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FACTORS IMPACTING THE COMMERCIAL POTENTIAL OF TECHNOLOGIES: EXPERT APPROACH

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Abstract. In order to ensure the harmonious activity of the institutions engaged in R&D and to reduce the uncertainty of the commercialization of technologies, an advanced tool for verifying decisions on technology development at early stages of commercialization, i.e. an instrument for assessing the commercial potential of technology, is needed.

The article is aimed at defining the importance of factors in the commercial potential of technologies with the help of expert research. To achieve the goal, the following tasks have been approached: (1) on the basis of the created system for factors in the commercial potential of technologies, to conduct expert research aimed at collecting information on the importance of factors in technologies; (2) to apply the methods of mathematical statistics in order to determine the compatibility level of expert opinions and the significance of factors.

The system of factors in the commercial potential of technologies and the identified significance of factors can be used as recommended guidelines for technology developers, investors and potential owners in the decision-making processes of commercialization, investment or purchase of technology as well as at the next stage of research on the development model for assessing the commercial potential of technologies.

Keywords: technologies, commercial potential, multi-criteria decision making methods, assessment.

JEL Classification: O32.

Introduction

Ever since ancient times, almost without any exception, in order to create or invent all necessary tools and reach technological solutions, scientific experiments and ongoing knowledge development have been needed. By the time when modern economic principles are beyond the concept based on natural resources, knowledge has become a major driving force of economic and social development, increase in competitiveness of organizations

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and countries (Balkytė, Tvaronavičienė 2010; Travkina, Tvaronavičienė 2011; Lankauskienė, Tvaronavičienė 2011; Lapinskienė *et al.* 2014; Vasiliūnaitė 2014; Dudzevičiūtė *et al.* 2014; Tvaronavičienė *et al.* 2015a, 2015b).

Academic and professional literature dealing with the problems of technology commercialization declares that the commercialization of technologies creating new technology-based products is a source of a competitive advantage ensuring company's prosperity and, at the same time, represents very risky activity. Christensen and Raynor (2003) have stated that over 60% of all new product development efforts are stopped before they are commercialized, and 40% of the remaining products are withdrawn from the market (Allen 2003). Failure rate by Christensen and Raynor is high but quite optimistic compared to research by Corporate Strategy Board according to which, failure rate of new business ventures is over 90% and could be as high as 99% (Sharma *et al.* 2008). Although the results of both researches slightly differ, but similar failure rates of commercialization could be expected (Tvaronavičienė 2016).

It is known that each project on technology commercialization is extremely receptive to both time and financial investment. In order to avoid non-productive investments, the organizations performing R&D activities use measures for assessing the commercial potential of technologies to substantiate decisions on the purposefulness of technology commercialization, i.e. measures for assessing the commercial potential of technologies. According to Dereli and Altun (2013), the commercial potential of technologies is power that determines a possibility of technology to satisfy market needs, flourish and thrive in an ever-changing and unpredictable business environment. The assessment of commercial potential in literature is also referred to as the evaluation of successful technology, commercialization possibilities, commercial viability, feasibility and economic validity.

The article focuses on defining the importance of factors in the commercial potential of technologies with the help of expert research. To achieve the goal, the following tasks have been approached: (1) on the basis of the created system for factors in the commercial potential of technologies, to conduct expert research aimed at collecting information on the importance of factors in technologies; (2) to apply the methods of mathematical statistics in order to determine the compatibility level of expert opinions and the significance of factors.

The assessment of the commercial potential of technologies is purposeful at the initial stage of technology commercialization due to (1) the sufficiency of information required for evaluation and (2) the need for significant investment at the subsequent stages of technology commercialization. At this particular stage of technology commercialization, a purified concept of producing a planned product on the basis of technology is formulated and the initial feasibility and market analysis has been carried out, although the proposed plans have not reached their implementation stage yet.

1. Forming a set of factors in the commercial potential of technologies

The current global economic trends clearly reflect that the only way to remain competitive leads to the development of new technologies; therefore, this process has become an object of discussions of both researchers and practitioners (Tvaronavičienė 2014; Travkina, Tvaronavičienė 2015).

A lot of recent cases illustrating possibilities of adoption of new technology could be provided. The ability to more objectively assess the commercial potential of technology has become aspiration for a number of organizations performing R&D activities. Scientific literature and information sources provided by different organizations allow detecting the methods and models assessing the commercial potential of technologies recommended and used by G. R. Cooper (2009), A. D. Rahal (2005), J. Cho and J. Lee (2013), VentureQuest Ltd (2014), C. Price *et al.* (2008), The NASA Commercial Technology Office (2013), T. Dereli and K. Altun (2013), R. Bandarian (2007), International Islamic University Malaysia (2013) Here it need to be pointed out that decisions about commercial potential of technologies in many cases are being made by cluster member, in those cases, when companies participate in such networks (Tvaronavičienė *et al.* 2015b; Fuschi, Tvaronavičienė 2016; Tvaronavičienė, Černevičiūtė 2015; Ignatavičius *et al.* 2015).

The analysis of measures for assessing the commercial potential of technologies draws a conclusion that the assessment of commercial potential takes into account different factors and their groups. To make the assessment of the commercial potential of technologies more objective, a decision on preparing a new system for factors in estimating the commercial potential of technologies using critical analysis and synthesis methods was reached. The assessment system was formed according to Belton and Stewart (2002). In identifying criteria for decision analysis, the following considerations are relevant to all approaches to multi-criteria decision analysis:

(1) value relevance, (2) understandability, (3) measurability, (4) non-redundancy, (5) judgmental independence, (6) balancing completeness and conciseness, (7) operability and (8) simplicity (Raudeliūnienė *et al.* 2014).

The system for factors and sub-factors is shown in Figure 1. This particular set stemmed from contemporary scientific literature: situation on the market: need and readiness; value for the customer (Mostenska, Bilan 2015); financial environment; competence of technology developers; legal environment (Tvaronavičienė 2012); circumstances relating to investor (Lankauskienė, Tvaronavičienė 2012; Tvaronavičienė *et al.* 2013); institution's internal policy.

With reference to the above introduced system for factors, an expert evaluation questionnaire was designed providing concepts-interpretations of every factor and preparing the list of the experts planned to be interviewed. The surveyed experts were selected considering: 1) experience in the process of technology commercialization in Lithuania and other countries, 2) and positions held by the experts in the institutions developing technologies as well as in the establishments responsible for the promotion and control of technology commercialization. Having surveyed the experts, 12 correctly completed questionnaires in which they expressed their views in relation to the significance of factors were received.

