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Adam MAZURKIEWICZ
Institute for Sustainable Technologies – National Research Institute, Radom, Poland
adam.mazurkiewicz@itee.radom.pl

BARRIERS OF TECHNOLOGICAL INNOVATION DEVELOPMENT AND IMPLEMENTATION ENCOUNTERED BY R&D ORGANISATIONS

Key words: technology transfer barrier, R&D organisation, technological innovations.

Abstract: The application of innovations is acknowledged as a driver for economic and social development. However, the processes of technology development and transfer are affected by numerous barriers, which are understood as any kind of limitations that hamper the effective functioning of a system of the generation, execution, and transfer of innovative technologies, and, as a result, block co-operation between the R&D and enterprises in the implementation and commercialisation processes. The paper tackles the problems of barriers in the field of innovation activity encountered by R&D organisations in the course of their co-operation with industry. The author presents barriers observed at different levels: strategic, tactical, and operational ones. Against this background, the examples of barriers met in practice in the selected domains, surface engineering and optomechatronics, are presented. Technology transfer processes hampered by the influence of different types of barriers are real barriers encountered in practice by the author in his many-year involvement in co-operation with enterprises and the implementation of innovative research results into economic practice at a Polish research organisation (Institute for Sustainable Technologies – National Research Institute – ITeE – PIB). Finally, the author presents possible instruments of weakening or eliminating technology transfer barriers. One of the methods proposed is an application of an original IT tool developed at ITeE-PIB, which is called an "innovative project generator," gathering information on partners, possible projects and calls for proposals and possible barriers. It is an idea based on the assumption of the close cooperation of an R&D organisation with potential industrial partners consisting in gathering information about the research needs of the economic milieu and the suggested innovative undertakings.

Bariery i wyzwania instytucji B+R w obszarze rozwoju i wdrażania innowacji technologicznych

Słowa kluczowe: bariery transferu technologii, instytucja B+R, innowacje technologiczne.

Streszczenie: Innowacje uważane są za główny czynnik przyczyniający się do rozwoju gospodarczego i społecznego. Jednakże na procesy rozwoju technologii i ich transferu do gospodarki wpływają liczne bariery rozumiane jako ograniczenia utrudniające skuteczne funkcjonowanie systemu generowania, realizacji i transferu innowacyjnych technologii, a w rezultacie utrudniające procesy wdrażania i komercjalizacji innowacyjnych rozwiązań. Artykuł poświęcony jest problematyce barier w obszarze działalności innowacyjnej napotykanych przez instytucje badawczo-rozwojowe w trakcie współpracy z przemysłem. Zaprezentowano w nim bariery występujące na różnych poziomach zarządzania: strategicznym, taktycznym i operacyjnym. Na tym tle zostały przedstawione przykłady barier w praktyce w wybranych dziedzinach: inżynierii powierzchni i optomechatronice. Wskazano na rzeczywiste bariery transferu technologii, z którymi zetknął się autor w trakcie wieloletniej współpracy z przedsiębiorstwami i wdrażania innowacyjnych wyników prac badawczych do praktyki gospodarczej przez Instytut Technologii Eksploatacji – Państwowy Instytut Badawczy – ITeE – PIB. Ponadto zaprezentowano instrumenty, których zastosowanie umożliwia zmniejszenie znaczenia lub eliminację barier transferu technologii. Jeden z nich stanowi oryginalne narzędzie informatyczne pod nazwą „innowacyjny generator projektu" opracowane i wdrożone w ITeE – PIB, wykorzystywane do gromadzenia informacji o partnerach, potencjalnych projektach i konkursach na projekty oraz możliwych barierach rozwoju i wdrażania innowacji. Generator projektów stanowi ideę bazującą na ścisłej współpracy instytucji B+R z potencjalnymi partnerami przemysłowymi, polegającej na gromadzeniu informacji o potrzebach badawczych środowiska gospodarczego i proponowanych innowacyjnych przedsięwzięciach.

Introduction

Economic growth directly depends on the generation, development, and implementation of innovations. These processes are executed differently in various countries, regions, and organisations, but they all face significant barriers that need to be removed or overcome at the following levels: the strategic level including the R&D national or even transnational policy, the tactical level mainly regarding cooperation between scientific and business entities, and the operational level focused on solving particular R&D problems. Innovation-related matters are generated and solved by transnational corporations, small start-ups, as well as scientific and R&D organisations oriented towards commercialising both breakthrough and incremental solutions. The author devoted many years of his scientific and R&D activity to the theoretical and practical aspects of technology transfer and related barriers. As opposed to works of many researchers who mainly focused on the theory and drew conclusions based on literature review or surveys, this article gives an insight into the practical aspects of technology transfer. It presents the author's experience in science-business cooperation regarding advanced innovative solutions that were generated, developed, and brought to the market with the author's cooperation and whose path to actual implementation was hampered by numerous barriers.

