a rigorous procedure that is determined by the project schedule and budget. In the context of the conditions and problems listed here, project management of R&D is a particularly complex and difficult decision-making process, where special qualifications and competencies of the project manager are required. The project manager's own experience and expert knowledge used in the collaborative management of the project have a significant influence on the decision process. More and more often, in order to support R&D project management, analytical methods are applied to track the level of the advancement of the project and to assess the results obtained in terms of their implementation and commercialization.

An important issue is the prediction of the designed solution development and the assessment of the effectiveness of the project, using the method of result assessment conducted in subsequent stages of the project. Another tool for project management is a computer simulation, where, after entering the requirements and assumptions, a collection of research predictions is provided. The information about the current progress of the project and the identification of risks in different spheres of its implementation allows taking appropriate corrective actions on a continuing basis. This article presents a practical application of a complex assessment of the maturity level of implementation and commercial potential in tracking and predicting the development of innovative technological solutions in the developed research projects.

1. Methods for tracking and assessment of the progress level of R&D projects – the state of the art

The beginning of a significant development of methods of assessing the innovative technological solutions took place in the end of the sixties of the last century (Porter et al., 1980). The methods for assessing technology solutions quickly found their use in the operational management and decision-making systems (Cagnin et al., 2008). The first significant practical achievement in the development of methods for assessing technology is the development and practical application of the qualitative assessment method – Technology Readiness Levels (TRL) by NASA in the 1980s (Mankins, 1995). The US Defense Department launched the program of the TRL implementation in their projects in progress in 1999, which is now a global standard used in the evaluation of innovation (Defense Acquisition Guidebook, 2011). The result of the development and improvement of the TRL is a quantitative assessment method – Technology Readiness and Risk Assessments (TRRA), which incorporates aspects related to the risk (Mankins, 2009). Based on the gathered practical experience regarding the uses of the TRL methods, the users in a number of publications presented verified advantages of the method, as well as revealed its limitations (Fernandez, 2010).

The most important advantages of the TRL method were indicated as follows:

- a conceptual system accessible to future recipients of the developed solution and business people;
- a hierarchical algorithm for the evaluation, which is easy to understand and to use;
- the structure and the procedures that ensure repeatability of the evaluation process.

The main disadvantages that became apparent in practical applications of the TRL method include the following:

- no reference to the problem of uncertainty in the process of developing and implementing technological solutions;
- the lack of mechanisms for using the analysis results of the design process to manage R&D projects;
- limited integration with tools for simulation and analysis of risks and costs;
- lack of inclusion of product specificity such as innovative systems and information technologies.

When using the TRL, it should be remembered that the TRL scale is not linear. The technical value increments of a solution in TRL, and the expenses and labour input are different at various skill levels. A new approach, which takes into account the critical observations about the TRL evaluation, is presented in the Integrated Technology Analysis Methodology (ITAM), (Mankins, 2002). The ITAM method is a quantitative assessment of ΔTRL increments, including the difficulty of a given R&D (Research and Development Degree of Difficulty – R&D3). The ITAM method is dedicated primarily to tracking projects that are concerned with creating complex technical systems. The systemic approach for the assessment of the maturity level of technological solution implementation has been recognized and accepted as a standard by many international organizations, for example, by the European Commission (ISO 16290:2013 (Final Draft). Space systems – Definition of the Technology Readiness Levels (TRLs) and their criteria of assessment, 2013). However, the developed standard presents only a general evaluation algorithm on a scale (TRL1 – TRL9), without a detailed assessment which would take into account solution specificity. As a consequence, the proposed standard is characterized by similar limitations as the TRL method, such as failure to take important aspects of the solution development on the market. The TRL method has been recommended to assess the level of R&D progress in the course of reviewing applications for the financing of R&D projects within the framework of the European Union and also for national programmes. Its major limitation, in this case, is purely qualitative assessment of projects, which does not provide means to identify problems in the different areas. The identified weaknesses and limitations of the basic TRL method, as well as new challenges arising from technological developments, necessitate the development of more advanced and efficient methods for assessing the qualitative and quantitative solutions for R&D projects.