On the basis of the system for assessing the commercial potential of technologies, an expert evaluation questionnaire was designed and a two-stage expert survey was conducted. Following the first stage of the survey, focus was switched on listening to the position of the experts and on specifying the system for the factors assessing the commercial potential of technologies; as for the second stage, the experts expressed their position on the significance of system factors: a position on the importance of provided factors and sub-factors was asked to be taken thus distributing 100% among possible groups of factors and factors.

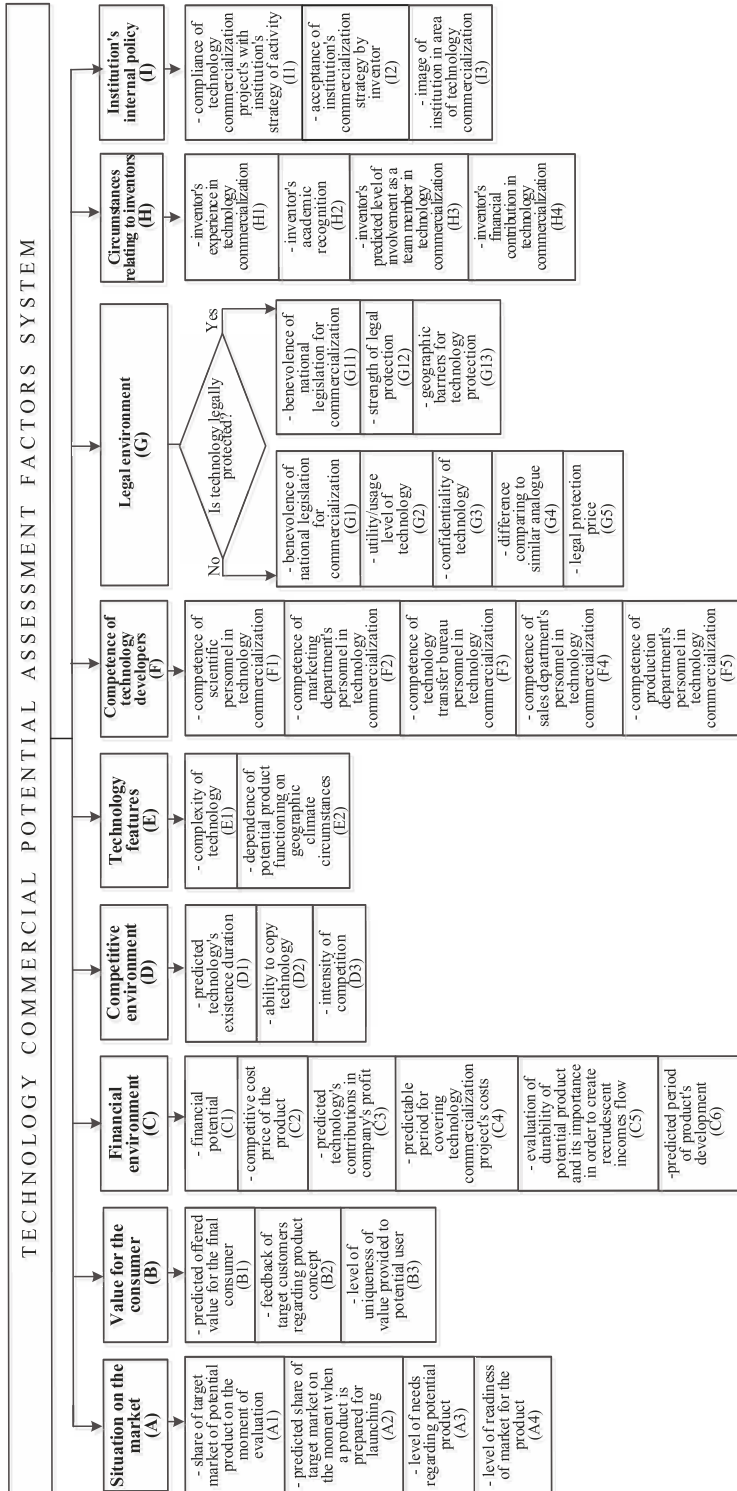


Fig. 1. System of factors used for technology commercial potential assessment
Source: authors.

2. Determination possibilities to use the research data for definition the importance of factors in assessing the commercial potential of technologies

The impact of factors defining the assessed technologies on the investigated goal is different, and therefore, for conducting quantitative multi-criteria evaluation, the significance of factors must be established. With reference to literature analysis and the findings of the first stage of expert research, the system of factors was formed. At the second stage, the experts expressed their opinion on the groups and significance of factors. The basis of calculating significance is made of expert research. The obtained results can be applied in practice if the sufficient concordance of expert opinions is established. Concordance is determined by concordance coefficient W (Kendall 1955) that varies from 0 to 1 ($0 < W < 1$). To calculate the coefficient, only the results of ranking expert factors are suitable. The experts assessed the significance of factors and the groups of factors in the course of the conducted research, and therefore, on the basis of the above introduced findings, the factors were provided with preliminary ranks. Ranking is a procedure when the most important factor is provided with the rank equal to 1, the second factor according to importance is given 2, etc. and the last factor according to significance takes rank m . Equivalent factors are provided with an equal value – the arithmetic average of ordinary ranks. When expert opinions are more concordant, the value of concordance coefficient W is closer to 1, whereas when estimates vary widely, the value of W is closer to zero. Concordance coefficient W is calculated according to the formula (Kendall 1955):

$$W = \frac{12S}{r^2 m(m^2 - 1)}, \quad (1)$$

where m – number of compared factors; r – number of experts; W – concordance coefficient; S – dispersion analogue calculated according to the formula:

$$S = \sum_{i=1}^m (e_i - \bar{e})^2. \quad (2)$$

The sum of ranks in terms of all experts e_i is calculated according to the formula:

$$e_i = \sum_{j=1}^r e_{ij}, \quad (3)$$

where e_{ij} – the j -th factor evaluated by the j -th expert.

A deviation from general average \bar{e} is calculated according to the formula:

$$\bar{e} = \frac{\sum_{i=1}^m e_i}{m} = \frac{\sum_{i=1}^m \sum_{j=1}^r e_{ij}}{m}. \quad (4)$$

When the number of objects (factors) $m > 7$, the significance of the concordance coefficient (*probability*) and the concordance of the opinions of the expert group is established using criterion χ^2 calculated according to the provided formula in case of related ranks:

$$\chi^2 = Wr(m-1) = \frac{12S}{rm(m+1) \sum_{j=1}^p T_j}. \quad (5)$$

M. Kendall (1955) proved that expert evaluations were in concordance when value χ^2 was higher than χ^2_{kr} taken from the distribution table of χ^2 where the degree of freedom $v = m - 1$ and the selected reliability level α were close to zero (in practice $\alpha = 0.05$ or 0.01).