1. State of the art

The transfer of innovations is affected by numerous barriers understood as any kind of limitations that hamper the effective functioning of a technology transfer system, and, as a result, disturb the co-operation of R&D organisations with enterprises in the implementation and commercialisation processes.

The topic of barriers concerning technology transfer, because of its importance for the economy, is a field of interest for numerous scholars and practitioners. The first studies on barriers to the successful movement of technologies from scientific organisations to industry can be found in the 1950s and 1960s [34], but the majority of early publications on this issue actually date back to the 1970s and 1980s [19, 27, 35]. One of the very first researchers to deal with this complex issue was Jung [19], who mainly focused on human and organisational barriers to the successful transfer of technologies. Most authors concentrate on the relations between barriers and the socio-political and economic situation of a given country, and their analyses typically concern only a particular domain [22, 29, 41].

Technology transfer barriers may be observed at different levels: strategic, tactical, and operational ones. Strategic activities concern actions outside the R&D organisation at the level of national or local government. Tactical activities comprise interactions between organisations generating innovations, end users, and the business environment. Operational activities are in-house actions taken by a given entity with reference to particular R&D and implementation tasks. The results of the state of the art analysis concerning technology transfer barriers observed at three management levels, strategic, tactical, and operational ones, are presented in the table.

Strategic level	
Authors	**Technology transfer barrier**
Haug 1992; Jung 1980, Matusiak, Guliński, 2010, Dardak and Adham, 2014, Christowa, 2015	The lack of developed infrastructures, market and public incentives
Kilian-Kowerko, 2013; Munari, Sobrero, Toschi, 2018	The absence of effective financial support for innovation, including seed capital, start-up, venture capital, and spin-off support
Lis, 2013	Low outlays on science in relation to GDP, a focus on basic and applied research in the R&D sector with the development works neglected, making cooperation with the business sector difficult
Gilsing, Bekkers, Freitas, van der Steen, 2011, Lis, 2013	Low absorption capacity (particularly SMEs) for innovative products, mainly caused by insufficient funds
Haug 1992; Harder and Benke 2005	Lobbies or interest groups effectively impeding change and amelioration in the legal system, making technology transfer impossible or inefficient
Tactical level	
Authors	**Technology transfer barrier**
Mysore S., 2015	Growing trends concerning the confidentiality of innovative solutions impeding their implementation across sectors, or even making it impossible, although their development was not inspired by the applying unit
Sieniawska, 2013, Brodnicki and Odlanicka-Poczobutt, 2015,	The absence of special purpose vehicles for research commercialisation and technology transfer, which significantly hampers the effectiveness of the transfer process

Jung, 1980, Bernardos Barbolla, Corredera, 2009	Different orientations existing between the technology provider (R&D organisation) and its user (business) concerning the aspect of time (long vs. short term), goal (scientific vs. techno-economic market), and risk (high risk vs. low risk expectance
Burhanuddin et al. 2009	Large asymmetries existing between the provider and the recipient in terms of having different characteristics, e.g., skills, prices, endowments, internal structure, size, and experience, etc.
Harder and Benke, 2005; Derakhshani, 1983	Different approaches taken by the technology provider and recipient towards the desired results. Usually, these approaches include innovation-oriented vs. market-oriented approaches or focus on superior technologies vs. easily implemented technologies
Siegel, Waldman, Atwater, Link, 2004; Arvanitis, Kubli, Wörter, 2005	The lack of understanding regarding different culture / constraints / interests of industry and scientists
Hall, Link, Scott 2001; Bruneel, D'Este, Salter, 2010	R&D organisations focusing too much on the advancement and dissemination of knowledge, e.g., making results public before their patenting, which deeply collide with the demands of industry
Kilian-Kowerko, 2013, Mohamed et al., 2012, Sieniawska, 2013, Trzmielak and Grzegorczyk, 2014	Ineffective communication and insufficient integration between R&D organisations and enterprises
Siegel, Veugelers and Wright, 2007	The problem of asymmetric information between industry and science on the value of the inventions. Firms typically cannot assess the quality of the invention ex ante, while researchers may find it difficult to assess the commercial profitability of their inventions
Gilsing, Bekkers, Freitas, van der Steen, 2011	Scientific knowledge being too general to be useful for firms and lacking sufficient specificity to address a firm's specialised knowledge needs
Haug, 1992, Burhanuddin et al. 2009	Technologies which are so sophisticated that it is impossible to adapt them quickly and make suitable for the requesting market
Haug 1992	Unsatisfactory or poor business management and negotiation skills on both sides (the technology provider and recipient); however, this problem is usually mostly on the provider's side
Operational level	
Authors	**Technology transfer barrier**
Dardak and Adham, 2014	Management's problems with effective support for R&D directions with the highest innovation, application, and commercialisation potential
Creighton, Jolly, Denning, 1972, Derakhshani, 1983, Reisman, 2004, Ramanathan, 2008	Problems with selecting the most appropriate technology transfer mechanisms
Harder and Benke, 2005	Frequently insufficient time for testing and the demonstration of new technologies before they can compete with well-established technologies, which hampers the process of the practical application of technology
Decter, Bennett, Leseure, 2007; Christowa, 2015; Brodnicki and Odlanicka-Poczobutt, 2015	Competence shortage concerning insufficient knowledge, skills, and experience of employees regarding technology transfer and research commercialisation, particularly knowledge of management processes and financial mechanisms; lack of entrepreneurs at universities
Siegel, Waldman, Atwater, Link, 2004	The exaggerated focus of scientists on intellectual property rights, resulting in a hard line on negotiations and excess concern on the part of university administrators that they will not realize sufficient revenue and insufficient rewards for researchers
Smilor and Gibson, 1991 Mojaveri et al, 2011,	A high level of tacit knowledge included in technologies making technology transfer more difficult (especially with regard to the newest solutions)
Dardak and Adham, 2014	Low innovation absorption potential due to technical, financial, organisational, and market feedback-related reasons, which limit the scale of technology transfer
Gwarda-Gruszczyńska, 2013; Dardak and Adham, 2014	Limited technical capabilities and resources necessary for the verification and manufacture of a new solution as well as ill-recognised technical capabilities of the technology user versus business capabilities
Guilfoos, 1989	Technical risk, and the lack of operational test data and defined requirements
Siegel, Waldman, Atwater, Link, 2004	Bureaucracy, inflexibility and the lack of clear specifications of procedures to be followed by managers and scientists

