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Abstract

Higher education institutions (HEIs) play the key role as the link to encourage science and business partnerships within innovation systems worldwide. Notwithstanding one of the most important issue is to increase Lithuanian innovation potential. This dissertation analyses the problems of inefficient technology transfer (TT) and commercialization process, financial and human resource allocation at universities. The object of the research is the efficiency of technology transfer process (TTP) in higher education institutions. The analysis of technology transfer offices (TTOs) within the TTP allows the best model to be suggested for the evaluation of TTP as well as the improvement of TT results in the future perspective. This model is designed to assess the performance of the HEIs, to identify key indicators that demonstrate the efficiency of TTP, allowing to design future strategies to improve the efficiency of HEIs TTP financial and human capital.

The goal of the dissertation is to examine TT process, propose and empirically test the efficiency evaluation model of the technology transfer process at HEIs. It is important to assess how the institutional (TTO employees, tasks, PhD-share) and regional (industry concentration, start-ups, patent applications) factors of TTO influence TT performance and commercialization.

This research work resolves a few key tasks: 1. To conduct a theoretical analysis of the TTP (discussing the concept of the TTP and the key attributes, reviewing the foreign TT models, discussing factors encouraging the improvement of the TTP); 2. To perform a theoretical analysis of the efficiency of the TTP activities; 3. To create an original TTP efficiency evaluation model based on a comparative analysis of multi-criteria research methods suitable to perform evaluation of TT activities of HEIs; 4. To conduct an empirical research and to validate the efficiency evaluation model of TTP using multi-criteria research tools (FARE, TOPSIS, MULTIMOORA, COPRAS and DEA), to gather and aggregate the research data needed to evaluate the efficiency of the TTP, and to create a database for empirical research; 5. To analyse and discuss the research results of TTP, to formulate final conclusions to assess HEIs' TTP efficiency, which would help to improve the performance of economic and other indicators through a more efficient allocation of financial and human resources.

Analysis of research results shows that the number of employees working in TTO correlates with the number of intellectual (inventions) products that are being developed during the research and development (R&D) process.

Reziumė

Visame pasaulyje aukštojo mokslo institucijos (AMI) atlieka svarbų vaidmenį jungiant ir skatinant mokslo ir verslo partnerystę inovacijų sistemoje. Lietuvos AMI vienas iš svarbiausių iššūkių yra didinti Lietuvos inovacijų potencialą. Disertaciniame tyrime analizuojama technologijų perdavimo (TP) ir finansų bei žmogiškųjų išteklių efektyvaus paskirstymo problematika Lietuvos universitetuose. Disertacijos tyrimo objektas yra AMI technologijų perdavimo proceso efektyvumas. Atliekamos technologijų perdavimo biurų (TPB) veiklos ir TP proceso (TPP) analizės pagrindu kuriamas TPP veiklos vertinimo modelis, leidžiantis efektyvinti TP procesą ir gerinti TP rezultatus ateityje. Šis modelis skirtas įvertinti AMI TPP veiklos efektyvumą ir nustatyti pagrindinius TPP efektyvumo rodiklius. Tai leidžia numatyti ateities strategijas pagerinti AMI TPP finansinių ir žmogiškųjų išteklių kapitalo efektyvumą.

Disertacijoje siekiama ištirti TP procesą, sukurti ir empiriškai aprobuoti aukštojo mokslo institucijų technologijų perdavimo proceso efektyvumo vertinimo modelį, įvertinant TPB institucinių (TPB darbuotojai, užduotys, akademinio personalo, turinčio mokslinį laipsnį, dalis) ir regioninių (pramonės koncentracija, startuoliai, patentinės paraiškos) veiksnių įtaką TP veiklai bei komercinimo rezultatyvumui.

Šiame moksliniame darbe sprendžiami tokie tyrimo uždaviniai: atlikti teorinę TP proceso analizę (pristatant TPP sampratą ir pagrindines sąvokas, apžvelgiant užsienio šalių TP modelius, ir veiksnius, skatinančius TPP tobulėjimą); atlikti teorinę TPP veiklos efektyvumo vertinimo analizę; pasiūlyti originalų TPP efektyvumo vertinimo modelį, besiremiantį lyginamąja daugiakriterių tyrimo metodų analize ir tinkantį AMI veiklos TP srityje įvertinimui atlikti; atlikti empirinį tyrimą ir aprobuoti pasiūlytą TPP efektyvumo vertinimo modelį naudojant daugiakriterius tyrimo įrankius (FARE, TOPSIS, MULTIMOORA, COPRAS ir DEA), surinkti ir agreguoti tyrimo duomenis, reikalingus TPP efektyvumui vertinti, sukurti duomenų bazę, reikalingą empiriniam tyrimui atlikti; išanalizuoti ir aptarti gautus TPP tyrimo rezultatus, suformuluoti galutines išvadas apie AMI TPP efektyvumą, kuris padėtų pagerinti ekonominių ir kitų rodiklių rezultatus per efektyvesnį finansinių ir žmogiškųjų išteklių paskirstymą.

Tyrimo rezultatų analizė rodo, kad darbuotojų, dirbančių TPB, skaičius koreliuoja su intelekto (išradimų) produktų, kurie kuriami mokslinių tyrimų ir eksperimentinės plėtros (MTEP) proceso metu, skaičiumi.

Notations

Abbreviations

TT – technology transfer;
TTO – technology transfer office;
TTP – technology transfer process;
HEI – higher education institution;
TTVO – technology transfer and valorization office.

Contents

1 The annexes are supplied in the enclosed compacty disc.

Introduction

Problem Formulation

Technology transfer (TT) processes including knowledge transfer and application in industry, are not sufficient enough in Lithuanian higher education institutions (HEIs). The innovativity level of the country is not satisfactory. Therefore, the government is encouraging HEIs to improve the transfer of the knowledge generated at universities, find the application of it in industry, seek the greatest return from innovative technology commercialization, and, this way, to make a greater contribution into the economic development of the country.

According to the strategy *Europe 2020,* developed by of the European Commission, the priority should be given to national and private investments on R&D (that should seek 3% of GDP), and which are closely related to the needs of economy development based on knowledge and innovation (European Commission, 2016b). Lithuanian National Progress Programme of 2014–2020 foresees that till 2020 Lithuanian investments on R&D should seek 1.9% of GDP (Lietuvos Respublikos Vyriausybė 2012). The analysis of the situation show a gradual but not sufficient enough increase of the expenditures on R&D. According to the statistical data, provided by Statistics Lithuania (2014a, 2015, 2016, 2017), the expenditures on R&D were as follows: 0.89% GDP (0.57% GDP – HEI; 0.32% – business) in 2017; 0.85% (0.55% GDP – HEI; 0.30% – business) in 2016, 1.04%

GDP (0.76% – HEI; 0.28% – business) in 2015. While in the European Union, expenditures on R&D were stagnated at around 2.03% GDP between 2014 and 2016 (Eurostat 2018). Although the situation is improving, the cooperation between business and science sectors is still unproductive (*the Global Competitiveness Report 2017–2018)*. Under *the Lithuanian Progress Strategy* ("Lietuva 2030"), one of the most important problems raised is not flexible higher education system, giving not enough attention to improvement of TT system in general and to encouraging the creation of new innovative businesses (like spin-offs at HEIs). According to the European Commission's *European Innovation Scoreboard*, the results for Lithuania are as follow: the 21st place (out of 29 countries) in 2017, the 25th place in 2016, the 26th place in 2015 (European Commission 2017, 2016a, 2015).

Summing up the facts, it is seen that the process of knowledge and TT in HEIs is not efficient enough in Lithuania, the innovation level is quite low. Moreover, the expenditures on R&D are not satisfactory when compared with European HEIs. Therefore, there is a growing demand and necessity to evaluate TT and make decisions, which would promote the efficiency of HEIs.

Relevance of the Thesis

According to *the Lithuanian Innovation Development Programme of 2014–2020*, low innovativeness in the country is the result of insufficient expenditures on R&D and low business innovation capacity.

Considering no previous research was conducted, with the focus on evaluation of efficiency of HEIs (universities, research institutes, university hospitals etc.), organizing and taking part in the process of technology transfer. There are only several research studies suggesting ways of performance measurement of education institutions in general, and no studies on evaluation of TT and commercialization processes to refine economic results. This research aims to fill this current gap.

Aiming to address this issue, the research problem was formulated in order to answer the following questions: what problems are higher education institutions facing in the field of technology transfer? Can the experience of successful development of technology transfer in higher education of other countries be used in Lithuania? What are the factors promoting TTP development? How the efficiency of technology transfer process, conducted at Lithuanian HEIs, can be evaluated and measured? What efficiency evaluation model and research methods would be suitable for evaluation of technology transfer process organized at Lithuanian HEIs?

The Object of the Research

The object of the research is the efficiency of technology transfer process in higher education institutions.

The Aim of the Thesis

The aim of the dissertation is to develop the model for the evaluation of the efficiency of the technology transfer process at higher education institutions.

The Tasks of the Thesis

1. To conduct the theoretical analysis of technology transfer process in higher education institutions (including the discussion of the main concepts, related to technology transfer process; the description of existing technology transfer models in other countries and discussion of factors, promoting TTP development).
2. To analyse evaluation of efficiency of TTP at HEIs (estimating implemented TTP activities, related parties, concomitant performance indicators, influencing factors, highlighting the consistent pattern and tendencies in the field of TT and commercialization at HEIs).
3. To propose the original TTP efficiency evaluation model, based on comparative analysis of multi-criteria research methods and tools, suitable for evaluation of TTP in HEIs.
4. To perform an empirical research, aimed at approbation of a proposed TTP efficiency evaluation model for HEIs, using multi-criteria research tools (FARE, TOPSIS, MULTIMOORA, COPRAS, and DEA), conducting interviews, collecting and aggregating the empirical data.
5. To analyse and discuss the final results of investigation the TTP specifics in HEIs, to draw general conclusions regarding the efficiency evaluation of HEIs TTP performance that helps to get greater results of economic indicators during efficient allocation of financial and human resources.

Research Methodology

The following research methods are chosen: quantitative analysis through interviews with TTO managers to highlight the most valued indicators with which to evaluate TTP performance at HEIs; the Factor Relationship (FARE) method was chosen to set weights for indicators of TTP performance by the highest impact (importance) on the TTP; the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS)) method is suitable to rank indicators by the greatest performance results, and conclude on the indicators for the empirical research; afterwards, the Multi-Objective Optimization by Ratio Analysis (MULTIMOORA) and Complex Proportional Assessment (COPRAS) multi-criteria decision-making (MCDM) tools, which are able to rank HEIs and select the sample for the research; the Data Envelopment Analysis (DEA) method is intended for efficiency evaluation of TTP performance of HEIs, implementing TT and commercialization activities. The validity of the study (data validity) lies in the triangulation of data analysed from the different theoretical and methodological perspectives.

Scientific Novelty of the Thesis

This doctoral dissertation provides these new results for social sciences:

1. Proposed original model to evaluate the economic efficiency of HEIs' TTP performance. The model is oriented to the specificity of the TT activity in HEIs, and can also be adapted to HEIs in other countries.
2. The methodology of scientific novelty is based on a set of selected target group of indicators and a set of suitable research-tested tools integrated into the model, which allows the measurement of the efficiency of HEIs' TTP performance.

Practical Value of the Research Findings

1. The created and empirically tested original TTP efficiency evaluation model, with available resources and without losing the quality of activities, is serving: the heads of HEIs to evaluate the efficiency of R&D and innovation performance results, for targeted use (revise) of financial and human resources, and to set improvement goals to increase economical and other indicators (the number of patents, income from international, national projects, contract works, etc.); for TTO unit to

evaluate achieved results, taking into account influencing factors' group, and foreseeing a strategy for increasing the efficiency of indicators; at the level of public authorities, as a useful tool for allocating financial resources for higher education institutions.

2. The dissertation has identified the group of success factors influencing the TTP, the efficiency of R&D and innovation performance results. The knowledge relating to these factors enables decision-makers to make more efficient decisions on the use and allocation of resources to anticipate necessary changes.
3. Empirically tested model will be useful for policymaking and implementing institutions is useful for achieving the envisaged R&D and innovation goals at the country, and for evaluating HEIs and funding them; and for HEIs for self-evaluation to improve the efficiency of TT activity. Improved HEI efficiency will help to achieve the goals of the Lithuanian Strategy 2030 and bring Lithuania closer to a higher level in the area of R&D and innovation. Thus, the fully improved Lithuanian results will have a positive influence on the position of Lithuania on the European Innovation Scoreboard and strengthen the indicators of competitiveness.

The Defended Statements

1. The research on the evaluation of TTP has shown that the following indicators are suitable to assess the efficiency of HEIs' performance: the revenues from international R&D projects and from order-based R&D works; funding per researcher; international patent applications; income from national R&D projects; the number of staff in the TTO; the number of researchers at HEI and other among others.
2. The group of factors (entrepreneurial culture; R&D production implemented in the market; the inventor of technologies; academic recognition; the competitiveness of the region; dissemination of works; the country's policy on TT; motivation tools; the accessibility of technologies for industry; IP protection; TT skills; the organizational structure; the ability to change and make decisions; communication skills) influences the efficiency of TT.
3. The framework of proposed tools of FARE, TOPSIS, MULTIMOORA, COPRAS, DEA, integrated into the original model, which allows the efficiency of HEIs performance from the TT aspect to be evaluated. FARE and TOPSIS matchmaking served in choosing the indicators for the evaluation of the efficiency of TTP performance;

COPRAS and MULTIMOORA were selected as the ranking tools to choose HEIs for empirical research. Meanwhile, the DEA tool measures the efficiency of HEIs' TTP.

Approval of the Research Findings

The dissertation research findings were disseminated among three publications focusing on the subject of the dissertation (in the Clarivate Analytics databases articles collection) (Stankevičienė *et al.* 2017; Stankevičienė, Dimitrios, & Kraujalienė, 2019; Kraujalienė 2019). The results were also presented at the conference on the subject at international level.

The author has made five presentations at the international scientific conferences and scientific seminars:

- Kraujalienė, L. "COPRAS approach for efficiency assessment of R&D expenditures in technology transfer process", Contemporary Issues in Business, Management and Education, Vilnius, Lithuania, 2017.
- Kraujalienė, L. Four scientific presentations have been made at the scientific seminars for PhD students at the Faculty of Business Management (one each academic year during the period of 2015–2019).

Six scientific visits during doctoral studies have been made:

- Visit at the New University of Lisbon, Portugal, 2016.
- Visit at the conference "Edu Data Summit" at Great Britain, London, 2016.
- Visit at the Technical University (TU) Darmstadt, Germany, 2017.
- Visit at the University of Latvia, Riga, Latvia, in parallel participating at the "European Quality Assurance forum", 2017.
- Visit at the Riga Technical University, Riga, Latvia, 2018.
- Visit at the "Baltic Science Day", Riga, Latvia, 2019.

Structure of the Dissertation

The structure of the dissertation is as follows: the introduction, three chapters of the dissertation, general conclusions, references, author's publications on the subject of the defended dissertation, related 6 annexes. The total scope of work is 140 pages, excluding annexes; 52 numbered formulas are used, 17 pictures and 18 tables, 230 references are included in the dissertation.

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1

The Theoretical Analysis of Meaning and Main Concepts of Technology Transfer Process in Higher Education Institutions

This part of the dissertation reviews the scientific literature on the topic of TTP economic performance in HEIs, and discusses TT challenges and unmet needs.

The findings of Chapter 1 have been published in 2 scientific papers (Stankevičienė, Kraujalienė, Vaiciukevičiūtė 2017; Stankevičienė, Kraujalienė 2017).

1.1. The Analysis of the Main Concepts Related to Technology Transfer Process

Higher education institutions (HEIs) are playing an important role within innovation lifecycle as the concentration of science knowledge inside HEIs. This knowledge should be converted into innovative solutions and commercialized to get the economic profit. Latter action will bring economic benefit firstly for HEI and for the country economy as well.

The general concept of technology transfer (TT) is used to define the new phenomenon. The core objective of TT is to find applications in industry and society for the knowledge generated at higher education institutions. An effective technology transfer process leads to close cooperation and interaction of researchers and developers at scientific institutions with the business institutions.

TT activities include processing and evaluating of inventions, filling for patents, technology marketing, licensing, protecting intellectual property arising from research activities and assisting in creating new businesses and promoting the success of existing ones.

Technology transfer (TT) in this dissertation is understandable as a number of actions of dissemination and the transfer of R&D and innovation knowledge and results, conducted at HEIs, to the market.

Technologies in this dissertation are the products of the intellect of HEI scientists.

Technology transfer and valorization offices (TTVOs), or technology transfer offices (TTOs) in HEIs have the mission to develop innovative ideas from within the walls of university laboratories, help HEIs to find business partner institutions interested in implementation of innovations, and finally to sell science knowledge to meet the market needs. In other words, TTVOs ensure a balanced symbiosis between HEIs and the private sector. The developed public-private partnerships help to encourage TT activities and acquire lucrative deals. These results are concomitant with HEI prosperity, growing recognition and prominence, so much desired by all HEIs and their academic staff.

Overviewing contemporary research papers, which analyse problematic TT areas, one can notice that much attention has been paid to the TT and valorisation phenomenon at HEIs. Presented research results show that TT activities conducted in HEIs are insufficient and often not productive enough to bring great economic results; besides there is no suitable tool to measure the efficiency of TT performance of HEIs.

This doctoral dissertation aims at development of the framework and the tool to measure the efficiency level of TTP performance in HEIs necessary for improvement of economic situation of HEIs.

Van Dooren *et al.* (2010) state, that the performance management in the public sector is a very important indicator to show the efficiency of institutions, including HEIs, namely, abilities of HEIs to create and implement new knowledge, conduct TT and organize commercialization activities. In this dissertation, the technology transfer performance is understood as performance of organizational system and as a competence or capacity. The quality of performance can be measured by the quality of the number of actions being performed, or by the quality of achieved goals because of mentioned actions. Performance is conceptualized as quality of actions and quality of achievements (Van Dooren *et al.* 2010).

The meaning of "efficiency" in this dissertation means that in TT activities an efficient HEI is not able to produce more R&D and innovation output (without reducing quality), given its existing current financial and human capital and other inputs. The efficiency of TT activities is a valid performance measure, as the provision and support of R&D and innovation by HEIs at a given level of quality, taking into account current resource constraints, is a major goal of HEIs when the science production is directly related to government financial support (Abbott, Doucouliagos 2003).

In economics, there are two main flows of the use of the term "efficiency". One involves such variants as Pareto efficiency. This relates to the allocation of organizations' outcomes within different players. The main idea of Pareto efficiency can be applied to the input-output multidimensional vector of technological systems and marks out that an (input) vector is efficient technically only if the increasing of any output or decreasing of any input is feasible only by decreasing some other output indicators or increasing some other input measures. The second term is widely used in business economics and qualitative principles of simplified business operations that are seen as a "philosophy of efficiency" (Scholz, Wellmer 2015).

Efficiency is a tool and not a panacea. Efficiency concept is perceived as an evaluation of the organization's overall impacts. In this respect, an efficiency concept is close to the total benefit in its meaning. The assessment of efficiency is implemented by input and output quantification and numerical representation (Scholz, Wellmer 2015).

There is also dimensionless efficiency and efficiency based on dimensions: efficiency results (scores) can be measured for quantitative output and input. The calculated efficiency score (input and output) depends on the construction's goal and the use of the efficiency result. The dimensions on their own do not change efficiency's significance. Efficiency results have to be interpreted in a concrete context of measure (Scholz, Wellmer 2015).

This Subchapter discusses the meaning of efficiency, TT, valorization and commercialization activities' performance results, important performance indicators of TTP, and suitable research techniques to measure the performance.

In the past years, and still today, knowledge is a significant resource of every organization. Knowledge should be interpreted in the most understandable way for the target group or information recipients (Alavi, Leidner 2001). This means that scientists may have great ideas but they must be able to explain what is in their minds in a simple, comprehensible way, but this often is not the case. For instance, communication is often very difficult between scientists and business people, because scientists express their thoughts in deep science language, when business wants to understand the sense of an idea quickly. TTO staff provide help in communication, converting scientific meaning into easy understandable language. Thus, TTOs play an important role in TTP.

According to Lee and Choi (2003), knowledge is very important and plays a critical role as the basis of being competitive in the market. Going further, authors mentioned that the next three factors of knowledge management to get the profit from TT are as follows:

– executors (trust, learning, collaboration, formalization, centralization, information technology support and T-shaped skills);
– processes (combination, internalization, externalization, socialization);
– performance.

Information technology instruments help in the knowledge combination issue (Lee, Choi 2003). Therefore, the tool for measuring the efficiency of TTP should incorporate information technology's solutions to make the evaluation easier for users.

One research study was intended to analyse the role of TTOs in HEIs in China, and to identify the process of TT from university to industry players in China (Abbas *et al.* 2018). Going forward, TT is interpreted as the process of sharing and spreading scientific discoveries and production methods, skills and knowledge, and innovative solutions among science-business organizations, such as universities, government agencies, private companies, and other institutions (Audretsch *et al.* 2012a, 2012b).

Stages of technology transfer. Metcalfe and Cantner (2003) state that TT consists of several stages: disclosure of inventions that could be converted into patent applications (depending on certain conditions: the invention can be used in industry, is an obvious improvement on existing or a newly discovered method or technology); the application becoming a national or international patent; an acquiring exclusive or non-exclusive license; income from the license and (or) an engaged start-up company. Szulanski (2000) noted that TT is not an act, it is about process, while Spenser (2006) named TT as an art.

Friedman and Silberman (2003) explain TT as the process whereby invention, know-how or other intellectual property (IP) from academic research stages is transferred to industry and in that way commercialized using the licensing method, which causes economic growth.

Knowledge and TT is built on the interaction between tacit and articulated knowledge to take into account such conditions as the level of the individual, the small group, the institution, as well as the inter-organizational indicators (suppliers, customers, competitors). This model is constructed on Western and Japanese knowledge and a TT management model regarding organization structure, characteristics of organizations, staff engagement, career possibilities. To ensure effective knowledge and TT, the authors wrote that management (as the important part of the process in efficient allocation of financial resources) is similar to the N-form organization's structure in Fig. 1.1 (Hedlund 1994):

– combining things rather than dividing them;
– focusing the company on combining knowledge items rather than diversification;
– temporary combining of staff and HEIs rather than constant structures;
– choosing lateral communication is better than vertical;
– the importance of staff at "lower" levels in interdivisional, inter-functional, as well as international dialogue, excluding coordination within managers' at high positions;
– heterarchy as the basic structure rather than hierarchy;
– top management as those who play the role of architect or catalyst of communications.

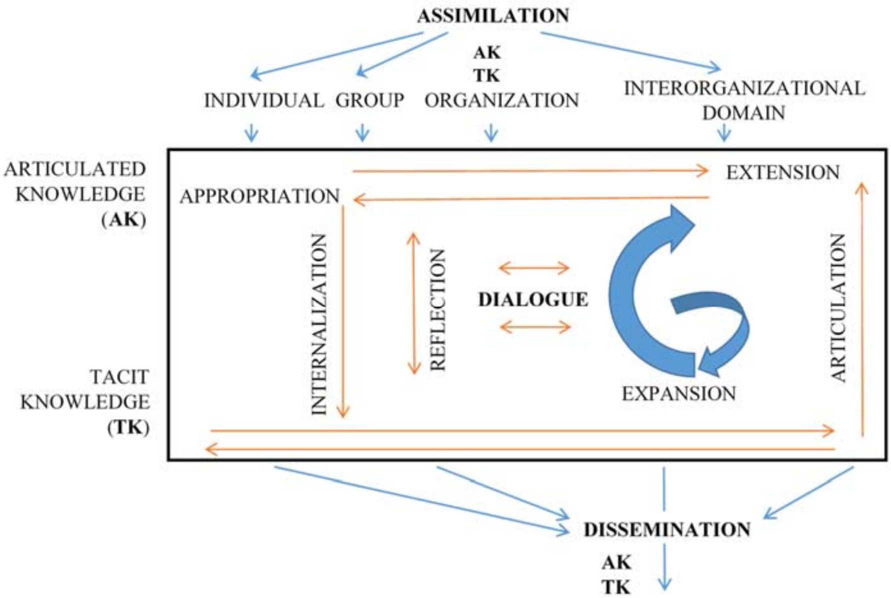


Fig. 1.1. The key parties participating in economic evaluation of technology transfer process in higher education institutions (adapted from Hedlund 1994)

Economic TT and the valorization process play an important role in connecting researchers with business to obtain economic utility. Science-business activity is an important instrument in the valorization of research capital to realize it into products or services.

For a clearer understanding of the terms “TT” and “valorization”, further details are provided. TT is concomitant with the following complex activities:

1. Identification of ideas (through internal marketing works, ownership dilemmas).
2. Protection of intellectual property (IP), based on the internal patenting strategy.
3. Conversion of ideas to understandable language.
4. Marketing steps towards customers to promote the technologies.
5. Economic realization of IP through licensing (evaluation and negotiation processes), or creation of spin-offs (started from business plan).

TT is complemented by the valorization process to obtain economic results, which is finally completed by commercialization activities and bringing economic performance results (see Fig. 1.2).

Commercialization is led by a number of selling steps in the economy towards invoking an idea (valuable knowledge, technology, solution) to become an attractive and successful product, service or result for the market need served.

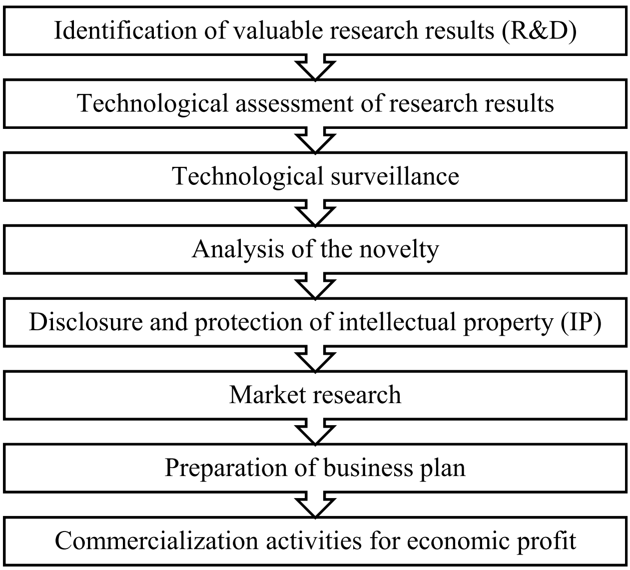


Fig. 1.2. The main actions performing in economic evaluation of technology transfer and valorization process in higher education institutions (compiled by author, adapted from Train2 2017)

It is recommended to be aware of commercialization process elements, such as the identification of a possible market for IP realization, the preparation of marketing strategy, brainstorming for solutions, attractive design, production line, trainings needed, IP management, and financial aspects such as raising capital.

Research results should be commercialized through selling, patenting or using other ways to gain economic benefit. There are a number of studies in the literature regarding licensing, patenting, innovation, venture capitals, alliances and strategic groups that play important roles in commercialization processes and economic growth for universities (Becerra *et al.* 2008; Cavusgil *et al.* 2003; Cooke, Mayes 1996; Keil 2004). Research studies to evaluate the cost of resources in TTP have been performed many years ago, such as, for instance, by Teece in 1977.

Metcalfe and Cantner (2003) also wrote that of about half the invention disclosures accepted for patent applications, only a half become patents, and a third of patents had license way while about 10–20% of licenses yield a significantly high income. Therefore, it is not as easy to license patents and achieve great results from licenses as the Lithuanian government expects.

The results of TT and valorization processes show the HEIs' level of efficiency and abilities to implement industry-university commercialization activities to gain economic benefits. In other words, the performance of TT and valorization activities show entrepreneurial matchmaking among the ideas' authors, TT staff and industry players for financial advantage. The main actors in TT and valorization activities in HEIs are scientists, administration human resources (especially heads of departments), TT and valorization staff, industry representatives, country's government.

1.2. Technology Transfer Models: Foreign Experience

The Lithuanian market is insufficient for the TTP to bring higher results to the government (Kiškienė 2009). According to Kiškienė (2009), a TT model helps to improve scientific knowledge and innovation within universities. Therefore, effective science as well as IP results could also depend on economic efficiency of TTP. TT performance can be measured by the quantity of patents comparing all Lithuanian universities. Efficiency could be influenced by the staff of TTOs (inside factor), and outside factors (e.g., concentration of industry). This dissertation will cover the assessment and collected data of possible indicators that could influence the economic performance of TTP. In this dissertation, the problem is in assessing unsuccessful economic performance of HEIs'. This is the result of unsuccessful management of scientific knowledge and TT. The main mission of

Lithuanian universities is the implementation of education activities, rather than doing business. Lithuanian government encourages Lithuanian universities to give more attention to improving the management of knowledge transfer is requiring incorporating good management and entrepreneurial abilities and selling or licensing university intellectual property, to start new businesses (spin-off) companies.

Examples of good practice from abroad show that, unfortunately, to acquire such management and entrepreneurial abilities and good skills in economic commercialization of science results will take years of development and study before good management abilities can be achieved by HEIs. The existing TT model in Lithuania is inefficient if it is valued the position of the country's innovation level on the European Innovation Scoreboard, when Lithuania is somewhere in the end. TT activities started to be implemented over 10 years ago in Lithuania, but it was seen as sharing information from university to society, realizing science works with industry, organizing qualification trainings, consulting, etc. However, these activities were not the main priorities of HEIs. Nowadays, Lithuanian universities are just beginning to create a certain structure and culture within universities to form TTOs and manage science and innovation processes, to encourage science-business collaboration and commercialization of IP. Now the Lithuanian government is pushing HEIs to earn money, and in that way to reduce the government budget. For this purpose, the recommendations were prepared for universities to conclude on IP policy and prepare all the necessary documentation to manage IP inside universities, to prepare rules for starting young companies (start-ups, spin-offs) and conditions of sharing future economic benefits (royalties) among related parties.

Universities should think of ways to utilize research outcomes, such as IP. In order to realize this purpose, HEIs need to build very good cooperative ways with industry to prepare the platform for promoting IP through TT activities. Although, according to Clarysse *et al.* (2007), usually the problem of unsuccessful commercialization exists when HEIs, as a rule, overestimate their IP (technology, patent or know-how), which is an important barrier to attracting venture capital or private funds of investment in technology development, thus negotiations could be complicated.

Thursby *et al.* (J. G. Thursby, M. C. Thursby 2001; Thursby, Kemp 2002) performed the research studies regarding economic commercialization of IP (for example, licensing), and provide recommendations to increase the efficiency of TTP. While Davis *et al.* (2018) provided comprehensive analyses on the law and legislation of governing patents, trademarks, designs and copyright.

There are several TT models in Europe and America that are presented in this dissertation. Why does the American model not work in Europe? The main difference is that for European society, trust is very important (TTO and scientists, students). For that reason, European universities as a rule have TTOs inside universities so as to be as close as possible to research staff (idea generators), although TTOs can be situated outside HEIs, or be virtual-based. However, in the latter case, the communication between research staff and TTO should be ensured by a plan for frequent communication in order to foster the trust aspect. In that way, scientists would find it as easy speaking with TTO managers as with own "family" members. If this communication path is not established, then if the TTOs are outside universities, as c is the case in a TT model in America (e.g. Silicon Valley in Boston), Lithuanian scientists will not have contact with TTO staff at all, because of a lack of trust. This is one of the main differences in cultures in different parts of the world. Thus, the American TT model would not work efficiently in Lithuania.

The importance of trust in the TTP in Europe was shown by Lee and Choi (2003), whose study confirmed that trust has an impact on knowledge creation. In addition, the importance of trust was discussed by Mike Smith during his presentation "Co-creation of Innovation" at the fourth International Conference on "Innovation through Knowledge Transfer − InnovationKT-2012", when the influence of trust on risk through co-creation of innovation between science institutions (universities) and business companies was highlighted (Howlett 2010).

Bjorkman and other authors (2004) in their research work, using the methodology of personal interviews, gave evidence that nationality of staff between organizations does not have an influence on knowledge and the TTP in terms of economic performance results (Björkman *et al.* 2004).

In this work, I observe existing TT models of Lithuanian universities, and finally conclude that the TT model is influential on the economic performance of the TTP. TT in different countries is acting differently. Several good experiences of some countries as USA, Germany, and Belgium are presenting in this dissertation. Selection of the certain TT model from abroad and adapting it or the exact case affect the overall economic performance of HEI.

Kiškienė wrote that on the basis of analysis of the situation in the USA, where there is clear policy of knowledge and TT and that model is based on a market failure paradigm, the USA model corresponds to the existing economic, social and technological conditions in the USA. According to good practice in the USA, income generated from taxes is increasing the implementation of knowledge and TT measures (Kiškienė 2009).

The case of TTP model in the US state of Massachusetts is a region where an advanced biotechnology cluster exists. It starts with basic research and fundamental support by the Federal Government, leading to research in the biotech sphere. Favourite research institutions then take the following steps: they implement their discoveries, develop the IP, and train the researchers and scientists who form the biotech spin-off companies; where a cluster of research institutions exists, new spin-offs eventually form. Alliances are important between the biotech companies (spin-offs) and the big pharmaceutical companies. More important for the region are supplies of investment capital (such as experienced investors), executive talent, trained researchers and support actors: accountants, lawyers, real estate professionals helping to establish companies. All mentioned aspects and professional teams are very important to get economic profit for HEIs. Massachusetts Institute of Technology (MIT) is situated in the USA; the Boston/Cambridge area has a large concentration of the most famous research institutions as universities and research hospitals, which are funded by the US Federal Government (the bigger part), and particularly the National Institutes of Health (NIHs) (the lower part), for performing the basic discovery research works in biology and biomedicine. Educational institutions in MIT select the best and brightest national and foreign students for studies, ensuring an inward brain drain. Around 40 per cent of the high-technology spin-off companies are formed by alumni of MIT. The admission criterion for students is leadership because they usually possess the self-confidence to think unconventionally and the responsibility to take risks (failure is a learning opportunity, not a black mark), including the risk of forming or joining an entrepreneurial company. Many alumni and friends of MIT students visit the campus. They have started their companies based on MIT technology. The culture in MIT leads others to think in terms of "I can do it too", and it offers many opportunities (e.g. business plan competitions) to seek advice and strategies. Dozens of students' business plans achieve venture capital funding. Biotechnology companies require licensed IP, therefore HEIs should protect this and file it into the portfolio. MIT has a Technology Licensing Office situated outside universities and university hospitals. The function of this office is that of a virtual incubation that accelerates and encourages the formation and growth of start-ups, supporting in areas such as: organizing meetings with inventors to help in defining the direction of the start-up and their own career, which can lead to introducing inventors to consultants to create a business strategy and write business plans; introducing inventors to venture capitalists or angels. The MIT model for initiating start-ups is dependent on a nature, and having an entrepreneurial community surrounding HEIs. To achieve the success of TT, a legal, relatively non-bureaucratic infrastructure must be created, and sufficient funds to protect their IP and file patents must be available for HEIs. The formation of start-ups and development of clusters requires talent: world-class researchers; trained and talented TT professionals; entrepreneurial founders of companies; staff with scientists and managers for the companies; knowledgeable investors to fund as well as guide the company, and support staff professionals (Nelsen 2005).

Belgium is placed among the most innovative countries in the EU (top 10) (European Innovation Scoreboard, 2017). The Flanders region in particular is the most advanced among the three regions of Belgium and has a strong life sciences and biotechnology sector. There is a huge industry and business sector, comprising financial groups, universities and research centres, so the technology transfer and commercialization of new inventions and innovations has been successfully developed. The Flanders region has established the institute without borders, with a technology transfer office within it. The Flemish Institute of Biotechnology, VIB, was founded in 1996 as a non-profit organization. This institute collaborates with four different universities (Ghent University, University of Antwerp, University of Louvain, Brussels Free University), and connects the best research teams working in the field of life sciences. This institute should meet the requirements planned for the next 5 years and ensure that the investment will produce the desired results. The VIB has a TTO for the commercialization of inventions, which serves the four mentioned universities. The entire team consists of 16 employees (12 technology transfer or invention scouting specialists), specializing in the relevant fields: 4 IP managers (two of them are patent attorneys); 4 or 5 are business development managers; 2 are start-up managers (managers new venture); 1 technology manager (business development manager); and 4 administration specialists, working in each of the cooperating universities. All 12 technology transfer specialists have a scientific (at least a master) degree. Eight professionals have at least 2 years' experience in industry, although none have a master of business administration or a doctorate in economics. Also, each of them has 6 years of TT experience. The specialization of the VIB TTO team is divided into three groups: IP management (identifying inventions, coordinating the registry of inventions, managing the IP, analysing the freedom to operate, assisting in licensing, TT, and starting new businesses (start-ups); TT (searching for inventions, business partners, negotiations with business, sales pitch, etc.); entrepreneurship (identifying commercialization of appropriate inventions, contributing to the creation of new enterprises, seeking investment, etc.). The VIB TTO team is fully responsible for scouting for and identifying inventions, and has meetings with the group of scientists at least once a month. It is very important to create a climate of mutual trust, which requires close and frequent communication between the TTO specialists and the scientists. The VIB TTO team has a clearly defined methodology for the successful finding of inventions and ideas' identification process. Therefore, trust is important in this example (Kurgonaitė 2015).

Within the EU countries Germany is the most developed in the R&D sphere. It is ranked in sixth place on the European Innovation Scoreboard 2017. However, if the innovation criterion was calculated according to the regions of the countries, the most innovative regions would be the southern regions of Baden-Württemberg and Bavaria. The German research centre Helmholtz-Zentrum Dresden-Rossendorf (HZDR) was founded in 1992. It belongs to the Helmholtz Association. This association was founded about 24 years ago. It connects 18 different research centres (situated in different German regions) into one network. The HZDR research centre has merged scientific groups from Dresden, Leipzig, Freiberg. The HZDR has a specialized department responsible for the commercialization of inventions: the TTO, which belongs to the Helmholtz Association's TTO network. The HZDR TTO consists of 10 teams of professionals: one IP lawyer, one patent attorney, one administrator and seven innovation scouters. These specialists are distributed in different institutions, according to their scientific knowledge and competence, to be as close as possible to the scientists with whom they have frequent meetings (1 or 2 times per month). The main roles of the invention identification specialist are: to be a contact person in collaboration with scientists and identifying scientific ideas; to be a contact person for communication with business (industry); to be a TT manager; to collaborate with the joint services TTO specialists in IP, licensing, entrepreneurship, funding spheres. In turn, the joint services TTO team collaborates with external services providers on IP management and licensing questions Ascenion GmbH), outsourcing (GWT-TUD GmbH), and entrepreneurship questions. The HZDR has implemented activities in three commercial channels: cooperation with industry (joint projects, strategic partnership, outsourcing, use of infrastructure for external users); licensing and selling of IP-protected technologies (exclusive licensing rights (as per the situation), exclusive licensing rights in a particular case, sales in a particular case, different contracts and payment models); entrepreneurship (creation of new businesses, creation of new companies on the basis of IP-protected technologies and know-how, use of local infrastructure, communication, etc.). The TTO has developed a clearly defined idea-finding and identification model for the invention, selection criteria electronic tools that determine whether the invention has commercial potential, what principle to apply for implementation and commercialization paths. Thus, the trust aspect is important to achieve effective collaboration results between the TTO and scientists (Kurgonaitė 2015).

