Some aspects of technology transfer

Alexei Toca*, *Vadim* Iațchevici, *Tatiana* Nițulenco and *Nicolae* Rusu

Techinical University of Moldova, Department of Machines Manufacturing Technology, str. Studentilor, 9, Chisinau, Republic of Moldova

Abstract. Technological transfer is a complex and varied process, being realized out at different stages of technology readiness level. Being essentially a trading, technology transfer is fully subject to market laws. The technology transfer strategy and tactics are strongly influenced by the degree of technology's readiness level, systemic character, functional orientation and universality, technical and economic determination degrees that can be specified and determined in accordance with the stages of technology life cycle.

1 Introduction

The phenomenon of technology transfer is, on the one hand, recognized as an important source of the technique and technology development, and on the other hand it is often treated simplistically and unilaterally. The reality is another - technology transfer is a complex process that requires an intellectual, financial and organizational effort made by many "actors" in the teamwork [1 - 4]. Moreover, without deep knowledge of the subject (itself technology, processes of technology transfer) and without a well-systematized its knowledge the technology transfer may be inefficient or may be considered inefficient. Consequently, the technology transfer is underestimated.

The technology transfer is essentially commercialization of the technology and a process of transforming of the technology into a cost-effective product. This product is the result of a combination of a several components:

- a technical effort required to convert technology into a useful product and to organize its production in sufficient quantities and at the appropriate level of quality;
- a business management and an marketing in order to determine the real needs of the market in this product-technology, to perform the intellectual property operations, to ensure the good functioning of newly created or existing companies that are in the business area with the new technology (manufacturing, production, distribution, maintenance and so on);
- the factors of production (access to technical, organizational and financial resources, to infrastructure and logistics, to suitable qualification workforce, etc.).

The key technical aspects of technology transfer are: product development and the creation of the adequate production technology.

The first aspect requires the combined efforts of researchers, conception engineers and technologists to transform innovation into a particular product with relevant technical and

*Corresponding author: a_toca@mail.utm.md

aesthetic features that are attractive to prospective buyers and at the same time allow for efficient production processes.

The second aspect - the creation of the production technology (which is only a sequence of the general process) and the setting of process control parameters.

In the context of technology transfer, it is very important to evaluate technologies in terms of the readiness level. We can mention the nine Technology Readiness Levels (TRLs) developed by the European Commission [5]. Earlier for the flight's conditions by NASA has been developed the similar system of Technology Readiness Levels [5].

The nine Technology Readiness Levels (European Commission):

TRL1: Basic principles observed;
TRL2: Technology concept formulated;
TRL3: Experimental proof of concept;
TRL4: Technology validated in laboratory;
TRL5: Technology validated in relevant environment (industrially relevant environment in the case of key enabling technologies);
TRL6: Technology demonstrated in relevant environment (industrially relevant environment in the case of key enabling technologies);
TRL7: System prototype demonstration in operational environment;
TRL8: System complete and qualified;
TRL9: Actual system proven in operational environment (competitive manufacturing in the case of key enabling technologies or in space).

Manufacturing Readiness Levels (MRLs) and assessments of manufacturing readiness have been designed to manage manufacturing risk in acquisition while increasing the ability of the technology development projects to transition new technology to weapon system applications [6]:

MRL1: Basic Manufacturing Implications Identified;
MRL2: Manufacturing Concepts Identified;
MRL3: Manufacturing Proof of Concept Developed;
MRL4: Capability to produce the technology in a laboratory environment;
MRL5: Capability to produce prototype components in a production relevant environment;
MRL6: Capability to produce a prototype system or subsystem in a production relevant environment;
MRL7: Capability to produce systems, subsystems, or components in a production representative environment;
MRL8: Pilot line capability demonstrated; Ready to begin Low Rate Initial Production;
MRL9: Low rate production demonstrated; Capability in place to begin Full Rate Production;
MRL10: Full Rate Production demonstrated and lean production practices in place.

Although both systems (TRLs and MRLs) are of a general nature, any developed technology may be subject to the TRL and / or MRL expertise especially when it comes to its transfer.

2 Evaluation of the technologies

Technology evaluation can be done with TRLs and MRLs instruments that can and should be used together. Both instruments offer the possibility of determining the risks associated with the inclusion of technology in a technology system, because the "power" of a system is determined by the "power" of the weakest element. It is well understood that the manufacturing readiness is determined by technology readiness and by product stability.

The modern industry is characterized by the fact that product stability is increasingly being replaced with product variety so that the use of instruments TRLs and MRLs becomes iterative, dynamic with reliable results in relatively small time intervals.

TRLs and MRLs have a systemic character and from this reason can be used to define manufacturing readiness and risks at the system and/or subsystem levels.

The systemic analysis of technologies should be done at three levels:

- technology as an element of a technology system in links and relationships with other technologies with its role and functions;
- technology itself to detect its integrative properties, the extent of these properties (parameters, indicators), other properties that do not come from analysis of the technology within the technology system;
- technology consisting of elements, which is the most complex analysis because it has to answer questions related to the physic-technical principle of operation, the number and character of the elements, the role of the elements, the number and the character of the links between the elements, the role of the links, the functions of the elements, etc.

