Halyna Rachynska, PhD in Economics
Lviv Polytechnic National University, Ukraine

DEVELOPMENT OF THE TECHNOLOGICAL STRATEGY OF A COMPANY: APPLIED ASPECTS

The article develops methodical approaches to the formation of the technological strategy of a company. The development of the technological strategy has three main stages: 1) evaluation of technologies; 2) selection of technologies; 3) definition of a technological projects' portfolio. Within each stage, the author has identified practical steps for the definition of the most important technological needs of a company, factors for evaluation of its technological potential, and ways to use tools specific to a given company so that technological and business strategies of a company correlated. The new method for calculation of economic efficiency of capital investments has been proposed. It is based on the data regarding necessary capital investments for each year of the project implementation and the profit received from its implementation during the same period. The qualitative factors, which should be taken into account when selecting projects with financial indicators, have been distinguished.
Key words: technology, strategy, portfolio of technological projects, capital investment, efficiency.

Statement of the problem. Technological transformations in the field of artificial intelligence, the blockchain, and Internet of Things are the features of the modern economy and society, which change the processes of production, construction, commerce, education, and many others. There is a rapid spread of technologies and knowledge from producers to business, which promote innovations capable of shaping new forms of labor organization and productivity growth in various fields and economic growth in general. That is why the problem of identification of the most important technological needs for a particular company does not lose its topicality. In this regard, the formation of the technological strategy of a company, within which it is rational to invest money and choose promising technological projects, is quite sensible.

The purpose of this article is to develop methodical approaches to the formation of the technological strategy of a company on the production of metal products with the aim to ensure its competitiveness on the market.

Analysis of recent research and publications. According to I. Koshelupov's definition, any technological strategy includes solutions on such issues as the nature of technology, the degree of technological stability, R&D and technology upgrades, technological gaps[1]. German scholars Dichter and Schneider stated that in the development of a technological strategy it was necessary to consider the following sustainable technological framework conditions: 1) discontinuity of technological development and the dynamics of technology change: markets are experiencing technological leaps, i.e., the turbulence of technological development, which is an increased and heavy assessed risk, moreover, technological know-how become obsolete as fast as production equipment; 2) mergers of traditionally separate technological spheres (the concept of CIM – computer integrated production, which involves the integrated use of industrial, transport, communication, and computer robotics, etc.); 3) the increase of technological complexity, caused, in particular, by growth in the volume of technological innovations and the growing merger of different business activities[2].

A. Andybur[3] describes the next algorithm for the implementation of technological innovations: 1) system analysis of the company's innovation strategy, its structuring and hierarchical representation;

---

[1] Кошелупов, І.Ф. (2009). Система конкурентних стратегій підприємства. *Вісник соціально-економічних досліджень*, 36, 90-96.

[2] Дихтер, И.Г. Шнайдер (2003). *Технологический маркетинг*. Москва: Янус-К.

[3] Андибур, А.П. (2005). Методичний підхід до визначення пріоритетів технологічних інновацій на підприємствах. *Проблеми науки*, 7, 19-24.

2) definition of criteria which evaluate the problem at each level of the goal tree and their interrelation; 3) definition of the real state of development of the structural components of the hierarchy; 4) development of characterizing tables for the evaluation of quantitative and qualitative basic parameters of technological innovations; 5) deliberation of technological innovations according to the system of criteria of each level, calculation of quantitative characteristics and selection of priority directions for innovation processes.

L. Fedulova has noted in her research that determination of the leading role of high-tech manufacturing at the macro level is an important precondition for the development and implementation of the technological development strategy at the micro level; this is possible due to a clear and consistent scientific and industrial policy on the implementation of the country's socio-economic development strategy with clear goals, objectives, and effective social and economic mechanisms for production adaption in accordance with the demands of a changing market. Such an approach will give Ukraine's economy a chance to resolve two main problems: 1) to enter the global context of world affairs and 2) to give dynamics to the scientific and technological development[1].

Considering all mentioned above, practical steps to the formation of the technological strategy of a company and methods of using certain tools for identification of important technological needs require scientific development, in order to link the technological strategy with a strategy of any particular company in general, so that its technological strategy correlated with its business strategy. After all, it is well known that quite often technological strategies suppose only decision-making for the improvement of production processes or equipment upgrade for the needs of a particular company.