The analysis of these last TT models shows that TTO should be established as close to universities as possible, or the use of other models, but ensuring the building of trust and establishing frequent periodic cooperation with scientists. Therefore, the efficiency evaluation model requires HEIs' internal TTO indicators to be taken into account for evaluation.

Kiškienė identified that a clear policy at a country level has a direct influence on the knowledge and TT model. Lithuania has no clearly expressed policy on the model of knowledge and TT. Every university has its own position and policy on this issue. Only some Lithuanian universities have prepared and accepted the documentation regarding the management of IP in HEIs: Vilnius University (VU), Kaunas University of Technology (KTU), Vilnius Gediminas Technical University (VGTU).

Kiškienė suggested a model for knowledge and TT for Lithuania based on the importance of strengthening the commercialization between science, business and the public sector to build a more efficient innovation process. This proposed model suggests paying more attention to additional TT management, improving general conditions and creating a favourable environment for knowledge and TT in order to obtain greater economic performance results.

Summing up, it was identified the challenge of not sufficient enough TTP economic performance in HEIs. Moreover, there is a need to evaluate the TTP, and to make decisions to improve the efficiency of TTP economic performance.

1.3. Theoretical Views of Technology Transfer Process and Relating Factors

The problem occurs when the sphere of knowledge and TT at HEIs is unsuccessful in terms of economic efficiency and performance results. Massachusetts scientists and students generate the highest results of TT by creating young companies (start-ups, spin-offs) and commercializing their results to get economic utility. The reasons for Massachusett's success are several: TT models are suited to the American public, as well as the cultural peculiarity; the concentration of similar "thinkers" and the best consultants (experts) in one area, as the campus in Stanford city.

This dissertation analyses TTO staff and its influence in an already created platform supported with resources, in comparison with new ones. The analysis and research will be oriented toward internal HEIs' TTP economic performance. Entrepreneurship helps to form the conditions that are favourable to knowledge and TTP (Kiškienė 2009). Entrepreneurship was identified as a mechanism facilitating the commercialization of HEIs' knowledge. Research analysis found a significant moderating role of cognitive abilities in the impact of transferrable knowledge on economic performance, while absorptive capacity plays the role of an effective mechanism for the penetration of the obstacles preventing knowledge commercialization. Entrepreneurship provides additional positive influence on the commercialization of HEIs' knowledge (Qian, Jung 2017).

Entrepreneurship could be named as a mechanism for knowledge spillovers. Earlier, companies and universities invested financial resources in new knowledge creation, but this does not guarantee that created knowledge or know-how will be commercialized and will bring economic profit. Entrepreneurship is very important here to contribute and push knowledge toward the commercialization process and create value and economic performance. Entrepreneurial performance depends on how close the knowledge sources are situated to the market. In other words, good entrepreneurship results are dependent on location, which means the geographic proximity of science and business (Acs, Szerb 2007; Audretsch *et al.* 2012a, 2012b).

The fact is that commercialization goals and government pressure leads to an increase in the return of public financial investment, which was spent on the research works for HEIs, with the idea that universities will increase commercialization economic revenue and support themselves (Markman *et al.* 2008).

According to Link *et al.* (2008), universities should note that "academics are primarily motivated by recognition within the scientific community, which requires that they quickly disseminate and publish their findings". This is contrary to the attitude of business companies, who are willing to capture and invest in knowledge and maximally increase the financial return converted to money (Link *et al.* 2008).

One of the approaches to becoming entrepreneurial is to establish a special administrative division aligning managerial and academic opinions in the centre's faculty-department at organizational level. At the same time, faculty members have the possibility of incorporating the university's central groups in the responsibility for interests on an institutional level. New financial revenue streams of economic income were fully diversified as well as governmental support. Institutional self-conceptions have changed due to the work of entrepreneurial domination. The main purpose of operational departments is to trust in medium and long-term planning (Burton 1998).

Location is also important for the generation of innovative ideas within the concentration of creative and innovative people. An important factor for growing companies is location in an area with economic benefit and a strong geographic network, and a concentration of innovative communities is an advantage (Burton 1998). In the case of Lithuania, here there is no one special area for start-ups like Silicon Valley. In Lithuania, there are many separate distributed areas for the incubating and consulting of start-ups. This could be a reason for the low number of innovative companies, which have the possibility to be economically growed in Lithuania. In addition, a lack of geographic concentrations is also an issue for the innovation ecosystem.

One more success factor for start-up companies is being located near to major HEIs as feeders, with their knowledge and mentorship abilities. Universities have these players in terms of entrepreneurship: students, professors, research labs, entrepreneurship programmes, and TTOs. TTOs are useful in licensing university IP to start-ups or spin-offs to create economic profit for the HEI. Here the issues of financial royalties exist; difficult licensing and lack of experience of contracting university IP could inhibit innovations. According to Feld (2012), TTO is intended to generate as much economic revenue as possible through the licensing of IP. Culture plays a key role in the university entrepreneurial start-up community. For instance, in Stanford, professors are usually founders of multibillion-dollar companies or engage with students (Feld 2012). Unfortunately, in the Lithuanian case, not all HEIs see the importance of entrepreneurship in universities.

Market research is a significant factor in performing commercialization activities in HEIs to ensure positive economic results. Market research is an excellent instrument with which to evaluate the potential of IP. Furthermore, the role of the HEIs' TTOs is not only to be a broker between university and industry, but also to assist in avoiding possible market failure.

According to Markman *et al.* (2008), the main facilitators of commercialization activities are the business parks or incubators, which are described as being the organizations that accelerate start-ups in reaching economic success and growth, consulting and supporting them, providing resources and other services. Business incubators have several missions: entrepreneurship; economic development (job creation); commercialization of technology; development of real estate. Incubators were created with the purpose of encouraging university students and scientists to create start-up companies (Markman *et al.* 2008), and in turn to earn money and bring economic profit to the university through future royalties.

How can the cooperation between universities and industry be improved? One solution is the provision of technical consultations regarding attracting financial support from industry. Universities could increase the cooperation between university and industry in the aforementioned way and improve HEI research results, increasing science production and related economic benefits (Carlsson, Fridh 2002; Fritsch, Schwirten 1999). Effective TT in university could increase the industry demand for academic technology (Thursby, Kemp 2002). Industry cooperation must be driven by human resources, which is one of the most significant factors of TT success in HEIs (J. G. Thursby, M. C. Thursby 2001). One strong example and evidence that human resources play a critical role in TT is the good practice of the USA.

After the evaluation of USA universities over the last 20 years Gregorio and Shane (2003) come to the core factors ensuring good knowledge transfer to the industry (see Fig. 1.3).

Every mentioned factor in Fig. 1.3 depends on the staff in the HEIs (Gregorio, Shane 2003).

Research capital in the meaning of science (university) and business cooperation, as a rule, is based on activities by groups of researchers at HEIs, as well as TTO staff, and industry staff (Etzkowitz, Leydesdorff 2000).

Based on Gupta and Govindarajan (2000), research, knowledge and TTP relate to the employment of socialization practices, such as knowledge sharing through various training programmes, establishing task forces, committees, organizing visits across the HEI organizations. Therefore, training programmes and other socialization tasks for employees is important in sharing knowledge.

Pfeffer (1992, 1995) demonstrates that a workforce can perform well by effective management that requires time to develop.

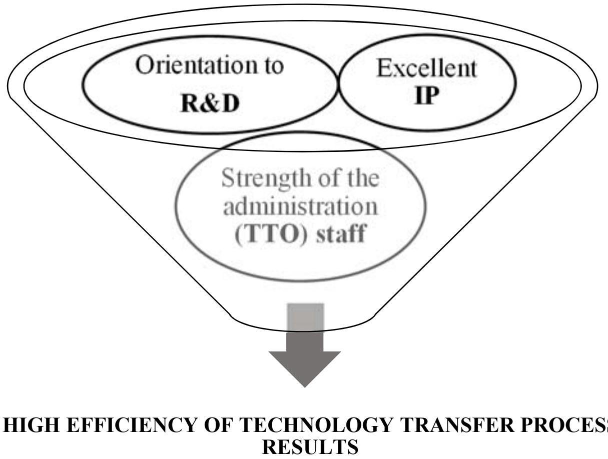


Fig. 1.3. Core factors of good efficiency of technology transfer process performance (compiled by author based on Gregorio, Shane 2003)

Roberts (1999) wrote that IP proving the statement that IP is knowledge that works for the organization and creates value as a result. Intellectual capital is the mix of resources and activities that allows an institution to transform a bundle of material, financial, and human capital into a system capable of creating stakeholder economic value (European Commission, 2006).

Invention is the technical or technological character leading to solutions, which could be implemented for mass production or which until their invention are unknown to a certain area of specialists (Išradimų patentavimas ir komercializavimas 2014). An invention can be patented and in that way protected against the technology or method being copied in certain countries' market (it is important to choose territories) where is needed to protect the invention (here invention's creators should agree on royalties between parties, so the part of sales from this patent), and provide the legal right to sell it for economic profit. IP rights are the tool to improve a company's competitiveness and become innovative in the market (Ernst 2001).

Patents actually contribute as one of the performance indicators to measure an HEI's academic performance. In this dissertation, the number of patent applications (as the variable showing HEIs' high skills and ability of producing intellectual property), is selected as the most important indicator to identify the HEIs for the research sample. Patent is the tool for commercialization. Patenting is a form of protection of academics' inventions. An invention must be new, and the level of invention must have industrial applicability, this means that inventions can be realized in industry. The State Patent Bureau of the Republic of Lithuania is responsible for patent procedures in Lithuania. Patents give exclusive rights to the owner to use the patent in Lithuanian territory. The main legislation regulating rights of patent protection, and a person's rights and responsibilities concerning inventions is the RL Patent law accepted since 1994.

Ernst (2001) in his work of "Patent applications and subsequent changes of performance", concluded on the propensity to patent. It was described as a part of valuable patentable inventions selected for patenting. It is right strategy because not all inventions could be patented.

A patentable invention could be named "patentable" if the invention meets these three requirements: it must be new; it must be on invention level; it can be used in industry.

It is very important to check the novelty of the invention in certain patent databases. On the other hand, if the invention is new, the next very important step is to implement market research and check the possible market in which to sell the patent through licence or other ways and so achieve economic profit.

An invention is new if at the time of the date of publication of the patent application it meets these requirements: an invention must not have been published or used in Lithuania or abroad. An invention is on the invention level when it is not known to a certain field of specialists. The invention must be industry usable, which means that the invention could be produced or used in industry: in agriculture, health protection or other fields.

The patented object could be material, a product or method of production, or the new use of all three of these objects mixed.

Based on the information above, it could be stated that patents (starting from patent applications) bring high status to HEIs, while scientists have new ideas and perform science works. Patents show the high level of an institution that is able to produce IP (science production), and technological knowledge is at a high level and suitable to be patented.

It is important to appreciate the worth of TTO staff because the determinants of successful knowledge and the TTP are closely related with the actors involved (Araújo, Teixeira 2014).

Working with scientists and forming good relationships with them is a very important goal and issue for the TTO, especially in the case of the Lithuanian mindset. During discussions and communication with scientists, the latter start to trust the TTO staff working inside the universities. Trust is a very important factor, which influences the effectiveness of patenting. It is related with know-how disclosure to the TTO because only after disclosure can the universities know about the new IP results of university scientists and researchers.

According to Coupe (2003), many and various research studies have shown the indirect impact of academic research on industry patents. After American's Bayh-Dole Act came into force, universities became interested in patenting and protecting inventions (their own), sponsored by government financial resources, thus maintaining economic royalties from patented products or services. Coupe (2003) found the rule similar for business companies: the more money spent on academic research the more university patents are generated.

The main purpose of the Bayh-Dole Act is that inventions, arising from government grants for research, should be commercialized by licensing to business companies. This is one more additional source for HEI financial revenues (Friedman, Silberman 2003).

Knowledge and the TTP tend to be stimulated by the next most important facilitators: trust, prior experience and social connectedness (Santoro, Bierly 2006). Araújo states that TT is achieved due to these factors: trust, human capital, absorptive capacity, international experience, prior experience with partnerships during cooperation, social connectedness (Araújo, Teixeira 2014).

In addition, it should be evaluated university indicators such as the number of students, university funding per researcher and number of publications per researcher.

Economical value creation is also related to networking within universities, government investments, structural funds and economic indicators, emigration, strategic management concepts, market-oriented students, management methods, (Dumciuviene *et al.* 2015; Ejdys *et al.* 2015; Ivanauskas *et al.* 2015; Kahraman *et al.* 2013; Kvedaraite *et al.* 2015; Mainardes *et al.* 2015; Nugaras, Ginevičius 2015).

Publication as a research performance indicator is a widespread way for scientists at universities and other science staff to share and distribute new knowledge, ideas or research results with society (Feng *et al.* 2012).

This group of authors conducted in-depth research into TT issues, analysing over 100 cases in five American HEIs in the year 1999, and concluded that the most important person playing the key role in the successful transfer of innovative solutions is the technology inventor. In addition, research results showed that nearly 56% of the TT cases were completed perfectly by the inventors of technology (Feng *et al.* 2012). This means that the TTO should work closely with scientists and motivate, help and consult them to achieve better TT performance.

Knowledge and TT depends on industry characteristics (Araújo, Teixeira 2014). This is why industry characteristics are assessed in this dissertation. Data of regional factors such as industry concentration and the number of start-ups will be collected based on interviews (about start-ups) with TTO managers and taken from Statistics Lithuania (2014c).

HEIs have an influence on the growth of local technology-based start-up companies, but they do not have impact on the growth of new business companies in industry. Innovation activities of HEIs influence the local industry through universities' knowledge spillover and positive research. Companies from industry are usually located near the knowledge source: university areas (Colombo *et al.* 2010).

Bozeman (2000) research work shows that technology efficiency depends on the market impact (outside factor), including political efficiency and capacity-building criteria.

All these indicators are important to measure the TTP performance of Lithuanian HEIs. Internal and external factors are analysed in this dissertation in terms of how they correlate to each other and influence knowledge and TTP. Which factors influence most and which less, which factor should be taken into account to improve knowledge and TTP in HEIs?

Unfortunately, the TTP in Europe is still unsuccessful. To analyse the reasons of this, let us look at the main actors of TTP (see Fig. 1.4). Starting from R&D activities (basic, applied, and experimental), the next actors in TTP are: public and business entities (government or private companies); idea generators (scientists, researchers, etc.); staff of the TT office (science and innovation managers) who help in such activities as disclosure of inventions (ideas), IP evaluation and protection, market research, commercializing IP (licensing, science-business cooperation, spin-offs), initiation of new ideas, and initiatives to develop further innovations.

Obviously, every country should invest financial resources in R&D works with the intention of pushing on the creation of innovative solutions in several governments' chosen strategic directions. Unfortunately, government investment for research and experimental works in HEIs does not generate the equal financial return or revenues. This process usually takes a long period of time. Certainly, HEIs try to implement science-business activities, commercialization activities (licensing, contract works, projects, consulting, training, etc.). Various national and international reports deploy the fact that commercialization activities do not bring high economic results these days (Jeffrey 2014). The evaluation of the performance of TT activities at HEIs is usually an issue.

Successful TTP is ensured by co-work between scientists and TTO staff. Performance of HEI also depends on the level of competence of organization and its staff (Argote, Ingram 2000). The TTO's role at HEIs is important to promote the inventions or technologies outside the laboratory walls and sell them to earn financial benefit.

Simonin's (1999) research results show the direct relation with and critical effect on knowledge and TT the following factors have full mediator of tacitness; cultural distance (as, for instance, language for interpreting information); complexity of technology; individuals (because knowledge transfer is built on individual exchange) and routines; past experience; organizational distance (ease of communication).

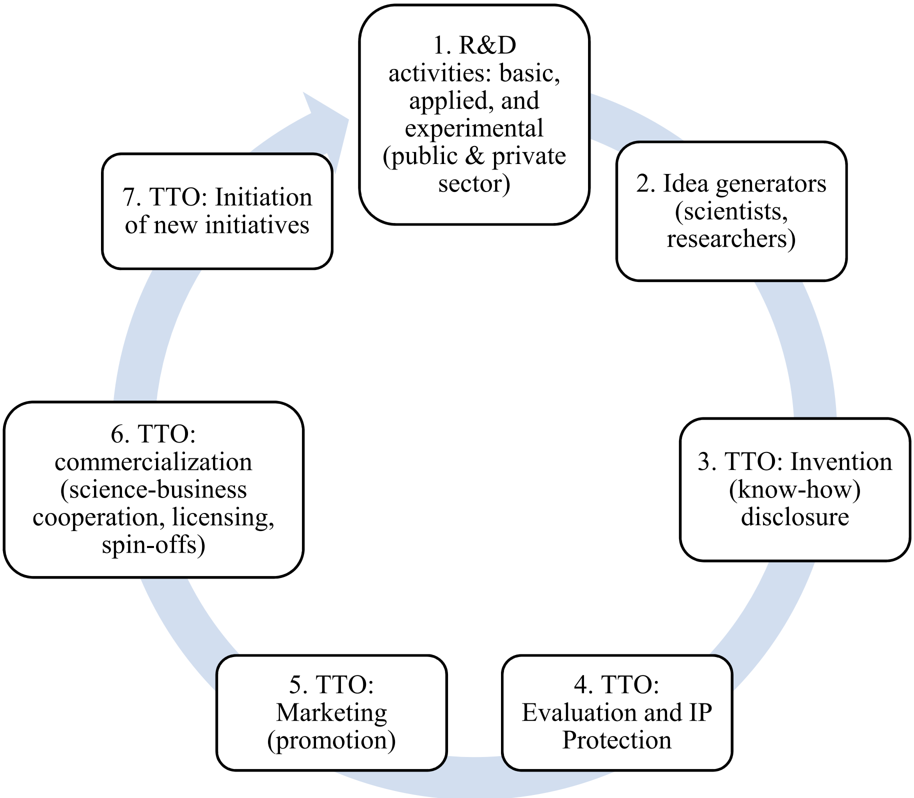


Fig. 1.4. The main stages of technology transfer process in higher education institutions (compiled by author)

A deficiency in commercialization experience in Lithuanian universities, not clear, different commercialization models, and TT policies is creating a significant absence of high economic performance results. Regarding Lithuanian laws, HEIs have the right to select their own model for TT and commercialisation of intellectual property. The experience of the commercialization has been motivated since the order of the Minister of education and science came into effect in 2009 December (Lietuvos Respublikos švietimo ir mokslo ministerija 2009).

The most important link in the chain to promote innovative R&D activities within universities are the academics (Feng *et al.* 2012).

HEIs need to be more oriented toward business, become entrepreneurial and in that way push the commercialization process for economic growth. Markman *et al.* (2008) confirm this statement and noted that the innovation system does exist in entrepreneurial universities. Innovation systems do not exist without students and researchers, incubators, technology and science parks, entrepreneurs, business angels or venture capitals.

There is a lack of information on the TT ecosystem and its components that affect academic entrepreneurship. Therefore, it is seen that TT should be analysed and improved to contribute to the economic performance of HEIs. University-industry collaboration is treated as a vehicle to strengthen innovation activities through knowledge exchange performed by TTOs (Ankrah, Al-Tabbaa 2015; Good *et al.* 2019). The government plays a significant role with its strategy and funding policy for innovation and scientific activities. Kiškienė (2009) identified that a clear policy at the country level has a direct influence on the TT and valorization model. This is the challenging situation in Lithuania, with its unclear policy relating to TT and valorization at HEIs. Every HEI has the right to approve their own rules for managing IP at university. The latter is led by HEI heads, who have a crucial influence on strategy and policy development of TT and valorization activities inside HEIs. Only strong leadership can drive the institutions and influence the performance of HEIs. Such leaders understand the importance of TT and valorization staff in order to achieve great economic returns through the commercialization of research and development (R&D) products. The TT ecosystem, entrepreneurial universities and university-industry collaboration are considered in a number of research works. The research works show that effective collaboration between industry (market need) and end-users has significant influence on HEIs' TT. Research results show existing parties' dependency and aspect of organizational culture. Moreover, there are challenges regarding the scarcity of resource allocation and the willingness and ability of researchers to cooperate with industry players and end-users. Therefore, there is a need to improve HEIs, industry, government and end-user cooperation, to change HEIs' strategy and align them with organizational processes and mechanisms (McAdam *et al.* 2017). In recent years, HEIs have transferred knowledge generated by researches through the creation of spin-off companies. Research findings prove that TT business models that are oriented toward high-quality research and the creation of start-ups are more economically useful. To improve TTO results, research authors suggest policymakers to include a business model typology (directed toward science-business collaboration) in the HEI evaluation systems. Due to the fact, that HEIs are designing their own TT models, policymakers have the power to change these models into more efficient ones (Baglieri *et al.* 2018; Miranda *et al.* 2018). After analysing the case of commercialized patents, researchers conclude that the most efficient performance results could be achieved during formal and informal interaction channels, which help created knowledge (during formal transfer activities) to be transferred to the market (by informal channels) (Azagra-Caro *et al.* 2017). These days, the third mission of HEIs has become knowledge transfer to industry to strengthen economic growth and social welfare. To realize this purpose, venture capital and private equity funds help in the quick commercialization of perspective ideas raised from HEI research, therefore this should be taken into account (Croce *et al.* 2014). Fini *et al.* (2018) analysed the societal impact of science commercialization and concluded that there is a need to consider ethical concerns. The economic impact of HEIs is dependent on the success of established university-affiliated companies. Researchers find that HEI research staff are focused on the individual ecosystem instead of strategic conceptualizations of entrepreneurship ecosystems. Therefore, the researchers conclude that the ecosystem potential has not been fully exploited to influence policy decisions to make an economic impact of HEIs. Future research could analyse the problems by including researchers of HEI companies in the strategic policy formation of HEIs (Hayter *et al.* 2018a). Other researchers have worked on understanding how scientific knowledge evolves to the social and industrial market, and also how knowledge is shared, accessed, transferred, translated, and transformed, while pointing out that researchers have a significant impact on communication with the TTOs and with industry, when from the other side the TTO should properly protect the ideas of researchers, help in negotiations with industry, select the right method for commercialization and then also be active in understanding the need from industry and transferring it to the research environment inside HEIs (Hayter *et al.* 2018b). Some papers analyse the legal aspects and how the law impacts HEIs' TT. According to some authors, the law, legal structures, and the uniqueness of IP law have a significant effect on TT performance results. Legislation in most cases helps to regulate and control many activities, for example, TT activities and HEIs orient their works and comply with requirements. Legislation would help to improve the TTP as well (Hayter, Rooksby 2016). Many researchers transfer inventions directly to the marketplace and bypass TTOs. The research papers state that most researchers are not aware of TTOs' existence. TTO awareness is greater if researchers have contact with industry. Therefore, HEIs should be more informative about themselves for HEI researchers, because this can affect both the HEIs TT and the country's performance (Huyghe *et al.* 2016). Another study, based on the analysis of 21 European countries, provides the recommendation that the mix of policy with funding tools should develop with the maturity of the TT national infrastructure (Munari *et al.* 2016). Steinmo, Rasmussen (2016) have analysed what is important for science-business collaboration. The proximity aspect, such as geographical, organizational, cognitive, and social, are important facilitators in collaboration between organizations. Based on the research of 15 successful innovation projects of HEIs and industry companies was found that the different proximity dimensions are important in the establishment of new collaborations. Engineering-based companies rely on social and geographical proximity to HEIs, while science-based firms rely on organizational and cognitive proximity. These aspects are necessary in building university-industry collaborations. In the case of small and medium enterprises (SMEs), explicit knowledge sharing is contingent upon technical formalized support, and together with trust, it is an important antecedent of sharing the tacit knowledge (Günsel *et al.* 2018).

Lithuanian policy aspects relating to TT activities are discussed next. Motivation tools and the accessibility of HEIs' innovative solutions (technologies) and know-how have significant effect on TTP performance (Decter *et al.* 2007). Universities in Lithuania should agree on their policy. Mentioned facts deploy why TT activities are still not efficient in the economic performance results in Lithuania.

During the yearly evaluation stage of HEIs, heads of institutions should rethink their policy and make decisions regarding improving it for the next year. This is very similar to the innovation concept, which states that innovation is not about the product, but about process. If you are designing a new product now, you should already be considering the next model. Innovation process means thinking several steps ahead of today. This strategy ensures regular increased economic performance results for the organization.

TT economic performance should be lucrative; however, in comparison with the Silicon Valley example Lithuanian HEIs do not have such high performance results. Therefore, the first step is to find and apply a certain framework to evaluate the economic performance of HEIs.

The economic performance results of the TTP depend on the successful work of TTOs at HEIs, and on the self-motivation of university academics, who are working close with industry (related to the clear and beneficial motivation system of HEIs and the well-being inside certain universities). The latter aspect is also important in the context of academic recognition. The main issue for every country is to find the proper method and framework to evaluate TT performance of HEIs and to increase their economic efficiency.

Moreover, other authors add that not only the production of R&D, but also the competitiveness of the region and the dissemination of universities' work all have a strong effect on TT and valorization process activities in terms of every entrepreneurial organization to gain economic profit and more effective financial and human resource allocation (Audretsch *et al.* 2012a, 2012b). Decter *et al.* (2007) analysed the case of America and the United Kingdom, and they pointed to significant factors for TTP: a country policy on TT; motivation tools; and accessibility of HEIs' cutting-edge technologies and know-how for outside business companies. Meanwhile, Gold *et al.* (2001) distinguish further important criteria and capabilities: technology and protection; culture and knowledge in the TTP; structure; the ability to change and make decisions. Other authors found that the technology inventor (creator) is one of the most important persons who plays a key role in the successful transfer of innovations. Research results Feng *et al.*

2012) showed that the inventor (completed about 50 per cent of TT cases converted to economic deals.

Clark and Bruno-Jofre (2000) even identified the key element for entrepreneurial success, namely establishing administrative divisions on the organizational level, and calling it TTVO, referring the symbiotic TT relationship between managers and academic staff.

Every HEI converts its capacity into results using the available resources to get estimated outcomes and outputs. University TTVOs fill the industrial-academic gap (Munari *et al.* 2016). The previously mentioned structural departments connect HEIs and industry to stimulate commercialization activities for the economic growth of HEIs and, as a result, of the country. The main function of a TTVO is to moderate the relationship between HEI staff (researchers, scientists, other) and outside stakeholders, such as interested industry companies, venture capitalists, business angels, start-ups accelerators, etc. Good communication here is an essential capability for TTVOs and directly influences the industry-academic partnership, converting into fees and economic royalties earned through commercialization actions of HEIs' IP. The technology marketing stage is also performed by the TTVO, and demonstrates the success during the dissemination of research results (Rood, 2018).

What are the main performance indicators to measure HEIs' economic performance results?

Based on the literature analysis, the TTP of HEIs can be measured by such indicators as funding (per researcher); the number of students; the number of publications (per researcher and year); the number of start-ups (Hulsbeck *et al.* 2011). Taking into account the case of Lithuania, the collection of data for indicators 1, 3 and 4 would be complicated, because these data are interpreted differently in HEIs' rectors' reports (the methodology for the calculation of indicators is not provided to the public). Hulsbeck *et al.* (2011) also foresee the following performance indicators of TTVO: the number of employees (in full-time equivalent, FTE), the number of tasks (per employee), the number of researchers with PhD degree (Hulsbeck *et al.* 2011). Araújo and Teixeira (2014) highlights key aspects and the main elements of TT: human capital (technical capabilities, training, human capital); absorptive capacity (absorptive capacity implying the ability of industry to use contemporary technologies); connectedness (communication, relationship, social connectedness, which is an essential factor for the university TTVO); trust; past experience (past and prior experience, number of partners, foreign experience, especially with universities from abroad); size (organization's size); sector (the sector). Therefore, this proves that international relations of HEIs have a direct impact on TT economic performance results.

Analysis of rectors' reports of Lithuanian HEIs rely on several basic criteria of performance, such as contract works (sponsored research), national and international projects. Licensing is not such a popular way of commercialization in Lithuania, so the economic performance is very low. Taking into account this aspect, licensing results are not included in the calculations.

Kiškienė (2009) provided empirical evidence that the Lithuanian market is insufficient within the TTP. This is reflected in the unsuccessful performance influenced by insufficient management of scientific knowledge and IP in HEIs. The reason for this is the lack of experience on managing science production, when the TTVOs were conditionally established not long time ago, around 6 years. Every year the Lithuanian government requires constantly improved economic results on the side of the HEIs. This is views the university as an industrial company earning money. The government is enforcing HEIs to increase the financial return of public investment and to become more independent. It is leading HEIs to foster an entrepreneurial culture inside universities and to invest in TTVO staff professional abilities. In 2009, the Lithuanian government was recommended to approve the policy of IP management at HEIs and prepare a specific package of legal documents to manage IP inside HEIs (disclosure rules, protection of IP, evaluation procedure, commercialization, starting the rules on patenting issues, licensing, selling, starting young start-up companies, stocks, sharing the economic profit between parties, among others). This is the first step towards making HEIs commercialize IP in order to bring economic growth. Therefore, good practice from abroad (for example, Stanford) shows that, unfortunately, good commercialization results of HEIs' TTVOs do not occur until at least 10 years after intensive work with the surrounding environment of all stakeholders (staff, industry, government, etc.).

Building a successful start-up community at HEIs brings good economic result from entrepreneurial activities. Since the 1970s, Silicon Valley started to cultivate the culture of developing young perspective companies. Great examples are Facebook, Twitter, or LinkedIn, which were born there. The next key players in the creation of a start-up community are government, HEIs, investors, mentors, service providers, and large companies, which altogether help in developing young prospective companies. TTVOs' commercialization action might be the licensing of university IP to start-ups. Economic royalties, a lack of licensing and contracting practice of IP protection could inhibit innovations (Feld 2012). The number of university-based start-ups in Lithuanian HEIs is low, so this indicator is not included in the research. Lithuanian universities are just beginning to form entrepreneurial ground within universities, and to train TTVO science managers to get successful economic results from public-private collaboration. Link *et al.* (2008) stated that academics are driven by academic recognition, getting the results of R&D activities quickly published, while industry has the opposite approach: gathering ideas and disseminating them only after the decision has been made to present new products or services to the customers. The entrepreneurial abilities are develop over a period of time.

There are many factors influencing the economic performance results of HEIs.

However, for sudden progress, every HEI should be competitive in the market. A competitive advantage base for organizations creates innovation management and transfer of knowledge from the organization to the market environment. TT process in firms is the process when one division of the firm (e.g. department, or division) is influenced by another division's accumulated experience (Argote, Ingram 2000). Based on this statement, in case of HEIs, it is important to understand that within the TTP the collaboration between scientists and TTO staff is very important.

Characteristics of tasks (the number of elements) also affect knowledge and TT, such as similarity across tasks in different contexts, which increase TT. People (or staff) are more problematic and provide challenges to TT and commercialization because of compatibility and differences among people (also staff changes more often), while tools or tasks tend to be more constant. Specific people have the most important role in the economic success of TTP in organization. The main issues are to identify the conditions under which people will contribute to the TTP economic performance result. New staff, who move to work within new circumstances, become "minorities" in the existing majority, and this could lead to a discussion on understand how minorities can influence TT economic performance results. Socialization, trainings, social networks and the communication process could be the tools used to help new staff adapt to the new conditions (Argote, Ingram 2000).

Negative effect on TTP economic performance could occur when the knowledge and technology just cannot be adapted to the new context (Baum, Ingram 1998).

Argote and Ingram (2000) highlighted that the staff are very important, but also organizational performance is enhanced when tasks are implemented by the most qualified members. Based on this statement, it is clear that TTP economic performance depends on the level of competence of the organization and its staff.

Edström and Galbraith (1977) performed research into the transfer of heads in multinational organizations, where the research was related to recruitment and selection, trainings, problems in foreign cultures. The problems identified were of expatriates experiencing bad management of the firm's human resources, and the role of human management practice as a management tool (Edström, Galbraith 1977). This is one more fact that TTO staff should be motivated based on HEIs motivation system to achieve more effective performance results.

The quality of HEIs' TTP economic performance results can be assessed by these indicators: the number of patent applications (that later can be converted to patents); patents; the TTO (employees, tasks, PhD-share); 21 Lithuanian universities: 14 – governmental and 7 – non-governmental universities (funding, students, publications – 3 years average per researcher); regional aspects (industry concentration in regions, the number of start-ups, patents generated by the industry) (Hulsbeck *et al.* 2011). The table of HEIs is provided in the annexes.

Every organization converts its capacity into results from resources to outcomes and outputs. The university TTO fills the industrial-academic gap, connecting the university and industry to the maintenance of the mechanisms of TT and commercialization, and the workforce of the TTO depends on the marketplace (Feng *et al.* 2012). The TTO's function is to moderate the relationship between staff (including scientists), and the TT management process (TTMP) (Fig. 1.5).

Lithuania does not use all its potential to become more innovative (only a small part), therefore, this dissertation is actually intended for Lithuania to evaluate and improve TT and commercialization economic performance results.

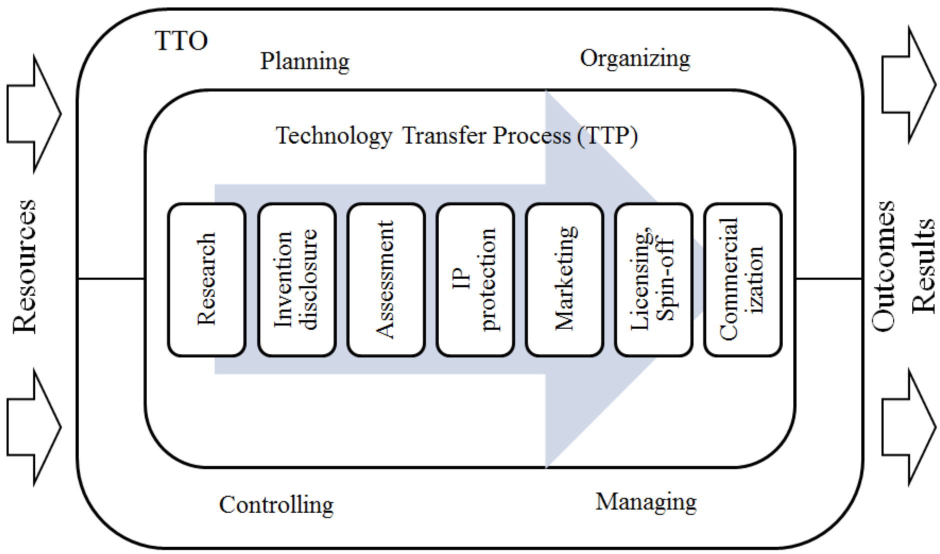


Fig. 1.5. Steps of technology transfer process in higher education institutions (compiled by author)

The TTO should have very clear actions of TTMP going through Deming's cycle of Plan Do Check Act. Lithuanian HEIs usually do not know what actions are right for commercialization because they lack experience.

How can be evaluated the potential efficiency of TTP performance? Capital and information on TT, and financial and human resource management should be assessed. Two levers were identified as influencing management capacity: leadership and information. Leaders have the core role of making decisions, showing the right direction, developing the institution's mission, vision and strategy and bringing the right message to staff. Information delivery contributes to the results, and information plays a key role between the team and the outside world (Van Dooren *et al.* 2010).

National absorptive capacity depends on economic policy as well as investments targeted on technical and scientific training. Other factors are not so important: channels for TT, trade restrictions, etc. (Mowery, Oxley 1995).

The most important link in the chain to promote R&D and innovation activities within the university are the academics. For scientists, it is very important to feel comfortable in a well-established HEI during their research work, and also important is having the possibility of using modern and unique equipment, having abundant research funding, and a good portfolio of books and journals (Feng *et al.* 2012).

Performance management systems are ongoing while evaluation is episodic (Van Dooren *et al.* 2010). This means that after every evaluation stage, institutions should rethink and make decisions to improve the allocation of human and financial resources, and their policy to achieve better economic performance results for the future. This is like innovation, meaning that it's not about the product but about the process. If you are designing a new product now, you should already be imagining the next product. This way of thinking is called thinking several steps ahead of today. It brings great outcomes of performance.

According to Audretsch (2012a) and other authors, regional competitiveness and HEI dispersion both have a strong effect on innovation and TTP activities for every entrepreneurial organization.

What could be the possible issues and important key factors for the successful economic performance of TTO?

It was estimated that the success of HEIs licensing a way of commercialization directly depend on the company's structure, institutional capability, and motivation systems for researchers to participate in TTP (Phan, Siegel 2006).

Performance is the realization of public values (public interest), like successful practices, innovation, etc. The five main activities of performance assessment are defining the measurement object; the formulation of certain indicators; the collection of data; analysis preparation; and conclusions (Van Dooren *et al.* 2010). These activities are discussed and explicated in more detail in the Subchapter with the empirical research results. Therefore, performance measurement is described as the process of receiving performance information, while performance management means the use of performance information in the decision-making stage (Van Dooren *et al.* 2010).

Decter's *et al.* (2007) research results showed that firstly, countries' policy on TT, secondly, motivation tools and thirdly, the accessibility of university technologies and know-how for business companies have a significant effect on TTP economic performance results in universities in America and United Kingdom.

Friedman and Silberman (2003) noted that the most necessary objective for the TTO is financial fees and royalties earned by commercialized inventions sold to the industry. However, in the case of Lithuania, licensing is not a popular way of commercialization. Based on the information in the tables in the third Chapter, the financial performance of Lithuanian HEIs is shown in such indicators as contract works, national and international projects. Lithuania does not have much experience in commercialization through licenses in over the last few years, so competence is not very yet very strong, but on the other hand, a few Lithuanian HEIs have already signed license contracts as well as earned revenues. Confirmed by Metcalfe and Cantner (2003) research analysis, most TTOs began their function in HEIs around the middle of the 1980s.

Garud and Nayyar (1994) wrote that the ability to transfer capacity depends on the right decisions in choosing technologies, and on the ability to maintain the technology constantly. This statement mostly applies to companies, but in the case of HEIs, it should be maintained idea generation and invention processes and taken the responsibility for quick decisions regarding commercialization, because otherwise, invented technology will become too old for industry.

According to Gold *et al.* (2001), an institution's effective TT and valorization management infrastructure consists of these several important indicators and capabilities: technology; protection; culture along with a knowledge and TTP; structure; and the ability to change and apply decisions to improve the financial return of HEIs. In the case of Lithuania, there are barriers starting with the TTP and finishing with culture.

