PROBLEMY EKSPLOATACJI

MAINTENANCE PROBLEMS

no 4/2015

Problemy Eksploatacji – Maintenance Problems
Scientific quarterly of the Institute for Sustainable Technologies – National Research Institute (ITeE – PIB)

Information about articles printed in the Journal can be fund in the following three renowned databases:

- Index Copernicus – the international specialized platform promoting scientific achievements, and supporting national and international collaboration between scientists, publishers of scientific journals and R&D units;
- BazTech – bibliographic and abstract database about Polish technical journals, in which articles from selected Polish journals in the field of technical sciences and environmental protection are stored;
- TEMA (Technology and Menagement) WTI-Frankfurt eG, Frankfurt am Main.

Articles are reviewed by reviewers constantly cooperating with the Journal. The list of them is presented on the website of the Journal:
http://www.problemyeksploatacji.itee.radom.pl/index.php/wskazówki/lista-recenzentów.html

Adress:
ul. K. Pułaskiego 6/10, 26-600 Radom
tel. (0-48) 364-42-41 w. 298, fax (0-48) 364-47-60
e-mail: beata.belina@itee.radom.pl

Journal co-funded by the Ministry of Science and Higher Education

ISSN 1232-9312

Editing: Bożena Mazur, Joanna Iwanowska

Edition: 200 copies.

2542. publication of the Institute for Sustainable Technologies – National Research Institute (ITeE – PIB)

ITeE – PIB Press
K. Pułaskiego 6/10, 26-600 Radom, tel. (0048) 48 364-42-41, fax (048) 364-47-65
e-mail: instytut@itee.radom.pl http://www.itee.radom.pl

PROBLEMY
EKSPLOATACJI
**MAINTENANCE
PROBLEMS**

4/2015 (99)

Contents

INNOVATIVE ECONOMY
NATIONAL COHESION STRATEGY
INSTITUTE FOR SUSTAINABLE TECHNOLOGIES
NATIONAL RESEARCH INSTITUTE IN RADOM
EUROPEAN UNION
EUROPEAN REGIONAL DEVELOPMENT FUND

Project co-financed by the European Union from the European Regional Development Fund

Adam MAZURKIEWICZ, Beata POTERALSKA,
Marzena WALASIK
Institute for Sustainable Technologies – National Research Institute, Radom
adam.mazurkiewicz@itee.radom.pl
beata.poteralska@itee.radom.pl
marzena.walasik @itee.radom.pl

THE ROLE OF TECHNOLOGY PLATFORM IN THE PROCESS OF KNOWLEDGE MANAGEMENT

Key words

Technology Platform, network cooperation, knowledge management in the commercialization process.

Abstract

Knowledge management takes on various forms depending on the character of the enterprise, the specificity of the industry, and the adopted strategy. The technology platform model created at the Research Institute is a tool supporting the process of knowledge management and particularly the process of the knowledge codification. The platform allows both the codification of the knowledge of partners and projects, and the accumulation of knowledge about innovative technological solutions. The platform allows the dissemination of knowledge into the economy. Moreover, it identifies the needs and expectations of the market in the field of innovative technologies. The article presents the best practices in the functioning of the Technology Platform as an operational mechanism in knowledge management for the process of commercializing R&D results conducted in the scientific research units.

Introduction

Since the globalization processes (and with them the technological advancement) have been intensifying, the more extensive the network between businesses and research and development units, the better are its chances to maintain a competitive advantage in the market. An important aspect of building a strong economic position of the business is not only skilful management of resources, such as, property, finances, and information, but primarily the effective development and use of their competencies, and adequate knowledge management. In the age of globalisation and internationalisation, any economic entity that wants to develop and strengthen its position on the market must be innovative, and this is possible through the acquisition and use of knowledge. An adequate knowledge management process affects the pace and nature of innovative activities and the creation of technologically advanced products.

The requirements of knowledge-based economy present new challenges for research and scientific institutions, particularly in the process of commercializing R&D results, where it becomes important to implement research motivated by the needs of the market. The transfer of knowledge is not only the implementation of the R&D results into the industry, but also a wide range of cooperation between the scientific community and entrepreneurs in solving business and production problems.

The conducted analyses indicate that the level of cooperation between research institutions and businesses in Poland is still unsatisfactory, encumbered with multiple obstacles [16]. The proportion of companies declaring cooperation with researchers is 75–80% in foreign countries, whereas, in Poland, this cooperation is lower by more than 30% [6].

One report [25] indicates that 20% of Polish entrepreneurs do not have knowledge about the possibilities of cooperation with the scientific community, while almost 40% of the companies do not know how to reach the scientific units designed to commercialize research.

One of the ways that can contribute to the improvement of the cooperation between science and business, and can support the process of knowledge management, is building a cooperative network.

International experience suggests that network forms of cooperation provide benefits to both research institutions and businesses; they intensify processes of commercialization, eliminate negative phenomena on the labour market, and increase the competitiveness of the companies.

Moreover, the conducted analyses indicate [29] that network cooperation facilitates the process of collection, processing, and the use of knowledge, and the transfer of technology; it advances communication among the parties interested in the implementation of innovations. Networking cooperation brings benefits of scale, increases innovation processes in companies, and it allows the transformation of knowledge into products by providing concentrated operational tools, often including financial resources necessary for that process, which would be impossible to amass within one enterprise, in particular, in the SME sector.

Networks can be created through the construction of project consortia (e.g. Industriell Dynamik, Sweden) or based on Web applications (e.g. Madri+d, Spain). Cooperation networks help businesses in initiating innovation-related activities (e.g. Syntens, Netherlands), promote the development of research and innovation stimulating policy (e.g. Setn, United Kingdom), organise conferences, fairs (e.g. Syntens, Netherlands), offer support in finding partners for projects and trade partners (e.g. NanoBioNet, Germany). Technology Platforms aid the conversion of solutions that are research results into innovative products, processes, and services that generate added value (e.g. Jinnove, France), promote the development of start-up and spin-out businesses (e.g. Yet2. com, USA), deal with economic consulting for businesses (e.g. Syntens, Netherlands), run support programmes for entrepreneurs, for example, in the form of grants (e.g. Jinnove, France), carry out marketing activities in support of entrepreneurs (e.g. Syntens, Netherlands), engage in the promotion of science and technology and offer internships, scholarships, training (e.g. Syntens, Netherlands, Madri+d, Spain) [29].

In order to strengthen the cooperation between science and business, the Institute for Sustainable Technologies – National Research Institute (ITeE – PIB) initiated the creation of a technology platform model, which presents the results of the scientific research and development projects conducted at the Institute, ranging from advanced material technologies, modern mechatronic systems, control systems, IT applications, to technical safety and environmental support systems, and experimental and testing equipment. Knowledge management in the platform includes product and process solutions that are the result of the implementation of the Strategic Programme: “Innovative Technical Support Systems for Sustainable Development of the Economy” and the results of other research and development projects.

The article describes the use of a technology platform as a support tool for knowledge management in the improvement of cooperation efficiency and as being conducive to removing barriers that occur among participants in the process of commercializing the R&D results.

1. State of the art – knowledge and knowledge management

A survey of literature on the subject indicates that there is some ambiguity in the understanding of the “knowledge” concept [13, 19, 22].

Knowledge can be defined as the totality of competences and information used by the employees to solve problems. It contains both theoretical and practical elements, and general and detailed guidelines for action. Knowledge base is provided by data and information; however, knowledge always is related to a specific person [24].

For the purposes of this study, the definition proposed by the Jashapar has been adopted. It defines knowledge as an effective learning process, related to the search, use, and dissemination of knowledge (explicit and implicit), using appropriate technologies, and cultural environment, the purpose of which is to increase intellectual capital and the efficiency of the organization [12].

Following M. Polanyi, implicit knowledge exists only in the mind of the person who possesses it; it is formed by experience and is not fully conscious, manifesting itself only through capable action. On the other hand, explicit knowledge is expressed in the written form and saved on the knowledge media [23].

Knowledge management in organisations has become a key concept of management theory and practice. It is extensively described in the literature [4; 26; 9; 15]. General definition of knowledge management (Schermerhorn) says that knowledge management is "a process of using the intellectual capital to gain competitive advantage" [18].

From the point of view of strategic management, knowledge management is understood as managing the function responsible for the regular selection, implementation, and evaluation of the purpose-oriented strategies, aimed at the increase of the value of the organization through the use of explicit and implicit knowledge for the improvement of its functioning [18]. In this sense, the term "knowledge management" means the improvement of organisational abilities at all levels of the company for a better use of knowledge resources. Thus, it can be seen as the management of activities and processes that can raise the efficient use of knowledge and thereby the competitive ability. The efficient use of knowledge means that gained knowledge has to be purposefully integrated in the development of products and processes [14].

Knowledge management in a scientific research institution is a process through which a research unit can become fully competitive in the ever-changing market. Conversely, knowledge management in an enterprise can be defined as the set of actions undertaken by management and employees, whose aim is the attainment of specific tasks.

The general purpose of the knowledge management application in any organization is to facilitate the recognition of knowledge by the management as a resource and to inspire it to seek practical applications of this resource [24]. Viewing knowledge management more analytically, it can be regarded as the following [27]:

- A basic tool of future management;
- An opportunity for a radical reorientation in ways of thinking;
- An effective and efficient tool for improving quality;
- A collection of experience and intuition that make up the platform for the creation and absorption of new experiences and information; and,
- An opportunity to reveal the existing areas of knowledge insufficiency.

The objectives of knowledge management defined by R. Maier [18] are the following:

- Obtaining transparency of knowledge;
- Implementing documentation of knowledge;
- Changing organizational culture;
- Improving communication and cooperation;
- Transforming implicit into explicit knowledge (externalising), improving educational processes, training, and networking for newly recruited employees;
- Improving the processes of employees' development;
- Improving knowledge retention (organization memory);
- Improving access to existing knowledge;
- Improving knowledge distribution;
- Improving innovation management;
- Reducing cost; and,
- Sales knowledge.

Knowledge management system[1] can be defined as set of rules, methods, resources, collections of information, people and their interconnections, which allows accepting and implementing the strategies and objectives of knowledge management for the achievement of the objectives of the organization.

2. Knowledge management within the network of cooperation

The requirements of a knowledge-based economy result in knowledge being perceived as a strategic resource, and the transfer of knowledge, based on the communication within the network of cooperation, has a crucial importance for innovation processes. Relevant literature increasingly underlines the importance of external resources to which the unit has access to through the network of relationships [10], and which translates into achieving a competitive advantage on the market. The network can be defined as a set of specific relations among defined groups of people, objects, or events [20]. In organisation sciences, a network is defined as a system or area consisting of organisations and inter-organisational relationships [8]. This article defines network as a long-term relationship among partners, connected by ventures that delineate the scope of their cooperation [29]. The results of empirical studies confirm that networks and goods associated with a particular relationship provide access to resources that may not be available in the traditional market exchange, help build competitive advantage [2], and increase innovation level among the network members [5, 1].

Networks are crucial to the development of processes related to the creation, diffusion, absorption, and use of knowledge. Companies in the network more

[1] Ernst & Young defines it as „a system designed to help businesses in the acquisition, analysis, and use of knowledge in order to make faster, smarter, and better decisions leading to the achievement of competitive advantage" [28].

frequently have connections to knowledge resources, which enable them to acquire more precise knowledge, share it [11], and use it for the development of new business concepts [7].

Knowledge management in the context of network cooperation requires activity in the field of explicit (possible to codify) and implicit (know-how) knowledge, where types of knowledge are complementary to each other, and both are necessary in the process of knowledge management. Explicit knowledge can be communicated, processed, and stored relatively easily, while implicit knowledge is difficult to formalize and communicate and requires specific competences.

Another important aspect is the expected return on knowledge sharing, which affects the relationship with the participants within the network, since it is the expected profit for sharing knowledge. Knowledge within a network can be formal or informal. The formal form includes structured inter-organisational teams, joint training, conferences, or systems based on IT (e.g. Internet platform). Knowledge made available in this way is explicit. Sharing knowledge in an informal way is based on the "relational" channels that allow face-to-face communication and encourage a climate of trust among the network participants. An important factor is also the culture of network cooperation (conflict resolution).

Creating a network of knowledge-sharing cooperation facilitates the process of generating new ideas and the management of innovative projects, improves the time and cost efficiency of network participants, and creates added value. It often leads to the implementation of (product, process, service, marketing, organizational, institutional) innovation.

Networking cooperation is a system of knowledge management within which collective activities are conducted, which are varied in terms of industry, meeting the variety needs of the network participants' market. A significant value of such an organization is not based on the ready and defined character of a product, but on meeting the diverse and complex needs of the customer.

3. The concept and the main objectives of the Technology Platform

In the age of the changing face of a modern scientific research, the Institute for Sustainable Technologies – National Research Institute has created a model network of cooperation – a Technology Platform that integrates science and economy.

The Technology Platform (Fig. 1) promotes innovative processes and product technologies, creates effective structures and mechanisms for the transfer of innovation, and assesses the effectiveness of these structures. Moreover, there are analyses conducted concerning potential growth areas for innovation, resulting from the needs of the industry (mainly regional), and trends in the economy. There are IT tools created to facilitate the process of collection, processing, and use of knowledge, and also technology transfer, all to improve the communication among innovation stakeholders.

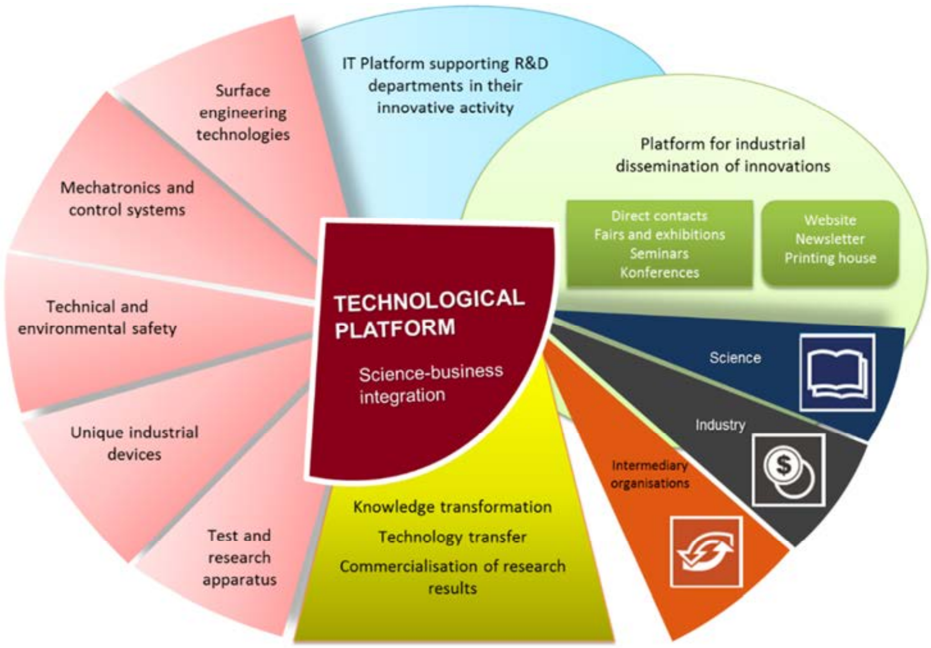

Fig. 1. Technology Platform

The qualities justifying the creation and functioning of the Technology Platform (which, unlike most such entities operating on the Polish market, is not financed with external (budgetary) resources) include the following:

- It provides a knowledge dissemination tool through the exchange, acquisition, and application of innovative solutions on the regional scale, and their transfer within the cooperation networks.
- It creates an accumulation of knowledge from different areas of competence and experience, which are helpful in solving complex, innovative, technical, and technological problems.
- It allows collecting, analysing, and processing information.
- It represents a source of creative, innovative solutions, tailored to the needs of regional and national markets.
- It creates a pro-market approach of scientific research units and the implementation of planned projects.
- It increases the phenomenon of the synergy of competences among the network participants.

The tasks carried out within the platform allow effective coordination among its members, facilitating the establishment of business contacts, and they influence building partnerships, simplify the path and the implementation of joint ventures in the form of contracts, projects, and thus create opportunities and significantly reduce the traditional means of achieving success on the market.

4. The model of knowledge management within a Technology Platform

The Technology Platform created in ITeE – PIB facilitates the process of knowledge acquisition and dissemination, and it can be simultaneously used within different scopes. Knowledge management within the network cooperation refers to communication of know-how, the creation of new concepts, and it undoubtedly is of great importance for creating innovation processes among the participants of the network. The proposed knowledge management model is implemented in the created Technological Platform.

The model consists of three main components (Fig. 2):

1. Correlation module generates interaction among network participants, defines their knowledge, and specifies the state of knowledge by the Institute necessary for cooperation, enabling a definition of the position of each its members in the network.
2. Operational module of knowledge management includes the following activities:
   - Acquiring knowledge (from internal and external sources); and,
   - The dissemination of knowledge – a developed form of knowledge sharing in order to make given knowledge generally available.
3. Diffusion module, including the transfer of knowledge, is a mutual transfer of knowledge in the process of communication. Moreover, identifying the knowledge that should be acquired, transferred, manufactured, thanks to the projects by the platform, for both its participants and entities outside the network is included in this module.

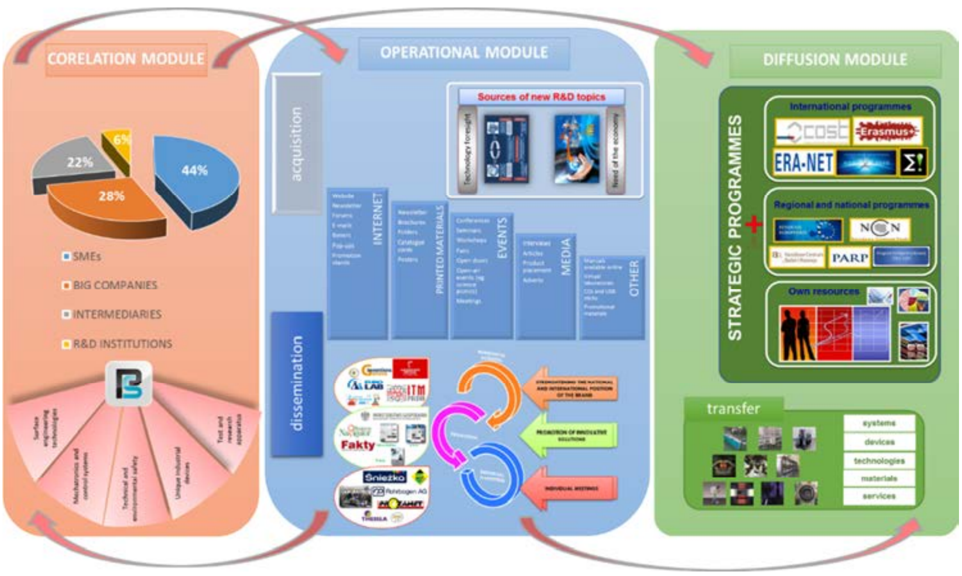

Fig. 2. Knowledge management model within the network

Correlation module

The Technology Platform created in ITeE – PIB is addressed to recipients from across Poland, in particular to entrepreneurs, institutions in the business environment, and scientific research units, as well as to foreign organizations. The platform has a formal structure in which the official participation is confirmed by signing the document "Declaration of creating a platform for the dissemination of innovative solutions in the economy". So far, more than 40 economic entities joined the platform structures. Mostly these are companies, and they account for nearly 75% of all members of the platform, of which 60% are representatives of the SME sector, and 40% are representatives of large companies. Its backbone is formed by companies located or having their branches in Mazowsze.

This entity has an open structure, which can include other partners who share the objectives of the platform and who see the benefits they can obtain in cooperation within its framework. The platform, which is a network structure, brings benefits for its direct participants, and it indirectly generates many positive effects for the environment (Table 1).

Table 1. Benefits for the participants of the Technology Platform

Benefits for the Institute	**Benefits for platform members**
❑ The development of innovative service area ❑ Increased interest in the offer of the Institute ❑ Commercialization of innovative solutions	❑ The use of new knowledge and innovative solutions ❑ Taking action resulting in the implementation of innovative solutions in companies ❑ Cost optimization in the business

The purpose of the first module is to identify relationships that may occur with individual partners. They can be both vertical in nature (reflecting the classic supply chain) and horizontal (e.g. competitors, which are other scientific research units or the companies in the business environment).

Identifying and developing a relationship of cooperation between the Institute and the network participants in the network, as a consequence their suppliers, contractors, customers, and service providers, ensure co-operation, provides increased collective performance, and increases efficiency in the implementation of innovative products, together with the recommendations made by the direction of the manufacture of technologically advanced solutions. Each participant is additionally characterized in terms of ownership type, its industry, or areas in which cooperation may occur. For companies, especially in the SME sector, participating in a network form of organization affects the growth of innovation, raises competitiveness, and, at the macro-economic level, stimulates business development.

The operational module

Network participation allows sharing, exchange, and use of know-how by the members of the network, providing access to knowledge, its collection, the transfer of experience and competence, and the use of knowledge to create innovation. There are two main sources of acquiring knowledge within the platform:

- Foresight-type analysis to select future-oriented research in accordance with market demand and research directions; and,
- The demand for knowledge from direct industry input, resulting in the creation and development of innovation-generating projects of a commercial nature, the effect of which is to implement a new product or new technology on the market.

Effective coordination and configuration of the platform work, characterized by creative relationships with partners, allows the dissemination of innovation among the participants and beyond. To this end, an operational procedure was created for the dissemination of innovative solutions consisting of 7 stages: market situation analysis, the segmentation process, creating a distinguishing feature of solutions, marketing strategy development, the dissemination phase organisation, the follow-up phase, monitoring the effects of dissemination, which together form an Innovation Dissemination System [30] (Fig. 3).

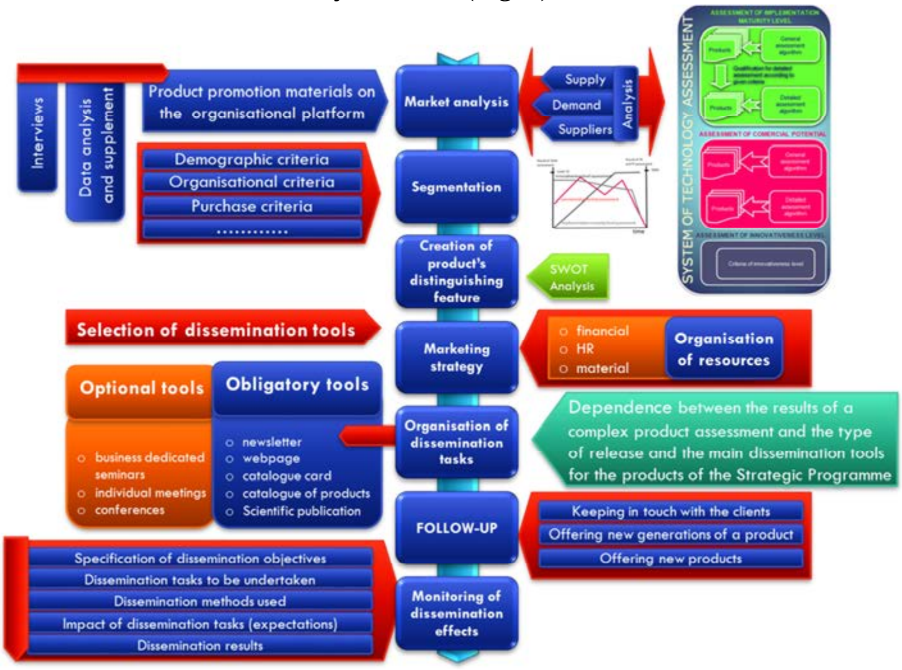

Fig. 3. A system of dissemination of innovative solutions

This system of the dissemination of innovative solutions has been tested on dozens of examples and is used at the Institute for research results created there, R&D, and implementation projects. One of the tools to support dissemination is the comprehensive technology assessment system created in the ITeE – PIB, which consists of an assessment of the degree of implementation maturity (SDW), an assessment of the commercial potential (PK), and an assessment of the innovation level (PI) of technologies, products, and process solutions, which allow an in-depth analysis of application technology [17].

Thanks to the systemic approach in the dissemination of R&D results, their efficiency has increased, for example, by concentrating on providing information on finalised results, as in the Strategic Programme, implemented at the Institute, "Innovative Technical Support Systems for Sustainable Development of the Economy", where entities using similar solutions (producing a success by relevant communications, using effective operational tools, for the respective target groups). Dissemination activities influence the development of cooperation between the Institute and the enterprises interested in the implementation of innovation. Moreover, they facilitate carrying out systemic activities related to the promotion of the innovative process and product technologies created during the ongoing projects at the Institute.

One form of effective communication used by the platform is the organization of cyclical seminars, whose primary purpose is (in addition to presenting the scope of scientific research, project and implementation work of the Institute for Sustainable Technologies – PIB) to establish and intensify cooperation between the representatives of businesses and the Institute. So far, seven such meetings have been held, in which 170 representatives of the economic sector participated from all over the country, and (II) editions of the Business and Science Conference "Engineering the Future" (September 2014, May 2015) were organised with more than 300 participants[2] in attendance. The main objectives of the conference was the integration of the scientific community with the economic environment, increasing the cooperation between science and business, and the promotion of the application types of technological and system innovations developed by the R&D sector units or centres and research laboratories at companies.

Diffusion module

The initiatives undertaken within the platform intensify activities undertaken at the Institute for the commercialization of research results (sales, services, licensing, the creation of spin-off entities), and thus lead to the strengthening of the position (brand) of ITeE – PIB in the social, business, and scientific community. They ensure, through the mutually beneficial ties, strengthening partnerships, building a strong foundation for the development of

[2] http://www.future.engineering.itee.radom.pl/

knowledge, skills, abilities, and competences of all the participants in the network.

Through the Technology Platform, joint initiatives undertaken by scientists and entrepreneurs, and projects with a high implementation potential, are created and developed. As a consequence, direct contracts from the industry for the Institute have increased.

Examples of subjects and projects carried out at the Institute include the following:

1. Surface engineering:
   - High heat resistance coatings to increase the durability of the mould for pressure aluminium die casting for the aerospace and automotive industry;
   - Technology of increasing the durability of special tools for the metal industry.
2. Mechatronics and optomechatronics:
   - Automatic optical inspection systems and qualitative selection the tobacco industry;
   - Hybrid video systems for monitoring technological processes for the glass industry.
3. Pro-ecological technologies:
   - Optimization of water and wastewater management (reduction of water consumption and waste water disposal) for a company in the chemical industry;
   - Manufacturing technology of pro-ecological greases for the sugar industry.
4. The production of prototypes:
   - Range of equipment for testing mechanical properties of furniture elements;
   - Technological equipment for efficient recovery of working fluids from metal shavings in large-scale production for the metal industry.

The indirect effects of the platform’s functioning are contracts for the Institute for industry expertise, opinions about innovation, and conducting technical analyses. Because of the high quality of services, access to specialized laboratories, and punctual work, the number of entrepreneurs benefiting from services provided by the Institute increases steadily.

Cooperation within the platform allows undertaking joint initiatives and innovative activities, using a variety of unique skills, and creating a specialized configuration of the competences of the participants in the network, which greatly increases the effectiveness of combining the world of science and business. An important aspect is increasing the involvement of companies in science and research, and in joint applications for funding for projects from external sources – regional, national, and international.

Conclusions

The requirements of a knowledge-based economy affect how the new relationships between the world of science and business are defined, and the transfer and commercialisation of R&D sector knowledge to the economy becomes a key factor that allows gaining and maintaining a competitive advantage. One of the tools that make it possible to more effectively implement and commercialize the R&D results is a Technology Platform.

Knowledge management within a scientific research unit established in the form of network cooperation allows generating an added value in terms of the following:

- Improving the effectiveness through promotion of best practices, concepts, and the development of projects firmly planted in the economic environment;
- Increasing loyalty by developing and building enduring relationships within network partners, customers, suppliers, and increasing the quality of these relationships, which are shaped by the level of mutual trust;
- Increasing chances for future success by creating product innovation, reducing the time of implementation, and upgrading products and matching them to market requirements;
- Creating culture based on the paradigm of values by shaping attitudes, and competences for generating values for the society and the economy; and,
- Increasing the effectiveness of decision-making by making relevant decisions, thanks to the information supplied to the competent persons at the right time.

The network of connections created within the platform is a system built with great care, consisting of interrelated components that make up the competitive forces throughout the organizational network. The platform, through its activities, reinforces member integration within the network, facilitates knowledge coordination processes, enables the development of the skills of its participants, and (on the macro level) supports building a knowledge-based economy through the implementation of R&D innovation.

Scientific work executed within the Strategic Programme "Innovative Systems of Technical Support for Sustainable Development of Economy" within Innovative Economy Operational Programme.

References

1. Abrahamson E., Rosenkopf L. (1997): Social network effects on the extent of innovation diffusion: A computer simulation. Organization Science 8, 1997, pp. 289–309.
2. Arya B., Lin Z.: Understanding collaboration outcomes from an extended resource based perspective: The roles of organizational

characteristics, partner attributes, and network structures, Journal of Management 33, 2007, pp. 697–723.
3. Bukowitz W.R., Wiliams R.L.: The Knowledge Management Fieldbook, Financial Times, Prentice Hall, Great Britain 1999.
4. Davenport T.H., Prusak L.: Working Knowledge. How Organizations Manage What They Know, Harvard Business School Press, Boston, Massachusetts 1998.
5. Demirkan I., Demirkan S.: Network Characteristics and Patenting in Biotechnology, 1990–2006, Journal of Management, Vol. 38 No. 6, November, 2012, 1892–1927.
6. Gabryś A. (red.): Najlepsze praktyki w zakresie współpracy ośrodków naukowych i biznesu przy wykorzystaniu środków z UE, Fundacja Aurea Mediocritas, Warszawa 2008, s. 7–8.
7. Galunic D.C., Rodan S.: Resource recombinations in the firm: Knowledge structures and the potential for Schumpeterian innovation, Strategic Management Journal 19, 1998, pp. 1193–1201.
8. Gamm L.: An introduction to research in interorganizational relations, Journal of Voluntary Action Research 1981, 10(1), pp. 18–52.
9. Gibbert M., Leibold M. Probst G.: Five Styles of Customer Knowledge Management, and How Smart Companies Use Them To Create Value, European Management Journal 2002, 20 (5), pp. 45–469.
10. Gnyawali D.R., Madhavan R.: Cooperative Networks and Competitive Dynamics: A Structural Embeddedness Perspective, The Academy of Management Review Vol. 26, No. 3 (Jul., 2001), pp. 431–445.
11. Hansen M.T.: Knowledge networks: Explaining effective knowledge sharing in multiunit companies, Organization Science 13, 2002, pp. 232–248.
12. Jashapara A.: Zarządzanie wiedzą, PWE, Warszawa 2006, s. 28.
13. Jemielniak D., Koźmiński A.K. (red): Zarządzanie wiedzą, Oficyna a Wolters Kluwer bussines, Warszawa 2012.
14. Kaiser J.M., Conrad J., Koehler C., Wanke W., Weber C.: Classification of Tools and Methods for Knowledge Management in Product Development, International Design Conference – Design 2008, Dubrovnik, Croatia, May 19–22, 2008.
15. Leydesdorff L.: The Knowledge-Based Economy Modeled, Measured, Simulated, Universal-Publishers, Boca Raton, Florida, USA 2006.
16. Mazurkiewicz A., Poteralska B.: Barriers of Practical Application of Innovative Technologies in Economy, Problemy Eksploatacji, 4/2014, Radom 2014, pp. 5–17.
17. Mazurkiewicz A., Poteralska B.: System of complex technology assessment, Problemy Eksploatacji, 4/2012 (87), Radom 2012, pp. 5–18.
18. Mikuła B.: Istota zarządzania wiedzą w organizacji, w: Komunikacja w procesach zarządzania wiedzą. Red. Potocki A., Uniwersytet Ekonomiczny w Krakowie, Kraków 2011.

19. Mikuła B.: Zadania organizacji w zakresie zarządzania wiedzą, E-mentor nr 5(17)/2006.
20. Mitchell J.C.: The concept and use of social network, w: J.C. Mitchell (ed.), Social Network in Urban Situations, Manchester: University of Manchester Press, 1969.
21. Murray P., Myers A.: The facts about knowledge. Special report "Information Strategy", 1997 nr 11.
22. Nonaka I., Takeuchi H.: Kreowanie wiedzy w organizacji, Poltext, Warszawa 2000.
23. Polanyi M.: Science and Man's Place in the Universe, w: H. Wolf (ed.), Science as Cultural Force, The Johns Hopkins Press, Baltimore 1964, pp. 54–55.
24. Probst G., Raub S., Romhardt K.: Zarzadzanie wiedzą w organizacji, Oficyna Ekonomiczna, Kraków 2002, 42.
25. Raport: Bariery współpracy przedsiębiorców i ośrodków naukowych, Ministerstwo Nauki i Szkolnictwa Wyższego, Departament Wdrożeń i Innowacji, Warszawa 2006, 4.
26. Senge P.: Sharing Knowledge, Executive Excellence 1998, 15(6), pp. 11–12.
27. Skrzypek E.: Miejsce zarządzania informacją I wiedzą w strategii przedsiębiorstwa, w: Zarządzanie firmą w społeczeństwie informacyjnym, red. A. Stabryła, Materiały konferencyjne, Szczawnica, 26–29 września 2002, EJB, Kraków 2002, 683.
28. Strojny M.: Zarządzanie wiedzą – ogólny zarys koncepcji, „Przegląd Organizacji" 2000, nr 2, 20.
29. Walasik M.: Model technology platform for cooperation of research centres with business sector, Transactions of the Institute of Aviation number 227, Warsaw 2012, pp. 55–71.
30. Walasik M.: System działań upowszechniania innowacyjnych rozwiązań technologicznych zaimplementowany w instytucie naukowo-badawczym, PWE, Marketing i Rynek 3/2014, pp. 433–452.

Rola Platformy Technologicznej w procesie zarządzania wiedzą

Słowa kluczowe

Platforma Technologiczna, sieciowe formy współpracy, zarządzanie wiedzą w procesie komercjalizacji.

Streszczenie

Zarządzanie wiedzą przybiera różne formy w zależności od charakteru działalności podmiotu, specyfiki branży i przyjętej strategii. Utworzona w instytucie

badawczym modelowa Platforma Technologiczna jest narzędziem wspomagającym proces zarządzania wiedzą, a w szczególności proces kodyfikacji wiedzy. Platforma umożliwia zarówno kodyfikację wiedzy o partnerach i realizowanych projektach, jak i gromadzenie wiedzy o innowacyjnych rozwiązaniach technologicznych. Platforma umożliwia dyfuzję wiedzy do gospodarki. Jest jednocześnie podmiotem identyfikacji potrzeb i oczekiwań rynku w zakresie innowacyjnych technologii. Celem artykułu była analiza i prezentacja wykorzystania Platformy Technologicznej jako operacyjnego mechanizmu wykorzystywanego w zarządzaniu wiedzą w procesie komercjalizacji wyników prac B+R prowadzonych w jednostce naukowo-badawczej.