The values of the groups and symbols of the factors are provided in Table 1.

Table 1. Ranking the groups of factors in the commercial potential of technologies

| V. s. | E1 | E2 | E3 | E4 | E5 | E6 | E7 | E8 | E9 | E10 | E11 | E12 | Sum of ranks | The final rank |
|-------|----|-----|----|----|-----|----|----|----|----|-----|-----|-----|--------------|----------------|
| A | 4 | 5 | 2 | 2 | 4.5 | 4 | 4 | 5 | 1 | 2 | 2 | 4 | 39.5 | 3 |
| B | 6 | 2.5 | 1 | 3 | 2 | 3 | 3 | 1 | 3 | 1 | 2 | 1 | 28.5 | 1 |
| C | 3 | 7.5 | 5 | 4 | 4.5 | 2 | 2 | 4 | 6 | 9 | 2 | 8 | 57.0 | 5 |
| D | 2 | 2.5 | 3 | 1 | 2 | 1 | 1 | 2 | 5 | 8 | 4.5 | 2 | 34.0 | 2 |
| E | 5 | 1 | 6 | 6 | 7.5 | 5 | 5 | 6 | 4 | 5 | 4.5 | 5 | 60.0 | 6 |
| F | 1 | 7.5 | 4 | 5 | 2 | 6 | 6 | 3 | 2 | 4 | 6 | 3 | 49.5 | 4 |
| G | 9 | 5 | 8 | 7 | 7.5 | 8 | 8 | 8 | 9 | 6 | 8.5 | 6 | 90.0 | 8 |
| H | 7 | 5 | 7 | 9 | 7.5 | 7 | 7 | 7 | 7 | 3 | 7 | 7 | 80.5 | 7 |
| I | 8 | 9 | 9 | 8 | 7.5 | 9 | 9 | 9 | 8 | 7 | 8.5 | 9 | 101.0 | 9 |

With reference to the findings of the conducted investigation (Table 1) and formulas 1–5, the following results were obtained: $e_i = 540.0$; $\bar{e} = 60.0$; $S = 5209.0$; $W = 0.6$; $\chi^2 = 57.88$; $v = 8$; $\alpha = 0.01$; $\chi^2_{kr} = 20.09$. When $W > 0.5$, χ^2 exceeds χ^2_{kr} ; this proves that expert opinions are concordant, and the significance of the groups of factors calculated on the basis of expert evaluation can be applied to multi-criteria evaluation.

Table 2. Ranking factors in the group of the situation on the market regarding the commercial potential of technologies

| V. s. | E1 | E2 | E3 | E4 | E5 | E6 | E7 | E8 | E9 | E10 | E11 | E12 | Sum of ranks | The final rank |
|-------|----|-----|----|----|----|----|----|----|----|-----|-----|-----|--------------|----------------|
| A1 | 2 | 1.5 | 2 | 2 | 3 | 3 | 3 | 3 | 3 | 3 | 2.5 | 3.5 | 31.5 | 2 |
| A2 | 4 | 3 | 3 | 3 | 1 | 4 | 2 | 2 | 2 | 2 | 2.5 | 3.5 | 32.0 | 3 |
| A3 | 1 | 1.5 | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1.5 | 14.0 | 1 |
| A4 | 3 | 4 | 4 | 4 | 4 | 2 | 4 | 4 | 4 | 4 | 4 | 1.5 | 42.5 | 4 |

With reference to the findings of the conducted investigation (Table 2) and formulas 1–5, the following results were obtained: $e_i = 120.0$; $\bar{e} = 30$; $S = 418$; $W = 0.58$; $\chi^2 = 20.93$; $v = 3$; $\alpha = 0.01$; $\chi^2_{kr} = 11.34$. When $W > 0.5$, χ^2 exceeds χ^2_{kr} ; this proves that expert opinions are concordant, and the significance of the groups of factors calculated on the basis of expert evaluation can be applied to multi-criteria evaluation.

With reference to the findings of the conducted investigation (Table 3) and formulas 1–5, the following results were obtained: $e_i = 72.0$; $\bar{e} = 24.0$; $S = 168.5$; $W = 0.59$; $\chi^2 = 14.04$; $v = 2$; $\alpha = 0.01$; $\chi^2_{kr} = 9.21$. When $W > 0.5$, χ^2 exceeds χ^2_{kr} ; this proves that expert opinions are concordant, and the significance of the groups of factors calculated on the basis of expert evaluation can be applied to multi-criteria evaluation.

Table 3. Ranking factors in the group of value for the consumer regarding the commercial potential of technologies

| V. s. | E1 | E2 | E3 | E4 | E5 | E6 | E7 | E8 | E9 | E10 | E11 | E12 | Sum of ranks | The final rank |
|-------|----|----|----|----|-----|-----|----|----|----|-----|-----|-----|--------------|----------------|
| B1 | 1 | 1 | 1 | 1 | 1 | 1.5 | 1 | 2 | 2 | 2 | 2 | 2 | 17.5 | 1 |
| B2 | 3 | 2 | 3 | 3 | 2.5 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 34.5 | 3 |
| B3 | 2 | 3 | 2 | 2 | 2.5 | 1.5 | 2 | 1 | 1 | 1 | 1 | 1 | 20.0 | 2 |

Table 4. Ranking factors in the group of a financial environment regarding the commercial potential of technologies

| V. s. | E1 | E2 | E3 | E4 | E5 | E6 | E7 | E8 | E9 | E10 | E11 | E12 | Sum of ranks | The final rank |
|-------|-----|----|----|----|-----|-----|----|-----|-----|-----|-----|-----|--------------|----------------|
| C1 | 2.5 | 3 | 5 | 3 | 4.5 | 4 | 3 | 4.5 | 1 | 4.5 | 3 | 4 | 42.0 | 4 |
| C2 | 4 | 4 | 2 | 4 | 1 | 1 | 2 | 1.5 | 6 | 1.5 | 2 | 4 | 33.0 | 2 |
| C3 | 2.5 | 1 | 1 | 1 | 2 | 2.5 | 1 | 1.5 | 2 | 1.5 | 1 | 1 | 18.0 | 1 |
| C4 | 5 | 2 | 3 | 2 | 4.5 | 2.5 | 4 | 4.5 | 3 | 4.5 | 4 | 2 | 41.0 | 3 |
| C5 | 6 | 5 | 6 | 5 | 6 | 6 | 6 | 6 | 4.5 | 6 | 6 | 6 | 68.5 | 6 |
| C6 | 1 | 6 | 4 | 6 | 3 | 5 | 5 | 3 | 4.5 | 3 | 5 | 4 | 49.5 | 5 |

With reference to the findings of the conducted investigation (Table 4) and formulas 1–5, the following results were obtained: $e_i = 252.0$; $\bar{e} = 42.0$; $S = 1416.5$; $W = 0.56$; $\chi^2 = 33.73$; $\nu = 5$; $\alpha = 0.01$; $\chi_{kr}^2 = 15.09$. When $W > 0.5$, χ^2 exceeds χ_{kr}^2 ; this proves that expert opinions are concordant, and the significance of the groups of factors calculated on the basis of expert evaluation can be applied to multi-criteria evaluation.