Inkpen and Tsang (2005) identified some network types: strategic alliances; intracorporate networks; and industrial districts. Here there are a number of conditions that promote TT (Inkpen, Tsang 2005). TTO in Lithuania should use possible networks more actively.

Kedia and Bhagat (1988) research results found evidence that when choosing the team for TTO it should be taken into account the culture to cooperate with other countries more readily. Therefore, the difference in cultures helps the TTO to achieve better economic performance results.

Kotabe *et al.* (2003) research findings provide the answer that supplier performance (in my case – the TTO staff) directly depends on a good communication-relation among the buyer, supplier and industry (TTO and business) This is the key to effective transfer of productive knowledge (relationship duration does not have an effect on supplier performance). Hence, in the case of choosing employees for the TTO it is important to engage non-conflicting, smart and sociable persons.

This is the evidence for the fact that good communication skills are relevant and could translate into a gold standard of TTO economic performance outcome.

Whereas Lane *et al.* (2001) have concluded with evidence that management support and trust from foreign partners are connected with international joint ventures performance. The ability to understand foreign companies' processes and structures, and understand knowledge from foreign companies is also important and directly influences absorptive capacity; trainings are suggested to be based on the demand to apply new knowledge for staff.

Thus, good communication skills are important to understand company's efficient processes.

Implementation of technologies is the core ability of the TTO, and it shows the performance of TT economic success, reflected in whether technologies invented in the university are of actual use by outside users. The implementation of technology is described as broughted from the walls of the laboratory and presented for the consumer use (Leonard 2011). In addition, it is very important for TTO staff to ask about possible technology implementation. In this way, it is eliminated the situation whereby university scientists and researchers are performing research works in the right direction. This means scientists are performing research works through which it is expected that new technologies will be converted later to inventions, which will be useful in industry. It ensures the selling or licensing of technology to the industry, which is included in TTO economic performance results.

Commercialization. In the article regarding research and technology commercialization by Markman *et al.* (2008), the authors look at internal and partly internal approaches (as incubators), academic start-ups and also spin-offs, licensing activities, open science and innovation, university science parks, regional clusters, consultancy and contract-based research, and venture capitals. Why has there been an increase in the commercialization processes? The reasons are several: the changing of legislation, especially after the coming into force, in the USA, of the Bayh-Dole act in 1980, and similar Europe legislation, such as the OECD, 2003, caused a rise in science and business cooperation economic results. In addition, governmental initiatives appeared to sponsor science and business research works, pushing the commercialization process into the light. Universities, business companies and government have undergone internal organizational changes, as well as dealing with managerial issues regarding the valorization process.

Every HEI decides on their own commercialization strategy. While one HEI keeps itself at an advanced stage and has a strategy concentrating on world-class innovations as a priority (radical innovation policy) (Thornhill, White 2007), others have a strategy focusing their priorities on incremental or generic innovations intended for local, regional and national use (Clarysse *et al.* 2005).

Consultancy and contract-based research are also tools for the commercialization of technology, which is more economically effective when HEIs are providing consultancy through centres of research excellence in specific actual spheres (Markman *et al.* 2008).

Joint companies with industry partners (spin-offs) ensure HEIs implement TT activities because of the easy access to the necessary resources. For comparison, it could be stated that commercialization activities are unsuccessful in the case of venture capital. Business partners play the key role in accessing a number of business companies through their ready-built platform of partners; they also help to share the knowledge of good managerial abilities, accelerate spin-offs and bring spin-offs to a higher level quite quickly, ensuring the scalability and economic results (Markman *et al.* 2008).

One issue for HEIs and the reason for inefficient TT is that faculties are not interested in disclosing inventions because of bureaucracy procedures, therefore new ideas for technologies leak out of HEIs walls, resulting in HEIs possibly losing money (Link *et al.* 2008).

National absorptive capacity depends on economic policy as well as on investments aimed at technical and scientific training. Other factors are not so important: channels for TT, trade restrictions, among others (Mowery, Oxley 1995).

Stock and Tatikonda (2000) discussed the organizational interrelation of technology supplier and technology recipient.

The following provides information about a few of the methods for collecting data.

Environments, created around TT activities encourage relationships between each other and could act as conductors in the knowledge transfer process (Santoro, Bierly 2006). Sherwood and Covin (2008) investigated one more crucial factor, namely fostering knowledge achieving success between HEI and business corporations. Thus, trust is empowered between the message, message-providing and information-getting sides. Companies with their experience have a stronger chance on the road to success. Through experience, parties come to understand about the possibilities of partnership, and how to control and administer the organization in order to gain possible benefits (Arvanitis *et al.* 2005; Sherwood, Covin 2008).

Surveys are sometimes the only possible way to get information for research, but this method costs a lot and it is very difficult to obtain a good response rate.

Table 1.1. Elements of technology transfer in a Triple Helix system (Araújo, Teixeira 2014)

No.	Key aspects	Main elements
1	Human capital	Technical capabilities
		Training
		Human capital
2	Absorptive capacity	Absorptive capacity
3	Connectedness	Relationship
		Communication
		Social connectedness
4	Trust	Trust
5	Past experience with collaborations	Prior experience
		Alliance experience
		Number of partners
		Experience in foreign countries
		Possession of contacts with HEIs from abroad
6	Size	Company size
7	Sector	Sector

Key elements of TTP. According to the empirical evidence in Keller's research, a country's human resource skills ensure the advent of technology (2004). This confirms that human capital strongly contributes to TT performance results inside and outside the country boundaries (Keller 2004).

The data for the research gathering from both inside and outside sources. TTP really depends on the outside factors such as the market and industry. The private sector should evaluate some critically important factors and assess their own ability to adapt technology and commercialize it. These conditions are very important to ensure efficient TT. Commercialization ability depends on size, prior experience and some other factors.

Based on Araújo's (Araújo, Teixeira 2014) research results, international TT has a direct relation with institution staff and its endowment (Table 1.1). Thus, it is important to understand that companies should constantly care about its human resource, providing trainings, motivating staff to participate in conferences, absorb the newest information, and build high competence. Absorptive capacity is an important factor for the industry sector, reflecting the ability to use technologies in the most effective way and realizing technology, get back the revenues to the company further to the country's economy. Just as connectedness is a significant factor for industry, so too it is an essential factor for TTOs' work at universities.

Furthermore, capital of staff has a direct relation with research financial income results within the TTP (Feng *et al.* 2012).

In many cases, during implementation of economic research it is important to apply quantitative research during interviews. In that dissertation, mentioned type of research is important because there is no information about the most important variables valuing the TTP. Quantitative research can be implemented through interviews with focus groups.

Interviews can be very formalized and structured, providing standardized questions for every research participant in a certain survey. Conversations can be informal or unstructured. Interviews may be categorized by types: structured interviews; semi-structured interviews; unstructured or "in-depth" interviews (Saunders *et al.* 2009).

The quantitative approach is intended to study personal experience for analysis and interpretation. This kind of interview, called "realistic evaluation", aims to identify the relationship between the organization and professional groups. Most statistical methods offer quantitative estimates of standard errors, which can be used to assess the confidence with which performance rankings are held. During the analysis of the collected data, performance data should be accompanied by appropriate measures of uncertainty (Boyne *et al.* 2006).

Quantitative data is usually divided into two separate groups: categorical and numerical. The research results, which are usually represented in tables, diagrams and graphics, can be manually analysed, using personal, mainframe computers or computer programs (Brown, Saunders 2007; Saunders *et al.* 2009). Categorical data cannot be measuring using programming, but can be classified into a number of categories placed by the characteristics that describe the variable. Numerical data can be described as the data that can be measured as quantities. Quantitative analysis can be performed by collecting data and coding it using different scales of the research (Brown, Saunders 2007).

The research of this dissertation on evaluating the efficiency of technology transfer process in higher education institutions will incorporate quantitative research methods. The data for the research was gathered from inside and outside sources, starting with HEI rectors' reports, Eurostat, reports by the Research Council of Lithuania and interviews.

1.4. The Evaluation of the Efficiency of Technology Transfer Process Performance in Higher Education Institutions

After tracking HEIs R&D activities, innovation management issues, efficiency evaluation models, TTP's most important factors influencing the performance, the concept of evaluating the efficiency of HEIs TTP performance can be arranged.

Among the many different HEI performance indicators, their calculation methods and delivering the results to society (in the form of different HEI reports), there exist such problems as converging performance results to one platform, as well as finding the appropriate method for evaluation and facilitation of TT performance at HEIs. Furthermore, there is the issue of determining the indicators and improving them moving forward in order to raise the level of institutions' economic performance results.

Decision-making methods help to analyse the performance measures of HEIs. A large volume of research papers prove that the more the government invests, the better the TT results attained by the HEIs. R&D activities here are very important point. Countries have strategic priority areas and governments invest in these fields to strengthen and develop innovative activities in certain fields for economic benefits.

Based on the literature analysis, the concept of a TT model is formed, taking into account the cultural aspect, finding performance indicators to evaluate the TTP, data-gathering nuances, matchmaking appropriate tools and methods, and finally creating the model to evaluate HEIs' TTP economic performance. The literature analysis showed that some examples of American and European TT models. In this dissertation, the European model has been chosen, because it fits more to European culture that is more closed. The performance indicators were identified with expert help and literature analysis, and special tools applied to search for the most important ones. There were some limitations met in collecting the data (e.g. the lack of data), and therefore there were limitations in forming the database for research, and in applying certain tools due to restrictions of methods.

The advantages and disadvantages of multi-criteria decision-making methods are presented in the table (Table 1.2), published in the article (Kraujalienė 2019).

Each multi-criteria method has advantages and disadvantages (see Annex C), therefore the simultaneous use of several methods is recommended. The first stage in the formation of the TTP performance evaluation model is intended to identify indicators suitable for measuring the efficiency of TTP performance. The FARE tool is fitting to realize this goal and to set weights of TT performance indicators, because when you have a number of various indicators, the weights of their

Table 1.2. Comparative analysis on advantages and disadvantages of multicriteria decision-making methods (compiled by author)

Method	Multicriteria evaluation	Used in performance–type problems	Concordance coef. of Kendall is required	Maximizing / minim. criteria values	Compare and evaluate the criteria	Not requiring to minimize criteria	More robust involving all stakeholders and interrelations between alternatives and	Non–subjective	Subjective	Absolute evaluation	Normalization needed	Does not need external normalization	Pair–wise comparisons	A mixture of percentiles, ratios and raw data is permissible	To measure weights	Needs initial weights	Minor amount of initial data is required	Direction and strength, asked from experts	Assessing the best and the worst alternatives	Provides the most stable results in the case of input data oscillating	Easy to use	Programmable	Used in case of all maximizing criteria	Inconsistent	All the values should be positive	Expected utility theory	Huge amount of data required	Retrieves similar cases from existing database, proposes similar solution
COPRAS	X	X	–	X	X	X	X	X	–	X	X	–	–	X	–	–	–	–	X	X	X	–	–	–	–	–	–	–
MULTIMOORA	X	X	–	X	X	–	X	X	–	X	X	X	–	X	–	–	–	–	X	X	X	–	–	–	X	–	–	–
DEA	X	X	–	X	X	–	X	X	–	X	X	–	–	X	–	–	–	–	X	X	X	X	–	–	X	–	–	–
FARE	X	X	X	–	X	–	X	X	–	X	X	–	–	X	X	–	X	X	X	X	X	–	–	–	–	–	–	–
TOPSIS	X	X	–	–	X	–	X	X	–	X	X	–	–	X		–	–	–	X	X	X	X	–	–	–	–	–	–
SAW	X	X	–	–	X	–	–	X	–	X	X	–	–	X		–	–	–	X	–	X	X	X	–	X	–	–	–
PROMETHEE	X	X	–	–	X	X	–	X	–	X	X	–	–	X	–	–	–	–	X	–	X	X	–	–	–	–	–	–
VIKOR	X	–	–	–	X	–	–	X	–	X	X	–	–	X	–	X	–	–	X	–	–	X	–	–	–	–	–	–
MAUT	X	–	X	–	X	–	–	–	X	–	X	–	–	–	–	–	–	–	X	–	–	–	–	–	–	X	X	–
AHP	X	X	–	–	X	–	–	X		X	X	–	X	X	–	–	–	–	X	–	–	–	–	X	–	–	–	–
CBR	X	X	–	–	X	–	–	X		X	X	–	–	–	–	–	–	–	X	–	–	–	–	X	–	–	–	X
SMART	X	–	X	–	X	–	–	–	X	–	X	–	–	–	–	–	–	–	X	–	–	–	–	–	–	X	X	–

importance are unknown. The FARE tool needs experts from the TT, valorization and innovation management sphere. Experts help in the estimation of the importance of a number of criteria to find the most important one, and the distances of all of the remaining criteria in accordance with the most important. This approach is able to highlight indicators regarding the impact on the TTP. In the second stage, it is important to choose the HEIs. In the next stage, it is necessary to select the sample for the research; therefore, the ranking tools are needed. MULTIMOORA and COPRAS multi-criteria tools are identified to rank the HEIs. Once the research sample and indicators are known, the final stage is intended for the evaluation of the efficiency of the TTP performance. The DEA tool is intended to evaluate the efficiency of HEIs' economic performance results.

The FARE multi-criteria decision-making method is suitable to evaluate HEIs' TTP performance. Ginevičius developed the FARE method with the aim of estimating criteria weights (only one from Table 1.2) in an MCDM background, to assess the importance of the criteria. The FARE tool helps to provide consistency of the decision matrix. The main aspect of the method, having performed a superiority comparison of one from all other criteria in the sample is leading to creating of decision matrix. Then, the most important criterion has been selected from among the rest of the criteria. The criterion that has the highest total of superiority values is selected as the most important since the superiority level of the most important criterion, is equal to 1, or higher than 1 in comparison with the others (Chatterjee *et al.* 2017; Kazan *et al.* 2015).

The FARE method is selected for the research because in the first stage a minor amount of initial data on the relationships is required. In comparison with other methods, SMART is not suitable because it is more fitting to converting weights into actual numbers, moreover this framework method is complicated. AHP is not useful for identification of indicators because the principle differs and is based on pair-wise comparisons.

CBR is not suitable because it requires an existing database of various cases (there is no existing database for this work's research), and it proposes the solution of similar cases. MAUT is also not applicable for this research because it is an expected utility theory calculating the best possible utility, instead of identification of indicators by its importance. PROMETHEE does not provide a clear method intended to assign weights. VIKOR needs initial weights, but there are no weights in this research − only names of indicators (from the literature review).

In turn, the TOPSIS tool determines the best and the worst values for TTP indicators. TOPSIS is the tool abling to choose the best alternative from a number of alternatives in the sample. The basic advantage of TOPSIS tool is that the best-selected alternative not only has the shortest distance from the ideal best solution but also has the longest distance from the ideal negative (worst) solution. TOPSIS results supply with information for the head of organization and help to make decisions on one hand close to the best possible, and from another hand far from the worst. This is ensuring decision makers to make decisions that are more efficient, therefore finally selecting the right decision for the institution (Ginting *et al.* 2017; Džunić *et al.* 2018; Ding, Zeng 2015).

TOPSIS was selected for the research because it is simple to apply, programmable, and provides the most stable results in the case of the input data oscillating. The created model is input-oriented, so TOPSIS ideally suitable for evaluating every alternative, its deviation magnitude assessing the best and the worst alternatives from the average attained.

The MULTIMOORA method is selected as a non-subjective and more robust tool in comparison with methods using subjective estimations. It enables the maximizing and minimizing of criteria values, as well as COPRAS. MULTIMOORA is based on cardinal numbers, as in the case of this dissertation, so it fits the research. In addition, it has the only one limitation: the data should be positive.

The COPRAS tool allows the comparison of the data and ranking it to assess the economic efficiency. In 1994, researchers from Vilnius Gediminas Technical University (VGTU) – Zavadskas, Kaklauskas and Sarka − introduced the complex proportional multi-criteria evaluation method, called COPRAS (Zavadskas *et al.* 1994). This method is suitable for quantitative multi-criteria evaluation of minimizing and maximizing complex indicators of different criteria.

The instrument to measure the efficiency is Data Envelopment Analysis (DEA). This dissertation incorporates this tool into the whole TTP efficiency evaluation model. Efficiency in HEIs could also be evaluated with DEA complex proportional assessment tool (Nazarko, Saparauskas 2014; Stefano *et al.* 2015). DEA is a tool for the relative evaluation of individual efficiency or the tool for evaluating the performance of a decision-making unit (DMU) within an estimated target group of interest and acts in a certain field of activity, such as banking, health care, the agricultural industry, education (including higher education) sector, etc. DMU, in other words, could be named as HEI production. DEA is the instrument that helps to identify sources of inefficiency, evaluate management (to benchmark manufacturing and service operations), rank the HEIs, evaluate the efficiency of policies or programmes, evaluate resources on a quantitative basis and reallocate them, emissions efficiency, energy efficiency, etc. (Liu *et al.* 2013; Wang *et al.* 2013; Zhang, Choi 2013; Zhang *et al.* 2013).

The COPRAS quantitative multi-criteria method is used for multi-criteria evaluation of maximizing and minimizing criteria values. It allows results of calculations to be easily compared and checked. COPRAS may be less stable compared to SAW or TOPSIS methods in the case of data variation, therefore it is used separately. This method is able to compare and evaluate criteria, characterizing hierarchically structured complex magnitudes, being of the same hierarchical level, so it is suitable for evaluating HEIs.

DEA is selected for the research, as it is a convenient efficiency evaluation tool, employing an input-output oriented method, which minimizes input and maximizes output criteria, and is available as a mixture of percentiles, ratios and raw data. Efficiency with DEA tool can be analysed and quantified, which is important at the end of the research.

There are other general economic efficiency evaluation methods, but those methods have not previously been used for the evaluation of TTP. The purpose of economic analyses is often the optimization of control, prevention, or monitoring investments and to minimize the total costs. The choices of control, detection, and prevention are interdependent, and managers should evaluate the cost-efficiency of alternatives at each step when developing new policies and/or strategies for activities (Epanchin-Niell 2017).

There are some methodologies that evaluate the efficiency of activity. The potential approaches are applied for identifying efficient resource investments or cost-effective management (Shen *et al.* 2017). One of these approaches is cost-benefit analysis, which is able to determine the efficiency of the project cost in relation to investments. Latter analysis model determines whether benefits are higher than the costs. The approach of return on investment analysis prioritizes the allocation of budget resources across a set of independent, discrete projects (e.g. ranking projects by cost efficiency). The methodology of the latter approach is able to select projects in decreasing order, when the ratio is benefits divided by costs. The third approach is called "optimization", which determines investment's efficiency level (maximizing net utility) and creates such management schemes to reach the best objective. The methodology for optimization is optimal control, dynamic optimization. Another efficiency evaluation approach is optimal activity's design, which determines the optimal parameters for changing private decision-making. The following methods for applying the latter approach are suggested: optimal control, dynamic optimization, etc., which account for private decision-making (Beikler, Flemmig 2015; Epanchin-Niell 2017).

There are a number of analytical models for evaluating the economics of, for example, Health-care interventions. The Consolidated Health Economic Evaluation Reporting Standards (CHEERS) Statement means the assessment of cost-consequence analyses and benefits of interventions, and leaves the interpretation of information up to the manager. Cost-minimization analyses (CMA) allows the comparison of the costs of interventions that have equivalent outcomes (focus on costs and exclude outcomes). The cost-effectiveness analyses (CEA) model relates outcome measures with costs, which informs on the additional outcome improvement between several interventions, a measure often delivered in terms of incremental cost-effectiveness ratios ICERs). ICERs relate the difference in effectiveness to the difference in costs between alternative interventions 0 and 1 (Beikler *et al.* 2015).

The economic evaluation methods mentioned here do not solve the TTP evaluation problem; therefore, the model proposed in this dissertation is original. Finally, the data for the research was selected in different periods (various times from 2004 to 2015) according to the limitations of available open public data.

For empirical analysis, information for the research was gathered mostly based on interviews from a direct focus group of TTO managers, official Lithuanian and HEI reports and Eurostat. The reason for this is that some information is not open to the public and not publicized.

Hence, taking into account the mentioned aspects, the model to evaluate the efficiency of HEIs' TTP economic performance is described in the next Chapters.

1.5. Conclusions of Chapter 1 and Formulation of the Tasks of the Thesis

The major conclusions of Chapter 1 are provided in the following statements.

1. Due to the fact, that technology transfer and commercialization processes are not efficient enough in Lithuanian higher education institutions‘, there is a need to improve the efficiency of their technology transfer economic performance. The efficiency of higher education institutions technology transfer process should be calculated first (the tool is unknown.) to have a picture of itself in comparison with other universities. Higher education institutions need new solutions for the efficient allocation of financial and human resources, strategies to improve technology transfer process indicators for improvement of the realization of science production, foster university-industry collaboration, disclose IP, encourage and form an entrepreneurship culture. Lithuania is lacking a breakthrough innovation strategy and technology transfer actions, and entrepreneurship platforms to make progress.
2. Technology transfer plays an important role as conductor in researchers-business cooperation. University-industry partnership is the core instrument to commercialize research findings resulting in economic growth. Successful technology transfer process is ensured by co-work between scientists and technology transfer office‘s staff.
3. There does exist a demand on a national and international level to find a tool able to evaluate the performance of technology transfer process.
4. Many authors have highlighted the important factors influencing technology transfer process performance: technology transfer office‘s competence; cooperation strength between higher education institutions‘ researchers and technology transfer office‘s staff (aspect of

trust); self-motivation of academics; university-industry communication; technologies actuality; higher education institutions' geographic location near entrepreneurial network; industry concentration; strategy for government grants and estimated obligation to commercialize patents to business (e.g. Bayh-Dole Act); government strategy and funding policy for innovation and scientific activities; and many others mentioned in literature review.

5. Chapter 1 provides the concept of a technology transfer process efficiency evaluation model that is able to calculate the economic efficiency of the technology transfer process of higher education institutions. The proposed model integrates several tools and their roles. FARE − to crystallize technology transfer process key performance indicators (KPIs) and set their weights; TOPSIS − the ranking of higher education institutions' KPIs; MULTIMOORA and COPRAS − to rank higher education institutions and select the sample for the research; DEA − for the evaluation of higher education institutions' economic efficiency of technology transfer process.

The tasks for the dissertation:

1. Based on the literature analysis, to select indicators (KPIs) that enable the evaluation of the efficiency of the technology transfer process at higher education institutions.
2. To apply a quantitative method and perform the research with technology transfer experts to identify KPIs (indicators) for the research.
3. To analyse the tools (advantages, disadvantages and limits) selected for efficiency evaluation model to value the technology transfer process economic performance of HEIs. To prepare the framework and methodology to evaluate the efficiency of the technology transfer process economic performance of HEIs, implementing R&D and innovation activities, including foreign countries.
4. To gather the data and design the database for empirical research.
5. To approbate the created technology transfer process efficiency evaluation model of higher education institutions.
6. To analyse the research findings, evaluate influencing factors on technology transfer process, and provide insights to improve the efficiency of higher education institutions' technology transfer process economic performance.

2

The Model of Efficiency Evaluation of Technology Transfer Process in Higher Education Institutions: Research Design, Methodology and Application

After the in-depth analysis of the literature on TTP and relating factors, the efficiency evaluation model of HEIs is prepared and the framework of methodology provided in this Chapter 2.

The findings of Chapter 2 have been published in 2 scientific papers (Stankevičienė, Kraujalienė 2019; Kraujalienė 2019).

2.1. The Concept of the Formation of the Criteria System of Higher Education Institutions' Technology Transfer Process Performance

The processual approach is very important for the quality management system within HEIs. This approach generates the value for HEIs' activities, and helps to improve existing processes to acquire economic growth by evaluating actual data and information. The management of the process encompasses methods and tools that allow not only the organizing and executing, but also the measuring of the processes by indicators of HEIs' economic performance.

For evaluation of the economic performance, HEIs are required to know about the performance indicators.

One of the most widespread tendencies during the last two decades has been performance measurement in the public sector. Economic rationality and efficiency of the public sector, and also belief in its beneficial effects, are two common characteristics in innovative public management processes (Spekle, Verbeeten 2014).

For controlling the achievement of HEIs' goals of processes and measuring the process's economic performance, HEIs' activity is based on the key metrics of higher education, known as key performance indicators (KPIs) (Wetzstein *et al.* 2008).

According to any quality theories and concepts, a quality indicator measures every process. The use of these indicators has well-defined measurement characteristics important for monitoring TTP performance, and identifying the possibilities for improvement (Sciacovelli *et al.* 2016). The performance management process requires making available indicators for decision-makers, such as elements that allow making a tangible context, in order to enable valuations, predictions, comparisons and making decisions. The complex of indicators is a tool that makes the concept of the target operational for a certain context and represents the systems, permitting the analysis and collection of information for monitoring the development of the system. Many authors provided several definitions to describe the term "indicator" term, for example: "a measure of the behavior of a system in terms of significant and perceptive attributes" and "variables that describe a system in which the variable is an operational representation of an attribute of the system, and an image that represents the attribute defined in terms of a specific measurement and observation". Other authors have characterized performance indicators as quantitative indicators that reflect the progress and status of a company, individual or unit, a particular aspect of a quantitative measure of an entity's performance or its service level. Indicators are described as measures aimed towards managers of specialized systems (Vilanova *et al.* 2015). These kinds of performance indicators may exist in the research papers, including the quality, cost, financial benefit, delivery reliability, flexibility, employees' satisfaction, safety, customer satisfaction, learning and growth, environment/community (Bhatti *et al.* 2014).

More attention is paid in this Subchapter to measuring the outcomes of HEIs TTP activities. This dissertation presents a framework for HEIs to select KPIs for measuring, monitoring and improving their TTP economic performance results.

This framework can be used for identifying possible KPIs, defining and valuing new potential KPIs, selecting appropriate KPIs based on TTP influencing factors, and compiling the selected KPIs with assigned weights into a database of selected KPIs. The main factor in KPI development is the definition of organizational goals (e.g. strategic plans), which must be ranked taking into account their importance (Kibira *et al.* 2018).

Indicators should be selected in the management of the TTP, based on the relevance, analytical (technical and scientific) conditions, measurability (costs and data availability), data comparability and quality (Vilanova *et al.* 2015).

Performance measurement indicators used in different systems and countries, are usually similar, despite differences in data availability and different nomenclatures. Indicators are categorized according to their nature (Vilanova *et al.* 2015). The performance indicators could be described as physical values that are used to measure, manage and compare the overall performance of the institution. Performance measures are useful for evaluation and controlling the overall operations of the organization (Bhatti *et al.* 2014).

Economic efficiency corresponds to the minimal possible cost for production of outcome or increasing the production attainable with the same investment level (Vilanova *et al.* 2015).

Performance measurement has the following objectives: to support decision-making; to increase motivation and change behaviour; to monitor trends of performance; to decide on priorities and actions; to verify the efficiency of already implemented optimization measures; to help in the dissemination of organizational performance results via marketing; and to assist benchmarking processes (Vilanova *et al.* 2015).

The link between performance indicators and performance targets should be established; organizations can deploy the mechanisms of performance measurement and in this way identify weak points in order to make decisions to achieve estimated organizational goals (Vilanova *et al.* 2015).

Thus, the start of the performance measurement begins with the identification of TTP performance indicators, which required the detailed specification of the process performance. Authors selected two main groups of indicators that are used to evaluate the performance of the institution. The first is called the financial (cost-based) group of indicators, while the second group is called the non-financial (non-cost-based) measures of performance (Bhatti *et al.* 2014).

Previous aspects are important and must be taken into account to form the criteria system for the evaluation of the efficiency of HEIs' TTP economic performance.

2.2. The Estimation of Significant Criteria of Higher Education Institutions' Technology Transfer Process

The present research is focused on developing a model to evaluate the efficiency of TTP economic performance outcome at HEIs. The indicators foreseen to measure a process. In addition, the indicators evaluate every process.

Possible indicators was identified from the literature review and taking into account inside and outside factors, to measure TTP performance of HEIs.

For the first research (FARE and TOPSIS tools) in this dissertation, the following categories of TTP performance indicators were selected.

To evaluate the performance of TTOs the following categories of variables, data sources, descriptions and names for the research are taken: patent applications (number generated per HEI); TTOs (employees, PhD-share, tasks); 21 Lithuanian HEIs (funding, students, publications – 3 years/researcher); regional aspects (industry concentration, start-ups).

The research method incorporates the mentioned categories of variables of Lithuanian HEIs, TTO and regional indicators of TTP while identified indicators framework is the novelty in this research work. Table 2.1 details the variables, descriptions and data sources chosen for the research.

The research with mentioned indicators started with the collection and analysis of the data: TTO (telephone surveys) with question on the number of employees working in TTO (FTE, in full-time equivalent), tasks measured per employee, the number of persons with a PhD academic degree employed in TTO; HEIs are characterized by research and teaching activities (data collected from HEI annual reports and the Association of Lithuanian Higher Education Institutions for the General Admission), and funding (3-year average for researcher) data, the number of students, publications (3-year average publications for researcher) data; regional aspects of economic activities are industry concentration (the number of staff in the region), entrepreneurial activity (Start-up companies at universities). Pfeffer (1995) demonstrates that a workforce can perform well with effective management and that requires a period of time. That is why the period selected for the research is 2011–2013.

To implement the research of TTP economic performance it is possible to choose other indicators. For instance, after tracking for other efficiency evaluation indicators in comparison with the previous ones, there are some indicators based on official public data of the Research Council of Lithuania valid for all HEIs in Lithuania. Therefore, the Research Council of Lithuania has defined such indicators, provided later on, appropriate for the evaluation of Lithuanian HEIs through TT and commercialization performance results.

Table 2.1. Variables and measurement of the research method (adapted from Hulsbeck *et al.* 2011)

Category	Name	Description	Source
Endogenous	Patent applications	3-year average	Lithuanian Patent Office
TTO	Employees	Number of employees in the TTO (full-time work)	Interviews with TTO managers
	Tasks	The number of tasks per employee at TTO	Interviews with TTO managers
	PhD Share	The number of full-time working researchers with PhD academic degree	Interviews with TTO managers
HEI	Funding	3-year average of funding per one researcher	Universities' reports
	Students	The number of students in HEI	Association of Lithuanian Higher Education Institutions for the General Admission
	Publication	3-year average of publications per researcher and year	Universities' reports
REG	Industry concentration	Industry concentration coefficient based on the number per employees in certain regional industries	The Lithuanian Department of Statistics
	Start-ups	The number of Start-ups of certain HEIs	Interviews with TTO managers

The Research Council of Lithuania highlighted those indicators to measure TT performance indicators of HEIs: *Si(TPP)* – the amount of financial resources received by the HEI during participation in international research projects of international programmes; *Si(USU)* – the amount of financial resources received by the HEI during implementation of basic, applied and experimental (social, cultural) research works with industry; PLE_i – full-time equivalent (FTE) of scientists (artists) at the HEI; Σ EVV – number of points at the field of 1st-level educational (art) work; Σ AIV – the number of points at the field of 2nd-level educational (art) work; d_{si}– declared number of research works in a certain field; F_i– measure of formal valuation; E_i – normalized summed measure of research works in a certain field; SE_i – summed measure of evaluation of experimental research works; LE_i – normalized summed measure of research works in a certain field. Every university has to provide at least 5 or more experimental science works. T_i – the number of points attributable to the FTE of one scientist (artist); LF_i – measure of formal valuation, calculated for those HEIs whose FTE of scientists (artists) was equal to or more than 5. Among the mentioned indicators, for instance, was distinguished for research using the MULTIMOORA tool in this dissertation based on the official data provided by the Research Council.

Going deeper, HEIs' TT performance results depend not only on successful innovative TT activities and university-industry cooperation, but also on government financial funding, distributed according to the priority for certain R&D fields. Eurostat database is suitable for searching of indicators to measure the economic performance.

Therefore, beyond all the mentioned indicators, some other indicators exist in the Eurostat database. There are some indicators to assess the efficiency of R&D funding by sector of performance in European countries. The Eurostat database provides the possibility to evaluate the performance for the period of 2005−2014, which is very important to provide insights and help in making decisions for responsible decision-making staff.

It should be noticed, that every analysed sector of performance invests a different part of their budget in the R&D processes. Investments contribute to innovation and economic growth. To compare indicators of different countries, all performance indicators should be placed on one platform, comparing the data of R&D expenditures by sector of performance. For this purpose, it should be chosen choose one of the decision-making methods.

European documents show the priority to invest in R&D.

Performance indicators of R&D expenditures in TTP are important to see the picture of different sectors with their investment in R&D. The performance of innovation and TTPs depends on the amount of investments send for innovation activities. Therefore, it is needed a clear picture of investments from the different sides: business, higher education, government, non-profit organizations.

For the efficiency assessment four (4) different sectors of performance are chosen, identified in the Eurostat official database, on the level of the country (Eurostat 2017):

1. The business enterprise sector.
2. The government sector.
3. The higher education sector.
4. The private non-profit sector.

All the mentioned sectors and their parties (business, science or government institutions) are involved in the TT process. Usually innovative solutions are creating in the public sector (universities, institutes), when business is playing commercialisation point of scaling created technologies. Only big companies could allow to invest into the laboratories to implement R&D solutions. Therefore, it is more useful and cheaper ordering research works from higher education institutions. On the other hand, economic return from R&D also depends on the investments from the government.

Therefore, indicators selected for efficiency evaluation are the following:

1. Intramural R&D expenditure (GERD) (euros per inhabitant).
2. Intramural R&D expenditure (GERD) (purchasing power standard (PPS) per inhabitant at constant prices).
3. Sector of fund − all sectors (euros per inhabitant).
4. Total R&D expenditure (euros per inhabitant).
5. Total R&D activity (euros per inhabitant).

These indicators were distinguished for the research using the COPRAS tool in this work. The same performance indicators were evaluated in every four sectors of performance. In total, a calculation was performed for 20 performance indicators in four sectors, analysing 28 European countries.

Taking into account various limitations and pitfalls, for the DEA tool in the dissertation, the input and output indicators were selected next, from the official public report of the Lithuanian Research Council. The logic of indicator selection is yearly performance results of 2013 and 2014 of inputs produced yearly performance results for 2015 and 2016 outputs. Two years of performance for inputs and outputs were selected taking into consideration the limitation of available official data.

Due to DEA pitfall on the number of indicators in relation to the number of HEIs (see Subchapter 2.3), three *inputs* and three *outputs* were selected, in this dissertation to measure the efficiency of TTP economic performance of seven HEIs, implementing TT and commercialization activities.

For this research, these TTP performance indicators were identified:

$S_i(TPP)$ – the amount of financial resources received by HEI during participation in international research projects; $S_i(USU)$ – the amount of financial resources received by HEI during implementation of research and experimental (social, cultural) development science works with industry; PLE_i – full-time equivalent (FTE) of the HEI's scientists (artists); ds_i – the number of declarative science jobs in a certain field.

Hence, for the inputs the following three indicators were identified:

1. $S_i(TPP)$ (IN 1).
2. $S_i(USU)$ (IN 2).
3. ds_i (IN 3).

Meanwhile for the outputs the following were selected:

1. PLE_i (OUT 1).

2. The number of *PhD* students (OUT 2).
3. The number of *Master* students (OUT 3).

The data for the indicators of $S_i(TPP)$, $S_i(USU)$, ds_i, PLE_i was gathered from the official public report of the Research Council of Lithuania and intended to evaluate Lithuanian HEIs by science-business economic performance results. The number of *PhD* and *Master* students were collected from the official legal document: the order of the head of the Ministry of Education and Science. In this dissertation, the calculations will be performed in two major fields: social (H, S, M) and physical (P, A, B, T).

Summing up, a necessary aspect during selection of certain indicators to measure the TTP economic performance is to select indicators homogeneous for every HEI, taking into account the limitations and pitfalls of the selected tools. This will ensure the selection of suitable indicators for the TTP measuring tools and evaluate the performance results. The first step in performance evaluation is to decide on indicators suitable for measuring the economic performance of HEIs in the TT and commercialization sphere. The second step is to apply the appropriate model using the available tools.

A detailed description of the possible tools for the model proposed to measure the efficiency of TTP economic performance is provided in Subchapter 2.3.

2.3. The Efficiency Evaluation of Higher Education Institutions' Technology Transfer Process Performance: Selection of Tools and Application Aspects

One of the main problems and issues occurring in the higher education sphere is unsuccessful TTP performance. In this dissertation, the survey research method and multi-criteria decision-making (MCDM) mathematical tools are selected in order to acquiret primary quantitative data on the topic. Hence, the following MCDM methods are incorporated in the efficiency evaluation model of TTP performance of HEIs: 1. FARE; 2. TOPSIS; 3. COPRAS; 4. MULTIMOORA; 5. DEA.

There are several tools to evaluate the economic performance of activities.

In the contemporary world, quantitative MCDM methods have been used as a rule for the comparative evaluation of technological and economic or social processes, and also to determine the best alternative within a number of options, and rank those alternatives by their performance results (Podvezko 2011).

The main concept of quantitative evaluation tools is to convert the values of criteria, which characterize a certain process, and the weights of criteria into one dimension: the criterion of the method. In the case of maximizing criteria, the best is the largest value, while in another case, during the calculation of minimizing criteria, the best is the smallest value. Performance indicators of criteria and their units are also different. All alternatives are compared with each other and ranked in accordance with calculated values of a certain criterion (Podvezko 2011).

During recent years previous researchers (T. Baležentis, A. Baležentis 2014; Hashemkhani Zolfani *et al.* 2018; Kabak, Dagdeviren 2014; Mardani *et al.* 2015a, 2015b) have developed, proposed and applied various MCDM methods (Ghorabaee *et al.* 2014; Hashemkhani Zolfani *et al.* 2014; Madic *et al.* 2016), intending to solve complicated problems in met decision-making issues.

The following research stages were distinguished to solve the research problem on the topic of estimating the indicators for HEIs' TTP performance (see the figure below).

The efficiency evaluation framework was designed (Fig. 2.1) consisting of three stages to evaluate HEIs TTP economic performance, implemented by TTOs. Firstly, indicators were identified, and the data were gathered from experts' interviews and HEI rectors' reports. Later, the FARE method was selected to estimate the weights of the TTP performance indicators. Then, the TOPSIS method was applied to rank HEIs by the greatest economic performance results.

Ginevičius previous research results (2006, 2007, 2008) produced the base for new Factor Relationship (FARE) method (Ginevičius 2011), which was proved as credible as other multi-criteria methods. This method enables the possibility with less initial information get wider range of calculations. In the case of TTOs performance evaluation in HEIs with many criteria, this method can capture the most rigorous results in the context of available data. In order to use this method, the fallowing sequence needs to be applied:

The frame of method application: based on the systems theory all elements need to be inter-connected in one or another way.

