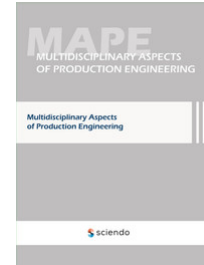


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INTRODUCTION

The Authors' intention is to share their knowledge as well as scientific and professional experience, in the field of research results commercialization and technology transfer, gained at the KOMAG Institute of Mining Technology. They analyzed in detail six case-studies, including three research projects whose results were commercialized successfully and three research projects whose commercialized processes failed. The analyses are based on the Integrated Commercialization Model (ICM), developed by them. It is used at KOMAG commonly, reflecting the relationships among the stakeholders involved in the process of creating and implementing innovative solutions of mining machines and equipment. These stakeholders are: KOMAG as a research institute, a producer of mining machines and equipment as well as an end-user of these machines, representing producers of minerals. In this activity a transfer process management of innovative solutions plays an important role, enabling to avoid potential risks, overcome barriers and when it turns out necessary – to take corrective measures. The article is related to "Engineering of Innovation", being an important part of "Production Engineering", oriented onto an implementation of innovative solutions. The Authors identified a research problem, paying special attention to thresholds, barriers and risks impeding a successful implementation of research results. They developed some guidelines, facilitating the commercialization process, conducted according to the Integrated Commercialization Model, being an intentional transformation and reflection of processes taking place in real life. The scientific and research problem, described in the article, concerns a creation of optimum procedures, enabling to avoid barriers and minimize risks in commercialization processes of research results. It should be highlighted that the research work, described in the article was mainly oriented onto phenomena, events and processes, taking place in the transfer channels of research results between a creator of innovative solutions, in this case the KOMAG Institute, and their users, representing

producers of mining machines and equipment as well as producers of minerals (Turek 2008). Industry of minerals closely collaborates with producers of different mining machines and equipment. Due to continuously changing mining, geological, environmental, economic etc. conditions, there is a demand for improved technologies, design solutions and other technical and organizational innovations to reduce production costs, including an introduction of IT technologies and robotics. In Poland the production of mining machines and equipment is based on Polish technical solutions. In the conditions of the global competition a continuous demand for up-graded technologies and up-graded designs of mining machines and equipment can be observed. In the field of commercialization of research results there are different principles and models available. In theory they seem to guarantee a success, but in practice a realization of commercialization processes faces difficulties and barriers of formal, legal, organizational and economic character. At present the development rate of technique and technology causes that only enterprises which are capable of introducing innovative changes can be successful. The source of innovations for industrial enterprises includes a transfer of novel technical and technological solutions which is closely connected with an adaptation of research projects results, development project results or patents to their practical use. At present a clear shift of accent from the supply of technique and technology to a creation of the demand for it occurs. That is why, in general more attention is paid to the needs of industrial partners by research institutes. It concerns different branches of industry, including the mining industry. A transfer of innovative solutions of mining machines and equipment enables mines to conduct safe and economically efficient exploitation of minerals. The basic problem in the transfer processes of innovative solutions from science to industry and in commercialization of research and development project results often consists in defining the roles and responsibilities of the stakeholders and in establishing relationships among them. There are several factors which have an impact on an efficient realization of commercialization methods, so it is important to establish criteria of efficiency assessment.

LITERATURE REVIEW

The literature review, conducted by the Authors, showed that so far there have been no comprehensive analyses, identifying thresholds and barriers to a realization of commercialization processes of research results from the point of view of scientists, developing innovative solutions in the research institutes. (Drucker P. 1992), concentrated his research of on innovations being a particular tool of entrepreneurs, enabling them to undertake a new economic activity or render new services. It should be borne in mind that a transfer of innovative solutions can be regarded as a measure of technical progress and its intensification has a decisive impact on a product business attractiveness and ensures a market supremacy (Adams et al., 2006; Arnold et al., 2007; Buckley 1997; Daszkiewicz 2008).