INNOVATIVE ECONOMY
NATIONAL COHESION STRATEGY
INSTITUTE FOR SUSTAINABLE TECHNOLOGIES
NATIONAL RESEARCH INSTITUTE IN RADOM
EUROPEAN UNION
EUROPEAN REGIONAL DEVELOPMENT FUND

Project co-financed by the European Union from the European Regional Development Fund

Joanna ŁABĘDZKA
Institute for Sustainable Technologies – National Research Institute, Radom
joanna.labedzka@itee.radom.pl

DIVERSIFIED COMPUTER SYSTEM FOR SUPPORT OF NETWORK-BASED VIRTUAL STRUCTURES

Key words

Virtual organisation, virtual structures, computer system, ICT, information platforms.

Abstract

Traditional management methods and structures are failing to adequately accommodate a complex reality, which is characterized by discontinuous change, hypercompetition and the exponential explosion of information science. Therefore, it demands a fundamental rethink and the development of a management paradigm that can withstand the pressure of rapid change in a borderless, connected, and wired world relying more and more on virtual structures. Inevitable changes in business environment and the redefinition of management methods and styles address new challenges for computer science in offering new services and products tailored to virtual organisational structures. The paper explores more attentively the potential and advantages of the usage of advanced information and communication technologies for support of network-based virtual organisations.

The paper presents a specialised computer system, i.e. Computer PINF Platform designed to support virtual organisations in the efficient exchange, diffusion, and transfer of knowledge and innovations. The main features and

functions offered by the PINF Platform were selected based on in-depth analyses of its potential users and stakeholders, i.e. research institutions, academia, and SMEs. The genesis of performed scientific and application works, architecture, main functions, and practical areas of the application of the Computer PINF Platform are also revealed in the paper.

The implemented computer PINF Platform is a complex, modular IT tool to support geographically distributed entities of virtual organisations that aims at efficient transfer of knowledge and innovation into science, industry, and the business sector.

1. Virtual organisation as a new management paradigm

Since the dawn of civilisation, new technologies have transformed human lives. Traditional management methods, structures, and styles are failing to appropriately adapt to complexity-based world, which is characterized by constant change, hypercompetition, and the exponential explosion of information science and shows how the management paradigm has been updated by the new era of the virtual structures [1]. A shift from the traditional management paradigm to a new paradigm more conducive to the effective and efficient operation of virtual management has influenced a dynamic development of virtual structures.

The concept of virtual structures results from several factors, including a constantly changing and evolving society as well as the development in the information and communication technologies (ITCs). In the management literature, many different new forms of organisations like the ‘inverted organisation’, ‘spiders web organisation’, or ‘intelligent enterprise’ are discussed. However, the central theme of the debate during the last years is the ‘virtual organisation’ [2].

Unfortunately, it is quite hard to find a precise and fixed definition of fundamental notions such as virtual organization or virtual company [3]. The term virtual organization (VO) ensued from the phrase ‘virtual reality’ and implies the novel and innovative relationships between organizations and individuals supported by computer technologies [4], [5].

In the paper, the feature of virtual organisational structure concerning the usage of advance information technologies for the support of virtual structures will be explored more attentively. Therefore, few definitions concerning the significance of ITC in VOs are mentioned. L. Edvinsson, for instance, states that a VO, for easy transformation in real-time, uses a combination of advance technologies and well-trained adaptive professionals [6]. L. Kiełtyka and M. Dolińska in one accord claim that a virtual organisational structure is a dynamic management tool of network cooperation based on computer networks and information banks, such as the Internet, which are suitable for communication and gaining the competitive advantage on the global market [7],

[8]. B. Mikuła states that the foundations for the functioning of the virtual organisation are communication and computer networks that, through computers and other audiovisual devices, enable quick contact between cooperating partners [9]. A VO is able to flexible adapt to changes occurring in the surrounding environment that is under constant monitoring. Moreover, the usage of IT systems eliminates barriers, such as the geographical distribution of cooperation organisations and reduces or eliminates costs (for instance, travelling expenses) [10]. Another link of a virtual organisation to IT is indicated by M. Kostera and B. Travica: A VO uses telecommunication technologies to coordinate spatially dispersed actions of entities that belong to it [11], [12].

Aforementioned definitions precisely outline the leading principle of a virtual organization, which holds the form of a real (conventional) corporation from the outside, but it does not actually exist physically and implicates an entirely digital process relying on independent web associates [13]. Therefore, virtual organizations are centred on technology and possess limited physical resources as value is added through knowledge rather than equipment [4]. Crucial factors in a virtual organization are communication processes, because they are responsible of its efficiency and even to its survival. The collaboration between associates might also get quite complicated, because this type of organization denotes only a slight amount of face-to-face interaction. Because of a lack of multiple communication approaches observed in virtual organizations [14], it is an ambitious challenge for ICTs to propose tools for exchanging data and information among locally distributed units of VOs.

2. Computer system for support of virtual organisational cluster

The introduction of new IT technologies has led to a knowledge-based economy, in terms of which organizations have become increasingly complex. The technologically induced emergence of a ‘virtual’ environment has resulted in the adoption of new organizational structures and has created new challenges for the computer science. The emergence of such technologies as e-mail, the Internet, telecommuting, and voice mail has spawned such products as the virtual office, the virtual company, and virtual teams [1]. Virtual organizations have also become increasingly common in the area of research and development, with often far-flung organizations forming alliances that amount to a ‘Virtual Research Laboratory’ [15, 16].

To come across the on-going changes in the management paradigm and to offer innovative IT technologies and services, the Institute for Sustainable Technologies – National Research Institute (ITeE – NRI) within the Strategic Programme “Innovative Systems of Technical Support for Sustainable Development of Economy” created a model virtual organisation – the Technology Platform that gathers representatives of research centres, institutes, enterprises, academia, and experts from the advanced technologies domain.

The Technology Platform can be described as a group of network-based systems that can simulate the structure and behaviour of the real domain organisations and quickly and actively exploit fast-changing business and research opportunities in the area of advanced technologies, such as, inter alia, surface engineering, mechatronics, control systems, automation, environmental technologies, and safety systems. Moreover, within the project, a computer system (the Computer Platform PINF) was developed and implemented for supporting virtual organisations (dedicated especially for the Technology Platform) that deal with knowledge and technology transfer into business, R&D, education, and the industry sector (Fig. 1). The core of the PINF Platform is a research technological institute (ITeE – NRI) that creates a virtual organisational structure (Technology Platform) with cooperating partners from various environments of research, the economy, and the public sector. The backbone of the economy and the most prolific entities in developing new ideas are Small and Medium Enterprises; therefore, the Technology Platform gathers more than 50 representatives of SMEs, and this number is constantly growing.

The main goal while designing the Platform was to connect stakeholders from various environments (business, science, academia) in order to reach out easily to the various sectors that have common needs that can be mapped with each other in accordance with their requirement for their mutual benefits. This approach results in the creation of interdisciplinary teams among the Platform members that are able to more efficiently tackle engineering problems and economic needs and offer innovative technological products and technologies that meet market demands.

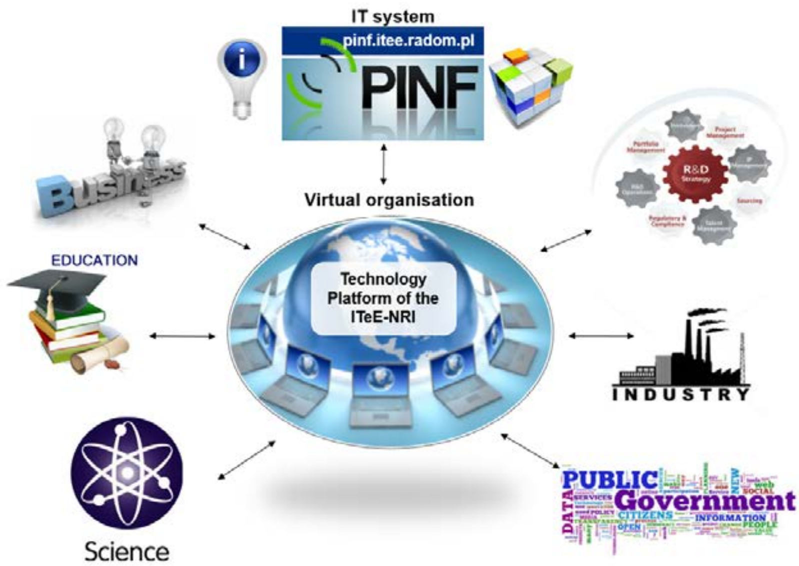

Fig. 1. The structure of the computer platform PINF for supporting innovative processes

The created IT solution is perfectly settled in the concept of a knowledge-based society and economy that assume the common use of tele-information systems to exchange and remotely process information [17]. The PINF Platform's vision is to become a European network connecting individuals and institutions and to enable the sharing of knowledge, data, and tools supporting the development of innovative technical solutions.

3. Computer platform PINF – main features and future development

The presented, multipurpose Platform PINF is a complex set of knowledge-based systems and applications designed to support business, research, and educational processes within a virtual organisation. The platform has a classical, multitier architecture that enables its functioning in cyberspace (Fig. 2). Resources available within the PINF Platform through the Internet include the following:

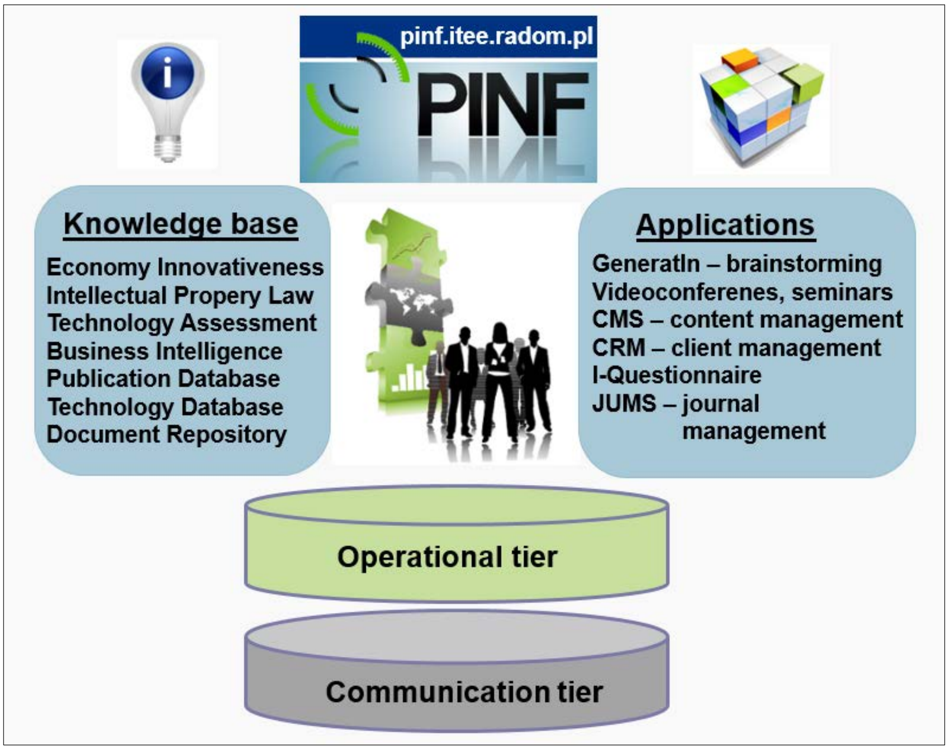

Fig. 2. Structure of the computer platform PINF

– Thematic databases, knowledge bases and repositories containing information related to broadly defined innovativeness, i.e. complex assessment of technological products, Business Intelligence, innovation financing, the economy innovativeness, intellectual property, scientific browsers and portals, current project calls, product and technologies databases; and,
– Computer applications intended for communication, supporting interdisciplinary research teams in idea creation, innovation elaboration, the management of client relations, marketing activities, the dissemination of research results, the management of scientific journals, and communication.

The resources of the PINF Platform are continuously growing to meet the requirements of its users.

Because of the fact that the crucial aim of the platform is to maintain the business processes within the organisation, more attention in this paper was paid to computer applications that are available to the platform users. The Platform PINF consists of the following computer applications:

– A system to organise remote video conferences and video seminars without the necessity of relocation, on short notice, with time and money savings;
– The system GeneratInn to develop ideas for innovative solutions, projects, device designs, and problem solving with the use of the brainstorm method;
– The system I-Survey to create, store, and publish market and research surveys through the Internet based on the CAWI method (Computer-assisted web interviewing);
– The CRM system to manage partners or customers relationships, plan the realisation of work schedules for research and business teams, provide complete and homogeneous information, plan and promote marketing campaigns; and,
– The system JUMS to manage publishing processes, i.e. reviewing, in scientific journals.

The presented applications have individual interfaces and operate autonomously in the computational cloud. The PINF Platform outlines a broad continuum of possible virtual relationships, ranging from relatively simple outsourcing by a central organization to tightly knit consortia of collaborating teams. The Computer PINF Platform (user interface – Fig. 3) appears under the following link: http://www.pinf.itee.radom.pl.

The created IT Platform PINF is a tool for all registered members of the Technology Platform, and it is intended for sharing resources (knowledge, computer applications) in the area of broadly understood innovativeness and communication. The usefulness and efficiency of the PINF Platform and its computer technologies and applications in supporting the realisation and dissemination of the results of innovative processes has already been proven by many successful events supported by the presented tool, such as projects scheduling, videoconferences, videoseminars, market surveys, and brainstorming sessions.

Fig. 3. The computer platform PINF

The age of the virtual organization is under dynamic development; therefore, the PINF Platform has a modular structure, and it is prepared to deal with the adoption or the introduction of ever-newer technologies and the emerging trends in ICT. The future directions of the platform development include a module for remote access not only to research results, but also to modern laboratory apparatus at least at the national scale.

Summary

Conventional management theories and practices no longer provide the necessary guidance and support for decision-making in a world of change, complexity, and uncertainty. This situation is driving the move towards a new management paradigm, in terms of which the management function will be radically redefined to take emerging realities into consideration.

Therefore, the presented Computer Platform PINF is a dynamic, scalable, and virtual structure intended for efficient communication, integration, dissemination, and information processing, while providing a selective fusion of knowledge resources of corporations, research institutes, research units and advisers, and experts that aim at developing innovative technical solutions and new technologies. The heterogeneous, distributed structure of the platform enables one to successively widen its information scope and include new databases and software. The implemented platform PINF ensures stable and continuous cooperation between research and business organisations directed at solving complex technical problems. Most importantly, it has a potential to become an inherent part of modern management framework and tool for virtual structures that are still under dynamic development and evidently will continue to manifest at an exponential rate.

Scientific work executed within the Strategic Programme "Innovative Systems of Technical Support for Sustainable Development of Economy" within Innovative Economy Operational Programme.

References

1. Murphy J.J.: Virtual Management – a new business organization paradigm, [online] available at http://www.calumcoburn.co.uk.Murphy
2. Schwarzer B., Krcmar H.: Neue Organisationsformen. New organisation models. [In]: Information Management, Vol. 9, 1994, pp. 20–27.
3. Afsarmanes H., Camarinha M.: Processes and Foundations for virtual organizations. USA: Kluwer Academic Publisher, 2004.
4. The Economist, 2009. The virtual organisation. [online] Accessible at: <http://www.economist.com/node/14301746> [Accessed the 25th February 2015].
5. Greenberg D., Heneman R.: Human Resource Management in Virtual Organizations. USA: Information Age Publishing, 2002.
6. Edvinsson L.: Kapitał intelektualny, Wydawnictwo Naukowe PWN, Warszawa 2001, ISBN: 83-01-13509-3.
7. Kiełtyka L.: Komunikacja w zarządzaniu. Techniki, narzędzia i formy przekazu informacji, Placet, Warszawa 2002, ISBN: 83-85428-78-X.

8. Dolińska M.: Projektowanie systemów informacyjnych na przykładzie zarządzania marketingiem, Placet, Warszawa 2003, ISBN: 83-85428-81-X.
9. Mikuła B.: Organizacje oparte na wiedzy, Wydawnictwo Akademii Ekonomicznej w Krakowie, Kraków 2006, ISBN: 8372523029.
10. Appel W., Behr R.: Towards the theory of Virtual Organisations: A description of their formation and figure, Newsletter Vol. 2, No. 2, pp. 15–36.
11. Kostera M. (ed.): Nowe kierunki w zarządzaniu, Wydawnictwa Akademicki i Profesjonalne, Warszawa 2008, ISBN: 978-83-60807-66-8.
12. Travica B.: The Design of the Virtual Organization: A Research Model Gupta, Jatinder N.D., Association for Information Systems Proceedings of the Americas Conference on Information Systems, August 15–17, 1997, Indianapolis, 1997, pp. 417–419.
13. Burn J., Barnett M., Marshall P.: e-Business strategies for Virtual Organizations, Oxford: Taylor & Francis Ltd., 2002.
14. Lee M.: Leading Virtual Project Teams: Adapting Leadership Theories and Communications Techniques to 21st Century Organizations, New York: CRC Press Taylor & Francis Group, 2014.
15. Russell M.G.: The 'Virtual Laboratory': Alliances for Technology Transfer, Proc. Twenty-Seventh Annual Hawaii International Conference on System Sciences, 1994, pp. 478–482.
16. Kobrin S.J., Battenberg J.T., Hewitt P., Jennings P. J., Joerres J., Kumar S., Mer F.: Worldsourcing's Next Frontier: R&D, World Economic Forum Annual Meeting, Davos, Switzerland, 2004.
17. Łabędzka J.: Multidisciplinary computer platform as a tool for knowledge transfer into science and business, Problemy Eksploatacji. Maintenance Problems, 4/2013, pp. 67–77.

Zdywersyfikowany system komputerowy do wspomagania sieciowych struktur wirtualnych

Słowa kluczowe

Wirtualna organizacja, wirtualna struktura, system komputerowy, ICT, platformy informatyczne.

Streszczenie

Tradycyjne metody i style zarządzania nie spełniają już wymogów adekwatności w stosunku do złożonej rzeczywistości, która charakteryzuje się nieustanną dynamiką oraz wszechobecnością technologii informatycznych.

Zatem konieczne jest wprowadzanie nowych paradygmatów zarządzania, takich jak struktury wirtualne, które w bardziej efektywny sposób odpowiadają na zachodzące w otoczeniu gwałtowne zmiany ekonomiczne, technologiczne, społeczne i kulturowe. Nieuchronne zmiany w otoczeniu biznesowym, które wymuszają redefinicję metod i stylów zarządzania, mają także ogromny wpływ na pojawiające się nowe wyzwania stawiane informatyce oraz technologiom ICT w zakresie oferowania nowych usług i produktów dostosowanych do tzw. wirtualnych struktur organizacyjnych. W artykule przedstawiono potencjał wykorzystania technologii teleinformatycznych w zakresie wspomagania funkcjonowania organizacji wirtualnych (OV).

Artykuł prezentuje specjalizowany system komputerowy w formule Platformy informatycznej PINF, która należy do instrumentarium systemów komputerowych dedykowanych do wspierania funkcjonowania wirtualnego klastra instytucjonalnego ukierunkowanego na dyfuzję innowacyjnych technologii oraz wyników prac badawczych. Analiza potrzeb informacyjnych z zakresu szeroko pojętej innowacyjności wśród przedstawicieli jednostek badawczych i przedsiębiorstw sektora MSP umożliwiła opracowanie założeń technicznych oraz struktury logicznej i fizycznej efektywnego narzędzia komputerowego w formule platformy informatycznej. W artykule zaprezentowano genezę architektury, funkcjonalności oraz praktyczne obszary wykorzystania opracowanej Platformy informatycznej.

Opracowana multisycyplinarna platforma PINF stanowi kompleksowe, modułowe i elastyczne narzędzie wspomagające pracę interdyscyplinarnych zespołów badawczych oraz efektywny transfer wiedzy i innowacji do sektora nauki, przemysłu oraz biznesu.

Sabina MOTYKA, Natalia ŁUKASIK
Politechnika Krakowska
motyka@mech.pk.edu.pl
nat.lukasik@gmail.com

CREATING A CLIMATE OF INNOVATION AS A CONDITION OF THE DEVELOPMENT SME

Key words

Innovation, personnel, business innovation, culture innovation, SME.

Abstract

Environmental instability pressures companies constantly to change their products, services and processes. Not taking innovative activities in organisations possess a risk of losing their market position. Taking action in the innovation area and creating an environment supporting the development of new ideas is very important for SMEs. Introducing innovation in organisations is often joined with resistance from workers. This depends on the ossification of organisational structures, stereotyping, the lack of resources, or the fear of the novelty. Creating and introducing innovation in a company could be inhibited by a series of barriers: economic or psychosocial. Resistance to change is a complex process and affects the speed and quality of improvements. One should especially consider the types of barriers that the organisation can independently affect or even prevent, e.g., psychosocial barriers from workers. The issue of creating a climate of innovation in a Polish company from the SME sector is not often researched, but it happens in international companies. Research over the years by the authors about manufacturing companies confirms that the problem of psychological barriers is common. The aim of the article is to show the special role of employees in supporting innovation of Polish companies from the

SME sector. Every company has a chance to be innovative, but it has to be consciously and systematically pursued. Innovation in organizations should be planned and consistent with strategy of the company. Searching for sources of innovation and evaluating the possibilities of their implementation in specific conditions, including one of the most important factors – humans, innovation activities can bring success.

Introduction

In today's volatile economic environment for businesses, the dynamic processes of globalization in the maintenance and development of the organization is the ability to create innovation. The ability of innovative companies is determined by their intrinsic ability to create new products and technologies, methods of organization, and by their ability to absorb and use knowledge generated outside the company [1]. These activities require appropriate technical competence, managerial skill, and the ability to learn. This encourages organizations to undertake and develop their skills, resources, and learning.

The process of building a competitive advantage for SMEs on the domestic market and the related problems are often associated with a low level of innovation in companies. At the same time, the transfer of research results to the Polish economy producing development is due to the low interest among entrepreneurs in activities and the commercialization of innovative research and the lack of competence of persons involved in these processes [2]. To effectively mitigate these barriers, it is advisable to undertake educational and promotional activities aimed directly at employees of companies who have the greatest impact on the quality and development of the technology needed to compete in the market [3].

Product innovation, process innovation, organizational innovation, and marketing innovation are fundamental factors in the company's position in the market. The need to introduce continuous developments and improvements by the owners and managers of businesses as well as the entire staff seems particularly important. The aim of this article is to develop a set of actions to be implemented in companies in order to reduce barriers to innovation by staff, which is a significant problem in today's SMEs.

1. Innovation in SMEs

Researches into innovation level of domestic SMEs were carried out recently by Haffer [4], Mizgajska [5], Jasiński [6], Żołnierski [7]. The scope of the research projects comprised selected companies of different branches from various locations in Poland. Only research done by Jasiński and Żołnierski covered generally all provinces of Poland. In most cases significant obstacles for innovations were identified, with lack of specialists and resistance to changes as the dominant ones.

Over the years, there have been many of barriers existing in the setting up of innovative companies in Poland, including SMEs, which is also confirmed by a recent study on mechanical engineering companies carried out by the author [8]. They focused on the analysis and evaluation of the level of innovation of Polish machine based enterprises on surveys conducted during the International Trade Fair of Machine Tools, Tools, Devices, and Equipment for Material Processing EUROTOOL 2014 in Cracow. The study involved only manufacturers in the domestic market. The study involved 35 companies, mainly small and medium-sized enterprises. In addition, a similar study was carried out in previous years, as described in [9]. It directly results from a study from 2014 that the main barriers to innovation for the surveyed companies, next to a limited budget (54% of companies) and difficulty in obtaining outside funding (for 51% of companies), are the employees themselves – 14 companies (40%) answered that the barrier is the reluctance of workers to change. Compared to the 2009 study [9], there is a growing barrier on the side of the companies' employees themselves – their aversion and concerns about the changes, and the lack of appropriate qualifications and experience is increasingly becoming an obstacle to innovation.

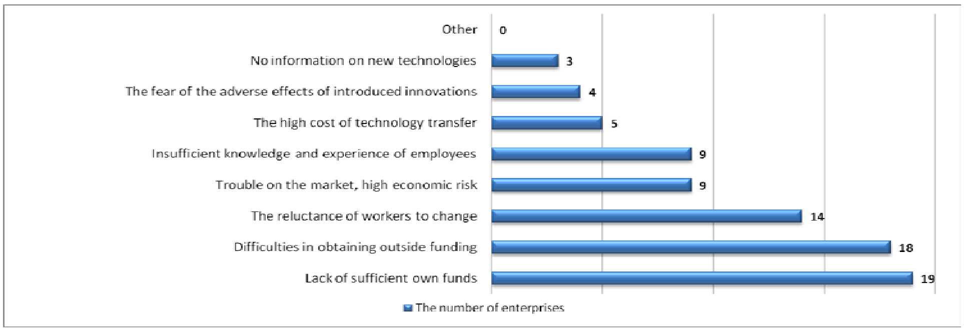

Fig. 1. Barriers to implementation of innovations [8]

To the question whether employees participate in trainings, seminars, or workshops regarding innovation, nearly half of the respondents answered that their employees participate in such meetings. These companies use both third-party services, as well as provide training or seminars internally. 17 companies participating in the study answered that their employees do not participate in such meetings. The results of these studies confirm that major problems in the development of the innovation potential of the SMEs sector are psychosocial barriers, from both workers and managers. The results indicate that the examined enterprises need action in the form of training, working meetings/design workshops, self-education, training grants, etc. Due to the fact that Polish companies has been said to be too little innovative it seems necessary to start changes in areas of innovation process organisation and creation of relevant culture supporting innovation [10, 11, 12]. Polish companies still lack the competence for innovation.

Despite little sample of companies studied (due to restrictions set by criteria of selection: capital – Polish, size – SME, type – manufacturing) one can conclude that situation of studied companies is similar to those presented in results of other researchers [4, 5, 6, 7]. Therefore, authors of the paper consider model proposed herein as relevant for Polish industrial companies of different branches.

As a result of rapidly developing technologies and changing internal and external environment, including law, companies face the challenge of developing a system of continuing education to prepare staff for the implementation of innovative processes in modern enterprises.

2. Innovation culture in company

Managing knowledge accumulated by the company is the basis for the development of innovation. The intellectual capital of the company based on processes of continuous learning, gathering knowledge and their dissemination are all elements that help to create a culture of innovation.

Organizational culture is a set of certain values and norms of conduct prevailing in the organization. This culture is reflected in the behaviour, attitudes and reactions, the approach to solving the problems individuals, or being in social groups.

The influence on the culture of the organization is also found in workplace – production areas, offices, and interior aesthetics. The climate of innovation culture is characterized by flexibility, high tolerance for uncertainty, and dynamics of action. The main task of an innovation culture in a company is to support the innovation process.

In terms of system innovation processes, an interdisciplinary process involving the creation, diffusion, adaptation and innovation analysis and result of innovation [13] or the result of a kind of complicated, continuous relationships and interactions between individuals, community organizations and their activities are important [14]. The concept of showing the innovation process as a result of analysis is found in the relationships between the creation of a learning organization and the organization of knowledge and innovation organizations, and it is expressed in a spiral model [15].

The company focused on innovation should stand out with clearly defined strategies and innovation purposes. The achievement of planned objectives should be supported through cooperation and teamwork. A culture of innovation is based on the frequent training of employees, training creativity, and building a positive atmosphere in the company. Innovation is a process developed by all departments of the company such as manufacturing, commercial, administrative, and marketing. To make the process run smoothly and make sure innovation will have positive effect, the organizational structure should have integrated departments with a high degree of communication and flow of information or cooperation between the departments. An important factor is having the right people in the highest positions – executive board. To succeed, we need people full of energy and enthusiasm, able to face the challenges.

Summing up, the internal components that have a direct influence on the growth of the innovation climate are a unified vision of organization, leadership, a willingness to be innovative, an appropriate organizational structure, creative teams, and the involvement of employees (Fig. 2). With these components, one can effectively implement the objectives of the innovative organization.

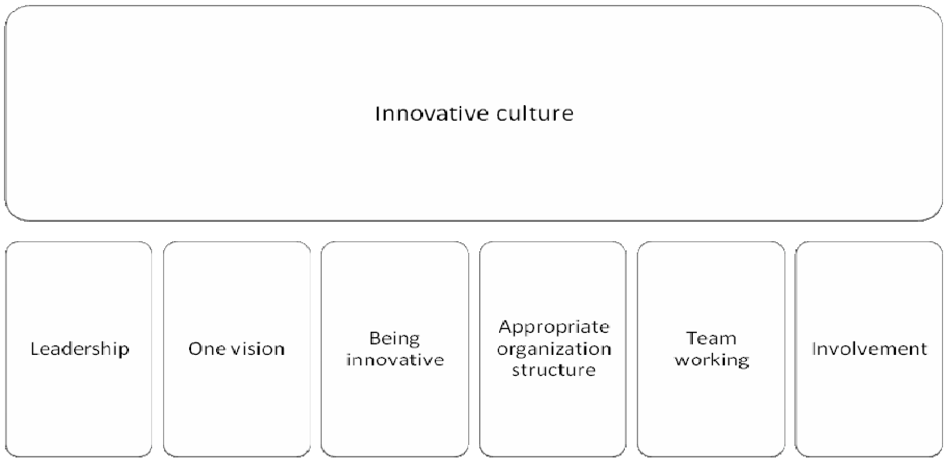

Fig. 2. Influences on the culture of innovation [16]

Innovative company culture is an element that needs to be constantly improved. The main cultural visions needed to support innovation are a focus on the future, openness to change, willingness to take risks and experiment, creativity, mutual tolerance for mistakes, and multiple support and cooperation. There must be a common goal, vision, and faith in action leading to a desired result.

The main exemplars for the culture of innovation is taking risks, tolerance, teamwork, speed of action, and making decisions. In companies where there is a culture of innovation, employees are likely to cope with uncertainty, based on their knowledge and experience.

They are formed a cooperative network by setting up task forces. Managers use a management style that is conducive to independent actions of employees, so that they have the initiative and make their own decisions. A culture of innovation means an atmosphere of freedom, time, and a place of work where a level of mistakes is tolerated. Innovation in a company should begin with the right people. At the recruitment level for companies of different industries, there should be a search for people who are graduates of Management and Production Engineering, where they learned about management strategy, the development and implementation of innovation, production management, quality, service, and innovative product development.

Also noteworthy are any issues about the social impact of innovation known as "Technology Assessment" [17] or competence in the assessment of the implementation of new technologies and products to various aspects of society, taught in the context of the Management and Production Engineering.

Production engineering is an interdisciplinary field of study at the Faculty of Mechanical Engineering of the Cracow, which is adapted to the needs and expectations of employers and labour market requirements, allowing one to obtain knowledge of the design of products and processes, basic control, operation, organization, and management of manufacturing processes. Production engineering graduates find employment in small, medium, and large manufacturing and service companies, in the design and consulting firms, and other economic and administrative units, which require technical expertise, information technology, and economic understanding. During the course, students learn the about issues in the following areas: creating a climate of innovation in organizations, technology transfer and innovation management within the subjects of innovation and technology transfer and intellectual property protection.

3. The role of employees in creating a climate of innovation in SMEs

Based on the analysis of domestic and foreign companies with a highly developed level of innovation, the authors have created a model of implementation innovation. It could be used as a guide by the company creating the role of employees in the process of innovation.

Tips are created mainly for small and medium-sized companies in which innovative activity is not started or is still in the early level of implementation.

People in all positions in company are responsible for innovation, so the innovation process should start at the recruitment. It is important to hire people with the innovators personal characteristics who are not afraid to take risks. A company can create workplaces, where personal duties include responsibility for the management of the innovation process. It is important that system work is flexible and determined in relation to the position of employment. It is important to provide a personal space for each worker that is ergonomically adapted to the needs of the staff. In the process of creating innovation, a huge role is the implementation of an organizational culture based on teamwork. Grouping project teams should be done in terms of culture, experience, or skills. This operation contributes to the wider horizon approach.

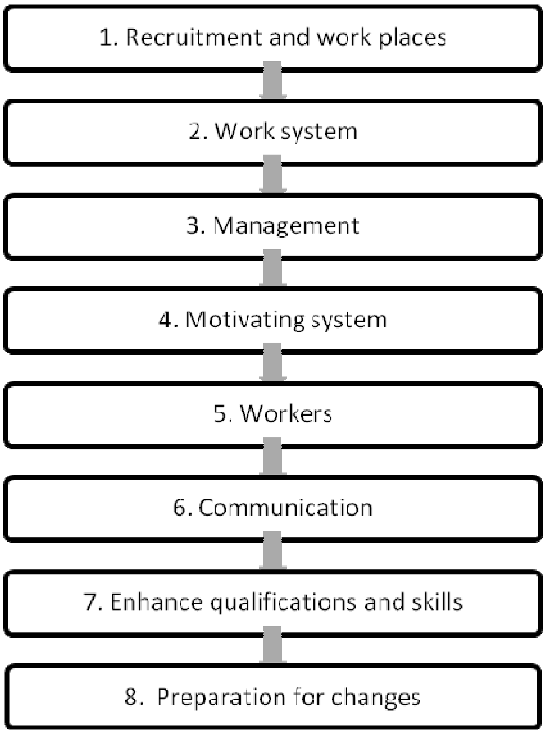

Fig. 3. Impact on innovation company (own work)

Creating a workplace conducive to the development of innovation, the company must pay attention to communication in the company and management’s approach to their subordinates. The company should be particularly concerned about the creation of a positive relationship between the head of management and employees. Regular information meetings with middle management are helpful. The company should demonstrate a willingness to create two-way communication and open dialogue with employees, which may include a lot of trainings and workshops for the staff. Forming a public database of information about a current projects, the composition of the teams, and suggestions for the company's operations should also be done. These activities give employees the opportunity to decide about the company and then increase their involvement in the company’s issues.

Management must demonstrate their commitment and understand the process of the implementation of innovations to effectively lead the subordinates and organization through the changes that are related with this process. The leader should have the ability to create a workplace conducive to creative approaches for the performance of duties. In each innovated project, there is an inscribed risk related to the failure of a new project and material losses. Effective risk management is another feature of a good leader. Managers who use an innovation-oriented approach to personnel management actions often persuade employees to action rather than give specific commands. They create a strong team, with commitment, and share awards and recognition. The foundation for leaders to pursue innovation is the combination of team management skills and motivation as well and the proper level of sharing information with employees.

Management should take the following actions:

- Motivate and encourage the activities of employees;
- Determine ambitious goals, while developing competence;
- Have an openness to ideas and a tolerance of mistakes, while rewarding all work efforts;
- Take an individual approach to each employee and his or her needs;
- Pass the company's philosophy down to subordinates; and,
- Overcome the barriers produced by the fear of failure in workers.

The innovative organization should be aware of the importance of a bonus system for employees. The system will be appreciated where the staff awards are valuable to the employees. The most common motivators are praise, reward, and material and non-material (e.g. promotions) incentives. The company should develop a system to motivate employees based on the following features:

– A personalized reward system corresponding to the aspirations and expectations of employees (funding courses of study, training, conferences relevant to your interests, and a learning profile);
  - Rewarding innovative idea competitions;
  - Benefits (e.g. discounts for sports centres and cultural events); and,
  - Celebration of individual success, as well as corporate events.

People are the foundation of innovation, and their satisfaction with the performance of their duties directly reflects in the results of their work. The innovation potential of a company depends on the people working there. Employees should be aware of the company's mission, and know the impact of their work on the development and on the position of the company. They should have a chance to develop, expand their horizons, and get satisfaction from these things. Employees represent the company, and their attitudes represent the ideas, principles, and the company's brand. Their development should benefit themselves and the organization.

