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APPLICATION OF THE TOPSIS METHOD FOR PRELIMINARY ASSESSMENT OF TECHNOLOGICAL TRANSFER OPTIONS

In modern times, the business success of enterprises is increasingly the result of the development of science and the accelerated introduction of new advances. Innovations is becoming the key to success. Under these conditions, the importance of technology transfer is also becoming a main "strategic way of meeting the challenges of globalization in business" (Mayer and Blaas, 2002). With the increasing importance of technological transfer, increases the interest in the theoretical elucidation and empirical research of various aspects of its implementation in enterprises.
In view of the above, the aim of this paper is to propose a method for the preliminary assessment of alternative technology transfer options based on the use of the TOPSIS method (The Technique for Order of Preference by Similarity to Ideal Solution) (Hwang and Yoon, 1981). It allows an initial assessment and selection of technological transfer options on the base of preliminary selected important criteria. As a result, businesses can reduce the number of options that will later be subject to a more in-depth assessment, from the list of already selected ones, by choosing only those who have good potential and are in their capabilities. In this way the experts' efforts are focused and their work, concerning the selection of a transfer option in which to invest, is also significantly relieved.
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Introduction

Nowadays, the exchange of technological knowledge is of utmost importance to businesses. In the context of a globalizing economy and trade liberalization, it is becoming the engine of their economic development (Manfield, 1975; Grossman and Helman, 1991; Romer, 1990).

Deepening globalization leads to more intensive and complicated competition between companies. In addition, the rapidly evolving scientific and technological progress and

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the world-wide "knowledge economy" dynamize the competitive struggle and pose new challenges for them. Changes in needs and requirements of consumers, as well as the rapid pace at which current knowledge, techniques and technologies become obsolete make their competitive positions unstable. New requirements for their functioning appear, at the basis of which is the necessity for constant and rapid changes and improvement. Business success is increasingly the result of the development of science and the rapid introduction of new advances. Innovations are becoming the key to success. The relative importance of intangible assets, of the social and cultural capital, as conditions for accelerated innovation and renewal, grows. Less and less can be relied on cheap natural resources and labour.

At the same time, the development of science cannot be only the doing of a single person, separate laboratory, research organization, university or state. It is the collective deed of millions of people from various nations. In these conditions, the innovative activity of enterprises cannot rely solely on their own strength, but also on outside achievements. The enterprise will make use of them through technological transfer, which is becoming a main "strategic way of meeting the challenges of globalization in business" (Mayer, Blaas, 2002). Coe and Helman, as well as a number of other authors (Coe, Helman, 1995; Griffith et al., 2004), emphasize that new knowledge flows that do not recognize boundaries become a main source for productivity gains.

Through the introduction of technological transfer, businesses not only benefit from the knowledge, experience and technical advances of others but also accelerate and increase the effectiveness of their own innovation activities. They acquire technological knowledge tried out in practice, which reduces mistakes and failures. Through the acquisition of new advances at the appropriate stage of their life cycle, they overcome the initial, lengthy, highly risky and very expensive stages of their development. This reduces investment for innovation and ensures success. There is no need to maintain large research departments. At the same time, new knowledge is accumulated in enterprises and it positively impacts not only its innovation activity but also its overall activity. The transfer of new technologies in enterprises is also related to the replacement of obsolete products, increase in effectiveness through the introduction of improved technological methods, new equipments, cheaper components, etc., attracting engineers and consumers, meeting the specific technological requirements of consumers (Larson, Wall, Norstrom, Crnkovic, 2006) and others. As a result, important competitive advantages are created and maintained and high competitiveness is achieved (Belderbos, Van Roy, Duvivier, 2012).

Enterprises often face various opportunities for technological transfer. They will evaluate each of these options and choose the best for themselves in accordance with their resource constraints and the desire to achieve maximum business results. Therefore, the assessment of alternative technological transfer options is of great importance for making informed decisions for the choice of options. It helps to properly target investments and achieve high firm competitiveness. Without its implementation, it is not possible to plan properly the innovation activities and maximize economic results.

The assessment allows to determine the expected impact of each possible transfer option and the innovation, as a result of its implementation, on the business performance of the enterprise and to make comparisons with other alternative transfer options. On its basis, the strengths and weaknesses of the transfer alternatives are analyzed. Through its help to analyze various alternatives for managerial decisions, it also becomes a condition for developing and choosing development strategies.