Presentation of the main material. The development of the technological strategy has three main stages: 1) evaluation of technologies; 2) selection of technologies; 3) definition of a technological projects' portfolio[2].

The key task which should be resolved by the procedure of the evaluation of technologies is to determine the spectrum of analyzed technologies, to analyze the impact of technologies on competitiveness, and to evaluate the technological potential. When evaluating the technological potential, it is sensible to consider such factors as:

– R&D expenses (in absolute figures and as a percentage of sales);

– expenses for technical renovation;

– human resources (a range of specialties, which company employees have and their level of qualification);

– equipment and tools, patents or other intellectual property;

– distribution of financial resources, and other.

The result of this work is the conclusion of the weaknesses and strengths of specific critical technologies. Technologies, fully developed by a company and not critical in terms of its competitiveness, may be offered for licensing to other users.

Selection of technologies aims to identify those critical technologies, on which a company needs to focus its interests and to direct its investment opportunities. On the basis of this analysis, the matrix in coordinates "importance" – "benefits" of technologies was elaborated.

Table 1

The matrix "importance" – "benefits" of technologies

Critical technologies	The scale of benefits (1-5)				
	1	2	3	4	5

---

[1] Федулова, Л.І. (2008). Стратегія технологічного розвитку: мікроекономічний підхід. *Вісник Національного університету "Львівська політехніка": Проблеми економіки та управління*, 674-681.

[2] Чухрай, Н.І. (2014). *Сучасний інструментарій та галузеві особливості управління підприємствами України: монографія*. Львів: Видавництво Львівської політехніки, 62.

This matrix has an evaluation of each technology from the position of the current and desired state. This creates a foundation for the formulation of a technological strategy, i.e., planning the measures necessary to achieve the desired competitive position. For this reason, the evaluation of a technology's potential helps to identify the areas in which a specific technology needs to be improved (equipment, personnel, expenses). The matrix "importance" – "benefits" of technologies also explains how sensible it is to choose a strategy for technological leadership (attainment of a leading position in the market, development of new technologies, retention of one or another position among the leaders) or a "catching-up" strategy (copying what market leaders are doing, belated access to the market with new products). If a company cedes to competitors in the most important technologies, then the strategy of leadership has no perspectives. However, as this company accumulates resources in one or another technological industry and overcomes a gap with competitors, the situation may change. Since this matrix is crucial in terms of decision-making, it must be drawn up and made a working document for the senior management and technical managers of a company. The result of this stage is a list of foreground measures in the technological field.

It should be noted that academic literature distinguishes some types of innovation strategies[1], which may be acceptable in the development of technological strategies: 1) offensive – is typical for companies that base their activities on the principles of entrepreneurial competition. Usually used by small innovative firms; 2) defensive – is aimed to retain the company's competitive positions in existing markets. The main function of this strategy is to intensify the ratio of "costs-result" in the innovation process. Suchlike strategy requires intensive R&D; 3) imitation – is used by companies with strong market and technological positions. Usually is applied by companies that are not pioneers in the release of certain innovations to the market. It copies the main consumer properties (but not necessarily technical parameters) of innovations released to the market by small innovative firms or leading companies.

When formed, a portfolio of technological projects may be classified according to two features:

1) R&D engineering projects (research, development, and engineering with respect to a product or process). The process needs to be understood in the broad sense, including in this concept the entire production cycle and not only the manufacturing of products. It is sensible to include raw materials, the development of component parts, and the development of supplier systems and the provision of services to consumers into this group;

2) projects which involve capital investment (procurement of production and laboratory equipment).

It is important to understand that a particular company may lack financial resources to support all prepared projects. At the stage of the feasibility study and the choice of the best option, when plans for scientific, research and development work are elaborated and evaluation of technical innovations is made, we need an approach that takes into account all possible consequences – economic, social, environmental, etc. The stages for implementation of this approach are the following:

– among potential options choose those that satisfy the specified limitations;

– results, costs, and economic effect are calculated for each of the selected options;

– option, which provides the maximum value of the economic effect is recognized as the best, and if the maximum value of the economic effect is similar in several options – an option with minimal costs for its achievement.