Two main implications need to be considered:

1. Total impact on the investigation increase when the number of criteria that transfers its potential also increase.
2. The opposite reaction will occur when the number of criteria that transfers its potential decreases.

Then the equation of the impact of criterion is calculated by formula 2.1 below (Ginevičius 2011):

$$P = S\,(m - 1), \tag{2.1}$$

where, P is the impact of criterion; S is the maximum value of evaluation used; m is the number of the criteria.

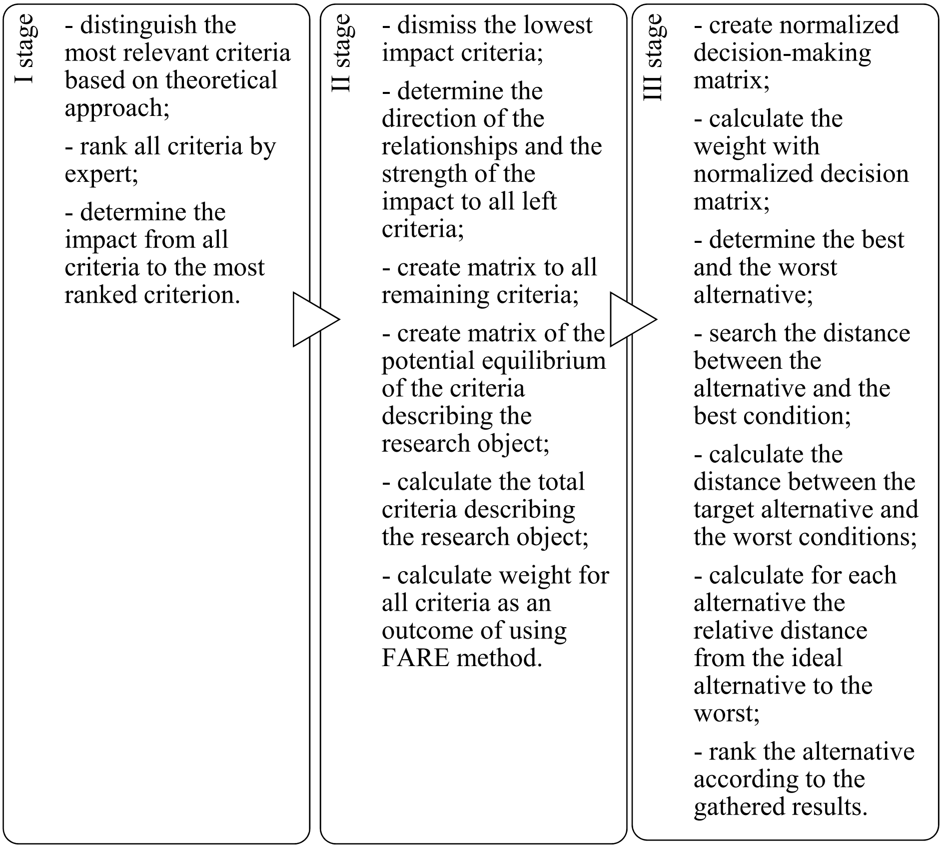


Fig. 2.1. Structure of the research stages with FARE and TOPSIS performance evaluation tools (Stankevičiene *et al.* 2017)

In the next step, experts in the TT and commercialization field evaluate each criterion, based on their uncertainty, with the purpose of seeking the main criterion in comparison with the rest of the other criteria.

Moving forward, experts ascertain the scope of the transfer by defining the impact of formula 2.2 of the criteria a_i on the main criterion (Ginevičius 2011):

$$a_{1i} = S - \widetilde{a_{1i}}, \tag{2.2}$$

where a_i is the impact of *i*-th criterion on the first major criterion; $\widetilde{a_i}$ is the part of *i*-the criterion's potential impact transferred to the major criterion.

Then, based on Kendall's (Kendall 1970) coefficient, the coherence between the direct group of experts' united opinions must be verified. The concordance coefficient W varies from 0 to 1 ($0 < W < 1$); 0 means total incompatibility; 1 – full compatibility. The following hypotheses are formulated and tested: H_o – expert judgments are contradictory ($W = 0$); H_A – expert assessments are similar ($W>0$) (Kendall 1970).

The average value of ranks − a is calculated by the formula 2.3 (Kendall 1970):

$$a = 0{,}5m \cdot (k + 1), \tag{2.3}$$

where m − number of experts; k − number of objects of expertise.

Deviation from the ranks of the average squared sum is calculated by formula 2.4 (Kendall 1970):

$$S^2 = \sum_{j=1}^{k} \left(\sum_{i=1}^{m} x_{ij} - a \right)^2 , \tag{2.4}$$

where S^2 − deviation from the ranks of the average squared sum; a – average value of ranks; x_{ij} − i-th expert j-th alternative assessment (rank), when $i = 1, 2, ..., m$ and $j = 1, 2, ..., k$.

If there are no overlapping values, the concordance coefficient is calculated by the formula 2.5. Maximum possible deviation from the average squared deviation sum from the ranks can only be calculated in case of total overlap of expert opinion (Kendall 1970):

$$W = \frac{12S^2}{m^2\left(k^3 - k\right)}, \tag{2.5}$$

where W – the value of the concordance coefficient; where m – the number of experts, k – the number of alternatives provided; S − dispersion analogue, which is calculated by formula 2.6:

$$S = \sum_{i=1}^{m} \left(e_i - \bar{e}\right)^2 . \tag{2.6}$$

The amount of ranks in respect of all the experts e_i is calculated by formula 2.7 (Kendall 1970).

$$e_i = \sum_{j=1}^{r} e_{ij} , \tag{2.7}$$

where, e_i – the sum of ranks of the i – indicator with respect to all the experts (Kendall 1970).

The deviation from the overall average value $\bar{e}$ is calculated by formula 2.8 (Kendall 1970):

$$\overline{e} = \frac{\sum_{i=1}^{m} e_i}{m} = \frac{\sum_{i=1}^{m}\sum_{j=1}^{r} e_{ij}}{m}. \tag{2.8}$$

It should be selected the significance level α. If the number of alternatives is large enough (k>7), the criterion x^2 (taken from the distribution table) can be used to check the significance of the concordance coefficient (Kendall 1970).

The value $Wm(k-1)$ has a distribution of X^2 with degrees of freedom f, calculated by formula 2.9 (Kendall 1970):

$$f = k - 1. \tag{2.9}$$

The compatibility of the expert group opinions is determined using a criterion X^2 calculated according to the formula 2.10 given in the case of linked rank (Kendall 1970):

$$\chi^2 = Wm(k-1). \tag{2.10}$$

If the calculated value of the statistics (factual) $X_f^2 = Wm(k-1)$ is near the α and f situated over the calculated critical value, then the hypothesis H_o, that expert evaluations are contradictory, is rejected.

All the interconnections between the criteria, their strength, together with the relationships created at the first steps, are evaluated analytically (Ginevičius 2011).

The direction is as follows: the lower rank criterion transfers a part of its potential to a higher rank criterion. Therefore, the impact is measured by formula 2.11 (Ginevičius 2011):

$$\widetilde{a_\iota} = \pm(\widetilde{a_{1\iota}} - \widetilde{a_{\iota 2}}). \tag{2.11}$$

The structure is $a_{ij} = -a_{ij}$, where the matrix substantiates the total dependence of a criterion on other criteria (Ginevičius 2011).

Afterwards, the impact P_i is calculated by formula 2.12 (Ginevičius 2011):

$$P_i = P_i - m \cdot a_{1i}\,, \tag{2.12}$$

where the total impact of each criterion is collated with the total potential (P_S) of the criteria, calculated by formula 2.13:

$$P_S = m \cdot P = mS\,(m-1). \tag{2.13}$$

Now the factual potential is ready to be found using formula 2.14 (Ginevičius 2011):

$$P_i^f = P_i + , \tag{2.14}$$

where P_i^f is the factual impact of the i-th criterion; P_i is the total impact produced by the i-th criterion or its dependency on other criteria.

Finally, the values w_i of the total impact of the criteria are estimated by formula 2.15 (Ginevičius 2011):

$$w_i = \frac{P_i^f}{P_S} = \frac{P_1 - ma_{1i} + S(m-1)}{mS(m-1)} . \tag{2.15}$$

There are many decision-making approaches and techniques used by scientists (T. Baležentis, A. Baležentis 2014; Kabak, Dagdeviren 2014; Mardani *et al.* 2015a; Zavadskas *et al.* 2014). The TOPSIS method is popular with many authors in their scientific works (Choudhury 2015; Ding, Zeng 2015; Song, Zheng 2015).

The framework for the application of the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) tool is set out below.

The TOPSIS is a multi-criteria decision analysis method created by Hwang and Yoon (1981). This method is able to select the best alternative that has the shortest distance from the positive-ideal solution (PIS) and the longest distance from the negative-ideal solution (NIS) (Wang, Chang 2007). This tool helps theoretically ascertain the highest (mostly desirable) and the lowest (mostly avoidable) values for all criteria. Therefore, the method widely used (Choudhury 2015; Ding *et al.* 2015; Song, Zheng 2015; Zavadskas *et al.* 2016; Hashemkhani Zolfani *et al.* 2014) by decision-makers to rank the variety of alternatives estimated on a group of conflicting and disproportionate criteria. The sequence of the following steps of the TOPSIS method should be implemented as described in the following further steps.

Step 1. To create the normalized decision-making matrix consisting of m alternatives and n criteria, with the intersection of each alternative and criteria given as x_{ij}, with the comparison matrix in formula 2.16 (Zavadskas *et al.* 2016):

$$\left(x_{ij}\right) m \times n; \tag{2.16}$$

$$\bar{x}_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i-1}^{m} x_{ij}^2}} , \tag{2.17}$$

where m – alternatives, n – criteria, $i = 1, 2, 3, \ldots m$; $j = 1, 2, 3, \ldots n$. Normalized decision matrix of intersection of alternatives and criteria – $\bar{x}_{ij}$ is calculated by formula 2.17.

Step 2. To calculate the weights with normalized decision matrix with formula 2.18 (Zavadskas *et al.* 2016):

$$\hat{x}_{ij} = \bar{x}_{ij} w_j , \tag{2.18}$$

where w_j – weights.

Step 3. To determine the best and the worst alternative from all alternatives (formulas 2.19–2.22) (Zavadskas *et al.* 2016):

$$x_{pj} = max_i \, x_{ij} \; ; \tag{2.19}$$

$$x_{pj} = min_i x_{ij} \; ; \tag{2.20}$$

$$x_{bj} = max_i x_{ij} \; ; \tag{2.21}$$

$$x_{bj} = min_i x_{ij} \; , \tag{2.22}$$

here x_{pj} – the best alternative; x_{bj} – the worst alternative.

Step 4. Calculation of the distance between the alternative *i* and the best condition of d_{pi} is performed by formula 2.23 (Zavadskas *et al.* 2016):

$$d_{pi} = \sqrt{\sum_{j=1}^{n} \left(x_{ij} - x_{pj} \right)^2} \; . \tag{2.23}$$

Step 5. The distance between the target alternative *i* and the worst condition of d_{bi} is calculated by formula 2.24 (Zavadskas *et al.* 2016):

$$d_{bi} = \sqrt{\sum_{j=1}^{n} \left(x_{ij} - x_{bj} \right)^2} \; . \tag{2.24}$$

Step 6. Calculation of the relative distance K_i for each alternative from the ideal alternative to worst is performed by formula 2.25 (Zavadskas *et al.* 2016):

$$K_i = \frac{d_{bi}}{d_{pi} + d_{bi}} \, . \tag{2.25}$$

Step 7. Finally, rank the alternatives according to the gathered results.

Let us look at another tool, MULTIMOORA, which allows the measurement of the TTP performance of different HEI activities (e.g. science works in numbers, money, full-time equivalent, points, etc.) afterwards, to rank HEIs according to the highest results.

A number of scientific studies indicate prevailing issues in the higher education sphere: the absence of efficiency of TTP performance, implementing TT and commercialization activities, such as connecting university with business entities, innovation management, commercialization (licensing, spin-offs, entrepreneurship, etc. (Bin Ab Hamid 2015; Guerrero *et al.* 2016; Hsu *et al.* 2015; Kwon, Yoon 2015; Nielsen, 2015; Oehler *et al.* 2015; Sharifi *et al.* 2014).

The Multi-Objective Optimization by Ratio Analysis (MOORA) method was introduced by Brauers and Zavadskas (2006). This method was developed (Brauers, Zavadskas 2010) and became MULTIMOORA (MOORA plus the full multiplicative form). These methods have been applied in different studies (Akkaya *et al.* 2015; Hafezalkotob, Hafezalkotob 2015; Hafezalkotob *et al.* 2016; Karabasevic *et al.* 2014, 2015; Liu *et al.* 2014, 2015; Stanujkic 2015, 2016; Stanujkic *et al.* 2015).

The MOORA method begins with the matrix X, where its elements denote j-th alternative of i-th objective ($i = 1, 2, \dots, n$ and $j = 1, 2, \dots, m$). In this case, $m = 7$ alternatives (Lithuanian universities) and $n = 22$ objectives (indicators). The MOORA method consists of two parts: the ratio system and the reference point approach.

The ratio system of MOORA. The ratio system defines data normalization by comparing an alternatives of an objective to all values of the objective in formula 2.26 (Brauers, Zavadskas 2010):

$$x_{ij}^{*} = \frac{x_{ij}}{\sqrt{\sum_{j=1}^{m} x_{ij}^{2}}}, \tag{2.26}$$

where x_{ij} − response of alternative j on objective i; $j = 1, 2, ..., m$; m – number of alternatives; $i = 1, 2, \dots, n$; n – number of objectives; x_{ij}^{*} – a dimension less the number representing the normalized response of alternative j on objective i. These responses of the alternatives to the objectives belong to the interval [0; 1].

These indicators are added (if desirable value is maximal) or subtracted (if desirable value is minimal) and the summary index of state is derived accordingly by formula 2.27 (Brauers, Zavadskas 2010):

$$y_{j}^{*} = \sum_{i=1}^{i=g} x_{ij}^{*} - \sum_{i=g+1}^{i=n} x_{ij}^{*}, \tag{2.27}$$

where $i = 1, 2, \dots, g,$ as the objectives to be maximized; $i = g + 1, g + 2, \dots, n$, as the objectives to be minimized; y_j^* – the normalized assessment of alternative j with respect to all objectives.

The reference point of MOORA. This reference point in theory starts from the already normalized ratios, as defined in the MOORA method. The j-th coordinate of the reference point can be described as $rj = max\ x \times ij$ in the maximization case. Every coordinate of this vector represents the maximum or minimum of certain objectives. Then every element of the normalized responses matrix is recalculated and the final rank given according to the deviation from the reference point and the Min-Max Metric of Chebyshev, see formula 2.28 (Brauers, Zavadskas 2010):

$$\min_i(\max_j | r_j - x_{ij}^* |) . \tag{2.28}$$

The full multiplicative form of multiple objectives and MULTIMOORA. Brauers and Zavadskas (2010) proposed the updated MOORA with the full multiplicative form method embodying maximization as well as minimization of purely multiplicative utility function. The overall utility of the *j*-th alternative can be expressed as a dimensionless number by formula 2.29 (Brauers, Zavadskas 2010):

$$U'_j = \frac{A_j}{B_j} , \tag{2.29}$$

where $A_j = \prod_{g=1}^{i} x_{gi}$ j = 1, 2, …, m; m – number of alternatives; i – number of objectives to be maximized; $B_j = \prod_{k=i+1}^{n} x_{kj}$ $n - i$ – number of objectives to be minimized – utility of alternative j with objectives to be maximized and objectives to be minimized.

Thus, MULTIMOORA assembles MOORA (which includes the ratio system and reference point) and the full multiplicative form. The MULTIMOORA tool is easy to use and apply for evaluations.

There is one more tool – COPRAS, which is suitable for multi-criteria ranking as the tool for analysis and decision-making.

This thesis will show the approbation of this tool in the case of R&D funding by sector of performance in European countries (see Chapter 3). This approach of an eight (8) step by step-by-step framework could also be used to assess any other performance results and prioritize them according to the greatest.

A number of authors have applyed COPRAS (and its extension), or other MCDM methods in their research papers (Bausys *et al.* 2015; Ghorabaee *et al.* 2014; Ginevičius 2008; Hashemkhani Zolfani, Bahrami 2014; Koçak *et al.* 2017; Kracka *et al.* 2010; Liou *et al.* 2016; Mousavi-Nasab, Sotoudeh-Anvari 2017; Mulliner *et al.* 2016; Nguyen *et al.* 2015; Rezazadeh *et al.* 2017; Rivera *et al.* 2017; Sen *et al.* 2017; Zavadskas *et al.* 2014; Zolfani *et al.* 2017).

The systematic framework to apply COPRAS is presented below.

COPRAS Step 1 is intended to form data matrix for decision-making.

To solve certain problems in the business-science issues, first of all a decision-making matrix should be formed from the data, in this case, Eurostat. Later on, the matrix is constructed using formula 2.30 below (Organ *et al.* 2016):

$$D = \begin{matrix} A_1 \\ A_2 \\ A_3 \\ . \\ A_m \end{matrix} \begin{bmatrix} x_{11} & x_{11} & x_{13} & . & x_{1n} \\ x_{21} & x_{22} & x_{23} & . & x_{2n} \\ x_{31} & x_{32} & x_{33} & . & x_{3n} \\ . & . & . & . & . \\ x_{m1} & x_{m2} & x_{m3} & . & x_{mn} \end{bmatrix}. \quad (2.30)$$

Here: D – decision-making matrix, A – selected European countries for the research, x – the data from the Eurostat database for every country in a certain year, m – the number of alternatives, n – the number of chosen criteria.

COPRAS Step 2 is intended to normalize of decision-making matrix.

The second step is necessary to convert performance indicators to normalized dimension values and later use them for the calculation. The COPRAS method normalization formula is presented below in formula 2.31 (Organ *et al.* 2016):

$$\widetilde{x}_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}}, \quad (2.31)$$

where x_{ij} – *i*-th alternative performance of the *j*-th criterion; $\widetilde{x}_{ij}$ – the normalized value of *j*-th criterion; *m* – the number of alternatives.

COPRAS Step 3 is intended to define of the weighted normalized decision-making matrix.

The weighted normalized decision-making matrix is formed after the construction of the normalized decision-making matrix step. The weighted normalized decision-making matrix is designed by the next formula 2.32 (Organ *et al.* 2016):

$$D = d_{ij} = x_{ij}^{*} \times w_j, \quad (2.32)$$

here: x_{ij} – the performance of *i*-th alternative; w_j – weight of criterion.

COPRAS Step 4 is intended to maximize and minimize of index calculation for every alternative.

This stage is intended for identifying which alternatives will be maximized and which will be minimized. Therefore, each alternative is categorized as a minimized and maximized index. See the formulas below for those purposes (Organ *et al.* 2016).

The maximizing index calculation is performed by formula 2.33 (Organ *et al.* 2016):

$$S_{i+} = \sum_{j=1}^{k} d_{ij}, \quad (2.33)$$

where $j = 1, 2, 3, \ldots, k$.

The minimizing index calculation is performed by formula 2.34 (Organ *et al.* 2016):

$$S_{i-} = \sum_{j=k+1}^{n} d_{ij} , \tag{2.34}$$

where $j = k + 1, k + 2, \ldots, n$.

COPRAS Step 5 is intended to relative weight's calculation for every alternative.

The relative weight's Q_i calculation for *i*-th alternative is performed using the formula 2.35 as follows (Organ *et al.* 2016):

$$Q_i = S_{+i} + \frac{\min_i S_{-i} \sum_{i=1}^{m} S_{-i}}{S_{-i} \sum_{i=1}^{m} \frac{\min_i S_{-i}}{S_{-i}}} . \tag{2.35}$$

COPRAS Step 6 is intended to determine the priority order for each alternative.

The priority order is given based on the weight of each alternative; the results are distributed by comparing alternative weights between each other. The essence is that the higher rank has the alternative with the higher relative weight. This alternative with the highest weight is the most acceptable alternative in comparison with all the rest (Organ *et al.* 2016). See formula 2.36:

$$A^* = \left\{ A_i \middle| \max_i Q_i \right\}, \tag{2.36}$$

where A – the priority order of alternatives.

COPRAS Step 7 is intended to calculate the performance index.

The performance index calculation is carried out by the next formula, 2.37 (Organ *et al.* 2016):

$$P_i = \frac{Q_i}{Q_{\max}} \times 100\% , \tag{2.37}$$

where P_i – performance index of alternatives.

The alternative with 100 per cent means it is the best one. The ranking of alternatives is performed in order, from the best to the worst (Organ *et al.* 2016).

COPRAS Step 8 is intended for ultimate ranking of alternatives.

This step follows the calculation of the performance index P_i of alternatives. The aim of this step is to distribute the results of P_i from the best to the worst to draw a conclusion and prepare the final results of the research.

The Data envelopment analysis (DEA) tool (Fig. 2.2) is used for efficiency evaluation. The necessary calculation aspects of the DEA tool are explicated in the following text.

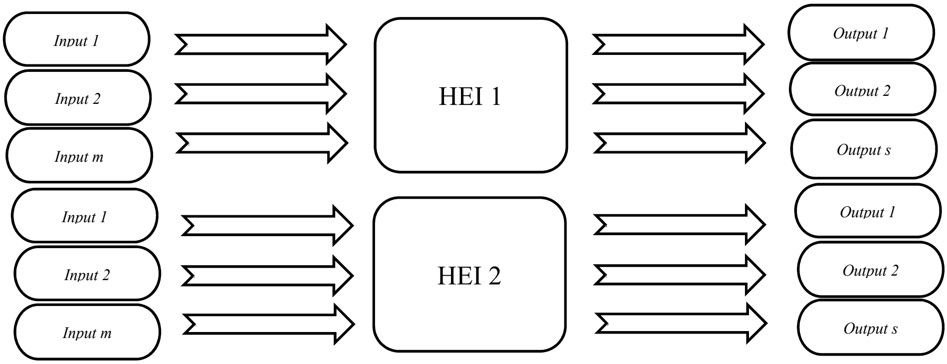


Fig. 2.2. The outline of the DEA model
(compiled by author adapted from Feruś 2008)

In general, there are several DEA models calculating the relative efficiency, which relates to similar companies, universities, banks or other decision-making HEIs in the sample. The original DEA model was created by American economists Charnes, Cooper and Rhodes and widely used in efficiency analysis (Charnes *et al.* 1978, 1981; Feruś 2008).

The DEA is an input-output oriented (the ratio of outputs to inputs) frontier-based linear mathematical programming-based approach which can be used for multiple-criteria evaluation of HEIs as alternatives with own performances (inputs and outputs) (Cook *et al.* 2014).

In the case of inversion of this tool, the output-oriented minimization model is meant. However, in this dissertation it is analysed the input-oriented model (Cook *et al.* 2014).

Hence, the DEA method calculates the efficiency of a certain variable (HEI) in relation to all other variables (HEIs) from a homogeneous group. Effective variables (HEIs) within a homogeneous group make a production frontier (efficiency curve) (Fig. 2.4). Meanwhile, the efficiency of other homogeneous variables (HEIs) is calculated in relation to the efficiency curve, which is found by solving the linear programming issue (DEA method). For those HEIs that are close to the efficiency curve (Fig. 2.4), the coefficient of efficiency is equal to 1. Moving forward, the HEIs located below the efficiency frontier have an efficiency less than 1. And, this scenario is quite enough indication for the level of technical efficiency (Feruś, 2008). In other words, the DEA evaluates observed data of non-frontier

HEIs and the level of efficiency that is relative to a non-parametric, maximum possibility estimate of a true frontier, which is unobserved (Simar, Wilson 2007).

Data selection should be clearly defined. Moving forward, the first concern met is in setting out the performance results into inputs and outputs, which should be clearly selected. In some cases, inputs and outputs could be the same performance indicator. As an example, PhD students at university in one case could act the role of output (as outcome), in another case it could act as input, when it should be treated PhD students as a resource in the scientific production process. Therefore, inputs and outputs should be clearly selected by the author, and substantiated by the reasons for selecting in this way. The DEA approach could also evaluate the services, such as the satisfaction of students (as outputs), when inputs could be such measures as resources expended by the HEI. The most clear inputs and outputs are in the process of production. It should be pointed out here that the DEA method minimizes input and maximizes output criteria (Cook *et al.* 2014).

One peculiarity is to fix the number of HEIs. The DEA model invokes a rule, that the number of HEIs should be at least half less than the number of inputs and outputs combined (Cook *et al.* 2014). While Banker *et al.* (1989) state that the number of HEIs should be at least three times greater than the number of inputs and outputs.

Some research papers state that a potential problem during the selection of indicators for DEA is that the raw data (the number of employees, revenues, profits, assets, etc.) and ratios (as returns on investment and profit per employee) could not be used in the one model. On the other hand, a mixture of percentiles, ratios and raw data is permissible in one measurement of efficiency with the DEA tool. For example, two inputs selected are the number of employees (p_i) and the total average employees' salary (c_i), when the output chosen is annual average sales (d_i) produced by employee. DEA is calculated by $u_i(d_i / p_i) / (v_i(c_i / p_i) + v_2 p_i)$, where u_1, v_1, v_2 are weights. The latter ratio is equivalent to $u_1 d_i / (v_1 c_i + v_2 p_i^2)$. Here is seen that the greatest attention is dedicated to the number of employees, by squaring it, while all the other indicators are evaluated in the linear principle. This example shows that when a factor (in this case – the number of employees) exists between factors of both inputs and outputs, then a concomitant problem could occur in not properly mixing raw data with ratio data. However, research papers do not provide clear justification of this issue (Cook *et al*., 2014).

Moreover, the issues with indicators may also arise in the constant returns to sale (CRS) model. If the indicator (or factor) value is the same at all chosen HEIs, when one input (in the CRS model − output-oriented) or one output (in the CRS model − input-oriented) has the same value as all HEIs, the CRS model becomes a variable returns to scale (VRS) model. The reason for this is that the input or output constraint turns to the convexity constraint within the CRS model. Another peculiarity is that if the indicators of the VRS model are in percentages (the ratio data), then the DEA projections will be in the normal range from 0% up to 100%. However, in the CRS model (output-oriented), the projection of output indicators can reach more than 100%. Thus, bear this in the mind when using a CRS model (Cook *et al.* 2014).

The DEA is a multiple-criteria evaluation methodology, where multiple criteria are modelled in the form of the ratio system. For example, a CCR (introduced by Charnes, Cooper and Rhode) ratio model, when there are no slacks (excess in inputs, and shortfalls in outputs) in any optimal solution, when the efficiency is equal to one (Cook *et al.* 2014). Sometimes, DEA is called "balanced benchmarking" (Deafrontier 2018).

It is preconditioned that each HEI contains at least 1 input and 1 output (Feruś 2008).

Maximum e_{j_0};

Subject to (see formulas 2.38 and 2.39) (Cook, Seiford 2009):

$$e_j < 1\,; \tag{2.38}$$

$$e_j = \frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}}, \tag{2.39}$$

where x_{ij} – DEA inputs, and y_{rj} – DEA outputs, v_i and u_r – unknown weights. For a simple understanding, e_j is the ratio of benefit and cost (Cook, Seiford 2009).

Formula 2.40 is intended for the minimization of the inverse ratio ($1/e_{j_0}$), and it is an output-oriented model, when a change of orientation still be the same. However, such a transformation does not obviously imply a change of orientation.

Farrell (1957) was the first to introduce the study of the efficient frontier, which suggested a simple measure of the efficiency of organization. His model consisted of two stages: the technical and allocative evaluation of efficiency. The technical efficiency was described as an organization's ability to produce maximum output from a number of inputs. Allocative efficiency was described as an organization's ability to use inputs in an optimal proportion in accordance with respective prices. Farrell named this process "cost efficiency" (Palecková 2016).

The CCR model (1978), named after its creators Charnes, Cooper and Rhodes in their study, becomes a CRS model (Palecková 2016). As with the ratio forms of the DEA model – the CCR ratio model is based on proportional reduction (or increase) of input (or output) vectors without slacks (Cook *et al.* 2014). Later, Banker *et al.* (1984) modified the CCR model of the VRS and name it thes BCC model (created by Banker, Charnes and Cooper) (Palecková 2016).

The BCC model eliminates the measures of inefficiencies caused by inadequate HEI size. The presumption of the VRS provides a measurement of absolute technical efficiency, and this implies the lack of scale efficiency impact (Palecková 2016). CRS and VRS efficiency are the constructs of radial projection (Cook *et al.* 2014).

Fig. 2.3 deploys the CCR model based on the assumption of constant returns to scale (CRS) of an organization's activities, as represented by the production frontier in the case of single input and single output (Palecková 2016).

The production frontier of the BCC model with its single input and single output is presented in Fig. 2.4. It is seen that BCC model with its production frontiers looks like the convex body of the existing HEIs. The frontiers have the characteristics of piece-wise linear and concave forms which leads to variable returns to scale (VRS). Fig. 2.4 shows that increasing returns to scale occur in the first segment of the solid line; in the second segment decreasing returns to scale, and constant returns to scale occur in the point of transition from the first to the second segment (Palecková 2016).

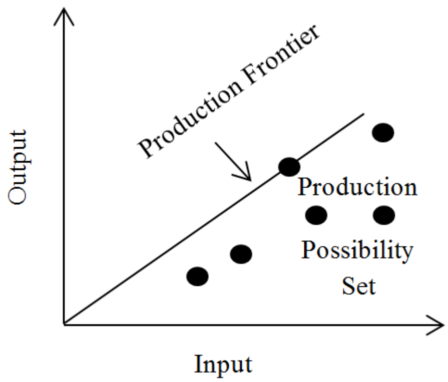


Fig. 2.3. Production frontier of the CCR model (Palecková 2016)

The variable returns to scale (VRS) frontier in Figure 2.4 is shown in the lines 1–2 and 2–3. The frontier line from 1 up to (but not including) point 2 means the increasing returns to scale, while the frontier line from point 2 up to 3 incurs constant returns to scale and means the decreasing returns to scale part of the frontier. Productivity is expressed by the ratio of outputs-to-inputs (Cook, Seiford *et al.*

2009). The efficiency of those HEIs, which are under the frontier efficiency line, means ineffective results (Feruś 2008).

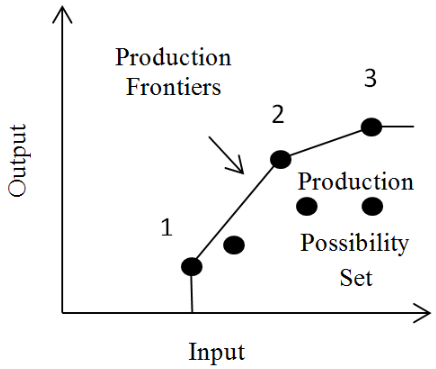


Fig. 2.4. Production frontier (efficiency curve) of the BCC model (Palecková 2016)

The BCC ratio model is applied using the formula 2.40, subject to formula 2.41, taking into account the circumstances of 2.42 (Cook, Seiford *et al.* 2009):

$$e_0 = \max; \left[\sum_r u_r y_{ro} - u_0\right] / \sum_i v_i x_{io}\ ; \tag{2.40}$$

$$\text{subject to: } \sum_r u_r y_{rj} - u_o - \sum_i v_i x_{ij} \leq 0, \text{ when } j = 1, ..., n; \tag{2.41}$$

$$u_r \geq \varepsilon\ ,\ v_i \geq \varepsilon,\ \forall i, r\ , \tag{2.42}$$

here u_0 – unrestricted in sign, ε – is a non-Archimedean value to keep strict positivity of variables; *j* – each HEI; *m* – amount of inputs x_{ij} ($i = 1, ..., m$); *s* – amount of outputs y_{rj} ($r = 1, ..., s$); *u* and *v* – are weights (Cook, Seiford 2009).

The linear programming method (input-oriented model) is calculated by the formulas 2.43, subject to 2.44, taking into account the circumstances of 2.45 (Cook, Seiford 2009):

$$e_0 = \max; \sum_r \mu_r y_0 - \mu_0\ ; \tag{2.43}$$

$$\text{subject to: } \sum_i \omega_i x_{i0} = 1; \quad (2.44)$$

$$\sum_r \mu_r y_{rj} - \sum_i \omega_i x_{ij} \leq 0, \quad (2.45)$$

when $j = 1, ..., n$;

$$\mu_r \geq \varepsilon \text{ , } \omega_i \geq \varepsilon \text{ ; } \forall i, r \text{ .}$$

In this method, μ_0 – unrestricted weight, and variables (Cook, Seiford 2009):

$$\mu_r = tu_r \text{ .} \quad (2.46)$$

In formula 2.46 u – weight. ω – vector of variable's transposition, is calculated by formula 2.47 (Cook, Seiford 2009):

$$\omega_i = tv_i \text{ ,} \quad (2.47)$$

where, t – shows transposition in formula 2.48 (Cook, Seiford 2009):

$$t = \left(\sum_i v_i x_{io}\right)^{-1} \text{ .} \quad (2.48)$$

The latter problem, based on the dual principle, is equivalent to next linear programming model as followed, mean output-oriented minimization model shown in formula 2.49 (Cook, Seiford 2009):

$$\min \ \theta_0 - \varepsilon\left(\sum_i s_i^- + \sum_r s_r^+\right) \text{ .} \quad (2.49)$$

Subject to 2.50, 2.51 and 2.52 (Cook, Seiford 2009):

$$\sum_j \lambda_j x_{ij} + s_i^- = \theta_0 x_{i0} \text{ , } i = 1, \ldots, m; \quad (2.50)$$

$$\sum_j \lambda_j y_{r0} - s_r^+ = y_{r0} \text{ , } r = 1, \ldots, s; \quad (2.51)$$

$$\sum_j \lambda_j = 1 \text{ , } \lambda_j, s_i^-, s_r^+ \geq 0, \quad \forall i, r, j \text{ ,} \quad (2.52)$$

where θ_0 is unrestricted. Here θ – proportionality factor; s_i^- and s_r^+ are slacks, and λ is convexity constraint.

This Subchapter provides the tools and significant aspects of their application. Every tool differs in its advantages and calculation methodologies, however the most important point is to select suitable tools and integrate them into the model to evaluate the efficiency of TTP economic performance of HEIs. The next Subchapter provides the description of the efficiency evaluation model of HEIs' TTP economic performance results. In the Table 1.2 is provided comparative analysis on advantages and disadvantages of multi-criteria decision-making methods, which has been chosen for the research.

2.4. Description of the Efficiency Evaluation Model of Higher Education Institutions' Technology Transfer Process Performance

The present investigation is aimed at developing the efficiency evaluation model for HEIs' TTP economic performance. The model is constructed on the following approaches: tools for searching for and selecting the indicators to measure TTP performance of HEIs (FARE, TOPSIS) and quantitative research with TTO experts; tools to identify the number of samples for the research (MULTIMOORA, COPRAS); tools to measure the economic performance of HEIs' TTP.

It has been tested all methods in Chapter 3 using different data and indicators to measure the efficiency of TTP in HEIs. It was proved whether the methods are suitable for estimated purposes.

The description of the efficiency evaluation model of HEIs' TTP economic performance follows.

Efficiency evaluation theories are dedicated to searching for the most efficient approach to minimize inputs and maximize outputs in order to reach an efficient economic outcome and therefore achieve the most efficient way during decision-making to improve economic performance results. HEIs are no exception. Every policy in the country is intended to upgrade the economy and bring better performance results. HEIs strongly contribute to the economy through the creation of new inventions, technologies and know-how, which can be converted into radical world-class innovations, thereby carrying financial benefit.

Hence, the first step is aimed at identifying certain indicators that are suitable for measuring the economic performance of HEIs' TTP. First, it is important to imagine and map out the TTP of HEIs, starting from all related parties and operations carried out. Based on the theory, please take into account that TT activities are implemented by TTOs, which are situated inside the HEIs (based on the European models). During the implementation of this task, a necessary objective is to find the input and output variables. After identifying of TTP, its related actors, TTO functions, tasks, the concept of possible TTP performance indicators will be designed in our mind. This dissertation provides the literature analysis with defined suitable TTP performance indicators and influencing factors, therefore this will help in painting a picture of the TTP of HEIs. The FARE method is suitable for finding out the most important performance indicators. To realize this step, experts help to distinguish the weight for each indicator through interviews (quantitative research). Accordingly, the most important indicators will be selected for the research. The TOPSIS tool will help to rank these indicators and to choose the sample of performance indicators for the research.

The second step is data gathering for the chosen performance indicators. The easiest way to do this is to search for official data, which are public and easily accessed from open sources. This dissertation provides such examples of data collecting from the following sources: Eurostat (but these data are based only on the country level); the Research Council of Lithuania (HEI-level data, and with the advantage of there being only one methodology for every HEI); HEI rectors' reports (separate HEI level, however the pitfall here is the data interpretation on own mind-set and HEIs' methodology, which usually is not made public). Practice showed that the best source of data is the official information on HEIs' data, calculated using the same methodology for all HEIs. Possible indicators to measure the performance of the TTP of HEIs are provided in Subchapter 2.2.

After decision on the TTP performance indicators, the next step is to choose the number of HEIs, considering such criteria as the implementation of TT activities, and showing at least minimum results in that sphere. Sometimes measuring tools have limitations on the number of HEIs, so this aspect needs to be taken into consideration regarding the final number of HEIs chosen for the study. Subchapter 2.3 provides the advantages and pitfalls of every tool suggested for the TTP efficiency evaluation model of HEIs in this dissertation. This work suggest using MULTIMOORA or COPRAS ranking methods to select HEIs for the research sample.

The last step is to apply the appropriate tools and measure the TTP performance of selected HEIs. The DEA tool is easy to use. DEA is an input-output-oriented frontier-based linear mathematical programming-based approach, which is suggested to evaluate the economic performance of every HEI as an alternative to own performance results. It is noticed that this tool has its own limitations and pitfalls, therefore it is important to be familiar with this tool before application. The mentioned tool is easy to use: after understanding the steps on how to apply this tool, the data should be added into the system and soon the economic performance results will be obtained.