Evaluation of transferability of the technologies is done in situations where technological development does not have a single solution many parallel constraints and development opportunities exist. For this purpose, the evaluation tool may need to be integrated, generic and fast.

The integrated character is treated in the sense that technology is evaluated taking into account the dynamics of all segments of the technology chain and the many possible implications that development would have in these segments. The effects of this dynamics are assessed from an expanded development perspective in accordance with the objectives of the vision for sustainable industrial development, as opposed to partial approaches that focus on one or fewer constraints on development in the technology chain.

The generic character is treated in the sense that valuation tool can be applied to any chain of industrial technologies, regardless of their physic, technical and organizational nature. However, the tool is not a detailed plan for analyzing the technology chain in a specific situation. It is up to the analysts to adapt the tool to specific situations and make further analyses and interpretations.

Rapid in the sense of being simple, its application can be accomplished in a short period of time and at low cost, but however it is an effective way to get relevant information. This tool is therefore not designed to replace sophisticated analysis tools for technology chains that require substantial resources for data collection and analysis, generating very detailed information that can be used to implement the project.

The evaluation tool essentially can generate three results:

- a detailed mapping of the technologies in a specific technological chain in a given the interactions amongst them;
- a description of the level of development in the technological chain with regard to several dimensions, including the sourcing of inputs and outputs, process capability, end-product, sustainable manufacturing and energy use, and industrial environment and socio-economical context;
- an identification of constraints to and opportunities for technological chain development leading to strategies that support its development.

The evaluation using this tool should be seen as part of the wider process of industrial technological chain development. This process is by concurrent nature and must match development opportunities with demands of potential products and processes.

The technological chain's development efforts do not start from zero. Typically, there are a number of technological development interventions coming from a large number of studies dealing with different aspects of the chain. The technology's evaluation is necessary at all stages to detect the lack of technological elements in chain development. The

technology's evaluation is necessary at all stages to detect the lack of technological elements in chain development and to adjust and the complementing the development's impact.

The quality of the evaluation process will depend on the character of information it builds on. For significant results, users of the evaluation will need to be involved in substantial data collection. This includes conducting interviews with a range of specialists and other key stakeholders, especially from the enterprises in the technologic chain. The analyst may deliberately use the existing technologic chain's analyses, which are available for most chains, to cover various pieces of information as suggested in the diagnostics framework. However, it is important to verify the information in these documents. The correct organization and processing of this information is essential to make the results of the evaluation significant for technologic development.

Given the scope of the technology's evaluation, it is preferable to form a multidisciplinary team coming from different engineering fields and from such as marketing, finance, economics, business administration and environmental. Team activity can be organized, for example, according to the Quality Function Deployment methodology.

Technologic chains encompass all the activities and interactions required in the creation of a product or service from idea, conception, manufacturing to commercialization, utilization and liquidation. The term “technologic chain” refers to the all process of continued transformation, conservation and addition of product's properties that occurs while the product passes from one of the stage of life cycle to the next, gradually increasing its degree of readiness level. They are supported by a range of IT, technical, expertise, business and financial services providers. In a technologic chain the various activities in the different stages become connected, coordinated and finally integrated.

Evaluation of the technologic chain must offer the understanding how on the different stage are coordinated the transformation of the properties under given framework conditions operate and how are oriented their processes to ensure that the product obtains the required qualities. Evaluation also must offer a looks at the various effects that operations in the technologic chain have on the operators, employments, people, e.g., with regard the health, company's development, economic growth and environmental sustainability.

Evaluation of the technologic chain must be oriented to receive the answers to a series of questions:

- What are the product's life cycle technologies?
- Are there technological results that can be used as important milestones for the coordination of other technologies from the technology chain?
- What are the inputs and outputs accepted by the technologies from the chain according to the technical, economic, environmental criteria etc?
- How are produce the exchange of data between the components of the technology chain and how this exchange orient the chain towards improving the performance of processes, products and business in its entirety?
- What technical, informational, economic and financial services are available to support the technologies from the chain and the technological chain as a whole?
- What are the added values (in terms of transformed, added, preserved properties) of the component technology from the chain and what are their costs?
- What are the interdependencies relations from the technologies in the chain and to what extent do these relationships determine how the technical and economic gains and risks are distributed?
- What types of barriers exist for the technologies to make them the component of the chain and to bring the added value?

- What are the readiness levels of the technologies-components and of the technologic chain as a whole and what are their levels of performance?
- What bottlenecks exist or may exist and what possibilities are available to overcome them to develop the technology chain and its components?
- What policies at the company, branch, industry, economy level constrain or support the development of technologies from the chain and the technology chain in its entirety?

3 Technology transfer

Several stages can be highlighted in the process of developing a technology, at the end of which technology transfer is possible: 1. Generate and formulate an idea of innovative technology; 2. Confirmation of the principal possibility to realize the concept of technology through laboratory research; 3. Technology development; 4. Creating a production system based on developed innovative technology; 5. Manufacturing and commercialization of products manufactured through developed innovative technology.

