UDC 658.5.012.1. 001.76 DOI: 10.5862/JE.240.9

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DESIGNING THE OPERATION CYCLE OF A MANUFACTURING AND TECHNOLOGICAL SYSTEM

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ПРОЕКТИРОВАНИЕ ОПЕРАЦИОННОГО ЦИКЛА ПРОИЗВОДСТВЕННО-ТЕХНОЛОГИЧЕСКОЙ СИСТЕМЫ

In order to manage innovating projects, he paper offers a method for estimating the degree by which a manufacturing and technological system (ECO – system) has been converted during the operation cycle into an economic system. The operation cycle of a manufacturing and technological system is seen as a circular integrated set of vectors of cash or cash equivalent flows arising as a result of converting technological processes into products in the form of technological stages or end products with market cost. The operation cycle consists of two contours formed by five vectors of cash equivalent flows. The first contour is a right-angled triangle of vectors that is formed by: the vector of direct technological operation costs, the vector of tangible and intangible assets and their summation being the vector of manufacturing capital. The second contour is also a right-angled triangle of vectors formed by: the vector of direct technological operation costs, the vector of net income and their summation being the vector of sales value. The modules and directions of all vectors are variables. The level of converting technological processes into money equivalent flows has been offered to estimate by the conversion coefficients. The ideal manufacturing and technological system has some upper limits of the conversion coefficients of the operation cycle. Namely, the vector of sales value divided by the vector of a manufacturing capital and the vector of tangible and intangible assets divided by the net income vector are equal to one. The graphical interpretation of an ideal operation cycle is an equilateral triangle. In the operation cycle of a real manufacturing and technological system the conversion coefficients are less than one. Every criterion in this integrated set may change simultaneously when any innovation is implemented in a manufacturing and technological system.

IDEAL (REAL) OPERATION CYCLE; VECTOR FIELD OF ECONOMIC POTENTIAL (LIABILITIES; ASSETS); CONVERSION OF TECHNOLOGICAL PROCESSES; MANUFACTURING AND TECHNOLOGICAL SYSTEM; VECTORS OF CASH EQUIVALENT FLOWS.

Для управления инновационными проектами предложен способ оценки уровня конверсии в операционном цикле производственно – технологической системы (ECO – systems) в экономическую систему. Операционный цикл производственно – технологической системы рассматривается как замкнутый интегрированный комплекс векторов денежных или их эквивалентов потоков, возникших как результат конвертации технологических процессов в продукты в форме технологических переделов или конечных продуктов, имеющих рыночную стоимость. Операционный цикл состоит из двух контуров, сформированных векторами потоков денежных эквивалентов. Первый контур является прямоугольным треугольником векторов, сформированным: вектором прямых технологических операционных затрат, вектором материальных и нематериальных активов и их суммой, являющейся вектором производственного капитала. Второй контур является также прямоугольным треугольником векторов, сформированным: вектором прямых технологических операционных затрат, вектором чистого дохода и их суммой, являющейся вектором объема продаж. Модули и направления всех векторов являются переменными величинами. Уровень конвертации технологических процессов в потоки денежных эквивалентов предложено оценивать коэффициентами конверсии. Идеальная производственно – технологическая система имеет верхний предел коэффициентов конверсии операционного цикла. А именно, вектор объема продаж, деленный на вектор производственного капитала и вектор материальных и нематериальных активов деленный на вектор чистого дохода равны единице. Графической интерпретацией идеального операционного цикла является равносторонний треугольник. В операционном цикле реальной производственно – технологической системы коэффициенты конверсии меньше единицы. Каждый критерий интегрированного комплекса изменяется когда (если) осваивается любая инновация.

ИДЕАЛЬНЫЙ (РЕАЛЬНЫЙ) ОПЕРАЦИОННЫЙ ЦИКЛ; ВЕКТОРНОЕ ПОЛЕ ЭКОНОМИЧЕСКИХ ПОТЕНЦИАЛОВ (ПАССИВЫ; АКТИВЫ); КОНВЕРСИЯ ТЕХНОЛОГИЧЕСКИХ ПРОЦЕССОВ; ПРОИЗВОДСТВЕННО-ТЕХНОЛОГИЧЕСКАЯ СИСТЕМА; ВЕКТОРЫ ПОТОКОВ ДЕНЕЖНЫХ ЭКВИВАЛЕНТОВ.