Table 5. Ranking factors in the group of a competitive environment regarding the commercial potential of technologies

| V. s. | E1 | E2 | E3 | E4 | E5 | E6 | E7 | E8 | E9 | E10 | E11 | E12 | Sum of ranks | The final rank |
|-------|----|-----|----|----|-----|-----|----|----|-----|-----|-----|-----|--------------|----------------|
| D1 | 1 | 1 | 1 | 2 | 1.5 | 1 | 1 | 1 | 1 | 1 | 2 | 1.5 | 15.0 | 1 |
| D2 | 3 | 2.5 | 3 | 3 | 3 | 2.5 | 2 | 3 | 2.5 | 3 | 3 | 3 | 33.5 | 3 |
| D3 | 2 | 2.5 | 2 | 1 | 1.5 | 2.5 | 3 | 2 | 2.5 | 2 | 1 | 1.5 | 23.5 | 2 |

With reference to the findings of the conducted investigation (Table 5) and formulas 1–5, the following results were obtained: $e_i = 72.0$; $\bar{e} = 24.0$; $S = 171.5$; $W = 0.6$; $\chi^2 = 14.29$; $\nu = 2$; $\alpha = 0.01$; $\chi_{kr}^2 = 9.21$. When $W > 0.5$, χ^2 exceeds χ_{kr}^2 ; this proves that expert opinions are concordant, and the significance of the groups of factors calculated on the basis of expert evaluation can be applied to multi-criteria evaluation.

Table 6. Ranking factors in the group of technology features regarding the commercial potential of technologies

| V. s. | E1 | E2 | E3 | E4 | E5 | E6 | E7 | E8 | E9 | E10 | E11 | E12 | Sum of ranks | The final rank |
|-------|----|----|----|----|----|----|----|-----|----|-----|-----|-----|--------------|----------------|
| E1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1.5 | 1 | 1 | 1 | 2 | 13.5 | 1 |
| E2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 1.5 | 2 | 2 | 2 | 1 | 22.5 | 2 |

With reference to the findings of the conducted investigation (Table 6) and formulas 1–5, the following results were obtained: $e_i = 36.0$; $\bar{e} = 18.0$; $S = 40.5$; $W = 0.56$; $\chi^2 = 6.75$; $\nu = 1$; $\alpha = 0.01$; $\chi^2_{kr} = 6.64$. When $W > 0.5$, χ^2 exceeds χ^2_{kr} ; this proves that expert opinions are concordant, and the significance of the groups of factors calculated on the basis of expert evaluation can be applied to multi-criteria evaluation.

Table 7. Ranking factors in the group of the competence of technology developers regarding the commercial potential of technologies

| V. s. | E1 | E2 | E3 | E4 | E5 | E6 | E7 | E8 | E9 | E10 | E11 | E12 | Sum of ranks | The final rank |
|-------|----|-----|----|----|-----|----|----|----|-----|-----|-----|-----|--------------|----------------|
| F1 | 1 | 1.5 | 1 | 2 | 3 | 1 | 1 | 2 | 1.5 | 1 | 4.5 | 1 | 20.5 | 1 |
| F2 | 3 | 4.5 | 3 | 3 | 1.5 | 3 | 2 | 3 | 4.5 | 3 | 1.5 | 2 | 34.0 | 3 |
| F3 | 5 | 4.5 | 4 | 4 | 4.5 | 5 | 4 | 5 | 4.5 | 5 | 4.5 | 5 | 55.0 | 5 |
| F4 | 4 | 3 | 5 | 5 | 1.5 | 4 | 3 | 4 | 3 | 4 | 3 | 4 | 43.5 | 4 |
| F5 | 2 | 1.5 | 2 | 1 | 4.5 | 2 | 5 | 1 | 1.5 | 2 | 1.5 | 3 | 27.0 | 2 |

With reference to the findings of the conducted investigation (Table 7) and formulas 1–5, the following results were obtained: $e_i = 180.0$; $\bar{e} = 36.0$; $S = 742.5$; $W = 0.52$; $\chi^2 = 24.75$; $\nu = 4$; $\alpha = 0.01$; $\chi^2_{kr} = 13.28$. When $W > 0.5$, χ^2 exceeds χ^2_{kr} ; this proves that expert opinions are concordant, and the significance of the groups of factors calculated on the basis of expert evaluation can be applied to multi-criteria evaluation.

Table 8. Ranking factors in the group of a legal environment (for unprotected technology) regarding the commercial potential of technologies

| V. s. | E1 | E2 | E3 | E4 | E5 | E6 | E7 | E8 | E9 | E10 | E11 | E12 | Sum of ranks | The final rank |
|-------|----|----|-----|----|-----|----|----|----|----|-----|-----|-----|--------------|----------------|
| G1 | 5 | 5 | 5 | 3 | 4.5 | 5 | 5 | 5 | 4 | 4 | 5 | 5 | 55.5 | 1 |
| G2 | 1 | 1 | 1.5 | 2 | 2 | 2 | 1 | 1 | 1 | 2 | 4 | 2 | 20.5 | 4 |
| G3 | 4 | 3 | 3 | 4 | 3 | 3 | 3 | 3 | 5 | 3 | 3 | 3 | 40 | 3 |
| G4 | 3 | 2 | 1.5 | 1 | 1 | 1 | 2 | 2 | 2 | 1 | 2 | 1 | 19.5 | 5 |
| G5 | 2 | 4 | 4 | 5 | 4.5 | 4 | 4 | 4 | 3 | 5 | 1 | 5 | 45.5 | 2 |

With reference to the findings of the conducted investigation (Table 8) and formulas 1–5, the following results were obtained: $e_i = 333.0$; $\bar{e} = 47.57$; $S = 2249.21$; $W = 0.56$; $\chi^2 = 40.17$; $\nu = 6$; $\alpha = 0.01$; $\chi^2_{kr} = 16.81$. When $W > 0.5$, χ^2 exceeds χ^2_{kr} ; this proves that expert opinions are concordant, and the significance of the groups of factors calculated on the basis of expert evaluation can be applied to multi-criteria evaluation.