Primarily, the examples implemented by the US Defense Department are (Department of Defense Instruction 5000.02, Operation of the Defense Acquisition System, 2015) the Manufacturing Readiness Level (MRL) method for determining the level of preparedness for production and identifying the deficiencies and risks, and the Integration Readiness Level (IRL) method, which is implemented for assessing the maturity level of the integration and compatibility of complex systems (Gove, 2007). Critical evaluations of the TRL method primarily indicate the non-inclusion of the full preparation of the developed solution for placing it on the market and its use in the nine-point scale.

Publication (Hicks et al., 2009) presents the concept of an expanded scale of TRL, where the levels 10 and 11 represent the processes of product use and development according to the Product Lifecycle Model. In addition to the TRL method, the following are suggested: System Readiness Level, Design Readiness Level, Software Readiness Level, Operational Readiness Level, Human Readiness Level, the Habitation Level Readiness, and Capability Readiness Levels (Sauser et al., 2008). The issue of the effectiveness of the R&D projects and the methods of its comprehensive measurement are presented in a few publications (Sanchez, Perez, 2002; Laliene, Sakalas, 2014). The publications (Hage et al., 2013), (Hudson, Khazragui, 2013; Weyant, 2011) indicate that the problem of effective tracking and predicting the efficiency of conducted work is directly connected with the main causes of project failures. An example of the practical application of the TRL analysis and numerical methods to assess the level of advancement of R&D projects, and to estimate the probability of success, is presented in literature (Eckhause et. al., 2009).

The Institute for Sustainable Technologies – National Research Institute in Radom (ITeE-PIB) has proposed an original approach in assessing the development of technological solutions, taking into account the various aspects of their development. The basis of a methodology of the technological solutions evaluation (SDW) developed in 2010 is broad experience of the ITeE-PIB in the implementation of many research projects and implementation of innovative solutions in the industry. The SDW methodology is used for the quantitative evaluation of technological advancement and implementation maturity of solutions developed in R&D projects (Mazurkiewicz et al., 2010). The effect of the continued work takes into account services in the categories of rated products (Mazurkiewicz et al., 2011) and the development of a method of assessing commercial potential (PK), (Belina et al., 2012). The method of innovative solutions evaluation uses an information system that integrates both modules of assessment SDW and PK. The methodology, which developed in the ITeE-PIB, is a complex assessment of innovative technological solutions including the evaluation of implementation maturity SDW, commercial potential PK, and the level of innovation, PI (Mazurkiewicz, Poteralska, 2012). The concept of applying the evaluation of implementation maturity (SDW) and commercial potential (PK) to the tracking and evaluation of strategic projects is presented in literature (Łopacińska, 2015). Improving the effectiveness of the R&D project management using the multicriterial methods of solution evaluation is currently one of the main directions of research conducted in the ITeE-PIB in the area of project management of research projects and the transfer of innovative solutions to economic application.

2. Methodology for tracking and predicting

For tracking and prediction of innovative technological solutions, two methods were used: the maturity of implementation assessment (SDW) and commercial potential assessment (PK). The SDW method in its basic assumptions about the overall structure of the evaluation algorithm and assessment criteria base for the evaluation is similar to the method of Technology Readiness Levels (TRL), (Tab. 1).

The main features that distinguish the SDW method are: the diversity of development and applying the main division into materials, process technology, equipment, systems, and services.

The developed categorization system is two tier and open, which enables the introduction of new categories and subcategories of the developed products. In accordance with the adopted approach, the SDW system includes developed criteria bases tailored to the specificity of a given solution category. Depending on the category, the criteria base for evaluating the progress of the project implementation includes from 200 to 240 specific points concerning various aspects of the solution development.