Vector field of an economy ECO-system

In an innovation market economy all needs of people are bought and sold and, therefore, these needs have a market cost in cash or cash equivalent. Thus, from a physical and mathematical point of view, the economy is the field of economic potentials (Liabilities *L* and Assets *A*) where the «buy-sell» process (difference of potentials) is a dual process of forming cash flows with magnitude and direction. It is known that mathematical functions with magnitude and direction are vectors [1–3]. The gradient of potentials, i. e., Liabilities and Assets, forms the vector of cash or cash-equivalent flows. The engineering business is seen as an engine working on the basis of the gradient of potentials (Liabilities and Assets). In this case, liabilities and assets fulfill the functions of potentials of economic fields: «buy-sell» or «resources-results». For example, the results of business such as the assets of technological stages and taxes become liabilities in the subsequent technological stages (zones of financial responsibility) of enterprises and in the municipality budget. Therefore, the terms «liabilities and assets» determine the function of potentials.

In this context, we understand by **production management** [4] an economic system the infrastructure of which realizes the function of an engineering change order (ECO) [5] on the basis of the balance of supply and demand of products and services using different markets (fields of potentials).

An operation cycle is a circular integrated set of engineering and technological processes on the basis of mechanical, electrical, chemical, thermodynamical, optical and any other physical systems arising during the accounting period in the course of the ordinary activities of a manufacturing and technological system and as a result of the synergetic effect [6–8] are converted to an economic system in the form of cash-equivalent flows of sold products. In other words, an operation cycle is an integrated set of continuous processes ensuring the conversion of technological systems into economic systems. In this sense, manufacturing and technological systems (ECO-systems) are the tools for the processes of conversion. It means that the manufacturing and technological system should be estimated in relation to the parameters of economic benefits. The main economic results of the conversion operation cycle are:

«**Net income** is an increase in the economic benefits emerging during the accounting period in the form of inflows or enhancements of assets or some decreases of liabilities that result in increases in equity, other than those related to contributions from equity participants» [9–11].

«**Revenue** is a gross inflow of economic benefits emerging during the accounting period in the course of ordinary activities of the entity. These inflows result in an increase in the equity of the shareholders, with investments calculated on the basis of the direct share in the equity» [9–11].

«**Profit** is the residual amount that remains after expenses (including capital maintenance adjustments, where appropriate) have been deducted from income. Any amount over and above that is required to maintain the capital at the beginning of the period is profit» [9, 10, 11]. Net profit is the property of owners, members and participants of equity. It consists of two parts. Net profit is the amount required to pay for non-operating expenses and to pay dividends on the basis of shareholders' meeting decision. Therefore, managers of an enterprise try to reduce the need in a net profit. Maintenance adjustments capital is the main tool to manage the taxable base of operating profit. As a rule, innovative enterprises do not have a taxable base of operating profit.

The main function of **operation management** is to organize the production ensuring the manufacturing of products with the required structure of direct technological costs in an operation cycle and consumer properties having competitive advantages and, consequently, having market cost.

The priority structure of direct technological costs $G_0 W_0$ of the operation cycle:

According to Chapter 25 of the Tax Code of the Russian Federation, tax accounting should substantiate the planned net profit.

As for management accounting, it has to implement an operation cycle with a required coefficient of capitalization λ:

$$\lambda = \frac{V_{sv}}{G_0 W_0}, \quad (1)$$

where V_{sv} is sales value of the operation cycle, G_0 is the designed production volume and W_0 is the designed unit costs.

If direct operating costs C_{oc} of the operation cycle are equal to 100 %, then material costs C_{mc} should be equal to 30 %; additional costs C_{ac} should be equal to 20 %; labor payment costs C_{lp} should be equal to 25 % and finally, depreciation of tangible costs C_{dc} should be equal to 15 %.