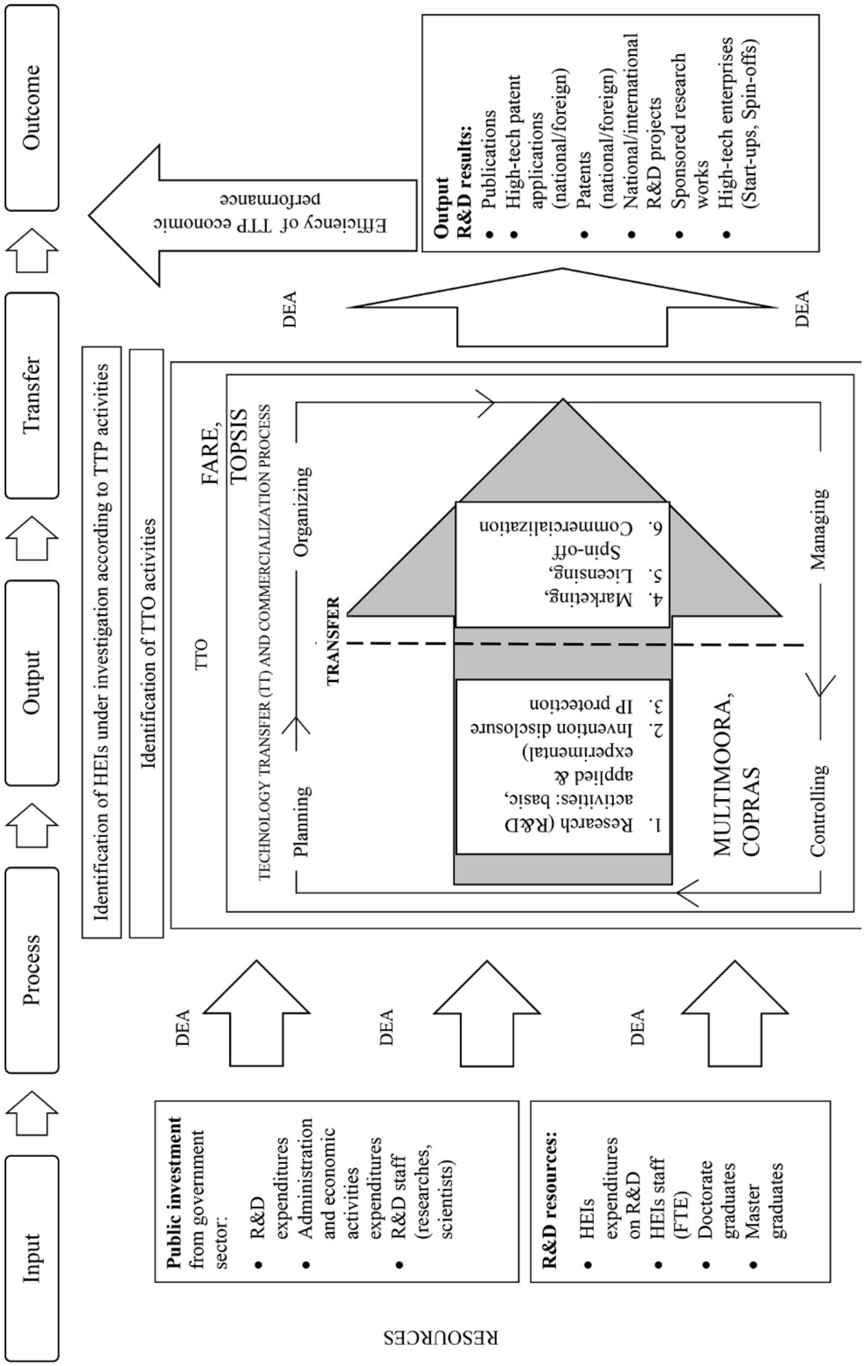


Fig. 2.5. The main resources, parties and actions of higher education institutions' technology transfer process to reach necessary outcome (designed by author)

Performance results and findings are valued by decision-makers in efficiently allocating financial resources and human capital, and making decisions for further improvement of HEIs’ TTP economic performance results.

The next figure is designed to show possible inputs and outputs of TTP inside HEIs (Fig. 2.5). Starting with R&D activities, disclosure of inventions and IP protection, the transfer of IP begins. Therefore, marketing, licensing and commercialization process is implemented. The following indicators may be chosen for inputs: public investments (expenditures on R&D, administration and economic activities, R&D staff: researchers/scientists), R&D resources (HEI expenditures on R&D, HEI staff, doctorates and masters graduates). The following outputs could occur after transferring activities of TTP: publications, patent applications, patents, R&D projects, sponsored research works, high-tech enterprises, etc. To achieve the efficiency of improved economic performance results, it is needed the TTP to be analysed in detail: its actors, the TTO activities, and to measure TTP economic performance and make decisions on steps for improvement. Previous actions will lead to an improvement in the outcome of HEIs TTOs.

2.5. Conclusions of Chapter 2

This subchapter presents the practical magnitude and main conclusions of the second Chapter, which provides the description of the efficiency evaluation model for measuring the technology transfer process in higher education institutions.

1. Several tools have been proposed to integrate into the technology transfer process efficiency evaluation model of higher education institutions. All processes should be measured with estimated indicators suitable for a certain process. Based on this concept, HEIs’ technology transfer process performance indicators have been proposed in the categories of higher education, technology transfer office, regional, when for endogenous category was chosen patent applications. Indicators from open sources are easy to use, and the use of the same methodology to calculate the results of indicators for every higher education institutions helps towards achieving reliable results. However, in comparison with the data in higher education institutions’ rectors’ reports, the information could be interpreted and calculated applying different methods not made public to users. In this case, it is difficult to ensure reliability.
2. Quantitative research methods were chosen to gather these data. The direct (selected) group of experts were given the ranks of the most important indicators, identified from the literature analysis, to measure the efficiency of technology transfer process performance, and the most important ones were selected for the research. Data of every separate higher

education institution was collected from higher education institutions' rectors' reports, Eurostat or The Research Council of Lithuania.

3. The FARE method is suggested to estimate the weights of higher education institutions indicators by their importance of technology transfer process performance with the experts' help. Then, the TOPSIS method is applied to rank higher education institutions by the greatest performance results and to choose the sample for the research. The MULTIMOORA or COPRAS ranking methods are suggested to decide on the number of higher education institutions for the research sample. The DEA tool is easy to apply and is suggested for evaluating the performance of every higher education institution. Finally, the DEA tool is proposed for evaluating the HEIs' efficiency of technology transfer process. According to the advantages and pitfalls of the DEA approaches, three input and three output criteria were selected to measure the performance of seven higher education institutions.
4. A necessary aspect during selection of indicators to measure higher education institution technology transfer process performance is to select indicators that are homogeneous for every higher education institution, taking into account the limitations and pitfalls of the selected tools. The first step is aimed at identifying certain indicators (inputs and outputs), which are suitable for measuring the performance of higher education institutions' technology transfer process economic performance. The second step is gathering the data for the chosen performance indicators. The easiest way to do this is to search for official data, which is public, easily accessed from open sources and reliable. The next step is to choose the number of higher education institutions for the research. Efficiency measuring tools have limitations on the number of higher education institutions, so this aspect needs to be taken into consideration regarding the final number of higher education institutions chosen for the study. This section provides the advantages and pitfalls of every tool suggested for the technology transfer process efficiency evaluation model of higher education institutions. The last step is to apply the appropriate tools and evaluate the technology transfer process performance of selected higher education institutions.
5. After applying the suggested model to evaluate the performance of higher education institutions' technology transfer process, the calculated performance results and findings are circulated among the decision-makers and become the instrument for the efficient allocation of financial and human resources and help them to decide on the future steps necessary to improve higher education institutions' technology transfer process economic performance results.

3

The Empirical Research and Approbation of the Efficiency Evaluation Model of Technology Transfer Process: The Case of Lithuanian Universities

This part of the dissertation is intended for the approbation of the proposed efficiency evaluation model of HEIs' TTP economic performance in the case of Lithuanian universities.

The findings of Chapter 3 have been published in 3 scientific papers (Stankevičienė, Kraujalienė 2017; Stankevičienė, Kraujalienė 2019; Kraujalienė 2019).

3.1. The Framework of Empirical Research

The framework of the research was created at the Faculty of Business Management at *Vilnius Gediminas Technical University*.

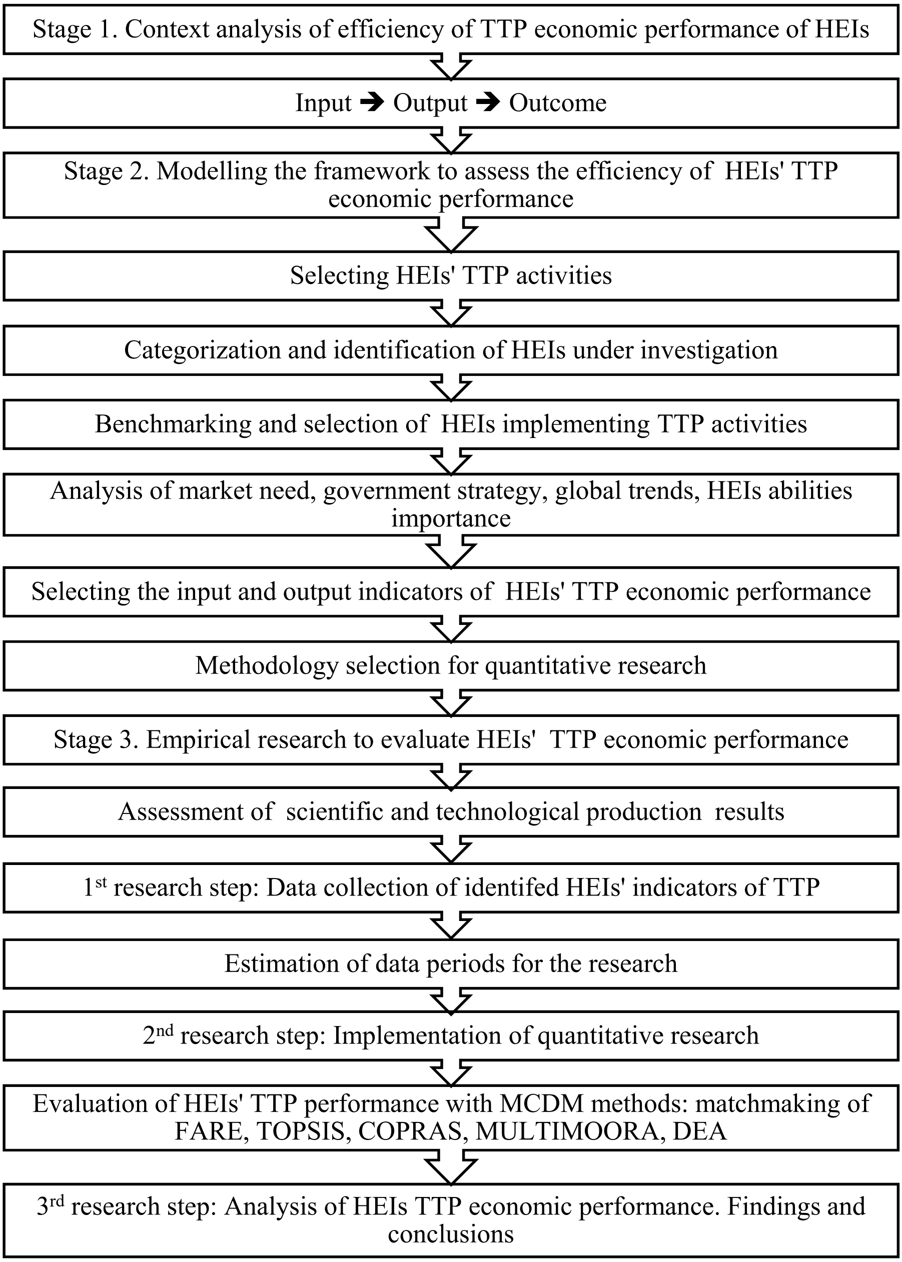


Fig. 3.1. The model to evaluate the efficiency of higher education institutions' technology transfer process (compiled by author)

The following objectives of the empirical research have been pursued: to design the framework to evaluate the efficiency of HEIs TTP economic performance; to design the model and test it in the case of Lithuanian universities.

The model designed in Fig. 3.1 is intended to evaluate the efficiency of HEIs' TTP economic performance. Hence, the first step in stage one is to analyse the context of efficiency of TTP economic performance in HEIs. Moreover, the TTP and its actors, factors, history and facts, input, output and outcome indicators should be carefully analysed before empirical research. In that sense, the next step is to design the model to assess the efficiency of HEIs' TTP economic performance. First, TTP activities within HEI duties should be found. Afterwards, the HEIs under investigation are categorized and identified. The next step is the benchmarking and selection of HEIs that are implementing TTP activities. After analysing the market need, government strategy, global trends, the strength of HEIs' abilities', the input and output indicators of HEIs' TTP are selected. For empirical research, first of all the methodology is selected for implementing quantitative research. With this purpose, several multi-criteria decision-making (MCDM) methods are matched (FARE, TOPSIS, COPRAS, MULTIMOORA, DEA) for modelling the framework of empirical research. The object of the evaluation is R&D production and the results of scientific and technological research. After applying the calculation model, the last step is the analysis of HEIs' TTP performance results, the findings and conclusions.

To go into the model structure in more depth, take a look at the logical structure of empirical research in Fig. 3.2. Here steps are set out from the first (to the top) to the last (at the bottom) step to implement empirical research. The first part of the research is dedicated to the literature review and the analysis of the TTP at HEIs. The second part is intended for modelling the framework to evaluate HEIs' TTP economic performance. In the third part, the empirical research is implemented on the case of Lithuanian universities.

Figure 3.2 presents the logical structure of empirical research. Starting from the first step: disclosure of the context of TTP in the field of higher education, the context should be specified for the justification of the methodological study. This step is also dedicated to the literature analysis and thematization of research, so the in-depth analysis of HEIs' input, output and outcome results is required, as well as the designing of the TTP activity framework (scope), selection of a homogeneous group of HEIs, evaluation of market need, government strategy, global trends, the strength of HEIs' abilities, benchmarking of scientific and technological innovative activity, output of scientific and technological activity. The second step is intended for modelling the framework to evaluate the efficiency of TTP economic performance of HEIs. The goal of this step is designing the model for the efficiency evaluation of HEIs' TTP economic performance, while a later

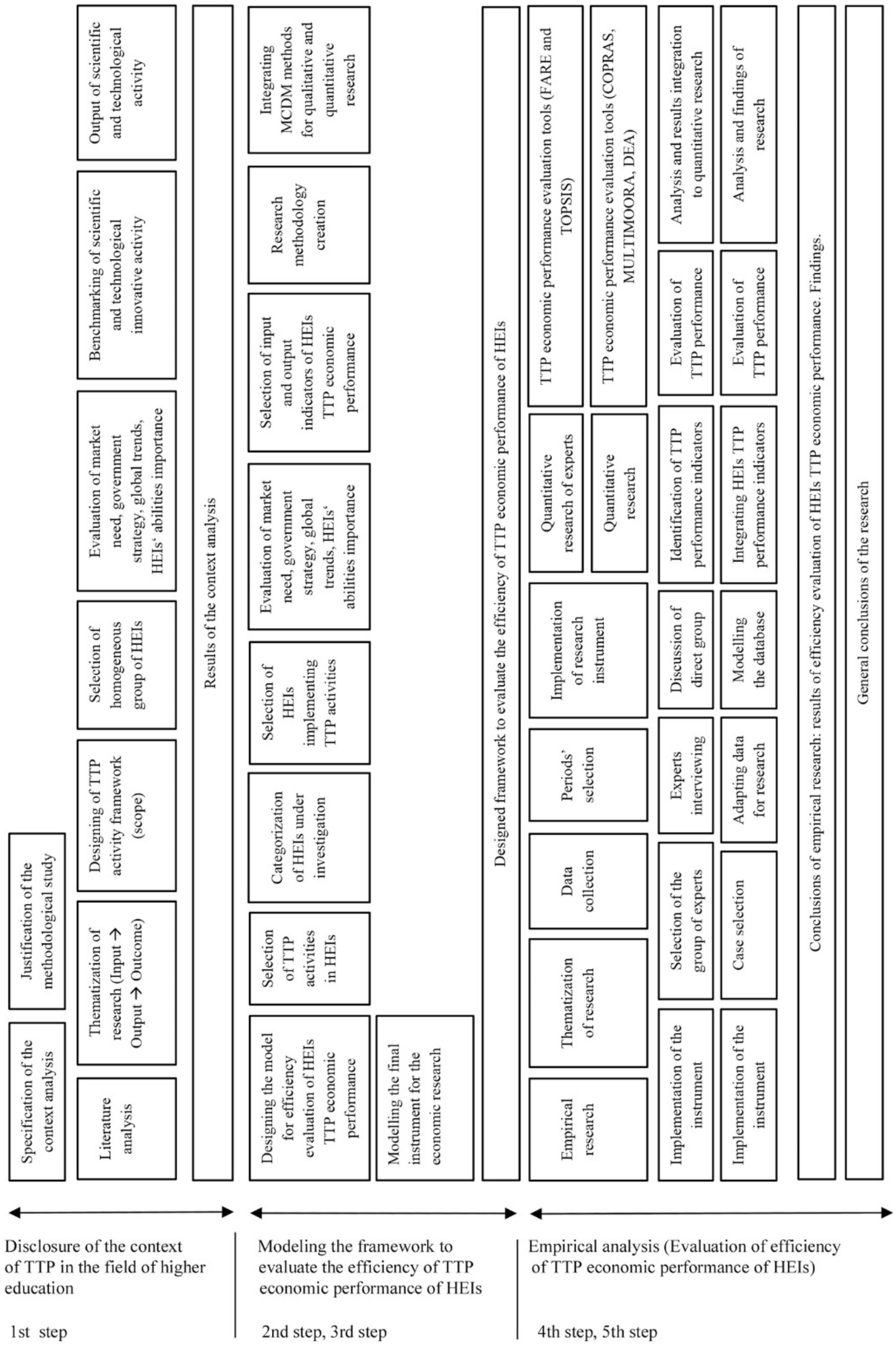


Fig. 3.2. The logical structure of the model for empirical research (compiled by author)

activity is the selection of TTP activities in HEIs, the categorization of HEIs under investigation, selection of HEIs implementing TTP activities, the evaluation of market need, government strategy, global trends, the strength of HEIs' abilities, selection of input and output indicators of HEIs' TTP economic performance, research methodology creation, integrating MCDM methods for quantitative research, modelling the final instrument for the research.The third step is dedicated to the empirical analysis to evaluate the efficiency of the TTP performance of HEIs. This step will be implemented after the following sub-activities: thematization of research, data collection, periods' selection, implementation of research instrument, quantitative research. The model starts from the quantitative analysis and the goal is to evaluate the performance of the TTP economic performance. The first step is the FARE and TOPSIS matchmaking, which are selected to choose the indicators to evaluate the TTP peformance. First of all the selected group of experts should be selected and interviewed, and based on discussion with the direct group, identification of the TTP performance indicators comes next. Thus, the evaluation of the TTP economic performance is implemented. The COPRAS, MULTIMOORA, and DEA tools are then matched. COPRAS and MULTIMOORA are ranking tools selected to choose HEIs for the empirical research, the whole DEA tool is intended to measure the efficiency of the TTP at HEIs. The data for the research should be adapted, and the database modelled. The HEIs' TTP performance indicators re integratd into the model, and afterwardsthe evaluation of the TTP economic performance is accomplished. Analysis and findings finalize the whole research.

The present empirical research has pursued the following objectives: to find an approach to evaluate HEIs' TTP performance; to approve the suggested approach (model) suitable for evaluating the TTP performance of HEIs.

Table 3.1. The framework of higher education institutions' technology transfer process efficiency evaluation (designed by author)

Steps	TTO indicators	Ranking	Efficiency
Tools	FARE	MULTIMOORA	DEA
	TOPSIS	COPRAS	

What is the main aspect of the MCDM methods use? MCDM tools need precise determined data. This means that performance ratings of alternatives and weights of criteria should be precisely determined (Popovic *et al.* 2012).

This dissertation suggests the framework to evaluate the performance of HEIs with decision-making multi-criteria tools (Table 3.1). As it is seen, the evaluation of the TTP of HEIs combines several multi-criteria models leading to the evaluation of performance.

The first step is dedicated to the identification of TT performance indicators. The FARE method is proposed to set the weights of TTP performance indicators (with the experts' help), and to highlight these according to the greatest impact (importance) on the TTP. In the second step it is necessary to choose HEIs implementing TT activities, and at the same time to have the results of the most important indicators selected during the first step. Therefore, MULTIMOORA and COPRAS multi-criteria methods are approbated and appropriate to rank HEIs and to select the sample for the research. Finally, the third step is to evaluate the efficiency of HEIs participating in TTP. The DEA method is a suitable method for evaluating HEIs' efficiency in the field of TT.

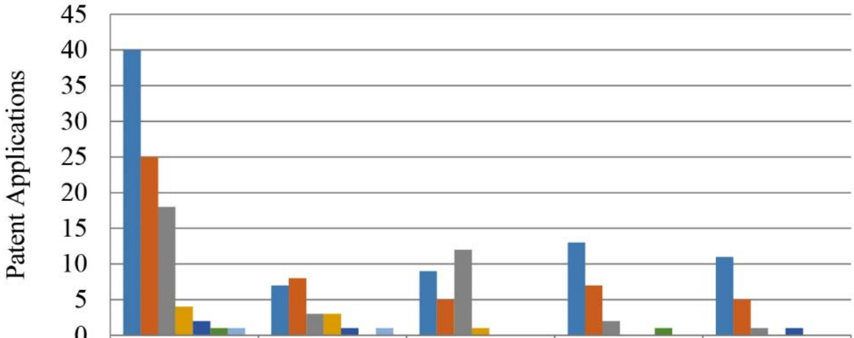
The framework of the empirical research was formed starting from the analysis of the context of HEIs TTP: the process and actors, TTO activities, factors, history and facts, input, output and outcome indicators. TTP activities within HEIs are taken into account. Afterwards, the HEIs under investigation are categorized and identifying. The next step is benchmarking and the selection of HEIs implementing TT and commercialization activities. After analysing the market need, government strategy, global trends, the strength of HEIs' abilities, input and output, indicators of HEIs' TTP are selected. The TTOs and related specialists are chosen as the selected group of experts to select the most important indicators to evaluate TTP performance of HEIs. Then, several MCDM tools are matched (FARE, TOPSIS, COPRAS, MULTIMOORA, DEA) for modelling the framework of empirical research. The object of the evaluation is R&D production and the results of scientific and technological research under science-business collaboration. The last step is the analysis of HEIs' TTP performance results, the findings and conclusions.

The logical structure of empirical research involves literature review and TTP analysis at HEIs; modelling the framework to evaluate HEIs' TTP performance; empirical research in the case of Lithuanian HEIs.

3.2. The Evaluation of Higher Education Institutions' Technology Transfer Process Efficiency Using the FARE and TOPSIS Methods

The FARE multi-criteria decision-making method is suitable to evaluate HEIs' TTP performance. This tool needs the key indicators, criteria weights, innovation and TT activities experts to be identified. This Subchapter provides the framework to assess the TTP performance using the FARE multi-criteria method. Moving forward, the next step will be to develop and implement the assessment methodology of how institutional and regional factors affect the TTP and value creation, as well as the commercialization process in HEIs.

First of all, it is necessary to identify variables (unknown before) to measure the efficiency of TTP at HEIs. For this purpose, practinioners with at least 5 years work experience in TT are involved into the research. The sample size of 30 respondents (25 responded) were randomly selected and included: managers of TT offices, experts from the science, technology and innovation agency, science and technological parks, start-up incubators and the Lithuanian innovation centre. The respondents were asked to answer the questions based on the practice of their organizations' and on personal experiences as well. The data gathered from these questionnaires were entered into the FARE database for analysis, while the TOPSIS method was selected to prioritize the performance indicators. The FARE tool is able to attribute priority weights for performance indicators and to measure the distance from the most important one.



	2010–2013	2013	2012	2011	2010
HEI 1	40	7	9	13	11
HEI 2	25	8	5	7	5
HEI 3	18	3	12	2	1
HEI 4	4	3	1	0	0
HEI 5	2	1	0	0	1
HEI 6	1	0	0	1	0
HEI 7	1	1	0	0	0

Fig. 3.3. The number of Lithuanian patent applications of higher education institutions' that have at least one patent application for the period of 2010–2013 (Stankevičienė *et al.* 2017 based on Lietuvos Respublikos valstybinis patentų biuras, 2014b)

The patent applications are proposed as the main performance measure of TT activities of HEIs. Fig. 3.3 shows the number of Lithuanian patent applications of Lithuanian HEIs. Detailed statistics of national patent applications of Lithuanian HEIs are provided in Appendix A, where you can see that only seven HEIs from

21 have at least one patent application, and while the other 14 have none, so they were eliminated from the research.

The situation with international patent applications is shown in the table in the appendices. There are only three Lithuanian universities identified as having several international patent applications. European patenting is quite expensive but over the last few years the Lithuanian Agency for Science, Innovation and Technology (MITA 2014) has offered financial support to pay the cost of acquiring European patents (up to the stage of distributing protection to other countries), so it helps universities very much to patent inventions at the European level. Thus, we see that we have only three universities that are patenting inventions to obtain a European patent. Vilnius University and Vilnius Gediminas Technical University are patenting most inventions at the European or (and) American or Asian level. This shows that Lithuanian inventions are strong and can compete with patents abroad. In comparison, Lithuanian patents are not strong, because the State Patent Bureau of the Republic of Lithuania does not check the novelty of inventions, and the cost for patenting is much lower than the European Patent Offices' (EPO) or The World Intellectual Property Organisation's (WIPO) patent procedures.

Therefore, the research methodology includes the factor relationship (FARE) method to estimate the weights of TTP indicators. Later on, the TOPSIS method is used to calculate weights for TTP criteria and to rank universities by the best results as well. The sample number is seven universities rather than 21. The data for the empirical research was gathered over the period of three years from 2011–2013. The primary data were collected during the interviewing of the focus group, which was composed of the managers of TT offices, experts from the science, technology and innovation agency, science parks, start-up incubators, the Lithuanian innovation centre, and from HEIs' annual public reports.

The results of the research are beneficial for HEI policymakers to formulate (or renew) the strategy for TT offices, TT models, policy approaches, intellectual property brokerage functions, university-industry collaboration. This provides a useful body of knowledge on the concept of assessing the efficiency of TTP in HEIs.

In recent years, previous research papers (T. Baležentis, A. Baležentis 2014; Hashemkhani Zolfani *et al.* 2014; Kabak, Dagdeviren 2014; Mardani *et al.* 2015a, 2015b; Urena *et al.* 2015; Zavadskas *et al.* 2014) have developed, proposed and applied different multicriteria decision-making methods (Ghorabaee *et al.* 2014; Hashemkhani Zolfani *et al.* 2018; Madic *et al.* 2016), solving complicated problems in decision-making issues. In the pursuance of effectively addressing the research problem, the following research stages were taken.

The first step. The model to assess the TT performance was designed based on the data collected from the quantitative interviews with the TTP experts. In the second step, the factor relationship (FARE) method was used to estimate the weights of the TTP indicators. Finally, the TOPSIS method was invoked, which allows the use of calculated criteria weights to rank HEIs by the best results (see Fig. 2.1).

Every year HEIs prepare annual reports of activity, in which are shown the main numbers of their science production (patents, publications, national and international projects, contract works), the number of students, study programmes and related information.

Stage I of the empirical analysis with FARE and TOPSIS tools starts from identifying the performance indicators of the TTP performance of HEIs in the case of Lithuania. The efficiency of HEIs' performance will be analysed by the empirical analysis of the TTOs (in Lithuanian universities), where the main commercialization results are produced. The intended variable categories, data sources, descriptions and names for the model of the research are as follow:

- patent applications (number generated per university);
- TT offices (employees, tasks, PhD-share);
- 7 Lithuanian universities (funding, students, publication – 3 years average per researcher);
- regional aspects (industry concentration, start-ups).

The research method comprises three categories of variables representing Lithuanian HEIs, TTOs and regional indicators of TTP.

Going deeper regarding interpretation of the data, it is seen that among the analysed HEIs, the greatest number of TTO staff (see Annex A, Fig. A4) are in HEI 2 and HEI 6. The variety in TTO staff differs from 15 (maximum) to 1 employee at HEI. Only a few universities have a bigger number of TTO employees: HEI 2 and HEI 6 (15 and 12 employees). Based on the literature and experience from abroad, the performance of the TTO depends on the quality and quantity of its working staff.

The total number of start-ups (See Annex A, Fig. A5) looks that way: HEI 6 does not have a strong performance of start-up companies (only 5 start-ups) in relation to the number of working staff in its TTO (12 in 2014). In contrast, HEI 1 has the highest result of start-ups (30 start-ups in 2014) while the number of working employees is quite low (only 2 in 2014).

The number of tasks in TTO (See Annex A, Fig. A6) varies: from 3 in HEI 4, to 12 in HEI 6. Interesting numbers appear in HEI 6: the number of TTO staff and functions is high, but the number of start-ups is quite low. Therefore, maybe the problem lies in employees performing a large number of tasks instead of effectively sharing functions. The number of functions of HEI 1, HEI 2 and HEI 6 is quite similar, but their performance in start-up companies is different. In addition, the concentration in regions could be one more issue for the creation of start-up companies and this should be taken into account.

The data on the number of publications (See Annex A, Fig. A7) were gathered from the HEIs' annual reports (Kauno technologijos universitetas 2011, 2013, 2014; Vilniaus Gedimino technikos universitetas 2012, 2013, 2014; Vilniaus universitetas 2013, 2014; Klapėdos universitetas 2013, 2014; Mykolo Riomerio universitetas 2013, 2014; Aleksandro Stulginskio universitetas 2012, 2013, 2014; Lietuvos sveikatos mokslų universitetas 2012, 2014). High numbers of publications differ among the presented seven HEIs. These numbers also depend on the education sphere of the university. An interesting factor is that technical university' publication numbers for the one researcher is about 1.5 publication/year (normal), when for social sciences the number is bigger. In Fig. A7 it is seen that HEI 1, HEI 2, HEI 3 are the leaders in the production of publications. On the other hand, publications are an important measure of HEIs' science production, which shows the ability of HEI scientists to produce science works and participate in projects. Moreover, the spectrum of publication shows the information about themes where new ideas may be born and potentially be patented. The issue met here is that scientists like to disseminate new ideas as soon as possible and share research results with society, so the easiest way to do this is to publish ideas through publications, rather than patenting them, which takes time. This leads to the situation where ideas are made public, which means they are no longer new and, unfortunately, cannot be patented, with potential for commercialization. The result is that universities are losing their IP.

Another indicator is the number of researchers in HEIs, which is very important both for education and teaching and for the research and innovation process (See Annex A, Fig. A8). HEI 3, HEI 4, HEI 5 have the highest numbers of researchers, so the possibilities to have the biggest TT results. The big potential of researchers directly contributes to the development of new cutting-edge ideas and technologies for the industry, so as a result these HEIs could become prominent both internally and externally. During university-industry meetings, scientists are specified as the core element in the success of the TT process. Prevailing practice showed that very often scientists bring projects and contract works to HEIs without the help of the TTO. This role is particularly valid in Lithuania because of the lack of trust between the two, when the TTO and researchers should be complementary to each other. An additional issue exists in the teaching and research process: how to find enough time to conduct research when according to Lithuanian legislation, scientists must spend at least one-third of all their time on teaching, and teaching staff should spend at least one-third of all time on the implementation of research works. When the teaching staff are educating, it takes a long time and psychologically is quite hard work, which means that after lectures they have no energy to do something more. In addition, there is not much time left for research because of the problem of the bureaucratic study process at HEIs, which involves carrying out many other duties, such as participating in committees, helping to organize conferences, writing reviews for new publications, supervising of students' works and many other duties. So, the bureaucratic process and real duties must be optimized for efficient results.

The number of researchers (FTE) (See Annex A, Fig. A9) is the important measure reflecting the science staff at every HEI. The group of respondents mark this indicator as one of the most important (third place out of 16) in the TTP. This means that it is important for the generation of TTP performance results. HEI 3 has the largest number and is the total leader for this indicator. However, in case of start-ups, in HEI 3, for example, it is not very high, with only 12 start-ups in 2014.

In the Annex A, Table A4 the numbers of publications per researcher (total number). The absolute leader is HEI 7, but these numbers are sometimes not adequate due to differences in calculation methodology, therefore it would be right to see other more specific indicators: income from projects, contract works, start-ups and so on.

In the Annex A, Fig. A10 the results of projects and contract works of the seven universities can be compared for the period of 2011−2013, where HEI 3, HEI 2 and HEI 4 generated the best results. These are extremely important results for universities, because every year the Lithuanian government decreases national assignations for universities, in that way encouraging them to "earn" money from other sources. Therefore, the results of projects and contract works show HEIs' ability to attract external finance. Of course, a strong and competent TTO team could help to enhance HEIs, which could lead to achieving better performance results. However, comparing financial results with the table explicating TTO staff, it is seen that a lack of TTO staff influences the performance results. In the Annex A, Figs. A1, A2, A3 showed the statistics on HEIs' performance results in the separate years from 2011 till 2013.

Based on the experience of working at a university, the motivation system and unclear IP policy is reflected in the TTP performance. The data on the funding per researcher can be seen in Annex A, Fig. A11 and A12. The Lithuanian Department of Statistics shows the data on the total number of students at Lithuanian HEIs. The number of students is decreasing yearly, hence from 2009 to 2012 the number of students decreased from 144 300 to 113 800, in total a decrease of 30 500 students (about 21.1%) (See Annex A, Fig. A13). HEI 3 has the highest number of students, and its performance results are also very high (as well as the number of national assignations).

Industry concentration was selected in the city of identified HEIs in the sample (see in the Annex A, Fig. A14). The highest concentration is in the capital Vilnius, less in other big cities like Kaunas and Klaipėda. In total, the number of employees at the beginning of 2014 was 865 974, and at the beginning of 2015 it was 901 343 employees. In 2011, the total number of employees in Lithuania reached 834 408, in 2012 it was 806 359, and in 2013 it was 847 365, and the total number in 2013 was increased (Lietuvos Respublikos valstybinis patentų biuras 2014a,b).

Going forward, the key performance indicators (KPIs) are presented, identified from the literature review, which are potentially suitable to evaluate the efficiency of HEIs' TTP.

The implementation of the FARE tool is presented below.

According to the literature review, the performance of the TTP should be evaluated by the next three major categories: university (HEI), TTO and regional indicators. KPIs in these three categories have the greatest power to influence the TT and commercialization process. In the explication of the Lithuanian universities' KPIs, there is clearly a variation in the results.

Table 3.2. The list of technology transfer process variables (Stankevičienė *et al.* 2017 based on the literature review)

Criteria	
National patent applications	The number of publications for the one researcher
European and international patent applications	Income from national projects, EUR
National patents	Income from international projects, EUR
The number of employees at TTO	Income from contract works, EUR
The number of start-ups	Funding per one researcher in FTE, EUR
The number of tasks for employees at TTO	The number of students at university
The number of publications at the university	GDP per capita in Lithuania
The number of researchers at the university (full-time equivalent, in FTE)	Industry concentration based on the number of employees (in units) in university region

This means that TTOs' activities are not the same in every HEI, so it is needed to look deeper to identify certain activities that will concentrate and improve future results. This is quite a challenging task for HEIs. Therefore, firstly the weights of the TTO activity indicators (KPIs) should be estimated. The results would redirect activities and diversify them for a renewed policy on TT and would help to focus on the improvement of certain activities of the TTOs. In order to compute the weights of criteria, the FARE method was used.

Based on literature review following criteria were selected (Table 3.2).

The group of experts carefully selected the most appropriate criteria, which, in their opinion, have the highest impact on TTP economic performance.

TTP performance indicators, which influence the HEIs' TT economic performance results, are compared against 16 criteria (KPIs). The latter criteria were grouped into three categories of variables (university (HEI), regional and TTO). Herein, the criteria are characterized by internal and external factors that might influence the TT and commercialization process.

The precision of the results measured by applying the multi-criteria evaluation approach usually depends on the weights of criteria (Ginevičius 2011). Hence, the FARE method implemented by Ginevičius (2011) was chosen as one of the most accurate these days. Based on formulas given in the second part of this work, the impact and strength of different criteria (KPIs) on overall TTO performance were calculated.

The experts rated all 16 criteria (KPIs). Based on the theory and on the HEIs' activity reports it the indicators influencing the TTP performance were identified. Moving forward, the most important criteria (from 16) were selected by experts who applied the ranking principle. Fifteen criteria will not be included in the research because they have no influence on the HEIs' TTP. Some limitations occur, like the availability of statistical data. Thus, now the whole process of the assessment to the criteria weights will be presented, based on the FARE tool.

Firstly, the experts needed to rank all the criteria in order to determine the relationships within them (Table 3.3). Leading the logic, the experts gave the value for 16 criteria ranging from 1 to 16, where the value 1 means the highest valued criteria, and accordingly a value of 16 means the lowest valued KPI. This means that the criterion with the highest value has the strongest influence on overall TT process performance in comparison with the other 15 criteria.

Table 3.3. Sixteen criteria ranked by experts (Stankevičienė *et al.* 2017)

Criterion	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Rank	16	3	15	8	6	12	11	4	7	9	5	1	2	14	13	10

The target group of 30 experts was selected and 25 responded to the questionnaire (see Appendix 2).

Later on, the experts set the scope of the transfer for the highest ranked criterion. This step was performed using the scale of quantitative estimation and interrelationship of criteria within the system (Table 3.4).

Table 3.4. The scale of quantitative estimation of criteria interrelationship in the system (Stankevičienė *et al.* 2017)

No.	Type of produced impact	Rating of the impact produced by connection (shown in points)
1	Almost none	1
2	Very weak	2
3	Weak	3
4	Lower than average	4
5	Average	5
6	Higher than average	6
7	Strong	7
8	Very strong	8
9	Almost absolute	9
10	Absolute	10

The sense of this ranking is that the criterion of a lower level has the smaller impact on the criteria. It follows that the ranks of measured weights of criteria should correspond to the priority list. This knowledge will help in further calculations to determine the strength and direction within the relationship between criteria (Table 3.5).

Table 3.5. The relationship of the core criterion (12) with the other 15 criteria (Stankevičienė *et al.* 2017)

Criteria	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
12	+1	+7	+1	+5	+1	+2	+3	+4	+2	+6	+9		+8	+1	+1	+2

After determining the relationship between the main criterion (in this case it is the 12th criterion), the concordance coefficient of Kendall was calculated and the obtained value ($w = 0.563$) showed a sufficient consistency with the experts' evaluations. The idea of the concordance coefficient is that the data were primarily converted into ranks, and later the ranks were displayed and finally calculated.

Lateron was analytically measured the interrelationship of the rest of the criteria measuring their strength, determined by the experts, to the main criterion (in this case, to the 12th criterion), in accordance with the relationships prepared during the first step in stage 1. It is understandable that, using formula (2.2), a part of the potential of each of the remaining criteria impact was transferred to the first main criterion (Table 3.6).

Table 3.6. The potential impact of each criterion on the 12th (core) criterion (Stankevičienė *et al.* 2017)

Cri-teria	12	11	13	2	10	4	8	7	16	9	6	5	3	1	15	14
12		+1	+2	+3	+4	+5	+6	+7	+8	+8	+8	+9	+9	+9	+9	+9

Thus, the graph (Figure 3.4), shown in bubble form, visually explains that the criterion with the biggest percentage of rank took the part of the potential of the lower ranked criterion.