Schumpeter J. (Schumpeter 1997) believes that innovations concern a product, a manufacturing process and an organization. However, barriers to a successful commercialization of innovative research project results are often caused by deleting the following actions (Malec et al., 2020):

- conducting the risk analysis before starting a realization of the research project and during its realization,
- defining all the tasks in the project management process, including the milestones, and determining the scope of duties and responsibilities,
- assessing an advisability of the project continuation when serious barriers appear.

A decision about the project advisability can be supported by the Quick Look method which includes a market research, an identification of potential users and an assessment of barriers. A regular assessment of the project development progress plays an important role and it is a sort of a project management must. It should include an analysis of different scenarios (Buckley 1997; Chakravorti 2004; Dogson & Hinze 2000; Chesbrough et al., 2006). This process enables to identify the impact factors which should be monitored on a regular basis, paying special attention to thresholds and barriers. It should be borne in mind that most of commercialization processes of research projects results are not successful due to an incorrect assessment of the reasons of experienced problems. It can be seen from literature (Chesbrough 2003; Paik et al., 2009; Gassman 2006; Kirkland 1996) that 90% of mistakes are caused by an incorrect perception and only 10% of them result from incorrect reasoning. An American experience, related to innovative entrepreneurship (Freeman 1992; Von Hippel 2006; Zasiadły & Trzmielak 2005) indicates practical guidelines. In China there are continues debates concerning an efficient commercialization of research results and how to be successful in this field. All the researchers highlight the fact that users of innovative solutions play a critical role in this process (Lundvall 2002; Mazurkiewicz & Poteralska 2011; Oygür & Thompson 2020). Research institutes, including the KOMAG Institute of Mining Technology, engage users in all the stages of the processes of designing, testing and implementing innovative solutions, i.e. producers of mining machines and equipment as well as end-users representing mines of minerals

INTEGRATED COMMERCIALIZATION MODEL (ICM) OF RESEARCH RESULTS

The presented Integrated Commercialization Model (ICM) (Fig. 1) reflects the Authors' professional experience resulting from a management of national and international research projects. It is based on an analysis of the available commercialization models such as the model developed by the Cracow University of Technology, Jolly's model, the united model (science + market), the linear-sequent model, the network-interactive model and the IpOp model developed by R. Cohen.