Unfortunately, the problem of assessment of alternative technological transfer options in enterprises is still not satisfactorily resolved. The analysis of the specialized literature has shown that there are many opinions on the ways in which it has to be carried out, but none of them has been accepted by all authors (Smits, Leyteh, 1988; Tran, Daim, Madu, 1988; McGrath, MacMillan, 2000, etc.). Firstly, there is still no single opinion on the evaluation criteria; secondly, there is no consensus on the indicators to assess the levels reached on these criteria, and thirdly, the methodologies used to make the assessments are objectionable. Moreover, the prevailing part of the methodological studies concerning the evaluation and selection of technological transfer options are related to international transfer from industrially developed countries to developing countries (Cohen, Levinthal, 1989; Girma, 2005; Fu, Pietrobelli, Soete, 2010; Eaton, Kortum, 1999; Xu, 2000, etc.).

The problem concerning the assessment and selection of alternative technological transfer options has not been satisfactorily resolved in the business practice of enterprises as well. Various methods ranging from general expert judgment to the use of formalized algorithms are used. Formalized methods are mainly used to evaluate and select variants of the transfer of physical objects (products, machines and equipment, components, facilities, plants, etc.) and of some new methods and processes. They are rarely used to evaluate patents, software products, and design. They cannot be applied for judging the transfer of new documentation, useful information and knowledge. They are usually incomplete because they are based on assessing and comparing only the technical characteristics and the price of new advances. They rarely take into account their full potential impact on the enterprise in the long run.

It can be concluded that, despite its practical significance, the problem of accurate assessment and selection of variants of new technologies for the needs of enterprises is not yet fully resolved. The lack of accurate and easy to use tools is most noticeable in business practice, where solutions for the implementation of new technologies are often taken without thorough analysis and justification.

In view of the above, the aim of this paper is to propose a method for the preliminary assessment of alternative technology transfer options based on the use of the TOPSIS method (The Technique for Order of Preference by Similarity to Ideal Solution) (Hwang, Yoon, 1981). It allows an initial assessment and selection of technological transfer options on the base of preliminary selected important criteria. As a result, businesses can reduce the number of options that will later be subject to a more in-depth assessment, from the list of already selected ones, by choosing only those who have good potential and are in their capabilities. In this way the experts' efforts are

focused and their work, concerning the selection of a transfer option in which to invest, is also significantly relieved.

Methodology

1. Overview

The "technological transfer" category is not new, but there is still no commonly accepted definition of it. This is mainly due to its complexity, the lack of agreement on the content of the transfer objects, the different points of view it is characterized (Chen, 1996, Spivey et al., 1997, Bozeman 2000). In view of this, for the purposes of this paper, the following working definition will be adopted here, which is in line with the subject of the study and focuses on the transfer between organizations:

Technological transfer is a complex, iterative process of informed, purposeful, normal and contractual interact between two or more organizations to transfer and apply new and useful information and knowledge, methods and processes, documentation, patents, software products, design, physical objects (products, machinery and equipment, components, facilities, factories, etc.) in the host organization, leading to an increase of its knowledge base and/or innovation to achieve its corporate goals (Velev, Atanasova, 2013).

Every enterprise learns from the achievements of others and perceives new advances. But not every innovation in the environment is suitable for transfer and absorption. The one thing that is appropriate for one enterprise is inappropriate for another. Moreover, the different options for a possible technological transfer require a different amount of investment and would have a different effect on business performance. Consequently, and because of their resource constraints, enterprises must take management decisions for the choice of such transfer options that lead to maximum business results. Errors can be fatal. In order to be correct, these decisions must be based on previously made estimates.

The method outlined herein is based on the use of the TOPSIS method, developed by Hwang and Yoon (Hwang, Yoon, 1981). It is one of the most commonly used methods for the multicriteria analysis of solution variants. Its use determines and selects the best alternative to a solution that is at least remote from the ideal solution and furthest from the worst decision on selected criteria. For the purpose of the preliminary assessment of technological transfer variants, the application of the TOPSIS method undergoes some adaptation.