Source: Author

2. Technology transfer barriers encountered by Polish R&D organisations

Barriers of technology transfer from science to economy are still a significant and current problem depending on the country, region, sector, where innovation is developed, economic and social policy, the substantive, and the economic and organisational potential at the disposal of the entity creating and implementing the innovation and on many other factors. The importance of this problem and ways to reduce or eliminate existing barriers for the technology transfer is evidenced by the increasing number of scientific publications devoted to this issue, including the European Commission report (EC 2007). Due to the multifaceted nature of the issue, the author of this publication focused on the problems of technology transfer occurring in the Polish economy and on the example of a technological R&D organisation, which he has been managing for many years, taking into account strategic, tactical, and operational barriers of system, technical and organisational-economic characters [25]. In the area of system barriers occurring at the strategic level, the most important seems to be the lack of structural, programmatic, financial, and legislative stabilisation. In highly developed countries, research structures focused on the development of advanced technologies have been built systematically, over a long period of time, mainly in the bottom-up approach, as are the intermediary structures in the transfer of technologies such as the TTO type. In developing countries that prioritise a knowledge-based economy, such as Poland, there is a tendency for continuous structural changes in the research sector, but in the top-down formula. Uncritical transfer of patterns, especially concerning structural solutions (e.g., combining R&D organisations into network structures, the creation of research centres in SMEs) seems doomed to failure. Such activities will not bring talented scientists and researchers capable of both creating and implementing the innovative technical solutions. The results of such actions are the subsequent years of organisational instability, without directing efforts to substantive activity and effectiveness of application. The key element in the elimination of system barriers are well-recognised, strategic directions for the development of scientific and R&D activities, in particular, taking into account specialisations adapted to the existing potential, including future research. Programmed development directions on the scale of state, region, or large economic organisations should be effectively implemented and enforced, and not only generated in the form of highly ambitious strategic programmes in which virtually every proposed research subject will be literally fit. It should be ensured that the proposed mechanisms enabling the acquisition of projects co-financed by the state budget or structural funds are stable, i.e. research workers and beneficiaries of these programmes could focus on the substantive side for many years instead of constantly changing the organisational and formal side of their implementation. Of course, the development of science and innovation does not allow excessively long stabilisation of the system, which may lead to stagnation, but it should be remembered that it should be systematically improved on the basis of solid knowledge and research and human resources, and not permanently changed structurally without significant substantive reasons. The sociologically maladjusted personnel of the sectors of science and industry are also a system barrier. On the part of science, there is usually a hierarchical academic structure, based on many years of promotions and knowledge, which does not always correspond to dynamic economic entities reaching for the young generation of talented people, managers working with huge involvement (also due to the ownership structure), and engineering and organisational staff. The interpenetration of both structures is an indispensable condition for the elimination of system barriers in the processes of the transformation of utilitarian knowledge and the transfer of advanced innovative scientific solutions to economic applications.