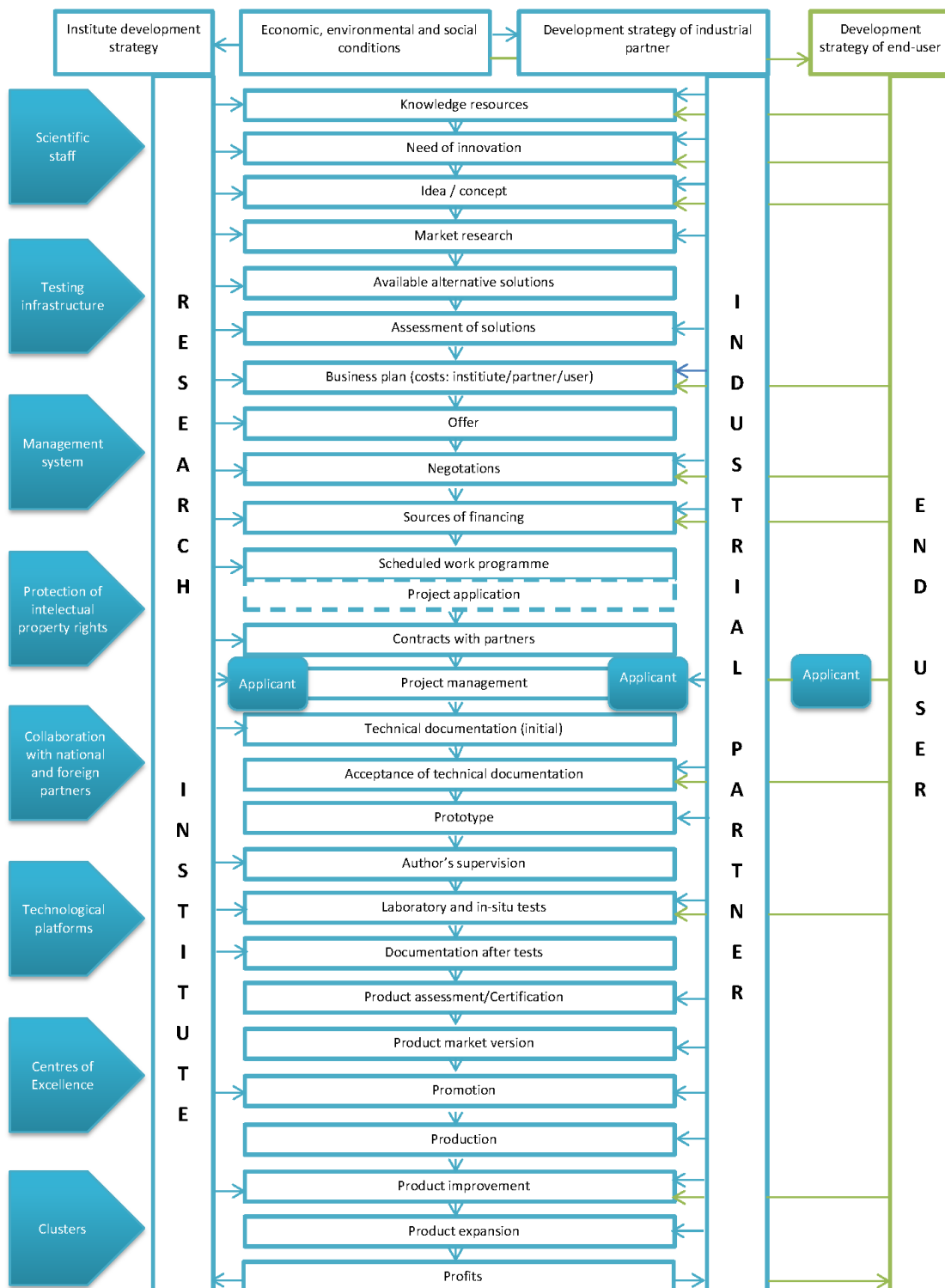


Fig. 1 Integrated commercialization model (ICM) of research results

Source: Malec et al., 2020

The ICM model shows the roles of stakeholders and it should be highlighted that in this model the institute takes an active part in all the stages of this process, except for the production phase. A big advantage is that this model gives not only theoretical but also pragmatic information to stakeholders, indicating

potential barriers and thresholds, which may impact a successful realization of the research project, including a commercialization of its results. It can be seen that there is a clear impact of economic, environmental and social conditions on the strategy of stakeholders. One of the most important aspects of the whole process includes an evaluation of the market potential. A mistake, made at this stage of the project realization, can be a barrier impossible to overcome, as it can cause irreversible damage. The SWOT analysis, benchmarking or the method of awarding points can be used for assessing the market potential.

An active participation of industrial partners in a realization of individual project phases enables to verify its results. Analyzing the ICM model step by step, it can be seen that the project management process plays an important role in the process of eliminating barriers. The mistakes in this field concern the management of:

- the project scope including a verification of performance activities and changes,
- the project integration including correct planning and control,
- the project time schedule consisting in a control of the work programme,
- the project budget enabling a current monitoring of personnel, equipment, materials, costs,
- the project quality (internal and external audits),
- the project risk including an identification, an analysis and a reaction to negative phenomena,
- the project human resources (a division of tasks, duties and responsibilities),
- the project offers (a preparation of offers, elaborations and negotiations of contracts and a supervision of their realization),
- the project communication enabling a control of the smooth information flow to stakeholders.

The ICM model shows that an innovative solution can appear at any of the stakeholders, but it is essential that monitoring of the project realization is conducted by the research institute in close collaboration with the industrial partners to eliminate potential barriers and undertake corrective measures, when such a necessity arises. When the technical documentation is ready and approved by the producer, then the phase of making a prototype starts. Afterwards the prototype is subject to laboratory and in-situ tests. After having carried out the certification process, an innovative solution of a mining machine or equipment is ready to be introduced to the market.