"When designing the technological process (TP) special attention is always paid to its efficiency. By its nature, performance indicators are divided into economic and technical. Economic performance indicators include capital and consolidated costs and technological cost price of products in accordance with the designed TP"[2].

However, the application of only economic indicators does not allow to accurately evaluate the efficiency of the TP and to decide on its practical implementation, because there are no feedbacks between these indicators and other technical and economic characteristics of production.

Therefore, when the TP's evaluation is made, it is important to use technical indicators of efficiency or to combine technical and economic indicators into a complex indicator.

The technical indicators of the TP's efficiency include:

– TP's reliability indicators – percentage of technologically unrecoverable waste, downtime of technological equipment in scheduled repairs;

---

[1] Ильенкова, С.Д., Гохберг, Л.М. (2007). *Инновационный менеджмент*. Москва: Банки и биржи, 74.

[2] Сорочак, О.З., Рачинська, Г.В.(2010) Сучасні підходи до оцінювання ефективності технологічного процесу. *Вісник Національного університету "Львівська політехніка": Проблеми економіки та управління*, 408-412.

    – manufacturability indicators – flexibility, a coefficient of technological equipment, wasteless production, coefficient of TP's standardization, energy saving;

    – performance indicators – complexity and continuity, the output of finished products;

    – operational indicators of products that are the result of the TP.

The abovementioned indicators of the TP's efficiency can be combined into one complex indicator by application of the widely used method of comparative assessment of objects Data Envelopment Analysis (DEA)[1]. Some studies[2] give an example of DEA application by compiling an algorithm program in the MathCAD software package for serial linear programming.

There is a method based on discounting (depreciation) of the effect of invested capital, which helps to assess the economic efficiency of capital investments. The proposed method for calculating the economic efficiency of capital investments is based on the availability of data on the required capital investments (C_t) for every t-year of T=1 period, T+1 and profit (P_t) from the project for the same period.

The compensation of negative economic effect by positive during the period of investment return is a condition of economic efficiency of capital investments. Also, it is important to consider that the economic effect discounts (depreciates) over time by the rate of compound bank interest that invested capital could have make if held on a deposit in a bank, but not invested in an organizational and technical project (that is to say, these investments were frozen for a certain term).

Estimated profits from the development, implementation, and distribution of fundamentally new products and technology and all capital investments made for these activities in subsequent years (after the first year) can be determined by the proposed formulas:

$$P_t = P_1 \cdot k_{nt} + \Delta P \cdot k_{mt} \; ;$$

$$C_t = C_1 \cdot k_{nt} + \Delta C \cdot k_{lt} \, ,$$

where $P_{t\,-}$ is a profit from the project for the first year of implementation, in UAH; C_t – amount of capital investments for the first year of implementation, in UAH; ΔP and ΔC – average increments of profit and capital investments accordingly over the past years, thousands of UAH; k_{nt} and $k_{nt\,-}$ are correction factors conditioned by changes in profit and capital investments over time; k_{mt} and $k_{lt\,-}$ are correction factors for profits and capital costs in view of the risk.

Correction factors for values following the first year (t ≥2) can be determined by the following empirical dependencies:

$$k_{nt} = 2{,}4 \cdot e \; \cdot \frac{(t - 2{,}2)^2}{1{,}54^2} + 0{,}45$$

$$k_{kt} = 7{,}5 \cdot \frac{t - 0{,}35}{1 + 12{,}7 \cdot (t - 0{,}45)^2} + 0{,}125,$$

where t – index of the year for which these coefficients are calculated (t = 2,3,4 ...T + 1); e – the base of the exponent 2,718).

Due to increasing competition in the market of new products of industrial companies, the risk of obtaining project amounts of profits and future capital investments in the know-how industry also increases. Therefore, correction factors for profits and capital costs in view of the risk are introduced, which, depending on the implementation period of the know-how project, can be determined by such empirical dependencies:

$$k_{mt} = \begin{cases} 0{,}75 \div 0{,}95 \; when \; t > 5 \\ 0{,}95 \; \div 1{,}00 \; when \; 3 \leq t \leq 5 \\ 1{,}00 \; \div 1{,}50 \; when \; t < 3 \end{cases}$$

[1] Cooper, W.W.(2000) *Data Envelopment Analysis: A Comprehensive Text with Models, Applications, References and DEA- Solver Software*. Boston: Kluwer Academic Publishers.