The balance equation of costs in the operation cycle has the form:

$$100\ \% = C_{mc} / C_{oc} + C_{ac} / C_{oc} + C_{lp} / C_{oc} +$$

$$+ C_{dt} / C_{oc} \approx 30\ \% + 20\ \% + 35\ \% + 15\ \%.$$

If additional costs C_{ad} are 20 %, then the amortization of intangible assets C_{ai} is equal to 10 % and the summation of tax fixed assets N_{fa}, tax of land N_L and other costs are approximately equal to 10 % too.

Namely,

$$C_{ac} / C_{oc} \approx 20\ \% = C_{ai} / C_{ac} +$$

$$+ (\ldots N_{fa} + N_L + \ldots) / C_{ac} \approx 10\ \% + 10\ \%.$$

The net income D_0, including net profit P_0 and capital maintenance adjustments C_{ma} is the summation of depreciation of tangible assets C_{dt} and amortization of intangible assets C_{ai}. Herewith, the fund formed from C_{dt} should be used only for simple reproduction, while the fund formed from C_{ai} is the resource for funding the extended reproduction of fixed assets.

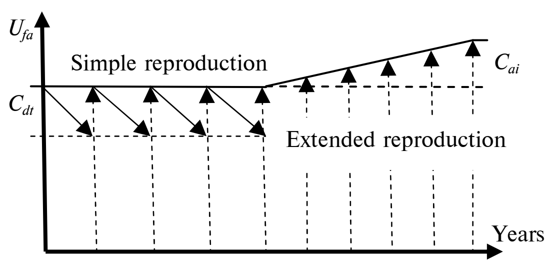

Fig. 1. Simple and extended reproduction of fixed assets U_{fa} of a manufacturing and technological system

Management accounting tends to increase the parameters of the operation cycle on which a coefficient of capitalization depends. It means that labor payment in the structure of assets in the operation cycle increases up to 35 %. In this case, an innovative enterprise will have competitive advantages on a labor market in a municipality. Besides, tax payments to all levels of budgets are prioritized for innovative enterprises of the municipality. Therefore, there is a tendency to try to achieve tax payments of 20 % in the structure of assets in management accounting.

Operating profit tax is the exception from the general rule. The fact is that the amortization of intangible assets decreases the taxable base of operating profit taxes; therefore, innovative enterprises with intangible assets do not pay the tax of operating profit. However, if enterprises have intangible assets, such enterprises pay more land taxes than enterprises without intangible assets.

The system of equations for an ideal operation cycle of ideal manufacturing and technological system

The equation for the cost of manufacturing and technological capital (balance cost of a manufacturing and technological system) consists of the summation U of tangible U_{fa} and intangible assets U_{ia} and direct technological operation costs $G_0 W_0$:

$$Q = U + G_0 W_0. \quad (2)$$

The equation of manufacturing and economic capital (economic system) consists of the sales value V_{sv} of products and services equal to the summation of direct technological operation costs $G_0 W_0$ and net income D_0:

$$V_{sv} = G_0 W_0 + D_0, \quad (3)$$

where any technological equipment, any manufacturing and technological system and any production enterprise have their characteristic GW in the form of parabola:

$$W = aG^2 + bG + c. \quad (4)$$

Project parameters of the manufacturing and technological system:

$$G_0 = -b / 2a; \quad W_0 = (4ac - b^2) / 4a.$$

Vector of direct technological operation costs G_0W_0

The designed parameters of business are:

G_0 is the production volume in physical units (unit/year);

W_0 is the unit costs (rub/unit).

If ΔG and ΔW are the limits of change of parameters in business, then coefficients *a, b, c* of equation (4) are found in three points from the range of change of production volume *G* and unit costs *W*.