As it has already been mentioned, a significant advantage of the ICM model consists in a possibility of checking up each stage of the commercialization process. This model enables to detect irregularities, i.e. thresholds and barriers in a relatively simple and quick way, being a kind of a diagnostic tool.

SUCCESSFUL AND FAILED COMMERCIALIZATION OF RESEARCH PROJECTS RESULTS – CASE STUDIES

The Authors analyzed commercialization processes of thirty research projects, carried out at KOMAG in the past. Twenty five of them were successful and five of them failed. Three most characteristic successful projects and three most characteristic failed projects were subject to a detailed analysis according to the Integrated Commercialization Model (ICM). In the result of the analysis some assessments of general character were formulated, in particular in the scope of barriers which caused failures of the projects. The following factors were taken into consideration during the analysis: project initiator, financial system, industrial partner, executor of tests, stakeholders: university, big enterprise, SME, planned costs, project duration, type of contract, reports, number of industrial implementations, royalties etc.

It should be highlighted that all the aforementioned processes were conducted according to the KOMAG Quality Management System shown in Fig. 2.

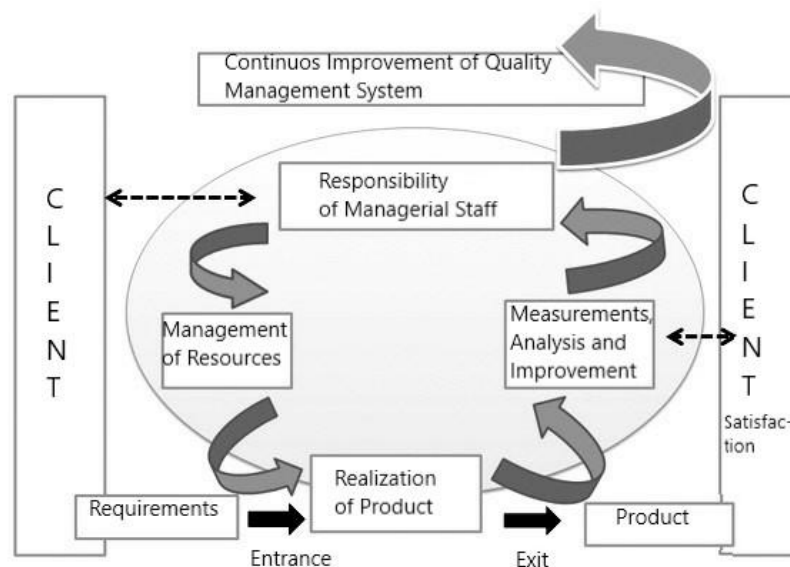


Fig. 2 Model of Quality Management System based on a process

Sources: Project ... 2006

This process takes into consideration added value activities as well as a flow of information, reducing possibilities of making mistakes at the stages of realizing individual processes. One of the model elements includes the Client's Satisfaction System, which enables an assessment of the quality of services rendered by the KOMAG Institute and the degree of meeting clients' requirements and expectations, an adaptation of scientific, research, technical and marketing activities to the requirements of industrial partners and also a determination of strong and weak features of the Institute, in particular as regards the areas which should be improved.

The successful projects were as follows:

- System of external spraying for a longwall shearer ensuring a safe operation in the conditions of methane hazard (Fig. 3).



Fig. 3 System of external spraying for a longwall shearer

The results of this project very important as they were directly related to safety of miners employed in underground workings, where the methane explosion hazard occurs. The demand for the innovative solution resulted from the market survey. Due to a close collaboration with industrial partners, a risk of facing barriers in the commercialization process was reduced to a minimum. The external spraying system enabled not only a prevention against methane ignition but also a significant dust reduction due to an application of air-and-water aerosol around the cutting heads.