The company should ensure that the following are provided:

– An awareness of the purpose, meaning, and impact of personal work to the development of the company;
  - Freedom of action, where the workers personally decide the quality of their work and the value of their hard work, commitment, and results;
  - Employees develop a passion for their word that provides opportunity for their development and promotion;
  - People with different experiences and skills are connected so that they can learn from each other and broaden their view of the problem; and,

- Innovative activities are include in the scope of the responsibilities of each employees;
- Continuous improvement skills of all employees - creating a learning organization: training and workshops.

Communication inside the organization has influence on the behaviour of people working in it. It is important to develop a system of effective communication in the company by the following:

- Direct Communication: regular information meetings;
- Communication: information boards, newsletters, newspapers, including Internet resources (e.g., email, forums, chat rooms, and video meetings) and Intranet (e.g., internal electronic portal, internal conferences, and webcasts);
- Having no barriers between the cells of the company – anyone can ask anyone regardless of their position;
- A place where you can share your ideas (e.g., a special information board or suggestion box);
- Regular meetings with groups of employees to inform them about the achievements and activities of the individual units; and,
- Training and workshops.

The task of employees is to prepare for rapidly changing markets by observing and analysing the actions of competitors. Management should ensure the capacity to build the organization, which allows a flexible response to change, and to use the opportunities and possibilities offered by the environment. Changes in the organization should provide the possibility for individual development to acquire new competencies, adapting to new roles, and overcoming barriers. The diversity of the organization and their specific activities in any business process of innovation implementation may look differently. Developing innovation system requires a lot of tests and learning based on making mistakes. The implementation process of innovation requires lot of work and commitment, and it is associated with many changes. This is connected with revolution in the company, tearing down existing structures, learning, and perfecting new solutions, so that they become an integral part of the company.

Summary

Modern organizations should strive to become learning organizations, constantly reinforcing opportunities to shape their own future [18]. With the learning processes taking place in them, they can make changes, even in the area of organizational culture, to adapt to progress in the environment.

Among the many elements of the contemporary system of the continuing education of employees, the following can be distinguished [19]: job rotation, reading professional literature, and the participation of workers in training and internships, mentoring, coaching, and employee participation in formal education, for example, extramural studies, and post-participation of employees in conferences and fairs. These actions, and especially those presented in the framework of the model (Fig. 3), should serve as the basis for national SMEs in starting or improving the climate and culture of innovation.

References

1. Stawasz E., Głodek P., Stos P., Wojtas J.: Potrzeby innowacyjne przedsiębiorstw z województwa łódzkiego. Łódź 2003. www.ris.lodzkie.lodz.pl/doc/innowacyjnosc.doc.
2. Łobejko S., Sosnowska A.: Komercjalizacja wyników badań naukowych. Praktyczny poradnik dla naukowców. Urząd Marszałkowski Województwa Mazowieckiego, Warszawa 2013.
3. Symela K.: Szkolenie specjalistów do spraw komercjalizacji innowacyjnych technologii. Edukacja Ustawiczna Dorosłych, 2/2014.
4. Haffer M. (red. nauk.), Haffer R. (red. nauk.): Aktywność innowacyjna małych i średnich przedsiębiorstw Pomorza i Kujaw. Wydawnictwo UMK, Toruń 2008.
5. Mizgajska H.: Aktywność innowacyjna małych i średnich przedsiębiorstw w Polsce – zmiany i uwarunkowania. Wydawnictwo UE w Poznaniu. Poznań 2013.
6. Jasiński H.J.: Innowacje małych i średnich przedsiębiorstw w świetle badań empirycznych. Promocja XXI, Warszawa 2009.
7. Żołnierski A.: Potencjał innowacyjny polskich małych i średniej wielkości przedsiębiorstw. Polska Agencja Rozwoju Przedsiębiorczości, Warszawa 2005.
8. Motyka S., Nowak J.: Innowacyjność polskich przedsiębiorstw przemysłu maszynowego (stan aktualny i prognozy). Innowacje w zarządzaniu i inżynierii produkcji pod redakcją R. Knosali. Oficyna Wydawnicza Polskiego Towarzystwa Zarządzania Produkcją, Opole, 2015, s. 128–140.
9. Motyka S., Jachimowski A.: Innowacyjność polskich przedsiębiorstw przemysłu maszynowego – bariery i szanse rozwoju. Oficyna Wydawnicza Polskiego Towarzystwa Zarządzania Produkcją, Opole 2010.
10. Trompenaars F.: Kultura innowacji. Kreatywność pracowników a sukces firmy. Oficyna a Wolters Kluwer business, Warszawa 2010.
11. Drucker P.F.: Praktyka zarządzania. AE w Krakowie, Kraków 1998.
12. Motyka S.: Wewnętrzne uwarunkowania kreowania systemu innowacji w organizacji. Innowacje w zarządzaniu i inżynierii produkcji, pod redakcją R. Knosali, t. I, Oficyna Wydawnicza Polskiego Towarzystwa Zarządzania Produkcją, Opole, 2013, s. 209–219.
13. Strambach S.: Change in the Innovation Proccess. New Knowledge Production and Competitive Cities – the Case of Stuttgart, Europe Planning Studies, t. 10, nr 2, 2002.

14. Podręcznik Oslo: Zasady gromadzenia i interpretacji danych dotyczących innowacji, 2008.
15. Merx-Chermin M. Nijhof W.F.: Factors Influencing Knowledge Creation and Innovation in an Organization, Journal of European Industrial Training, t. 29, nr 2, 2005.
16. Tidd J., Bessant J.: Zarządzanie innowacjami: integracja zmian technologicznych, rynkowych, organizacyjnych. Wydawnictwo Wolters Kluwer, Warszawa 2011.
17. Kaźmierczak J.: Zagadnienia interdyscyplinarne w programie studiów na kierunku „Zarządzanie i Inżynieria Produkcji". Innowacje w zarządzaniu i inżynierii produkcji pod redakcją R. Knosali. Oficyna Wydawnicza Polskiego Towarzystwa Zarządzania Produkcją, Opole 2015, T. II, s. 877–887.
18. Senge P.M.: Piąta dyscyplina. Teoria i praktyka organizacji uczących się. Wolters Kluwer, Kraków 2006.
19. Sison P.: Personnel and Human Resourses Management, Personnel Management Association of Philippines, Mandaluyong City, 1991.

Tworzenie klimatu innowacyjności jako warunek rozwoju MŚP

Słowa kluczowe

Innowacje, personel, innowacyjność przedsiębiorstwa, kultura innowacji, MŚP.

Streszczenie

Zmienność otoczenia zmusza firmy do ciągłych zmian swoich produktów, usług i procesów. Niepodejmowanie działalności innowacyjnej w organizacjach oznacza ryzyko utraty dotychczasowej pozycji rynkowej. Uświadomienie, zrozumienie i podjęcie działań w obszarze budowania innowacyjności oraz tworzenie środowiska sprzyjającego rozwojowi nowych idei ma współcześnie ogromne znaczenie dla rozwoju MŚP. Wprowadzanie innowacji w organizacjach napotyka często na różne opory ze strony personelu, wynikające zarówno ze skostnienia struktur organizacyjnych, stereotypowego myślenia, braku zasobów, obaw przed nowym. Kreowanie i wprowadzanie innowacji może być utrudniane (czasami nawet uniemożliwiane) przez szereg barier o charakterze biurokratycznym, ekonomicznym czy psychospołecznym. Opory wobec zmian mają złożoną naturę, wpływają na szybkość oraz jakość usprawnień oraz często są specyficzne tylko dla konkretnych organizacji. Na uwagę zasługują szczególnie te rodzaje barier, na które organizacja może samodzielnie oddziaływać, a nawet im przeciwdziałać, czyli bariery psychospołeczne istniejące po stronie personelu. Problematyka kształtowania klimatu innowacyjności w polskich przedsiębiorstwach z sektora MŚP jest rzadko badana w przeciwieństwie do firm międzynarodowych. Badania przedsiębiorstw przemysłu maszynowego przeprowadzone przez autorkę na przestrzeni lat potwierdzają aktualność tego problemu. Celem artykułu jest ukazanie szczególnej roli personelu we wspomaganiu innowacyjności polskich przedsiębiorstw z sektora MŚP. Każde przedsiębiorstwo ma szansę być innowacyjne, jednak musi do tego świadomie i systematycznie dążyć. Wprowadzanie innowacji w organizacjach powinno być działaniem zaplanowanym oraz spójnym z obraną strategią przedsiębiorstwa. Dzięki poszukiwaniu źródeł innowacji, jak i ocenie możliwości ich wprowadzenia w konkretnych warunkach, z uwzględnieniem jednego z najważniejszych czynników, jakim są ludzie, działalność innowacyjna może przynosić sukcesy.

INNOVATIVE ECONOMY
NATIONAL COHESION STRATEGY
INSTITUTE FOR SUSTAINABLE TECHNOLOGIES
NATIONAL RESEARCH INSTITUTE IN RADOM
EUROPEAN UNION
EUROPEAN REGIONAL DEVELOPMENT FUND

Project co-financed by the European Union from the European Regional Development Fund

Rozalia SITKOWSKA
Institute for Sustainable Technologies – National Research Institute, Radom
roza.sitkowska@itee.radom.pl

METHODS FOR RESEARCHING AND ASSESSING THE STATE AND GROWTH OF INNOVATION DETERMINANTS IN THE FIELD OF ADVANCED MANUFACTURING TECHNOLOGY

Key words

Innovation, monitoring, multidimensional assessment of innovation, advanced technologies.

Abstract

Intensive and uneven economic development of the world stimulates the undertaking of research and analysis aimed at identifying the state and the development directions of the innovation potential in different areas of the economy. This article describes a methodology of research in innovation supported by information technology, and in particular, the procedures for designating the key factors of growth promoting in innovation in the field of advanced and medium-advanced technologies. An application of this methodology makes it easier to see weak and strong points, and it indicates opportunities for improvement and development for the researched areas of the economy (industrial processing sectors, producer groups, and regions).

The developed methodology was applied in the research of selected sectors of industrial processing, producer groups, and of the economy at the regional level. Particular attention was given to providing the possibility of estimating the chances of product development belonging to the groups of advanced and

medium-advanced manufacturing technology and operation. The application of the methodology in the sector of highly advanced and medium-advanced technology of industrial processing is extremely important due to the need to address planned investments in the development of products with high innovative potential and promising commercial success, which in turn reduces the financial risk of the investment. The examples referred to in the article related to the use of the methodology of innovation studies have confirmed its usefulness and the possibility of further applications, such as in the planning of research and development of innovative products. The obtained results are of both strategic and operational importance, since they may be used for the formulation of the specialization of the Polish EU-28 production and determine the competitive position of Polish products in the industry. Moreover, research and innovation analyses provide relevant information that is useful to entrepreneurs in the creation of their development strategy, for example, in the decisions concerning the planning of the product volume by placing its own production in the competitive market of the industry.

Introduction

The purpose of this article is to present the changes in the results of the innovation evaluation of Polish industrial processing sectors, based on the example of comparative studies in 2009, 2011, and 2012, and, in particular, advanced technology branches of industrial processing whose products are appropriate for applications in Strategic Programme (PS), *Innovative Systems of Technical Support for Sustainable Development.*

The need for early detection of adverse trends in the economy in the area of innovation necessitates a multidimensional assessment with a view to developing appropriate mechanisms for the stimulation of the development of technology and the improvement of innovation.

Innovation is one of the many subjects (economics, marketing, finance, social statistics and economic analysis, organisation and management, insurance, regional analysis, and others) for which research must take into account the complexity of the phenomenon, and in its description – multi-dimensionality problems [1]. Moreover, innovation is one of the soft factors associated with the development of the creative category that produces new knowledge, related to the quality of infrastructure, including research and development and an effective (modern) industrial base [5].

The European Union comparative studies of sectoral innovation *Sectoral Innovation Watch* (SIW), used factors grouped in three thematic blocks (knowledge and technology, interactions between partners, and cooperation with institutions). In the assessment of *knowledge and technology,* the following indicators were used [2]:

– From the area outside the research and development activity[1]:
  - The intensity of raising funds from external sources,
  - The intensity of the investment into equipment and software;
– R&D intensity, which is the ratio of the expenditure on R&D activities to the value added or sold production;
– Participation of companies introducing new products to the market in agiven sector;
– Defining skills (HRST, the percentage of high-level, highly qualified managers, the proportion of highly skilled technicians, and the share of highly qualified specialists (ICT));
– Denoting the percentage of companies engaged in training activities.

Although the results of the work of the SIW are of particular importance for the determination of the technical distance within the European Union industry, they have been criticized by the authors from the Centre for European Economic Research (ZEW) [2] because of the use relative specialisation index in technology (RCA) [3]. One of the elements of the RCA was being questioned, namely, the productivity of a patent, which is the relationship between patent applications and the economic performance. It was considered that, in view of low patenting capabilities of many countries, patents could not be accepted as an element of European expertise assessment in technology.

The European studies carried out in 19 economic areas in the EU-27, Japan, and the United States, indicate that the European Union still focuses on the traditional industry (machinery, metal products), while the US and Japan focus mainly on industrial support technologies (biotechnology, nanotechnology and ICT).

The results presented in this article for a multidimensional evaluation of innovation pertain to a *selected area* of industry, including the production of chemicals and chemical products (NACE[2] 20: medium-high technology), metal products (NACE 25; medium-low), electronic and optical products (NACE 26; high), electrical equipment (NACE 27; medium-high), and machinery and equipment (NACE 28; medium-high). From the selected area of the industry, for the product analysis, products and services were selected that shared similar technical and functional characteristics to the planned and achieved results in PS [8–10].

1. A description of selected indicators for researched sectors

The researched sectors in the years 2009–2013 indicate that the importance of the selected Polish branches of industrial processing slightly decreased in the production of industrial processing sales (a decrease from 26.2% in 2009 to

[1] Non-R&D innovation activities.
[2] Polish enterprise classification number.

24.9% in 2013). Researched sectors, until 2012, showed an increase in the trend of production sales, with the exception electronic and optical equipment production where there had been a decline. The increase of production sales in 2013 occurred only in the production of electrical products (Fig. 1).

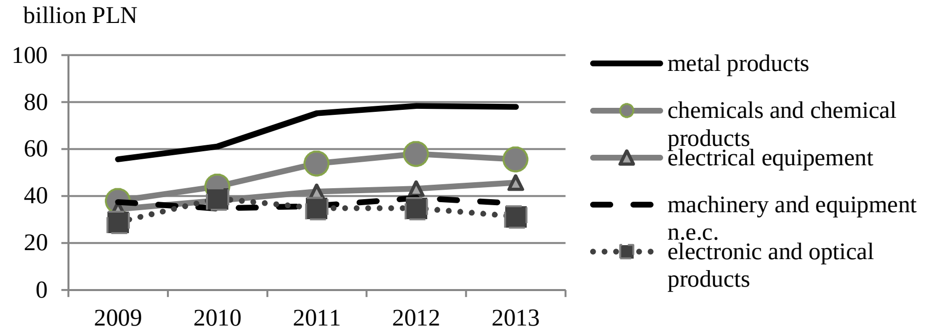

Fig. 1. Changes in the value of production sales in selected sectors of the industrial processing in the years 2009–2013 (elaboration based on GUS data – Central Statistical Office)[3].

The highest investment in innovation activities of the five researched sectors was made in *metal products manufacturing* (8.2% of the investments of industrial processing in 2013), and the lowest was in *electronic and optical equipment manufacturing* (2.7%) It should be noted that, in 2013, most of the surveyed sectored sustained significantly higher expenditures on R&D activities, per employee, than the average in industrial processing (Fig. 2).

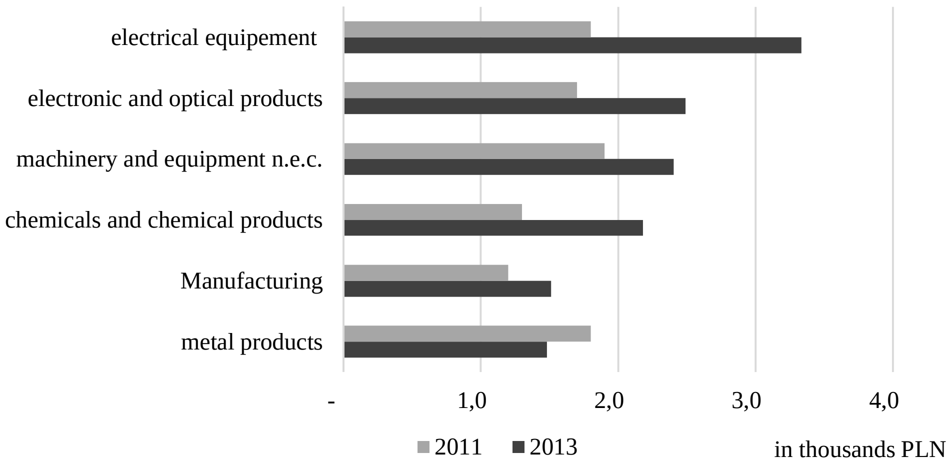

Fig. 2. The expenditure on R&D activities per one employee in the researched branches in comparison with the average in the processing industry in the years 2011–2013

[3] Also in the subsequent Tables, unless stated otherwise.

The presented issue, due to the importance of *selected sector* in modernising the economy, should meet with the interest of the companies from the researched sectors and constitute a contribution to sectoral analyses.

2. The methodology for multidimensional evaluation of innovation

To designate the synthetic evaluation of the innovation potential of industrial processing sectors, Regional National Summary Innovation Index (RNSII) was used, whose formula was included in the schema of the presented algorithmic model (Fig. 3).

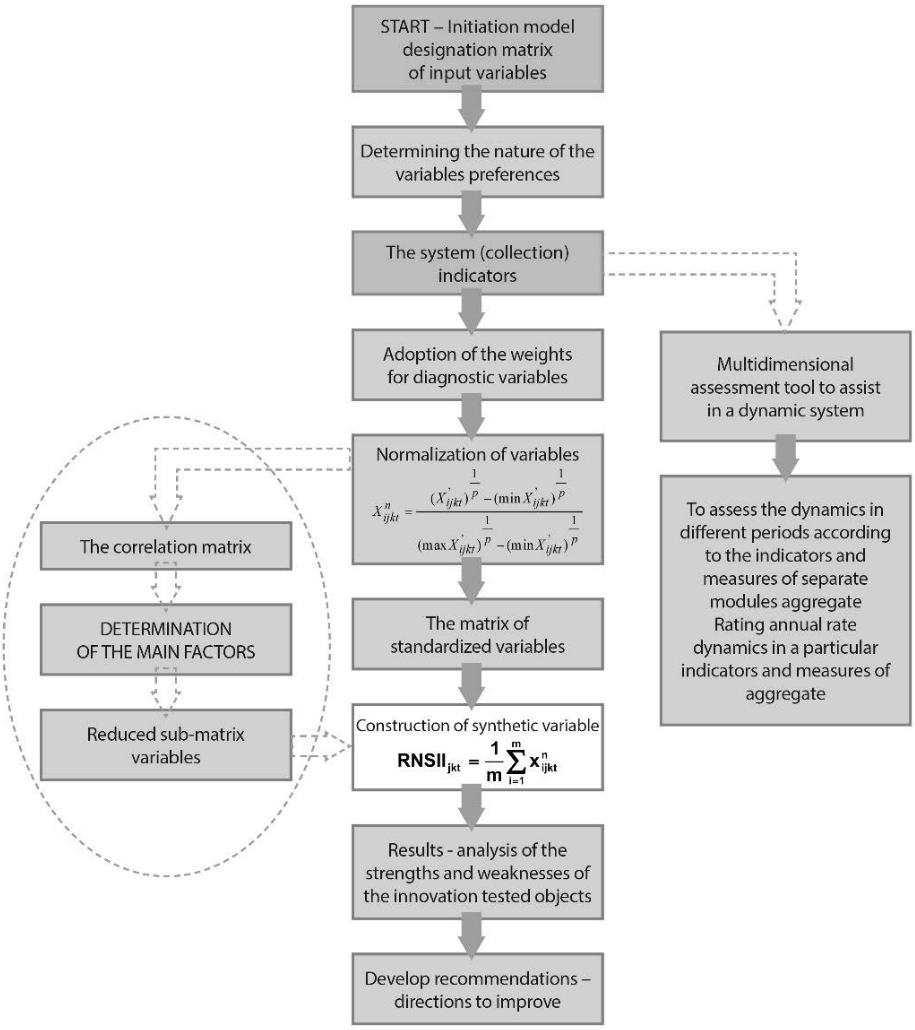

Fig. 3. The diagram of the algorithmic model for multidimensional comparative analysis of innovation [7].

The innovation of sectors in the *t* year is referred to as a matrix, X^t, which contains *n* groups (sectors) ($n = 24$), and *m*-dimensional ($m = 19$ factors). The design of the synthetic indicator of sector innovation was a model that aggregates the calculation of synthetic indicator [6].

An important aspect in the applied method of the multi-parameter evaluation of innovation in the selected sectors of the Polish industrial production is the matter of relativity, that is, the reference point of measurements. This reference point was the mean value for industrial processing.

In the assessment, the level of innovation in industrial processing sectors was established based on the following classification [11]:

I	Strong sector, when $dj \rangle \bar{d} + s$;	Medium-weak when $\bar{d} - s \langle d_{j \leq \bar{d}}$;	III
II	Medium-strong when $\bar{d} \langle d_{j \leq \bar{d}} + s$;	Weak (blank areas) when $dj \leq \bar{d} - s$	IV

where the measure of the development d_j corresponds to level of synthetic indicator of the sector innovation, and $\bar{d}$, *s*, respectively, mean the arithmetic mean and standard deviation of the studied factor.

Standardized factors for Polish sectors were reduced, and the modified matrix of indicators satisfying the condition of at least mean correlation was ordered. Indicators with the lowest correlation values were rejected. To carry out further assessments of innovation, a modified set of indicators was adopted which was presented during the discussion of surpluses and deficiencies of factors shaping innovation.

In the development of recommendations for decision support in the area of advanced technology, the procedure presented in Figure 4 was used.

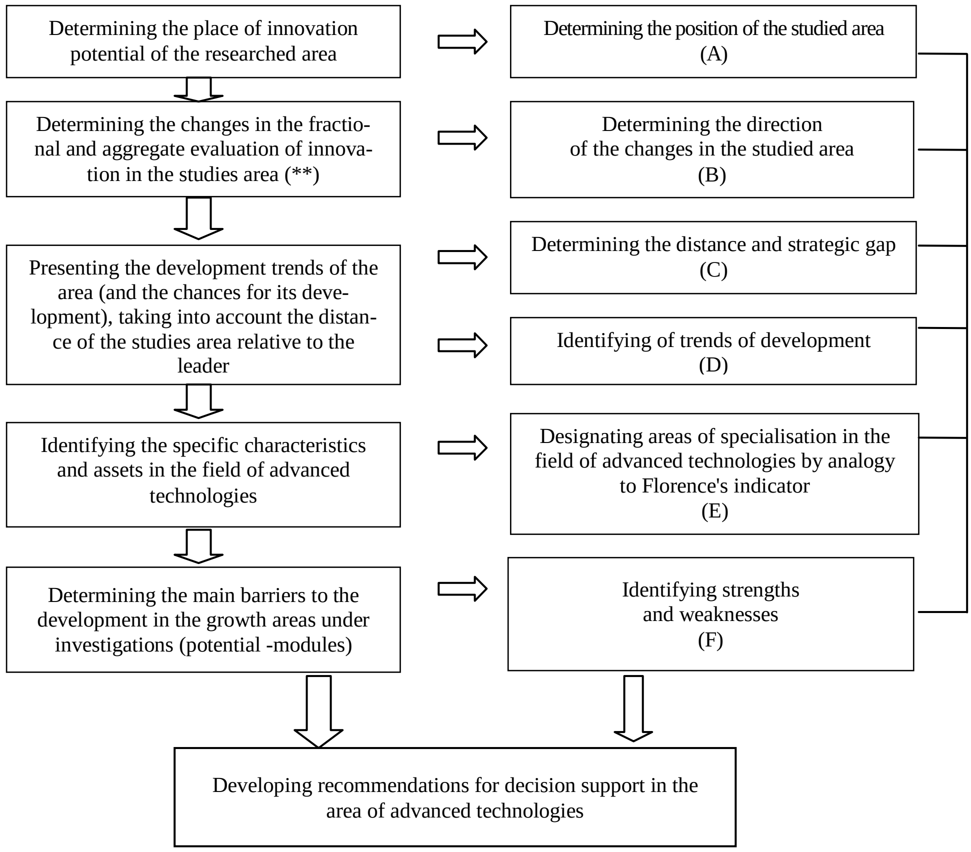

Fig. 4. The procedure for supporting decision-making process in the area of advanced technologies [4], [7].

Due to the limited scope of this article, only selected findings are presented.

3. The results of a multidimensional evaluation of innovation of selected sectors in industrial processing

The results of the conducted research, with an indication of the synthetic value of the innovative potential of sectors in 2009–2012, ranking sites and the obtained the level of innovation are shown in Table 1. Among the sectors accepted for research, the highest ranking (2nd place in 2012 with the synthetic innovation potential of 0.332) was received by electronic and optical equipment manufacturing.

Table 1. The level and the potential of innovation for industrial processing sectors in 2009, 2011, and 2012 (*order according to the results of 2012*)

Production sectors, taking into account the place in the ranking:	2009	2011	2012	Synthetic innovation potential (2012)
01. pharmaceutical products- *the leader*	I	I	I	0.427
02. electronic and optical equipment	I	I	I	0.332
08. metal products	II	II	II	0.253
12. electrical equipment	II	I	III	0.228
16. chemicals and chemical products	III	III	III	0.209
18. machinery and equipment	III	II	III	0.203

In the research, the impact of partial evaluation (modules) was studied on the synthetic evaluation of innovation for electronic and optical equipment manufacturing (Tab. 2).

Table 2. The impact of modules on the synthetic evaluation of innovation in electronic and optical equipment manufacturing in the years 2009 and 2011

Manufacturing of electronic and optical equipment (and computers)	Module share in %				
	Module I Work resources and the creation of new knowledge	Module II R&D Intensity	Module III innovation financing and non R&D	Module IV Modernity (**)	Module V Productivity of resources and energy
2009	18.6	1.0	3.0	36.8	40.5
2011	29.6	4.4	6.2	33.8	26.0
2012	21.7	1.3	4.5	40.4	32.2
Mean	23.3	2.2	4.6	37.0	32.9

The analysis of the data presented in Table 2 indicates that the synthetic assessment of the production innovation of electronic and optical devices was influenced the most by *modernisation* (37.0%), *the productivity of resources and energy* (33.9%) and *work resources*, and *the creation of new knowledge* (23.3%). At the same time, the share of other modules was very low, for example, *R&D intensity* (on average for the years 2009–2013 – 2.2%), and *innovation financing and non-R&D* (4.6%).

Assuming a uniform distribution of the importance of indicators (i.e., 5.26%, with 19 explanatory factors) each factor should have the same contribution to the development of innovation. However, in the production of electronic and optical devices, eight factors show higher impact, including two indicators from Module V, *Productivity of resources and energy (productivity of fixed assets and machinery, electricity consumption)*, two factors from Module I (*human resources and the creation of new knowledge,* including *participation of* *staff in R&D activities and the participation of researchers* and three related to the application of advanced technologies *(computers for the control and adjustment of automation processes, participation in investments, the computer-controlled production lines*). The remaining eleven factors show a much lower contribution (Fig. 5), which is particularly associated with very use of low innovative potential in the area of *innovation financing*, and a low level of training of human resources.

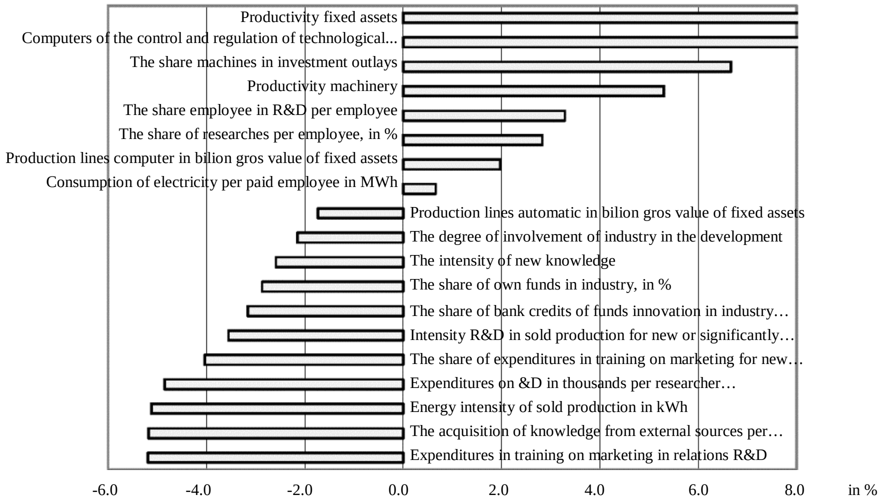

Fig. 5. Surpluses and shortages of factors shaping innovation in the production of electronic and optical equipment, taking into account an even distribution of the importance of factors (5.26%) (an average rating of 2009–2012)

In assessing innovation of selected industrial processing sectors, the condition has been maintained that the applied indicators are stimulants. In this case, the obtained negative aggregate deviations are the result of a deterioration in the comparable periods (t and t + 1). On the basis of the analysis, it can be concluded that, in the production of electronic and optical devices, the increase in synthetic impact deviation was positively influenced by the increase results of the following four modules: *work resources* and *creating new knowledge*, innovation *financing and non-R&D*, and *R&D intensity and modernisation*, while the results worsened in relation to the *productivity of resources and energy*.

The studies carried out in the Institute for Sustainable Technologies in Radom identified specific characteristics and assets in the field of advanced technologies. In the researched sectors, *the manufacture of machinery* and *metal products manufacturing* show a high rate of specialization in the field of machining centres, and the production of chemicals for automated and computer-controlled lines. Moreover, the quantification of the contribution (share) was taken into account of the explanatory variables for the modernisation variable (application of advanced techniques). This quantification in the production of electronic and optical devices suggests that the *computers for controlling and regulating processes* (on average, 37.9%) have the greatest influence on the aggregate variable assessment of modernisation and their influence shows a rising trend. This factor, together with the participation of the *machines in the investment*, more than doubles the advantage (70.5%) over other factors (29.5%).

Conclusion

The verification of the methodology provided results lead to the conclusion that the best rating was obtained for the manufacture of electronic and optical equipment, which, in the 4-level rating, received Level I for innovation, and the weakest was the manufacture of machinery and technical equipment (Level III of innovation).

The results of the conducted assessments of innovation in *industrial processing* have allowed a formulation of specific recommendations. The identified recommendations point to the need to support the decision-making processes in the designated sectors, mainly in the following areas: low intensity of R&D activities (including the purchase of new knowledge and software) and innovation outside the R&D activities (investments in machinery, marketing, provision of a suitable environment for innovation).

The areas that require external support and direction are the intensity of innovation in areas outside the R&D activities (mainly through purchases of machinery, including imports) are primarily manufacturers of electrical equipment, machinery and equipment, and the manufacture of electronic and optical equipment.

These sectors are an opportunity for the R&D sector to strengthen them through the ready products (applications), which are the results of the Strategic Programme, development programmes, as well as by strengthening the research potential of these industries in joint solutions for new or upgraded products.

Scientific work executed within the Strategic Programme "Innovative Systems of Technical Support for Sustainable Development of Economy" within Innovative Economy Operational Programme.

Bibliography

1. Balicki A.: Statystyczna analiza wielowymiarowa i jej zastosowania społeczno-ekonomiczne. Wydawnictwo Uniwersytetu Gdańskiego, Gdańsk 2009, s. 48–62.

2. Grimpe Ch., Leheyda N., Rammer Ch., Schmiele A., Sofka W.: Sectoral Innovation Systems in Europe: Monitoring, Analysing Trends and Identifying Challenges Machinery and Equipment Sector. Centre for European Economic Research (ZEW), Manmheim, April 2008; http://www.europe-innova.org/c/document_library/get_file?folderId=24913&name=DLFE-2663.pdf (lipiec 2011).
3. Identification of Europe's sectoral innovation leaders; Sectoral Innovation Watch (SIW) – (Europe INNOVA).
4. Karmowska G.: Badanie i pomiar rozwoju regionalnego na przykładzie województwa zachodniopomorskiego, „Roczniki Nauk Rolniczych" 2011, Seria G, t. 98, z. 2; http://www.wne.sggw.pl/czasopisma/pdf/RNR_2011_T98_z2_s85.pdf; czerwiec 2013.
5. Łaźniewska E., Gorynia M.: Konkurencyjność regionalna. Koncepcje – strategie – przykłady. PWN, Warszawa 2012, s. 137–139.
6. Sitkowska R.: Wielowymiarowa ocena innowacyjności wybranych grup producenckich. Problemy Eksploatacji 2012, nr 2, s. 155–166.
7. Sitkowska R.: Procedura wspomagania procesów decyzyjnych na szczeblu władz regionalnych w obszarze zaawansowanych technologii, z przykładem zastosowania w województwie mazowieckim. W: Danuta Strahl (red.), Andrzej Raszkowski (red.), Dariusz Głuszczuk (red.). Prace Naukowe Uniwersytetu Ekonomicznego we Wrocławiu PN 333 Gospodarka regionalna w teorii i praktyce. Wrocław 2014, s. 183–194.
8. Sitkowska R.: Tendencje rozwojowe wybranej grupy produktów zaawansowanej techniki. W: Rola innowacyjności w kształtowaniu jakości (red. J. Żuchowski, R. Zieliński), Wydawnictwo Naukowe: Politechnika Radomska, Wydział Ekonomiczny; Instytut Technologii Eksploatacji-Państwowy Instytut Badawczy w Radomiu, Radom 2012, s. 88–96.
9. Sitkowska R.: Zastosowanie metody badania tendencji rozwojowych produktów zaawansowanej techniki. Prace Naukowe Uniwersytetu Ekonomicznego we Wrocławiu Nr 300 pt. „Innowacje w zarządzaniu" (red. Jan Skalik, Anna Zabłocka-Kluczka), Wrocław 2013, s. 111–118.
10. Sitkowska R.: Zastosowanie procedury produktowej w działaniach projektowych przedsięwzięć naukowych (na przykładzie wybranych wyrobów produkcji instrumentów i przyrządów pomiarowych). Studia i Materiały „Miscellanea Oeconomicae" WZIA UJK Kielce. Nr 2/2012, s. 315–332.
11. Stańczyk E.: 2008, Innowacyjność w województwach. Wiadomości Statystyczne, nr 10, s. 53–69.

Metodyka badania oceny stanu i uwarunkowań wzrostu innowacyjności w obszarze zaawansowanych technologii wytwarzania

Słowa kluczowe

Innowacyjność, monitoring, wielowymiarowa ocena innowacyjności, zaawansowane technologie.

Streszczenie

Intensywny i nierównomierny rozwój gospodarczy świata skłania do przeprowadzania badań i analiz, których celem jest identyfikacja stanu, kierunków i możliwości rozwoju potencjału innowacyjnego w różnych obszarach gospodarowania. W artykule przedstawiono metodykę badania innowacyjności wspomaganą przez aplikację informatyczną, w szczególności uwzględniono procedury wyznaczania kluczowych czynników stymulujących wzrost innowacyjności w sektorze zaawansowanych i średniozaawansowanych technologii. Zastosowanie metodyki ułatwia prace związane z wyznaczaniem słabych i mocnych stron, ze wskazaniem możliwości poprawy i szans rozwojowych badanych obszarów gospodarki (działów przetwórstwa przemysłowego, grup producenckich oraz regionów).