Table 1

Example of the dependence of unit costs *W* on production volume *G* for a furniture enterprise [12]

Parameters of the manufacturing and technological system	First year	Second year	Third year
Production volume, *G*, thousand m^3/year	22.4	26.4	26.2
Unit costs of production, *W*, thousand rub./m^3	10.5	10.7	10.4

Based on Tab. 1, the system of equations is formed in order to find the numerical value for *a, b, c* (4):

$$501.8a + 22.4b + c = 10.5;$$

$$697.0a + 26.4b + c = 10.7;$$

$$686.4a + 26.2b + c = 10.4;$$

then $W = 0.29G^2 - 13.90G + 176.30.$

$G_0 = 13.90/2{\cdot}0.29 = 24.31$ thousand m^3/year;

$W_0 = (4{\cdot}0.29{\cdot}176.30 - 13.90)/4{\cdot}0.29 = 7.47$ thousand rub/m^3.

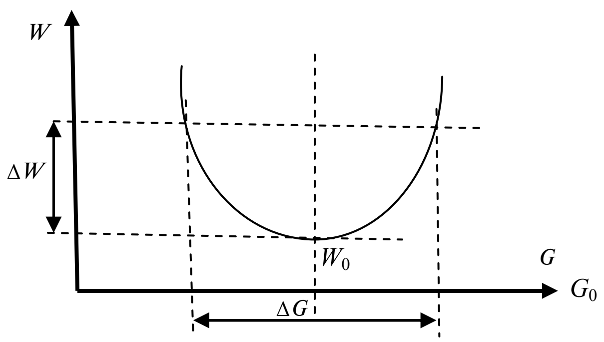

Fig. 2. Characteristic *GW* of any manufacturing and technological system

Productivity balance of technological and economic systems of the operation cycle

It is necessary to design an MTS that ensures the equality of the productivity of the wear of fixed assets and the productivity of operating costs. In this case the balance cost of fixed assets U_{fa} should be estimated by costs approach. The balance equation of productivity has the form:

$$T_{U_{fa}} \Rightarrow T_{G_0W_0} = \frac{U_{fa}}{R_G} = \frac{G_0W_0}{R_0}, \quad (5)$$

where R_G is the business constant determining annual resources of the useful life of fixed assets in hour/year; R_0 is business constant determining the annual resources of work time in hour/year. The equation (5) can be written in the form:

$$k = \frac{R_0}{R_G} = \frac{G_0W_0}{U_{fa}}, \quad (6)$$

where *k* is business constant determining its industry and which can be determined by industry. For example, a business relating to the metallurgical industry has $k = 0.5$, an engineering enterprise has $k = 1.0$, enterprises related to the «Gasprom» business have a numerical value of the constant k equaling 0.27. The business constant of forest industry enterprises has the *value of 0.8.*

Constant of business k for an enterprise as an integrated set of manufacturing and technological systems

Balance cost of fixed assets of an enterprise is equal to the summation of balance cost of each technological stage (MTSs):

$$U_{fa} = U_1 + U_2 + \ldots + U_i. \quad (7)$$

Operating costs of all technological stages are equal to the summation of operating costs of each technological stage (MTSs):

$$C_{oc} = C_1 + C_2 + \ldots + C_i. \quad (8)$$

These equations may be presented in the form:

$$\frac{C_{oc}}{U_{fa}}U_{fa} = \frac{C_1}{U_1}U_1 + \frac{C_2}{U_2}U_2 + \ldots + \frac{C_i}{U_i}U_i;$$

$$k_{mts}U_{fa} = k_1U_1 + k_2U_2 + \ldots + k_iU_i; \quad (9)$$

$$k_{mts}U_{fa} = k_i(U_1 + U_2 + \ldots + U_i).$$

$$k_{mts} = k_i, \text{ where } k_i = \frac{C_i}{U_i}.$$

Constant of business k of each technological stage is equal to the constant of businesses k of each MTS of the enterprise.

Five vectors of cash equivalent flows which implement the conversion of manufacturing and technological processes are the following:

$\bar{V}_{sv}$, ***rub/year***, is the ***sales value*** including taxes to budgets of all levels.

$\bar{G}_0\bar{W}_0$ is the ***direct technological costs*** including

– operating direct technological costs: the construction materials; energy resources; spare parts; repair and technological tools;

– labor payment including taxes and payments.

$\bar{D}_0$ is the ***net income for simple and extended reproduction of business*** including

– the capital maintenance adjustments consisting of the depreciation of tangible assets and the amortization of intangible assets;

– net profit to support joint stock capital in the form of dividends.