- Identification system of elements of powered roof support unit (Fig. 4).

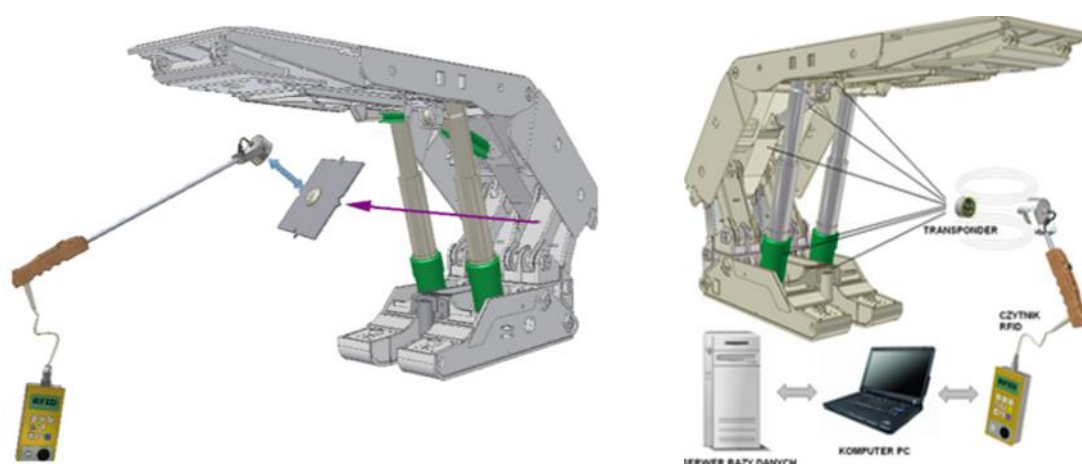


Fig. 4 Identification system of elements of powered roof support

This research project is characterized by a high level of innovativeness due to using the RFID system for an identification of elements of powered roof supports unit. The system enables to get information about individual load-carrying elements of a support unit. It contains electronic transponders, fixed to the support unit elements, the RFID reader consisting of a microcomputer together

with a lance for reading the data. The software enables an electronic preparation of reports, supporting the decision-making process in the scope of the support unit technical evaluation.

- WMD-150 small size drill rig (Fig. 5).



Fig. 5 WMD-150 small size drill rig

The machine is designed for making geological-and-exploration drillings, and also dewatering, degassing bore-holes in rocks of different hardness within the diameters from 46 mm for the depth of 150 m and 76 mm for the depth of 60 m. Due to a rotational installation of the turn-table on the gear-box, it is possible to drill in different directions covering 360°. The drill rig can be used in coal, metal ores and salt mines.

The failed projects were as follows:

- Development of solutions in the scope of using unconventional sources of energy.

KOMAG conducted the market research from which it could be concluded that there was a big demand for wind turbines of 1 kW power. The industrial partner was enthusiastic about the future market success, confirming the demand for this type of wind turbines. The costs of initial design project were covered by KOMAG, based only on an oral agreement about a future collaboration with the industrial partner. KOMAG also elaborated the business plan. It was agreed with the producer that the further stages of the project would be realized in the framework of the targeted project grant. Just before submitting the grant application forms, the producer changed his mind and without any financial consequences gave up his participation in the project.

- Improvement of coal winning technology oriented onto a reduction of costs through an application of mining prevention at the crossing between the longwall and the roadway.

The project was oriented onto a development of the resistance pack in collaboration with complex longwall equipment. Due to an implementation of innovative solutions, it was expected to increase production rates and to improve

occupational health and safety in the zone of crossing between the longwall and the roadway. The advantage of this solution consisted in a convergence reduction of roadways, a limitation of the rock mass deformation pressures as well as a reduction of methane and fire hazards. The project failure was caused by serious mistakes in the project management scheme. Incorrect communication and several misunderstandings caused big delays in the project realization schedule. In the end mining-and-geological conditions in that zone made an implementation of the research project result impossible.