Table 9. Ranking factors in the group of a legal environment (for protected technology) regarding the commercial potential of technologies

| V. s. | E1 | E2 | E3 | E4 | E5 | E6 | E7 | E8 | E9 | E10 | E11 | E12 | Sum of ranks | The final rank |
|-------|----|-----|----|----|----|-----|----|-----|----|-----|-----|-----|--------------|----------------|
| G11 | 3 | 2.5 | 3 | 2 | 3 | 2.5 | 2 | 2.5 | 3 | 2.5 | 3 | 2 | 31.0 | 3 |
| G12 | 1 | 1 | 2 | 1 | 1 | 2.5 | 1 | 1 | 1 | 1 | 1 | 1 | 14.5 | 1 |
| G13 | 2 | 2.5 | 1 | 3 | 2 | 1 | 3 | 2.5 | 2 | 2.5 | 2 | 3 | 26.5 | 2 |

With reference to the findings of the conducted investigation (Table 9) and formulas 1–5, the following results were obtained: $e_i = 72.00$; $\bar{e} = 24.00$; $S = 145.50$; $W = 0.505$; $\chi^2 = 12.125$; $\nu = 2$; $\alpha = 0.01$; $\chi_{kr}^2 = 9.21$. When $W > 0.5$, χ^2 exceeds χ^2_{kr} ; this proves that expert opinions are concordant, and the significance of the groups of factors calculated on the basis of expert evaluation can be applied to multi-criteria evaluation.

Table 10. Ranking factors in the group of circumstances relating to inventor/-s regarding the commercial potential of technologies

| V. s. | E1 | E2 | E3 | E4 | E5 | E6 | E7 | E8 | E9 | E10 | E11 | E12 | Sum of ranks | The final rank |
|-------|----|-----|----|----|-----|----|----|----|----|-----|-----|-----|--------------|----------------|
| H1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 1 | 1 | 1 | 3 | 1 | 16.0 | 1 |
| H2 | 4 | 3.5 | 4 | 4 | 3.5 | 4 | 4 | 3 | 2 | 2 | 4 | 4 | 42.0 | 4 |
| H3 | 2 | 2 | 2 | 2 | 2 | 3 | 1 | 2 | 3 | 3 | 2 | 2.5 | 26.5 | 2 |
| H4 | 3 | 3.5 | 3 | 3 | 3.5 | 1 | 3 | 4 | 4 | 4 | 1 | 2.5 | 35.5 | 3 |

With reference to the findings of the conducted investigation (Table 10) and formulas 1–5, the following results were obtained: $e_i = 120.0$; $\bar{e} = 30$; $S = 382.5$; $W = 0.53$; $\chi^2 = 19.13$; $\nu = 3$; $\alpha = 0.01$; $\chi_{kr}^2 = 11.34$. When $W > 0.5$, χ^2 exceeds χ^2_{kr} ; this proves that expert opinions are concordant, and the significance of the groups of factors calculated on the basis of expert evaluation can be applied to multi-criteria evaluation.

Table 11. Ranking factors in the group of the internal policy of the institution regarding the commercial potential of technologies

| V. s. | E1 | E2 | E3 | E4 | E5 | E6 | E7 | E8 | E9 | E10 | E11 | E12 | Sum of ranks | The final rank |
|-------|----|----|----|----|----|----|----|----|----|-----|-----|-----|--------------|----------------|
| I1 | 1 | 1 | 1 | 1 | 1 | 3 | 1 | 1 | 1 | 1 | 1 | 1 | 14.0 | 1 |
| I2 | 3 | 2 | 2 | 2 | 3 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 26.0 | 2 |
| I3 | 2 | 3 | 3 | 3 | 2 | 1 | 3 | 3 | 3 | 3 | 3 | 3 | 32.0 | 3 |

With reference to the findings of the conducted investigation (Table 11) and formulas 1–5, the following results were obtained: $e_i = 72.0$; $\bar{e} = 24.0$; $S = 168.0$; $W = 0.58$; $\chi^2 = 14.0$; $\nu = 2$; $\alpha = 0.01$; $\chi_{kr}^2 = 9.21$. When $W > 0.5$, χ^2 exceeds χ^2_{kr} ; this proves that expert opinions are concordant, and the significance of the groups of factors calculated on the basis of expert evaluation can be applied to multi-criteria evaluation.

3. Defining the importance of factors in assessing the commercial potential of technologies

Defining the significance of the applied factors is the next stage of multi-criteria evaluation. Subjective significances of the factors established by the experts are most commonly used in practice. A number of methods for determining significances were created, and their importance was assessed by experts (Saaty 1980; Ustinovičius *et al.* 2007; Podvezko 2009; Ginevičius, Podvezko 2004; Podvezko, Sivilevicius 2013). A general idea of evaluation presents that the most important factor or a group of factors have determined maximum significance and usually calculated significances are normalized, i.e:

$$\sum_{i=1}^m q_i = 1, \tag{6}$$

where m – number of the groups of factors; q_i – significance of the i – the group of factors.

$$\sum_{i=1}^m g_i = 1, \tag{7}$$

where m – number of factors; g_i – significance of the i – the factor in the group.

Next, the evaluation of the direct significance of the factors determined by the experts is applied, and the sum of all groups of the factors considered by every expert and factorial assessment makes 100%. The significance g_i of all groups of factors and the significance of the factors in group q_i are calculated according to formula:

$$g_i = \frac{\sum_{k=1}^r c_{ik}}{100 \sum_{i=1}^m \sum_{k=1}^r c_{ik}}; \tag{8}$$

$$q_i = \frac{\sum_{k=1}^r c_{ik}}{100 \sum_{i=1}^m \sum_{k=1}^r c_{ik}}, \tag{9}$$

where r – number of experts; c_{ik} – expert evaluation; i – number of the series of the factor; k – number of the series of the expert.

The results of evaluating factors and the groups of factors of the commercial potential of technologies are provided in Tables 12–22 and the values of the symbols of factors are shown in Figure 1.

The meanings of abbreviations in the tables are as follows: *S.f.* – symbol of factor, E_i – serial number of the surveyed expert, *Sm.evl.* – sum of the evaluations, *Sgnf.g.f.* – significance of the group of factors, *Sgnf.f.* – significance of the factor.