The proposed method can be further developed by changing or adding criteria, as well as by adjusting their relative weights for transfer assessment. Its practical applicability can be facilitated and enhanced by appropriate programming of computing procedures and the use of computer equipment.

2. Choice of criteria for preliminary evaluation of technological transfer options

The first and one of the most important problems in making all assessments is the right choice of judgment criteria. In view of the fact that the main purpose of this paper is to demonstrate primarily the method of preliminary evaluation it should be noted that it does

not pretend for the most detailed list of the proposed criteria. However, the criteria proposed here are broad enough and can be used by all businesses. They can be completed on a case-by-case basis, depending on the particular transfer and the objectives of the involved enterprise.

The preliminary assessment process begins with the identification of the needs of enterprises to put in new technologies through transfer. These necessities arise from the need to continually improve and maintain high competitiveness. The specific requirements of technological transfer and related innovations are discovered through periodic analysis of emerging issues in enterprise operations, environmental changes, and development strategies. The analyses are focused on:

- Outside environment (special attention is paid to regulatory regulation). This analysis should show the trends of change and the resulting opportunities and threats to the enterprise.
- Markets (including: consumers, competitors, commercial intermediaries, technology development, new practices and production methods, changing needs, emergence of new products, etc.);
- Efficiency of the business in terms of used equipment, methods and technologies for production and provided services, need for product improvement, etc.
- The enterprise's prospects and plans for development and improve of its competitiveness, etc.

As a result of these analyzes, the potential and necessary changes and innovations are determined to solve the company's problems, to take advantage of the existing or emerging favourable opportunities, to prevent the existing or emerging threats, to increase the efficiency of the enterprise's activity. Usually, these problems are solved through the use of the technological transfer.

Once an enterprise has determined its needs for new technologies, it explores the possibilities of implementing technology transfer, i.e. the transfer of knowledge and innovation, on the basis of which corporate innovations will be resolved to solve the problems encountered and to achieve higher economic results and competitiveness. For this purpose, it examines the new developments offered by universities and research organizations and the existing new advances in other organizations around the world. Sources of information can be used, such as: articles, reports, specialized publications, conferences, seminars, internet sites, social networks, etc.

The result of the study is to develop an expanded list of technological transfer opportunities that match the company profile and could provide solutions to its problems and ensure its improvement. These variants would lead to innovations that are of varying importance to the enterprise. Some of them are mandatory for implementation and must be done urgently. Such are, for example, those caused by changes in legal regulations – changes in the mandatory requirements to the equipment used, technological lines, methods and approaches to production and service, safety and working conditions, etc. An enterprise can not continue its business if it does not comply with those changes by making the necessary

innovations. However, not all changes in the legal regulation require strictly binding and urgent measures to change. Innovation in this case is desirable to improve the business, but could be postponed for later.

Desirable, but not strictly binding, with a possibility of some delay in time, are the innovations and the technological transfer necessary for their implementation, caused by changes in the market conditions (changes in the requirements of the consumers, changes in the behavior of competitors, new requirements of the intermediaries, new practices and strategies emerged, etc.).

Such are the innovations brought about by other innovations carried out or taking place in the enterprise. Similarly, is the state of the transfer of new technologies stemming from the aim to improve the business performance of the enterprise – to increase the competitiveness of products, increase sales, improve the quality of operations and increase staff productivity, reduce costs and more.

Due to the varying degree of importance of innovation for the enterprise, the technological transfer options for their provision, outlined in the developed list, also have a different priority for implementation. This priority must be determined and taken into account when assessing and determining the sequence of the transfer. The priority groups, according to the degree of importance or necessity for the transfer, are: Priority group 1 – strictly obligatory for implementation because of the necessity of changes in the activity of the enterprise imposed by new regulatory requirements; Priority group 2 – mandatory for implementation in order to reflect the changes in the market conditions, a significant problem in the enterprise or because of the necessity of other kinds of innovation; Priority Group 3 – these are desirable but not mandatory transfers, concerning the improvement of the business performance of the enterprise.

Variety of options for the implementation of each of the priority technological transfer groups are possible. These alternative options need to be further assessed in order to select the most effective for the enterprise. It has to invest in them.

The evaluation is carried out in two stages – preliminary and final evaluation.