As to the barriers at the tactical level, their main field represents the areas of cooperation between the research and economic sectors, while different technology transfer barriers refer to large high-tech enterprises and others to the SME sector. High specialisation and the uniqueness of propositions for research and application are the factors and skills expected by entrepreneurs, mainly from the sector of large enterprises and industrial corporations, which are the key to the economic success of innovation transfer. Obtaining a high, usually world-wide level of expected innovative solutions, however, requires consistent, constant training of the staff in the research unit (courses, domestic and foreign study trips), which is very expensive. The industry pays only for the final result, so there is a very significant financial gap, which must be covered by the R&D organisation with external subsidies for R&D or with its own funds, with a highly uncertain prospect of their recovery. In turn, the SME sector usually expects solving small technological issues, very useful for the commercial competitiveness of the product, but without a significant scientific contribution, which determines the huge difficulties with obtaining funding from budget subsidies for such small, scientifically inefficient innovation projects. In addition, the dissemination of a highly advanced innovative solution requires specific skills and a marketing talent that is often underestimated in the R&D sector, as well as high specialist knowledge. The latter, in particular with regard to unique solutions, can usually only be passed on by the creators. The lack of professional, effective, and efficient structures for the commercialisation of the developed solutions causes the need of focusing the highly qualified scientific staff, usually showing a lack of marketing skills, on non-essential activities, resulting in, at the same time, weakening the dynamics of research and development in the scientific unit. The establishment of specialist marketing units in a R&D organisation or the use of specialised external entities is usually an important financial and organisational barrier. Barriers at the operational level to transferring innovative solutions to the economy are manifold and have been presented in this article on selected examples from the author's research and application practice. The basic, and hardly realised by the representatives of both environments, barrier concerns the approach to the solved innovative problem. In the case of the scientific community, the idea and method leading to a solution that we can call a *cognitive approach* is important. In the case of the economic environment, apart from the substantive solution to the problem, it is very important to take into account specific technological, organisational, and economic conditions of implementation that we can call the *application approach*. Usually, the representatives of the research team do not realise how many additional factors must be taken into account (apart from obtaining the required technical parameters of the innovative solution), e.g., the possibility of introducing the solution into the existing technological line in the company, adjusting its service to the qualifications of the implementing unit's employees, the possibility of multiplying the solution or using it in other applications, economic efficiency and many, many more. Examples of technical, organisational-economic barriers at the operational level were presented by two examples from the field of optomechatronic systems and advanced surface engineering technologies.

Example 1. Technical and organisational-economic implementation barrier in optomechatronics

The intensive area of cooperation of the research unit (ITeE – PIB in Radom, Poland) with the industry are innovative optomechatronic systems for high-performance inspection of products in large-scale production processes, which increasingly determine the competitive position of the producer on the market. The highest degree of difficulty characterising the design of such devices and their implementation in the industry is due to very high requirements in terms of the efficiency of the optical inspection process carried out in real time, high accuracy parameters, the repeatability of measurements, and the immunity of the inspection system to various types of disturbing factors occurring in real working conditions. An innovative system for optical inspection of products was developed, which provided, in laboratory tests, the required efficiency of geometric dimension control at a level higher than 5,000 pieces/min with very small measurement scattering. However, the integration of the inspection system with the machine performing the production of inspected products revealed a critical technological problem, which was caused by the non-deterministic nature of the operation of the operating system, manifested by the random occurrence of system response delays beyond the acceptable time of a single inspection. Random disruptions in the inspection process were the cause of generating false results on the occurrence of faulty products (false-positive inspection error). The level of unjustified rejects of the products excluded the implementation of the inspection system in the original version. Alternatives have been developed to eliminate the resulting barrier. As the first solution, the separation of the main feed of products with a capacity of a minimum of 5,000 pieces/min into two parallel tracks and the use of two optical inspection systems (Figure 1) has been applied.

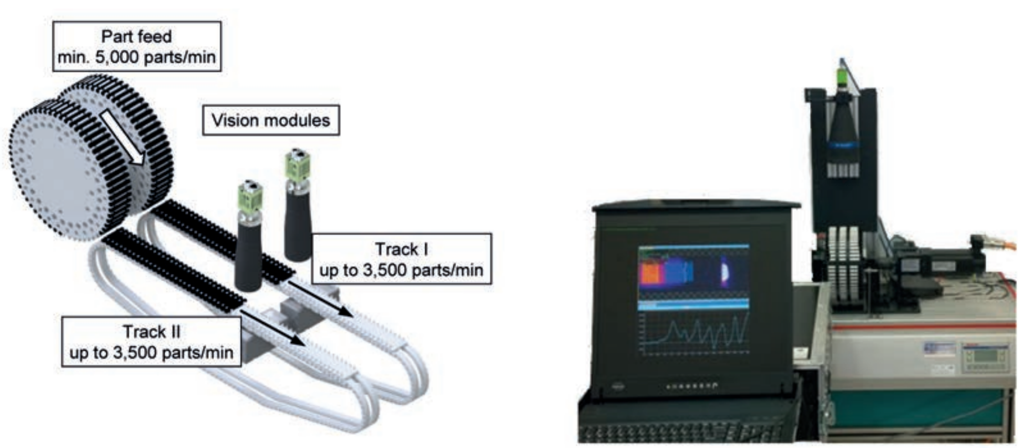

Fig. 1. The diagram to illustrate the increase of the inspection process efficiency by use of two parallel tracks: a) the schematic of the dual-track construction, b) the test stand for simulating the optical inspection processes

Source: Author.