Opracowana metodyka znalazła zastosowanie w badaniach wybranych działów przetwórstwa przemysłowego, grup producenckich oraz gospodarki w układzie regionalnym. Szczególną uwagę zwrócono na zapewnienie możliwości szacowania szans rozwojowych produktów należących do grup zaawansowanych i średniozaawansowanych technologii wytwarzania i eksploatacji. Zastosowanie metodyki w sektorze wysokiej i średniowysokiej techniki przetwórstwa przemysłowego jest niezwykle istotne ze względu na zapewnienie adresowania planowanych inwestycji finansowych w rozwój produktów o wysokim potencjale innowacyjnym i rokujących szanse sukcesu komercyjnego, co z kolei pozwala na zmniejszenie ryzyka finansowego inwestycji. Wymienione w artykule przykłady zastosowania metodyki badania innowacyjności potwierdziły jej przydatność i możliwości kolejnych aplikacji, m.in. w planowaniu badań i rozwoju innowacyjnych produktów. Uzyskane wyniki mają znaczenie zarówno strategiczne, jak i operacyjne, służą bowiem do sformułowania specjalizacji polskiej produkcji w UE-28 czy też określenia pozycji konkurencyjnej polskich produktów w branży. Badania i analizy innowacyjności dostarczają także istotnych informacji przydatnych przedsiębiorcom w tworzeniu strategii rozwojowych, np. w decyzjach dotyczących planowania wolumenu produktów przedsiębiorstwa poprzez umiejscowienie własnej produkcji na konkurencyjnym rynku danej branży.

Project co-financed by the European Union from the European Regional Development Fund

Urszula WNUK
Institute for Sustainable Technologies – National Research Institute, Radom
urszula.wnuk@itee.radom.pl

ORGANISATION AND MANAGEMENT OF KNOWLEDGE AND TECHNOLOGY TRANSFER PROCESSES AT RESEARCH ORGANISATIONS: EMPIRICAL STUDY

Key words

Knowledge transfer, technology transfer, commercialisation of research results, research organisation, Intellectual Property.

Abstract

The development of knowledge-based economies is dictated by the intensification of globalisation processes and the emergence of information societies characterised by the growing demand for knowledge and innovations. Effective execution of the knowledge and technology transfer processes is therefore the foundation of the contemporary knowledge-based economy because as a result of these processes novel technologies are brought to the market and the development of better products and services meeting the actual customer requirements is stimulated, and the national innovation performance and the level of competitiveness are improved. The author presents the issues connected with the organisation and management of knowledge and technology transfer from R&D organisations. The discussion is based on international case study analyses whose results helped to indicate the models and procedures

commonly applied by these institutions to ensure an effective execution of the transfer process.

Introduction

In the contemporary world, knowledge and technological innovations are viewed as the drivers of productivity and social and economic development. The changing understanding of knowledge and technology transfer in the knowledge-based economies complies with the priorities of the economic sustainable development. In this new reality it is extremely important for all entities (be it research institutes, universities, or businesses) engaged in the development and commercialisation of know-how and innovations to ensure effectiveness of these processes, and in order to do so, these organisations also need to properly manage their knowledge so as to be able to build and maintain their competitive advantage.

The knowledge management term was popularised by Ikujiro Nonaka [1] and it refers to the systematic creation, dissemination and use of knowledge. Knowledge management is a process involving different kinds of activities that define the objectives of a given system and help to achieve them. The individual functions intertwine, creating a management process within which the hierarchical and functional dependencies can be found. Effective management of knowledge translates into effective execution of knowledge and technology transfer processes, and therefore it decides on the competitiveness and innovativeness of both research organisations and businesses in which research results are practically implemented, and as a result constitutes the foundation of contemporary knowledge-based economies.

From the point of view of an organisation, knowledge and technology transfer are elements of competitive advantage building, and their effective execution is included in a strategic management process. The importance of strategic management was discussed in many works by e.g. A.D. Chandler (1962) [2], K.R. Andrews (1980) [3], H.I. Ansoff (1985) [4], P.F. Drucker (2002) [5], or R.L. Ackoff (2002) [6]. The objective of strategic management is long-term planning concerning the activity of an organisation focused particularly on the issues of effective management and development. In this view, maintaining close and efficient relations between science and industry is a must, and the flow of know-how between universities, research organisations and businesses, should be a strategic mission of all governments, local authorities, and most of all the science and R&D sector, as active participation in these processes helps to generate increased research funding, engages more scientists and business people in the development and diffusion of innovations and brings socio-economic benefits, not only to individual stakeholders engaged in the knowledge transfer project but also to the entire region or the country (Mansfield 1975 [7], Backer 2000 [8]).

The focus of knowledge and technology transfer processes is the dissemination of know-how regarding the scientific and innovative practice to individual organisations so as to help them manage the challenges of using that knowledge and/or its products to create change within their work settings (Backer 2000 [8]). Knowledge and technology transfer encompasses a complicated process involving the complexity of both the technology and the market as well as the complexity of interactions between the transferor and the beneficiary originating from many different sources (Saad et al. 2002 [9]; Lee et al. 2010 [10]; Gudek 2013 [11]). It therefore requires all involved entities to be properly equipped to manage and execute a knowledge and technology transfer process, and thus calls for the application of different models, systems and procedures that could facilitate the effective planning and practical implementation of know-how and technologies, and might also help to manage and overcome the barriers that may impede the success of the transfer process.

As shown in numerous scientific publications and expert reports (e.g. Office of Inspector General, 2012 [12]; European Commission, 2013 [13]), the transfer of knowledge and its material results is still a problematic issue and though nowadays governments, local authorities, science and research institutions and businesses have paid a lot of attention to the importance of the transfer of know-how and innovation commercialisation processes, the diffusion of knowledge is still not at a satisfactory level both in the developed and developing economies (see e.g. performance measures in the Knowledge Transfer Study 2010–2012 by the European Commission, 2013 [13]). The European economy, for instance, still seems to be based on old paradigms, in which insufficient emphasis is put on the market orientation of research results (Matusiak and Guliński 2011 [14]). Despite the fact that Europe has great experience in the execution of both basic and applied research, the ability to transfer its results to commercial use in the form of new technologies, products or services is still much lower compared to the EU's main competitor – the USA (Wnuk et. al. 2014 [15]). In the States, however, the problems of ineffective practical implementation of research results are also a common phenomenon, and even such renowned R&D centres as the NASA battle with ineffective transfer of knowledge and its material results (NASA 2012 [16]). In Poland, despite numerous socio-economic changes and reforms in the Polish R&D sector, which were first triggered by the economic transition process in 1989, few fundamental changes could in fact be noticed as far as the practical application of research results is concerned (Wnuk 2014 [17]).

No universal technology transfer models (TT models) can be found in literature, therefore, up to date analyses of case studies and good practices seem to be very important as the emulation of certain positive behaviours in this field may turn out to be beneficial for the organisation conducting a knowledge and technology transfer process. For that reason, the scope of the article is the review of literature and the empirical case study analysis focused on the organisation and management of the knowledge and technology transfer processes at selected research organisations. The author reviews the transfer models and procedures applied at these institutions and also analyses whether any dedicated systems and IT tools are employed to facilitate the successful dissemination and implementation of the know-how originating from these entities. The studies were conducted using a desk research method.

1. Sample selection methodology

In the course of her study, the author analysed seven (7) case studies in knowledge and technology transfer from different public research organisations (PROs) (both research institutes and universities) worldwide, which were selected based on the analysis of global PRO rankings. The main reference point was the Shanghai Ranking 2014 [18], however due to the fact that it only lists the best universities and does not include research organisations of non-academic character, the author also analysed the European Research Ranking 2013[1] [19], in order to add research institutions to the research sample as well. Moreover, a Polish institution was also selected so as to compare international practices with the ones implemented by the Polish PRO. The Polish organisation was selected based on the analysis of the 2014 University Ranking by Perspektywy [20]. Since this ranking only concerns universities and does not include research institutes, as they are not centres of education, and due to the fact that there is no separate ranking of Polish research institutes, the Polish PRO selected for analysis is the top university in the Perspektywy ranking that ranks high as far as the “Innovativeness” assessment criterion is concerned (the only criterion in the ranking that is directly connected to the issue of commercialisation of research results).

Additional criteria for the selection of the above-listed institutions included the availability of information on the organisation of the knowledge and technology transfer and the ease of its procurement, the existence of the TTO, and the implementation of internal knowledge and technology transfer policies and regulations, and systems (tools) facilitating the dissemination of know-how and commercialisation of research results.

The list of research institutions included in the case study analysis is presented in Table 1. A desk research method was employed in the study. The analysis of case studies encompassed the review of documents (e.g. annual reports, technology transfer regulations, guidebooks and procedures, etc.) and the analysis of the web pages of the institutions selected for the study and their technology transfer offices (TTOs).

[1] A more recent ranking is not available.

Table 1. Research institutions analysed by the author

– Harvard University (USA); – University of Cambridge (UK); – Swiss Federal Institute of Technology in Zurich (ETH Zurich) (CH); – Fraunhofer Society (DE); – Technical Research Centre of Finland (VTT) (FI); – Netherlands Organisation for Applied Scientific Research (TNO) (NL); – AGH University of Science and Technology (AGH) (PL)

2. Empirical analysis

a) Knowledge management in knowledge and technology transfer processes

The management of knowledge in the knowledge and technology transfer processes is incorporated and embedded in the strategic organisation management and thus plays a crucial role in all the institutions analysed by the author. Knowledge management in knowledge and technology transfer processes in the research organisations analysed is adjusted to the individual stages of the transfer process, e.g. the concept, prototype, verification, and transfer (Mazurkiewicz et. al., 2010) [21], at which different types of R&D and organisational tasks are undertaken. A simplified draft summarising the knowledge management procedure applied at the institutions analysed is presented in Table 2.

Table 2. Knowledge management in the transfer process

Stages of the transfer process	Key elements of knowledge management in the transfer process
Transfer	– Knowledge protection, codification and transfer
Verification **Prototype**	– Transformation of knowledge into material results and its verification
Concept	– Determination of the target of the knowledge management process – commercialisation of know-how and/or its material results – Development of a knowledge management strategy – Generation of knowledge

At the concept stage, crucial for the process of knowledge management in the transfer project are elements with a cognitive character, e.g. knowledge location and generation, while at the subsequent stages of the project essential are elements of an executive nature, including e.g. the practical application of knowledge (knowledge transformation into material results) and the transfer of its results for business use. In addition, at each stage, it is important to identify the key technological, market and business steps, implement a proper knowledge management strategy, and design suitable transfer models that will facilitate the effective execution of the transfer process.

b) Transfer models

The case study analysis revealed the existence of two types of knowledge and technology transfer models applied by each of the institutions covered by the research sample, i.e. process models which describe a step-by-step procedure of the knowledge and technology transfer process, and functional (institutional) models which aggregate important actors and activities and describe relationships between them (see also Wnuk et. al., 2014) [15]).

Despite some minor differences, the process models applied at the institutions analysed look more or less the same and include the stages presented in Fig. 1.

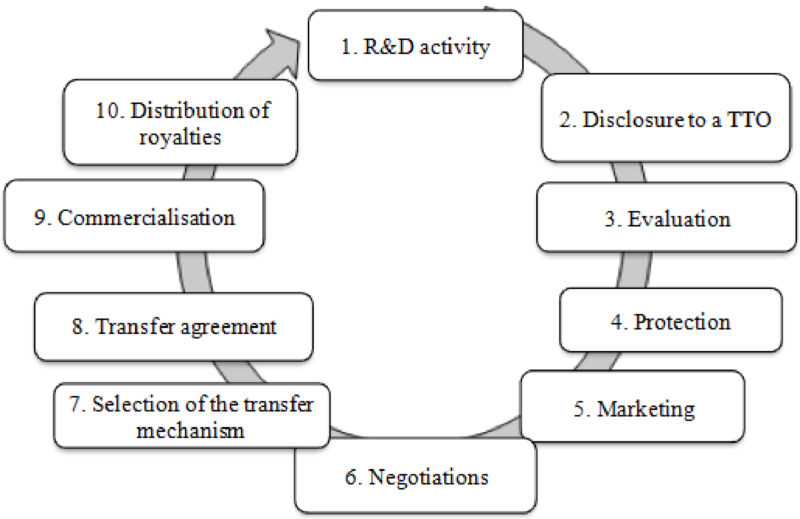

Fig. 1. Knowledge and technology transfer procedures as implemented at institutions analysed

The researchers are obliged to disclose the results of their research to the technology transfer office (TTO) which then takes control over the commercialisation process. Once the invention is disclosed, the rights are transferred onto the parent institutions (PRO or university) and then IPR is protected (patented in all the cases analysed). Following that, the market demand is analysed, the commercial potential of the invention assessed, and the product valuated. At the next stage of the transfer process the market is segmented and the marketing campaign tailored to the character of the innovation and the industry branch is launched, as a result of which the potential end user is selected, the commercialisation mechanism chosen, and the negotiations with the transferee initiated. Once the contract is signed, the royalties are distributed between the parent institution and the author of the invention.

Though the process models applied at the PROs and universities analysed do not significantly vary in terms of their stages, there are however discrepancies between the functional models that are in place. The following three models emerged from the case study analyses conducted by the author of the paper (Fig. 2–4).

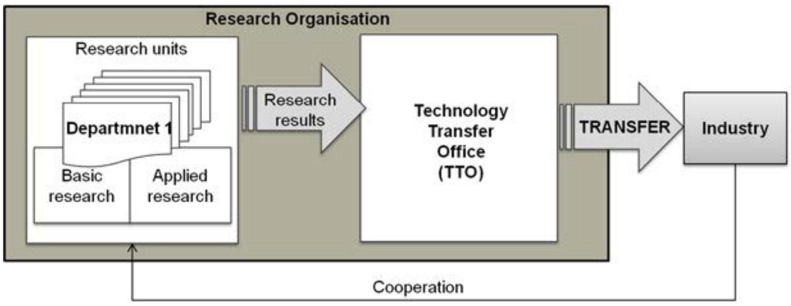

Fig. 2. Functional model I

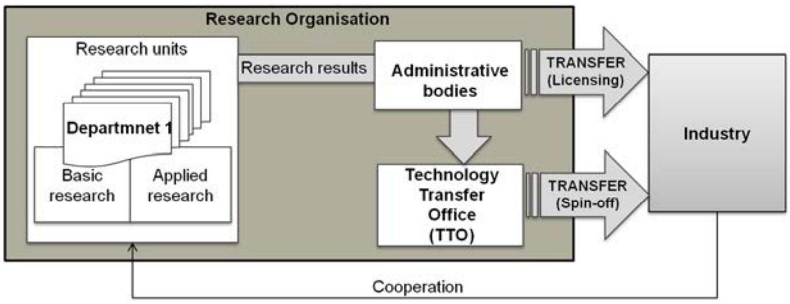

Fig. 3. Functional model II

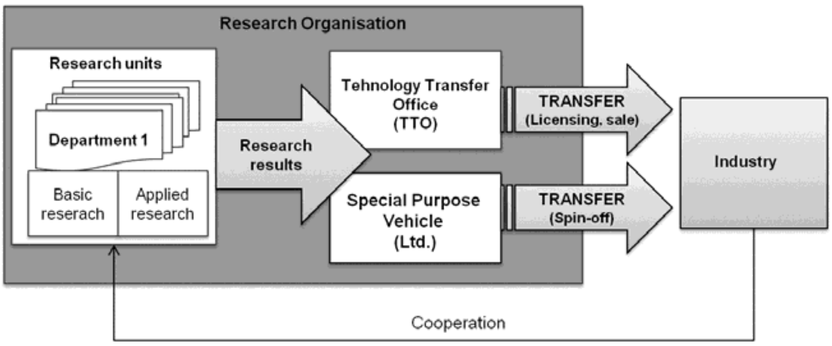

Fig. 4. Functional model III

Functional model I is implemented at the Harvard University, the University of Cambridge, the ETH Zurich and the VTT. The Fraunhofer Society and the TNO utilise model II, while AGH has implemented model III.

In all models a TTO is established to commercialise the results of research conducted at the individual research units of the parent PRO or university. However, the scope of responsibilities of this unit varies in the three models listed above.

In the case of the first model, this body is responsible for the management and execution of all transfer processes, regardless of the types of TT mechanisms selected. In the second model the TTO commercialises research results only by means of the establishment of spin-off ventures. In this model, commercialisation by means of external licensing lies in the hands of the administrative bodies of the research institution. In the third model there are two bodies responsible for the commercialisation of this university's research results. One of them is a technology transfer office, responsible for invention protection and commercialisation by means of licenses and sale, and the other unit, a Special Purpose Vehicle, organises and manages the commercialisation process by means of spin-off ventures.

Conclusions

The review of the selected 7 case studies indicated certain similarities as far as the organisation and the management of the transfer process is concerned and showed that knowledge and technology transfer constitute one of the strategic areas of activity of the institutions analysed. The PROs in question actively seek to make the transfer processes more effective by means of the following activities:

– The introduction of the tailor-made transfer policies and procedures, as well as clear commercialisation and IPR laws and TT guidebooks;
– The establishment of designated technology transfer units which support researchers in the complex issues of know-how dissemination and innovation commercialisation by offering specialist financial, business, and legal advice. Their active participation in the transfer of know-how and technologies lies in assessing their marketability opportunities, seeking potential customers, preparing procedures for the protection of intellectual property rights, and preparing business plans for spin-off ventures;
– Popularisation of different channels of non-commercial and commercial knowledge and technology transfer mechanisms

In all cases analysed, the success of the transfer processes is also based on strong industry orientation and connection, substantial autonomy of the individual departments of the PRO or university, or units affiliated to it.

Scientific work executed within the Strategic Programme "Innovative Systems of Technical Support for Sustainable Development of Economy" within Innovative Economy Operational Programme.

References

1. Nonaka I., Takeuchi H.: The Knowledge-Creating Company. How Japanese Companies Create the Dynamics of Innovation, Oxford University Press, New York, Oxford, 1995.
2. Chandler A.D. (1962): Strategy and structure. Chapters in history of industrial enterprise. MIT Press, Cambridge.
3. Andrews K.R. (1980): The concept of corporate strategy, Homewood.
4. Ansoff H.I. (1985): Zarządzanie strategiczne. PWE, Warszawa.
5. Drucker P.H. (2002): Myśli przewodnie Druckera. MT Biznes, Warszawa.
6. Ackoff R. (2002): The strategic management of intellectual capital and organizational knowledge: a collection of readings. Oxford University Press, Nowy Jork.
7. Mansfield E. (1975): East-West technological transfer issues and problems. International technology transfer: forms, resources, requirements, and policies, American Economic Review 65(2), pp. 372–376.
8. Backer T.E. (2000): "The failure of success: challenges of disseminating effective substance abuse prevention Programmes", Journal of Community Psychology, Vol. 28, No. 3, (2000) 363–373, p. 364.
9. Saad M., Cicmil S., Greenwood M. (2002): "Technology transfer projects in developing countries – furthering the Project Management perspectives", International Journal of Project Management 20 (2002) 617–625, p. 625.
10. Lee A.H.I., Wang W-M., Lin T-Y. (2010): "An evaluation framework for technology transfer of new equipment in high technology industry", Technological Forecasting and Social Change 77(2010) 135–150, p. 135.
11. Gudek A. (2013): Czy warto podejmować ryzyko związane z prowadzeniem projektów badawczych, 2013, http://laboratoria.net/pl/artykul/zarzadzanie_projektami.
12. Office of Inspector General (2012): Audit of NASA's Process for Transferring Technology to the Government and Private Sector, Report No. IG-12-013.
13. European Commission (2013): Knowledge Transfer Study 2010–2012, Final Report, Directorate-General for Research and Innovation, Innovation Union.
14. Matusiak K.B., Guliński J. (2011): Kierunki doskonalenia systemu transferu technologii i komercjalizacji wiedzy w Polsce. Zadania dla rządu i administracji centralnej, Zeszyty Naukowe Uniwersytetu Szczecińskiego (642) Ekonomiczne Problemy Usług 64/2011, s. 27–57.
15. Wnuk U., Mazurkiewicz A., Poteralska B.: Toward an Effective Model of Technology Transfer from Polish Public Research Organisations, Galbraith B. (ed.) Proceedings of the 9th European Conference on Innovation and Entrepreneurship, Version ISSN: 2049-1069 pp. 472–479.

16. NASA (2012) Office of Inspector General, Audit of NASA's Process for Transferring Technology to the Government and Private Sector, Report No. IG-12-013.
17. Wnuk U. (2014): Knowledge and Technology Transfer from Polish Public Research Organisations: A case study of the Institute for Sustainable Technologies – National Research Institute, Innovation through Knowledge Transfer, InImpact: The Journal of Innovation Impact Vol. 7. No. 1: pp. 34–49.
18. Academic Ranking of World Universities 2014, http://www.shanghairanking. com/.
19. European Research Ranking 2013, www.researchranking.org.
20. Perspektywy, Ranking Szkół Wyższych 2014
21. Mazurkiewicz A. Karsznia W., Giesko T., Belina B.: Metodyka oceny stopnia dojrzałości wdrożeniowej innowacji technicznych, Problemy Eksploatacji, 1/2010, s. 5–20.

Organizacja i zarządzanie procesem transferu wiedzy i technologii z jednostek naukowo-badawczych: badanie empiryczne

Słowa kluczowe

Transfer wiedzy, transfer technologii, komercjalizacja wyników prac B+R, jednostka naukowo-badawcza, prawa własności intelektualnej.

Streszczenie

Rozwój gospodarek opartych na wiedzy podyktowany jest intensyfikacją procesów globalizacyjnych i rozwojem społeczeństw informacyjnych, w których znacząco wzrasta zapotrzebowanie na wiedzę i innowacje. Skuteczna realizacja procesów transferu wiedzy i technologii stanowi zatem podwaliny współczesnej gospodarki opartej na wiedzy, gdyż w rezultacie tych procesów rynek zasilany jest innowacyjnymi rozwiązaniami technologicznymi, systemowymi i procesowymi stymulującymi rozwój lepszych produktów i usług odpowiadających faktycznemu zapotrzebowaniu konsumentów i jednocześnie odgrywa kluczową rolę w kreowaniu innowacyjności gospodarki i podnoszeniu poziomu jej konkurencyjności. W artykule omówiono zagadnienia organizacji i zarządzania procesem transferu wiedzy i technologii z jednostek naukowo-badawczych. Zaprezentowano wyniki przeprowadzonych międzynarodowych studiów przypadku, które pozwoliły na wyłonienie modeli i procedur powszechnie stosowanych w celu zapewnienia efektywnej realizacji tych procesów.

INNOVATIVE ECONOMY
NATIONAL COHESION STRATEGY
INSTITUTE FOR SUSTAINABLE TECHNOLOGIES
NATIONAL RESEARCH INSTITUTE IN RADOM
EUROPEAN UNION
EUROPEAN REGIONAL DEVELOPMENT FUND

Project co-financed by the European Union from the European Regional Development Fund

Urszula WNUK, Stefano TOMMEI
Institute for Sustainable Technologies – National Research Institute, Radom

PUBLIC RESEARCH-BASED SPIN-OFFS IN ITALY AND POLAND: SIMILARITIES AND DIFFERENCES IN POLICIES, PROCEDURES AND PERFORMANCE

Key words

Technology transfer, commercialisation of research results, spin-off, university, research institute, Italy, Poland.

Abstract

Since, along with licensing, research-based spin-offs have become the most promoted and desired mechanism of knowledge and technology commercialisation, the aim of this article is to contribute to the literature on public research spin-off activity in selected EU Member States. Based on literature review and empirical studies, the authors compare the major modes of creation and operation of research-based companies established by the Italian and Polish universities and non-academic public research organisations. The analyses the authors conducted for each country concerned the following three detailed research areas: (1) the national regulations governing the establishment of spin-offs at universities and research institutes introduced, (2) the institutional spin-off policies and procedures as implemented by the Italian and Polish research organisations, and last but not least (3) the statistical analysis on public research-based spin-offs in the two socio-economic contexts. The studies

employed a desk research method. Interviews with the representatives of units responsible for the commercialisation of research results at research organisations selected for analyses were also conducted.

Introduction

Research-based spin-offs are defined as new companies set up by a host institute (university, technical school, public/private R&D department) to transfer and commercialise inventions resulting from their R&D efforts (Clarysse et al. 2000) [1].

As discussed in Wnuk and Mazurkiewicz [2] there are different terms present in literature that are used with reference to scientific, particularly academic entrepreneurship, and the most commonly used ones are *academic spin-offs or spin-outs*. These terms refer to companies based on intellectual property (IP) owned by the parent research organisation. However, the literature [3, 4, 5] further differentiates between these two. Academic and non-academic research-based *spin-off companies* are independent of the parent institution and their creation is financed from external (e.g. venture capital) funds (Chiesa and Piccaluga [6]), whereas *spin-out companies* remain closely tied to the parent institution by means of financial or operational (i.e. shared professional and administrative) dependencies. The authors of this article have decided to use the *spin-off* term with reference to enterprises based on university (institute) know-how (IP) established by the scientific staff or the alumni of universities and PROs.

Research-based companies have received a lot of attention from policy makers, researchers, innovation managers, economists, and even sociologists. Such growing interest in this way of commercialising the results of publicly funded research stems from the fact, that research-based spin-offs are considered to be one of the key factors in the development of science and technology policy in all industrialised countries (Mustar 2001) [7]. They are of economic significance for innovation activity (Helm and Mauroner 2007) [8], stimulate economic development and boost market competitiveness by introducing state-of-the-art technologies (Shane 2005 [9], Varaldo and Minin [10]), and also trigger regional growth and modernisation through the establishment of a growing technology base (Parker 2001 [11], Bramwell et. al. 2008 [12], De Turi and Garzoni 2014 [13]). Apart from facilitating regional and national innovativeness, competitiveness and economic development, research-based spin-offs are also important for organisations from which they emerge. Shane (2005) [9] claims that they encourage entrepreneurial behaviour amongst researchers and involve the inventors in the process of technology commercialisation, an opinion which is also expressed by Clarysse and Moray 2004 [14], Visintin and Pittino 2014 [15], Tamowicz [16], Stawasz [17]). Nevertheless, some authors underline that such positive results depend strongly on the background and skills and competences (both academic and entrepreneurial) of the spin-off founders (Grandi and Grimaldi [18], Fini et al. [19]). Research-based spin-off companies also generate more income for the parent institution than licensing to established companies, and are an effective tool for the commercial implementation of emerging or breakthrough technologies originating from parent research institutions.

Research-based spin-offs have been a popular means of commercialisation of research results in the USA since 1950s, however nowadays the most advanced national economies also use this means of exploiting and diffusing public research to generate economic wealth (Clarysse et al., 2005) [20]. Contemporary policies of the US and EU governments stress the importance of research institutes and universities in the process of technology creation, transfer and commercialisation. As a result they have introduced various regulations that support commercialisation and foster entrepreneurship. Most of those regulations focus on enabling the research and educational institutes to commercially deploy their research through spin-off companies. Additionally, the universities and research institutes themselves have also introduced internal regulations and guidelines on technology transfer, particularly licensing and spin-off establishment. This means that the policies and procedures for spin-off processes vary across countries and among research institutions, as presented in the OECD's Report 2013 [21]). For that reason, the scope of the article is the analysis of regulations governing the establishment of spin-offs at universities and research institutes introduced at macro and micro levels. The authors review laws and governmental acts concerning protection and commercialisation of intellectual property. This is followed by an overview of the institutional spin-off policies and procedures as implemented by the Italian and Polish research institutes and universities, and statistical data concerning spin-offs in these two countries. The studies were conducted using a desk research method and interviews with technology transfer officers employed at research organisations selected for the analyses.

1. Legal regulations

What is considered to be a breakthrough regulation in the IPR protection and commercialisation of publicly funded research results is the American Bayh-Dole Act (1980) [22]. It established a consistent patent granting policy, gave the small businesses and non-profit organisations, including universities, intellectual property control over their inventions, even if they were discovered with government's support or under federally-funded research programmes, and resulted in the creation of technology transfer offices (TTOs) at most US universities, research institutes, and federal laboratories (Wnuk, 2010 [23]). The introduction of this legislation greatly facilitated patenting activity and the commercialisation of research results through research-based companies, and ever since the act was signed, the number of start-ups and spin-offs has significantly increased as well. The enormously successful Bayh-Dole Act soon became emulated in other countries. In the European Union, for example, many Member States have built a legal framework for the support of technology and innovation transfer and commercialisation that is somewhat based on the American Bayh-Dole Act. As stated in the OECD's report (2003) [24], the regulations introduced in the EU Member States have been mainly focused on encouraging ownership of innovations by the institution. Countries like Denmark, Finland, Germany, and Norway all introduced new laws and changed to university ownership models similar to the Bayh–Dole Act of 1980 (Damsgaard and Thursby 20013) [25]. However, not all countries have adopted the employer ownership model. The exceptions are, *inter alia*, Sweden and Italy, in which the professor's privilege has not been abolished. Polish regulations concerning IP ownership indicate that the IP generated in publicly funded research should belong to the employer – the research institution.

Italy

Intellectual property in Italy[1] has been regulated for many decades by numerous laws and governmental acts, which did not manage to introduce a coherent definition and understanding of the complex issue of IP ownership and commercialisation. It has only been from the 1990s onwards that, when the world started to rapidly change its scientific innovation rates and its economic balances, such regulations have been taken into consideration for a wide and comprehensive reform. The law that introduced an organic and well-structured regulation about protection and valorisation of industrial property rights, was the "Industrial Property Code" (IPC) of 10th February 2005 no. 30 [26], which significantly simplified more than 40 other laws and governmental acts, and reorganised the existing provisions on Intellectual Property. The Act also lists possible means to protect intellectual property that include trademarks, geographical indicators, designs and utility models, semiconductor topographies, and new plant varieties. Ever since its introduction, the IPC has been modified many times, and each modification has promoted harmonisation towards the EU legal evolution of the subject and simplified control system and bureaucracy. As far as the IP ownership is concerned, all regulations, according to the national

[1] In Italy the term "Intellectual Property", is mainly used with reference to all kind of "creations of the mind" Nevertheless, the latest legal doctrine has raised criticism towards this nomenclature, since it overlaps between contemporary concepts (like literary and artistic works, inventions, trademarks, brands, designs and competition) and concepts connected to a more traditional definition of property (namely material goods, belonging to Roman law). Therefore, as for the latest legal and judicial definition introduced by the "Industrial Property Code" (2005), the "Industrial Property" term is preferred.

law, grant the creator(s) the moral right to the innovation, no matter what their role in the university or research institute is. As far as IP ownership is concerned, the general rule for any employee who reaches a new invention is that the right belongs to the employer [27][2]. Nevertheless, while the rest of Europe was abandoning this position, the IPC has provided a specific regime for university and research institute employees [28][3]. Professors and researchers have the so-called "professor's privilege", which means they have the individual ownership of the invention and they are entitled to have priority on any emerging right regarding the invention. So, moral right and economic rights belong primarily to them. The moral right is also fully recognised to regular university or institute graduate students and interns, but their participation in the rights share is always in practice rapidly concluded with a one-time transaction. With regard to the right to register the patent, the IPC provides a sort of inventor's priority, but individual regulations diverge from this common framework. Differences are based on the room for maneuver given by the national law and the policies introduced by the Italian universities and research institutes concerning research management and commercialisation.

Legislation concerning research-based spin-offs in Italy has been introduced in 1999 with the issuing of the first legal act is the Legislative Decree of 27th July 1999, no. 297 *Tiding legislation up and procedure streamlining to support scientific and technological research, technology dissemination and researchers mobility* [29], which governs scientific and technological research activities, and gives Italian universities the right to establish spin-off companies to encourage youth employment, and foster transfer of university technologies. It was followed by the Ministerial Decree of 8th August 2000, no 593 [30], which implemented provisions of the Legislative Decree 297/99 and came into force in February 2001. This Ministerial Decree established a new system for financing public research, more strongly controlled by the Ministry of Education, University and Research. All funds, are provided by the national body "Fondo Ageviolazioni alla Ricerca" (FAR – Relief Fund for Research), which decides on beneficiaries and limits. The latest legal regulations concerning the matter of research-based spin-offs are the Law of 30th December 2010, no 240 concerning *Rules about University organization, academic personnel and its recruitment, as well as enabling act to the Government to foster quality and efficiency of the University system* [31], and the Ministerial Decree of 10th August 2011, no. 168. concerning *Rules defining criteria of professors and researchers' possibilities to participate to Research Spin-off (or Start up), implementing Article 6, paragraph 9 of Law 30th December 2010, nr. 240* [32]. The first of them just gives an insight into the subject, in which it states that university professors or researchers cannot participate in any form of commercial activity other than a

[2] IPC article 64.
[3] IPC article 65.

research-based spin-off. The latter, on the other hand, gives guidelines on eligible proposing parties, procedures, incompatibility and conflict of interests regarding the establishment of a research-based spin-off company.

Poland

The IP rights in Poland are governed and regulated by two legal acts: the Copyright Act of February 04, 1994 [33] and the Industrial Property Act of June 30, 2000 [34]. The Copyright Act recognises both the economic rights and the moral ownership of the creator and indicates that, unless the employment contract states differently, the copyright to work developed by the employee under the contract of employment, belongs to the employer (i.e. the PRO or the university) not inventors themselves. However, when the work has been commissioned to the researcher and executed outside their permanent employment contract, then the copyright is not automatically owned by the employer, and if they wish to have legal rights to the work developed, the contract should state so. The Industrial Property Act, on the other hand, defines the means to protect intellectual property (patents, registration of utility models, registration of industrial designs and registration of trademarks). It also maintains employer ownership over inventions stemming from work performed under the employment contract. However, the situation is more complicated in the case of research commissioned by external parties and financed from public funds. Here the Act states that the company that orders the university or research institute to conduct research for them has the right to patents, trademarks, industrial designs and utility models to research results, unless the contract between these two parties states differently.

The matter of research-based spin-offs in Poland is not regulated by any separate regulations concerning this form of commercialisation of research results, but it is included in two more generic acts, i.e. the Act on Research Institutes of 30th April 2010 [35], and the Law on Higher Education of 27th July 2005, recently amended by the Act of 11th July 2014 [36], and brought into force on 1st October 2014. The Act on Research Institutes grants these entities the right to diffuse research results, [4] create capital companies, purchase shares and stock in such enterprises, and attain income from them, [5] but only with the supervisory ministry's (the Ministry of Economy) official consent. Without the Ministry's consent PROs cannot engage in this form of business activity. The Law on Higher Education, as amended in 2014, extends the regulations concerning commercialisation of research results, and introduces important changes concerning the organisation and execution of commercialisation of university research. Before its amendment, the Law on Higher Education of 2005 stated that each university should develop its own rules and policies concerning

[4] Section 2.2 of the Act.
[5] Section 3.17 point 5 of the Act.

commercialisation of its technologies. However, new Act stipulates that, for the period of three months from the date of invention disclosure, the university is the owner of the rights to commercialise their employees' research results, but if no steps to commercialise the research results are taken within that time, the IP ownership is transferred to the creator. The Act also regulates the issues concerning the establishment of designated technology transfer units at universities and the matter of royalty distribution.