- Intrinsically safe system of dissipated structure for control and supervision. The project objective was to develop and intrinsically safe controller for individual mining machines and for groups of machines in a longwall system or in the run-of-mine haulage system with use of belt conveyors. The assumed main advantage of this system consisted in an operation of controllers with concentrated or dissipated machines. The applied PROFIBUS DP system allowed a configuration, in which a few units of “master” type could operate together with the “slave” units on one transmission bus-bar. The project failed due to an incorrect recognition of formal-and-legal requirements and possibilities of obtaining certifications for conformity with the ATEX Directive. Besides, the producer expressed a negative opinion about the applied technical solutions, suggested by KOMAG, which made the project continuation purposeless.

From the results of the detailed analyses of six case-studies, described in this chapter, it can be concluded that there are many different reasons, which form barriers to a successful realization of commercialization processes of research projects results.

These barriers are presented in the next chapter.

THRESHOLDS AND BARRIERS IN COMMERCIALIZATION PROCESSES OF RESEARCH RESULTS

Commercialization of research results is connected with significant costs and risk, so it is indispensable to analyze potential profits and losses which may result from a realization of such an activity. Generally a positive decision about a realization of the commercialization process is taken, when an internal rate of return is on the level of undertaken risk (Flisiuk & Gołabek 2015). Sometimes other reasons prevail such as an intention of getting a new or a bigger market due to an implementation of an innovative technology or an innovative product as well as gaining a competitive superiority on the market.

Commercialization processes of research results are not successful among others in the following cases:

- there is a small market for the products which are to be generated in relation to investments; the risk of failure is too big,
- there are other easier ways of getting high internal rate of return by investors at a smaller risk,

- it lacks examples, experience and commercialization skills as regards suppliers and receivers of research results.

The most frequent barriers, experienced by research institutes include:

- financial limitations – insufficient state grants for research projects, in particular for so called advance research projects which play an extremely crucial role in the case of institutes and lack of other sources of additional funding; it should be borne in mind that big producers, based mainly on foreign capital, have their own research and development centres, whereas at present SMEs do not have sufficient funds to make investments in the applied research,
- insufficient testing infrastructure enabling to meet high requirements and expectations of end-users; well-equipped laboratories enable a realization of interdisciplinary tests of innovative products,
- difficulties with unclear, continuously changed regulations and bureaucracy,
- lack of experienced staff ready to conduct commercialization processes and take a risk of a potential failure; it concerns both the research institute staff as well as the staff of the end-user,
- an conservative approach and a resistance to changes e.g. many producers are afraid of changes which may require additional effort from them, especially at the very beginning of implementing an innovative solution; they prefer to concentrate their thinking on potential risks instead of potential profits,
- lack of producers' interest in a collaboration with research institutes due to insufficient information or bad experience from the past,
- stereotypes still functioning among industrial partners who perceive scientists and researchers as those being far from real life, concentrating in their projects mainly on theory not in practice; in turn researchers complain that producers do not understand and usually underestimate the role of scientific achievements in industrial practice,
- incorrect marketing activities, in particular a misuse of state-of-the-art marketing communication channels,
- lack of coordinated and targeted activities in a realization of commercialization processes (Trzmielak 2013).

Based on the detailed analysis of six case-studies, presented in this article as well as on the available literature, the following types of barriers can be distinguished: systematic, structural, as well as the barriers of awareness, cultural and cognitive character. According to Trzmielak (2013) lack of financial means, lack of management competences within the scope of commercialization plan, also an insufficient knowledge and experience in this domain and quality resources belong to the barriers, most frequently experienced in commercialization processes. The barriers, resulting from a deficit of human resources and intellectual capital, should be overcome first of all as they belong to the crucial ones. Interdisciplinary knowledge from the

domain of protecting intellectual property rights is extremely important and indispensable. It should be mentioned that some organizations take a commercialization risk even when they are aware of the existing barriers. Most significant barriers are presented in a graphical form in Fig. 6.