Table 12. The significance of the groups of factors in the commercial potential of technologies

| <i>S.f.</i> | E1 | E2 | E3 | E4 | E5 | E6 | E7 | E8 | E9 | E10 | E11 | E12 | <i>Sm. evl.</i> | <i>Sgnf.g.f., g_i</i> |
|-------------|----|----|----|----|----|----|----|----|----|-----|-----|-----|-----------------|---------------------------------|
| A | 10 | 10 | 16 | 14 | 10 | 8 | 11 | 11 | 26 | 19 | 20 | 12 | 167.00 | 0.139 |
| B | 5 | 19 | 18 | 13 | 20 | 30 | 12 | 20 | 15 | 22 | 20 | 20 | 214.00 | 0.178 |
| C | 15 | 5 | 11 | 12 | 10 | 7 | 15 | 13 | 7 | 4 | 20 | 7 | 126.00 | 0.105 |
| D | 25 | 19 | 15 | 16 | 20 | 13 | 23 | 17 | 8 | 5 | 10 | 15 | 186.00 | 0.155 |
| E | 6 | 22 | 10 | 10 | 5 | 12 | 10 | 10 | 9 | 10 | 10 | 11 | 125.00 | 0.104 |
| F | 30 | 5 | 14 | 11 | 20 | 10 | 9 | 15 | 20 | 11 | 8 | 13 | 166.00 | 0.138 |
| G | 2 | 10 | 6 | 9 | 5 | 9 | 7 | 5 | 4 | 9 | 3 | 9 | 78.00 | 0.065 |
| H | 4 | 10 | 7 | 7 | 5 | 6 | 8 | 6 | 6 | 13 | 6 | 8 | 86.00 | 0.072 |
| I | 3 | 0 | 3 | 8 | 5 | 5 | 5 | 3 | 5 | 7 | 3 | 5 | 52.00 | 0.043 |

The carried out assessment has established that the commercial potential of technologies is mainly influenced by the following groups of factors: “value for the consumer” (0.178), “competitive environment” (0.155) and “situation on the market” (0.139). The

least impact is made by the “internal policy of the institution” (0.043), “legal environment” (0.065) and “circumstances related to the inventor(s)” (0.072). The “competence of technology developers” is in the 4th (0.138), “financial environment” – in the 5th (0.105) and the “characteristics of technology” – in the 6th position considering significance in terms of the groups of all factors.

Table 13. The significance of factors in the group of the situation on the market regarding the commercial potential of technologies

| S.f. | E1 | E2 | E3 | E4 | E5 | E6 | E7 | E8 | E9 | E10 | E11 | E12 | Sm. evl. | Sgnf. f., q_j |
|------|----|----|----|----|----|----|----|----|----|-----|-----|-----|----------|-----------------|
| A1 | 35 | 30 | 23 | 30 | 20 | 15 | 25 | 22 | 20 | 21 | 25 | 10 | 276 | 0.230 |
| A2 | 10 | 25 | 20 | 20 | 40 | 10 | 30 | 25 | 30 | 25 | 25 | 10 | 270 | 0.225 |
| A3 | 40 | 30 | 40 | 40 | 30 | 40 | 35 | 35 | 40 | 35 | 30 | 50 | 445 | 0.371 |
| A4 | 15 | 15 | 17 | 10 | 10 | 35 | 10 | 18 | 10 | 19 | 20 | 30 | 209 | 0.174 |

The *degree of needs with respect to the potential product* has the biggest impact (0.371) on the group of factors “situation on the market” regarding the commercial potential of technologies while the *degree of preparing the market for technology* (0.174) has the least impact.

Table 14. The significance of factors in the group of value for the consumer regarding the commercial potential of technologies

| S. f. | E1 | E2 | E3 | E4 | E5 | E6 | E7 | E8 | E9 | E10 | E11 | E12 | Sm. evl. | Sgnf. f., q_j |
|-------|----|----|----|----|----|----|----|----|----|-----|-----|-----|----------|-----------------|
| B1 | 58 | 39 | 40 | 45 | 56 | 33 | 50 | 30 | 35 | 30 | 30 | 40 | 486 | 0.405 |
| B2 | 17 | 33 | 25 | 25 | 22 | 34 | 20 | 20 | 20 | 20 | 20 | 10 | 266 | 0.222 |
| B3 | 25 | 28 | 35 | 30 | 22 | 33 | 30 | 50 | 45 | 50 | 50 | 50 | 448 | 0.373 |

The conducted assessment shows that the *value planned to be offered to the final consumer* (0.405) makes the biggest impact in the group of factors “value for the consumer” regarding the commercial potential of technologies. A *consumer’s response to product concept* has the least reaction (0.222). The impact made by the *uniqueness level of the factor value given to the potential user of technology* (0.373) is less significant than the *value planned to be offered to the final user* but greater than the *consumer’s response to product concept*.

Table 15. The significance of factors in the group of a financial environment regarding the commercial potential of technologies

| S. f. | E1 | E2 | E3 | E4 | E5 | E6 | E7 | E8 | E9 | E10 | E11 | E12 | Sm. evl. | Sgnf. f., q_j |
|-------|----|----|----|----|----|----|----|----|----|-----|-----|-----|----------|-----------------|
| C1 | 21 | 16 | 14 | 17 | 11 | 11 | 18 | 10 | 30 | 10 | 20 | 15 | 193 | 0.161 |
| C2 | 16 | 14 | 20 | 16 | 32 | 42 | 20 | 30 | 5 | 30 | 21 | 15 | 261 | 0.218 |
| C3 | 21 | 29 | 25 | 22 | 21 | 21 | 25 | 30 | 25 | 30 | 22 | 25 | 296 | 0.247 |
| C4 | 11 | 23 | 16 | 18 | 11 | 21 | 15 | 10 | 20 | 10 | 15 | 20 | 190 | 0.158 |
| C5 | 4 | 10 | 10 | 15 | 5 | 0 | 8 | 5 | 10 | 5 | 10 | 10 | 92 | 0.077 |
| C6 | 27 | 8 | 15 | 12 | 20 | 5 | 14 | 15 | 10 | 15 | 12 | 15 | 168 | 0.140 |

The carried out assessment demonstrates that the *predicted contribution of technology to company's profits* (0.247) and a *competitive product cost per unit* (0.218) are the greatest impact factors in the group “financial environment” regarding the commercial potential of technologies. A potential assessment of *product durability and its importance in order to create a renewable revenue stream* (0.077) has the strongest impact. *Financial potential* (0.161) takes the 3rd position, a *predicted period for covering the costs of the project on technology commercialization* (0.158) is in the 4th place and a *predicted period for technology development* goes 5th (0.140) considering significance in terms of all factors.