2. Institutional policies and procedures

Regardless of the governmental regulations concerning commercialisation of research results, which very often introduce general guidelines and serve as recommendations, universities and research institutes may develop own procedures to commercialise their innovations, and actually the majority of EU research organisations do so. In this section, the authors present the results of their analyses concerning institutional policies and procedures for commercialisation of research results.

a) Research sample selection methodology

The studies were conducted for selected Italian and Polish research organisations. The research sample was selected based on the analysis of national rankings of research organisations NETVAL Report (2014) [37] (Italy), and the 2014 University Ranking by Perspektywy [38] (Poland) and it includes the top institutions from the Italian and Polish rankings. In the case of Italy these are top 6 institutions, and Poland five. This discrepancy results from the fact that the Italian ranking takes into consideration both research institutes and universities, while the Polish one concerns only universities. Since research institutes in Poland are not centres of education, they are not incorporated in the national study conducted by the Perspektywy journal. As there is no separate ranking of Polish research institutes, these institutions are not further analysed by the authors. Regarding Italy, the NETVAL Report is a useful tool to understand the overall situation of commercialisation of public research results in the Peninsula. The Report mainly analyses patent regimes and spin-off activity run by all national public research organisations. Nevertheless, the report, even when pinpointing the presence of the Top 5 Institutions, never says clearly the names and never refers to a specific group. In order to select the Top 5 group, the authors decided to mix together the results concerning the list of Top Patentees and Top Spin-off Establishers, to create a list of 5 eminent public research traders. When analysing the 2014 Ranking of the Polish Universities, the authors took into consideration only one of the assessment criteria adopted in this study, i.e. "Innovativeness", as it is the only criterion directly connected to the issue of commercialisation of research results. The criterion includes the following data: the number of patents and protected IPR, the consumption of EU funds, the number of licenses and spin-off companies, policies and structures facilitating protection and commercialisation of university research.

The list of research institutions included in the case study analysis is presented in Table 1. A desk research method was employed in the study. The analysis of case studies encompassed the review of documents (e.g. annual reports, technology transfer regulations, guidebooks and procedures, etc.) and the analysis of web pages, and statistical data concerning commercialisation of research results in these organisations (e.g. commercialisation mechanisms used (i.e. sale, licensing, spin-off)). The latter data are presented in the next section of the article. Additionally, interviews with the representatives of units responsible for the commercialisation of research results were also conducted for organisations in which no data were publicly available.

Table 1. Research institutions analysed by the authors

	University	**Research Institute**
Italy	– Politecnico di Torino (POLITO), – Università degli Studi di Padova (UNIPD), – Università degli Studi di Bologna (UNIBO), – Scuola Superiore Sant'Anna di Pisa (SSPI) – Università degli Studi di Genova (UNIGE)	– Consiglio Nazionale delle Ricerche (C.N.R.)
Poland	– Akademia Górniczo-Hutnicza (AGH) – Politechnika Poznańska (PP) – Politechnika Wrocławska (PWr) – Uniwersytet Przyrodniczy we Wrocławiu (UPW) – Politechnika Łódzka (PŁ)	---

b) Regulations implemented by institutions covered by the analysis

Italy

In general, revenues from licence are divided between inventors and the U/Is they work for. The inventors gain, from a minimum of 50% to a maximum of 70% shares, which is also regulated by the national law. The 50% royalty division is the regular standard for C.N.R., UNIBO and UNIGE. POLITO provides 50%, but if the holders are the inventors, the quota goes up to 70%. UNIPD grants 60%. SSPI has a peculiar system: the inventors can gain 70%, 60% or 50% of revenues accordingly respectively to classes of < 25.000€, between 25.000 and 50.000€ and > 50.000€. In each case, the remaining quota is given to the U/Is, that usually can designate the main part for the central administration and a lower quota for the Department of origin of the patent/inventor(s). Moving on from this, not all U/Is make express reference to the possibility and potential of giving licence to

Spin-offs. The U/Is that state such a policy (C.N.R., UNIPD and SSPI[6]) just provides preferential licensing practices. All U/Is of the group have separate and quite detailed regulations for Spin-off establishment, usually recently updated in 2014. Regulations are composed of a minimum of 10 detailed articles (C.N.R., UNIPD and UNIBO) up to 12 (SSPI), 14 (POLITO) and a maximum of 19 articles (UNIGE). These regulations provide all the information concerning the establishment procedures, shareholding agreements, conventions on U/Is logo/know-how/facilities use, conventions about U/Is' personnel employment and IPR sharing between U/Is and spin-offs. As far as the spin-off establishment is concerned, all regulations pinpoint as possible and privileged promoters the natural persons like the teaching staff, technical and administrative staff, PhDs, Research Fellows and Scholarship Holders. Only POLITO and UNIGE consider the legal person of the U/I as a possible proposer. Only SSPI consider eligible to be proposer also graduate students and interns. As far as potential partners are concerned, besides the proposers who are natural partners with stronger duties towards the spin-off, there are almost no restrictions. All regulations give the possibility to U/Is to be a partner to the spin-off, and the participation is open to any external, but interested natural or legal person. The U/Is which exclude non-direct personnel (from PhDs to graduate students) from being a proposer, recognise the right to be a partner.

With regard to the establishment procedures provided by the regulations, it is possible to determine a sort of "standard procedure" since the sequence of phases and involved Bodies are very much like ones to the others. The proposal of the spin-off establishment must be submitted to the U/Is with a description of the activity (related to the exploitation of a U/I patent, if necessary), a duly fulfilled business plan and drafts of a shareholding agreement and a request, if needed, for U/I participation in the corporation stock. The proposal is analysed, at first, by a "Spin-off Commission". This commission has different names according to what is provided by each regulation. The composition generally is made of 5-7 high level professional, usually elected by the dean, if also the dean is not a member of the Commission (SSPI). Only C.N.R. requires the presence of two external professionals. Member re-election is never prohibited and there are no strict deadlines to the commission duration in charge, which can last from 3 up to 5 years. Its function is standardised. It has to make a professional and detailed analysis of the proposal, evaluating spin-off's practical and economic feasibility and, if requested, the feasibility of the U/I participation in the corporation stock.[7] If the commission's opinion is positive, the proposal is transmitted to the Administrative Council (AC). The AC is the final body involved which has to

[6] C.N.R. Patent Regulation article 26; UNIPD Patent Regulation article 5.3; SSPI Patent Regulation articles 5 and 6.2.

[7] Moreover, the Commission usually works as a monitoring Body, which receives annually information from the active Spin-offs about their business, and a Reviewer for Spin-offs' profitability.

deliberate on the matter and has the power to deny approval. When the AC gives its consent, the spin-off is officially authorised to be established. Moreover, with its deliberation the AC also issues the definitive text of the Shareholding Agreement and of all the conventions about U/I logo, know-how and facilities use and U/I personnel employment, as well as the nomination of the U/I representative in the Spin-Off AC and Spin-off Board of Statutory Auditors (one for each body). The procedure is not complex and not too long in average. The litmus test can be given with, on one side, the C.N.R.'s procedure as the quickest and, on the other side, the UNIPD's procedure, which asks for four different opinions before the AC deliberation. Referring to the Spin-off activity, and more precisely to the Spin-off interaction with the U/I of origin, the analysis passes on the agreements and conventions draft in the establishment procedure. Shareholding agreement includes all the aspects concerning the participation, in terms of corporation stock, of the U/I and of the Spin-off proposers and, in addition, it provides guidelines on how to deal with changes in the quota sharing, especially for the U/Is. As far as U/Is participation is concerned, if the AC decides for a direct participation, the Agreement provides the limits in terms of sharing percentage and years to detain it. These respectively are: C.N.R (up to max 25%, minimum 3 years), POLITO (from 4% to 40%, maximum 5 years, or less according to law), UNIPD (always participated, max 5%, minimum 2 years), UNIBO (up to max 10%, maximum participation 3 years, renewable only one time), SSPI (it says just to act accordingly to the law) and UNIGE (max 15%, max 3 years). For all U/Is it is provided that they must benefit from the possibility of receding and from a "put option" on their quota. Proposers, instead, are not always asked to hold a precise quota, but they are asked to participate and do not recede before a period that can be between 2 and 3 years. The exception here is the UNIPD, which also grants itself a right to compensation, in case the spin-off's commercial activity would not work. The agreements on the employment of U/I personnel in all/some spin-off activities are also very relevant. In order to have a transparent and efficient cooperation, all Regulations considered introduce specific norms on how to avoid, and in case sanction, situations of confidentiality infringements, incompatibility or conflict of interest. Especially, all U/I provides that the dean, their delegate, members of the AC, members of the Academic Senate or the Scientific Council and (except with dean's authorisation) department directors cannot participate in operating bodies of the spin-offs. In average, it can be said that all U/I provides that their personnel can work for the spin-off, without prejudice to their main employment duties at the U/I, and it is always requested to ask for a formal permission. Teaching staff benefits from a lighter regime, since often it can ask to the dean or the AC just once for permission (e.g. UNIPD). Some U/Is provide that for technical and administrative personnel the cooperation must be authorised each time (e.g. UNIBO and UNIGE). When considered, non-direct personnel can cooperate under specific authorisation and on desultory basis (e. g. SSPI, POLITO and UNIPD). The final aspect, in terms of Spin-off characteristics stated in the

Regulations, is the IPR management. In general, all U/I recognise that innovations created during the Spin-off activity belong to the spin-off itself. Nevertheless, all U/I requires the spin-off to give a free use licence (usually not sub-licensable) for all the time of the U/I participation in the corporation capital. On the other hand, only C.N.R, UNIPD and SSPI mentioned the idea of letting the establishing/just established spin-off to obtain U/I's licences more easily in comparison to other partners or industrial entities.

Poland

Contrary to their Italian counterparts, only one Polish university analysed (PP) has a separate regulation concerning commercialisation of research results through spin-off ventures[8], while the other four universities have only implemented general regulations concerning the protection, utilisation and commercialisation of university IP (both industrial property and copyright). However, taking into consideration the recent amendments to the Law on Higher Education, all the universities are now amending their internal regulations as well. This means, that the new acts are not made available to the public yet, or even (like in the case of PWr) they are not intended to be publicised at all, and they will only be available to the employees of the university. The contemporary biding regulations were prepared before the amended Law on Higher Education came into force. They were created based on the provisions of the following five national laws: (1) the Industrial Property Act (2000), (2) the Copyright Act (1994), (3) the Law on Higher Education (before amendment) (2005), (4) the Act on Combating Unfair Competition (1993), (5) and the Act on National Finances (2009). The regulations are composed of a minimum of 7 detailed articles (PŁ), up to 9 (AGH and PP) and 13 (PWr), and the maximum of 17 (UPW). They serve as guides to the ownership, distribution and commercial development of university IP, and provide information on the rights and responsibilities of universities as employers and their employees concerning dissemination and commercialisation of research results. They also provide a step-by-step description of the university IP protection procedure, list possible routes to commercialise university IP, and define royalty distribution. Additionally, the regulation implemented at the PŁ has four annexes, i.e. a template of a contract on royalty distribution, an innovation disclosure form, a template of a contract on the property rights transfer, and a template of a publishing agreement with the transfer of copyrights. According to the regulations analysed, the university is the body that bears the costs of IP protection (patenting). The shares from commercialisation of research results are divided between the researcher (creator), and the university. All but one regulation (except for AGH) further divide shares of the university between the department the researcher represents and/or the innovation commercialisation

[8] However this act is not available to non-employees.

unit (usually a technology transfer unit). The distribution of royalties in the universities analysed is as follows (1) AGH – 60% creator, 40% university, (2) UPW – 60% creator, 10% department, 30% university, (3) PWR and PP – 60% creator, department and university 20%, (4) PŁ – 60% creator, 30% department, 10% – technology transfer unit. The distribution of royalties can be negotiated and the shares of the university in a spin-off company can be individually determined in the company agreement. The regulation of the PŁ additionally states that the researcher, who in return for their remuneration from the utilisation of a technology receives shares in the spin-off company, is not entitled to any benefits the university obtains from this means of commercialisation, and the profits are shared only between the university and the technology transfer unit in the 25%–75% ratio.

The analysis of procedures applied by the selected Polish universities to transfer the results of their research revealed some similarities. Like in the case of the Italian research organisations, the authors observed a kind of a standard commercialisation procedure. The transfer of university research in Poland is always performed by technology transfer units. These are mainly technology transfer offices (in form of limited liability companies (sp. z o.o.)), however their activity is also frequently assisted by university non-faculty units and departments designated to protect and disseminate university inventions. In the case of AGH there are two bodies responsible for the commercialisation of this university's research results. One of them is a technology transfer office (CTT AGH – a non-faculty university unit) and InnoAGH sp. z o.o (Ltd). The first of them is responsible for invention protection and commercialisation by means of licenses and sale, while the latter organises and manages the commercialisation process by means of a spin-off company. Similar approach to the issue of university technology transfer has been adopted by UPW, where there are also two separate bodies responsible for the sale, licensing, and the creation of spin-off companies. The first of them is the Innovation, Implementation, and Commercialisation Department (a non-faculty university unit) and the latter – a special purpose vehicle UNINOVA S.A. (joint stock company). In the case of PWr the research results are first disclosed to the Department of Intellectual Property and Patent Information, which is responsible for the protection of inventions, and then to the Wroclaw Technology Transfer Centre, which promotes, disseminates and transfers university IP to industrial practice. The activities of the two above-listed units are coordinated by the Contact Point for Technology Transfer in the Centre for Scientific and Technical Knowledge and Information Centre (a university department within which the Department of Intellectual Property and Patent Information is located as well). The transfer of technologies developed at PŁ is organised in a manner similar to the procedure at PWr. The inventions are first disclosed to the Technology Transfer Department that offers consulting services and valuates the invention, and then to the Technology Transfer Office sp. z o.o. (Ltd.) that commercialises university results through sale, licensing and spin-off ventures. At PP, the Intellectual Property of the university is disclosed to and commercialised by the Innovation, Development, and Technology Transfer Centre[9].

It needs to be noted, that in all cases analysed, the technology transfer offices are not the only bodies responsible for the commercialisation of university research, and this matter is also managed by academic entrepreneurship incubators whose main role is to assist entrepreneurial researchers in their attempts to commercialise research results through spin-off companies. The presence of different structures designated to execute a commercialisation process is unfortunately frequently equivalent with the overlapping of their responsibilities, and though these are in fact the technology transfer offices that should supervise the entire technology transfer process, their employees often do not have information on the activity of the incubator.

3. Research-based spin-off companies: Empirical Analysis

The authors conducted a crossed empirical analysis in order to evaluate the specific and overall numbers of active spin-offs and the main specific and overall field of activities. What emerges is as follows:

Italy

- **Numbers of active spin-offs:** in order

University/Institute of origin	Number of active spin-offs
POLITO	69
C.N.R.	68
UNIPD	47
UNIGE	44
UNIBO	37
SSPI	35
TOTAL	**300**

At present, POLITO has the highest number of active spin-offs, followed by C.N.R (very close) and UNIPD with a significant gap. POLITO’s performance is impressive, if we consider that from NETVAL Report it successes in over passing C.N.R.. The C.N.R.’s performance is stable. Anyway, the selected group represents still a valid reference class, since on its own, according to the total number of spin-offs surveyed by NETVAL Report (1102), it counts alone for circa one fourth of all Italian Public Research spin-offs.

9 Currently there are attempts to reorganise this unit into a centre focused on the transfer of technologies only.

- **Sectorial fields:**

University/Institute of origin	**Main sectors (Number of spin-offs)**
POLITO	ICT (17) Energy&Environment (11) Electronics (11) Industrial Automation (11)
C.N.R.	ICT (12) Electronics (12) Nanotechnologies and new materials (11) Life Sciences (10)
UNIPD	ICT (8) Industrial Automation (8) Life Sciences (7) Energy&Environment (6)
UNIGE	Energy&Environment (13) ICT (10) Electronics (5) Industrial Automation (5)
UNIBO	Life Sciences (12) ICT(6) Electronics (5) Innovation Services (5)
SSPI	Biomedical (9) ICT (8) Life Sciences (4) Innovation Sciences (4)
TOTAL (300)	ICT (61) Life Sciences (40) Electronics (39) Energy&Environment (37) Industrial Automation (36) Innovation Services (34) Biomedical (25) Nanotechnologie and new materials (19) Others (9)

The analysis clearly indicates that the dominant sector in which university spin-offs operate is the ICT field.

Poland

- **Numbers of active spin-offs:** in order

University of origin	Number of active spin-offs
AGH	12
PP	9
PWr	2
PŁ	2
UPW	2
TOTAL	**27**

Being at the top of the Polish University Ranking 2014, AGH is at the same time the university with the greatest number of active spin-offs. Surprising is the fact that PŁ, which was the top-ranked university in terms of its innovativeness in 2013 has only two active spin-off companies.

- **Sectorial fields:**

University of origin	Main sectors (Number of spin-offs)
AGH	Innovation services (5) Nanotechnologies and new materials (2) Medicine (1) Aerospace (1) Technical safety (1) Mechatronics (1) ICT (1)
PP	Innovation services (5) Transportation (2) Mechatronics (1) ICT (1)
PWr	ICT (1) Electronics (1)
PŁ	Nanotechnologies and new materials (2)
UPW	Innovation services (1) ICT (1)
TOTAL (27)	Innovation services (11) Nanotechnologies and new materials (4) ICT (4) Transportation (2) Mechatronics (2) Medicine (1) Aerospace (1) Technical safety (1) Electronics (1)

The analysis shows that the spin-offs from the Polish universities analysed most frequently operate in the field of innovation services.

Conclusions

Commercialisation of research results is a valid and topical matter and both Italian and Polish research institutions strive to increase the effectiveness of the transfer of their technologies. The authors have observed a number of similarities concerning the governance and execution of the commercialisation process at the research institutions they analysed, however major differences concerned the regulations on the establishment of spin-off companies, as in Italy such acts have been adapted by all institutions analysed, whereas in Poland they are still a scarce phenomenon. Nevertheless, the Italian experience shows that the risk of establishing redundant procedures, harmful for the spin-offs success and efficiency, is high in the public research field. However, the empirical analysis shows that Italian research organisations are far more successful in the implementation of a spin-off as a mechanism for the commercialisation of research results, while in Poland even the most innovative universities have relatively low results in this field. The sectorial fields in which the research-based spin-offs operate also significantly vary between the countries.

The research was mainly conducted using a desk research method, but interviews with the representatives of units responsible for the commercialisation of research results at research organisations selected for analyses were also conducted in the case when the data were not disseminated or sometimes they were not even made public at all. This was particularly true in the case of the Polish universities that adopt different definitions of spin-off companies and frequently count student start-ups into this category. Additionally, obtaining information on the number of spin-offs was more difficult than in the case of Italian research institutions due to the fact that the commercialisation process at Polish universities is not conducted by one designated organisation, and technology transfer offices and academic entrepreneurship incubators seem not to disseminate the information even among each other. On the other hand, in Italy, all relevant U/Is have active and well-functioning Technology Transfer Offices, but it has to be underlined that the dissemination process still suffers from the lack of fluidity.

Scientific work executed within the Strategic Programme “Innovative Systems of Technical Support for Sustainable Development of Economy” within Innovative Economy Operational Programme.

References

1. Clarysse, B., Heirman, A., Degroof, J.J. (2000): *An Institutional and Resource based Explanation of Growth Patterns of Research Based Spin-offs in Europe*, [Online], Available: http://www.babson.edu/entrep /fer/XXIX/XXIXA/XXIXA.htm.
2. Wnuk U., Mazurkiewicz A. (2012): Research-based spin-off processes and models in different economic contexts, Maintenance Problems 2/2012, pp. 177–191.
3. Głodek P., Guliński J. (2008): Firma odpryskowa spin-off i/lub spin-out [in] Matusiak K.B. (ed.) Innowacje i transfer technologii. Słownik pojęć, PARP, pp. 97–99.
4. Chyba Z. (2008): Klastry przemysłowe a przedsiębiorstwa spin-off, *Economics and Organization of Enterprise (Ekonomika i Organizacja Przedsiębiorstwa)*, ISSN 0860-6846, No 3(698), s. 47.
5. Piccaluga A., Cesaroni F., Moscara P. (2005): Imprese spin-off della ricerca in Italia: modelli di sviluppo e percorsi di crescita, in Piccola impresa/Small business, n°276.
6. Chiesa V., Piccaluga A. (1999): La nascita di imprese ad alta tecnologia, in “Impresa e Stato” n. 43.
7. Mustar P. (2001): Spin-offs from Public Research: Trends and Outlook, STI Review, no. 26, Special Issue on Fostering High-tech Spin-offs: A Public Strategy for Innovation, OECD, pp. 165–172.
8. Helm R., Mauroner O. (2007): Success of research-based spin-offs. State-of-the-art and guidelines for further research.
9. Shane S. (2005): Academic entrepreneurship. University Spinoffs and Wealth Creation, Edward Elgar Publishing Ltd, Cheltenham, UK, Edward Elgar Publishing Inc., Northampton, MA, USA.
10. Varaldo R., Di Minin A. (2009): A new form of entrepreneurial capitalism based on innovation and Research in Italy, Finmeccanica Occasional Paper
11. Parker P. (2001) Local – global partnerships for high-tech development: integrating top-down and bottom-up models, Economic Development Quarterly, 15 (2001), pp. 149–167.
12. Bramwell A., Nelles J., Wolfe D.A. (2008): Knowledge, innovation and institutions: global and local dimensions of the ICT cluster in Waterloo, Canada Regional Studies, 42 (2008), pp. 101–116.
13. Garzoni A., De Turi I. (2014): The role of academic spin-offs in entrepreneurial innovation and regional development. The Apulia case, OFEL Conference 2014, Dubrovnik.
14. Clarysse B., Moray N. (2004): A process study of entrepreneurial team formation: the case of a research-based spin-off, *JOURNAL OF BUSINESS VENTURING*, Vol: 19, pp. 55–79.

15. Visintin F., Pittino D. (2014): Founding team composition and early performance of university-based spin-off companies, Technovation, 34 (1), pp. 31–43.
16. Tamowicz P. (2006): Przedsiębiorczość akademicka. Spółki spin-off w Polsce, PARP.
17. Stawasz E. (2007): Stymulowanie przedsiębiorczości środowiska naukowego w Polsce, Zeszyty Naukowe Uniwersytetu Szczecińskiego nr 453, Ekonomiczne Problemy Usług nr 8, s. 265–276.
18. Grandi A., Grimaldi R. (2005): Academics' organizational characteristics and the generation of successful business ideas, JOURNAL OF BUSINESS VENTURING, 2005, 20, pp. 821–845.
19. Fini R., Grimaldi R., Sobrero M. (2009): Factors fostering academics to start up new ventures: an assessment of Italian founders' incentives, JOURNAL OF TECHNOLOGY TRANSFER, 2009, 34, pp. 380–402.
20. Clarysse B., Wright M., Lockett A., van de Velde E., Vohora A.: Spinning out new ventures: a typology of incubation strategies from European research institutions Journal of Business Venturing, 20 (2) (2005), pp. 183–216.
21. OECD (2013), Commercialising Public Research: new trends and strategies
22. The Bayh-Dole Act at 25, Bayhdole25, Inc., 2006, http://bayhdolecentral.com/BayhDole25_WhitePaper.pdf.
23. Wnuk U. (2010): Legal Regulations and Governmental Initiatives Fostering Research Results Commercialisation, Problemy Eksploatacji 3/2010, pp. 175–185.
24. OECD (2003) Turning Science into Business. Patenting and Licensing at Public Research Organisations.
25. Damsgaard E.F., Thursby M.C. (2013): University Entrepreneurship and professor privilege, Industrial and Corporate Change, Vol. 22, No. 1, pp. 183–218.
26. Decreto legislativo 10 febbraio 2005, n. 30, Codice della proprietà industriale, a norma dell'articolo 15 della legge 12 dicembre 2002, n. 273".
27. Decreto Legislativo 27 luglio 1999, n. 297 "Riordino della disciplina e snellimento delle procedure per il sostegno alla ricerca scientifica e tecnologica, per la diffusione delle tecnologie, per la mobilità dei ricercatori".
28. Decreto Ministeriale 8 agosto 2000, n. 593 "Modalità procedurali per la concessione delle agevolazioni previste dal Decreto Legislativo 27 luglio 1999, n.297"
29. Legge 30 dicembre 2010, n. 240 "Norme in material di organizzazione delle Università, di personale accademico e di reclutamento, nonché delega al Governo per incentivare la qualità e l'efficienza del sistema universitario"
30. Decreto Ministeriale 10 agosto 2011, n. 168 "Regolamento concernente la definizione dei criteri di partecipazione di professori e ricercatori

universitari a società aventi caratteristiche di spin off o start up universitari in attuazione di quanto previsto all'articolo 6, comma 9, della legge 30 dicembre 2010, n. 240.
31. Copyright Act of February 04, 1994 (Ustawa o prawie autorskim i prawach pokrewnych, Dz. U. 1994 Nr 24 poz. 83).
32. Industrial Property Act of June 30, 2000 (Ustawa o prawie własności przemysłowej z dnia 30 czerwca 2000.
33. Act on Research Institutes (Ustawa o instytutach badawczych z dnia 30 kwietnia 2010, Dz.U. z 20100 nr 96 poz. 618).
34. Act of 11th July 2014 on the amendment of the Act on Higher Education and selected other acts (Ustawa o zmianie ustawy – Prawo o szkolnictwie wyższym oraz niektórych innych ustaw, Dz. U. 2014, poz. 1198).
35. XI Rapporto NETVAL (Network per la Valorizzazione della Ricerca Universitaria) sulla valorizzazione della ricerca pubblica in Italia "Unire I puntini per completare il disegno dell'innovazione", 2014.
36. Perspektywy, Ranking Szkół Wyższych 2014.

Firmy spin-off we Włoszech i w Polsce: podobieństwa i różnice w obrębie zasad i procedur tworzenia i działania

Słowa kluczowe

Transfer technologii, komercjalizacja wyników badań, spin-off, uczelnia, instytut badawczy, Włochy, Polska.

Streszczenie

Ze względu na fakt, że firmy spin-off są obecnie, obok licencjonowania, jednym z najbardziej promowanych i popularnych mechanizmów transferu wyników prac badawczych do zastosowań gospodarczych, zaprezentowany artykuł skupiony jest na kwestii tworzenia tego typu firm w wybranych krajach UE. Na podstawie analizy stanu wiedzy i badań empirycznych autorzy porównują zasady powstawania i funkcjonowania spółek typu spin-off tworzonych przez pracowników włoskich i polskich jednostek naukowo-badawczych. Autorzy skupili się na analizie czynników zewnętrznych (regulacji krajowych) jak i wewnętrznych (wewnątrzinstytucyjne przepisy i procedury) determinujących powstawanie tego typu struktur transferu technologii, a także dokonali analizy statystycznej z zakresu działalności firm spin-off we Włoszech i w Polsce. W badaniach wykorzystano metodę 'desk research' oraz wywiady z reprezentantami jednostek ds. transferu technologii przy uczelniach i instytutach objętych próbą badawczą.

INNOVATIVE ECONOMY
NATIONAL COHESION STRATEGY
INSTITUTE FOR SUSTAINABLE TECHNOLOGIES
NATIONAL RESEARCH INSTITUTE IN RADOM
EUROPEAN UNION
EUROPEAN REGIONAL DEVELOPMENT FUND

Project co-financed by the European Union from the European Regional Development Fund

Andrzej ZBROWSKI
Institute for Sustainable Technologies – NRI
andrzej.zbrowski@itee.radom.pl

METHOD FOR TESTING THE SINGULAR AND UNIQUE TECHNICAL DEVICES

Key words

Prototype testing, decomposition, prototyping, verification.

Abstract

The achieved level of design methods and manufacturing of technical equipment enables rapid production of a fully functional prototype or standalone device. The required efficiency of prototyping methodology introduces the need for testing prototypes with use of knowledge accumulated in a database that contains descriptions of historical problems of construction, testing, commissioning, and implementation.

The paper presents the methodology of testing the unique and singular technical solutions for supporting the advanced prototyping of new innovative products that were developed at the Institute for Sustainable Technologies.

The aim of this work was to develop a solution, in the form of a system of testing for prototypes, enabling the control of the process of testing with a method based on the resources of accumulated knowledge concerning the design, commissioning, and implementation of high-tech equipment, performed individually or in a series. The use of testing methodology increases the guarantee

of the development of prototype machines and devices that are characterised with the better quality and reliability as compared to solutions based only on the knowledge acquired and experience of the implementation team members. Pilot operated testing methodology has been applied to several prototype devices designed and constructed at the Institute for Sustainable Technologies.

Introduction

Prototyping of technical equipment is an activity that requires a methodical approach to ensure the achievement of planned targets in the time provided for the project while maintaining technical, qualitative, financial, and organizational rigor. This process is particularly difficult for the design of equipment that, in the current state-of-the-art, does not have equivalents, or earlier development versions. The issue becomes even more complex if the object representing the result of design is a unique solution, characterised by a high degree of innovation, which exists only in the form of a single prototype [1].

The achieved level of production and design methods for technical devices allows rapid production of a fully functional prototype of a singular device. That does not mean automatic development of a product with the required parameters of durability, functionality, and meeting customer expectations. A significant difficulty in prototyping of solutions is to guarantee the high quality of the outcome of the work. An increase in the efficiency of prototyping processes requires the use of a testing method for prototypes using resources such as knowledge accumulated in a database of historical problems of construction, testing, commissioning, and implementation.

1. Evolution of testing methods for prototype devices

The history of prototype testing is closely related to the history of inventions and the development of science and technology. Prehistoric, ancient, and antique machines built by man have always been prototypes. It was related to the limited access to knowledge resources and primitive methods of production that prevented accurate reproduction and production in a reproducible manner [2]. The first machines were invented and built for a specific application, in order to achieve a utilitarian aim, not considering the possibility of serial reproduction of practical solutions.

With the development of civilization, thanks to improvements in manufacturing technology, prototyping ceased to be associated with each new copy of the piece of equipment. The development of modern production techniques, the industrial revolution, and change in the organization of the manufacturing process have enabled the production of machine parts and finished devices in a reproducible manner that ensures the functional parameters of the solution.

Currently, the construction of machinery and equipment, as a result of a centuries-long process of cognitive and technological evolution, has reached a new quality. That quality depends on effective design, manufacturing, and implementation of unique prototypes in a commercially reasonable manner, with the highest requirements previously formulated only in mass production.

From individual solutions, built in past centuries, which uniqueness resulted from imperfect methods of production and reduced demand, through the industrial revolution of the nineteenth century, and the serial and mass production launched at the beginning of the twentieth century, thanks to technological progress achieved at the beginning of the XXI century, gave the possibility of building a unique, commercial prototypes, developed individually and customised. This is a momentous change in civilization, because the first machines were the prototypes for technological and social reasons, and present prototypes of unique machines are intentionally individualised, thanks to achieved technical capabilities. Modern prototype can be a fully functional product effectively meeting individual user's needs, being developed and produced in a unit scale.

2. General aims of the method

The basic premise for the development of a unique testing methodology for prototype devices is the lack of systemic measures aimed at gathering practical knowledge empirically gained in the process of prototyping and project management for the reuse of historical information in future operations, new initiatives in design, manufacturing, and implementation of innovative technical solutions, implemented in single copies or in a short series [3]. Most often, the use of information obtained based on the research is limited to use only for the current assessment of the test object at different stages of the implementation task.

Systematic intellectual capital that enables the processing of data is one of the main components used in the space of synergistic interactions taking place in the design process. Effective use of archival information resources contributes to the reduction of the risk in new projects and ensures effective risk management. Above all, however, it is a guarantee of the creation of prototype machines and devices that are characterized by better quality and reliability as compared to solutions based only on the knowledge acquired and experience of the implementation team members.

Management of testing of prototypes obliges one to acquire new knowledge and systematic storage of information in order to obtain the increasing efficiency of product implementation in less time and with the involvement of small financial outlay. Modern technical and economic factors have contributed to creating the need to build a database of findings and conclusions, accumulated at the end of each project, related to the implementation of unique and innovative technical equipment.

3. The organizational and technical conditions

The complexity of the machinery, equipment, and economic considerations lead to the conclusion that the process of testing the prototypes should focus only on selected issues, crucial for the correct operation and safety of operation. Exploration of all options, conditions, dependencies, and the configuration of cases at the stage of prototype testing involves spending too much time, financial and human resources, and equipment, in relation to the budget, which is not acceptable from the point of view of economics of the project. In this respect, the study of the prototypes of machines and equipment manufactured individually are in a particularly disadvantageous relationship to research of equipment manufactured in a series. Testing prototype devices individually made affect expenses the final price of the solution far more than in the case of mass production. In the extreme case of a single prototype, testing may be the dominant financial component of the developed unique solution, while, for mass-produced products, prototype testing costs can be negligible, in the settlement of all items offered to customers.

In the case of prototypes manufactured individually, it is required to reduce the complexity of the system under testing and the selection of the analysed signals, which are performed by omitting systems whose reliability is known or guaranteed by the supplier. This entails the risk of missing some of the dangers and can cause the formulation of an incorrect diagnosis and misevaluation of a prototype. These conditions mean that the risk is one of the important parameters of the process of the managing of testing of prototypes, particularly devices manufactured individually.

4. Characteristics of the testing system for prototypes

Prototype tests are used at all stages of life solutions, starting with design assumptions, then operation, and ending with recycling and disposal. Acquired and processed information from studies provide substantial support for current and future activities and organizational decision-making. Archiving research results is an activity that supports the creation of new knowledge about prototype solutions, stored in a common database accessible for designers. Replenishment of information in expert systems allows the use of previous experience in the design of new products.

In the assessment system for prototypes, there are two feedback loops (Fig. 1). The first is called “Small” and provides for the operation of the cycle of the product development. The second is called “|Large” and ensures the development of the research system.

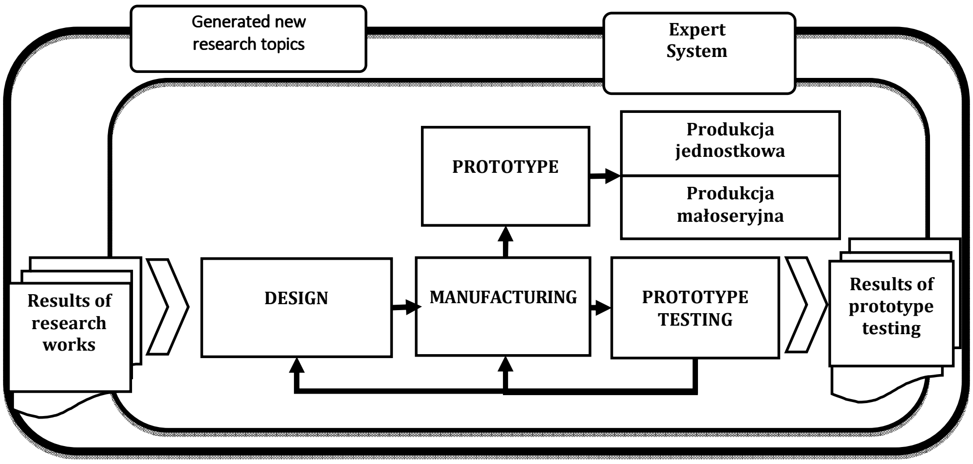

Fig. 1. Small and large feedback loops in the prototype testing system

The small feedback loop integrates design activities in the field of manufacturing design and testing prototypes. The prototype test results represent feedback that supplies the base of the expert system and is also a material used by a team of designers working on a new product. The collection of information, which is recorded in the database and processed in the context of the work of the expert system as a result of prototype tests, is a valuable source of information on similar solutions for structural and research problems. It is important to systematically supply data for all design changes and corrective actions taken, both effective and ineffective. As part of a small loop, the expert system is supplied with information on methods of testing devices, their effectiveness, and problems in specific applications for the examination of prototype devices. The large feedback loop integrates activities in the area between the research work and their results and the results of the testing of prototypes. In this case, the information contained in the expert system supports the generation of new research topics. Problems identified at the stage of the testing of prototypes or their preparation may be outstanding issues, which are structured and prepared as a subject for further research and development.