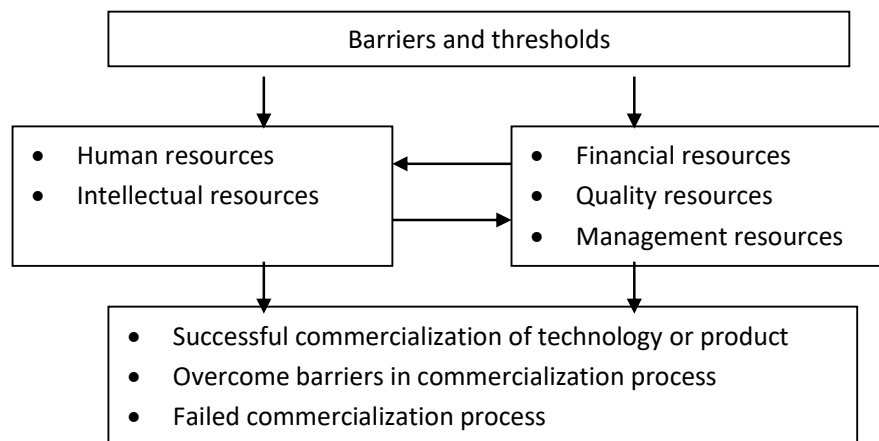


Fig. 6 Barriers in commercialization processes

The information, given in this chapter, does not highlight marketing communication barriers, which have a significant impact on a realization of commercialization processes of research results, so the Authors decided to dedicate a separate chapter to this issue.

ROLE OF MARKETING COMMUNICATION IN THE PROCESS OF COMMERCIALIZATION OF INNOVATIVE TECHNOLOGIES AND PRODUCTS

Marketing communication is a complex process enabling to strengthen collaborative relationships between science and industry within the framework of technology transfer and a creation of innovative solutions. In particular, it can be clearly seen in the area of all diffusion of innovations, which is possible due to a broad scope of available, state-of-the-art and efficient carriers of marketing information transfer. However, at present there are not many analyses of relationships between marketing activities and an innovativeness, changes in the global economy, dynamics of challenges and changes in enterprises, including an adaptation of an enterprise to the rate and scope of transformations in the environment and changeable role of stakeholders. The paradigm of functional efficiency, preferring specialistic methods and not an analytical approach to an issue of improving marketing processes seems to be common. A proper integration of technology, R&D activity of a production with marketing activities forms a basis of an efficient technology transfer and a commercialization of R&D results, having an impact on its dynamics. Thus, it should be borne in mind that marketing of innovations supports all the phases of an innovative process. In general three phases of an innovative process can be distinguished:

- a phase of creating an idea,
- a phase of development,
- a phase of implementation and commercialization.

Innovative products and technologies require marketing activities based on a new paradigm. However, at present instead of using the name “commercialization“, “innovation“, “technology transfer“, in the business jargon the expressions such as: “new product development“, “new software development“, “new service development“ are used more often (Koszembar-Wiklik 2016). The best marketing communication system should include:

- technology (Internet, Intranet, Social Media, a system of group work, decision-supporting systems),
- management systems and measurement methods of knowledge use efficiency (of intellectual capital),
- organizational culture oriented onto personnel.

In the commercialization process it is crucial to use the most appropriate marketing tools to disseminate innovative solutions. In the case of technology commercialization, direct marketing seems to be most efficient with use of personal contacts “face to face“. However, a development of Internet tools opens new possibilities to the marketing communication. Apart from information in social media, it is worth introducing other attractive forms of communication such webinars, undercasts - interviews with experts, as well as webcasts – films presented in the Internet. It is also worth considering a use of the blogs www.innogenerator.pl or www.pi.gov.pl/parp. In the case of some products Facebook seems to be useful in the scope of promotion (Facebook Ads, Pages & Events, Innovations). Marketing communication requires more than only typical promotion activities. New media opened new horizons for conducting public relations activities, in particular e-public relations (e-PR). A holistic approach to marketing communication enables to avoid barriers resulting from misunderstandings, incomplete and misleading information causing a misinterpretation of data.