Tab. 1. The scale of assessment of the SDW

	SDW	A general description of the solution advancement level
Product	9	Preparation of the product for the production and sales on a commercial basis
	8	Production of sample series and obtaining product compliance certificates and suitability for use permits
	7	Production of the final version of the product
Prototype	6	Verifying the prototype of the product in operating conditions
	5	Production and verification the prototype product in simulated conditions similar to actual conditions
Model	4	Checking the functioning of experimental model in simulated operating conditions
	3	Checking the functioning of the model under laboratory conditions
Concept	2	Confirmation of the correctness of the solution concept
	1	The formulation of the concept of a solution
	0	Identification and description of the basic principles of action

In the assessment of the commercial potential (PK), the analysis of a solution is carried out in the following areas: technological, market, economic, organisational, and legal. The criteria base for the evaluation contains 32 detailed points to enable the identification of the most important features of the solution. The total measure of the commercial potential is a percentage. A computer tool for conducting a complex SDW and PK assessment is a developed computer program functioning as a dedicated Web site.

The high level of the reliability of the conducted evaluations is provided by an independent external expert panel. Practical experience with the implementation of R&D projects in the ITeE-PIB showed that, for the purpose of the on-going project tracking, it is also possible to use evaluations by a team of internal experts with the participation of the project manager.

The combined SDW and PK methods for the evaluation has been applied to the current tracking of projects within the framework of the Strategic Programme, „Innovative technical support systems for sustainable development of the economy", implemented in the ITeE-PIB, between 2010-2015, including more than 60 projects where each had its own defined scientific, technological, implementation, and market goals. As part of project tracking, periodical assessment is carried out every six months concerning the level of implementation maturity of SDW and commercial potential (Fig. 1).

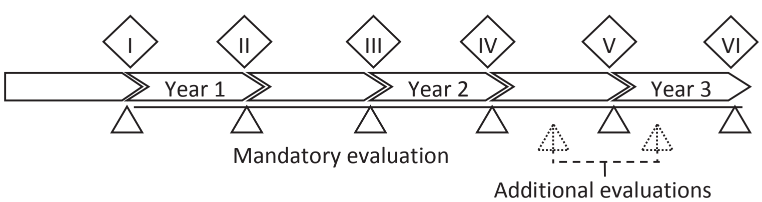

Fig. 1. Diagram of the periodical evaluations R&D project progress

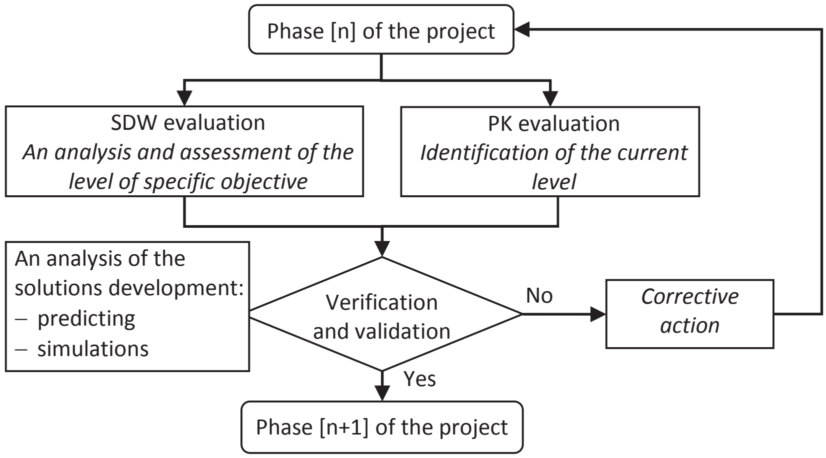

Fig. 2. An algorithm for tracking the progress of R&D projects

The tracking schedule has been correlated with milestones in projects. Depending on the specifics of the project and the progress of work, the possibility of conducting additional reviews at set points of the schedule was taken into account. Additional assessments are a particularly valuable source of information in the course of the project. The results of the evaluations were used by the project managers and the steering committee for the day-to-day management of the process, both at the operational level of individual projects, as well as at the level of the entire Programme.