The concept of the methodology is consistent with the methods of the testing of equipment, using simulation techniques, analysis and experimental verification conducted in the laboratory, in simulated real-world conditions, test site conditions, and under real operating conditions. The use of databases to collect the results of observations refers to the solutions used in operational research systems, operating based on the collection of observations of reliability [4]. In [5], concerning the research methodology of the exploitation of the mechanical objects presented, are the characteristics of several programs dedicated to the collection of data on the intensity of damage to various types of devices, launched in the past few decades in aerospace, electronics, electromechanics, power plants [6], and the oil industry [7].

The methodology of testing prototypes introduced the ability to use external sources of information on the intensity and causes of damage, when the data exists and is available. Particularly important are the data obtained from operational observations and used for managing the operation, stored in data banks [8, 9].

5. The assumptions for methodology

The methodology focused on the use of previously collected results in the management of testing prototypes and designing new equipment is a basis for systemic data acquisition from the process of prototyping and computer processing, integrated in the design, manufacture, verification and operation process. The methodology supports the process of managing tests of prototypes with respect to the activities relating to the collection, storage, and processing of data and the analysis of cause and effect, in order to re-use the data in the planning and implementation of research.

Underlying assumptions for prototype testing methodology are the following essential statements:

- In each prototype there is some unavoidable uncertainty level about the functionality, durability, and reliability associated with the strategy of the testing process.
- Prototype testing is always carried out in a limited extent.
- The quality of the equipment must satisfy the customer, but it should not exceed defined expectations.
- Examination is associated with the entire period of the development of the device.
- Prototype tests are a source of information to be used in the process of the prototyping of next-generation solutions and the development of other machinery and equipment.

The process of testing and verification of unique prototype devices is understood as an ordered set of tasks, operations, and procedures performed on specific test stands by assigned staff, using the necessary control-measuring equipment in the necessary time period.

In particular, the prototype test methodology developed uses the following assumptions [10]:

- Prototype methodology applies to technical objects made in single units, individually or in a short series, and processes are not included.
- Technical object prototype is built of systems, components, parts, and computer procedures that can be extracted and which can be identified and assigned their impact on the quality of the whole solution.

- The development of a test plan is an iterative process that requires expert knowledge.
- There are known limitations of time and money associated with the process of the research and testing of a prototype.
- Each element/component/system/procedure can be tested (if an item is a part of a component assembly and cannot be tested separately, it is subjected to tests of the containing element).
- There are no operating characteristics of all prototype solutions, in particular, there is at least one of the following options:
  - There is no information about which elements are the most often damaged.
  - There is no information about what are the causes of the damage.
  - There is no information on the potential damage impact on the functioning of the whole prototype solution.
- It is possible to acquire the knowledge of experts (users, designers, builders, prototype contractors).
- Testing methods are known for the testing and verifying the proper operation of the prototype solutions, using the available control-measurement apparatus, which can be used in the laboratory or test bench.
- The methodology includes support for the identification procedures based on the analysis of cause-and-effect relationships and tools to document them.
- The methodology requires the evolutionary collection of the expert knowledge and failure data on elements, components, and modules and their frequency and data on the test methods and test apparatus and standard requirements.
- The methodology should allow the determination of the empirical relationship between quality and technical parameters using functional analysis, experience, analysis of the complaints, the cost of repairs, etc.
- The identification of the meaning of parameters of the technical components, assemblies, modules, and procedures, is essential for the forthcoming methodology.
- The methodology takes into account the relation (correlation) between the technical parameters.
- Faults (defects) of prototype, particularly accurately analysed, include functions that the prototype is to execute, reliability during operation, ease of use by the user, and ease of repair in case of damage.
- The methodology includes procedures to support the selection of the working group (number and type of experts), the definition of the extent and timing of research, functional decomposition, data collection, and qualitative and quantitative analysis of defects.

– The methodology applies stages of the construction of assumptions, design, construction, commissioning, testing, and verification of post-implementation operation.
– Only new, original solutions that are the result of research and development are subjected to tests.
– Excluded from the study are commercial components and sub-assemblies that have been verified with positive results from previous projects, if the technical requirements and functions are applicable and unchanged.

Because of the focus on the prototypes of technical objects, the methodology should at least include a set of qualitative and quantitative parameters describing the following:

– The physical and chemical properties of the prototype solutions, e.g. dimensions, chemical composition, and physicochemical properties;
– Economic parameters, e.g. manufacturing costs, research costs, projected operating costs, depreciation period, etc.;
– Operational properties, e.g. safety, durability, reliability;
– Ergonomic properties;
– Aesthetic properties;
– Environmental parameters and characteristics, particularly in the context of sustainable development of the economy;
– The cause-and-effect (quantitative and qualitative) relationships between the used components, sub-assemblies or modules and their failures and defects and their influence on the failure to obtain the assumed parameters and technical characteristics of prototype solutions;
– Quality (functional) requirements of the recipient of a prototype;
– The relationship between customer requirements and technical parameters; and,
– The types of testing and verification research, including any destructive testing necessary.

The aims of the application of the methodology are the following:

- The improvement of the quality and reliability of the devices manufactured individually and in short series;
- The identification of hazards and their measurement and evaluation;
- The identification of processes and functions occurring in the test device;
- The identification of the structure of the research object;
- The identification of the weaknesses and knowledge of the advantages of the prototype solution;
- The identification of areas requiring corrective action;
- The prediction of corrective actions;
- Shortening of the time and reduction of the cost of prototype tests, taking into account the technical, financial, organizational, and time limitations;

- The collection of information resources that can be used in the structure of the knowledge base;
- The development of simulation models of the device, especially under conditions of start-up or in an emergency; and,
- The development of new or existing measurement techniques, in particular, for the study of unique prototype solutions.

The utilitarian goal is the application of the methodology in the form of a computer system for testing prototypes that enables the testing of process control based on the resources of accumulated knowledge concerning the design, commissioning, and implementation of high-tech equipment, manufactured individually or in short series.

6. Characteristics of the methodology

The methodology requires the selection of the expert group responsible for the testing of prototype. This group includes system analysts, metrologists, diagnosticians, specialists in the field of systems engineering, experts with knowledge of the elements, components, and modules used for the construction of a prototype (Fig. 2). This group should be complemented with persons performing development work involving the testing of the operation of the prototype and verification of whether it has the expected functionality.

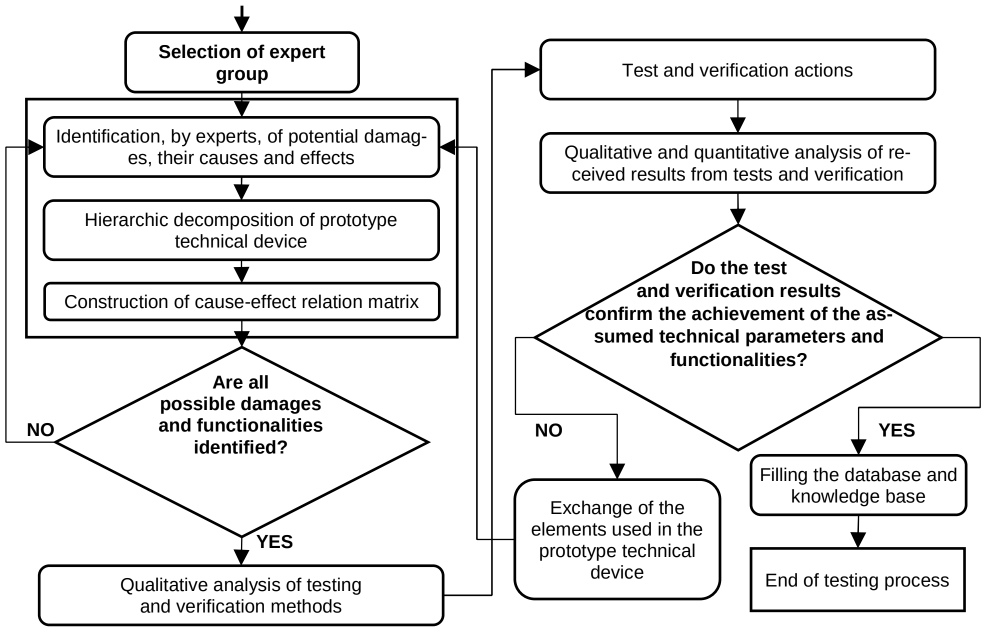

Fig. 2. Diagram of prototype testing methodology

System analysts in cooperation with the developers carry out the structural decomposition of the prototype solutions to elements, components, and modules [11]. The decomposition operation is completed with procedures to identify the physical, economic, ecological, and aesthetic properties of prototype. Before the examination, the specific operational objectives are formulated and matrix of technical parameters of the prototype is defined.

In order to verify the accuracy of the designation of a set of technical parameters, the use of kinship diagrams is proposed. The aim of their application is the organisation and logical presentation of relationships, including the correlation between technical parameters and quality features [12]. After the verification of the operation of a set of key components of the prototype solutions, various operations are performed that are aimed at acquiring data on the specific parameters of the technical components, subassemblies, and modules. Simultaneously, the procedures are carried out to identify dependencies between modules, technical parameters, and functional requirements [13]. Based on data collected in a database or expertise, potential failures and defects are forecasted. The relationships between the components, subassemblies, modules or computer procedures and failures and faults are determined using dependence graphs. These diagrams are also used to organise information and indications about which causes are responsible for a specific effect and what are the relationships between the causes. Based on a set of identified potential failures, faults, and insufficient functionality, a set of research methods is created which should be performed to verify the correctness of the operation of the prototype.

For each method, a set of measurement techniques is assigned, including test equipment and measurement methods. The number and, in some cases, the frequency of test and verification are determined. After taking into account the time constraints and cost scenarios, prototype test scenarios ("critical path" in the diagram) are generated. On this basis, decision tree diagrams are created. Experts responsible for carrying out the tests, verification, and development, based on selected, optimal scheduling of tests, develop plans for experiments. The experimental results are used to verify the hypothesis.

7. Areas of prototype testing

Prototype testing methodology applies to the full range of prototyping and takes into account the activities carried out at the stages of design, construction, functional verification, and the operation of the machine or device (Fig. 3).

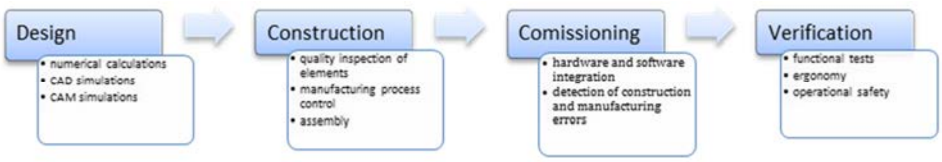

Fig. 3. Areas of prototype testing

Design includes activities related to the formulation of guidelines and the conceptual development of a prototype, represented as a mathematical model or by using a virtual construction and technological documentation. The design highlights the stage of the initial concept, the construction of the model, and the development of the process of building a physical prototype. Prototype testing at the design stage refers to the mathematical simulation model of a structure or calculations made based on a virtual model constructed in CAD. Elements of the prototype tests are also the simulations of machining processes using CAM systems.

In the process of building a physical prototype, the production stage and commissioning phase are important for further functional studies.

Manufacturing is regarded as a process in which the production of previously designed components is carried out, the assembly of machine parts is made, commercial components are purchased, and the modules of mechanical, electronic, electrical, optical, and other systems are formed. Prototype tests performed during the production relate to quality inspection on manufactured components and the monitoring of the manufacturing process. The manufacturing process is verified conditionally, only in the case of quality defects identified in the investigated objects. Verification of the technological process only applies to the range associated with product quality. Issues of cost, efficiency, logistics, safety, ergonomics, and others are ignored. The evaluation of the prototype conducted at the manufacturing stage is made according to the criteria of good, bad, or to be corrected. Particularly important is the correct classification of the defects deemed repairable by evidence. Considering expenses on the manufacturing of the element with known defects, it is necessary to consider modifications of the construction in such a way as to enable the use of the test piece, despite the identified deviations and inaccuracies.

The assembly of the unit is the first verification of the physical effects beyond the scheduled scope of the prototype tests. During the assembly, in a spontaneous manner, there all structural weaknesses are shown that have not been identified in the standard process of quality control and in the earlier stages of testing of the virtual model. This particularly applies to construction errors involving the mutual dimensional mismatch of mated elements.

Commissioning is performed after assembly and concerns the work to achieve a functioning solution, where there is the integration of mechanical, electronic, and software systems into a working, drivable prototype of a stand-alone device or functional module. Commissioning is part of the prototype test characterised by spontaneous, unplanned detection of errors and construction non-conformities or conditions that prevent the first start-up of the device. The approved plan defines the order of checks on the operation of individual modules and starting the entire system, which requires cooperation between the modules and non-autonomous systems installed. The first launch of the device is directed to obtain and confirm the fact that the technical operation of the complete system is possible, without performing evaluations related to the performance. This means that the runtime verification allows one to determine if it works but not how effectively it works. The quality of operation is an essential subject of the functional verification of a prototype device or module.

Functional verification is part of the prototype tests performed after starting, but before introduction for operation. It applies to the planned tests of a complete, running machine. In functional studies, the measurement results are verified and the assessment of in terms of ergonomics and safety in operation are performed. Functional verification is a separate stage in the process of prototyping, which determines the final level of the solution.

Examples of testing prototypes using the developed methodology are presented in publications [11, 12, 13].

Conclusion

The developed methodology allows for the determination of general and technical parameters of the prototype and its specific features which characterise the elements, components, modules, or computer procedures and then to assign the type of test to be carried out to get at the intended level of confidence that will ensure proper operation of the prototype solution. For each identified item, component, module, or computer procedure, there should be obtained the fullest information on their failures or impact on the expected functionality.

Performed evaluation of the prototype is a multi-level operation, conducted iteratively in successive phases of the development of the prototype. The subjects of evaluation are components of the device located at different levels of the complexity of the tested solution. Fractional properties, features, functions, etc. characteristic for the selected item are assessed. Tests can be multiplied, depending on the available methods for verification of the assessed level of development of the device. Final evaluation refers to the completed stage of development of the machine that is the design, manufacturing, and operation of the prototype. Performance of the final assessment, as in the case of partial evaluation, is an iterative process, carried out as part of a feedback loop until the fulfilment of required parameters, consistent with the specification of requirements of the customer, underlying the design assumptions.

Scientific work executed within the Strategic Programme “Innovative Systems of Technical Support for Sustainable Development of Economy” within Innovative Economy Operational Programme.

References

1. Mazurkiewicz A., Ruta R., Trzos M.: Badania prototypu. Metodyka wspomagania procesu weryfikacji własności eksploatacyjnych. Monograficzna seria wydawnicza Biblioteki Problemów Eksploatacji, Radom, s. 2004.
2. Lu P.: Early Precision Compound Machine from Ancient China. Science 6/ 2004, Vol. 304; 5677, 1638.
3. Skalik J.: Zarządzanie ryzykiem w projektach. Materiały konferencji naukowej „Zarządzanie ryzykiem – wyzwania XXI wieku", 12–22 czerwca Warszawa 2007, s. 245–252.
4. Cook R., Bedford T.: Reliability Databases in Perspective. IEEE Transactions on Reliability, Vol. 51, No. 3, Sept. 2002; pp. 294–310.
5. Młyńczak M.: Metodyka badań eksploatacyjnych obiektów mechanicznych. Oficyna Wydawnicza Politechniki Wrocławskiej, Wrocław 2012.
6. Lannoy A., Procaccia H.: The EDF failure reporting system process. Presentation and prospects. Reliability Engineering and System Safety, Vol. 51 (1996).
7. Langseth H., Haugen K., Sandtorv H.: Analysis of OREDA data for maintenance optimisation. Reliability Engineering and System Safety, No. 60 (1998); pp. 103–110.
8. Procaccia H., Arsenis S.P., Aufort P.: European Industry Reliability Data Bank. Eireda. Crete University Press '98.
9. Centralized Reliability and Events Database Reliability Data for Nuclear Power Plant Components. Report VGB-TW805e. VGB PowerTech e.V, Essen 2010.
10. Dobrodziej J., Mazurkiewicz A., Zbrowski A.: *Quality testing model for unit prototype technological devices*. Scientific Problems of Machines Operation and Maintenance. Zagadnienia Eksploatacji Maszyn. 1(165), Vol. 46, 2011, s. 29–44.
11. Zbrowski A.: *Badania prototypu działa pneumatycznego*. Problemy Eksploatacji 2011, nr 3, s. 217–234.
12. Zbrowski A., Jóźwik W.: *Badania weryfikacyjne modułowego systemu do zwalczania par substancji niebezpiecznych*. TTS Technika Transportu Szynowego 10/2013, s. 912–922.
13. Zbrowski A., Samborski T., Zacharski S.: *Badania prototypu linii technologicznej do wytwarzania kart wielowarstwowych*. TTS Technika Transportu Szynowego 10/2013, s. 963–973.

Metodyka badań jednostkowych i unikatowych obiektów technicznych

Słowa kluczowe

Badania prototypów, dekompozycja, prototypowanie, weryfikacja.

Streszczenie

Osiągnięty poziom metod projektowania i wytwarzania urządzeń technicznych umożliwia szybkie wyprodukowanie w pełni funkcjonalnego prototypu lub urządzenia jednostkowego. Wymagana efektywność procesu prototypowania wprowadza potrzebę stosowania metodyki badań prototypów wykorzystującej zasoby wiedzy zgromadzone w bazie danych historycznych problemów konstrukcyjnych, badawczych, uruchomieniowych i wdrożeniowych.

W artykule przedstawiono opracowaną w Instytucie Technologii Eksploatacji metodykę badań jednostkowych i unikatowych obiektów technicznych wspomagającą prototypowanie nowych rozwiązań zaawansowanych urządzeń innowacyjnych.

Celem przeprowadzonych prac było opracowanie rozwiązania w postaci systemu badań prototypów umożliwiającego sterowanie procesem badań w sposób oparty na zasobach zgromadzonej wiedzy dotyczącej projektowania, uruchamiania i wdrażania zaawansowanych technicznie urządzeń wykonywanych jednostkowo lub małoseryjnie. Wykorzystanie metodyki badań zwiększa gwarancję budowy prototypowych maszyn i urządzeń charakteryzujących się lepszą jakością i niezawodnością w stosunku do rozwiązań bazujących jedynie na wiedzy nabytej i doświadczeniu uczestników zespołu realizacyjnego. Metodykę badań pilotowo zastosowano w odniesieniu do kilkunastu prototypowych urządzeniach zaprojektowanych i wykonanych w Instytucie Technologii Eksploatacji.

Michał PAJĄK
University of Technology and Humanities in Radom,
Faculty of Mechanical Engineering,
Department of Thermal Technology,
m.pajak@uthrad.pl

OPERATIONAL POTENTIAL OF A COMPLEX TECHNICAL SYSTEM

Key words

Maintenance management, Complex technical systems, Operational potential.

Abstract

The amount of the operational potential included in the system is a main characteristic of the system operation possibility and profitability. A quantitative analysis of this characteristic should be the source of the information used in operation control of complex technical systems. Unfortunately, the definitions of the operational potential are mostly formulated in a qualitative way and the interpretations of them are different. In this paper, the definitions of the operational potential are presented. The description of each definition and the differences between them are also enclosed. Next, a new definition of the operation potential is formulated. The way of the definition implementation to calculate the amount of the operational potential included in a complex technical system is also described. At the end of the paper the analysis of the amount of the operational potential included in an exemplary real industrial system accomplished using the method presented above can be found.

Introduction

An operation phase of a technical system is a time period when the system accomplishes goals, which were the reason of the system designing and creation.

At the beginning of this phase the system is characterised by its ability to operating in assumed conditions with demanded efficiency in defined period of time. The value of this ability changes during operation phase as a result of operation and service processes executed in the technical system. The operation processes decrease this ability while service processes increase its value. At the end of the operation phase the operation ability of the system is so low that the system is designated to destruction.

One of the most important decisions taken in the process of the technical system maintenance management is the one about the system allocation. The system can be designated to further operation, service or destruction. This decision results from the analysis of the system operation ability. Therefore, the key issue of the optimal maintenance management of the technical systems is the definition and qualitative and quantitative description of the concerned feature.

In the literature the operation ability of the technical system is called the operation resource or the operation potential. Different authors propose different definitions and different interpretation of these terms. To analyse the definitions and interpretations that can be found in literature, the most common of them are cited and described in the next part of this paper.

1. Definitions of the operational potential

During theirs research [1], [2] authors introduce the term "operation resource". This term they use to define the operation phase as a sequence of stochastic events which express the operation position of the technical object and changes of this position or as a controlled stochastic process of the operation resource consumption in a range (1).

$$ZU_P \geq ZU \geq ZU_K \tag{1}$$

where: ZU – operation resource of the object, ZU_P – initial value of the operation resource, ZU_K – final value of the operation resource.

In the cited definition the operation resource is interpreted as the ability to accomplishing the utilitarian work according to design. The operation resource is composed into system during valuation, designing and production phases and extracted in the operation phase [3]. On the basis of the definition it is possible to conclude that exhaustion of the operation resource is equivalent to termination of the operation phase of the technical object.

In [4] the author introduces terms "operational potential" and "service potential" of the technical object. The operational potential is a feature of the object, which characterizes the resource of the object operation potentiality. The operational potential is expressed in the same units as the effects of the object operation (e.g. mass, volume, value). Whereas the service potential is the technical object's feature which characterizes the resource of the needs of the object handling if its' operational potential have to be restored. The service potential is expressed using the handling expenditures (e.g. amount and kind of service activities, service duration, service costs).

It should be noticed that, according to the presented above definition, the operational potential is expressed in the same units as the effects of the object functioning *and a constant efficiency of the transformation* of the operation *potential in the effect of the system* work is *assumed*.

Similarly, in [5] the author defines operational potential as a measure of the machine ability to operating [6] with defined effectiveness, and the ability ensuring potential as a measure of needs in the field of service and renewal activity. However, both of these potentials are interpreted as two kinds of the maintenance potential. The maintenance potential is defined as an important feature of the system, which characterizes its operation position. It deserves attention that the maintenance potential is closely related to the operation position of the machine. From concerned definition directly results that the amount of the operational potential is closely related to ability or inability state of the machine.

In the definitions analyzed above the discrepancies in naming the potential called service or ability ensuring one can be noticed. But the main objective of the service activity of the technical object is the restoration or maintaining the ability state of it. So, this goal is convergent with the definition of the ability ensuring process which describes it as an action carried in order to hold ability of the technical system or in case of the system inability in order to restore ability state [7]. On the basis of presented analysis it was stated that in the cited definitions the same feature of the technical system is considered.

In [8] the author also introduces the term “maintenance potential” but he defines it in a different way. The maintenance potential of the technical object is interpreted as a stochastic variable which describe its work, which can be done from the beginning of the operation phase or from the moment of the object’s state assessment since the moment when the object reaches the boundary state. There are distinguished two kinds of the potential: the maintenance potential to the next renovation or main overhaul and the maintenance potential to the system destruction. So, the maintenance potential is identified as the operational potential. The most important element of this definition is the distinction of operational potential to the next renovation and operational potential to the system destruction.

In [9], [10] the author introduces the term “maintenance potential”. The change of the maintenance potential results from the technical objects operation. Two kinds of the potential are distinguished: the used potential and restored one. During operation tasks execution the operation system of the technical object consumes the maintenance potential. The amount of used potential depends on a type of operation tasks, environment conditions, operation positions of the object and skill of operation staff. The wear process is related to the physical processes of mass and energy transformation, which run during the technical system operation. The amount of the maintenance potential is restored by service system. During the technical object operation the spontaneous consumption of maintenance potential takes place. The rate of this consumption is related to the object operation and conditions in which the object operates and increases with time.

Whereas, the considerations on technical objects maintenance in [11] and [12] are curried out based on a term „operation resource”. In this case it is stated that during operation phase takes place intentional action where the technical object is the object of the action. The result of this action is the change of the operation resource amount. The change consists in the operation resource consumption or the reconstruction of it.

In [13] the author defines the maintenance potential as a feature, which describes the reserve of the object ability to tasks execution. The amount of the maintenance potential of the object is the objective value which is built-in the object during design and construction processes. This value depends on the technical state of the object’s elements [14]. During the operation process the gradual loss of the potential takes place. Renovations regenerate the maintenance potential and service activities decrease the intensity of its consumption. It is assumed that the maintenance potential of the object is the resultant of the maintenance potential of its elements and the specified type of running, mean or major repair is the renovation of specified component or specified components of the maintenance potential of this technical object. Analyzing the changes of the maintenance potential, two types of this potential are distinguished: the potential consumed in the operation system and the potential restored in service system.

Sometimes the operational potential is treated as the durability. But the operational potential can be defined as a measure of the machine ability to operating with defined effectiveness [5] and durability is defined as the ability of the technical system to conservation of its features [15]. So, the durability is rather correlated with the rate of the operational potential consumption then with the amount of this potential. It means that the durability is inversely proportional to the time derivative of the operational potential consumption function not to the operational potential amount. Additionally, when the durability is assumed as the only parameter, which characterizes the rate of the operational potential consumption during the operating processes then the influence of environmental, conditions and control stimulations are not taken into consideration.

In contrast, in [7] the operational potential is treated as a functional of the technical object potential ability to achieve specified effects in the defined time interval. Its amount depends on the features of the device, the operational conditions and control stimulations. Very significant element of this definition is the connection of the amount of the operational potential included in a technical system with the effects of the system operation.

Detailed theory, which defines the operational potential in connection with the effect of a technical system operation, is presented in [16]. The theory introduces the term potentiality, which is defined as instantaneous ability of the technical system to accomplish the operation or maintenance task. Analogically, the effectiveness is defined as instantaneous measure of the system functioning results. The operational potential is the functional of potentiality and the duration of the system functioning (the integral of potentiality in a period of time) [17]. So, it is the range measure of the system maintenance possibility. Whereas, the effect is the functional of the effectiveness and the duration of the system functioning (the integral of effectiveness in a period of time). So, it is the range measure of the results of the system functioning. In case of operation tasks the theory considers the operational potential and the effect of the system operation, while in case of service tasks the service potential and the effect of service activities is considered. According to the theory, the potential included in the technical system is transformed into the effect of the system functioning during the execution of the operation and maintenance tasks. The amount of this potential should be bigger than the demanded amount of the effect. If this condition is not satisfied then the system is unable to perform the specified task and has to be renovated. It should be noticed that the operational potential is interpreted here in relation to the time between overhauls, not like in case of the definitions mentioned earlier where this potential was interpreted in relation to operation life of the system.

Presented above definitions have some similarities but also same differences can be found. According to all of the theories, the operational potential of the system is located in it during the designing and production phases. Next, during the maintenance and operation phase of the system the potential is extracted from it. At the beginning of the maintenance and operation phase, the system includes the initial amount of the potential. During the operation of the system, because of wearing factors influence, the initial amount decreases until the boundary value [18]. When the amount of the potential is equal to its boundary value, further operation is impossible. So, the service activities are performed to increase the amount of the operational potential in order to make possible the next operation tasks execution. At the end of the operation and maintenance phase the amount of the operational potential is very low and the system is designated to liquidation.

However, according to presented definitions, the system is in ability state when the amount of the operational potential enclosed in it is big enough to accomplished operation task. Otherwise, it is in inability state. But, when we consider the operation position of the system at the beginning of the operation and maintenance phase and at the end of it, the positions seems to be different. So, the amount of the operational potential included in the system at the beginning of the operation and maintenance phase is bigger than the value at the end of the operation and maintenance phase. Simultaneously, the system can be in inability state at the beginning of the operation phase and in the ability state at the end of it. Then, from one point of view the amount of the operational potential is bigger in the first situation, and from the other point of view in the second one.

As a solution of definitional and interpretational ambiguity, a new description of the operational potential was proposed. This new idea is presented below.

2. Operational potential expressed in the features' space of a system

If a set of cardinal features comprise only physical features then the state of the system, expressed in the defined space, is called the physical state of the system [19]. If the characteristic values and ranges of these features are defined in the context of the system ability to realise the aims of its operation, in the features' space the fields of reliability are obtained [20]. So, the reliability states of the system are determined in the features' space where points represent the technical states of the system. This space will be called the space of the technical states of the system [21].

During the studies, the technical states' space of the crucial, complex operational system was taken into consideration. The technical states' space of such system is strictly determined one. The real operation position of the system s_R is expressed as a point of this space. The coordinates of the point are equal to instantaneous values of the cardinal features of the system (Fig. 1).

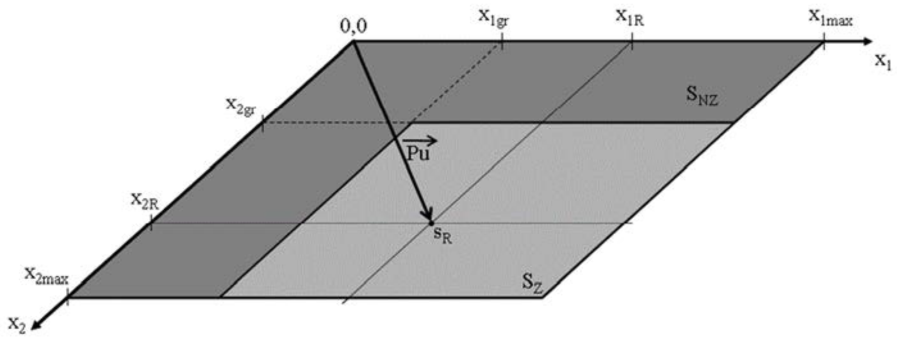

Fig. 1. Operational potential $\overrightarrow{Pu}$ included in a system in s_R state expressed in its technical states' space R^2, S_{NZ} – the inability states' subspace, S_Z – the ability states' subspace

The amount of the operational potential included in the system is a function of the operation position of it. So, it was stated that the operational potential included in the system is expressed in the space in a form of a vector. The starting point of this vector is the origin of the coordinates system and the end point of it is the point of the real operation position of the system s_R. The amount of the operational potential included in the system can be calculated as a length of the vector (Fig. 1).

Definition 1: *The amount of the operational potential included in the system in a state s_R is the length of a vector between the origin of the coordinates system and the point of the system operation position.*

The technical states' space of the system is the Cartesian one [22] so, the considered length is calculated in the Euclidean metrics [23], [24] according to the formula (2)

$$Pu(s_R) = \sqrt{\sum_{i=1}^{n} (x_{iR})^2} \quad (2)$$

where: $Pu\ (s_R)$ – the amount of the operational potential included in the system in a state s_R, x_{iR} – the value of a feature no. i of the real operation position of the system s_R.

In a strictly determined technical states' space, the point of the operation position of the system can belong to the ability states' subspace S_Z or to the inability states' subspace S_{NZ}. The inability states' subspace consists of the technical states' space points, which express the operation position of the system in which the system is unable to accomplish the demanded functions [25]. Assuming the amount of the operational potential Pu_{gr} included in the system in a boundary state as the lowest value for each the system operation is safe [26] it was stated that for each point of the inability states' subspace the amount of the operational potential included in the system is lower than Pu_{gr} value. Thus, the inability states' subspace is the unclosed one. Therefore, the ability states' subspace is closed from the side of the inability states' subspace, where the closed subspace is defined as a field with its boundary [27]. From the characteristic of the unclosed fields arise that the limit of the inability states' subspace is the set of the points belonging to the boundary of the ability states' subspace [28]. These points are the expression of the boundary states of the system s_{gr}.

The vector between a point which fulfils the condition (3), what means that the point belongs to the boundary [29] of the ability states' subspace, and the point of the real operation position of the system is interpreted as an operational potential which can be transformed to the effect of the system operation, included in the system in a moment t.

$$s_{BNZD} : x \in X_{ZD} \wedge \forall \varepsilon > 0 \exists x_i \notin X_{ZD} : |x_i - x| < \varepsilon \quad (3)$$

where: s_{BNZD} – the operation position of the system expressed by the point, which belongs to the boundary of the ability states' subspace, X_{ZD} – the range of unacceptable values of the system feature.

The length of this vector is equal to the amount of the operational potential, which can be transformed to the effect of the system operation, included in it in a moment t (Fig. 2). This amount was defined as the disposed amount of the operational potential.

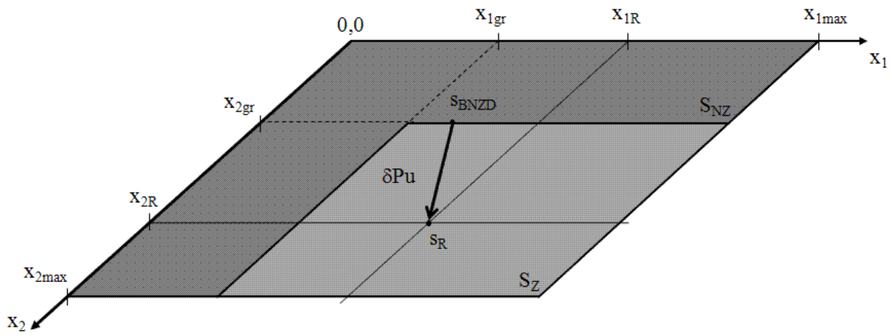

Fig. 2. Operational potential that can be transformed to the effect of the operation $\overrightarrow{\delta Pu}$ included in a system in s_R state expressed in its technical states' space R^2

Definition 2: *The disposed amount of the operational potential of the system is the amount, which can be transformed to the effect of the system operation, included in it in the specified moment t.*

The concerned length is an Euclidian distance and can be calculated according to the following formula (4)

$$\delta Pu = \sqrt{\sum_{i=1}^{n} (x_{iR} - x_{BNZDi})^2} \quad (4)$$

where: δPu – the disposed amount of the operational potential, x_{iR} – the value of a feature no. i of the real operation position of the system, x_{BNZDi} – the value of a feature no. i of the operation position of the system expressed by a point, which belongs to the boundary of the ability states subspace.

Because this length is an Euclidian distance it is always not negative value [30]. Therefore, it can be treated as the disposed amount of the operational potential only for points, which belongs to the ability states' subspace. Thus, the disposed amount of the operational potential was finally defined in the following form (5)

$$\delta Pu = \begin{cases} 0 \wedge s_R \in S_{NZ} \\ \sqrt{\sum_{i=1}^{n} (x_{iR} - x_{BNZDi})^2} \wedge s_R \in S_Z \end{cases} \quad (5)$$

where: S_{NZ} – the inability states' subspace, S_Z – the ability states' subspace.

Analyzing the expression (5) presented above, it was stated that the disposed amount of the operational potential is depended on a point of the boundary of the ability states' subspace, which is taken into calculations (Fig. 3).