The resulting double increase in the allowable time for a single inspection process in each track ensured the limitation of random disturbances to the assumed level below 1%, while maintaining the required overall process efficiency. The second solution uses a real-time operating system and concurrent processing, which ensured the elimination of random delays in system response times and the generation of false inspection results. The results of the work carried out to eliminate the implementation barrier are two innovative solutions that can be the subject of practical applications in other inspection systems with the required high performance parameters.

Example 2. Technical, organisational-economic implementation barrier in surface engineering

As part of cooperation with the automotive industry, R&D organisation (ITeE-PIB, Radom, Poland) developed an innovative, technological process for plasma surface treatment (PVD method) for treating the needles of fuel injectors used in internal combustion engines. The high level of the innovativeness of the subject process solution has been confirmed in many months of certification tests carried out by the injectors' receivers, i.e. from the USA and Canada. The result of marketing activities was the Polish manufacturer

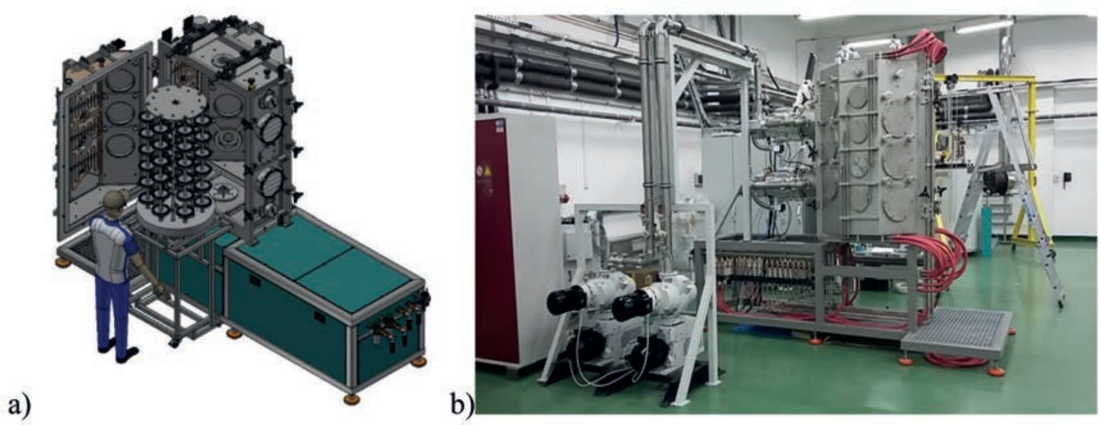

Fig. 2. A large-size device for the implementation of plasma technological processes; a) conceptual 3D design, b) prototype of the device at the stage of assembly
Source: Author.

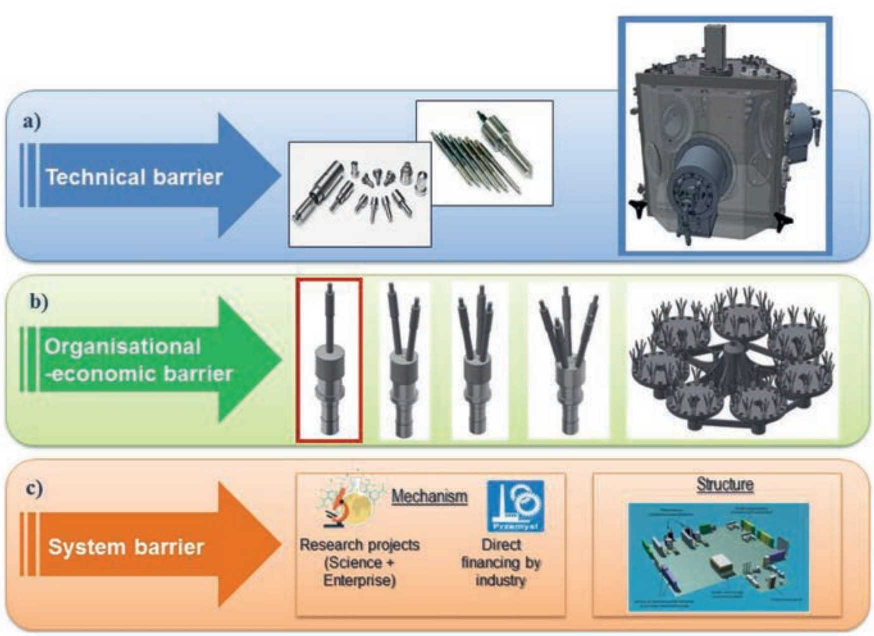

Fig. 3. An example of the combined occurrence of technical, organisational-economic and system barriers
Source: Author.