The management process of the Strategic Programme uses a systemic approach, which included systematic tracking of the projects implementation. The algorithm of progress tracking takes into account the feedback mechanism that triggers corrective and recovery actions, according to the results of the evaluation at a given stage in the project (Fig. 2).

The results of the SDW and PK assessments of the project progress presented in the chart make it possible to predict and simulate further development within a selected time frame, using a mathematical 2nd order polynomial trend line (Fig. 3). The estimates of the dynamics of changes in SDW and PK indicators can be used to verify the time and cost of reaching the final objective, as well as to assess the current risk of the project. In project tracking and prediction (individual and strategic), depending on the time frame, the following classification of assessments, predictions, and development simulation is proposed:

- on-going (up to 1 month),
- short-term (up to 3 months),
- medium-term (6-12 months),
- long term (2-3 years).

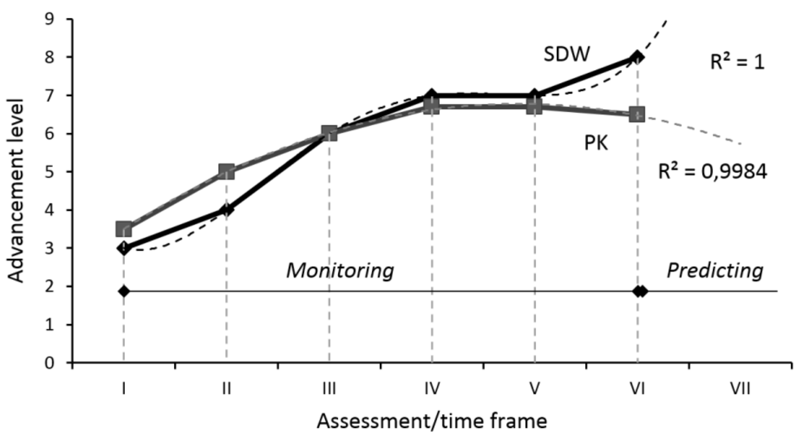

Fig. 3. A sample chart of changes in the project progress with the predictions for further development

Predicting and simulation the development of project results should take into account the significant impact of the trend line method on the process, and thus the result of obtained predictions. Reducing the uncertainty of prediction determination is possible by increasing the number of subsequent evaluations in stages prior to the point prediction. Taking into account this aspect, prediction using an analysis of trends in the characteristics of the SDW and PK should be treated with particular caution. Predicting in this form is mainly an element supporting the process of project management and requires a comparative verification using the results of other analyses. The results of the assessment of the progress level in reference to the timetable of the project implementation can be presented graphically (Fig. 4 and 5).