[2] Сорочак, О.З., Рачинська, Г.В.(2010) Сучасні підходи до оцінювання ефективності технологічного процесу. *Вісник Національного університету "Львівська політехніка": Проблеми економіки та управління*, 408-412.

$$k_{lt} = \begin{cases} 0,80 \div 0,95 \text{ when } t > 5 \\ 0,95 \div 1,05 \text{ when } 3 \le t \le 5 \\ 1,05 \div 1,50 \text{ when } t < 3 \end{cases}$$

In order to determine the annual economic efficiency of capital investments, it is necessary to make calculations for as many years as long as the sign of cumulation of the discounted effect does not change to the opposite (from negative to positive).

The payback period (T_{PB}) of capital investments (in years) is determined as follows:

if the discounted economic effect is positive for the first year, then

$$T_{PB} = \frac{C_1}{P_1}$$

if the discounted economic effect for the first year is negative, then

$$T_{PB} = T + \frac{|S_t|}{|S_t| + |S_t + 1|}$$

where S_t – is a cumulative of the discounted economic effect of capital investments.

The coefficient of economic efficiency of an investment project is determined by the next formula:

$$E_H = \frac{1}{T_{PB}}$$

In order to illustrate the application of this methodology and determine the economic efficiency of projected capital investments for the development and implementation of a new technological process for the production of drainage systems (in order to increase the capacity of the production process, m/ h), we have carried out appropriate calculations on the example Limited liability company "ROM Ltd".

Table 2

Initial data for calculations

Indicators	Unit	Symbol	1st year	
			1st option	2nd option
Profit for the first year.	thousands (*K*) UAH	P_{11}	420	650
Capital investments for the first year.	thousands (*K*) UAH	C_{11}	680	870
Discount rate	%	E_x	20	20
Payback period.	years	T_{PB}	<3	<3

1. For the first option, the company's estimated profit for the second year of implementation of the new line is calculated by the formula:

$$P_{21} = P_{11} \cdot kn_{21} + \Delta P_{21} \cdot km_{21}, \text{ UAH.}$$

where P_{11} – the company's estimated profit for the first year of implementation, UAH. kn_{21} – the correction factor caused by the change in profit for the second year; ΔP_{21} – average profit growth for the previous years in UAH, in our case, the average profit growth of the company for the previous years is 362,000 UAH; km_{21} – the correction factor to profit for the second year in view of the risk (when T<3 years $km_{21} = 1,45$).

The correction factor caused by the change in profit for the second year is calculated by the formula:

$$kn_{21} = 2,4 \cdot e \cdot \frac{(2 - 2,2)^2}{2,372} + 0,45 = 2,2$$

Then the estimated profit for the first option (P_{21}) is:

$$P_{21} = 420 * 2,20 + 362 * 1,45 = 924 + 525 = 1449 \ K \ \text{UAH.}$$

2. The estimated profit for the second option (P_{22}) is calculated by the formula:

$$P_{22} = P_{12} \cdot kn_{22} + \Delta P_{22} \cdot km_{22}, \ \text{UAH.}$$

where P_{12} – the company's estimated profit for the first year of implementation according to the second option, UAH; the correction factor caused by the change in profit for the second year according to the second option ($kn_{22} = kn_{21} = 2,20$); ΔP_{22} – average profit growth for the previous years in UAH ($\Delta P_{22} = 590,000$ UAH), km_{22} – the correction factor to profit for the second year in view of the risk according to the second option (when T<3 years $km_{22} = 1,45$).

It is now possible to calculate the estimated profit for the second option for the second year of the project's implementation:

$$P_{22} = 650 * 2,2 + 590 * 1,45 = 1430 + 855,5 = 2285,5 \ K \ \text{UAH.}$$

3. The amount of estimated capital investments into know-how according to both options is calculated by the following formulas:

$$C_{21} = C_{11} \cdot k_{k21} + \Delta C_{21} \ kl_{21}, \ \text{UAH.}$$

where C_{11} – the amount of capital investments for the first year of project's implementation, UAH; k_{k21} – the coefficient caused by the change of capital investments in time for the second year; ΔC_{21} – the average growth of capital investments for the previous years, UAH ($\Delta C_{21} = 212,000$ UAH); kl_{21} – the correction factor to capital investments in view of the risk.