obtaining yearly orders for several tens of thousands of injectors subjected to the developed surface treatment. The efficiency of the standard device for the implementation of the developed innovative plasma technology at the disposal of the contractor of innovative technology was not more than 500 needles per day, which puts the implementation on the verge of economic profitability. As a result, due to the limited efficiency of the technological device that the implementing entity had at its disposal, taking into account the necessity to conduct periodical maintenance and current repairs of the device, there were enormous difficulties with the timely and cost-effective implementation of orders. In order to eliminate the existing technical and economic barrier, it was decided that effective operation to eliminate the technology transfer barrier will be to design and build a unique device (Figure 2), which will enable the implementation of innovative plasma treatment in an increased volume of the process, and thus efficiency (minimum by 3 times) as compared to the previously used device.

Such a solution – a new advanced product innovation – enables the multiple quantitative increase of the process charge, and thus the cost-effective implementation of technological processes performed for large quantities of repetitive elements such as needles for fuel injectors used in internal combustion engines or other mass-produced elements requiring similar processing. In this way, the implemented process innovation generated product innovation while eliminating the existing barrier to a large extent, which was limiting the effective and efficient transfer of an innovative research solution for industrial applications.

It often happens that technical, organisational-economic barriers and system barriers occur together. Figure 3 shows the accumulation of this type of barriers by the example of the presented transfer process for the industrial applications of the innovative surface engineering technology.

Increasing the process scale for the sake of the economic barrier (Figure 3b) required the modification of the developed innovative technology, taking into account the economy of scale, and thus overcoming another operational barrier by developing a unique technological device (Figure 3a) adapted to implement the developed production process in the economic capacity of the process. In turn, the development of a high-performance device focused the application activities on the creation of a spin-off unit enabling the extension of the developed solutions related to process and product to a much richer range of industrial products for which it was not possible to obtain funds from the national, regional, or structural funds (Figure 3c).

3. Instruments to eliminate technology transfer barriers

The means to overcome technology transfer barriers should concentrate on strategic, tactical, and operational levels corresponding to the nature of the barriers themselves (Fig. 4).

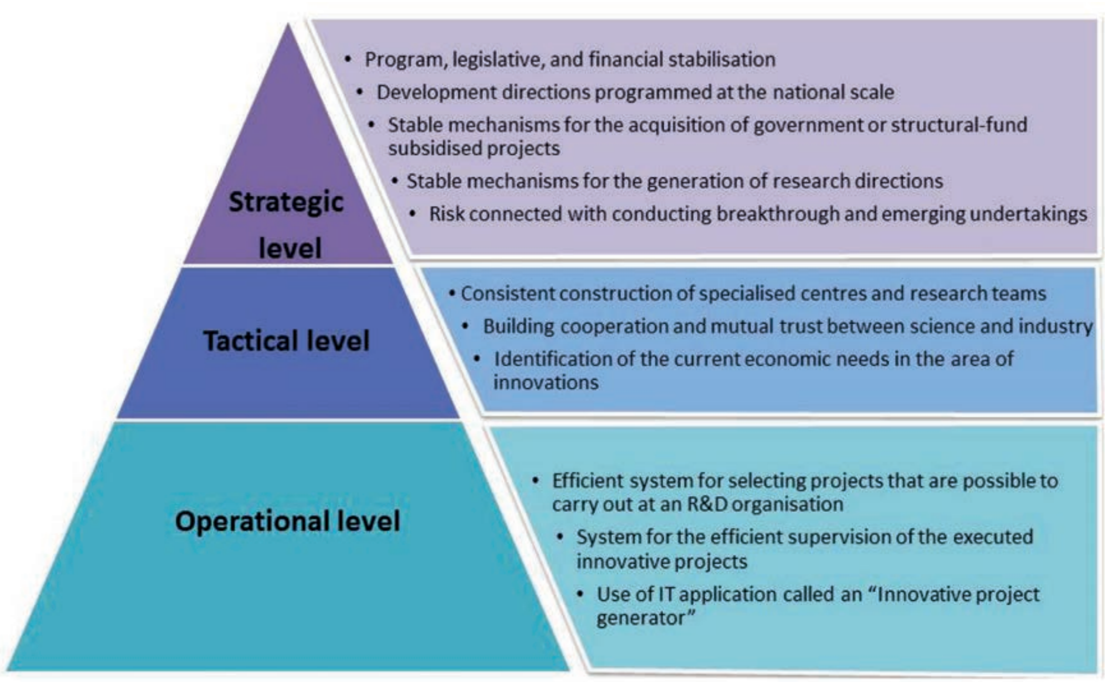

Fig. 4. Instruments of eliminating technology transfer barriers on strategic, tactical and operational levels
Source: Author.