The lower ranked criterion has a lower effect on the higher ranked criteria and the criteria with the lower rankings transfer the larger part of potential impact to them.

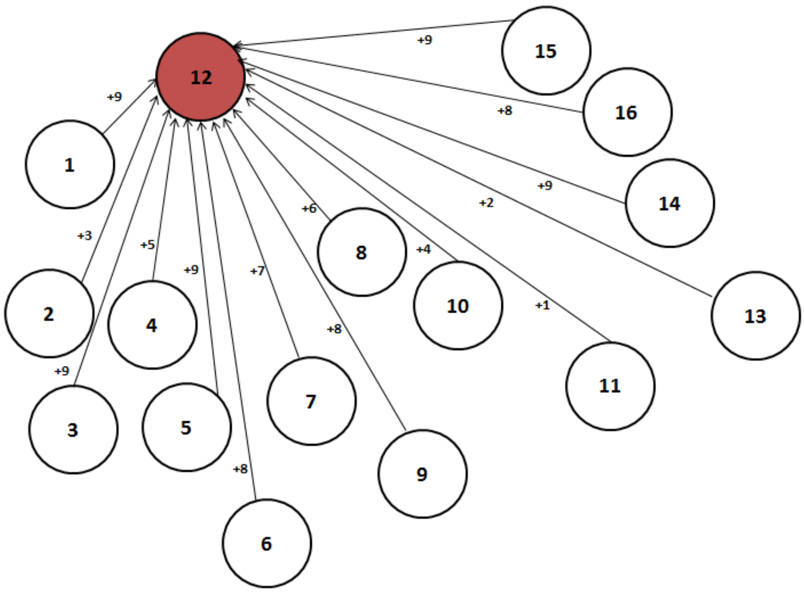


Fig. 3.4. The relation of the core (twelve) criterion with other criteria in the system (Stankevičienė *et al.* 2017)

The target group of experts for the research determined that criterion 10 was ranked by number +6 which means that the effect on our main criterion 12 from criterion 10 is higher than average. Therefore, criterion 10 should transfer only a potential impact equal to +4 (Table 3.6).

Table 3.3 shows that the first criterion ranked by experts is twelfth (12), while the thirteenth (13) is second. This means that the twelfth criterion (12) should transfer a part of the potential of its impact to the second, the thirteenth (13) criterion. The mentioned impact is shown in Figure 3.6 where, based on this idea, all the relationships are calculated.

In the graphical relationships between criteria, it is seen that all the criteria fulfil the precondition of the FARE method that all subsets of a set and their elements should be connected in some way.

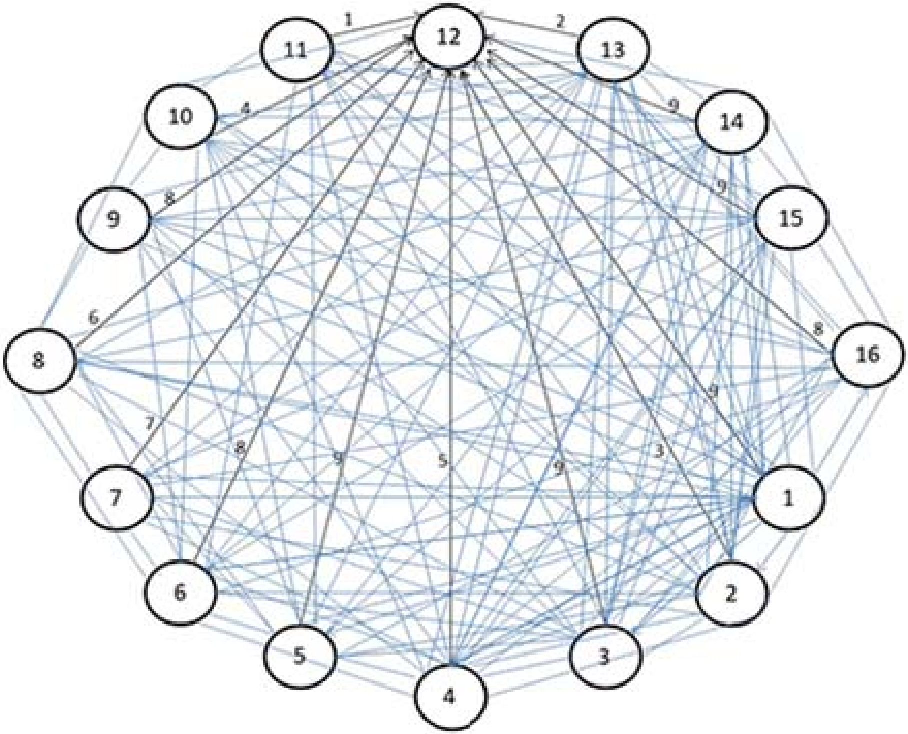


Fig. 3.5. The graphical relationships between criteria and strength of the impact on the main twelfth criterion (Stankevičienė *et al.* 2017)

At the second stage, it is needed to dismiss the lowest impact criteria in order to be able to calculate the most influential criteria weights, because as you can see in Figure 3.5 it is almost impossible to be accurate in such a high level of criteria.

Therefore, it should be chosen to leave the eight most influential criteria (avoiding the criteria, which have the weakest influence on the TTO performance) and to calculate their weights of rest most important variables on TTP performance.

Calculation results are marked with a plus (or minus) sign (Fig. 3.6). This means that the criterion has been assessed by the impact of another criterion in the system. For instance, a negative relationship means that the criterion is less important in comparison with the criterion related to it.

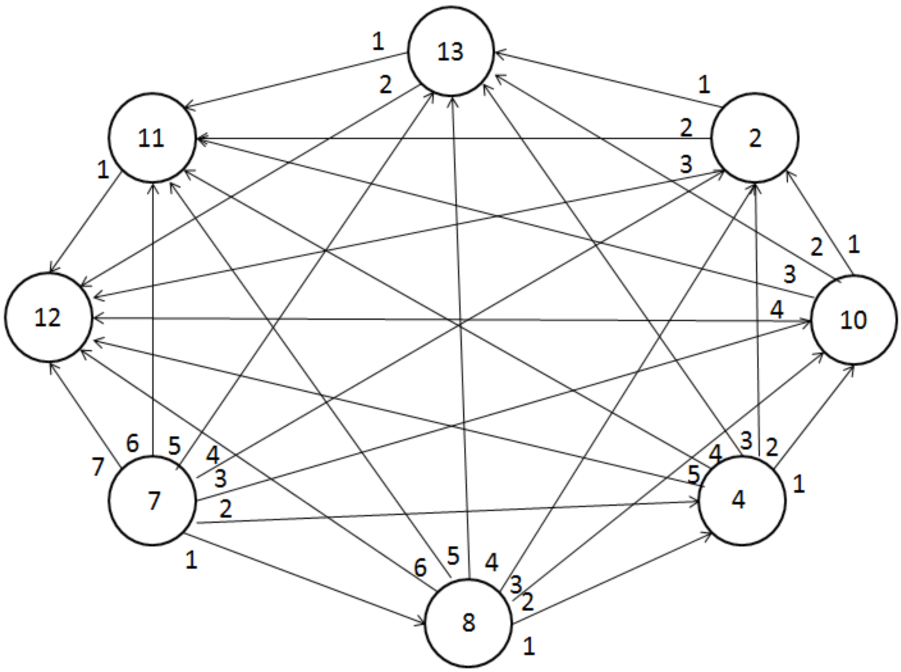


Fig. 3.6. Criteria relationships and directions of strengths of created impact (Stankevičienė *et al.* 2017)

In any case, it reflects the potential and influences the related criterion. When the relationship is positive, then the considered criterion absorbs another criterion's potential, here if the potential of positive relationship is rising. Then, the matrix based on the calculations gathered from Figure 3.6 was calculated (Table 3.7).

After designing the entire matrix, the total potential impact P_i, is calculated using formula (2.12). Next, the arithmetic steps are performed based on the data from the first row in the presented matrix. The results show that the total effect (dependence) should be equal to zero. This means that the results are compatible with each other.

Table 3.7. Criteria matrix of the potential balance of 8 technology transfer performance indicators (Stankevičienė *et al.* 2017)

Criteria group	Criteria group							
	12	11	13	2	10	4	8	7
12		+1	+2	+3	+4	+5	+6	+7
11	–1		+1	+2	+3	+4	+5	+6
13	–2	–1		+1	+2	+3	+4	+5
2	–3	–2	–1		+1	+2	+3	+4
10	–4	–3	–2	–1		+1	+2	+3
4	–5	–4	–3	–2	–1		+1	+2
8	–6	–5	–4	–3	–2	–1		+1
7	–7	–6	–5	–4	–3	–2	–1	
Total	–28	–20	–12	–4	+4	12	20	+28

In order to calculate the weights w_i based on formula (2.13) and formula (2.14), the actual total impact P_i^f was found with the impact of each criterion in the system on the research object (Table 3.8).

Table 3.8. Total impact of 8 criteria of technology transfer process performance indicators (Stankevičienė *et al.* 2017)

Criteria group	Criteria group								Total effect (dependence) $\boldsymbol{P_i}$	$\boldsymbol{P_i^f}$
	12	11	13	2	10	4	8	7		
12		+1	+2	+3	+4	+5	+6	+7	+28	+98
11	–1		+1	+2	+3	+4	+5	+6	+20	+90
13	–2	–1		+1	+2	+3	+4	+5	+12	+82
2	–3	–2	–1		+1	+2	+3	+4	+4	+74
10	–4	–3	–2	–1		+1	+2	+3	–4	+66
4	–5	–4	–3	–2	–1		+1	+2	–12	+58
8	–6	–5	–4	–3	–2	–1		+1	–20	+50
7	–7	–6	–5	–4	–3	–2	–1		–28	+42
Total	–28	–20	–12	–4	+4	12	20	+28	0	560

Finally, based on formula (2.15), the normalized values w_i were calculated from the total impact potential of eight criteria of TTP performance. The normalized value of criterion 12 was calculated first, and later the rest of the criteria from the created matrix in Table 3.10.

Table 3.9 The weights of 8 criteria of technology transfer process performance (Stankevičienė *et al.* 2017)

Criteria group	12	11	13	2	10	4	8	7	Total
The relation of the core criterion (12) with other criteria in the system		+1	+2	+3	+4	+5	+6	+7	$P_1 = 28$
Weights of criteria group w_i	0.18	0.16	0.15	0.13	0.12	0.10	0.09	0.07	$\sum_i^n w_i = 1.0$

Table 3.9 shows the distribution of total efficiency of each criterion (from 8) concerning TTP performance in HEIs.

Table 3.10. The calculation of the criteria weights by the FARE method (Stankevičienė *et al.* 2017)

Criteria group	Criteria group								Total effect (dependence) P_i	P_i^f	w_i
	12	11	13	2	10	4	8	7			
12		+1	+2	+3	+4	+5	+6	+7	+28	+98	0.18
11	–1		+1	+2	+3	+4	+5	+6	+20	+90	0.16
13	–2	–1		+1	+2	+3	+4	+5	+12	+82	0.15
2	–3	–2	–1		+1	+2	+3	+4	+4	+74	0.13
10	–4	–3	–2	–1		+1	+2	+3	–4	+66	0.12
4	–5	–4	–3	–2	–1		+1	+2	–12	+58	0.10
8	–6	–5	–4	–3	–2	–1		+1	–20	+50	0.09
7	–7	–6	–5	–4	–3	–2	–1		–28	+42	0,07
Total	–28	–20	–12	–4	+4	12	20	+28	0	560	1

Table 3.10 shows the calculated weights of eight TTP indicators, calculated with the FARE tool, while the average value data are taken from seven Lithuanian HEIs.

Table 3.11. The weights of varables calculated with FARE tool and average value of 7 Lithuanian universities in the period of 2011−2013 (Stankevičienė *et al.* 2017)

Criteria	Units of measure	Value average HEI 1	Value average HEI 2	Value average HEI 3	Value average HEI 4	Value average HEI 5	Value average HEI 6	Value average HEI 7	Calculated weights by FARE method
Income from contract works (EUR)	Thsd. EUR	2767.64	1541.01	718.13	79.03	1126.26	285.34	268.01	0.18
Income from international projects (EUR)	Thsd. EUR	778.11	2338.20	1475.13	3394.35	3963.68	231.28	662.26	0.16
Funding per one researcher – FTE (EUR)	Thsd. EUR./ researcher (FTE)	25.46	71.54	38.40	34.83	73.91	25.48	71.41	0.15
European and international patents applications	Number	2.00	1.30	6.30	0	0	0	0	0.13
Income from national projects (EUR)	Thsd. EUR	343.20	4157.98	17051.1	1826.05	864.39	469.19	433.95	0.12
The number of employees at TTO	Number	1.00	10.00	1.00	2.00	0.30	12.00	0	0.10
The number of researchers at university (FTE)	Number	124.84	127.67	492.98	152.00	109.01	38.48	20.00	0.09
The number of publications at university	Number	1210	2053	1954	702	417	757	1192	0.07

Table 3.11 shows the weights of TTP indicators calculated with the FARE tool and average values in the period of 2011−2013.

Calculated weights by FARE method show the weight and importance of every evaluated variable in the research. The biggest weight have those indicators: income from contract works (EUR); income from international projects (EUR); funding per one re-searcher – FTE (EUR).

After carrying out the calculations of KPI weights with the FARE method, the TOPSIS tool is applied to rank the Lithuanian HEIs by TTP performance results (based on data collected from the HEIs' annual reports) (see Table A12). Table A.12 shows the created normalized decision-making matrix composed from 7 Lithuanian HEIs and 8 KPIs. TOPSIS STEP 2 (Table A13) was performed by creating a weighted normalized decision-making matrix. Due to the importance of TT success factors, analysed from the literature review, it is recommended to collect the information about HEI spin-offs (income performance results) in Lithuania and incorporate this indicator in the TTP evaluation process. After completing STEP 3 (Table A14) and determination of the best and worst alternatives, the search for distance between the alternative and the best condition should be carried out (Table A15). Calculation results showed that HEI 3 has the greatest distance between the alternative and the best condition. STEP 5 of the TOPSIS approach is intended for the calculation of the distance between the target alternative and the worst conditions (Table A16). The greatest result of the distance between the target alternative and the worst condition is found in HEI 7. During calculation of STEP 6, the values of each alternative relative distance from the ideal alternative to the worst were identified (Table A17). The last step 7 should be prepared, which is intended to rank all alternatives according to the gathered results (Table 3.12).

Table 3.12. Ranking of Lithuanian higher education institutions according to technology transfer process performance results (TOPSIS STEP 7) (Stankevičienė *et al.* 2017)

Rank	University	Calculated results
1	HEI 3	0.564
2	HEI 2	0.452
3	HEI 1	0.430
4	HEI 5	0.373
5	HEI 4	0.276
6	HEI 6	0.235
7	HEI 7	0.175

It is seen after the number of calculations, the best TTP economic performance results are found in HEI 3 (first place), HEI 2 (second place) and HEI 3 (third place).

The research results were published in an article in an international journal with the title of "Assessment of technology transfer office performance for value creation in higher education institutions" (Stankevičienė *et al.* 2017).

3.3. Efficiency Evaluation of Technology Transfer Process in Higher Education Institutions with MULTIMOORA Tool

The data for this part of the research was taken from the report prepared by the Research Council of Lithuania intended to evaluate Lithuanian universities by their TT and commercialization performance results.

This research includes the following TT performance indicators of HEIs (mentioned in the Subchapter 2.2): *Si(TPP)*, *Si(USU)*, PLE_i, *Σ EVV*, *Σ AIV*, d_{si}, F_i, E_i, SE_i, LE_i, T_i, LF_i.

This Subchapter provides the calculation results of 7 Lithuanian HEIs. These universities were selected as the biggest in Lithuania and the most active in TT activities (patenting), leading with the best results in knowledge and TT compared to other Lithuanian universities. The MULTIMOORA tool will be applied to evaluate the performance of the HEIs and rank them by the highest results.

The data were processed for the period of 2012–2014 from the report by the Research Council of Lithuania. For the next years, the methodology of the calculating indicators of the Research Council of Lithuania has been changed. Therefore, other data is planning to include in the future research.

Hereinafter major calculation results are provide. The relation system of values and reference points of all indicators (*Si(USU)*, *Si(TPP)*, *Σ EVV*, *Σ AIV,* d_{si}, SE_i, E_i, T_i, F_i, LF_i, PLE_i) for 2012, 2013 and 2014 show that HEI 7, HEI 2 and HEI 3 are the leaders within those HEIs that are implementing higher education, research and innovation activities in the fields of: Humanitarian Sciences (H), Social Sciences (S) and Arts (M), Physical Sciences (P), Agricultural Sciences (A), Biomedical Sciences (B), Technological Sciences (T). HEI 7, HEI 2 and HEI 6 produced the highest results of the relation system values and reference points. The ranking HEIs by TTP performance results is implementing based on the final value of full multiplication form. Here it is seen the same results when HEI 7, HEI 2 and HEI 6 are the leaders.

Lithuania is ranked by the Global Innovation Index. In 2012 Lithuania was positioned in 38th place, in 2013 – 40th, in 2014 – 39th, in 2015 – 38th place

(Global Innovation Index 2016). This research shows that the TT performance results are moving, step by step, toward a better position every year. The fact is that HEIs are directly related with the innovation system's performance results through the production of intellectual property (IP) for the market need.

Next, the calculation results in the field of social sciences are discussed (see the table of TTP performance indicators of HEIs, in the field of Humanitarian Sciences (H), Social Sciences (S) and Arts (M), for 2012, 2013 and 2014, and calculation results in Annex A).

Looking more deep at the category of H, S, M of separate indicators (see Table A10) and its results it can be stated, that by participating in projects of international research programmes (*Si (TPP)*) HEI 2 had the highest income (742.37K LTL), followed by HEI 6 (320.78K LTL), and HEI 3 (113.51K LTL) in 2012. Meanwhile, in 2013 HEI 7 this was the best in terms of this indicator (1032.69K LTL), followed by HEI 2 (253.13K LTL), and HEI 6 (163.57K LTL). Then, in 2014 the university distribution, starting with the best, was HEI 2 (298.43K LTL), HEI 1 (247.54K LTL), and HEI 6 (216.49K LTL). After analysing calculation results of such an important TT indicator as *Si (USU)* − the performance of industry-academic cooperation results, it can be stated that a huge part of all the best results belongs HEI 3 (933.13K LTL), HEI 7 (407.74K LTL) and HEI 6 (199.25K LTL) in 2012. The rest of the HEIs income gap set about ten times. For example, HEI 1 has the result of 40K LTL, HEI 2 – 28K LTL, and so on. In 2013 *Si (USU)* results are as follows: HEI 7 (300.8K LTL), HEI 3 (214.57K LTL), HEI 2 (93.85K LTL), although 2014 shows another distribution: HEI 7 (1114.44K LTL), HEI 3 (757.55K LTL), and HEI 5 (278.52K LTL). Therefore, it is seen that the results of *Si (USU)* every year are different, except for HEI 7 (the leader in most of all the analysed TT performance indicators in this work). In 2013 and 2014, the rest of the universities income gap is set less than ten times.

It is seen the clear tendency that every year the results of the HEIs *Si (USU)* are becoming higher. Relating the indicator of scientists (in full-time equivalent), who are working in every analysed HEI, it is clearly seen the relation between the number of scientists and performance results at HEIs. In other words, the more scientists, the better the performance results, because actually scientists produce research (art) results (research outcomes). HEI 7 is the leader of PLE_i indicator. The result of this indicator is about two times greater in comparison with any other result of other HEIs participating in this research. PLE_i indicator is also interrelated with the results of the other two indicators: Σ *EVV* and Σ *AIV*, because the points attributed for these indicators were calculated based on the research results performed by the scientists of HEIs. Therefore, the following data for Σ *EVV* in 2012 was: HEI 7 (240.75), HEI 5 (112.25), and HEI 3 (88.25). In 2013, the highest performance of Σ *EVV* was: HEI 7 (239.5), HEI 2 (113.5), HEI 3 (99.25); and in 2014: HEI 7 (264.25), HEI 5 (120.5), and HEI 3 (143.25). All other economic calculation results are also related with the number of academic staff in FTE

Table 3.13. The evaluation of HEIs by technology transfer performance indicators using the MULTIMOORA tool for 2012, 2013 and 2014 (Stankevičienė *et al.* 2019)

University	Years	Relation system		Reference point		Full multiplication form		Sum of ranks	Final rank (MULTIMOORA group)	Sum average rank	Final average rank (MULTI-MOORA gr.)
		Relations	Rank	Relations	Rank	Relations	Rank				
HEI 1	2012	3.0153	7	0.8883	5	2.90E+28	5	17	5	16	5
	2013	3.4360	7	0.8778	4	5.39E+29	5	16	5		
	2014	3.7387	7	0.8359	4	1.90E+30	5	16	5		
HEI 2	2012	9.2757	2	0.8711	3	2.63183E+38	2	7	2	6	2
	2013	9.5679	2	0.7200	2	4.44025E+39	2	6	2		
	2014	9.4426	2	0.6678	2	4.51577E+39	2	6	2		
HEI 3	2012	6.9996	3	0.8765	4	1.16139E+35	4	11	4	11	4
	2013	5.8348	3	0.8775	5	2.55251E+33	4	12	4		
	2014	6.3056	3	0.8344	3	9.74671E+30	4	10	3		
HEI 4	2012	3.5743	6	0.9028	6	8.50898E+12	6	18	6	18	6
	2013	4.6761	5	0.9539	7	2.9578E+17	7	19	7		
	2014	4.1637	6	0.8359	4	3.93695E+15	7	17	6		
HEI 5	2012	3.7334	5	0.9271	7	16596837756	7	19	7	18	6
	2013	4.1894	6	0.9212	6	5.23846E+17	6	18	6		
	2014	4.6637	5	0.8845	6	1.9848E+26	6	17	6		
HEI 6	2012	6.6186	4	0.7865	1	4.1708E+35	3	8	3	10	3
	2013	5.8173	4	0.8254	3	4.06921E+34	3	10	3		
	2014	6.1395	4	0.8509	5	3.44908E+34	3	12	4		
HEI 7	2012	12.6754	1	0.8059	2	2.21569E+40	1	4	1	3	1
	2013	13.2702	1	0.4733	1	2.53385E+41	1	3	1		
	2014	13.0066	1	0.4721	1	2.6819E+41	1	3	1		

(PLE_i), see the results in the tables in Annex A. The situation and the main tendencies with the numbers in the field of P, A, B, T are quite analogous (see Annex A, Table A11), the leaders were HEI 7, HEI 2 and HEI 4 within all data of indicators.

Table 3.13 shows the evaluation results of HEIs by TT performance indicators using the MULTIMOORA tool for 2012, 2013 and 2014. There is a deficiency in high results related to knowledge and TT activities. The European Commission's Innovation Scoreboard shows that Lithuania is situated at the back of the ratings; for example, in 21st place out of 29 countries in 2017, in 25th place in 2016, 26th in 2015, and in 25th place in 2014 (European Commission, 2017, 2016a, 2015, 2014). Thus, there is and to evaluate the performance of Lithuanian HEIs to analyse the present situation and make decisions to improve TT and commercialization activities inside the HEIs. This research provides the concept of the assessment of the TTP economic performance of universities with the MCDM tool, MULTIMOORA.

The research findings showed that the highest results of TTP performance in Lithuania in the period of three years 2012–2014, were achieved by HEI 7, HEI 2 and HEI 6. These are the most entrepreneurial and have a much better developed innovation and TT system within the universities, as well as having more efficient-working TTOs with their staff, and motivated scientists. American practice shows that a good working TTP in the country requires at least a 10 year period before becoming successful.

Approbation of the results proves that the suggested MULTIMOORA tool is fully appropriate for evaluating the economic performance of efficiency of TTP of HEIs, putting universities on one platform and ranking them by the best results. The MULTIMOORA is suitable for measuring innovation and TTP performance results, expressed in different measured outputs: research works in numbers, financial resources, staff in full-time equivalent, points for the research works and so on. Furthermore, the MULTIMOORA method is easy to use and fits for measuring the performance of HEIs.

3.4. COPRAS Method Suitable to Evaluate the Technology Transfer Process in Higher Education Institutions

This Subchapter provides the calculation results of R&D expenditures using the COPRAS approach for the efficiency assessment.

HEIs' TT economic performance results depend not only on successful innovative TT activities and university-industry cooperation, but also on governance funding, distributed by priority for certain research and development (R&D) fields. The main goal of the research is to approbate the COPRAS tool and propose a concept to assess the efficiency of R&D funding in European countries, provide insights, recommendations, and point out tendencies for the future improvement of the European funding system for HEIs.

For the analysis, information from the Eurostat database was taken in the period of 2005−2014 (Eurostat 2017) and a decision-making matrix was formed. Every analysed sector of performance invests a different amount of their budget in R&D processes. Investments contribute to the innovation and economic growth as a result. It is necessary to see the investment measures and compare them with each other. All performance indicators should be on one platform. For this purpose, it should be chosen one of the decision-making methods.

During the selection of sector of performance for R&D investments, decision-making persons usually make a choice between different available alternative sectors of performance based on certain attributes. What is the multi-criteria decision-making problem in this research? The answer is the selection of the sector of performance for R&D investment can be considered a problem. Often multi-criteria decision-making (MCDM) methods are proposed to use for the selection of the most appropriate sector (Popovic *et al.* 2012).

The assessment of the efficiency of R&D funding by sector of performance in European countries is possible by applying the decision-making tool, COPRAS, which allows the normalization of the data and grouping them by priority. This tool was selected due to it being one of the quite simple and clearly understandable multi-criteria methods to use and analyse the funding "levels" of R&D.

COPRAS is a multi-criteria ranking tool for analysis and decision-making. Expenditure on R&D provides a fluent explication of European R&D funding (investments), emphasizing the execution of innovation and TT activities at HEIs. The proposed assessment model allows the comparison of performance results and countries to be ranked according to the efficiency of research funding.

This research is constructed on analysing European countries through comparing the data of R&D expenditure by sector of performance. The goal of this research is to approbate the COPRAS ranking tool for assessing the efficiency of R&D funding by sector of performance in European countries. Results will allow the provision of insights and recommendations, and point out the tendencies for the future improvement of the European funding system for HEIs.

European documents show investing in R&D as a priority. "Europe 2020" documents one of the priorities is to invest (publicly and privately) in R&D with at least 3% of the GDP (European Commission, 2016b). The latter need is related with the demand to base economic development on knowledge, innovation and TT activities. The same performance indicators were evaluated in each of the four sectors of performance. In total, a calculation was performed for 20 performance indicators in 4 sectors, analysing 28 European countries.

In comparison, the National 2014−2020 Progress Programme for Lithuania it is intended to reach R&D funding up to 1.9% of GDP for Lithuania. Statistics Lithuania provides the total R&D expenditure for 2015 which was 0.9% of GDP, meanwhile for Europe this indicator was 1.9% GDP in 2015 (Statistics Lithuania, 2015).

The object of this research is R&D expenditure by sectors of performance, identified by Eurostat as the main sectors participating in R&D activities (Eurostat 2017). In addition, sectors of performance were also selected based on TT and innovation activities, implemented by HEIs, business (also non-profit based) and government. It is important to evaluate R&D expenditures in every sector of performance to provide insights and recommendations to achieve better performance results.

Main research tasks:

– to create a data set of R&D expenditures in TTP by sectors of performance for European countries;
– to develop an approach to assess the efficiency of R&D funding by sector of performance in European countries;
– to analyse performance results: R&D expenditures by sectors of performance, provide insights and recommendations.

Performance indicators of R&D expenditures in TTP are important to see the picture of different sectors with their investment in R&D. The performance of innovation and TTP depends on the amount of investment for innovation activities. Therefore, a clear picture of investments from different sides is needed: business, higher education, government, non-profit organizations. Efficiency assessment in this research is performed in four different sectors of performance (business, government, higher education, private), identified in the Eurostat database mentioned in Subchapter 2.2 (Eurostat 2017):

Table 3.14. Performance indicators of R&D expenditures in technology transfer process (Stankevičienė *et al.* 2017)

Indicators				
Intramural R&D expenditure (GERD) (Euros per inhabitant)	Intramural R&D expenditure (GERD) (Purchasing Power Standard (PPS) per inhabitant at constant prices)	Sector of fund – All sectors (Euros per inhabitant)	Total R&D expenditure (Euros per inhabitant)	Total R&D activity (Euros per inhabitant)

All mentioned sectors and their parties (business, science or government institutions) are involved in the TT and innovation process.

This research involves such indicators as shown in the Table 3.14.

To apply the COPRAS method firstly it should be created the data decision matrix *D* of the criteria (*j* – criterion), which describes the alternatives i_j (j = 1, 2, …, n) compared with each other. The statistical data is needed or expert could estimate it, as well as the weights (significances) ω_i (i = 1, 2, …, m) of criteria, where n is the number of criteria and m is the number of the alternatives could be compared.

A deeper analysis will be performed to understand which of the four sectors: business, higher education, government, non-profit organizations are investing in R&D the most, comparing selected European countries. Analysis incorporates the data, which show how much investment the four sectors are investing in the selected sector: analysing the business sector, clear picture is seen and how much all four sectors invest in the chosen business sector.

Empirical results are described in order of chosen performance data in every year, starting from 2005 and going up to 2014 (Eurostat 2017). A 10-*year* range was selected to give a better view while comparing investment results on R&D looking at the four sectors implementing TT and innovation processes in their activities.

The research is constructed of 28 chosen European countries (alternatives) and 5 performance indicators of R&D expenditures in TTP (criteria), mentioned earlier in Table 3.20 (Eurostat 2017).

All steps from 1 to 8 were performed.

During the research, indicators were maximized. The weights for indicators were chosen to be equal, because the research was performed without the experts' surveys. Therefore, when 5 indicators have ta weight of 1, every indicator has the weight of 0.2 (1:5 = 0.2).

Calculation results showed (see Annex A, Tables A5−A9), that the greatest investments in the business sector's R&D were made by these countries: Sweden, Finland, Luxembourg, Denmark and Austria, among others. Lithuania is in 24th place out of 28.

The TOP 5 investors in R&D from the government sector were such countries as: Luxembourg, Germany, Finland, France and the Netherlands (Annex A). Lithuania is in 24th place out of 28. During evaluation of the biggest investors in R&D for higher education sector, the highest values are investing such countries as Denmark, Sweden, Finland, the Netherlands and Austria. Lithuania is in 19th place out of the 28.

Moving further, based on explicit analysis results of investors in R&D for the non-profit sector the greatest performance results are shown by the following countries: Portugal, Cyprus, the United Kingdom, Italy and France (Annex A).

Lithuania is in the 24th place out of 28. Covering all sectors to get a general picture of which European countries invest in R&D the most for all four sectors, the following results was seen: Finland, Luxembourg, Denmark, Sweden and France are investing in R&D the most. Lithuania is in the 22nd place in total from the 28.

The higher education sector is one of the most important sectors in terms of pushing countries to a higher level through innovations. Countries such as Denmark, Sweden, Finland, the Netherlands and Austria investing in R&D for higher education sector the most (see Table A9 in annexes). Northern countries are active in this activity. The lowest expenditures are shown in Bulgaria, Romania, Slovakia, Poland and Hungary.

Portugal, Cyprus, the United Kingdom, Italy and France invest in R&D for the private non-profit sector (see Table A8 in annexes). Lithuania spends much less money on R&D and is ranked 24th. Curiously, the worst result for the private non-profit sector shown is the Netherlands, when it seems this should be the opposite. Comparing the Netherlands' performance results on investments in R&D for the higher education sector, in this case, that country is in the TOP 5. This means that this country pays more attention to investing in the higher education sector, and this is the correct step to turn a country into the best achiever in TT and innovation activities and to increase performance results.

Approbated results showed that the COPRAS method enabled us to see the top countries when it comes to paying attention to and seeing the need to invest in R&D. The calculation results are distributed among the seven groups (Annex A). The best investors in R&D in all four analysed sectors are these countries from group 1: Finland, Luxembourg, Denmark and Sweden (three northern countries and Luxembourg). In group 2 are France, the United Kingdom, Austria and Germany. Group 3 is led by such countries as Belgium, Portugal, Italy and Netherlands. In addition, comparing calculation results of all groups the most economically developed countries invest in R&D the most. Lithuania is in the 22nd place out of the 28.

There are a number of various decision-making methods for evaluating performance results, however the COPRAS method is quite easy to use and allows multi-criteria indicators with different values to be taken (see Table 1.2 in more detail), putting them on the one platform, giving them certain weights and comparing them by ranking their performance. The advantage of COPRAS is that it allows separately maximize and minimize criteria for evaluation. The approach suggested in this paper was approbated using the COPRAS multi-criteria decision-making method. The results showed that this method is fully appropriate for assessing efficiency, in this case of R&D funding by sector of performance.

Empirical results reveal that the comparatively higher efficiency of research expenditures is in the northern European countries, Luxembourg and France. The latter tendency is encouraging HEIs to move forward, enhance their performance results and contribute to countries' economic growth.

3.5. Proposed DEA method for Higher Education Institutions to Evaluate the Efficiency of Technology Transfer Process

With the purpose of explicating the steps of the DEA framework, below can be seen the proposed model to measure HEIs' efficiency of TTP economic performance.

Step 1. Selection of research sample is needed to be done (Fig. 3.7) as well as steps necessary to evaluate the efficiency of TTP of HEIs using the DEA tool. Due to the homogeneity of the data set, seven Lithuanian HEIs, which have TTP performance results, are analysed and included in this paper's research.

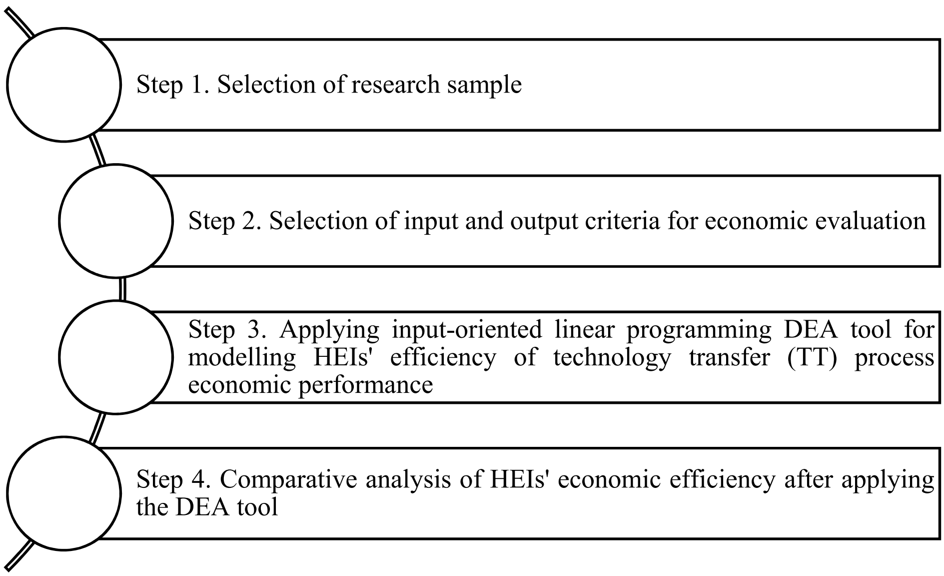


Fig 3.7. The model to assess higher education institutions efficiency of technology transfer process economic performance using the DEA tool (compiled by author)

Step 2. The input and output indicators are selected from the official public report of the Lithuanian Research Council. The logic of indicators' selection was drawn from the following: yearly results of 2013 and 2014 of inputs create yearly results of 2015 and 2016 outputs. Due to the DEA pitfall regarding the number of indicators in relation to the number of HEIs, three inputs and three outputs were selected to measure the efficiency of TT performance of seven HEIs. For this research these TT performance indicators are identified: $S_i(TPP)$ – the amount of money (in thsd. litas) received by the HEI during participation in international research projects; $S_i(USU)$ – the amount of money (in thsd. litas) received by the HEI during implementation of research and experimental (social, cultural) development science works with industry; PLE_i – full-time equivalent (FTE) of HEI's scientists (artists); ds_i – the number of declarative science jobs in a certain field.

For the inputs the following three indicators are identified: $S_i(TPP)$ (in 1), $S_i(USU)$ (in 2), ds_i (in 3); meanwhile for the outputs the following are identified: PLE_i (out 1), the number of *PhD* students (out 2), the number of *Master* students (out 3). The data for the indicators of $S_i(TPP)$, $S_i(USU)$, ds_i, PLE_i were used from the official public report implemented by the Research Council of Lithuania and intended to evaluate Lithuanian HEIs.

The number of *PhD* and *Masters* students was used from the official legal document in the order of the head of the Ministry of Education and Science (Lietuvos Respublikos švietimo ir mokslo ministerija 2012, 2013, 2014). Calculations will be performed in two major fields: social (H, S, M) and physical (P, A, B, T).

Step 3. After the selection of indicators the input-oriented linear programming DEA tool for modelling HEIs efficiency of technology transfer (TT) process performance should be applyed. First of all the data were collected (Table A18). Table A18 represents the data collected to measure the efficiency of TTP performance of seven Lithuanian universities in the field of P, A, B, T. When, Table A19 represents the data collected to measure the efficiency of TTP performance of seven Lithuanian universities in the field of H, S, M.

Table 3.15. DEA efficiency results of technology transfer process performance of Lithuanian universities in the field of (P, A, B, T) and (H, S, M) (compiled by authors)

HEI	Subject to	Efficiency coef.	Efficiency	HEI	Subject to	Efficiency coef.	Efficiency
Field	P, A, B, T	P, A, B, T	P, A, B, T	Field	H, S, M	H, S, M	H, S, M
HEI 7	0.093	0.373	37%	HEI 7	0.264	0.359	36%
HEI 2	0.215	0.175	18%	HEI 5	4.824	0.313	31%
HEI 6	1.000	0.110	11%	HEI 2	0.598	0.113	11%
HEI 4	0.171	0.091	9%	HEI 3	3.991	0.097	10%
HEI 3	0.187	0.051	5%	HEI 6	0.868	0.082	8%
HEI 1	0.571	0.042	4%	HEI 1	1.000	0.027	3%
HEI 5	1.000	0.001	0.1%	HEI 4	2.167	0.002	0.2%

For this calculation, the DEAFrontier Free Version was used. First of all, the SOLVER function should be installed into the Excel program under the DATA Tab. The next step is to set up the data sheet with inputs and outputs, and finally run the DEAFrontier software (Deafrontier 2018).