Table 16. The significance of factors in the group of a competitive environment regarding the commercial potential of technologies

| S. f. | E1 | E2 | E3 | E4 | E5 | E6 | E7 | E8 | E9 | E10 | E11 | E12 | Sm. evl. | Sgnf. f., q _j |
|-------|----|----|----|----|----|----|----|----|----|-----|-----|-----|----------|--------------------------|
| D1 | 40 | 60 | 40 | 35 | 40 | 80 | 50 | 50 | 40 | 50 | 30 | 40 | 555 | 0.463 |
| D2 | 25 | 20 | 25 | 25 | 20 | 10 | 30 | 20 | 30 | 20 | 10 | 20 | 255 | 0.213 |
| D3 | 35 | 20 | 35 | 40 | 40 | 10 | 20 | 30 | 30 | 30 | 60 | 40 | 390 | 0.325 |

The *predicted life expectancy of technology* (0.463) has the most powerful impact in the group of factors “competitive environment” regarding the commercial potential of technologies. *Competitive intensity* (0.325) takes the 2nd position and the *possibility of copying technology* (0.213) is the 3rd place, which indicates they are less important factors.

Table 17. The significance of factors in the group of technology features regarding the commercial potential of technologies

| S. f. | E1 | E2 | E3 | E4 | E5 | E6 | E7 | E8 | E9 | E10 | E11 | E12 | Sm. evl. | Sgnf. f., q _j |
|-------|----|----|----|----|----|----|----|----|----|-----|-----|-----|----------|--------------------------|
| E1 | 57 | 83 | 55 | 71 | 67 | 67 | 70 | 50 | 60 | 40 | 60 | 40 | 720 | 0.600 |
| E2 | 43 | 17 | 45 | 29 | 33 | 33 | 30 | 50 | 40 | 60 | 40 | 60 | 480 | 0.400 |

The *complexity of technology* (0.600) is a more significant factor than the *dependence of technological functioning on geographic/climatic circumstances* (0.400) in the group of factors “technology features” regarding the commercial potential of technologies’.

Table 18. The significance of factors in the group of the competence of technology developers regarding the commercial potential of technologies

| S. f. | E1 | E2 | E3 | E4 | E5 | E6 | E7 | E8 | E9 | E10 | E11 | E12 | Sm. evl. | Sgnf. f., q _j |
|-------|----|----|----|----|----|----|----|----|----|-----|-----|-----|----------|--------------------------|
| F1 | 30 | 40 | 30 | 25 | 20 | 32 | 30 | 25 | 30 | 40 | 10 | 27 | 339 | 0.283 |
| F2 | 20 | 5 | 20 | 20 | 30 | 18 | 29 | 21 | 10 | 16 | 30 | 20 | 239 | 0.199 |
| F3 | 10 | 5 | 15 | 15 | 10 | 15 | 15 | 8 | 10 | 12 | 10 | 16 | 141 | 0.118 |
| F4 | 15 | 10 | 10 | 10 | 30 | 16 | 16 | 20 | 20 | 13 | 20 | 18 | 198 | 0.165 |
| F5 | 25 | 40 | 25 | 30 | 10 | 19 | 10 | 26 | 30 | 19 | 30 | 19 | 283 | 0.236 |

The factors *competencies of technical/scientific staff in commercializing technologies* (0.283) and *competencies of a production unit in commercializing technologies* (0.236) have

the most profound impact in the group of factors “competence of technology developers” regarding the commercial potential of technologies. The factor *competencies of a technology transfer office in making technologies commercial* (0.118) has the lowest impact. The *competencies of the marketing department in commercializing technologies* (0.199) and *competencies of the sales department in commercializing technologies* (0.165) take the 3rd and 4th position respectively considering significance in terms of the evaluated factors.

Table 19. The significance of factors in the group of a legal environment (for legal unprotected technology) regarding the commercial potential of technologies

| S. f. | E1 | E2 | E3 | E4 | E5 | E6 | E7 | E8 | E9 | E10 | E11 | E12 | Sm. evl. | Sgnf. f., q_j |
|-------|----|----|----|----|----|----|----|----|----|-----|-----|-----|----------|-----------------|
| G1 | 10 | 17 | 15 | 20 | 14 | 11 | 13 | 12 | 14 | 18 | 14 | 17 | 175 | 0.146 |
| G2 | 30 | 24 | 23 | 21 | 24 | 27 | 26 | 25 | 29 | 22 | 15 | 24 | 290 | 0.242 |
| G3 | 15 | 19 | 22 | 19 | 19 | 20 | 23 | 22 | 13 | 20 | 19 | 20 | 231 | 0.193 |
| G4 | 20 | 22 | 23 | 23 | 29 | 29 | 24 | 24 | 23 | 23 | 24 | 25 | 289 | 0.241 |
| G5 | 25 | 18 | 17 | 17 | 14 | 13 | 14 | 17 | 21 | 17 | 28 | 14 | 215 | 0.179 |

The assessment of the significance of factors in the group “legal environment (for legal unprotected technology)” regarding the commercial potential of technologies points out two most important factors: *technology performance/usability level* (0.2417) and *difference from the most similar analogue* (0.2408). The *favourability of the national legislative framework for commercialization* (0.1458) and a *price for legal protection* (0.1792) have the lowest impact. The factor *technology confidentiality* (0.1925) takes an intermediate position considering significance.

Table 20. The significance of factors in the group of a legal environment (for legal protected technology) regarding the commercial potential of technologies

| S. f. | E1 | E2 | E3 | E4 | E5 | E6 | E7 | E8 | E9 | E10 | E11 | E12 | Sm. evl. | Sgnf. f., q_j |
|-------|----|----|----|----|----|----|----|----|----|-----|-----|-----|----------|-----------------|
| G11 | 21 | 8 | 25 | 36 | 23 | 6 | 30 | 30 | 20 | 30 | 20 | 35 | 284 | 0.237 |
| G12 | 43 | 84 | 35 | 45 | 44 | 6 | 50 | 40 | 50 | 40 | 50 | 40 | 527 | 0.439 |
| G13 | 36 | 8 | 40 | 19 | 33 | 88 | 20 | 30 | 30 | 30 | 30 | 25 | 389 | 0.324 |

The *strength of legal protection* (0.439) has the strongest impact in the group of “legal environment (for legal protected technology)” regarding the commercial potential of technologies. The factor *geographical barriers to technology protection* (0.324) takes the 2nd and the *favourability of the national legislative framework for commercialization* (0.237) – the 3rd position.