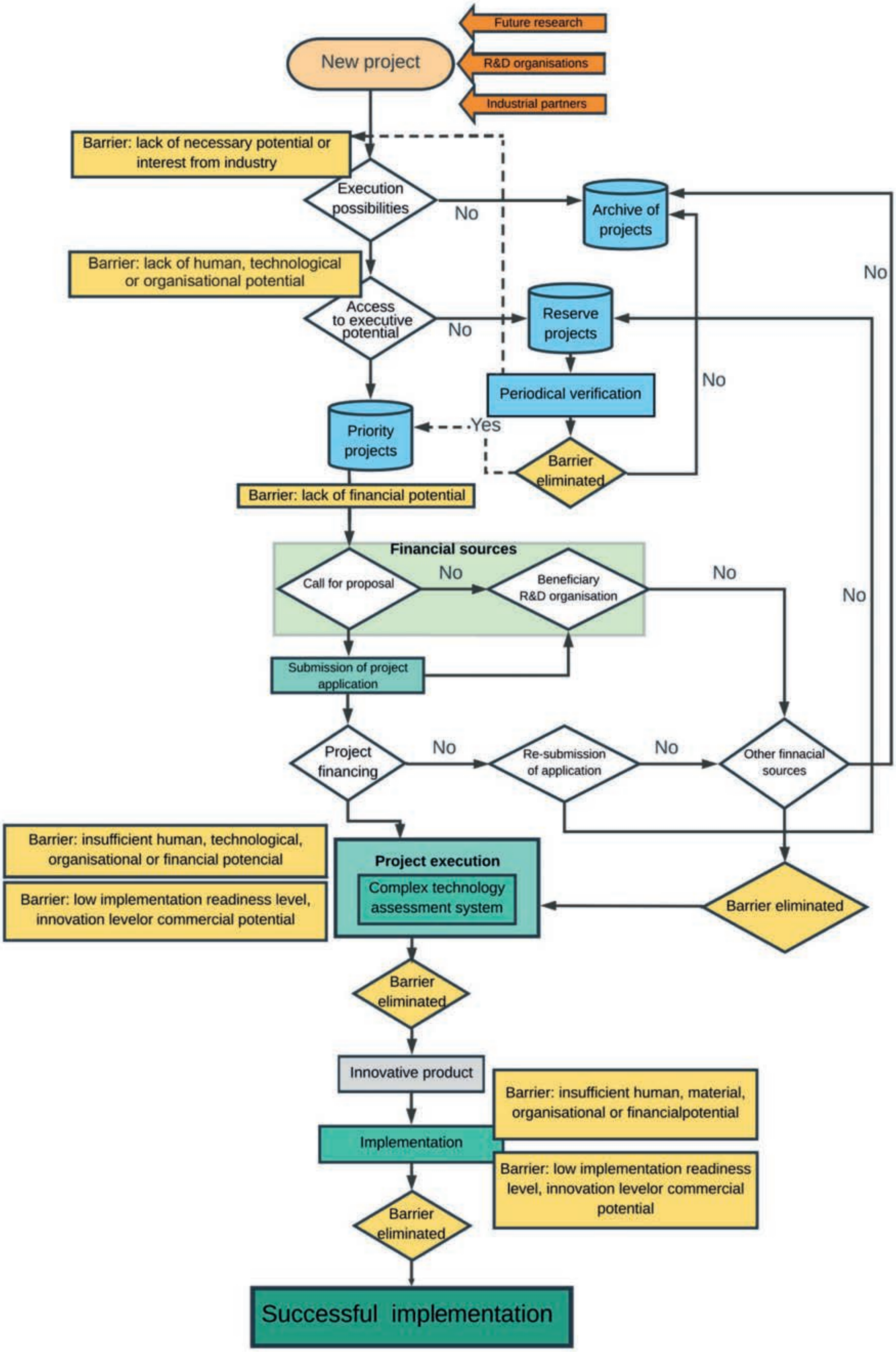

Fig. 5. Algorithm of the use of the project generation with possible barriers
Source: Author.

The presented examples of technical and organisational-economic barriers concern barriers encountered by the R&D organisation at the operational level. At that level, the suggested path towards diminishing the significance of technology transfer barriers includes an efficient system for selecting projects that are possible to carry out at an R&D organisation, while taking into account scientific, technical, financial, and organisational aspects. Moreover, the path should include a system for the efficient supervision of the executed innovative projects, including an analysis of technological advancement, implementation readiness, and supervision in terms of deadlines and expenses [24]. To effectively overcome barriers to technology transfer at the operational level, the author proposed and developed an IT application called an "Innovative project generator" [25, 26]. The project generator is a new idea based on the assumption of the close cooperation of the R&D organisation with potential industrial partners consisting in gathering information about the research needs of the economic milieu and the suggested innovative undertakings. The application of the project generator enables one to identify new potential research projects, select among them the projects with the biggest chances for success, and support the process of their realisation and industrial implementation. However, the processes of projects generation, realisation, and implementation are hampered by numerous barriers, including the lack of or insufficient human, technological, organisational, or financial potential or the lack of interest of industry (Fig. 5).