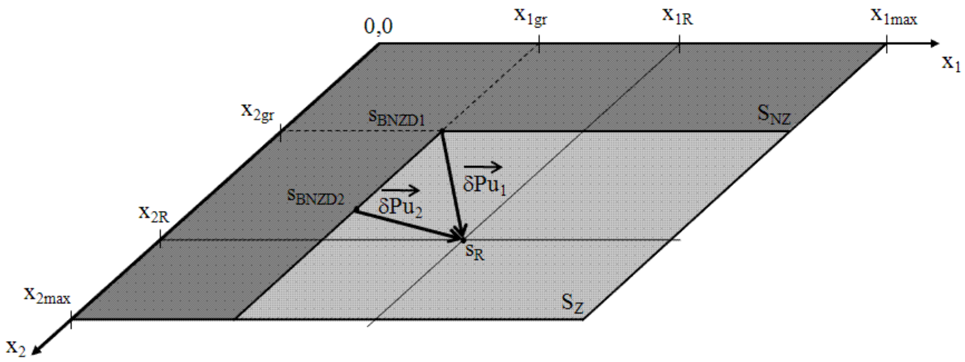

Fig. 3. Operational potential which can be transformed to the effect of the operation $\overrightarrow{\delta Pu_1}$, $\overrightarrow{\delta Pu_2}$ depended on the specified point of the boundary of the ability states subspace expressed in the system technical states space R^2

The definition of the operational potential and its disposed amount expressed in the space of the system features is formulated in the quantitative way. So, thanks to the definition implementation, it is possible to figure out if the disposed amount of the operational potential is big enough to execute specified operational task.

On the basis of the presented description it was stated that during the operating processes execution the values of the system features are changed. Therefore, the disposed amount of the operational potential of the system decreases. In the moment when the point of the system state reach the position on the border of the ability states' subspace, the system is designated to renovation. During the renovation process the values of the system features are restored, so the disposed amount of the operational potential of the system increases. However, if not all the system features belong to the renewable features set, then despite the performed service processes, during the operation and maintenance phase, the point of the system state moves along the trajectory which bring it closer and closer to the border of the inability states' subspace.

In spite of the fact that during the renewable processes the disposed amount of the operational potential is increased, its absolute value (defined in the relation to the origin of the coordinates system) decreasing. So, thanks to the presented above theory, the inconsistencies pointed during the analysis of the operational potential definitions are solved.

3. Analysis of the operational potential of the industrial technical system

During the curried out industrial research, the operational system of the OP-650k-040 power boiler was analyzed. According to the one of the most important operation objective of this system, the operation process should be executed with the efficiency as high as possible and the life-time of boiler elements should be optimal [31]. Because of a complex construction of the boiler and multidimensional connections between its elements it is hard to express in quantitative way mentioned above operation objectives. To solve this problem, the operation objectives were expressed in the following form:

- the minimum disposed amount of the operational potential of the system in each moment of the operation process should be greater than zero,
- the amount of the operational potential of the system in the moment when the system is designated to renovation should be minimum.

Next, it was stated that the operating position of the boiler is determined by values of the features that define its technical states' space. These features determine the quality of the system operation too. Therefore, the former considerations curried out to identify cardinal features of the system, were limited to the set of the deviations calculated in the Technical Operation Control method (TKE) [32]. This method is used to control the quality of the operation process of the power units. In the method, the deviations from the nominal value of the amount of the heat consumed in the process of 1kWh electrical energy production are calculated. As a result of the identification process, four deviations were chosen as cardinal features – the dimensions of the technical states' space of the analyzed boiler. These deviations are presented in the following list:

- *q3* – the deviation which occurs as a result of the reduced temperature of the reheated steam,
- *q4* – the deviation which occurs as a result of the pressure loses in the secondary reheater of the steam,
- *q5* – the deviation which occurs as a result of the injections of water to the secondary reheated steam,
- *q8* – the deviation, which occurs as a result of the reduced efficiency of the boiler operation.

Additionally, it was stated that, as far as operating position of the system is concerned, in case of distinguished features the range of accepted values is equal to the range of suboptimal ones. It means that the features are strictly determined.

On the basis of the measurements registered during industrial research, the values of the chosen deviations were calculated. Afterwards, implementing polynomial approximation, the time functions of each deviation were formulated. Next, the derivative of each function was calculated. The sign of each derivative is positive what means that functions are increasing in the analyzed domains. It confirms assumption that the values of the cardinal features of the system that determine its technical states' space, should change in the monotonic way during the operation process. For each function its minimum and maximum values were also calculated. On this basis it was confirmed that execution of the service processes decreases the values of the deviations. This means that all chosen cardinal features of the system are renovated during the service processes.

In the next step of the studies, the ability and inability states' subspaces were defined. These subspaces were defined in the space of the system features and were limited by the boundary values of them. In case of the analyzed system the features' space is described by the deviations *q3, q4, q5, q8*. Their boundary values were identified during the industrial research as the biggest values, which occur at the end of the power unit operation periods just before designation the unit to renovation and are equal respectively to the following values 16.8873, 41.1034, 131.9413, 398.9218 [kJ/kWh]. These values are interpreted as the biggest values for which the risk of the inability state occurrence is equal to 0%.

For the specified technical state of the system, the minimum disposed value of its operational potential is obtained calculating the distances between the system operating point and the boundary lines of the system ability states' subspace and choosing minimum one. Thus, the operating objective which consider the optimal life-time of the boiler elements for the analyzed system was formulated as follows (6):

$$\begin{gathered}\min(\left|q3_R - 16.8873\right|, \left|q4_R - 41.1034\right|, \\ \left|q5_R - 131.9413\right|, \left|q8_R - 398.9218\right|) > 0\end{gathered} \qquad (6)$$

where: qn_R – the value of the deviation no. *n* for the system operating point.

As it was mentioned above, all the cardinal features, which define the technical states' space of the analyzed boiler, are renovated during the executed service processes. So, the disposed amount of the operational potential is equal to the distance between the operating point of the system at the end of the operation process and the point whose coordinates are equal to the boundary values of the cardinal features of the system. Therefore, the operating objective, which considers minimization of the amount of the operational potential not transformed into the effect of the system operation, is expressed in the following form (7):

$$\sqrt{\begin{gathered}(q3_k - 16.8873)^2 + (q4_k - 41.1034)^2 + \\ (q5_k - 131.9413)^2 + (q8_k - 398.9218)^2\end{gathered}} \rightarrow \min \qquad (7)$$

where: qn_k – the value of the deviation no. *n* at the end of the operating process [kJ/kWh].

Summary

Summarizing the issues presented in the publication it was stated that:

1. The operation ability of the technical system is described in the literature as an operational potential or an operational resource, defined in the qualitative way and differently interpreted. Therefore it is not possible to apply these definitions to control the operating and maintenance processes in the efficient way without advanced mathematical tools implementation.
2. The amount of the operational potential included in the system is equal to the length of the vector between the origin of the coordinates system of the technical states' space and the point of the operating position of the system, while the amount of the operational potential which can be transformed into the effect of the system operation is equal to the length of the vector between the one of the points of the border of the ability states' subspace and the point of the operating position of the system.
3. Applying in the modelling process the definition of the operational potential in the space of the system features it is possible to formulate the operational objectives of the complex technical system as the algebraic expressions.
4. Thanks to the algebraic form of the operational objectives it is possible to automate the control of the operating and maintenance of the complex technical system.

References

1. Powierża L.: Zarys inżynierii systemów bioagrotechnicznych. ITeE, Radom – Płock 1997.
2. Oziemski S.: Człowiek w maszynie. ITeE, Radom 2004.
3. Pająk M.: The Analysis of Usefulness of Operational Potential Consumption Models to Control Complex Technical Systems Maintenance, Journal of KONES Powertrain and transport vol. 17 No. 2, Warsaw 2010, pp. 387–395.
4. Downarowicz O.: System eksploatacji. Zarządzanie zasobami techniki. ITeE, Gdańsk – Radom 2005.
5. Woropay M.: Podstawy racjonalnej eksploatacji maszyn. ITeE, Bydgoszcz – Radom 1996.
6. Żółtowski B., Żółtowski M.: Improvement the Systems of Exploitation Machine, Journal of KONBiN, 4(20), Warszawa 2011, pp. 119–132.
7. Woropay M., Muślewski Ł.: Jakość w ujęciu systemowym. ITeE, Radom 2005.
8. Hebda M.: Eksploatacja samochodów. ITeE, Radom 2005.
9. Girtler J.: Diagnostyka jako warunek sterowania eksploatacją okrętowych silników spalinowych. Maritime University in Szczecin, Szczecin 1997.

10. Girtler J.: Sterowanie procesem eksploatacji okrętowych silników spalinowych na podstawie diagnostycznego modelu decyzyjnego. Scientific books Nr 100a, Naval Academy, Gdynia 1989.
11. Dwiliński L.: O założeniach teorii eksploatacji maszyn rolniczych. Scientific works of The Warsaw Technical University, Mechanic 152, Warszawa 1992.
12. Dwiliński L.: Wstęp do teorii eksploatacji obiektu technicznego. The Warsaw Technical University, Warszawa 1991.
13. Niziński S.: Eksploatacja obiektów technicznych. ITeE, Radom 2002.
14. Smoczyński Z., Szcześniak K., Szumniak J.: Starzenie polimerowych kompozytów uzbrojenia i sprzętu wojskowego, Journal of Science of the gen. Tadeusz Kosciuszko Military Academy of Land Forces 1/2011, Wrocław 2011, pp. 271–285.
15. Ważyńska-Fiok K., Jaźwiński J.: Niezawodność systemów technicznych. PWN, Warszawa 1990.
16. Dąbrowski T.: Diagnozowanie systemów antropotechnicznych w ujęciu potencjałowo-efektowym. Habilitation dissertation. Military University of Technology, Warszawa 2001.
17. Bednarek M., Dąbrowski T., Będkowski L.: The Useful Safety of the Human Engineering System in a Potential Approach, Maintenance Problems, 1/2010, ITEe – PIB, Radom 2010, pp. 21–29.
18. Żółtowski B.: Elementy racjonalnej eksploatacji systemów technicznych, Inżynieria i Aparatura Chemiczna 2/2012, Gliwice, 2012, pp. 34–36.
19. Pająk M.: The Space of a Feature of a Complex Technical System, Scientific Problems of Machines Operation and Maintenance, 2/2010, ITEe – PIB, Radom 2010, pp. 31–41.
20. Pająk M.: Types of the States Space of Complex Technical Systems, Journal of KONES Powertrain and transport vol. 18 No. 3, Warsaw 2011, pp. 323–331.
21. Pająk M.: The Technical States' Space in the Modelling Process of Operation Tasks of a Complex Technical System, Maintenance Problems, 1/2014, ITEe – PIB, Radom 2014, pp. 15–33.
22. Muszyński J.: Analiza matematyczna p.I. The Warsaw Technical University, Warszawa 2000.
23. Dorst L., Fontijne D., Mann S.: Geometric Algebra for Computer Science. Elsevier 2007.
24. Saddique S., Khiyal M., Khan A., Khanum M.: Modified sequential algorithm using euclidean distance function for seed filling, Journal of Theoretical and Applied Information Technology, 2010, Vol. 19 Issue 1/2, p. 9.
25. Polish standard PN-93/N-50191: Słownik terminologiczny elektryki – Niezawodność, jakość usługi. Polish Standards Association, Warszawa 1993.

26. Zdoński M., Mcgeough J.A., Szpytko J.: On the use a maintenance developments to improve inherent reliability. Engineering achievements across the global village. International Journal of INGENIUM, Kraków – Glasgow 2005.
27. Rudin W.: Podstawy analizy matematycznej. PWN, Warszawa 1982.
28. Birkholc A.: Analiza matematyczna, funkcje wielu zmiennych. PWN, Warszawa 1986.
29. Kołodziej W.: Analiza matematyczna. PWN, Warszawa 1978.
30. Klaus J.: Topologia. PWN, Warszawa 1991.
31. Janiczek R.S.: Eksploatacja elektrowni parowych. WNT, Warszawa 1992.
32. Pająk M.: Rozmyte rozszerzenie metody TKE określania jakości procesu użytkowania bloków energetycznych, Scientific Problems of Machines Operation and Maintenance 4/2007, ITEe – PIB, Radom 2007, pp. 141–151.

Potencjał użytkowy złożonego systemu technicznego

Słowa kluczowe

Sterowanie eksploatacją, złożone systemy techniczne, potencjał użytkowy.

Streszczenie

Podczas fazy eksploatacji następuje zmiana zdolności systemu do funkcjonowania od wartości maksymalnej do wartości granicznej. Zdolność tę określa się jako potencjał użytkowy. Ilość potencjału użytkowego zawartego w systemie technicznym jest podstawową charakterystyką określającą możliwość i opłacalność jego eksploatacji. Analiza ilościowa tej charakterystyki powinna być źródłem informacji wykorzystywanych w sterowaniu eksploatacją złożonych systemów technicznych. Niestety definicje potencjału użytkowego są formułowane w większości na bazie opisu jakościowego. Jednocześnie ich interpretacja u różnych autorów jest odmienna. W pracy przedstawiono definicje potencjału użytkowego spotykane w literaturze, omawiając ich interpretację oraz występujące rozbieżności. Następnie zaproponowano nową definicję potencjału użytkowego wyrażonego w przestrzeni cech systemu oraz podano sposób jej zastosowania do wyliczenia ilości potencjału użytkowego zawartego w złożonym systemie technicznym. W opracowaniu przeprowadzono również analizę ilości potencjału użytkowego zawartego w rzeczywistym systemie technicznym przy zastosowaniu opisanej teorii.

INNOVATIVE ECONOMY
NATIONAL COHESION STRATEGY

INSTITUTE FOR SUSTAINABLE TECHNOLOGIES
NATIONAL RESEARCH INSTITUTE IN RADOM

EUROPEAN UNION
EUROPEAN REGIONAL DEVELOPMENT FUND

Project co-financed by the European Union from the European Regional Development Fund

Beata BELINA, Tomasz GIESKO, Wojciech KARSZNIA,
Adam MAZURKIEWICZ
Institute for Sustainable Technologies – National Research Institute, Radom
beata.belina@itee.radom.pl; tomasz.giesko@itee.radom.pl;
wojciech.karsznia@itee.radom.pl; adam.mazurkiewicz@itee.radom.pl

A PRACTICAL APPLICATION OF A METHOD FOR THE EVALUATION OF IMPLEMENTATION MATURITY AND COMMERCIAL POTENTIAL IN R&D PROJECTS

Key words

Implementation Maturity Level (SDW), commercial potential, technical innovation, technology transfer.

Abstract

A comprehensive evaluation of multifaceted R&D projects and their application potential should play a decisive role in the justification of research task continuation and a practical use of its results. It is therefore essential to use adequate, effective tools in directing these projects that allow assessing work progress and commercialization probability.

This article describes a practical application of simulation methods for the assessment of implementation maturity, commercial potential, and innovation for supporting the management of project implementation, based on selected examples of innovative solutions of the Strategic Programme, "Innovative Systems of Technical Support for Sustainable Development". The article presents the results of the evaluations and their interpretation, which facilitates taking appropriate corrective action. The examples of the application of assessment methods of the implementation maturity level (SDW), commercial potential (PK), and innovation potential presented in this article confirm the high suitability of the proposed methodology in the evaluation of R&D projects to rationalize product development processes. Moreover, a practical verification of assessment methods for innovative solutions facilitates the establishment of potential development directions of the methods themselves, and of the original, comprehensive assessment system of the efficiency and effectiveness of the research project implementation of innovative products as their result.

Introduction

In the era of the continuous pursuit of competitive advantage in goods, services, companies, and entire economies, it is very important to have tools that support accurate and efficient evaluation of the level of implementation readiness, commercial potential, as well as technological innovation, ventures, and research and development projects. When en route to a modern, innovative, and competitive economy, the ability to save time, labour, and primarily financial resources is of paramount importance. An investment based exclusively on intuition in all the "promising" products at some stage of their progress, in many cases, turns out to be inefficient and unreliable, and it leads to irreversible losses.

The problem of the still insufficient use of assessment tools projects R&D is essential in the context of the distribution by the government institutions of considerable financial resources from the EU funds for economic development. These tools (e.g. technology intelligence, technology acceptance model, technology foresight, foresight, technology assessment) are used with great success by the most innovative European countries [1]. The experiences of those countries confirm the importance of real assessment of the technological development and commercial potential of solutions with regard to the increase of their application efficiency and commercialisation.

Projects in research programmes still very rarely include the stage of the practical application of innovative solutions, while their results, in many cases, are not evaluated in terms of the application potential and the effectiveness of economic implementation. Therefore, the effectiveness of the practical application of scientific research results is still not satisfactory in Poland [2, 3]. This is further confirmed by the results analysis of national innovation strategies and research [4–9] that indicate a large gap between the phases of research, the development of the prototype, industrial application, and commercialization of advanced products and technologies.

Literature on the subject [10–11] also indicates a problem with the inadequacy of standard methods (for example, direct intelligence, statistical analyses, expert panels, workshops), the methods borrowed from strategic management practice (e.g. scoring method, the SWOT method) or even intuitive methods used in the evaluation of the strategic research programmes. Frequently, it does not take into account important aspects, such as market demand assessment, field of application, competitive solutions on the market, potential benefits for producers and consumers, and the protection of intellectual property rights. Strategic government documents [12–15] and research on the effectiveness of the transfer processes of innovative solutions under development into the economy [16–20] stress the importance of a real assessment of the implementation and commercial potential.

Moreover, the methods used so far for the evaluation of technical solutions do not sufficiently take into account the specificity of innovative solutions that results from scientific research work. There is a deficiency of integrated assessment methods that would take into account all aspects of technical solutions. In practice, there are only tools to evaluate selected aspects.

An analysis of the use of assessment methods in the world, concerning the degree of sophistication of technological and research programmes indicated the following NASA methods as the foundations and premises to be incorporated in designing the SDW methodologies: *Technology Readiness Levels* (TRL) [21], and a more advanced – *Engineering Manufacturing Readiness Levels* (EMRL) [22]. Adaptations of this kind of methodology for special purposes are increasingly used for assessing the maturity of solutions at the stages of research and development of technologies [23–25]. For technologically advanced and organisationally complex endeavours, the use of TRL methods is now the common practice that distinguishes innovative economies [26–28]. Furthermore, literature on the subject indicates only a few examples of methods for assessing the commercial potential of technological and research projects (mainly the methods used for the evaluation of commercial potential of new technologies: *Quicklook* and *In-Depth* [11], expert subjective evaluation methods and objective factual analysis for identifying the commercial potential of innovative solutions [29, 30]. The methods for assessing commercial potential by using computer-based methods for the analysis of information [31, 32] have become an inspiration to develop a comprehensive, an original method to evaluate commercial potential.

The ITeE – PIB in Radom adopted the insufficiency of support mechanisms for commercialization and implementation, the low level of implementation and commercial maturity for the developed innovative solutions, and the lack of purpose–designed methods for detailed comprehensive assessment of developed solutions as the premises for the development of practical, useful tools for evaluating the degree of technical advancement of solutions and product readiness to implement industrial and commercialization [34].

Within the framework of the Strategic Programme “Innovative Technical Support Systems for Sustainable Development of the Economy” [33], practical methods for monitoring the product development stages and readiness level of innovation transfer into business practice were developed and verified, including a method for assessing the level of implementation maturity (SDW) [35] and a method of commercial potential evaluation (PK) [36] for technical solutions.

These methods and the computer program are permanent elements of the monitoring procedures for research projects carried out in the ITeE – PIB, and SDW and PK are the assessments of their results. These verified and modified methods are now being used in cyclical assessments of innovative solutions, which are at various stages of completion, developed within the framework of the Strategic Programme, “Innovative Systems of Technical Support for Sustainable Development”. There are 173 solutions evaluated at fixed intervals and classified within a system of categories: Systems (S), Materials (M), Devices (U), Technologies (T), and Services (Z), which are further broken down into subcategories. The structure of the developed classification is open–ended, which allows its extension into further subcategories [35].

The developed system has been presented in several publications [35–38]. In this article, the authors focused on examples of the practical application of the system, and its applicability and evaluation effectiveness.

1. Examples of practical application of the developed methods for evaluating implementation maturity and commercial potential of selected innovative solutions (SDW)

Out of 173 solutions developed within the strategic programme, subject to systematic evaluation, four examples were selected that represent the different categories marked by the following letters:

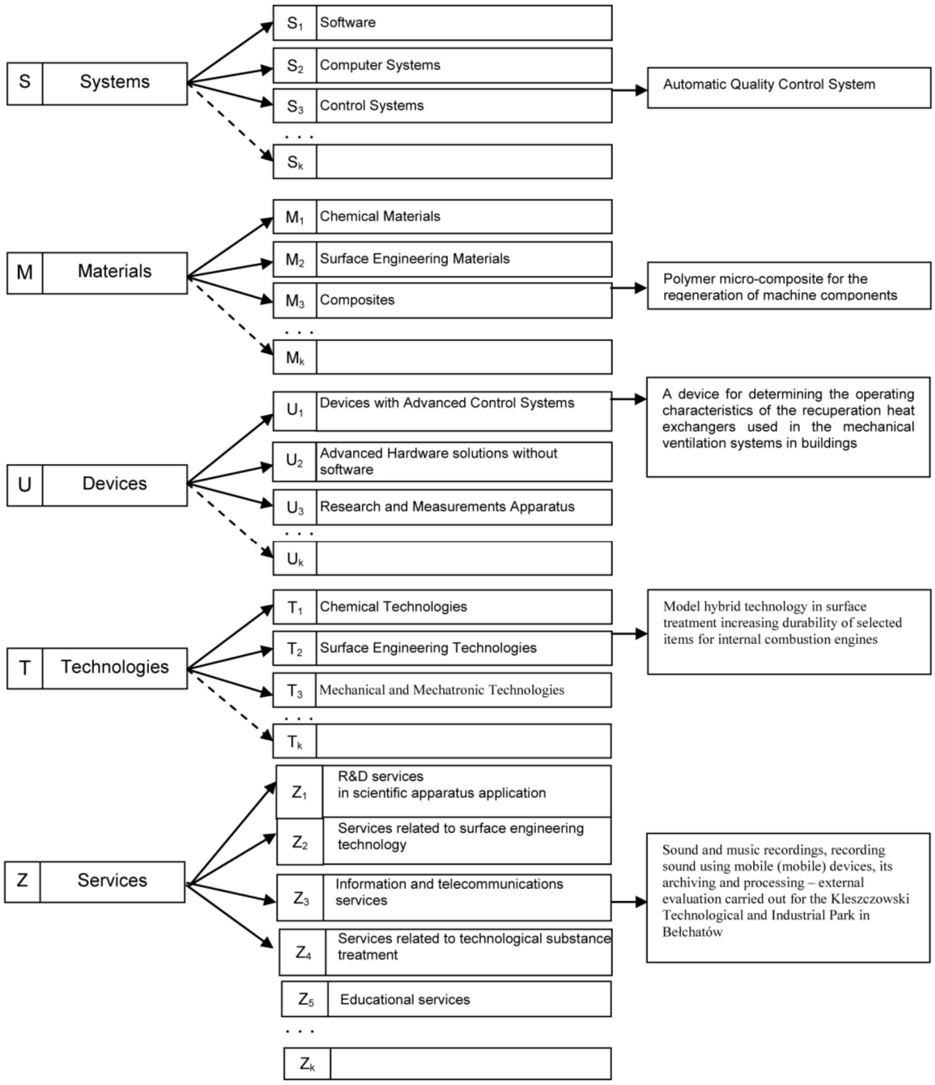

Fig. 1. Categorization of innovative solutions for specialized categories and subcategories

S: "System for automatic quality control" (category "system" subcategory "control system") developed in the framework of the research tasks of "Hybrid systems for automatic quality control in production processes; **M:** "Polymer micro-composite for regeneration of machine components" (category "materials", subcategory "composites") developed in the framework of the research task, "The use of polymer micro- and nano--composites in construction and regeneration of machine components"; **U:** "A device for determining operational characteristics of recuperation heat exchangers used in mechanical ventilation systems for buildings" (category "devices" subcategory "devices with advanced control systems") developed in the framework of the research tasks "Methods of improving environmental and engineering safety in ventilation systems"; **T:** "Model hybrid technology for surface treatment to increase the durability of selected components of internal combustion engines" (category "technology" subcategory "surface engineering technologies") developed in the framework of the research task, "Hybrid layers with higher resistance to thermos-mechanical fatigue".

The example does not include the "Service" category, since this type of product was not developed within the framework of the Strategic Programme. A detailed description of the specificities and the assessment of services constituting solutions, the effects of which are intangible products, along with a detailed assessment algorithm were presented in the publication [39].

The degree of the maturity of implementation solutions of the Strategic Programme (including selected sample solutions) was rated six times at half-yearly intervals at various stages of their development. Examples of assessment "screenshots" of SDW for selected solutions are presented in Figure 2.

The selected solutions, according to the assessment of the experts, were in the early stages of advancement in 2011: the system at level 1, micro-composite at 4, and devices and technology at 3.

With the progress of research and development, in 2012, those solutions reached the following levels, respectively: S and T – 3, that is the level of analytical and experimental verification, M – 7th level, a prototype status verified in real operating conditions and readiness for initial production on a small scale, solution U – 5th level, that is experimental model tested in operating, similar to real-life conditions.

The relatively small increase of S and T solutions during this period was due to the high degree of difficulty of the work related to the development of the model inspection scheme (S) and an experimental model of technology components (T). In the first quarter of 2013, S and T solutions reached level 4 (failing to reach level 5 was related to the criteria: testing the operation of the experimental model in conditions similar-to-life conditions, lack of project documentation, lack of risk analysis and management programme or arrangements with the end–user with regard to structural and functional parameters).

In the third stage of evaluation, the micro-composite (M) reached the eighth level, namely, readiness to implement in full-scale production. Having failed to meet the criteria in carrying out the integration of laboratory model, the verifying of the interaction of technology components, and verifying their compatibility, solution (T) remained at the fourth level.

For U solution, remaining at level 5 was decided by the failure to meet criteria, first and foremost, for creating the programme of risk analysis and risk management, the testing and verification of individual features and modules, testing the algorithms of the processor platform with parameters corresponding to the requirements, arranging with the end-user the constructional and functional parameters, and the development of design documentation for the manufacture of prototype.

Fig. 2. Screenshots with solutions description evaluated by the SDW method

In the subsequent stages of evaluation, solutions S and U reached levels 7 and 8, then 8 and 9 – levels of implementation readiness, during which the review was carried out for operational research prototypes in real conditions of use. Technology (T) eventually reached level 8. Micro-composite (M), with the last evaluation indicates level 9, i.e. the last stage of the verification phase, after the certification tests confirming the quality of the product, has been implemented in 38 manufacturing enterprises.

For system (S) and device (U), it was necessary to eliminate errors and faults in the prototype version, and to carry out certification procedures, after which both projects concluded in industrial implementation. The model implementation of the technology (T) was also performed. The results of subsequent evaluations of the selected solutions are presented in Figure 3, where the boundaries of the column charts indicate the gradually increasing level of implementation maturity.

Monitoring the status of the implementation of the established schedules and analysing assessment sheets and the results in the subsequent stages of evaluation enabled the identification of direct causes of the difficulties of subsequent tasks at the operational level, and consequently, their modification and fulfilling the minimum of 80% of the criteria that are assigned to a given level.

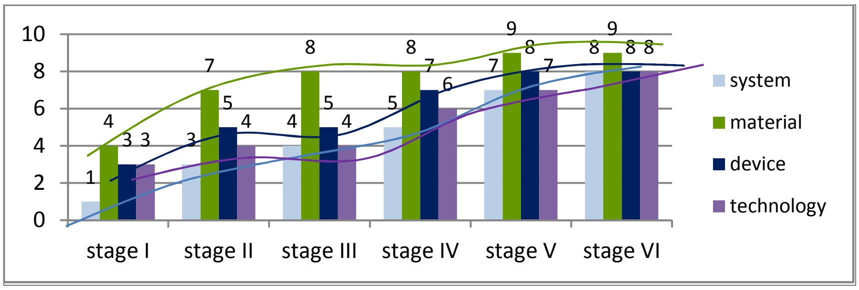

Fig. 3. The results of the six stages of the SDW evaluation of the four selected solutions developed in the Strategic Programme

The commercial potential of four selected solutions was evaluated five times in the half-yearly intervals. The results of the evaluations have been recorded in the database of the program (Fig. 4).

The analysis of the results indicated that two of the four analysed solutions already at the initial stage was characterised by low (solution M) and very low (solution S) commercial potential of respectively 45% and 39%. Technology (T) has reached the average commercial potential (55%). The device (U) obtained a high commercial potential (66%) due to its high technological level, a high level of functionality and innovation in relation to other existing solutions on the market, and a high level of market demand for a solution. In the subsequent stages of evaluation, together with an increase of work progress, there was a significant increase in the commercial potential for micro-composite (M) and technology (T) to the level of 73%. In the scale of commercial potential, achieving the set maximum level of 70% indicates high chances of commercializing the solution. The high result of commercial potential level for (M) and (T) was confirmed and verified by the market, with high market demand and the high demand for the solution.

Fig. 4. The screenshots of assessment sheets for solutions rated by PK method

In subsequent evaluations, the level of commercial potential for system (S) increased steadily, reaching 70% of the value in the last study (high level).

The results of subsequent evaluations of the selected solutions are presented in Figure 5.

A significant part of the innovative solutions developed within the Strategic Programme is single specialized solutions (often unique) of a non-repeatable or repeatable character. The former, developed to order for a specific client and in accordance with the adopted formula where their commercial potential is not tested, has a market potential of 100%. The second category of individual, specialized innovative solutions are the repeatable solutions, which are of interest to a wider range of receipts; the commercial potential of this group of solutions is subject to assessment [40].

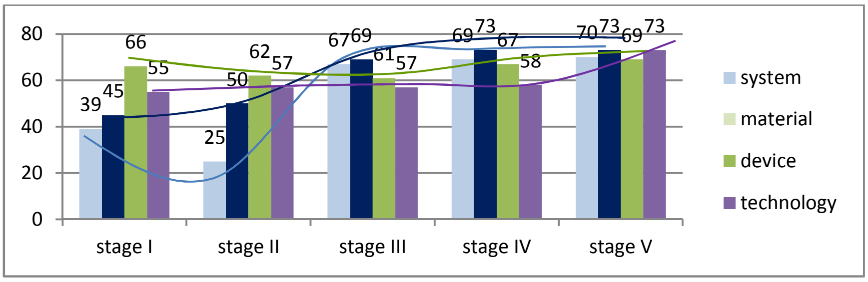

Fig. 5. The results of the five stages of commercial potential assessment of the four selected solutions developed in the Strategic Programme

The selected four solutions are assessed in terms of their level of innovation (PI assessment). However, significant modifications made to the methodology for evaluating PI make a comparison of all four evaluation results untenable. The results of the last two stages of the PI assessment indicate that innovation of T solutions increased from medium to high, solutions S and U declined slightly within the medium-level, while M maintained the same level (medium); in the last case, new areas of application were suggested allowing further development, which is a recommended strategy in creating competitive advantage.

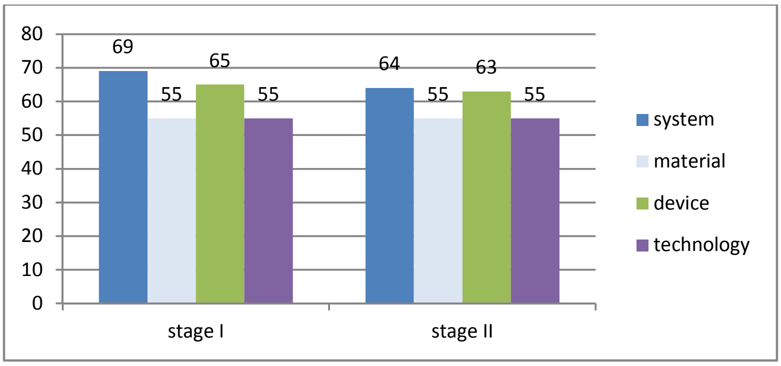

Fig. 6. The results of the two stages of innovation assessment of the four selected solutions developed within the Strategic Programme

When monitoring a large number of projects, for example, those carried out within the framework of the strategic programmes, important information about the overall progress of the work can be obtained based on the total analysis of the assessment results. The Excel Package helped to generate statistics showing the implementation and commercial potential of solutions, either globally or divided into thematic groups and categories of solutions, including the timeframe in the analysis indicated trends of observed changes. The summary results of the implementation and commercial potential carried out for 173 solutions of the Strategic Programme (SDW assessment at six stages of implementation, PK assessment at five stages of implementation) is shown in Figs. 6 and 7.

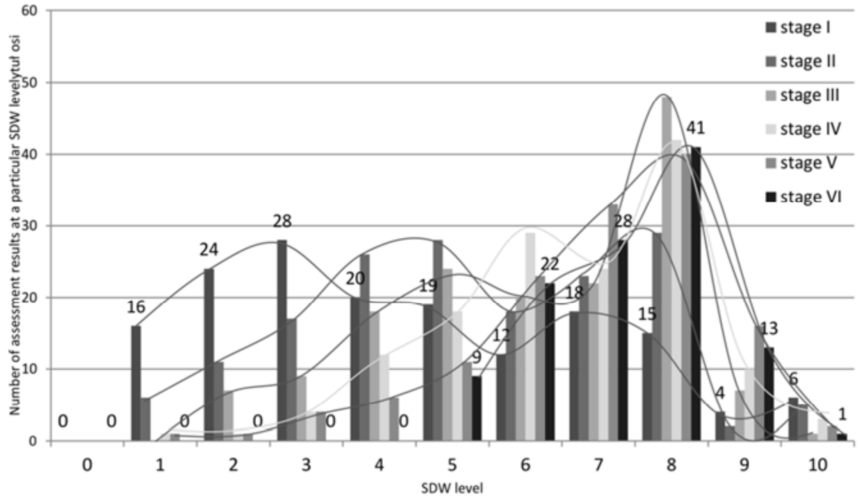

Fig. 7. The results of the six stages of the SDW assessment for 173 solutions that are the result of the Strategic Programme

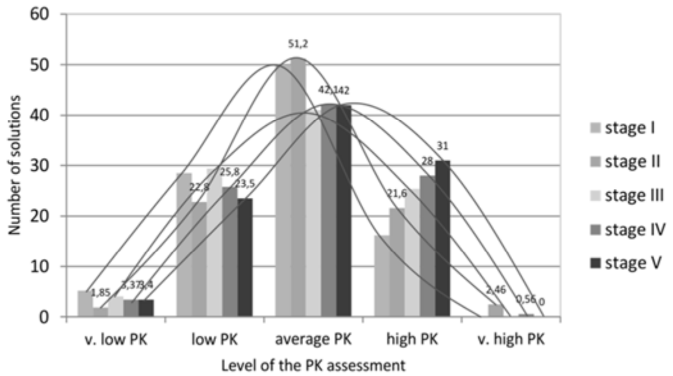

Fig. 8. The results of the five stages of the PK assessment for 173 solutions that are the result of the Strategic Programme

Based on the analysis of the results of assessment summaries of developed solutions, substantive conclusions can be formulated and appropriate decisions made in order to ensure high efficiency of the work carried out. The column bars shown in the global approach indicate the prevailing levels of advancement ranges of the developed solutions. The results of the subsequent stages of the evaluation point to the increasing share of solutions with a higher level of implementation maturity, and an increase during the periods between the assessments of solutions with a higher commercial potential.

The software system designed and constructed to support the developed, integrated methods for assessing implementation maturity, commercial potential, and innovation of engineering solutions is supported by an Internet application.

The system is divided into modules to assess SDW, PK, and PI that are expandable with other modules, for example, a module that takes into account environmental aspects, or the risk of implementing innovative solutions, or aspects of the social environment [41]. Each module allows creating multiple assessments of the same product (multi-stage assessments), and also exporting assessment sheets and aggregate results to external files in PDF format. The access to the system is authorized, with various levels of permission for users.