Preliminary judgment should reject the alternative options for technological transfer that do not meet pre-selected but relatively general criteria. As a result, a short list of selected alternative transfer options is developed, sorted by priority groups, which will be a subject for further detailed assessment in order to select the most suitable for transfer in the enterprise. In the preliminary assessment, all technological alternatives are evaluated according to the following criteria:

1. Capacity (capabilities) of an enterprise to take advantage of that technology

The capacity of an enterprise to benefit depends on the complexity of the new technology and its absorption capacity, including its innovation, production and market capacities. For this purpose, it is assessed:

- the scientific and innovative potential (capabilities) of an enterprise to develop and further develop new advances to the readiness for implementation/use;

- the potential of an enterprise to incorporate innovation – this includes the presence of qualified personnel, experience, availability of premises, availability of the necessary production facilities, equipment, etc.);
- the potential of the enterprise to use the new advance (incl. to produce it and marketing the results of the implemented innovation) – this includes the presence of qualified personnel, experience, the opportunity to supply specialized materials and parts, the possibility of finding partners and signing the necessary contracts, company reputation and image, etc.).

2. Expected results

The preliminary assessment of the expected results of each transfer variant is made by one or more of the following sub-criteria:

- expected sales growth;
- expected increase of the competitiveness of the products/services;
- expected improved compliance with standards;
- expected increase of the labor productivity in the enterprise;
- expected decrease of the product cost in the enterprise;
- expected improvement of the financial results of the enterprise.
- expected increase of the flexibility of the enterprise activity;
- expected improvement of environmental protection;
- expected improvement of the quality of the management and marketing activity, etc.

3. Required investment funds:

- acquisition cost;
- necessary funds to achieve new advance;
- necessary funds for implementation, incl. the preparation of personnel and investment in ancillary conditions.

4. Necessary time to take advantage:

- necessary time to develop the new advance;
- time needed to implement innovation.

5. Other:

- terms of payment;
- included staff training;
- restrictive conditions for using the acquired new advance placed by the seller;

- the expected degree of internal resistance;
- risk (probability of success/failure), etc.

The preliminary assessment of the technological alternatives might be realized using the main criteria, all or part of their sub-criteria. Sub-criteria assessment will be more precise because of their larger number and specificity, but this would greatly increase the work of the experts and the time to make the assessment. It is preferable to carry out the assessment only by basic criteria. This will be accurate enough to pre-screen only the most inappropriate alternatives for the enterprise. Later, the other alternatives will be subject to much more precise final judgment and choice.

3. TOPSIS method for multi-criterial preliminary assessment of technological transfer variants

The application of the TOPSIS method for prior assessment of technological transfer options requires the following steps:

3.1. Develop a matrix of solutions

For this aim, let Ai (i = 1, ... n) denote the alternative technological transfer options to be evaluated, and Cj (j = 1, ... m) the system of evaluation criteria. On this basis, a matrix of Dnxm solutions can be developed. It specifies the level of each alternative considered by each of the selected evaluation criteria, represented with Xij. The matrix has the following form:

	C_1	C_2	….	C_m
A_1	X_{11}	X_{12}	….	X_{1m}
A_2	X_{21}	X_{22}	….	X_{2m}
….	….	….	….	….
A_n	X_{n1}	X_{n2}	….	X_{nm}

3. 2. Normalize the decision matrix

Normalization is performed using the following formula:

$$y_{ij} = \frac{Xij}{\sqrt{\sum_{i=1}^{n} X_{ij}^2}}$$

In this way a new, normalized matrix Rnxm is obtained with the following form:

	C_1	C_2	….	C_m
A_1	Y_{11}	Y_{12}	….	Y_{1m}
A_2	Y_{21}	Y_{22}	….	Y_{2m}
….	….	….	….	….
A_n	Y_{n1}	Y_{n2}	….	Y_{nm}

3. 3. Calculate the weighted matrix

The levels of the indicators in this matrix are weighted with the different importance of the evaluation criteria. This is necessary because the individual criteria have a different significance for the evaluating enterprise. For this purpose, the coefficients of importance (weights) of each of the criteria Wj (j = 1, ... m) are determined and the values of the indicators from normalized matrix are corrected (by multiplication). This gives a new matrix Znxm (i = 1 ... n; j = 1 ... m) having the following form:

	C_1	C_2	….	C_m
A_1	Z_{11}	Z_{12}	….	Z_{1m}
A_2	Z_{21}	Z_{22}	….	Z_{2m}
….	….	….	….	….
A_n	Z_{n1}	Z_{n2}	….	Z_{nm}

Where: Zij = Yij . Wj

3. 4. Identify the Positive Ideal Solution (PIS) and the Negative Ideal Solution (NIS) to the problem

PIS is the solution (the technological alternative) with the best meanings for each evaluation criterion, and NIS – the solution (the technological alternative) with the worst meanings. They are defined as follows:

PIS = max Zij when the higher value of the corresponding criterion shows a better state and PIS = minZij when the lower value of the given criterion shows a better state.

NIS = min Zij when the criterion requires maximization of value and NIS = max Zij when the value of the relevant criterion is minimized.

3. 5. Determine the distance of each of the evaluated technological alternatives from PIS and NIS

The distances of the evaluated technological alternatives from PIS and NIS are denoted by Di+ and Di- respectively. They are determined by the following formulas:

$$D_i^+ = \sqrt{\sum_{j=1}^{m}\left(Z_{ij} - PIS_j\right)^2},\ i=1\ldots n,$$

$$D_i^- = \sqrt{\sum_{j=1}^{m}\left(Z_{ij} - NIS_j\right)^2},\ i=1\ldots n$$

3. 6. Determining the rank index

The Rank Index shows the relative proximity (likeness) of each alternative to PIS – the best state. It is calculated for each alternative by the following formula:

$$RC_i = \frac{D_i^-}{D_i^+ + D_i^-}, \; i=1...n$$

The level of RCi is defined within the range from 0 to 1, i. $0 \leq RCi \leq 1$.

3. 7. Technological transfer alternatives are ranked by the RCi levels in descending order. This determines the best of them. I.e. this alternative, which minimizes its distance from PIS and maximizes it against NIS. Therefore, the higher value of RCi indicates a better estimate of the corresponding alternative.

For the purpose of a preliminary evaluation of technological transfer options, some additions to the TOPSIS method are also needed. These are related to the determination of Xij and the coefficients of the importance of the individual evaluation criteria Wj.

Estimates of the various criteria for prior evaluation of technological alternatives are in different units of measurement. Some of them are directly measurable by supplier data, but others can only be determined by expert judgment. Therefore, in order to ensure uniformity between them, all data should be converted into grades. The grades vary from 1 to 7. Grade 1 is the lowest level and shows the worst compliance of the relevant criterion, and a level of 7 – excellent match.

When the value of alternatives can not be directly measured by a relevant criterion, the experts involved provide expert judgment within that range. When the parameters of the alternatives are measurable, their conversion into grades is as follows:

a) in cases where a large number of alternatives are evaluated and compared:

$$БО\ i_К = 6 \times \frac{(СТ\ i_К - СТ\ i\ min)}{(СТ\ i_{max} - СТ\ i\ min)} + 1,$$

where:

БО $i_К$ – grade of the i-th parameter for the k-th alternative;

СТ $i_К$ – value of the i-th parameter for the k-th alternative;

СТ i_{max} and СТ i min – respectively the maximum and minimum value of the i-th parameter for the whole set of analyzed alternatives.

b) in cases where only two alternatives are evaluated and compared:

The alternative with the higher value of the parameter gets a grade 7, the evaluation of the other alternative is determined by the formula:

$$БО\ i_К = 6 \times \frac{СТ\ i_К}{СТ\ i\ max} + 1,$$

In the preliminary assessment, each of the participating experts assess the analyzed technological alternatives in the range from 1 to 7 for each of the criteria used. For criteria that require minimization of values (for example: the necessary investment funds, the level of current costs, etc.), the higher grade for Xij is placed on the alternatives of lower level on the criterion and vice versa, the alternatives with a higher level on the relevant criterion is given a lower grade. Thereafter, the assessments are summarized to determine the corresponding grades of Xij. This can be done in the following way:

Let Ek (k = 1 ... K) denote the experts taking part in the preliminary assessment, and with Tik – the grades within the range from 1 to 7, which the k^{th} expert gives to the Ai alternative according to the relevant evaluation criterion. The following table can be used for each criterion Cj:

Table 1

Determining the meanings of Xij for the technological alternatives considered under the jth criterion of assessment