4. The value of the correction factor, caused by the change in capital investments for the second year is:

$$k_{kt} = 7,5 \frac{t - 0,35}{1 + 12,7(t - 0,45)^2} + 0,125 = 7,5 \frac{2 - 0,35}{1 + 12,7(2 - 0,45)^2} + 0,125 = 0,394 + 0,125 = 0,519$$

5. The correction factor to capital investments in view of the risk of increasing competition taken to be 1,25 (payback period of this activities taken to be up to three years).

6. It is now possible to calculate the amount of estimated capital investments according to both options:

a) for the first option (C_{21})

$$C_{21} = 680*0,519 + 212*1,25 = 353 + 265 = 618 \ K \ \text{UAH.}$$

b) for the second option, the amount of estimated capital investments (C_{22}) is calculated when $\Delta C_{22} = 274,000$ UAH.

$$C_{22} = 870*0,519 + 274*1,25 = 451 + 342,5 = 793,5 \ K \ \text{UAH.}$$

Thus, the compensation of negative economic effect by positive during the period of investment return is a condition of economic efficiency of capital investments. Also, there is the rate of compound bank interest that invested capital could have make if held on a deposit in a bank, but not invested in an organizational and technical project (that is to say, these investments were frozen for a certain time).

The payback period of capital investments is determined by the following formula:

$$\sum_{t=1}^{T+1} (P_t - C_t)A_t = 0$$

If $A_t = \dfrac{1}{(1+E_H)^{(t-1)}}$ – discount rate

where T – payback period of investments, in years; t – index of a current year, for which calculations are made. The value of the investment payback period (in years), in our case, is calculated by the formula:

if the discounted economic effect for the first year is negative, then

$$T + \frac{|S_t|}{|S_t| + |S_t + 1|} , years$$

In order to determine the payback period of production lines data from "ROM Ltd" reports was used.

a) according to the first option

$$T_{PB_1} = T_1 + \frac{|S_{t1}|}{|S_{t1}| + |S_{t1} + 1|} = 1 + \frac{260000}{260000 + 457000} = 1{,}36 \; years$$

b) according to the second option

$$T_{PB_2} = T_2 + \frac{|S_{t2}|}{|S_{t2}| + |S_{t2} + 1|} = 1 + \frac{220000}{220000 + 1102000} = 1{,}17 \; years$$

Then the economic efficiency of the project according to both options is:

a) according to the first option

$$E_{H_1} = \frac{1}{T_{PB_1}} = \frac{1}{1{,}36} = 0{,}73$$

b) according to the second option

$$E_{H_2} = \frac{1}{T_{PB_2}} = \frac{1}{1{,}17} = 0{,}85$$

Proceeding from the calculations of economic efficiency and the payback period of the project, it is evident that the proposed new technological line for the production of drainage systems is economically profitable, and the developed methodology is effective in determining the economic efficiency of investments in the developed technological project.

It is important to understand that it is possible to make a selection of projects and accept for consideration not only financial factors but subjective qualitative factors also, such as:

– the probability of technical success: a chance of obtaining a positive technical result estimated by technical staff;

– the probability of commercial success: a chance of getting a positive commercial result estimated by sales specialists;

– refunds to the company based on the project's cost: estimated financial income in relation to the project costs. This criterion includes the benefits achieved as a result of the project implementation (if the project was successful);

– strategic compliance: the level of compliance with the company's overall strategy, estimated by the board of directors or the strategic planning team (if any);

– compliance with basic technologies: the significance of a specific project for strengthening the company's position in strategic technologies;

– patenting of this technology: any R&D project becomes more attractive when the result can be protected by a patent;

– compliance with technological threats and opportunities which can occur.

So, if we set the weighting factor for each criterion, we'll be able to compile a table and evaluate the benefits of each project evaluated regarding a specific criterion, and then multiply the weight parameters by points (high -5, low -1). Thus, projects are arranged in the order of priority in accordance with the indicators of this table (Table 3).