The functioning of the system has been tested both in the development phase of the system, as well as practically, while carrying out evaluations of innovative solutions of the Strategic Programme and the assessments outsourced by external entities. As a result of the tests, necessary modifications were introduced designed to increase the functionality of the system. As part of the testing system, verification was also conducted for assessment methods, which included, among others, the efficiency of the developed methods in applications for designated categories of solutions, the adequacy of the criteria for the assessment of individual modules, and the choice of weights for the individual criteria.

The flexible structure of the software allows modifications of the system and its adaptation to specific applications.

Conclusions

The developed comprehensive solution in the form of methods of assessing the degree of implementation maturity SDW, commercial potential PK, executive procedures, and information system, is a tool to assist the transformation of knowledge and the transfer of technology, within the framework of the measures taken for the improvement of competitiveness and innovation economy, through more effective use of the results of scientific research.

The assessment methods can be used at different levels of the formation of innovative solutions, from the planning of research and development and developing the concept of a solution, to a detailed application in the assessment of innovative products at various stages of their completion. These methods have the typical nature of an application and can be used (as a complex or singly) in the systems for the development and implementation of the research results into practice, primarily to evaluate the maturity of technologies and new products at universities, institutes of scientific research, and the evaluation of the implementation of development projects in the industry. These methods provide a means for in-depth analyses of the progress of research and development projects and their degree of adaptation for practical applications, thus substantially reducing the risk of failure in implementing and commercializing of innovative solutions. The developed solution is an important element of the evaluation of the strategic research programmes in the ITeE – PIB in Radom. Due to its versatility, it can find broad applications in results assessment of research work and their readiness for application in the economy. The flexible structure of the software allows modifications of the system and its adaptation to specific applications. This is confirmed by examples of external implementation methods, including small and medium businesses (e.g. the SDW study of the IT system *Xerius* dedicated for business management) or in Bełchatowsko-Kleszczowski Industry – Technology Park. Many evaluation procedures have been carried out with the use of the developed system.

The authors foresee its further improvement and a development of optional solutions for other categories of research results, including educational projects. A risk assessment module of innovative ventures is in the process of development.

Scientific work executed within the Strategic Programme "Innovative Systems of Technical Support for Sustainable Development of Economy" within Innovative Economy Operational Programme.

Bibliography

1. Karczewska M., Materzok, J., Skonieczny J.: Współczesne narzędzia oceny technologii. Materiały konferencyjne „Innowacje w zarządzaniu i inżynierii produkcji", Zakopane 2011.
2. Założenia polityki naukowej i naukowo-technicznej i innowacyjnej państwa do 2020 r., Ministerstwo Nauki i Informatyzacji, Warszawa 2004.
3. Mazurkiewicz A. (red.): Prognozy rozwoju kierunków badań, Radom 2008.
4. Strategia Rozwoju Kraju 2007–2015, Ministerstwo Rozwoju Regionalnego, Warszawa, listopad 2006.
5. Strategia Rozwoju Nauki w Polsce do 2015 r. Warszawa, lipiec 2008.
6. Program Operacyjny Inteligentny Rozwój, 2014–2020, Ministerstwo Infrastruktury, Warszawa 2014.
7. Raport „Polska 2030. Wyzwania rozwojowe. Kancelaria Prezesa Rady Ministrów, lipiec 2009, http://www.wrpo.wielkopolskie.pl/zalaczniki1/2012/Raport_Polska_2030_wyzwania_rozwojowe.pdf
8. Raport 'Polska 2030. Trzecia fala nowoczesności. Długookresowa strategia rozwoju kraju. Ministerstwo Administracji i Cyfryzacji. Warszawa, 9 listopada 2012 r.

9. Mazurkiewicz A., Poteralska B.: Budowa scenariuszy rozwoju Polski do 2020 w Polu Badawczym „Zrównoważony Rozwój Polski”. W: M. Kleiber (red.) Wyniki Narodowego Programu Foresight „Polska 2020”. Ministerstwo Nauki i Szkolnictwa Wyższego, Warszawa, czerwiec 2009.
10. Łopacińska L.: Ponadstandardowe metody ewaluacji strategicznych programów badawczych. Problemy Eksploatacji. No 3/2011.
11. Gwarda-Gruszczyńska E.: Quicklook™ jako metoda oceny potencjału komercyjnego innowacji i technologii Acta Universitatis Lodziensis Folia Oeconomica 234, 2010.
12. Narodowe Strategiczne Ramy Odniesienia na lata 2007–2013; Program Operacyjny „Innowacyjna Gospodarka”. Ministerstwo Rozwoju Regionalnego, Warsaw 2006.
13. Krajowy Program Badań Naukowych i Prac Rozwojowych (KPBNiPR); Kierunki zwiększania innowacyjności gospodarki na lata 2007–2013; Założenia polityki naukowej i naukowo-technicznej i innowacyjnej państwa do 2020 r.
14. Belina B.: Strategiczne programowanie rozwoju innowacyjności i konkurencyjności polskiej gospodarki. Problemy Eksploatacji no 2/2008. ITeE – PIB, Radom, 2008.
15. Program „Horyzont 2020 – program ramowy w zakresie badań naukowych i innowacji”; Rozporządzenie Parlamentu Europejskiego i Rady ustanawiające program ramowy w zakresie badań naukowych i innowacji (2014––2020); Brussels, 30.11.2011.
16. Bandarian R.: Evaluation of commercial potential of a new technology at the early stage of development with fuzzy logic. Journal of Technology Management & Innovation, Vol. 2, no 4, 2007.
17. Balachandra R., Friar J.: Factors for success in R&D projects and new product innovation: a contextual framework, IEEE Transactions on Engineering Management, Vol. 44, 1997.
18. Jain R.K., Martyniuk A.O., Harris M.M., Niemann R.E., Woldman K.: Evaluating the commercial potential of emerging technologies. International Journal Technology Transfer and Commercialization, Vol. 2, no 1, 2003.
19. Martyniuk A.O., Jain R.K., Stone H.J.: Critical success factors and barriers to technology transfer: case studies and implications. International Journal Technology Transfer and Commercialization, Vol. 2, no 3, 2003.
20. Cooper R.G.: The dimensions of industrial new product success and failure. Journal of Marketing, Vol. 43, 1979.
21. Mankins J.C.: Technology Readiness Levels: A White Paper. Office of Space Access and Technology, NASA, April 6 1995.
22. Defence Research and Development Canada “A Technology Maturity Measurement System for the Department of National Defence. The TML System”. Contract Report DRDC Atlantic CR 2005–279; 2006.

23. Mankins J.C.: Technology readiness and risk assessments: A new approach. Acta Astronautica, 2009, v. 65, Issue 9–10, pp. 1208–1215.
24. Department of Homeland Security Science and Technology Readiness Level Calculator. Final Report. Homeland Security Institute, 2009.
25. Determining the Lines of System Maturity, System Readiness and Capability Readiness in the System Development Lifecycle. Conference Paper. CSER 2009.
26. Mankins J. C.: Approaches to strategic research and technology (R&T) analysis and road mapping. Acta Astronautica, 2002, v. 51, Issue 1–9, pp. 3–21.
27. UK Environmental Transformation Fund Strategy, 2008. http://www.berr.gov.uk/files/file47575.pdf
28. El-Genk M.S.: Energy conversion technologies for advanced radioisotope and nuclear reactor power systems for future planetary exploration. Thermoelectrics, 2002. Proceedings ICT apos; 02. Twenty-First International Conference. Issue 25–29. 2002, pp. 375–380.
29. Lucheng H., Yafei L., Feifei W.: A Conceptual Framework of Identifying the Commercialization Potential of Emerging Technology Based on Subjective Judgment and Objective Fact. Management Science and Engineering, Portland, 2007.
30. Ji-wu W., Lu-cheng H., Li jian, Wen-guang W.: An Integrated Method for Commercialization Potential Evaluation of Emerging Technology Based on TFA. Management Science and Engineering, Portland, 2007 Założenia polityki naukowej i naukowo-technicznej i innowacyjnej państwa do 2020 r., Ministerstwo Nauki i Informatyzacji, Warszawa 2004.
31. Hongjun W., Xiaofei Z., Rui L., Guiwu W.: An Approach to Potential Evaluation of Emerging Technology Commercialization with Uncertain Linguistic Information. Journal of Convergence Information Technology, No 7/2007.
32. Rui L., Xiaofei Z., Hongjun W., Guiwu W.: Model for Potential Evaluation of Emerging Technology Commercialization with Hesitant Fuzzy Information. Journal of Convergence Information Technology, No 4/2007.
33. Raport nr RC/7/I.3.1/PS z realizacji zadania badawczego pn. „Metody analizy potencjału wdrożeniowego i komercyjnego innowacyjnego produktu technicznego lub procesu technologicznego" realizowanego w ITeE–PIB w ramach Programu Strategicznego pn. "Innovative Systems of Technical Support for Sustainable Development."
34. Mazurkiewicz A., Karsznia W., Giesko T., Belina B.: Metodyka oceny stopnia dojrzałości wdrożeniowej innowacji technicznych. Problemy Eksploatacji 1/2010, s. 5–20.
35. Mazurkiewicz A., Belina B., Giesko T., Karsznia W.: Operational system for the assessment of the implementation maturity level of technical innovations. Problemy Eksploatacji 4/2013, s. 79–92.

36. Belina B., Giesko T., Łopacińska L., Walasik M.: Setting of criteria in the commercial potential assessment method of innovative technological solutions. Maintenance Problems, 2/2013, pp. 221–234.
37. Belina B., Łopacińska L., Karsznia W.: Commercial potential oriented evalutaion of innovative products. Maintenance Problems, 4/2012, pp. 23–32.
38. Belina B., Karsznia W.: System supporting the assessment of the degree of implementation maturity of technical innovations. Problemy Eksploatacji 3/2013, s. 87–102.
39. Mazurkiewicz A., Karsznia W., Giesko T., Belina B.: System operacyjny oceny stopnia dojrzałości wdrożeniowej innowacyjnych rozwiązań w zakresie usług. Problemy Eksploatacji 3/2011, s. 61–73.
40. Walaszczyk L.: Model ewaluacji programów badawczych w obszarze innowacji technicznych. Praca doktorska. Politechnika Warszawska 2015, s. 277–278
41. Belina B., Mazurkiewicz A., Giesko T., Karsznia W.: Tracking and predicting solution evelopment in r&d projects using a complex assessment method (artykuł złożony do opublikowania).

Praktyczne zastosowanie metody oceny stopnia dojrzałości wdrożeniowej oraz potencjału komercyjnego w realizacji projektów R&D

Słowa kluczowe

Stopień Dojrzałości Wdrożeniowej SDW, potencjał komercyjny, innowacje techniczne, transfer technologii.

Streszczenie

Kompleksowa wieloaspektowa ocena realizacji projektów R&D oraz potencjału aplikacyjnego uzyskanych wyników powinny odgrywać decydującą rolę w odniesieniu do zasadności kontynuacji podjętych zadań badawczych oraz praktycznego wykorzystania ich rezultatów. Dlatego istotne jest zastosowanie w sterowaniu tymi projektami odpowiednich, skutecznych narzędzi pozwalających na ocenę stanu zaawansowania prac oraz urealnienie szans komercjalizacji.

W artykule opisano praktyczne wykorzystanie autorskiej metody oceny dojrzałości wdrożeniowej, potencjału komercyjnego oraz innowacyjności do wspomagania zarządzania realizacją projektu na przykładzie wybranych, innowacyjnych rozwiązań stanowiących rezultat Programu Strategicznego pn. „Innowacyjne systemy wspomagania technicznego zrównoważonego rozwoju gospodarki”. Zaprezentowano wyniki ocen oraz ich interpretację umożliwiającą podjęcie właściwych działań korygujących. Przykłady zastosowań metod oceny stopnia dojrzałości wdrożeniowej (SDW), oceny potencjału komercyjnego (PK), a także potencjału innowacyjnego zaprezentowane w artykule potwierdzają wysoką przydatność proponowanej metodyki w ewaluacji projektów R&B do racjonalizacji procesów rozwoju produktu. Praktyczna weryfikacja metod oceny innowacyjnych rozwiązań pozwoliła także wyznaczyć potencjalne kierunki rozwoju samych metod i autorskiego systemu kompleksowej oceny skuteczności i efektywności realizacji projektów badawczych i innowacyjnych produktów stanowiących ich wynik.

INNOVATIVE ECONOMY
NATIONAL COHESION STRATEGY
INSTITUTE FOR SUSTAINABLE TECHNOLOGIES
NATIONAL RESEARCH INSTITUTE IN RADOM
EUROPEAN UNION
EUROPEAN REGIONAL DEVELOPMENT FUND

Project co-financed by the European Union from the European Regional Development Fund

Ludmiła WALASZCZYK, Adam MAZURKIEWICZ
Institute for Sustainable Technologies – National Research Institute, Radom
ludmila.walaszczyk@itee.radom.pl
adam.mazurkiewicz@itee.radom.pl

INTEGRATED MANAGEMENT AND EVALUATION SYSTEM FOR STRATEGIC RESEARCH PROGRAMMES

Key words

Evaluation, management system, strategic research programme, evaluation system, evaluation methodology.

Summary

The development of the knowledge-based economy requires undertaking many initiatives that contribute to the increase in the competitiveness of entreprises through the development and the implementation of innovative products. Such initiatives include, among others, strategic research programmes, which are characterised by a great number of levels, a multitude of objectives and results, and high budgets. It causes that the subject of strategic research programmes must be generated or fully accepted by national authorities responsible for this sphere. Therefore, it is necessary to develop a complex and effectiveness management and evaluation system dedicated to strategic research programmes. The authors present the concept and the structure of the system, and particular attention is paid to the evaluation, which enables systematic improvement of the effectiveness and the efficiency of a strategic research programme and research projects undertaken within such a programme.

The system designed is currently verified within *Innovative Systems of Technical Support for Sustainable Development of Economy* Strategic Programme executed in the Institute for Sustainable Technologies – National Research Institute in Radom (Poland).

Introduction

The R&D management is defined in the literature as "the use and the application of knowledge, skills, tools and techniques in the management area in the context of fulfilling the objectives in order the execution of the programme to contribute to the improvement of the value of the organisation in a measurable way" [3]. Moreover, the R&D management is "the process, taking into consideration in the organisation, for the achievement of profits and avoiding risk and loss" [3]. This definition does not consider the nature of management of a strategic programme, which is characterising by interdisciplinary character and high budget. A strategic research programme results from scientific and innovative policy of a country. It is executed in a long-term perspective, and it aims at the improvement of the competitiveness of a national economy through the development of innovative products and services and the execution of R&D activities enabling ways to solve scientific, technical, and social problems [28]. The important elements of a strategic research programme include the identification of the projects and the measurement of a programme results in order to ensure the greatest benefits for the organisation. Therefore, it is necessary to pay special attention to the evaluation understood as the study on the programme characteristics, with assessment criteria taken into consideration in order to analyse and interpret the achieved results and to make decisions on the launch of the programme, the way of its execution, the continuation of the whole programme or its individual elements, or termination [28].

1. Management system for strategic research programmes

Strategic programme management is a part of the project management area. According to the methodology designed by the American Project Management Institute [22], there are the following phases in the project or the programme management: launch, planning, execution, termination, and control during the project execution.

According to the *European Guide to the Evaluation of Socio-Economic Development* [11], the project or the programme management process includes the following phases: programming, identification, formulation, *ex-ante* evaluation, execution and monitoring, project termination, and *ex-post* evaluation of the final results. These phases are also considered by other authors, among others, by Mingus [20], Lewis [17], Kerzner [15], and Kanda [13].

The state-of-the-art concerning management systems for strategic research programmes[1] enabled the identification of the following basic management

---

[1] National Program of Research Infrastructure (Denmark), Advanced Technologies for Energy Acquisition (Poland), GRAF-TECH (Poland), Core Research for Evolutional Science and Technology (Japan), Industrial R&D Program (Korea), Small Business Innovation Research (United States), Solar Chemistry/Hydrogen (Switzerland),Telecommunications Electronics

phases: programming, planning, formulation, *ex-ante* evaluation, execution, and closure (Fig. 1).

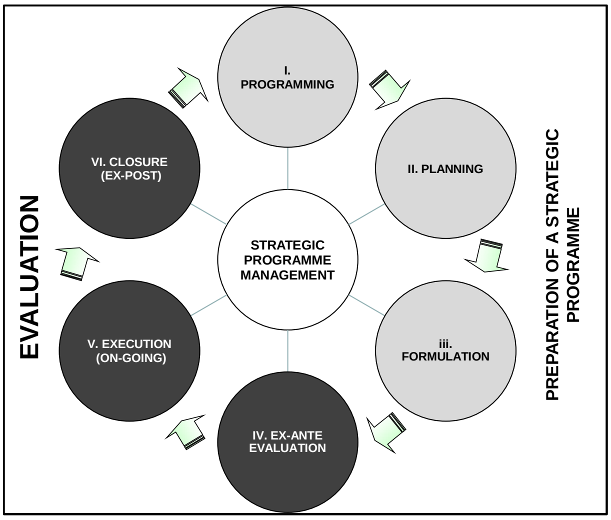

Fig. 1. The identified phases of a strategic research programme management

These phases form *the life cycle of a strategic research programme.* The phases enable the identification of the launch and the closure of a programme as well as indicating the timeframe needed for the execution of individual research tasks within a programme:

- Programming (detailed analysis of strategic documents at national or European levels, analysis of research directions, which are interesting for those supporting programme funding);
- Planning (identification of needs, which are the basis for the launch of a new strategic programme, analysis of potential problems, detailed description of programme objectives, preliminary estimation of the timeframe and the budget of a programme, identification of the results planned to be achieved);
- Formulation (analysis of the programme feasibility, design of the plan, how to use the results in a long-term perspective, detailed description of elements designed in the planning phase);
- *Ex-ante* evaluation of the proposal submitted by potential beneficiary;

(Finland), Exploratory Research for Advanced Technology (Japan), Danish Strategic Environmental Research Program, Systems Technology and Methodology for Development of Complex Technical Systems (Sweden), PINTA – Clear Surfaces (Finland), Superfund Innovative Technology Evaluation Program (United States) and Nutek-Vinnova Programme in Complex Technical Systems (Sweden).

- Execution (leadership of research teams, monitoring and *on-going* evaluation of the programme); and,
- Closure (formal closure of the programme and *ex-post* evaluation; the use of the evaluation results for the launch of future strategic research programme).

The most important conclusions coming from the analysis are the following:

1. The management phases of a strategic research programme, which were identified in the literature, are characterised by different level of detail. It means, for instance, that, in analysed strategic research programmes, the planning phase is very expanded; whereas, the closure phase is very general or even omitted.
2. *Ex-ante* evaluation phase is usually of an external character, which means that it is conducted by the experts, who are not engaged in the execution of a strategic research programme. In most cases, the internal evaluation was not identified, but it seems to be an important element of the management, as it contribues to the decrease of the risk of the rejection of the programme proposal.
3. The closure phase does not concern the formal closure of a programme but mainly the *ex-post* evaluation of the achieved results.
4. The phase of analysis and the use of the results aiming at the launch of a new programme were not identified.

All management phases for a strategic research programme are significant; however, as the analysis shows, the evaluation is particularly important, because it can be perceived in three management phases: preliminary phase (*ex-ante* evaluation), execution phase, and closure phase.

2. Evaluation of a strategic research programme

The occurrence of the evaluation in three management phases comes from its objectives: cognitive and instrumental. The cognitive objective enables the detailed presentation of a programme rules, the mechanisms, and the use of gained knowledge to conduct scientific research within a topic relevant for a strategic programme. The instrumental objective aims at the use of the evaluation results in order to make decisions related to the programmes executed [30].

The evaluation is conducted with the use of commonly accepted models, criteria, and research methods.

The literature review conducted revealed four (4) groups of evaluation models. The groups and models emerging from the aforementioned analysis are as follows:

1) Models directed at facilitating the effectiveness of R&D tasks undertaken within research programmes, or aimed at increasing staff responsibilities for the tasks realised: decision model [8], client-centered model [24], accreditation model [26];
2) Quasi-evaluation models (directed at finding answers to questions occurring at the time of the evaluation, and they use traditional research methods):

objective-based model [27], accountability model [16], outcome evaluation as value-added assessment model [23], performance testing model [26], experimental model [5], management information model [7], cost-benefit analysis [14], clarification hearing model [29], case study model [4], criticism and connoisseurship model [9], theory–driven model [10], and mixed-methods studies [26];
3) Social models (assuming that, apart from the experts and the project management board, beneficiaries of research projects should also participate in their evaluation, because they are the ones to use technologies developed within research programmes in the future): responsive & participatory model [25], constructivism model [26], deliberative and democratic model [12], and, utilisation-focused evaluation model [21];
4) Pseudo-evaluation models (concentrating on the positive effects of the programme and neglect any negative aspects of its realisation. They are mainly used by institutions that want to attract beneficiaries and persuade them to participate in the programme or to purchase its material results): public relations model [6], and politically controlled model [26].

Moreover, a state-of-the-art study on evaluation criteria and methods used in strategic research programmes was conducted. The results show that, in most cases, the evaluation only considers the criteria of relevance and effectiveness. The cost-efficiency was verified sporadically. The authors also identified other evaluation criteria, e.g., the impact and the usefulness.

In regarding these methods, mainly document analysis was used. In some cases, detailed documents were analysed, which were the base for the launch of initiatives, among others, in the case of programmes executed by the European Union institutions. The structured and non-structured interviews with beneficiaries and other organs interested in the use of the results were identified. In cases in which the number of beneficiaries was large, the authors also identified surveys – often conducted through Internet. The methods, which were identified more seldom, included workshops during which preliminary or final results were discussed. Some evaluations also included case studies.

The programmes, which were composed of some individual research projects, were analysed in a specific way. Such evaluations contained the analyses of individual projects according to selected criteria, which were later on used in the evaluation of the strategic research programme as a whole. However, such an approach was not used very often.

The identified evaluation models do not make it possible to evaluate a strategic research programme in a complex way on its different structural levels (research project level, thematic group level, or the complete strategic research programme level) and only its selected elements. Therefore, after the indept literature analysis, the authors decided to design a complex evaluation system composed of evaluation methodologies and methods, which can be applied from the launch of a strategic programme until its closure as well as some years after the closure.

3. Evaluation system for a strategic research programme

The basic elements of a proposed evaluation system for a strategic research programme include the following [28] (Fig. 2):

– Methodologies enabling the evaluation of a strategic research programme on its different structural levels;
– Standard methods used on each structural level of a strategic programme; and,
– Non-standard methods used for the assessment of products being the results of individual research projects in the area of technical innovation.

The authors designed the key methodologies (3) and the supplementary methodology (1). The key methodologies enable the evaluation of a programme on all of its structural levels and include the following: the assessment methodology for technical products, the evaluation methodology for research projects, and the evaluation and optimisation methodology for the strategic programme as a whole. The supplementary methodology supports the evaluation process and aims at the generation of future research projects and directions.

The assessment methodology for innovative technical products enables the assessment of material results on each stage of their development, which are directed to the implementation into economy or commercialisation. The results of the methodology are later used in the evaluation of research projects.

The evaluation methodology for research projects enables the conduction of formal and content-related evaluation of the project. The formal evaluation aims at the assessment of legal and organisational issues of a research project, among others, the relevance of the project subject to the legal rules and the priorities of national development, the level of the achievement of material and non-material results, and the budget level. The aim of the content-related evaluation is to assess scientific, technical, and application aspects, which are significant for the organisation commissioning the evaluation. The evaluation methodology for research projects is a tool supporting decision making on the continuation or termination of the individual product or project.

The evaluation and optimisation methodology for a strategic research programme is based on the results of the assessment methodology for innovative technical products and the evaluation methodology for research projects. It supports the decision making process on the continuation of works characterising by the highest level of the effectiveness of the research projects and thematic groups or on the continuation or termination of projects or groups characterising the lowest level of the effectiveness.

The supplementary methodology of generating future research projects and directions enables the selection of such directions for the needs of the launch of new projects and programmes, mainly based on the results of the assessment of technical products.

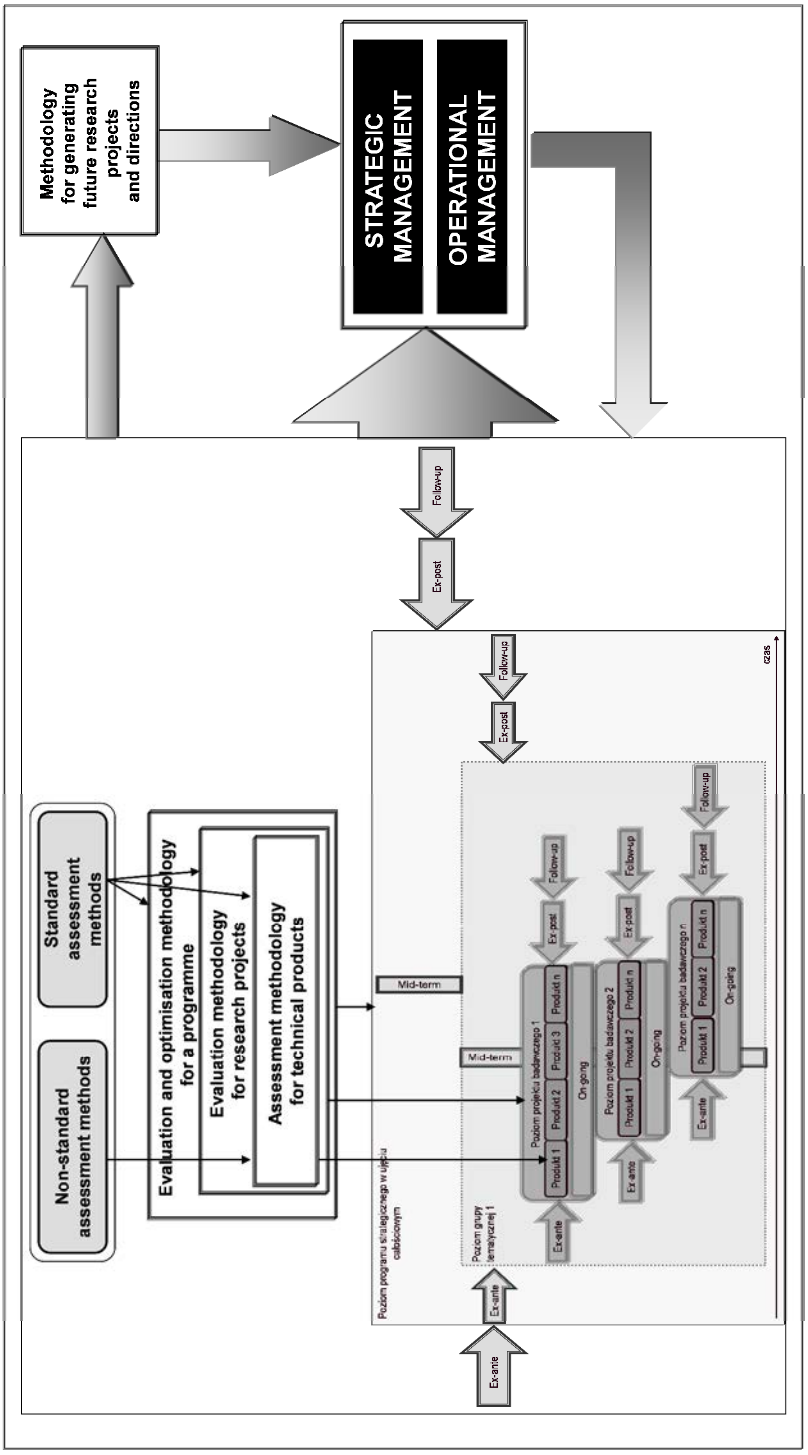

Fig. 2. Evaluation system for strategic research programme in the area of technical innovations

The methodologies designed assume the use of standard methods, commonly used in the evaluation of research projects executed in different thematic areas as well as original non-standard methods for the assessment of technical products, which were developed as a result of the execution of research projects (the technological readiness [19], the risk implementation [18], the commercial potential [1], the innovativeness level [2] assessment methods).

In order to confirm the correctness of the system operation, its verification on the current executed *Innovative Systems of Technical Support for Sustainable Development of Economy* strategic programme was performed. The evaluation of 165 innovative technical products and 30 research projects were conducted. The application of the designed system enabled the identification of technical products and research projects, which are "non-perspective" based on the set of selected assessment criteria, among others, because of low commercial potential, which makes the products impossible to be implemented into economy and "perspective" tasks, which should be continued. Moreover, the results achieved in the evaluation process enabled the researchers to identify and to analyse research directions, which should be the basis for the launch of a new strategic research programme or independent research projects [28].

Conclusions

The designed evaluation system for strategic research programmes in the area of technical products, as an important element of strategic programme management, is an instrument supporting management in a research organisation. The application of designed evaluation methodologies enables the assessment of such types of programmes on different structural levels in selected timeframes of a programme. The evaluation results are going to be used during the next evaluations in order to analyse tendencies and changes, which can take place during its execution. Moreover, considering selected assessment criteria, the evaluation results are going to be used to indicate the subject of new research projects and programmes.

The use of a proposed system enables the conduction of a complex evaluation of a strategic research programme.

Scientific work executed within the Strategic Programme "Innovative Systems of Technical Support for Sustainable Development of Economy" within Innovative Economy Operational Programme.

Literature

1. Belina B., Łopacińska L., Karsznia W.: Commercial Potential Oriented Evaluation of Innovative Products. Maintenance Problems, No 4/2012.

2. Belina B., Łopacińska L., Walasik M., Giesko T.: Setting of Criteria in the Commercial Potential Assessment Method of Innovative Technological Solutions, Maintenance Problems, No 2/2013.
3. Callahan K.R., Brooks L.M.: Essentials of Strategic Project Management. John Wiley & Sons, 2004.
4. Campbell D.T.: Degrees of Freedom and the Case Study, Comparative Political Studies, No 8, 1975.
5. Campbell D.T., Stanley J.C.: Experimental and Quasi–experimental Designs for Research on Teaching [in:] N.L. Gage (ed.), Handbook of Research on Training, Rand McNally, Chicago 1963.
6. Clancy T., Horner C.: Every Man a Tiger, G.P. Putnam's Sons, New York 1999.
7. Cook D.L.: Program Evaluation and Review Techniques, Applications in Education, U.S. Office of Education Cooperative Monograph, Washington 1966.
8. Cronbach L.J.: Course Improvement Through Evaluation, Teachers College Record, Vol. 64, 1963.
9. Eisner E.W.: The Perceptive Eye: Toward a Reformation of Educational Evaluation. American Educational Research Association, Washington 1975.
10. Glaser B.G., Strauss A.L.: The Discovery of Grounded Theory, Aldine, Chicago 1967.
11. Guide to the Evaluation of Socio-Economic Development, EVALSED 2013, http://ec.europa.eu/regional_policy/sources/docgener/evaluation/guide/guide_evalsed.pdf [access: 24.02.2015].
12. House E.R., Howe K.R.: Deliberative Democratic Evaluation in Practice, University of Colorado, Boulder 1998.
13. Kanda A.: Project Management. A Life Cycle Approach. New Delhi 2011.
14. Kee J.E.: Benefit-Cost Analysis in Program Evaluation, [in:] J.S. Wholey, H.P. Hatry, K.E. Newcomer, Handbook of Practical Program Evaluation, Jossey-Bass, San Francisco 1995.
15. Kerzner H.: Project Management. A Systems Approach to Planning, Scheduling and Controlling. John Wiley & Sons, New Jersey 2009.
16. Lessinger L.M.: Every Kid a Winner: Accountability in Education, Simon and Schuster, New York 1970.
17. Lewis J.: Fundamentals of Project Management. New York 2007.
18. Łopacińska L.: Ponadstandardowe Metody EwaluacjI Strategicznych Programów Badawczych w Obszarze Innowacji Technicznych. Problemy Eksploatacji, No 3/2011.
19. Mazurkiewicz A., Karsznia W., Giesko T., Belina B.: Metodyka Oceny Stopnia Dojrzałości Wdrożeniowej Innowacji Technicznych. Problemy Eksploatacji, No 1/2010.
20. Mingus N.: Zarządzanie Projektami, Wydawnictwo Helion, Gliwice 2002.

21. Patton M.Q.: Utilization-Focused Evaluation: the New Century Text (3rd ed.), Sage publications, Newbury Park 1997.
22. Project Management Institute http://www.pmi.org/ [access: 24.02.2015].
23. Sanders W.L., Horn S.P.: The Tennessee Value–Added Assessment System (TVAAS): Mixed Model Methodology in Educational Assessment, Journal of Personnel Evaluation in Education, No 8(3), 1994.
24. Scriven M.: Evaluation Perspectives and Procedures, [in:] W.J. Popham (ed.), Evaluation in Education: Current Applications, Berkeley, 1974.
25. Stake R.E.: The Countenance of Educational Evaluation, Teachers College Record, No 68, 1967.
26. Stufflebeam D.L.: Evaluation Models: Viewpoints on Education and Human Services Evaluation, Massachusetts 2000.
27. Tyler R.W.: General Statement on Evaluation, Journal of Educational Research, Vol. 35, 194.
28. Walaszczyk L.: Model Ewaluacji Programów Badawczych w Obszarze Innowacji Technicznych. Doctoral thesis under development. Politechnika Warszawska. Wydział Zarządzania 2015.
29. Wolf R.L.: Trial by Jury: a New Evaluation Method. Phi Delta Kappan, 1975, No 3(57).
30. Zysińska M.: Ewaluacja, monitorowanie i kontrola projektów europejskich [in:] M. Trocki, B. Grucza (ed.): Zarządzanie Projektem Europejskim. Polskie Wydawnictwo Ekonomiczne. Warszawa 2007.

Zintegrowany system zarządzania i ewaluacji strategicznych programów badawczych

Słowa kluczowe

Ewaluacja, system zarządzania, strategiczny program badawczy, system ewaluacji, metodyka ewaluacji.

Streszczenie

Rozwój gospodarki opartej na wiedzy wymaga podejmowania inicjatyw mających istotny wpływ na zwiększenie konkurencyjności przedsiębiorstw poprzez tworzenie i wdrażanie rozwiązań innowacyjnych. Do takich inicjatyw można zaliczyć między innymi strategiczne programy badawcze charakteryzujące się wielopoziomowością, mnogością celów oraz uzyskanych rezultatów i wysokim budżetem. Sprawia to, że problematyka strategicznych programów badawczych musi być generowana lub w pełni akceptowana przez odpowiedzialne za tę sferę struktury państwa. Dlatego też konieczne jest

opracowanie kompleksowego systemu zarządzania i ewaluacji w odniesieniu do tego typu programów.

Artykuł dotyczy zintegrowanego systemu zarządzania i ewaluacji dedykowanego strategicznym programom badawczym. Autorzy prezentują koncepcję oraz strukturę systemu, a szczególną uwagę poświęcają ewaluacji umożliwiającej systematyczną poprawę skuteczności i efektywności programu strategicznego oraz prowadzonych w jego ramach projektów badawczych.

Opracowany system zarządzania i ewaluacji jest obecnie weryfikowany w odniesieniu do Programu Strategicznego realizowanego w ITeE – PIB *Innowacyjne Systemy Wspomagania Technicznego Zrównoważonego Rozwoju Gospodarki*.