Table 21. The significance of factors in the group of circumstances relating to inventors regarding the commercial potential of technologies

| S. f. | E1 | E2 | E3 | E4 | E5 | E6 | E7 | E8 | E9 | E10 | E11 | E12 | Sm. evl. | Sgnf. f., q_j |
|-------|----|----|----|----|----|----|----|----|----|-----|-----|-----|----------|-----------------|
| H1 | 40 | 50 | 40 | 35 | 50 | 15 | 30 | 36 | 45 | 35 | 25 | 60 | 461 | 0.384 |
| H2 | 15 | 10 | 15 | 10 | 5 | 5 | 10 | 22 | 25 | 23 | 10 | 10 | 160 | 0.133 |
| H3 | 25 | 30 | 25 | 30 | 40 | 10 | 40 | 24 | 20 | 22 | 30 | 15 | 311 | 0.259 |
| H4 | 20 | 10 | 20 | 25 | 5 | 70 | 20 | 18 | 10 | 20 | 35 | 15 | 268 | 0.223 |

On the basis of the carried out assessment, a conclusion that *inventor's experience in commercializing technology* (0.384) makes the strongest and *academic inventor's recognition* – the lowest (0.133) impact in the group of “circumstances relating to inventors” regarding the commercial potential of technologies can be made. The *planned degree of involvement of the inventor as a team member in the commercialization of technology* (0.259) takes the 2nd and the *financial contribution of the inventor* (0.223) – the 3rd position considering significance.

Table 22. The significance of factors in the group of the internal policy of the institution regarding the commercial potential of technologies

| S. f. | E1 | E2 | E3 | E4 | E5 | E6 | E7 | E8 | E9 | E10 | E11 | E12 | Sm. evl. | Sgnf. f., q_j |
|-------|----|----|----|----|----|----|----|----|----|-----|-----|-----|----------|-----------------|
| I1 | 41 | 70 | 40 | 44 | 57 | 17 | 44 | 50 | 45 | 50 | 40 | 42 | 540 | 0.450 |
| I2 | 24 | 18 | 35 | 37 | 14 | 8 | 33 | 30 | 35 | 30 | 31 | 38 | 333 | 0.278 |
| I3 | 35 | 12 | 25 | 19 | 29 | 75 | 23 | 20 | 20 | 20 | 29 | 20 | 327 | 0.273 |

The *concordance of the project on technology commercialization with the institution's business strategy* (0.450) was found to have the highest impact in the group of factors “the internal policy of the institution” regarding the commercial potential of technologies. The *acceptability of the strategy for institutional commercialization to the inventor* (0.278) and the *image of the institution in the field of technology commercialization* (0.273) are equivalent, but less significant factors.

To conclude the conducted research, the significance ranks of the groups of factors in terms of the commercial potential of technologies are provided in Table 23.

Table 23. Ranking the significance of the groups of factors in the commercial potential of technologies

| Rank | Name of factors groups | Sgnf.g.f., q_j |
|------|--|------------------|
| 1 | Value for the consumer (B) | 0.178 |
| 2 | Competitive environment (D) | 0.155 |
| 3 | Situation on the market (A) | 0.139 |
| 4 | Competency of technology developers (F) | 0.138 |
| 5 | Financial environment (C) | 0.105 |
| 6 | Technology features (E) | 0.104 |
| 7 | Circumstances relating to the inventor/s (H) | 0.072 |
| 8 | Legal environment (G) | 0.065 |
| 9 | internal policy of the institution (I) | 0.043 |

At the second stage of the investigation, the significances of the factors and groups of factors were established, which reflects the impact of the factors and groups of factors in terms of the assessed object. The assessment of the factors and groups of factors resulted in significances that further were provided ranks: 1 – value for the consumer (B = 0.178); 2 – competitive environment (D = 0.155); 3 – situation on the market (A = 0.139); 4 – competency of technology developers (F = 0.138); 5 – financial environment (C = 0.105); 6 – technology features (E = 0.104); 7 – circumstances relating to the inventor/s (H = 0.072); 8 – legal environment (G = 0.065); 9 – internal policy of the institution (I = 0.043).

Conclusions

The commercialization of technologies creating new technology-based products is a source of a competitive advantage ensuring company's prosperity and, at the same time, represents very risky activity. Most of the attempts to commercialize technologies end in failure, and thus the ability to timely and objectively assess the expedience of technology commercialization, in order to avoid non-productive investments, is a crucial and unsafe move for the institutions engaged in scientific research and R&D, when the owner of technology, the potential investor or buyer must take a decision on the future of technology and to answer questions such as if it is worth developing this technology, investing in it or buying it? In order to answer these questions and to make the right decision, tools for assessing the commercial potential of technologies are in use.

Over the last decade, the analysis of the tools on a global scale led to the unequivocal conclusion – so far developed methodical basis has suffered from lack of maturity for its practical use in business. The analysis of measures for the commercial potential of technologies indicates that the assessment of commercial potential considers different factors and the groups of factors, which allows having doubts about the objectivity of these measures. However, the models used for assessing the commercial potential of technologies can be useful for the more objective development of a set of factors in the commercial potential of technologies.

The assessment carried out by qualified experts allowed identifying the significance and degree of the impact of factors and the groups of factors in the process of evaluating the commercial potential of technologies, whereas the employment of statistical methods for considering the concordance of expert opinions (M. Kendall rank correlation theory) assists in using a quantitative expression of the significance of factors enabling a possibility of benchmarking.

The assessment demonstrates that the commercial potential of technologies is mainly influenced by the factors such as the *value planned to be offered* (0.1742), *competitiveness* (0.1450) and *competence in technology developers* (0.1283). The *inner policy of the institution* (0.0492), *legal-political circumstances* (0.0792) and *circumstances relating to the inventor/s* (0.0825) make the least impact. In terms of all factors, considering significance, *situation on the market* (0.1267) goes in the 4th, *financial situation* – in the 5th and *technological circumstances* – in the 6th position. The group of factors “value for the customer” (B) consists of three factors, the major impact among which on commercial potential is made by the factor the *value planned to be offered to the final consumer* (B1); *respond of target consumers to product concept* (B2) is in the lowest position and the factor *uniqueness level of the value given to the potential user of technology* (B3) takes an intermediate position in terms of commercial potential. The *predicted life expectancy of technology* (D1) and the *intensity of competitiveness* (D3) play the major role in the group of factors “competitive environment”. The factors the *degree of needs in terms of a potential product* (A3) and a *share of the target market of the potential product within the assessment period* (A1) have the strongest impact in the group of factors “situation on the market”.

The system of factors the commercial potential of technologies and the identified significance of factors can be used as recommended guidelines for technology developers, investors and potential owners in the decision-making processes of commercialization, investment or purchase of technology and at the next stage of research on developing a model for assessing the commercial potential of technologies.

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