The project proposals gathered in the generator are analysed for implementation capabilities being, among others, the confirmed intention to cooperate in a given project of research organisation or industrial entity.

The project proposals and various types of research and innovation undertakings, aimed at economic applications, generated, among others, as a result of using foresight methods, business meetings with industry representatives, study visits, scientific conferences and specialist publications, research as well as the development and application needs observed or discussed in the scientific and industrial environment are collected in a specialised database of proprietary computer applications in the folder "New projects." At the short-term intervals, the proposals collected are analysed in terms of executive and application capabilities, including, among others, confirming the willingness of the interested research group, the industrial entity, or a group of industrial entities to cooperate in a given project. A letter of intent constitutes grounds for future activities and determines subsequent tasks to be performed, i.e. the recognition of performance capabilities, staff, equipment, infrastructure, time, and financial capabilities. In case of failure to meet one of the above-mentioned factors at a satisfactory level (operational barrier), the possibility is considered of supplementing the identified deficiencies in the structure of external substantive and organisational connections. Typically, the key barrier is the financing of research and the implementation of the proposed innovative solution. In such a case (if the declaration of direct financing of the task from the funds of the industrial beneficiary has not been received), the possibilities of project financing are analysed through available national and international research funding programmes and matched, while taking into account the topic and financial, temporal and organisational aspects. The meeting of all the above-mentioned requirements results in the introduction of the planned project to the "Priority Projects" folder. Tasks that did not meet the requirements with the possibility of their fulfilment in the future are sent to the folder "Reserve" (barrier: lack of human, technological, or organisational potential). On the other hand, those projects that do not show prospects for implementation in the foreseeable period of time are collected in the folder "Archival projects" (barrier: lack of the necessary potential or interest from industry).

Priority projects for which the implementation formula was chosen are prepared on the formal and substantive side in accordance with the requirements of the required procedure for their implementation. For projects with direct industrial financing, or joint funding by an R&D organisation and economic entity, and those that have been finalised as a result of a competitive tender for national or international funds, a feasibility study, and the required contracts that include matters of confidentiality, intellectual property, the schedule of financing and implementation, as well as partial and final acceptance conditions are prepared. Obtaining co-financing in the absence of other operational barriers (technological, personnel, and temporal) makes it possible to put an innovative project to implementation, during which the possibility of occurrence of barriers on, e.g., the implementation schedule, commercial potential, and the degree of the innovation of the solution are continuously monitored. The innovative product or process obtained as a result of R&D works is prepared for an industrial implementation where it may encounter further operational barriers regarding, among others, execution potential and the manner and scope of commercialisation.

Conclusions

The processes of technology development and transfer conducted by R&D organisations are hampered by various barriers hindering the practical application of innovative technologies and products in the economy. The barriers must be recognised before taking the decisions concerning technology development as well as in the course of the process. Some instruments of weakening or eliminating barriers are already known and applied; however, there is a need to develop more efficient ones.

System barriers on the strategic level require, in order to eliminate them, one to apply a stable and far-reaching scientific and economic policy on the scale of a country, a region, or a corporation, conditioned by scientific and technological potential, economic opportunities, and a vision of future research and application areas.

Barriers on the tactical level, i.e. in the area of cooperation between the scientific and research sector and industry, can be eliminated by strengthening direct relations between representatives of both sectors, creating joint implementation teams enabling the acquisition of experience, building trust and responsibility, and creating coherent, cognitively and applicably useful developmental visions.

Operational barriers occur most often, but are relatively easy to eliminate or mitigate by increasing competencies, developing executive and staffing potential, and using tools that enable the generation of innovative projects and the evaluation of their realisation and implementation, while taking into account identified barriers and instruments to overcome them.

The author of the paper, based on his experience in conducting research and implementation their results in economy, presented chosen barriers from the field of surface engineering and optomechatronics encountered at the operational level by a Polish R&D organisation. These types of barriers (organisational ones) are the most often met. Although the most frequent, they are also easier to cope compare to those at higher (strategic and tactical) levels, because they take place in a particular organisation, which can influence them. It does not mean that all barriers at the operational level may be successfully avoided or overcome, but all of them should be analysed and tackled with aim to be limited or eliminated using the instruments shown in the article.

Certainly, the enormous strategic, tactical, and operational barriers encountered at each stage of the creation of an innovative product are the reason for the great interest in this issue both from the cognitive and practical side. A deep comprehensive analysis of these issues, however, contributes to the on-going identification of existing and emerging barriers, and the search for ways to eliminate them, which translates directly into an increase in the efficiency of the knowledge-based economy.

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