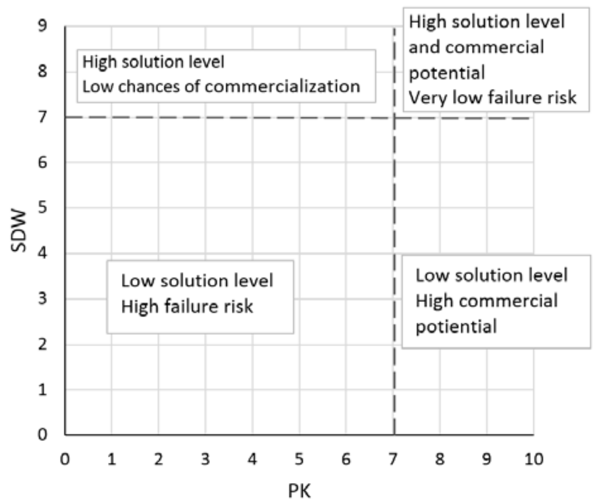

Fig. 4. Chart of the project progress of the SDW-PK framework

The methodology assumes that level 7 of the SDW scale represents highly advanced solutions, above which the technological risk of failure is very small. Similarly, in the scale of the commercial potential PK, the level of 70% marks set maximum level, above which there are high chances for commercializing the solution. In the tracking of the project implementation and the actual cost, the maximum acceptable value for both parameters is assumed to be 125% compared to the initially planned cost. A graphical presentation of the results of the SDW and PK evaluation, as well as predictions of the project deadline and budget can be used to analyse current project risks. When tracking a strategic project consisting of a number of specific research projects, the proposed charts provide a comprehensive analysis of the state of progress.

3. Examples of methodology application

The developed method has been applied to project tracking within the framework of the Strategic Programme, „Innovative Systems of Technical Support for Sustainable Development". The Programme planned the implementation of the more than 60 projects assigned to selected problem groups representing separate multidisciplinary areas of knowledge and technology. In the vast majority of projects, the planned targets include more than one result, which, in accordance with the adopted classification, are materials, process technology, methods, equipment, systems, and services. Tracking a project required, in most cases, following the

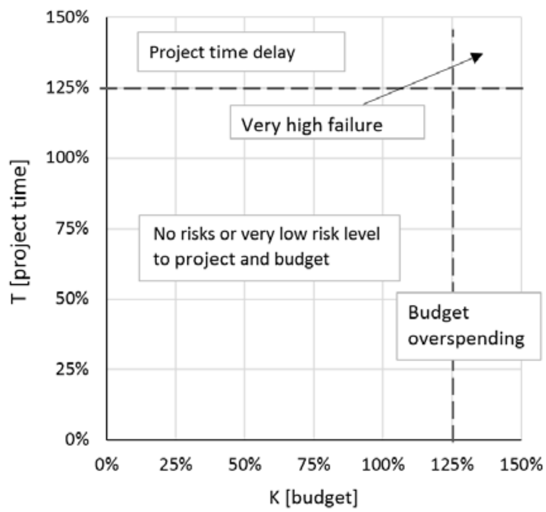

Fig. 5. The status of the project in relation to scheduled time and budget

progress of individual, planned targets. The objects of tracking and periodic evaluations for the entire Strategic Programme were nearly 150 solutions, many of which present a high level of innovation. The assessment procedures assumed a basic medium-term, six-month cycle of tracking and the prediction of the results of projects. The evaluations were carried out by a team of internal experts with the participation of the project manager and project contractors. The results of the analyses were important factors in determining the corrective actions to be taken.

Examples of the results of the implementation tracking of solutions within the framework of the project are shown in Fig. 6, where the subject of the development was a testing device for testing mechanical resistance RFID identifiers. The prediction of technology development based on the trend line indicated the possibility of achieving level 10, enabling the introduction of the solution into the

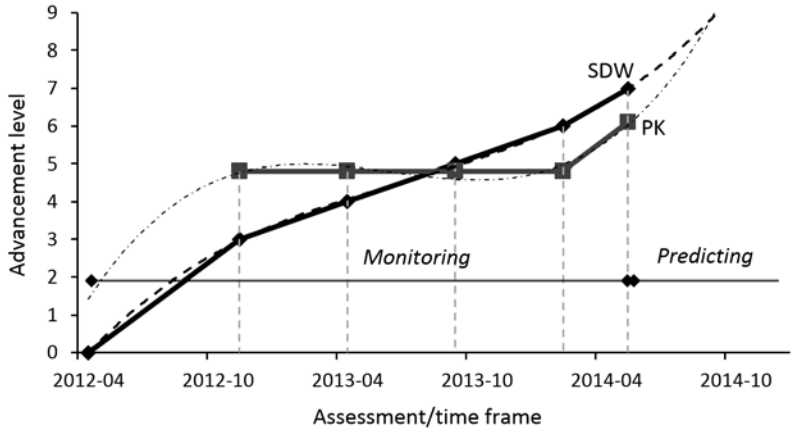

Fig. 6. The progress of the testing device development for mechanical resistance tests of RFID identifiers

market after time circa 6 months from the date on which level 7 was achieved. The observed increase in the commercial potential (PK) was primarily affected by the development of technical solutions confirmed during the verification tests of the prototype.