Алтернативи Ai	Експерт 1 E_1	Експерт 2 E_2	…….	Експерт K E_K	Xij
A_1	T_{11}	T_{12}	….	T_{1K}	$X_{1J}=\sum_{k=1}^{K} T1k/K$
A_2	T_{21}	T_{22}	….	T_{2K}	$X_{2J}=\sum_{k=1}^{K} T2k/K$
…..	…	…	….	….	……..
A_n	T_{n1}	T_{n2}	….	T_{nK}	$X_{nJ}=\sum_{k=1}^{K} Tnk/K$

When determining the coefficients of importance Wj of the individual evaluation criteria, the following conditions must be met:

$$(0 \leq Wj \leq 1)$$

and $\sum_{j}^{m} Wj = 1$

The following table can be used:

Table 2

Determing the coefficients of importance Wj of the evaluation criteria

Criteria Cj	Expert 1 E_1	Expert 2 E_2	…….	Expert K E_K	Wj
C_1	I_{11}	I_{12}	….	I_{1K}	$W_1=\sum_{k=1}^{K} I1k$
C_2	I_{21}	I_{22}	….	I_{2K}	$W_2=\sum_{k=1}^{K} I2k$
…..	…	…	….	….	……..
C_m	I_{m1}	I_{m2}	….	I_{mK}	$W_m=\sum_{k=1}^{K} Imk$
Overall:	1	1	…	1	1

Because of the peculiarities of the method used here for identifying Xij, some modification is needed in the way in which the Positive Ideal Solution (PIS) and the Negative Ideal

Solution (NIS) of the problem are determined. PIS is defined only as the solution (the technological alternative) with the best Zij values for each evaluation criterion, ie PIS = max Zij, and NIS as the solution (the technological alternative) with the worst Zij value in each of criteria, ie. NIS = min Zij.

4. Approbation of TOPSIS method relevancy for preliminary evaluation and selection of technological transfer options

The main purpose here is to demonstrate the practical applicability of the presented approach for preliminary evaluation and selection of technological transfer options. A real industrial enterprise has been chosen for the algorithm approbation. Its main activity is the production of railings of various types. In order to overcome the management's concern that the information may be used in an unfavourable way for the enterprise, the authors made a confidentiality commitment. For this reason, we use the provisional name of the enterprise "X" Ltd. The information required for the approbation was obtained with the help of executive director (owner) of the enterprise, director and production manager of the plant.

As a result of a situation analysis carried out in ""X" Ltd., the following main problems were identified in the company's activity:

- a bottleneck in the production of railings (powder painting sector) due to the limited capacity and functions of the available powder painting equipment;
- low customer satisfaction due to delayed orders.

In order to achieve higher business results and competitiveness of the company, together with the director and the production manager, an in-depth study has been made of the techniques and technologies available on the market able to remove the existing bottlenecks in production and the resulting difficulties in enterprise operations. For this purpose, web sites of companies and representatives of companies – sales representatives offering equipment and technologies, meeting the needs of "X" Ltd., have been researched. Selected are those, whose technical characteristics correspond to the most of the company's needs. As a result of the survey, a list of 3 possible technological transfer options has been prepared, on the basis of which company innovations can be made to solve the above problems. The list contains the following options:

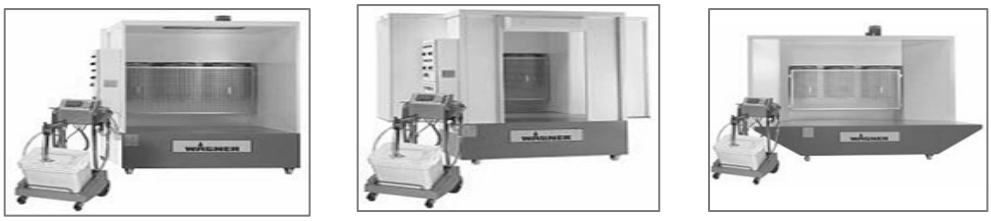
- Option 01. Purchase of 2 powder coating booths "Non-transition" type, Figure 1(a) – for a painting of smaller size parts in relatively small batches and various colors, dimensions: width – 1500 mm; height – 2485 mm; depth – 1900 mm. Clear working opening – 1440 x 1530 mm. Power – 2.2 kW. Required quantity of compressed air – 20 Nm/h. Price 80 000 lv./num.
- Variant 02. Purchase of 1 powder coating booth of "Transition" type, Figure 1(b) – for the painting of medium and large batches of parts with maximum dimensions of 450 x 1300 mm. Also available with two working places. Dimensions: Width – 1500 mm; height – 2485 mm; depth – 1900 mm. Working opening – width 500 mm; height – 1530 mm. Power – 2.2 kW. Required quantity of compressed air – 20 Nm/h. Wood effect. Price 120 000 lv./num.