$\bar{Q}$ is the ***manufacturing capital*** including

– the direct operating technological costs $\bar{G}_0\bar{W}_0$ and the fixed assets and intangible assets $\bar{U}$.

The mathematical model of the operation cycle in an ideal manufacturing and technological system

Eqs. (2) and (3) can be written in the form:

$$\frac{V_{sv}}{G_0W_0 + D_0} = 1, \quad (10)$$

$$\frac{Q}{U + G_0W_0} = 1. \quad (11)$$

Consequently, Eqs. (10) and (11) may be equated:

$$\frac{Q}{U + G_0W_0} = \frac{V_{sv}}{G_0W_0 + D_0}. \quad (12)$$

Eq. (12) in a dimensionless form is the following:

$$\frac{V_{sv}}{Q} = \frac{G_0W_0 + D_0}{U_{fa} + U_{ia} + G_0W_0} =$$

$$= \frac{\frac{G_0W_0}{U_{fa}} + \frac{P_0}{U_{fa}} + \alpha + \beta\frac{U_{ia}}{U_{fa}}}{1 + \frac{U_{ia}}{U_{fa}} + \frac{G_0W_0}{U_{fa}}} = \frac{k + \alpha + \beta\frac{U_{ia}}{U_{fa}} + \frac{P_0}{U_{fa}}}{1 + k + \frac{U_{ia}}{U_{fa}}}. \quad (13)$$

If $V_{sv}/Q = \upsilon$ is the conversion coefficient, $k = G_0W_0/U_{fa}$ is the characteristic of business, $D_0/U_{fa} = m$ is the coefficient of capital maintenance adjustments, then the parametric equation (13) of the operation cycle of the ideal manufacturing and technological system has the form:

$$\vartheta = \frac{k + m}{1 + k + \frac{U_{ia}}{U_{fa}}}, \quad (14)$$

where $m = \frac{P_0}{U_{fa}} + \alpha + \beta\frac{U_{ia}}{U_{fa}}$. (15)

Analysis of parametric dependence (14) for the ideal manufacturing and technological system

If the limit of the coefficient of capital maintenance and fixed assets adjustments m tends to one, then the limit of the conversion coefficient in a technological system will also tend to one. In this case dependence (13) can be written in the form:

$$k + \alpha + \beta\frac{U_{ia}}{U_{fa}} + \frac{P_0}{U_{fa}} = 1 + k + \frac{U_{ia}}{U_{fa}},$$

$$\alpha + (\beta - 1)\frac{U_{ia}}{U_{fa}} + \frac{P_0}{U_{fa}} = 1, \quad (16)$$

$$D_0 = U_{ia} + U_{fa} = U,$$

where α is the depreciation rate of tangible assets (fixed assets); β is the amortization rate of intangible assets; U_{ia} is the balance cost of intangible assets in the MTS equal to its balance cost estimated by the income approach U_{mia} minus the cost of the MTS estimated by the costs approach U_{fa}.

The upper limit of the conversion coefficient of the ideal manufacturing and technological system is equal to one:

$$Lim\vartheta_{m\to1} = Lim_{m\to1}\frac{k + m}{1 + k + \frac{U_{ia}}{U_{fa}}} = 1. \quad (17)$$

An integrated set of systems the parameters of which are described by equation (17) is the following:

The technological machine (TM) is the technological equipment which presents an integrated set of tangible and intangible assets, consisting of mechanical, electrical and/or chemical engineering solutions, tools for manufacturing the elements of technological (operation) stages or whole technological (operating) stages having a market cost.

The manufacturing and technological system (MTS) is an integrated set of technological machines (tangible and intangible assets) providing the manufacturing of technological stages and/or end products with a market cost. The results of this operation cycle are net income and sales value.

The enterprise is an integrated set of manufacturing and technological systems; the results of the operation cycle are net revenue, sales value and tax payment to budgets of all levels.

Municipality is an integrated set of a system of industrial enterprises, the results of operation cycles of which are the budgets necessary and sufficient for ensuring the life activity of people in the municipality.

The subjects of the Russian Federation.