One of the tasks of the steering committee for the strategic Programme was to track the status of project implementation within problem groups and within the entire Programme. Examples of charts showing the aggregated results of the periodic evaluations of projects carried out in the final stage of the Programme are presented in Fig. 7 and 8. These charts show the results of the evaluations of solutions in the group of devices. Within this group, 30 products are classified. A definite majority of solutions achieved a high level in SDW and a medium or high level of PK. The projects in the group of devices were completed on schedule.

Only in one case (Fig. 8) the deadline was extended and the budget increased to circa 125% of originally assumed values for these parameters, due to the extension of the scope of work and planned results. The purpose of the extended scope of the project was the development of additional specialized machinery for which new buyers on the market were identified.

In the final stage of the implementation of the Strategic Programme, it was justified, and in some situations it was necessary to apply short-term monitoring cycles to individual projects. The tracking of particularly accountable and complex projects on a shorter-term basis increased the level of control and helped to reduce the risk of potential problems and failures.

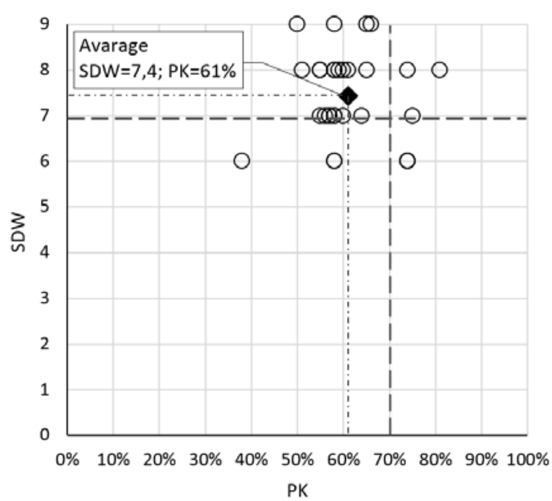

Fig. 7. A cumulative chart of progress of the projects in the SDW-PK system, for device solutions

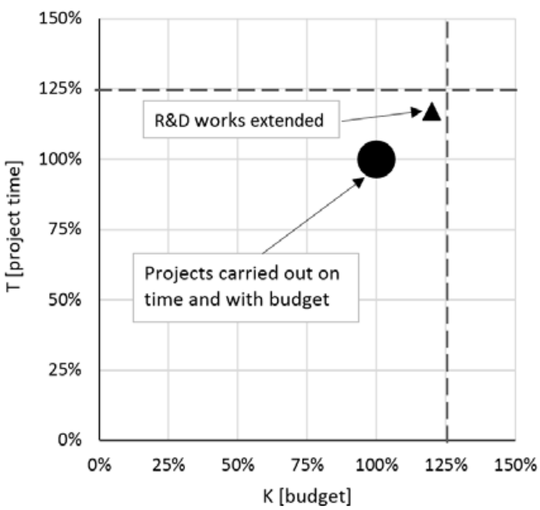

Fig. 8. The status of projects in relation to scheduled deadline and budget for device solutions

Conclusions

The method developed by the ITeE-PIB for a complex assessment of the maturity level of implementation and commercial potential makes possible to track and predict the development of innovative technological solutions in R&D projects. The method takes into account the specificities of projects which results are innovative solutions. The analysis of the results of numerous practical applications of the method for tracking project progress has confirmed its usefulness and effectiveness. Practical experience during the Strategic Programme showed that for the management support of the projects realisation in critical situations it is crucial to increase the frequency of evaluations and use their results to corrective actions at the operational level[1].