Table 3

The matrix of projects' selection by quality factors

Project selection criteria	Weighting factor	Projects						
		A	B	C	D	E	F	G
The probability of technical success								
The probability of commercial success								
Refunds based on project costs								
Strategic compliance								
Compliance with the basic specialization of the company								
Level of compliance with technological threats and opportunities								
The level of patentability of the technology								

Projects are accepted for implementation, starting from the highest in the list and stopped only when the budget is depleted. At this stage, the formed portfolio is reviewed for balance with regard to such parameters as risk, return and timing. This procedure ensures a portfolio balance relative to a specific variable. For example, all projects are extremely promising, however, they are very risky and long-lasting. If this portfolio is not acceptable for the company, i.e., not balanced by some parameters, the projects must be reworked, and the whole process is repeated again. Reworking projects means that, for example, two projects may be combined into one by changing the goal and put their synergistic properties and common components together. Or any project may be allocated with more money in order to reduce the time of its implementation, etc. The final portfolio of projects is formed as a result of this iterative process.

At the stage when the priority of technological projects has already been determined, it is necessary to develop a strategy for the implementation of each of them. The development of these reference points is usually associated with the technological needs of the company, but the following strategic approaches will be relevant when choosing how to get technology (for projects that combine R&D and engineering): internal development, research on contracts with research institutes or universities, takeover of companies with the necessary technological potential, licensing, internal venture groups, joint ventures or other forms of associations, employment of staff with the required qualification, etc.

Conclusions. The technological strategy of the company is a prerequisite for its dynamic economic development. The main reasons for the development of the company's technological strategy are to ensure the competitiveness of its products, improve its image on the market, conquer new markets, reduce the resource consumption of products, and increase in cash flow.

Therefore, the availability of modern databases, information support, formed portfolio of technological projects, developed methodological recommendations and instructions on monitoring the technological condition and opportunities of the company has strategic significance. It is obvious that the implementation of technological innovations requires material, organizational and investment resources. Thus, the issue of the development of own technologies or their purchase in the market (transfer) is resolved by manufacturers independently, depending on the level of complexity, the scope of application, and dynamics of certain technologies.

References:

1. Koshelupov, I. F. (2009). *Systema konkurentnykh stratehii pidpryiemstva* [The system of competitive strategic companies]. *Visnyk sotsialno-ekonomichnykh doslidzhen* [Bulletin of socio-economic research], 36, 90-96. [in Ukrainian].
2. Dichter, I.G. Schneider (2003). *Tekhnologicheskiy marketing*. [Technology Marketing]. Moscow: Janus-K. [in Russian].
3. Andibur, A.P. (2005). Metodychnyi pidkhid do vyznachennia priorytetiv tekhnolohichnykh innovatsii na pidpryiemstvakh. [Methodical approach to the definition of priorities of technological innovations at enterprises]. *Problemy nauky* [Problems of Science], 7, 19-24.[in Ukrainian].
4. Fedulova, L.I. (2008). Stratehiia tekhnolohichnoho rozvytku: mikroekonomichnyi pidkhid. [Technology Development Strategy: Microeconomic Approach]. *Visnyk Natsionalnoho universytetu "Lvivska politekhnika": Problemy ekonomiky ta upravlinnia* [Bulletin of the Lviv Polytechnic National University: Problems of Economics and Management], 628, 674-681. [in Ukrainian].
5. Chukhray, N.I. (2014). *Suchasnyi instrumentarii ta haluzevi osoblyvosti upravlinnia pidpryiemstvamy Ukrainy* [Modern toolkits and branch features of management of enterprises of Ukraine]. Lviv: Vydavnytstvo Lvivskoi politekhniky [in Ukrainian].
6. Ilyenkov, S.D., Gohberg, L.M (2007). *Innovacionnyj menedzhment.* [Innovative management: the manual]. Moscow: Banki i birzhi [in Russian].
7. Sorochak, O.Z., Rachinskaya, G.V. (2010). Suchasni pidkhody do otsiniuvannia efektyvnosti tekhnolohichnoho protsesu [Modern approaches to assessing the effectiveness of the technological process.] *Visnyk Natsionalnoho universytetu "Lvivska politekhnika": Problemy ekonomiky ta upravlinnia* [Bulletin of the Lviv Polytechnic National University: Problems of Economics and Management], 668, 408-412. [in Ukrainian].
8. Cooper, W.W. (2000) *Data Envelopment Analysis: A Comprehensive Text with Models, Applications, References and DEA- Solver Software*. Boston: Kluwer Academic Publishers. [in English].