- Variant 03. Purchase of 1 "Open type" powder coating booth, Figure 1(c) – intended for the painting of large-scale parts or of a complex configuration which do not allow them to pass through the openings of the "Transition" types. Dimensions: Width – 1500 mm; height – 2485 mm; depth – 1900 mm. Power – 2.2 kW. Required quantity of compressed air – 20 Nm/h. Wood effect. Price 170 000 lv./num.

Figure 1

Powder coating booths

a) *b)* *c)*



The available powder painting technique does not have the necessary capacity for the company and is a bottleneck in its production. It is precisely for the elimination of this major problem that there is a need for a technological transfer – the purchase of a new powder coating booth. This gives reason to assume that this technology transfer (one of the listed options) is mandatory for implementation and falls under Priority Group 2.

In view of its resource constraint and the desire to achieve maximum business results, the firm must evaluate each of the possible transfer options. The evaluation is carried out in two stages – preliminary and final evaluation. Preliminary judgment should reject these alternative options for technological transfer that do not meet pre-selected and fairly common criteria. The aim is at an early stage to reject the alternative options that are not appropriate for the company. The remaining options will later be subjected to a detailed assessment in order to select the most suitable of them for transfer in the enterprise.

In this case, the following general criteria have been used in the preliminary assessment of the technological alternatives:

1. Capacity (capabilities) of an enterprise to benefit from the technology;
2. Expected results;
3. Required investment funds;
4. Necessary time to take advantage;
5. Other considerations.

The preliminary assessment of technological transfer options was carried out on the basis of these criteria and with the application of the TOPSIS method. The options are assessed by three internal experts (owner, director and production manager).

The sequence of steps specified in the methodological part of this paper is used:

4.1. Develop a matrix of solutions

For this purpose, the alternative technological transfer options are denoted by Ai (i = 1, ... 3) and the criteria to be evaluated with Cj (j = 1 ... 5).

To develop the decision matrix, it is necessary to define Xij's grades. Each of the experts Ek (k = 1-3) taking part in the preliminary assessment indicates their grades for each of the criteria ranging from 1 to 7. The following feature is considered: for the criteria requiring the minimization of values (for example here are Criterion 3 Required Investment Funds and 4 Required Time to Benefit), a higher value for Xij ranging from 1 to 7 is placed on alternatives of lower value on the criterion and vice versa, on alternatives with a higher value on relevant criterion a lower grade is given.

Grades for each individual criterion are given in a series of tables with the following form:

Table 3

Defining the grades of X_{i1} for technological alternatives on the criterion "Capacity (capabilities) of the enterprise to take advantage of the specific technology"

Alternatives Ai	Expert 1 E_1	Expert 2 E_2	Expert 3 E_3	X_{i1}
A_1	7	7	6	6.67
A_2	7	6	5	6.00
A_3	6	5	4	5.00

Similarly, the values of Xij on the other criteria are determined. On this basis, the matrix of D3x4 solutions has been developed, which has the following form:

	C_1	C_2	C_3	C_4	C_5
A_1	6.67	6.50	7.00	6.00	5.33
A_2	6.00	6.50	6.33	6.00	6.33
A_3	5.00	6.33	5.67	6.00	5.67

4.2. Normalize the decision matrix

Normalization was performed using the formula:

$$y_{ij} = \frac{Xij}{\sqrt{\sum_{i=1}^{n} X_{ij}^2}}$$

Thus, the normalized matrix R3x4 is obtained with the following form:

	C_1	C_2	C3	C_4	C_5
A_1	0.587481498	0.582383	0.635792	0.57735	0.531338
A_2	0.621673543	0.582383	0.574937	0.57735	0.631026
A_3	0.518061286	0.567151	0.514991	0.57735	0.565232

4.3. Calculate the weighted matrix

The evaluation criteria have a different importance for the enterprise. For this purpose, we first determine the coefficients of importance (weights) of each of the criteria Wj (j = 1, ... m).