The process of the efficiency measurement with BCC model without slacks was started. While the Solver function already installed, specific formulas for the DEA calculation should be indicated. In the *Solver* window set the objective (first HEI's calculated measure of "Subject to"). Then mark the "Max"' (for maximization purpose). In the cell "By changing variable cells" the range starting with inputs and ending with outputs is marked (in case of six criteria, the marked range was composed from six boxes, and before the calculations were made, in every box should be entered 1). Please note that after the calculations, variables from 1 will change automatically. In the next cell of "Subject to the constraints", certain formulas should be considered: constraints for the left-hand side (LHS) and the right-hand side (RHS) variables of inputs and outputs for each specific HEI. In the latter cell, firstly the constraint for variables of weights should be entered to make its positive (≥0). Then, LHS (outputs) marked ≤ RHS (inputs), when = 1. Going forward, mark "Make unconstrained variables non-negative". Select Solving – *Simplex LP* (linear programming). The process is finished by clicking "Solve". Please note that this process should be invoked for every HEI.

Step 4. After applying the DEA tool the comparative analysis of HEIs' efficiency should be implemented. The results of DEA calculations (using the envelopment model – BCC) are presented in the Table 3.15, where it is presented the efficiency of the HEIs in two major fields (social and physical). The research results showed the efficiency of TT of Lithuanian HEIs in the field of physical sciences (P, A, B, T) (HEI 7, HEI 2 and HEI 6 are leaders) and in social sciences (H, S, M), where HEI 7, HEI 5 and HEI 2 are the leaders in TT. Hence, the DEA tool is appropriate for the evaluation of HEIs TTP performance.

3.6. Discussion of Obtained Results

Answering the research questions, HEIs have facing the problem of not efficient enough TT economic results during implementing of the innovation and TT process activities. It means that the level of TT process performance in universities is low, therefore the funding from the government needs to be used in more rational way, as well as HEIs inside funds. The government in Lithuania legally allows HEIs to estimate their own rules relating management and commercialization of intellectual property and implementing TT activities. Therefore, the rules and TT model differs in separate universities in Lithuania, the experience in commercialization is not big, what could influence also the overall TT economic performance in Lithuania.

Successful development of TT in HEIs from other countries can be transferred to Lithuania with some adaptations. Thus, for instance, the case of MIT difficult to adapt for Lithuania. MIT, as the region of biology and biomedicine, situated in the USA in the large concentration of the most accomplished research institutions organizations, including universities and research hospitals. In comparison with Lithuania, here there is no the most big universities and hospitals in one area, as well as 40 per cent of the spin-off companies formed by alumni. The entrepreneurial culture and surrounding community is not so great developed. Since 2011, only two public HEIs have the result of established spin-off companies (see Fig. A5). The concept when Technology Licensing Office is situated outside universities will not work in Lithuania because of the different culture aspect and the lack of trust. The case of Germany, when a number of research groups from different research centres were connected into one association, is also difficult to transfer in Lithuania, because every university has established research groups in own university with no connection with other HEIs, only in separate cases it is possible. Association's TTO would not working efficiently with a lack of trust from separate HEIs' sides. From the other hand, the staff of TTO apply the method of periodically meetings with scientists 1 or 2 times per month. This experience can be transferred to Lithuania to build more trust from researchers and to play the role of a contact person in building relations with industry to help in licensing of IP, and entrepreneurship (creation of new spin-off companies). Lithuania needs also the certain tools like in Germany for electronic evaluation of commercial potential of the invention to help during evaluation of potential ideas. Belgium as the most innovative country has a strong life sciences and biotechnology sector, a huge industry and business sector with financial groups, HEIs and research centres. In Lithuania, there is no strong industry and investors, biotechnology sector is rising but not very high. Belgium have the similar situation like in Germany, when TTO service is providing for several universities outside them, and the best research teams. For the reason of lack of trust in Lithuania, TTO specialists should be situated inside universities. TTO team in Belgium consists of 16 employees including patent attorneys and experience in industry at least 6 years, when in Lithuania the service of patent attorney mostly is outsourced, and there is not existing so big team (see Fig. A4). Most of full time employed staff are working on the project contracts; it means no continuity for staff, so not very efficient. Belgium TTO team has a clearly defined methodology for the successful finding of inventions and ideas' identification process. In Lithuania, HEIs do not have clear methodology of implementing the scouting of ideas. Therefore, some useful success factors should be taken into account in building effective TTO team to reach high performance results.

Searching for the most important factors, influencing the economic results of HEIs TTOs, has been identified some factors. Entrepreneurial performance depending on the well-developed location like in MIT, where the similar thinkers are concentrated to support each other, and when the ideas are very close to the market. Lithuania has distributed parties within innovation and TT ecosystem, and it could be one of the reason of low TT performance. The ideas and intellectual property is quite far from the industry. TTOs in Lithuanian HEIs are working separately, there is a lack of staff and theirs level of competence, lack of ensured conditions to keep employees for longer than two or three years. Based on the literature, scientists are identified as the one of the core factor for success in TT performance (Hayter *et al.* 2018b). Research results depend on the organizational culture. The challenge exists also between HEIs resources allocation and the willingness and ability of scientists to develop research works with industry. Therefore, there is a need to change HEIs' strategy and align it with organizational processes (McAdam *et al.* 2017). Lithuania need to review HEIs financial flows and rethink the funding system to motivate researchers and TTO staff for seeking benefits from science-business activities. This way the organizational culture could be oriented more for growing entrepreneurship atmosphere in HEIs, reaching financial benefits. However, to support the change of HEIs policy, the government should provide clear directions relating TT and commercialisation.

HEIs has become knowledge transferring point for the market. This mission should be supported by strong venture capital and private equity funds (Croce *et al.* 2014), when Lithuania does not have them enough. Therefore, this factor is also very important to strengthen TT economic results. University-affiliated companies, which are established on the strong university intellectual property, bring economic benefit for HEIs (Hayter *et al.* 2018a). High competent TTO staff is very important to foster commercialization of university intellectual property, self-motivation of university academics, who are working close with industry and will to get self-recognition. The competence of Lithuanian TTOs is under developing period; it could be evaluated in the future works. Other authors add that not only R&D production, but also the competitiveness of the region and the dissemination of universities' work all together have a strong effect on TT and valorisation process (Audretsch *et al.* 2012a, 2012b). The competitiveness of Lithuanian region is not high in comparison with other European countries. The competitiveness of the cities in Lithuania is related with the size of the city, when the industry companies are mostly concentrated in the biggest cities. The amount of R&D production is related with the number of researchers (see Figs A7–A11): the biggest number of researchers, the bigger R&D results (in publications, projects, contract works).

By Hulsbeck *et al.* (2011), the number of tasks (per TTO employee) also important. During analysis of good experience of TT models in Germany, Belgium and MIT it could be stated that the functions should be strictly differentiated with optimal number of tasks, when in case of Lithuania the number of tasks differs from 3 to 12 (see Fig. A6). Araújo (2013) highlights the key elements of TT: human capital, abilities of industry to use state-of-the-art technologies, communication abilities, trust, past experience and foreign partners, the size of organization, and the sector of activity. Lithuania has the most developed two spheres in lasers and biotechnology, so HEIs working in these spheres have more successful economic results in cooperation with partners from abroad, but still have to improve the efficiency.

The efficiency evaluation of HEIs TT process can be implemented during measuring of identified indicators. Literature review deployed a number of possible variables, which was evaluated by respondents with innovation management, TT and commercialization experience, and selected for the research (Suchapter 2.2) by the weights (Subchapter 3.2) and importance for the TT process. Since the variables of TTP are identified, the methods measuring the efficiency could be applied.

The efficiency evaluation of HEIs TTP can be implemented during measuring the process with some methods. Efficiency evaluation model proposed in this dissertation is constructed in that way: TOPSIS and FARE methods are applied to identify the variables of TTP; COPRAS and MULIMOORA – to rank and select HEIs for the research; and DEA – to evaluate the efficiency of selected HEIs.

Research findings show that Lithuanian HEIs is not efficient enough. The highest efficiency is only 38%, so the problem to rise TTP efficiency exists. The concept of TT model can be transferred with some practices from abroad (Germany and Belgium cases are more close to Lithuanian culture): to locate the biggest universities and hospitals to the one area; to build stronger relation between TTO staff and researchers on periodically meetings; to build research teams; to promote spin–offs' creation; to develop support flows from venture capital, business angels, etc.; to expand and maintain TTO team and their competence during knowledge strengthening instruments; to change legislation relating TT and commercialization leading to improve certain TTP variables (or change the variables) seeking economic benefits and effective allocation of financial resources. The process to create entrepreneurial culture inside HEIs take time. Strategies and policies of universities and the government should be improved. During literature analysis was identified, that the researcher plays an important role in communication between TTO and business company. Excellent IP and competent TTO staff is necessary for implementation of TTP, communication abilities and trust of TTO, basis of partners, the size of HEI, the sector of activity, etc. The research results have been identified the most important variables to measure TTP (in Subchapter 2.2 and 3.2), propose the original model for measuring the efficiency of TTP in HEIs.

Practical results show, that FARE method is suitable to identify variable for the research, giving assigning weights for every variable. TOPSIS method helps to rank variables and select them for the research. MULTIMOORA and COPRAS methods was practically approbated, and the findings show, that they fit to rank universities and select them for the research sample. Approbation of efficiency evaluation tool shows that DEA method ideally fits to measure the efficiency of TTP. Created model can be used also useful for other countries. This model and its results are useful for HEIs heads first to evaluate current results of R&D and innovation performance, and based on the results estimate new or update current targets and economic variables, orienting HEI's strategy for better allocation of financial resources. For TTOs, this model is useful to evaluate yourself. For public authorities this model serves as the tool for evaluating Lithuanian HEIs, and based on the results it helps to decide on the strategy of allocation financial resources. Success factors identified is necessary for efficient TTP and influencing the efficiency research results. For policymaking institutions, proposed TTP efficiency evaluation model is useful to seek country's economic strategic goals, beneficial to evaluate HEIs and fund them. In addition, improved overall country's economic results would be profitable to achieve the goals of the Lithuanian Strategy 2030, herewith to raise Lithuania closer to the leaders of TT performance results. Therefore, the overall position of Lithuania would rise on the European Innovation Scoreboard.

Some limitations occur for selected methods. FARE method is the human judgment based technique. Therefore, the Kendall concordance coefficient is required (to evaluate expert's consistency). TOPSIS tool uses of the Euclidean distance, which does not consider the correlation of the attributes. Also, application of this method is difficult with need to weight and keep consistency of judgment. MULTIMOORA tool's major limit is the data of objectives that could not be zero or negative. COPRAS may be less stable than TOPSIS method in the case of data variation. In addition, the results may be sensitive to slight the data variation, and the ranks may differ from ones using other methods. Limitations for DEA: the number of alternatives analysed should be less than twice to the number of inputs and outputs combined; the problem during selection of variables for the research in numbers and ratios when these data could not be integrated in the one model; the tool assumes that all input and output measures are exactly known, when in reality this assumption could be not the true; the calculation results can be sensitive depending on the inputs and outputs selected.

For the future research would be beneficial to value the economic change after implementing new or updated legislation (strategy with goals and variables) relating HEI's TT and commercialisation. Would also interesting to analyse the positive effect of implementing new motivation tools for TTO team, researchers and establishing more spin-offs based on university intellectual property. In order to improve the efficiency of TTP, for universities is suggesting: to estimate the efficient allocation of financial and human resources; to develop the policy and organisational strategy aimed at improvement of TTP indicators and maximization of economic outputs; to reorient the internal university culture into entrepreneurial culture, which would create favourable conditions for industry oriented R&D that would lead to better innovation results.

3.7. Conclusions of Chapter 3

The third Chapter concludes with these results.

1. The research findings provide an original model able to evaluate the technology transfer process of Lithuanian higher education institutions. The model is consisting from several stages. Thus, the FARE method is able to select technology transfer process indicators and their weights, and the TOPSIS method ranks them by greatest impact. The MULTIMOORA and COPRAS multi-criteria methods enable the ranking of the higher education institutions and selecting the sample for the research. The DEA method is useful for evaluating the efficiency of higher education institutions' technology transfer process performance. The research results made it possible to evaluate the efficiency in the field of technology transfer in Lithuania.
2. The research results with the FARE and TOPSIS tools of seven Lithuanian higher education institutions have identified eight the most important indicators, presented in order of importance to evaluate technology transfer process performance: income from contract works (weight − 0.18); income from international projects (weight − 0.16); funding per researcher – FTE (weight − 0.15); European and international patent applications (weight − 0.13); income from national projects (EUR) (weight − 0.12); the number of employees at technology transfer office (weight − 0.10); the number of researchers at higher education institution (FTE) (weight − 0,09); the number of publications at higher education institution (weight − 0.07). TOPSIS results ensure the ranking of higher education institutions by results of selected performance indicators: HEI 3 (0.564), HEI 2 (0.452), HEI 1 (0.430), HEI 5 (0.373), etc.
3. MULTIMOORA calculation results of the seven Lithuanian higher education institutions in the period of three years show, that the relation system of values and reference points of all indicators (Si(USU), Si(TPP), Σ EVV, Σ AIV, d_{si}, SE_i, E_i, T_i, F_i, LF_i, PLE_i) at HEI 7, HEI 2 and HEI 3 are the highest in the sample, therefore these are the leaders implementing the higher education, research and innovation activities in all fields: Humanitarian Sciences (H), Social Sciences (S) and Arts (M), Physical Sciences (P), Agricultural Sciences (A), Biomedical Sciences (B), Technological Sciences (T). The leaders of the final value of the full multiplication form are HEI 7, HEI 2 and HEI 6, which are the most entrepreneurial and have a better-developed technology transfer system with technology transfer office staff inside the

higher education institutions. The research results have proved that the suggested MULTIMOORA tool is fully suitable for evaluating the economic performance of the efficiency of the technology transfer process of higher education institutions, ranking them by the best results.

4. The COPRAS empirical results, performed for 20 performance indicators in four sectors, analysing 28 European countries in a 10-year range, showed that the top five investors in R&D from the government sector were Luxembourg, Germany, Finland, France and the Netherlands. Lithuania is in the 25th place out of 28. The highest results as investors in R&D for the higher education sector were for Denmark, Sweden, Finland, the Netherlands and Austria. Lithuania is in 19th place out of 28. The best investors in R&D in all four analysed sectors are the following countries from group 1: Finland, Luxembourg, Denmark and Sweden. Approbated results showed that the COPRAS method allowed the ranking of countries (or in other cases – higher education institutions) paying attention to and making decisions about investing in R&D.
5. The research results of efficiency evaluation using the DEA method among the analysed seven higher education institutions implementing technology transfer and commercialization activities in Lithuania in the field of physical sciences (P, A, B, T) showed that efficiency: HEI 7 (37%), HEI 2 (18%) and HEI 6 (11%) have the best results, whereas in the field of social sciences (H, S, M) the leaders of TT are HEI 7 (36%), HEI 5 (31%) and HEI 2 (11%). The worst results belong to HEI 4 (0.2%) in social sciences, and HEI 5 (0.1%) in physical sciences. Research results allow to state that the DEA method is suitable for evaluating of HEIs' technology transfer process performance.
6. Conducted case analysis of Lithuanian universities and obtained results showed that the suggested model is fitting to evaluate the technology transfer process of higher education institutions in Lithuania and could be adapted for other higher education institutions.

General Conclusions

1. The conducted theoretical analysis of the TTP, based on literature analysis, has shown that, though there are different interpretations, there a common understanding exists of the main concepts defining the phenomenon of TT in HEIs. There is a commonly understood necessity to promote a greater involvement of HEIs in knowledge and TTP aimed at development of smart, innovative economy of the country.
2. The analysis of the foreign (the USA, Belgium and Germany) experience and discussion of factors, promoting the TT, make it obvious, that the success of developed TT models at university level depends on the following: efficient allocation of financial and human resources to TTP in HEIs, so as to find applications in industry and society for the new knowledge generated at HEIs and consequently to achieve better performance results; competence of staff of TT offices (TTOs) to manage the TTP and to develop the entrepreneurship culture of HEIs; the interuniversity and university-business cooperation, for efficient TT takes place when researchers and innovation developers directly interact with business and assist in creation of new enterprises.
3. The conducted theoretical and empirical analysis of the issues, related to efficiency evaluation of HEIs performance in the TT field provides the

evidence about the suitability of the indicators chosen to assess the efficiency. They are as follows: the revenues from international R&D projects and from order-based R&D works; funding per researcher; international patent applications; income from national R&D projects; the number of staff in the TTO; the number of researchers at HEI.

4. The identified set of factors, influencing the development of TT efficiency, include: entrepreneurship culture; dissemination of R&D production implemented in the market; the invention of technologies; academic recognition; the competitiveness of the region; the country's policy on TT; motivation tools; the accessibility of technologies for industry; IP protection; TT skills; the organizational structure; the ability to change and make decisions; communication skills.
5. The novelty and practical significance is in the designed and empirically tested original model to evaluate the efficiency of TTP in HEIs. The model is proposed to use for Lithuania and can be adapted for other countries. TTP efficiency evaluation model can be obtained for ministries, universities and technology transfer offices for a short and long term planning, and for decision making. The scientific methodology is based on a set of proposed multi-criteria methods. With FARE and TOPSIS tools are suggesting to choose the indicators for the evaluation of the efficiency of TTP; with COPRAS and MULTIMOORA – to rank and select HEIs; with DEA tool – to measure the efficiency of TTP in HEIs.
6. Conducted case analysis of Lithuanian universities on efficiency evaluation of technology transfer process show that the efficiency of TTP in investigated HEIs is not enough and should be improved in the future.

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Summary in Lithuanian

Įvadas

Problemos formulavimas

Technologijų perdavimo (TP) procesai, įskaitant žinių perdavimą ir pritaikymą pramonėje Lietuvos aukštojo mokslo institucijose (AMI) yra nepakankamai efektyvūs. Todėl vyriausybė skatina aukštąsias mokyklas efektyviau perduoti universitetuose sugeneruotas žinias, rasti jų pritaikymą pramonėje. Akivaizdu, kad TP procesas vaidina svarbų vaidmenį jungiant akademinius tyrimus su verslo sektoriumi.

Pagal Europos Komisijos parengtą strategiją „Europa 2020“, pirmenybė turėtų būti teikiama nacionalinėms ir privačioms investicijoms į mokslinius tyrimus ir eksperimentinę plėtrą (MTEP). Investicijos į MTEP turėtų siekti 3 % BVP (Europos Komisija, 2016b). Tuo tarpu 2014–2020 m. Lietuvos nacionalinėje pažangos programoje numatyta, kad iki 2020 m. Lietuvos investicijos į MTEP turėtų sudaryti 1,9 % BVP (Lietuvos Respublikos Vyriausybė 2012). Situacijos analizė rodo laipsnišką, tačiau nepakankamą MTEP išlaidų padidėjimą. Remiantis Lietuvos statistikos departamento duomenimis (2014a, 2015, 2016, 2017), išlaidos MTEP siekė: 2017 m. – 0,89 % BVP; 0,85 % – 2016 m.; 1,04 % BVP – 2015 m. Europos Sąjungoje išlaidos moksliniams tyrimams ir plėtrai 2014–2016 m. sudarė apie 2,03 % BVP (Eurostatas 2018). O pagal universitetų ir verslo bendradarbiavimo „2017–2018 m. Pasaulinio konkurencingumo ataskaitą“, 2016–2017 m. Lietuva užėmė 35 vietą tarp 148 pasaulio šalių; 36 vietą 2015–2016 m.; 41 vietą 2014–2015 m. (Pasaulio ekonomikos forumas 2015, 2016, 2017, 2018). Nors padėtis gerėja, verslo ir mokslo sektorių bendradarbiavimas vis dar neproduktyvus (2017–2018 m.

Pasaulinio konkurencingumo ataskaita). Pagal Lietuvos pažangos strategiją („Lietuva 2030“) pagrindinė iškelta problema yra nelanksti aukštojo mokslo sistema, skiriama per mažai dėmesio TP sistemos tobulinimui, novatoriškų verslų (pvz., atžalinių įmonių) kūrimo skatinimui. Pagal Europos Komisijos Europos inovacijų švieslentę, Lietuvos pasiekimai yra: 21 vieta (iš 29 šalių) 2017 m., 25 vieta – 2016 m., 26 vieta – 2015 m., 25 vieta – 2014 m. (Europos Komisija 2017, 2016a, 2015, 2014).

Apibendrinant faktus galima teigti, kad žinių ir TP procesas aukštojo mokslo institucijose Lietuvoje nėra pakankamai efektyvus, inovacijų lygis yra gana žemas. Be to, išlaidos tyrimams ir plėtrai nėra patenkinamos, palyginti su Europos aukštosiomis mokyklomis. Todėl auga poreikis ir svarba vertinti TPP bei priimti atitinkamus sprendimus, kurie skatintų aukštojo mokslo institucijų efektyvumą.

Darbo aktualumas

Remiantis 2014–2020 m. Lietuvos inovacijų plėtros programa, mažą inovatyvumo lygį šalyje lemia nepakankamas finansavimas MTEP bei mažas verslo pajėgumas inovacijoms diegti.

Dabartinė Lietuvos AMI TP ir komercinimo veiklos rezultatų apžvalga rodo, kad viešoji ir privati partnerystė tarp AMI ir verslo organizacijų yra neproduktyvi. Yra tik keletas mokslinių tyrimų, analizuojančių aukštojo mokslo veiklos efektyvumo vertinimą ir vertinimo metodus. Nėra tyrimų, analizuojančių TP ir komercinimo proceso efektyvumo vertinimą, siekiant pagerinti ekonominius veiklos rezultatus. Disertacinio tyrimo aktualumas siejamas su nuosekliu poreikiu įvertinti ir priimti tinkamus sprendimus siekiant pagerinti ne tik finansinių ir žmogiškųjų išteklių paskirstymą, bet ir TP bei komercinimo proceso ekonominę naudą AMI. Tokio modelio, kuris galėtų įvertinti AMI TPP veiklos efektyvumą ekonomine prasme nėra.

Tyrimui atlikti buvo iškelti šie klausimai: su kokiomis problemomis susiduria AMI TP srityje? Ar kitų šalių sėkminga patirtis technologijų perdavimo srityje gali būti pritaikoma Lietuvoje? Kokie veiksniai skatina TP proceso tobulėjimą? Kaip gali būti vertinama ir matuojama TP veikla, vykdoma Lietuvos AMI? Koks TP efektyvumo vertinimo modelis ir kokie metodai būtų tinkami įvertinti TP procesą, organizuojamą AMI?

Tyrimo objektas

Tyrimo objektas yra aukštojo mokslo institucijų technologijų perdavimo proceso efektyvumas.

Darbo tikslas

Disertacijos tikslas – sukurti technologijų perdavimo proceso aukštojo mokslo institucijose efektyvumo vertinimo modelį.

Darbo uždaviniai

1. Atlikti teorinę TP proceso AMI analizę (aptariant TP sampratą ir pagrindines sąvokas, pateikiant kitų šalių TP modelių analizę bei išskiriant veiksnius, skatinančius TP veiklos plėtrą).
2. Išanalizuoti TP proceso efektyvumo vertinimą AMI (vykdomas TPP veiklas, proceso dalyvius, veiklos rodiklius ir veiksnius, darančius įtaką ir išryškinančius esamus TP dėsningumus ir tendencijas komercinimo srityje).
3. Pasiūlyti originalų TPP efektyvumo vertinimo modelį, besiremiantį lyginamąja daugiakriterių tyrimo metodų analize ir tinkantį aukštojo mokslo institucijų veiklos TP srityje įvertinimui atlikti.
4. Atlikti empirinį tyrimą ir aprobuoti pasiūlytą TPP efektyvumo vertinimo modelį naudojant daugiakriterius tyrimo įrankius (FARE, TOPSIS, MULTIMOORA, COPRAS, DEA), surinkti ir agreguoti tyrimo duomenis, reikalingus TPP efektyvumui vertinti, sukurti duomenų bazę empiriniam tyrimui atlikti.
5. Išanalizuoti ir apibendrinti gautus TPP tyrimo rezultatus, suformuluoti galutines išvadas apie aukštojo mokslo institucijų TPP efektyvumą. Tai padėtų gauti geresnius ekonominius rodiklius per efektyvesnį finansinių ir žmogiškųjų išteklių paskirstymą.

Tyrimų metodika

Šis tyrimas suplanuotas kaip studija, kuri remiasi kiekybinio tyrimo metodologija. Teorinei analizei atlikti buvo taikomi mokslinės literatūros ir dokumentų analizės bei modeliavimo (kuriamas originalus TP efektyvumo vertinimo modelis) metodai. Duomenys buvo renkami taikant atskiro atvejo analizės metodą užsienio šalių ir Lietuvos aukštojo mokslo institucijų TP modelių analizei atlikti. Su technologijų perdavimo biurų vadovais, kurie vertino TPP veiklą AMI, buvo taikomas ekspertų apklausos metodas, kuris buvo derinamas su kitais pasirinktais daugiakriteriais tyrimo metodais: FARE (veiksnių tarpusavio sąryšio metodas), leidžiantis nustatyti TPP rodiklių pagal didžiausią poveikį svarbą TPP; TOPSIS (preferencijų eilės tvarka pagal panašumą idealiam sprendimui) metodas yra tinkamas rodikliams ranguoti pagal didžiausius veiklos rezultatus ir nustatyti rodiklius empiriniam tyrimui; MULTIMOORA (daugiafunkcis optimizavimas pagal santykio analizę); COPRAS (kompleksinis proporcinis vertinimas) daugiakriterių sprendimų priėmimo įrankiai, galintys reitinguoti AMI ir atrinkti jas empiriniam tyrimui; duomenų rinkinio apgaubimo analizės (DEA) metodas, skirtas įvertinti TPP veiklos efektyvumą vykdant TP veiklą AMI. Tyrimo validumas (duomenų pagrįstumas) slypi duomenų, analizuojamų iš skirtingų teorinių ir metodologinių perspektyvų, trianguliacijoje.

Mokslinis naujumas

1. Pasiūlytas originalusis modelis įvertinti AMI TPP ekonominį efektyvumą. Modelis skirtas į TP veiklos specifiškumo vertinimui AMI bei gali būti pritaikytas ir kitų šalių aukštosioms mokykloms.

2. Mokslinės metodologijos naujumas yra grindžiamas TPP tikslinių rodiklių grupės ir tyrimais patikrintų metodų sąrangomis, integruotomis į modelį, kuris leidžia pamatuoti aukštųjų mokyklų technologijų perdavimo proceso efektyvumą.

Darbo rezultatų praktinė reikšmė

1. Sukurtas ir empiriškai išbandytas originalus TPP efektyvumo vertinimo modelis, esant turimiems ištekliams ir neprarandant veiklų kokybės, naudingas: aukštojo mokslo institucijų vadovybei vertinti MTEP ir inovacijų veiklos rezultatų efektyvumą, tikslingai paskirstyti finansinius ir žmogiškuosius išteklius bei numatyti strateginius gerinimo tikslus didinti ekonominius ir kt. rodiklius (patentų skaičius, pajamos iš tarptautinių ir nacionalinių projektų, užsakomųjų darbų ir pan.); TP biurams modelis naudingas įvertinti pasiektus rezultatus, įtaką darančią veiksnių grupę ir numatyti strategiją dėl rodiklių efektyvumo didinimo; valdžios institucijoms (ministerijoms) įrankis naudingas atliekant ilgalaikį politikos prognozavimą ir vertinimą, paskirstant finansinius išteklius aukštojo mokslo institucijoms.
2. Darbe išskirta sėkmingų veiksnių grupė, daranti įtaką TP procesui, MTEP ir inovacijų veiklos rezultatų efektyvumui. Žinios apie šiuos faktorius leidžia sprendimų priėmėjams efektyviau išnaudoti ir paskirstyti išteklius ir numatyti reikalingus pokyčius.
3. Empiriškai išbandytas modelis bus praktiškai naudingas siekti numatytų MTEP ir inovacijų tikslų politikos formavimo ir politikos įgyvendinimo institucijoms valstybėje, kai vertinamas aukštųjų mokyklų MTEP ir inovacijų veiklos efektyvumas, kai skiriamas finansavimas, tiek ir aukštojo mokslo institucijoms įsivertinimui atlikti, siekiant patobulinti aukštosios mokyklos TP veiklos efektyvumą. Tai padės įgyvendinti Lietuvos vyriausybės strategijos 2030 m. tikslus ir priartinti Lietuvą prie aukštesnio lygio MTEP ir inovacijų TP veiklos srityje. Pagerėję Lietuvos rezultatai gali turėti įtakos aukštesnei Lietuvos pozicijai Europos inovacijų švieslentėje ir pagerinti konkurencingumo rodiklius.

Ginamieji teiginiai

1. TP proceso efektyvumą rodo šie rodikliai: pajamos iš tarptautinių MTEP projektų, užsakomųjų MTEP darbų, finansavimas vienam tyrėjui, tarptautinių patentinių paraiškų skaičius, pajamos iš nacionalinių MTEP projektų, personalo skaičius TP biure, tyrėjų skaičius AMI ir kiti, kurie yra tinkami įvertinti AM institucijų pasiektų rezultatų efektyvumą.
2. Veiksnių grupės (antreprenerystės (verslumo) kultūra, realizuojama rinkoje MTEP produkcija, technologijų išradėjas, akademinis pripažinimas, regiono konkurencingumas, sklaidos darbai, šalies politika TP klausimu, motyvacinės priemonės, technologijų prieinamumas pramonei, intelektinės nuosavybės (IN) apsauga, TP gebėjimai, organizacinė struktūra, gebėjimas keistis ir priimti sprendimus, bendravimo įgūdžiai) sąranga daro įtaką TP efektyvumui.

3. Pasiūlytų įrankių (FARE, TOPSIS, MULTIMOORA, COPRAS, DEA) sąranga integruota į originalų TPP efektyvumo vertinimo modelį leidžia įvertinti AMI veiklos rezultatų efektyvumą TP aspektu. FARE ir TOPSIS metodų jungtis leidžia atrinkti rodiklius, skirtus įvertinti TPP efektyvumą. COPRAS ir MULTIMOORA yra pasirinktos kaip reitingavimo priemonės, skirtos atrinkti AMI empiriniam tyrimui. Tuo tarpu DEA priemonė matuoja AMI TPP efektyvumą.

Darbo rezultatų aprobavimas

Disertacijos tema yra parengti trys moksliniai straipsniai mokslo žurnaluose, įtrauktuose į Clarivate Analytics Web of Science duomenų bazę. Vienas iš šių žurnalų turi citavimo rodiklį. Disertacijos rezultatai buvo pristatyti tarptautinėje konferencijoje ir moksliniuose seminaruose:

1. Kraujalienė, L. „COPRAS metodas efektyviam MTEP išlaidų vertinimui technologijų perdavimo procese“, Contemporary Issues in Business, Management and Education, Vilnius, Lietuva, 2017 m.
2. Kraujalienė, L. Keturi pranešimai moksliniuose seminaruose doktorantūros studijų studentams Verslo vadybos fakultete (po vieną kiekvienais akademiniais metais 2015–2019 m. studijų laikotarpyje).

Doktorantūros metu buvo įvykdyti šeši moksliniai vizitai:

1. Vizitas į Naująjį Lisabonos universitetą, Portugalijoje, 2016 m.
2. Vizitas į konferenciją „Edu Data Summit“ Jungtinėje Karalystėje, Londone, 2016 m.
3. Vizitas į Darmštato technikos universitetą, Vokietijoje, 2016 m.
4. Vizitas į Latvijos universitetą, Rygoje, Latvijoje, kartu dalyvaujant Europos kokybės užtikrinimo forume, 2017 m.
5. Vizitas į Rygos technikos universitetą, Rygoje, Latvijoje, 2018 m.
6. Vizitas į „Baltijos mokslo dieną“, Rygoje, Latvijoje, 2019 m.

Disertacijos struktūra

Darbą sudaro įvadas, trys pagrindiniai skyriai, bendrosios išvados, literatūros sąrašas, autoriaus publikacijų disertacijos tema sąrašas ir 6 priedai. Disertacijos apimtis (be priedų) – 140 puslapių, 17 paveikslų ir 18 lentelių, išanalizuota 230 literatūros šaltinių.

1. Aukštojo mokslo institucijų technologijų perdavimo proceso pagrindinių sąvokų ir koncepcijų teorinė analizė

Pirmajame disertacijos skyriuje atlikta literatūros šaltinių apžvalga disertacijos tematika. Nemažą šio skyriaus dalį sudaro technologijų perdavimo proceso (TPP) sampratos ir pagrindinių sąvokų bei užsienio šalių TP modelių analizė. Aptariami pagrindiniai TP veiksniai, skatinantys TP veiklos efektyvumą, ir veiklos efektyvumo vertinimo reikšmingi veiksniai, jų svarba TPP kontekste. Apžvelgti esminiai TPP efektyvumo vertinimo modeliai ir jų pagrindiniai skirtumai. Atliktos lyginamosios daugiakriterių tyrimo metodų analizės pagrindu konstruojamas originalus TP veiklos, vykdomos AMI, efektyvumo vertinimo modelis, pristatoma jo koncepcija. Pateikiamos 1 skyrių apibendrinančios išvados.

AMI TP veikla yra svarbi, nešanti ekonominę naudą AMI ir šalies ekonomikai. Pažymima, kad nėra tinkamo modelio įvertinti TPB vykdomą veiklą. Iki šiol nebuvo priemonių įvertinti minėtą efektyvumą. AMI atlieka svarbų vaidmenį inovacijų gyvavimo cikle kaip žinių ir inovatyvių sprendimų, kurie turi būti komercinami ir iš jų turi būti gaunama ekonominė nauda, generatorius.

TP aiškinamas kaip mokslinių atradimų ir gamybos metodų, įgūdžių ir žinių, novatoriškų mokslo ir verslo organizacijų, tokių kaip universitetų, vyriausybinių agentūrų, ir kitų institucijų, pasidalijimo ir sklaidos procesas (Audretsch *et al.* 2012a, 2012b). Šioje disertacijoje TP yra suprantamas kaip veiklos, skirtos mokslinių tyrimų ir inovacijų bei žinių, kuriamų AMI, rezultatų sklaida ir jų perdavimas rinkai, o technologijos suprantamos kaip AMI mokslininkų intelekto produktai. AMI technologijų perdavimo biurų (TPB) universitetuose misija – užtikrinti subalansuotą AMI ir privataus sektoriaus simbiozę. Disertacijoje įvykdymas reiškia organizacinės sistemos įvykdytos veiklos rezultatus panaudojant organizacijos kompetencijas ar gebėjimus (Van Dooren ir kt., 2010). Efektyvumas moksliniame darbe suprantamas kaip AMI efektyvi veikla. TP veiklos efektyvumas yra galiojanti veiklos vertinimo priemonė, aprūpinanti AMI mokslo ir inovacijų rezultatais, kai AMI finansinė parama priklauso nuo mokslo produkcijos rezultatų (Abbott, Doucouliagos, 2003). TP papildomas valorizacijos procesu, kurio tikslas – gauti ekonominius rezultatus, kurie galiausiai atsiranda per komercinimo veiklą. Komercinimas yra vienas iš TP proceso etapų.

Kiškienė (2009) teigia, kad Lietuvos rinka yra neefektyvi TP veikloms vykdyti (Kiškienė, 2009). Tradiciškai pagrindinė Lietuvos universitetų misija yra švietimo ir akademinės veiklos įgyvendinimas, o ne verslas.

Išskiriamos pagrindinės veiklos, atliekant TP ir valorizacijos proceso ekonominį vertinimą: vertingų tyrimo rezultatų identifikavimas, jų technologinis vertinimas, priežiūra, naujumo vertinimas, IN atskleidimas ir apsauga, rinkos tyrimai, verslo plano parengimas, ir komercinimo veiksmai siekiant ekonominės naudos (Train2 2017). Disertaciniame tyrime siekiama aptarti įvairius veiksnius ir išryškinti rodiklius, galinčius turėti įtakos TP proceso efektyvumui.

Esamas TP modelis Lietuvoje yra neveiksmingas. TP veikla Lietuvoje buvo pradėta įgyvendinti maždaug prieš 10 metų. Ši veikla universitetuose buvo suprantama kaip dalijimasis informacija, jos sklaida visuomenėje, kaip mokslo produkcijos realizavimas verslui, kvalifikacijos mokymų organizavimas, konsultavimas ir pan. Tačiau šios veiklos nebuvo pagrindiniai AMI prioritetai. Šiuo metu Lietuvos universitetai yra kelyje kuriant tam tikrą struktūrą ir TP kultūrą.

Geroji užsienio praktika TP srityje rodo, kad efektyviam valdymui ir verslumo gebėjimams bei geriems ekonomikos rezultatams pasiekti, reikia daug laiko ir kryptingų pastangų.

JAV Masačiusetso valstijoje egzistuoja pažangus biotechnologijų klasteris. MIT (angl. *Massachusetts Institute of Technology*) yra pirmaujanti mokslinių tyrimų institucija šiame regione. MIT yra didžiausia koncentracija žinomų mokslinių tyrimų institucijų:

universitetų ir mokslinių tyrimų ligoninių. Maždaug 40 proc. aukštųjų technologijų įmonių yra įsteigtos MIT absolventų (alumnų). MIT kultūra skatina kitus galvoti, kad ir „aš galiu tai padaryti“, o taip pat ir aplinka siūlo daugybę galimybių (pvz., organizuojami verslo plano konkursai) gauti patarimus ir suformuoti strategijas. MIT turi technologijų licencijavimo biurą, esantį už universiteto ir ligoninių ribų. MIT modelis priklauso nuo verslumo aplinkos ir bendruomenės, supančios AMI. Norint pasiekti TP sėkmę, turi būti sukurta teisinė, santykinai ne biurokratinė, infrastruktūra, o AMI turi būti skirta pakankamai lėšų apsaugoti IN ir patentams palaikyti. Pradedančiųjų įmonių kūrimui ir klasterių plėtrai reikalingi talentai: pasaulinio lygio mokslininkai, apmokyti ir talentingi TP specialistai, įmonės steigėjai, įmonių personalas su mokslininkais ir vadybininkais, patyrę investuotojai, galintys finansuoti ir vesti įmonę, taip pat reikia pagalbinių darbuotojų profesionalų (Nelsen, 2005).

Belgija yra tarp novatoriškiausių ES šalių (TOP 10) (Europos inovacijų švieslentė, 2017). Ypač pažangus yra Flandrijos regionas, turintis stiprią gyvybės mokslų ir biotechnologijų sektorių. Flandrijos regionas įkūrė institutą be sienų su jame esančiu technologijų perdavimo biuru. 1996 m. buvo įkurtas FIB (angl. *Flemish Institute of Biotechnology*). Jis yra grįstas tarpuniversitetiniu bendradarbiavimu 4 skirtingų universitetų (Gento, Antverpeno, Liuveno ir Briuselio laisvojo universiteto) geriausių mokslininkų grupių, dirbančių gyvybės mokslų srityje. FIB turi mokslo išradimams komercinti skirtą TPB, kuris aptarnauja visus 4 universitetus. TPB komanda sudaryta iš 3 grupių, kurios atsakingos už: IN valdymą, licencijavimą, padeda TP veikloje ir dalyvauja naujų įmonių kūrimo procese; technologijų perdavimą; verslininkystę. Su mokslininku grupe susitinkama ne mažiau kaip kartą per mėnesį tam, kad būtų kuriama abipusio pasitikėjimo aplinka (Kurgonaitė, 2015).