RECOMMENDATIONS AND GUIDELINES IN THE SCOPE OF AVOIDING THRESHOLDS AND BARRIERS IN THE COMMERCIALIZATION PROCESS OF R&D RESULTS

The following thresholds and barriers may appear during a realization of technology transfer processes and during a commercialization of R&D results:

- An incorrect recognition of economic, environmental and social conditions.
- A misunderstanding of the industrial sector needs (an overestimation of the market demand).
- An incorrect determination of the product market potential (available alternative products, product innovativeness, costs, manufacturing possibilities).

- Lack of attention paid to legislative, financial, organizational and institutional barriers.
- Mistakes made during a formulation of a consortium, during a preparation of business plans and an elaboration of offers.
- Lack of flexibility during negotiations (the win-win system seems to be most advantageous).
- Unclear formulation of the contract which should include the scheduled work programme, financial means, duties and responsibilities of the parties as well as milestones enabling to control the research project realization continuously.
- Mistakes made in the scope of the management (underestimated risk, incorrect risk assessment and risk management).
- Inefficient marketing and promotional activities.
- Wrongly identified factors fostering a transfer of innovative solutions and a commercialization of R&D results and incorrectly identified barriers which impede these processes.
- Lack of coordinated and targeted activities in a realization of the commercialization process.

It should be borne in mind that a successful transfer of innovative solutions is a measure of a technical progress and it ensures a market supremacy. An intellectual structure of collaborative links between the stakeholders of this process can be a good inspiration for all the researchers who intend to bridge science and industry.

CONCLUSIONS

- There is no universal commercialization method, because each implementation of an innovative solution is realized in a different environment. However, there are certain methods which enable to prevent against thresholds and barriers or when it happens that they occur these methods enable to overcome such barriers.
- The ICM model, used in detailed analyses of six case-studies, presented in this article, indicates the areas of potential mistakes and failures, showing explicitly how those difficult issues and situations could be controlled and monitored.
- Innovative project results have bigger chances for a successful commercialization within a scientific-and-industrial consortium, but sometimes a sales of an innovative solution in a form of a patent or know-how can also be an advantageous form of commercialization (Flisiuk & Gołabek 2017).
- Research institutes bridge science and industry, being really successful in technology transfer and commercialization of research results.
- It should be highlighted that the European Union is ready to support research projects, in which a collaboration between science and industry is

ended with technology transfer and a commercialization of research results. It concerns, in particular, the EU programmes such as: HORIZON 2020, HORIZON EUROPE and RESEARCH FUND FOR COAL AND STEEL.

- Inefficient marketing communication concerning innovations can be considered as one of significant barriers in the technology transfer and commercialization of research results.
- A holistic approach to commercialization of R&D results includes process, technological, product, organizational and marketing innovations. It enables to obtain the effect of synergy and guarantees a sustainable development of the research institute and its business partners.

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Abstract: Commercialization processes of research and development project results are costly and risky. That is why it is indispensable to analyze all the advantages and disadvantages very thoroughly as well as to identify potential risks and barriers which may emerge during commercialization processes of innovative solutions. The Authors presented in the article the results of their research work results oriented onto an identification potential barriers based on analyses of case studies carried out according to the Integrated Commercialization Model (ICM), developed by them. They highlighted the role of marketing communication in commercialization processes, giving some examples of mistakes commonly made and suggesting a new paradigm of marketing activities with use of the state-of-the-art efficient carriers of marketing information e.g. Internet, Intranet, Social Media etc. Marketing communication is presented as a complex tool enabling to strengthen collaborative relationships between science and industry within the framework of creating and implementing innovative solutions. The article also contains some recommendations and guidelines concerning thresholds and barriers impeding a successful transition of commercialization processes of R&D results and of technology transfer.

Keywords: Integrated Commercialization Model (ICM), Marketing communication, commercialization of results, R&D works, technology transfer