Table 4

Determination of the coefficients of importance Wj of the evaluation criteria

Criteria Cj	Expert 1 E_1	Expert 2 E_2	Expert 3 E_K	Wj
C_1	0.1	0.12	0.1	0.107
C_2	0.4	0.35	0.3	0.35
C_3	0.3	0.3	0.4	0.333
C_4	0.1	0.1	0.08	0.093
C_5	0.1	0.13	0.12	0.117
Overall:	1	1	1	1.00

With the values of Wj (j = 1, ... m), the values of the parameters of the normalized matrix are corrected (by multiplication). Thus, the weighted matrix Z_{3x4} having the following values was obtained:

	C_1	C_2	C3	C_4	C_5
A_1	0.063	0.204	0.212	0.054	0.062
A_2	0.066	0.204	0.191	0.054	0.074
A_3	0.055	0.199	0.171	0.054	0.066

4.4. Identify the Positive Ideal Solution (PIS) and the Negative Ideal Solution (NIS) to the problem

In view of the method used here for determining Xij, PIS is the solution (the technological alternative) with the best Zij meanings for each evaluation criterion, i.e. PIS = max Zij, and NIS is the solution (the technological alternative) of the worst meaning of Zij on each of the criteria, i. NIS = min. The defined meanings of PIS for each of the assessment criteria are:

	C_1	C_2	C3	C_4	C_5
A_1		0.204	0.212	0.054	
A_2	0.066				0.074
A_3					

The NIS values are:

	C_1	C_2	C3	C_4	C_5
A_1					0.062
A_2				0.054	
A_3	0.055	0.199	0.171		

4.5. Determine the distance of each of the evaluated technological alternatives from PIS and NIS

The distances of the evaluated technological alternatives from PIS and NIS are denoted by Di + and Di- respectively. Using the formulas already defined, their values are calculated:

	D_i^+	D_i^-
A_1	0,012377	0,041779
A_2	0,020549	0,026586
A_3	0,043084	0,004072

4.6. Determining the rank index

The Rank Index shows the relative proximity (likeness) of each alternative to PIS – the best state. It is calculated for each alternative, and its values are in the range between 0 and 1, i. $0 \leq RCi \leq 1$. For the specific case they are:

RC1 = 0.77145;

RC2 = 0.564045;

RC3 = 0.086357.

4.7. Technology transfer alternatives are ranked by the RCi values in a descending order

Alternative A1: RC1 = 0.77145;

Alternative A2: RC2 = 0.564045;

Alternative A3: RC3 = 0.086357.

The higher value of RCi shows a better estimate of the alternative, because it minimizes its distance from PIS and maximizes it against NIS. Therefore, alternative A1 is the best of the three analyzed. It should be selected for further evaluation. It is also advisable alternative A2 to undergo such evaluation, due to the value of RC2, which is close to the best.

From the approbation of the TOPSIS method application for preliminary evaluation and selection of technological transfer options, it can be concluded that the algorithm is applicable in the economic practice. It can be successfully used to evaluate alternative technological transfer options and to elect those of them that have the highest potential to improve business performance. It can help a number of management decisions related to effective technological transfer implementation in enterprises and activation of their innovation activity in order to increase their competitiveness.

Conclusion

The aim of this paper is to propose a method for the preliminary assessment of alternative technology transfer options based on the use of the TOPSIS method (The Technique for Order of Preference by Similarity to Ideal Solution) (Hwang and Yoon, 1981). It allows an

initial assessment and selection of technological transfer options on the base of preliminary selected important criteria. As a result, businesses can reduce the number of options that will later be subject to a more in-depth assessment, from the list of already selected ones, by choosing only those who have good potential and are in their capabilities. In this way, the experts' efforts are focused and their work, concerning the selection of a transfer option in which to invest, is also significantly relieved.

Approbation of the method has confirmed that it is applicable in business practice. It can help to take a number of management decisions related to the implementation of effective technological transfer in enterprises and to stimulate their innovation activity in order to increase their competitiveness.

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