Literature

Belina B., Łopacińska L., Karsznia W. (2012), Commercial Potiencial Oriented Evalutaion of Innavitive Products, Maintenance Problems 4, pp. 23-32

Cagnin C., Keenan M., Johnston R., Scapolo F., Barré R. (2008), Future-Oriented Technology Analysis, Springer-Verlag, Berlin

Defense Acquisition Guidebook. Defense Acquisition University (2011), https://dag.dau.mil/Pages/Default.aspx [20.07.2015]

Department of Defense Instruction 5000.02 (2015), Operation of the Defense Acquisition System

Eckhause J.M., Hughes D.R., Gabriel S.A. (2009), Evaluating real options for mitigating technical risk in public sector B+R acquisitions, International Journal of Project Management 27, pp. 365-377

Fernandez J.A. (2010), Contextual Role of TRLs and MRLs, Technology Management, Sandia National Laboratories

Gove R. (2007), Development of an Integration Ontology for Systems Operational Effectiveness, M.S. Thesis, Stevens Institute of Technology

Hage J., Mote J.E., Jordan G.B. (2013), Ideas, innovations, and networks: a new policy model based on the evolution of knowledge, Policy Sciences 46 (2), pp. 199-216

Hicks B., Larsson A., Culley S., Larsson T. (2009), A Methodology for Evaluating Technology Readiness during Product Development, Proceedings of ICED 09, the 17th International Conference on Engineering Design 3

Hudson J., Khazragui H.F. (2013), Into the valley of death: Research to innovation, Drug Discovery Today

ISO 16290:2013 (2013), (Final Draft), Space systems – Definition of the Technology Readiness Levels (TRLs) and their criteria of assessment, ISO

Laliene R., Sakalas A. (2014), Development of B+R effectiveness assessment system in the research organizations, Procedia – Social and Behavioral Sciences 156, pp. 340-344

Łopacińska L. (2015), Model procesu ewaluacji strategicznych programów badawczych w obszarze innowacji technicznych, praca doktorska, Oficyna Wydawnicza Politechnika Warszawska

Mankins J.C. (1995), Technology Readiness Levels: A White Paper, Office of Space Access and Technology, NASA

Mankins J.C. (2002), Approaches to Strategic Research and Technology (R&T) Analysis and Road Mapping, Acta Astronautica 51 (1-9), pp. 3-21

Mankins J.C. (2009), Technology readiness and risk assessments: A new approach, Acta Astronautica 65 (9-10), pp. 1208-1215

Mazurkiewicz A., Karsznia W., Giesko T., Belina B. (2010), Metodyka oceny stopnia dojrzałości wdrożeniowej innowacji technicznych, Problemy Eksploatacji 1, pp. 5-20

Mazurkiewicz A., Karsznia W., Giesko T., Belina B. (2011), System operacyjny oceny stopnia dojrzałości wdrożeniowej innowacyjnych rozwiązań w zakresie usług, Problemy Eksploatacji 3, pp. 61-73

Mazurkiewicz A., Poteralska B. (2012), System of a complex assessment of technological innovative solutions, Maintenance Problems 4, pp. 5-22

Porter A.L., Rossini G.A., Carpenter S.R., Roper A.T. (1980), A Guidebook for Technology Assessment and Impact Analysis, Noth-Holland, New York

Sanchez A.M., Perez M.P. (2002), B+R project efficiency management in the Spanish industry, International Journal of Project Management 20, pp. 545-560

Sauser B., Ramirez-Marquez J.E., Magnaye R., Tan W. (2008), A Systems Approach to Expanding the Technology Readiness Level within Defense Acquisition, International Journal of Defense Acquisition Management 1, pp. 39-58

Weyant J.P. (2011), Accelerating the development and diffusion of new energy technologies: Beyond the „valley of death", Energy Economics 33, pp. 674-682

1 Research conducted within the Strategic Programme: „Innovative Systems of Technical Support for Sustainable Development" part of Operational Programme – Innovative Economy.