Vokietija yra viena iš labiausiai išsivysčiusių šalių mokslinių tyrimų ir inovacijų srityje ES šalyse. Ji užima 6 vietą pagal *Europos inovacijų švieslentę* (2017). Inovatyviausi yra du pietiniai Badeno-Viurtembergo ir Bavarijos regionai. „Helmholtz-Zentrum Dresden-Rossendorf“ (HZDR) Vokietijos tyrimų centras buvo įkurtas 1992 m. ir priklauso „Helmholtzo“ asociacijai, kuri buvo įkurta prieš 20 metų. Asociacija jungia 18 įvairių mokslinių tyrimų centrų į bendrą tinklą. HZDR centras yra subūręs mokslines grupes iš Drezdeno, Leipcigo, Freibergo miestų, o taip pat turi specializuotą padalinį, TPB, kuris yra atsakingas už išradimų komercinimą ir priklauso „Helmholtzo“ asociacijos TPB tinklui. TPB darbuotojai susitinka su mokslininku 1 ar 2 kartus per mėnesį. TPB turi šias veiklas ir 3 komercinimo kanalus: bendradarbiavimas su pramone; IN licencijavimas ir apsaugotų technologijų pardavimas; verslininkystė (naujų atžalinių įmonių kūrimas) (Kurgonaitė, 2015).

Remiantis literatūros analize, AMI TPP gali būti vertinamas tokiais rodikliais: 1) finansavimas (vienam tyrėjui); 2) studentų skaičius; 3) publikacijų skaičius (vienam mokslo darbuotojui per metus); 4) naujų pradedančiųjų įmonių skaičius (Hulsbeck *et al*., 2011). Atsižvelgiant į Lietuvos atvejį, 1, 3 ir 4 rodiklių duomenų rinkimas būtų sudėtingas, nes šie duomenys skirtingai interpretuojami AMI rektorių ataskaitose (skaičiavimo rodiklių metodika nėra viešai prieinama).

Hulsbeck *et al.* (2011) siūlo tokius TPB veiklos įvykdymo rodiklius: darbuotojų skaičius (visos darbo dienos ekvivalentas), užduočių skaičius (vienam darbuotojui), mokslininkų, turinčių daktaro laipsnį, skaičius (Hulsbeck *et al.*, 2011).

Araújo (Araújo, Teixeira, 2014) išskiria pagrindinius TP veiklos aspektus ir elementus: žmogiškąjį kapitalą (techninius pajėgumus, mokymą, darbuotojus); sugeriamumo gebėjimą (pramonės gebėjimas naudoti šiuolaikines technologijas); ryšį (santykiai, socialinis ryšys – esminis TPB universiteto veiksnys); pasitikėjimą; ankstesnę patirtį (partnerių skaičius, užsienio patirtis, ypač su užsienio universitetais); dydį (organizacijos dydis); sektorių. Tai įrodo, kad AMI tarptautiniai santykiai turi tiesioginį poveikį TP ekonominiams įvykdymo rezultatams.

AMI TPP ekonominių rezultatų kokybė gali būti vertinama pagal šiuos rodiklius: patentų paraiškų (vėliau konvertuotų į patentus) skaičių, TPB (darbuotojai, užduotys, daktaro laipsnį turinčių darbuotojų dalis), universitetus (21 Lietuvos universitetas: 14 – valstybiniai ir 7 – nevalstybiniai universitetai (finansavimas, studentai, publikacijos – 3 metų vidurkis vienam mokslo darbuotojui)), regioninius aspektus (pramonės koncentracija regione, pradedančiųjų įmonių skaičius, pramonės sugeneruoti patentai) (Hulsbeck *et al.* 2011).

Kiekviena organizacija, naudodamasi žmogiškaisiais ir finansiniais ištekliais, savo pajėgumus paverčia ekonomine nauda. TPP etapų struktūra susideda iš šių etapų: tyrimai, išradimų atskleidimas, vertinimas, IN apsauga, rinkodara, licencijavimas/ įmonių kūrimas, komercinimas.

Universiteto TPB yra panašus į verslo ir akademinio atotrūkio mažinimo grandis, kurios jungia universitetą ir pramonę tam, kad palaikytų TP ir komercinimo būdus, o TPB darbas priklauso nuo rinkos vietos (Feng *et al.* 2012). TPB funkcija yra pagerinti personalo (įskaitant mokslininkus) ir TP valdymo proceso ryšį siekiant komercinimo ekonominės naudos universitetams.

AMI TPP veiklos koncepcijos formavimas prasideda nuo tinkamiausio TP modelio pasirinkimo atsižvelgiant į kultūros aspektą. Buvo pasirinktas Europinių modelių pagrindas, nes jis labiau atitinka uždarą Europos kultūros specifiškumą. TP veiklos vertinimo rodikliai identifikuojami padedant ekspertams ir atliekant literatūros analizę. Darbe buvo pasirinkti tokie TP efektyvumo vertinimo veiklos įrankiai kaip FARE, TOPSIS, MULTIMOORA, COPRAS ir DEA, atsižvelgiant į jų privalumus ir trūkumus (žr. C priedą).

Tyrimai buvo vykdomi remiantis TPB specialistų ir vadovų tikslinės grupės apklausomis, oficialiomis Lietuvos mokslo tarybos (LMT) ir AMI ataskaitomis, Eurostato duomenų baze. Šie informacijos šaltiniai pasirinkti dėl jų atvirumo ir prieinamumo visuomenei.

TP vaidina svarbų laidininko vaidmenį tyrėjų ir verslo bendradarbiavimo procese.

Daugelis autorių pabrėžia svarbius veiksnius, darančius įtaką TPP veiklai: TPB specialistų kompetencijos lygį, AMI ir TPB darbuotojų bendradarbiavimo stiprumo (pasitikėjimo) aspektą, akademinio personalo savarankiškumą (mokslininkas), universitetų ir pramonės ryšius, technologijų aktualumą, AMI geografinę vietą, esančią šalia verslumą skatinančio tinklo, pramonės koncentraciją, vyriausybės dotacijų strategiją ir numatomą pareigą komercinti patentus versle (pvz., pagal „*Bayh-Dole*“ aktą, 1980), vyriausybės strategiją ir inovacijų bei mokslo veiklos finansavimo politiką ir daugelį kitų veiksnių, paminėtų literatūros analizėje pirmame skyriuje.

2. Aukštojo mokslo institucijų technologijų perdavimo proceso veiklos efektyvumo vertinimo modelis

Šiame skyriuje pateiktas autorės sukurtas modelis, leidžiantis įvertinti AMI TPP veiklos ekonominį efektyvumą.

S2.1 paveiksle parodytas TPP galimų įvesties ir išvesties rodiklių principas. TP procese vykdomos MTEP veiklos, išradimų atskleidimo ir IN apsauga. Todėl vykdomi rinkodaros diegimo, licencijavimo ir komercinimo procesai. Įvesties rodikliais, identifikuotais literatūros analizėje, gali būti laikomi: valstybės sektoriaus viešosios investicijos (išlaidos MTEP, administravimui ir ekonominei veiklai, MTEP darbuotojai: mokslininkai), MTEP ištekliai (AMI išlaidos MTEP, AMI personalas, doktorantų ir magistrų absolventų skaičiai). Tolimesni TPP rezultatai gali sukurti tokius išvesties rodiklius: publikacijos, patentinės paraiškos, patentai, MTEP nacionaliniai ir tarptautiniai projektai, užsakomieji mokslinių tyrimų darbai, atžalinės / pradedančios įmonės (angl. *spin-off*, *start-up*) ir kt. Norint pasiekti geresnių ekonominių rezultatų, būtina išsamiai išanalizuoti TPP, jo dalyvius, TPB veiklą.

AMI TPP efektyvumo vertinimo modelio sandara sujungus kiekybinius metodus: FARE ir TOPSIS (TPB rodikliams identifikuoti); MULTIMOORA ir COPRAS (sureitinguoti AMI); DEA (apskaičiuoti efektyvumą).

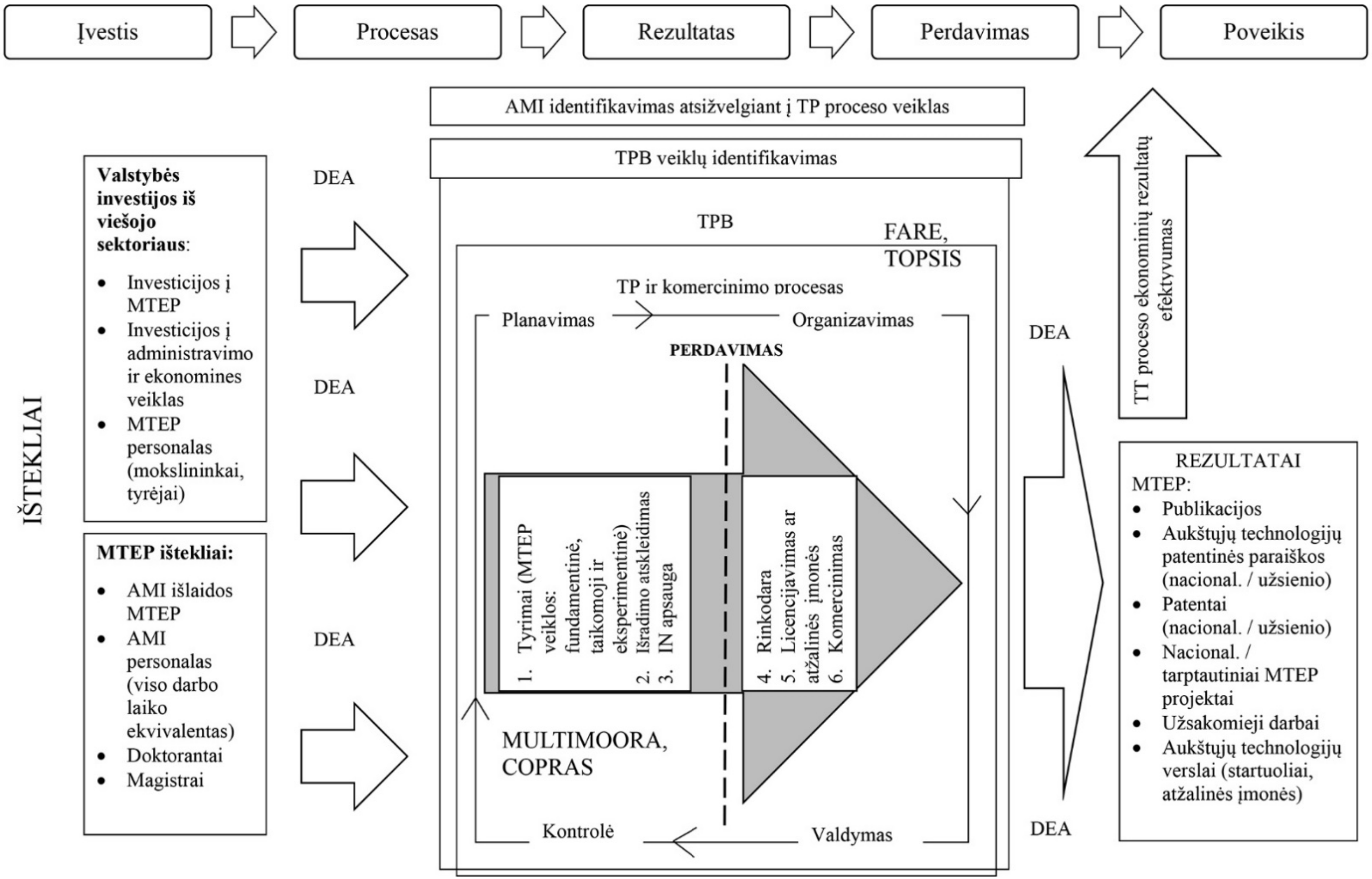
FARE metodas yra siūlomas įvertinti AMI rodiklius pagal jų svarbą TPP rezultatams. TOPSIS metodas pritaikomas sureitinguoti AMI pagal atrinktų svarbiausių rodiklių rezultatus. MULTIMOORA ir COPRAS metodai modelyje skirti sureitinguoti ir atrinkti AMI imtį tyrimui. DEA metodas skirtas apskaičiuoti AMI TPP efektyvumą.

Šiame skyriuje pateikiamas praktinio modelio, skirto įvertinti AMI TPP ekonominių rezultatų efektyvumą, aprašymas. Pradedant nuo koncepcijos sudarymo, siūlomų reikšmingiausių rodiklių, tinkamų įvertinti AMI TPP veiklą, o taip pat tinkamų vertinimo metodų, jų privalumų, trūkumų, apribojimų ir taikymo aspektų.

Visi procesai yra matuojami rodikliais, tinkamais konkrečiam procesui įvertinti. Todėl siūlomi AMI TPP veiklos matavimo rodikliai, tokie, kaip, patentinės paraiškos, TPB efektyvumo vertinimo rodikliai, ir kiti.

Duomenims surinkti buvo pasirinkti kiekybiniai tyrimo metodai. Remiantis literatūros analize ekspertų grupė atrinko reikšmingiausius TPP rodiklius. Duomenys rodikliams buvo surinkti iš AMI rektorių metinių ataskaitų, Lietuvos mokslo tarybos (LMT) mokslo produkcijos vertinimo ataskaitų, Eurostato duomenų bazės, Švietimo ir mokslo ministerijos įsakymų (2012–2014).

Kiti, rodiklių duomenys yra pagrįsti oficialiomis LMT viešai prieinamomis ataskaitomis. Iš LMT ataskaitų duomenys buvo renkami šiems rodikliams: *Si*(*TPP*)*,* *Si*(*USU*)*,* PLE_i, Σ EVV, Σ AIV, d_{si}, F_i, E_i, SE_i, LE_i, T_i, LF_i. Pastarieji rodikliai buvo atrinkti tyrimui su MULTIMOORA įrankiu. Minėtus rodiklius lengva naudoti dėl jų prieinamumo viešojoje erdvėje, ir dėl vienodos naudojamos rodiklių apskaičiavimo metodikos, tai užtikrina jų patikimumą. Lyginant su AMI, rektorių ataskaitų duomenys yra mažiau patikimi dėl skirtingos rodiklių skaičiavimo metodikos, interpretacijos, kai skaičiavimo metodika nėra vieša. Todėl sunku užtikrinti visišką duomenų patikimumą.



S2.1 pav. Pagrindiniai aukštojo mokslo institucijos technologijų perdavimo proceso ištekliai, dalyviai ir veiksmai pasiekti reikiamą efektyvų rezultatą (sudaryta autorės)

Eurostato duomenų bazė yra patikima, nes remiamasi ta pačia duomenų rinkimo ir apskaičiavimo metodika, todėl disertacijoje tyrimui vykdyti buvo pasirinkti rodikliai ir iš šio šaltinio. Taigi šalies lygio pjūviu COPRAS buvo patikrintas praktiškai. Rezultatai parodė, kad jis tinka įvertinti numatytų objektų efektyvumą, sureitinguoti ir atrinkti efektyviausius objektus.

Galiausiai, siūloma DEA priemonė, skirta AMI TPP efektyvumo vertinimui. Šiame darbe parinkti trys įvesties (*Si*(*TPP*)*,* *Si*(*USU*), d_{si},) ir trys išvesties (PLE_i, doktorantų (*PhD*) skaičius ir magistrų (*Masters)* skaičius) rodikliai, kad būtų galima įvertinti 7 AMI TPP efektyvumą. Duomenys buvo surinkti iš oficialios Lietuvos mokslo tarybos (LMT) ataskaitos. Iš oficialaus teisės akto, Švietimo ir mokslo ministerijos vadovo įsakymo, buvo surinkti magistrų ir doktorantų studentų skaičiai. Skaičiavimai buvo atlikti dviejose pagrindinėse kryptyse: socialiniuose (H, S, M) ir fiziniuose (P, A, B, T) moksluose.

TPP efektyvumo vertinimas prasideda nuo tam tikrų rodiklių (įvesties ir išvesties) pasirinkimo. Tam pirmiausiai turime įsivaizduoti TP procesą AMI: visus susijusius dalyvius, jų atliekamus veiksmus, atsižvelgiant į TP veiklos specifiką, kurią vykdo TPB specialistai, esantys institucijos viduje (remiantis Europinių modelių pasitikėjimo aspektu).

TPP efektyvumo vertinimo modelyje FARE integruotas metodas padeda atrinkti tinkamus TPP rodiklius (ekspertų pagalba), priskiriant jiems svorius, išrūšiuoti pagal svarbiausius, o TOPSIS juos padeda suranguoti, taip atrenkant rodiklių tyrimo imtį. Turint atrinktus rodiklius, toliau renkami ir agreguojami duomenys. Lengviausias būdas yra rasti oficialias duomenų bazes / ataskaitas, kurios yra viešai prieinamos ir patikimos. Toliau svarbu atrinkti tinkamas AMI tyrimui. Efektyvumo vertinimo metodai riboja AMI skaičių, todėl šis aspektas yra būtinas AMI imčiai nustatyti. Disertacijoje siūlomi MULTIMOORA arba COPRAS reitingavimo įrankiai kaip tik yra pasirinkti nustatyti AMI tyrimo imtį. O DEA metodas skaičiuoja atrinktų AMI TPP efektyvumą. DEA įrankis yra lengvai taikomas. Jis yra orientuotas į įvesties ir išvesties linijinę matematinę programavimo techniką, kuri siūloma įvertinti TPP efektyvumą kiekvienos AMI kaip alternatyvos atskirai, skaičiuojant atskiros institucijos ekonominį TPP efektyvumą. Antrame disertacijos skyriuje aptariami visų metodų, siūlomų TPP efektyvumo vertinimo modeliui, privalumai ir trūkumai.

AMI TPP efektyvumo skaičiavimo rezultatai ir išvados yra pateikiamos vadovams, turintiems teisę priimti sprendimus, ir tampa efektyvia finansinių ir žmogiškųjų išteklių paskirstymo priemone, turinčia įtaką AMI ateities žingsniams pagerinti AMI TPP veiklos efektyvumą.

3. Technologijų perdavimo proceso efektyvumo vertinimo modelio empiriniai tyrimai ir aprobavimas: Lietuvos universitetų atvejis

Moksliniai tyrimai darbe buvo atlikti nustatyti pagrindinius TP, valorizacijos ir komercinimo principus AMI, jų specifiką, dalyvaujančius TPP subjektus, vykdomas veiklas, išteklių paskirstymo schemas, susijusius TPP rodiklius ir darančius įtaką veiksnius, siekiant įvertinti TPP rezultatus ir priimti sprendimus dėl efektyvaus finansinių ir žmogiškųjų išteklių efektyvaus paskirstymo gauti didesnius TP ir komercinimo rezultatus tyrėjams bendradarbiaujant su verslu (patentų skaičių, pajamas iš tarptautinių ir nacionalinių projektų, užsakomųjų darbų ir pan.). Trečiajame skyriuje pateikti AMI TPP efektyvumo vertinimo modelio aprobavimo tyrimų rezultatai. Pasiūlytas originalus modelis įvertinti AMI TPP efektyvumą yra patikrintas, įrodytas jo tinkamumas įvertinti AMI TPP efektyvumą.

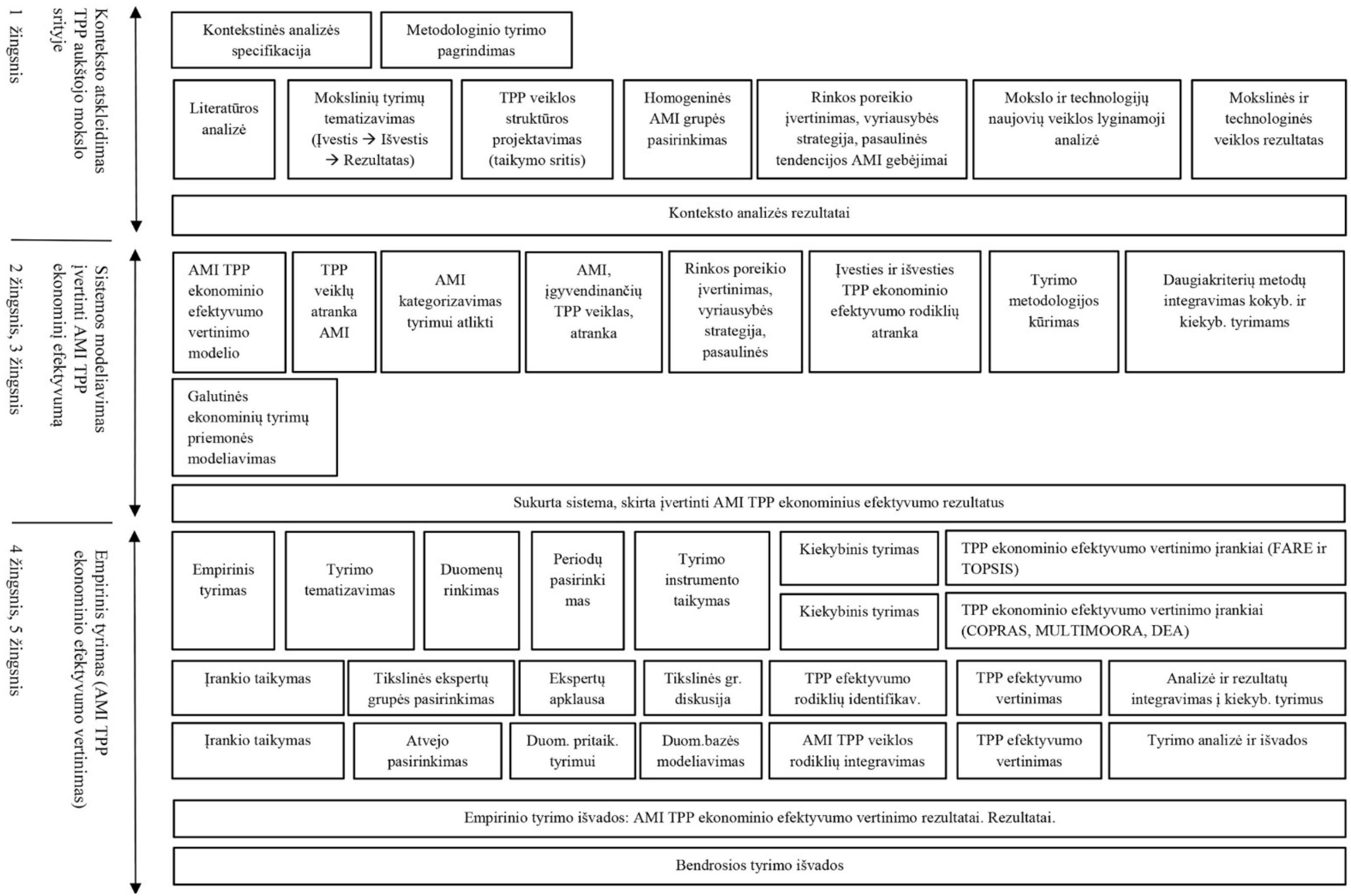
Empiriniams tyrimams pasirenkama metodologija, grįsta kiekybiniais tyrimais. Tam pasirenkami keli daugiakriteriai sprendimų priėmimo (MCDM) metodai (FARE, TOPSIS, COPRAS, MULTIMOORA, DEA) sumodeliuoti empirinio tyrimo sistemą. Modelis vertina mokslinių tyrimų ir inovacijų rezultatyvumą. Paskutiniu žingsniu yra vykdoma AMI TPP efektyvumo vertinimo veiklos rezultatų ir išvadų analizė.

Loginė empirinio tyrimo struktūra (S3.1 pav.). Pirmasis žingsnis: TPP konteksto atskleidimas aukštojo mokslo srityje apibrėžti metodologinio tyrimo pagrindimą. Pradedant AMI įvesties ir išvesties rezultatų analize, TPP veiklos sistemos (apimties) projektavimu, homogenišku AMI grupės parinkimu, ir baigiant rinkos poreikio ir vyriausybės strategijos vertinimu, pasaulinės tendencijos analize, AMI gebėjimų svarba, mokslinių tyrimų ir inovacijų veiklos lyginamąja ir duomenų analize. Antrasis žingsnis skirtas modeliuoti sistemą. Tikslas – sukurti modelį įvertinti AMI TPP ekonominį rezultatų efektyvumą, o toliau vyksta TPP veiklos atranka AMI, tiriamųjų AMI kategorizavimas, TPP veiklą vykdančių AMI atranka, rinkos poreikių įvertinimas, vyriausybės strategijos įvertinimas, pasaulinės tendencijos analizė, AMI gebėjimų svarba, AMI įvesties / išvesties rodiklių parinkimas, mokslinių tyrimų metodikos parinkimas, daugiakriterių sprendimo priėmimo metodų integravimas kiekybiniam tyrimui, galutinės tyrimo priemonės modeliavimas. Trečiasis žingsnis skirtas įvertinti AMI TPP veiklos ekonominį efektyvumą, po mokslinių tyrimų tematizavimo, duomenų rinkimo, laikotarpių pasirinkimo, mokslinių tyrimų priemonės įgyvendinimo, suskaidymo į kiekybinius tyrimus. Modelis sukonstruotas pradedant kiekybine analize. FARE ir TOPSIS metodų sujungimas leidžia atrinkti rodiklius, skirtus įvertinti TPP efektyvumą. COPRAS ir MULTIMOORA metodų derinimas padeda sureitinguoti AMI ir atrinkti jas empiriniams tyrimams. AMI TPP veiklos rodikliai integruojami į modelį ir atliekamas TPP ekonominių rezultatų vertinimas su DEA priemone, kuri yra skirta nustatyti AMI TPP efektyvumą. Tyrimą užbaigia mokslinių tyrimų analizė ir išvados.

Tiriamieji. Buvo atrinkta 30 respondentų tikslinė grupė, kurią sudaro universitetų TPB dirbantys specialistai (vadovai ir vadybininkai), Mokslo, technologijų ir inovacijų agentūros (MITA) ekspertai, mokslo ir technologijų parkų konsultantai, pradedančiųjų (angl. *start-up*) įmonių inkubatorių atstovai, Lietuvos inovacijų centro ekspertai.

Patentinės paraiškos buvo pasiūlytos kaip pagrindinis aukštojo mokslo įstaigų TP proceso vertinimo aspektas. Statistika parodė, kad iš 21 tik 7 AMI turi bent vieną patentinę paraišką, todėl pastarieji 7 AMI buvo atrinkti empiriniam tyrimui.

TPP efektyvumo vertinimo empiriniam tyrimui AMI su FARE ir TOPSIS įrankiais buvo parinktos šios kintamųjų kategorijos: patentų paraiškos, TP biurai (darbuotojai, užduotys, darbuotojų su daktaro laipsniu dalis), 7 Lietuvos universitetai (finansavimas, studentai, publikacijos – 3 metų vidurkis vienam tyrėjui), regioniniai aspektai (pramonės koncentracija, pradedančiųjų įmonių skaičius).



S3.1 pav. Loginė empirinio tyrimo struktūra (sudaryta autorės)

Atlikus literatūros analizę buvo atrinkti TPP 16 kriterijų, iš kurių ekspertai atrinko 8, ir jiems buvo apskaičiuoti svoriai: nacionalinės ir tarptautinės patentų paraiškos; darbuotojų skaičius TPB; publikacijų skaičius AMI; tyrėjų skaičius AMI (viso darbo laiko ekvivalentas); pajamos, gautos iš nacionalinių projektų (EUR); pajamos, gautos iš tarptautinių projektų (EUR); pajamos, gautos iš užsakomųjų darbų (EUR); finansavimas vienam tyrėjui – viso darbo laiko ekvivalentas (EUR).

FARE ir TOPSIS tyrimo dalies duomenys empiriniam tyrimui buvo paimti iš Lietuvos mokslo tarybos (LMT) prieinamos ataskaitos. Tyrimai padėjo išskirti svarbiausius rodiklius, darančius įtaką TPP: MTEP užsakomųjų darbų pajamos (EUR) – svoris 0,18; pajamos iš tarptautinių MTEP projektų (EUR) – svoris 0,16; finansavimas vienam tyrėjui ir mokslininkui visu darbo laiko ekvivalentu (EUR) – svoris 0,15; ir kt.

Tyrimas MULTIMOORA įrankiu apima kitus AMI TP rodiklius: *Si(TPP)*, *Si(USU)*, PLE_i, $\Sigma\ EVV$, $\Sigma\ AIV$, d_{si}, F_i, E_i, SE_i, LE_i, T_i, LF_i. Tyrimo rezultatai parodė, kad pagal 2012–2014 metų vidurkį didžiausius TPP veiklos rezultatus Lietuvoje parodė AMI 7, AMI 2 ir AMI 6. MULTIMOORA įrankis yra tinkamas įvertinti AMI TPP efektyvumą, reitinguojant AMI pagal didžiausius TP rezultatus.

COPRAS tyrimui buvo naudojami Eurostato duomenys ir sukurta 2005–2014 m. duomenų bazė (*Eurostatas*, 2017). Tyrime buvo vertinamas finansavimo efektyvumas pagal veiklos sektorius Europos šalių lygiu. Pasirinkti šie investicijų į mokslinius tyrimus rodikliai: bendrosios MTEP išlaidos (GERD) (eurų vienam gyventojui); MTEP išlaidos (GERD) (perkamosios galios standartas (PGS) vienam gyventojui nuolatinėmis kainomis); finansavimo sektorius – visi sektoriai (eurų vienam gyventojui); iš viso MTEP išlaidos (eurų vienam gyventojui); bendra MTEP veikla (eurų vienam gyventojui). Tie patys veiklos rodikliai buvo vertinami 4 veiklos sektoriuose (verslo, aukštojo mokslo, vyriausybės, ne pelno organizacijos). Iš viso įvertinta 20 veiklos rodiklių 4 sektoriuose, analizuojant 28 Europos šalis. Tyrimo rezultatai parodė, kad Danija, Švedija, Suomija, Olandija ir Austrija investuoja į mokslinius tyrimus daugiausia. Geriausi investuotojai į mokslinius tyrimus, vertinant visus keturis analizuojamus sektorius, yra šios šalys 1 grupėje: Suomija, Liuksemburgas, Danija ir Švedija. Pastebima, kad daugiausia į MTEP investuoja ekonomiškai išsivysčiusios šalys. Lietuva yra 22-oje vietoje iš 28.

Toliau buvo išskirti šie žingsniai apskaičiuoti TPP efektyvumo vertinimo ekonominius AMI rezultatus su DEA įrankiu: 1. tyrimo imties identifikavimas; 2. įvesties ir išvesties rodiklių identifikavimas; 3. linijinio DEA metodo taikymas įvertinti AMI TPP efektyvumą; 4. AMI ekonominio efektyvumo palyginamoji analizė.

Dėl duomenų rinkinio homogeniškumo analizuojamos septynios Lietuvos AMI (S3.1 lentelė), turinčios TPP veiklos rezultatus. Įvesties ir išvesties rodikliai parenkami iš oficialios LMT ataskaitos. Pasirinkimo logika: 2013 m. ir 2014 m. metiniai rezultatai sukuria 2015 ir 2016 m. metinius rezultatus. Dėl DEA rodiklių skaičiaus apribojimų buvo pasirinkti trys įvesties ir trys išvesties rodikliai, tinkami įvertinti TP veiklos efektyvumą. Įvesties rodikliai: *Si*(*TPP*), *Si*(*USU*), d_{si}, o išvesties rodikliai pasirinkti šie: PLE_i, magistrų studentų skaičius, doktorantų studentų skaičius. Duomenys apie *Si*(*TPP*), *Si*(*USU*), d_{si}, PLE_i rodiklius buvo paimti iš oficialiai prieinamos LMT ataskaitos. Duomenys apie studentus buvo paimti iš švietimo ir mokslo ministro įsakymų (2012, 2013, 2014).

S3.1 lentelė. Lietuvos universitetų technologijų perdavimo proceso efektyvumo vertinimo ekonominiai rezultatai taikant DEA įrankį fiziniuose (P, A, B, T) ir socialiniuose (H, S, M) moksluose (sudaryta autorės)

AMI	Tikslo funk-cija	Efektyvumo koef.	Efektyvumas	AMI	Tikslo funk-cija	Efektyvumo koef.	Efektyvumas
Sritis	P, A, B, T	P, A, B, T	P, A, B, T	Sritis	H, S, M	H, S, M	H, S, M
AMI 7	0,093	0,373	37 %	AMI 7	0,264	0,359	36 %
AMI 2	0,215	0,175	18 %	AMI 5	4,824	0,313	31 %
AMI 6	1,000	0,110	11 %	AMI 2	0,598	0,113	11 %
AMI 4	0,171	0,091	9 %	AMI 3	3,991	0,097	10 %
AMI 3	0,187	0,051	5 %	AMI 6	0,868	0,082	8 %
AMI 1	0,571	0,042	4 %	AMI 1	1,000	0,027	3 %
AMI 5	1,000	0,001	0,1 %	AMI 4	2,167	0,002	0,2 %

Skaičiavimai su DEA įrankiu buvo atlikti dviejose srityse: socialinių (H, S, M) ir fizinių (P, A, B, T) mokslų rezultatai. Iš septynių AMI fizinių mokslų (P, A, B, T) srityje, tokie universitetai kaip AMI 7 (37 %), AMI 2 (18 %) ir AMI 6 (11 %) turi geriausius TPP veiklos rezultatus. Socialinių mokslų (H, S, M) srityje TP lyderiai yra AMI 7 (36 %), AMI 5 (31 %) ir AMI 2 (11 %). Žemiausius rezultatus parodė AMI 4 (0,2 %) socialiniuose moksluose ir AMI 5 (0,1 %) fiziniuose moksluose. Tyrimų rezultatai leidžia teigti, kad DEA įrankis yra taikytinas įvertinti AMI TPP efektyvumą. Įžvelgiama, kad TP proceso efektyvumui gerinti AMI galėtų: nustatyti, ar skiriami finansiniai ir žmogiškieji ištekliai yra efektyviai panaudojami; kurti politiką ir organizacinę strategiją, kuri gerintų TPP rodiklius ir siektų maksimizuoti ekonomikos rezultatus; perorientuoti egzistuojančią vidinę universitetinę kultūrą į verslumą, kaip akcentuojama literatūros šaltiniuose, tarpuniversitetinį bei universitetų ir verslo bendradarbiavimą plėtojančią kultūrą, kuri leidžia sukurti palankias sąlygas MTEP veikloms plėtoti, siekti aukštesnio inovacijų lygio atskiruose Lietuvos universitetuose, padedant sukurti vieningą, efektyviai funkcionuojančią TP sistemą šalyje.

Bendrosios išvados

Apibendrinus literatūros analizės ir tyrimo rezultatus, pateikiamos šios išvados:

1. Atlikta technologijų perdavimo proceso (TPP) teorinė analizė parodė, kad, nepaisant skirtingų TPP interpretacijų, egzistuoja bendra samprata, kuri apibūdina technologijų perdavimo (TP) procesą, vykstantį aukštojo mokslo institucijose (AMI). Ši analizė taip pat išryškino būtinumą skatinti AMI aktyviau įsitraukti į žinių ir TP procesą, kurio galutinis tikslas yra plėtoti išmaniąją, inovacijomis grįstą, šalies ekonomiką.

2. Užsienio šalių (JAV, Belgijos ir Vokietijos) patirties TP srityje ir veiksnių, skatinančių TP procesą, analizė atskleidė, kad sėkmė lydi tokį AMI modeliuojamą TP procesą, kuris remiasi: efektyviu finansinių ir žmogiškųjų išteklių panaudojimu TP procesui plėtoti bei pritaikyti naujas mokslines žinias pramonėje ir visuomenėje; TP biurų personalo kompetencija valdyti TP procesą ir kurti verslumą plėtojančią AMI, organizacinę kultūrą; tarpuniversitetiniu ir universiteto bei verslo įmonių bendradarbiavimu.
3. Atlikus teorinę ir empirinę TP proceso efektyvumo vertinimo analizę buvo išskirta TP proceso efektyvumą matuojančių rodiklių sąranga: pajamos, gautos iš tarptautinių projektų ir MTEP darbų; mokslininkų finansavimas (vienam tyrėjui); tarptautinių ir nacionalinių patentų skaičius; pajamos iš nacionalinių MTEP projektų; TP biurų personalo skaičius, mokslininkų AMI skaičius.
4. Identifikuota veiksnių grupė, daranti poveikį TP proceso efektyvumui, kurią sudaro šie veiksniai: antreprenerystės kultūra; MTEP produktų rinkoje sklaida; išradimų technologijos; akademinis pripažinimas; regiono konkurencingumas; šalies politika TP srityje; technologijų prieinamumas pramonėje; intelektinės nuosavybės apsauga; TP gebėjimai; gebėjimas keistis ir priimti sprendimus; kt.
5. Disertacinio tyrimo mokslinį naujumą atskleidžia sukurtas ir empiriškai aprobuotas originalus modelis, skirtas AMI TP proceso efektyvumui įvertinti, kuris siūlomas taikyti Lietuvoje ir gali būti pritaikomas kitose šalyse. Modelis tinka universitetų, ministerijų ir technologijų perdavimo biurų trumpalaikiam ir ilgalaikiam TPP planavimui ir sprendimų priėmimui. Mokslinė metodologija grindžiama daugiakriterinių metodų sąranga. FARE ir TOPSIS įrankiais siūloma atrinkti rodiklius, TP proceso efektyvumui įvertinti; COPRAS ir MULTIMOORA – reitinguoti ir atrinkti AMI; DEA – AMI TP proceso efektyvumui pamatuoti.
6. Lietuvos universitetų technologijų perdavimo proceso efektyvumo vertinimo tyrimo rezultatai rodo, kad TP proceso efektyvumo lygis tirtuose universitetuose yra nepakankamas, turėtų būti gerinamas ateityje.

Annexes[1]

Annex A. The Data Gathered for the Empirical Research
Annex B. Questionnaire for Experts
Annex C. Comparative Analysis of Decision-Making Methods
Annex D. Declaration of Academic Integrity
Annex E. The Co-authors' Agreements to Present Publications Material in the Doctoral Dissertation
Annex F. Copies of Scientific Publications by the Author on the Topic of the Dissertation

[1]The annexes are supplied in the enclosed compact disc.

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EFFICIENCY EVALUATION OF TECHNOLOGY TRANSFER PROCESS IN HIGHER EDUCATION INSTITUTIONS

Doctoral Dissertation

Social Sciences,
Economics (S 004)

TECHNOLOGIJŲ PERDAVIMO PROCESO AUKŠTOJO MOKSLO INSTITUCIJOSE EFEKTYVUMO VERTINIMAS

Daktaro disertacija

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