In this context, the technology transfer can be treated as the marketing of the finalities obtained after each of the steps mentioned.

Figure 1 presents the stages of the technology's development after which technological transfer is possible or occurs in a two-coordinate system: the degree of economic determination - the degree of technical determination. Along the way of the stages of technology development, the levels of its determination both in technical and economic terms increase. From a technical point of view, the functions, parameters, areas of application, restrictions, etc. become clearer. From an economic point of view, the economic effects and the conditions in which the profit takes place become clearer.

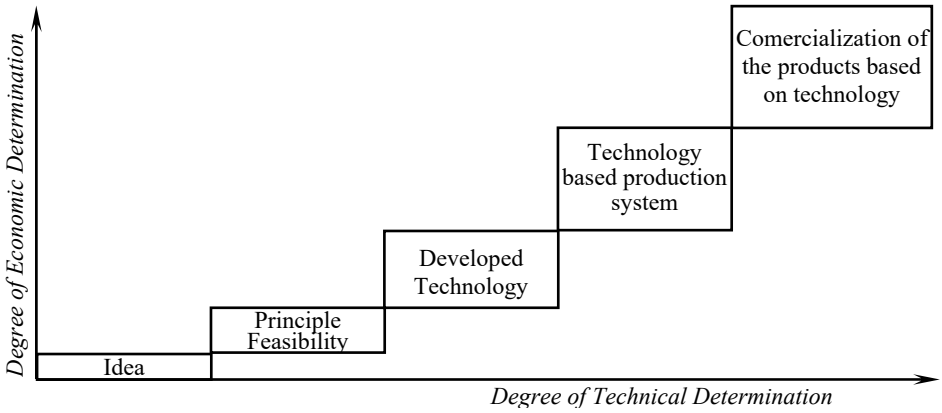

Fig. 1. The technical and economical values of the results of development stages of the technology.

Each stage requires new investment, the work and knowledge and can be finalized with the sale of technology to the respectively degree of development. Sale of technology does not interrupt the chain of development stages, but changes the technology developer. It is noticed that with the advancement of the stages from the technology's idea to the commercialization of the products based on the technology, the financial flows resulting from the sales are increase, as well as the expenses.

Commercialization of the idea of technology. The formation of the technology idea can be accomplished through several activities. From the legal point of view, the innovative ideas of technologies are object of the rights that protect the form but not the content of the

idea, because once it (the idea) becomes known to others, its value suddenly falls. Thus, selling of the idea occurs with complications and at a price often low. The low price is also caused by the uncertainty of the technical reproduction of the technology idea under the characteristic conditions for practice.

Commercialization of the results of scientific research. The basic result of a research is the principal confirmation of the feasibility of the innovative technology idea, the determination of the parameter intervals and the restrictions for them. Another result of scientific research is the objects of intellectual property obtained (patents, utility models, know-how etc.). These results represent a material asset. The commercialization of technology at this stage is more expensive than the previous one, but the price of licenses is low enough because of the risk of its widespread use.

Commercialization of the developed technology. The technology development phase can finished with: results of constructive and/or technological development, conception projects and technical projects, detailed design documentation, technological regulations, sample manufacturing and testing, acceptance tests, etc. These results are objects of intellectual law and the main technology commercialization scheme is the licensing agreement for technology transfer. The licensing agreement may contain, besides the license, references to: technical and technological documentation, technological machines and equipments, technical assistance, personnel training, post-sales services, etc. Each component is valued as part of the price.

The technology transfer through the commercialization of the technology-based production system is an important concern for innovation companies, because the price in this case is well above the price of the technology. The technology-based production system offers an extra degree of protection, technology being "hidden" in the structure of machines, devices, tools, control systems, etc. Commercialization of these systems makes technology more "open", but "opening" requires effort, sometimes substantial.

The commercialization of "products manufactured through technology" is based on the broad knowledge of the results of the use of technology, the latter remaining practically unknown by the final beneficiary. The attractiveness of the transfer of technology through marketed products is fully related to the quality of the manufactured products and this technology-quality link, which performance must be clearly seen by the end-user.

4 Conclusions

Technological transfer is a complex and varied process, being realized out at different stages of technology readiness level. The technology transfer strategy and tactics are strongly influenced by the degree of technology's readiness level, systemic character, functional orientation and universality, technical and economic determination degrees that can be specified and determined in accordance with the stages of technology life cycle.

References

1. B. Belina, A. Mazurkiewicz, T. Giesko, W. Karsznia, Economics and Management, **7**, 3 (2015)
2. A.V. Gavrilûk, Èkonomika i upravlrnie. Èkonomičeskie nauki, **1,** 122 (2015)
3. American Bureau of Shipping. Guidance notes on qualifying new technologies (2017)
4. U.S. Department of Energy, Technology Readiness Assessment Guide (2011)
5. M. Héder. The Innov. J.: The Public Sector Innov. J., **22**(**2**), 3 (2017)
6. Manufacturing Readiness Level (MRL) Deskbook. Version 2.0 (2011)