Parameters of an operation cycle of real manufacturing and technological systems

Operation cycle of metallurgical enterprises

Three metallurgical enterprises, JSC «Severstal», JSC «Magnitogorsk metallurgical company» and JSC «Novolipetsky metallurgical company», are similar in their technological and economic parameters.

The technological similarity of enterprises is determined by similar manufacturing and technological systems that produce steel sheets of practically equal volume and equal sales value.

Economical similarity of enterprises is confirmed by the equal numerical value of business characteristics and net income.

Geometrical interpretation of the operation cycle in the form of a vector triangle allows to combine two approaches to estimate technological and economic similarities of enterprises.

The main criteria of technological and economic similarities of enterprises are parametric equations.

Parameters determining the economic ECO-system of a manufacturing and technological system of an enterprise:

– operating profit, $P = V_{sv}/r$, where V_{sv} is the sales value with a value added tax (+18 % if products are sold on domestic market), r is the return on sales (40–15 %);

– operating profit tax, $Np = (P - N_{fa})\psi_p$ (ψ_p is the tax rate on operating profit: 20 % in budgets of two levels is equal to 2 % + 18 %) [14];

Table 2

The initial economic parameters of three similar metallurgical enterprises that manufacture steel sheets [13]

Parameters in mln $ USA	JSC «MMC»	JSC «NLMC»	JSC «Severstal»
Cost of equity capital, A in 2006 (19.04.2006) in 2002	7892.94 725 10.9 (10.1)	13964.22 1575 8.9 (9.8)	7452.80 1214 6.1 (11.3)
Sales value, Vsv, $/year	5380.00 1707 3.2	4468.73 1322 3.4	5055.17 1747 2.9
Return on sales, $r = P/V \cdot 100$ %	24.6 % 15.7 % 1.6	41.6 % 23.9 % 1.7	35.2 % 17.7 % 2.0
Net profit, P_0	947.00 179.2 5.3	1385.34 207.3 4.7	1212.00 190.9 6.4

– fixed assets tax, $N_{fa} = \psi_{fa} U_{fa}$ (ψ_{fa} is the tax rate on fixed assets: 0–2.2 %) [14];

– planned net profit, $P_0 = (P - N_{fa})(1 - \psi_p)$;

– operating costs, $C_{oc} = V_{sv} - P$;

-balance cost of fixed assets, $U_{fa} = C_{oc}/k$ (k is the business characteristic, for metallurgical enterprises $k = 0.5$);

– depreciation of tangible assets, $C_{dt} = \alpha U_{fa}$ (α is the depreciation rate of tangible assets: for $\alpha > \psi_{fa}$, α should be greater than ψ_{fa});

– amortization of intangible assets, $C_{ai} = \beta U_{ia}$ (β is the amortization rate of intangible assets: as rule $\beta U_{ia} = (P - P_0)$, then $\beta = (P - P_0)/U_{ia}$);

– balance cost of intangible assets, U_{ia} ($U_{ia} = U_{fa(ia)} - U_{fa}$, where $U_{fa(ia)}$ is the fixed assets estimated by income approach);

– net income, $D_0 = P_0 + C_{dt} + C_{ai}$.

Graphical interpretation of parameteric equation (14) developed on the basis of the Pythagorean Theorem [15, 16].

Eqs. (10) and (11) will be written in the form:

$$\frac{V_{sv}^2}{(G_0 W_0)^2 + D_0^2} = 1, \qquad (17)$$

$$\frac{Q^2}{U_{fa}^2 + (G_0 W_0)^2} = 1. \qquad (18)$$

Consequently, Eqs. (17) and (18) may be equated:

$$\frac{Q^2}{U_{fa}^2 + (G_0 W_0)^2} = \frac{V_{sv}^2}{(G_0 W_0)^2 + D_0^2}. \qquad (19)$$

Table 3

The analysis of the parameters of the enterprise on the basis of Eq. [14]

Cost of equity capital on stock market, mln $	JSC «MMC»		JSC «NLMC»		JSC «Severstal»	
	2002 725	2006 7892.94	2002 1575	2006 7892.94	2002 1214	2006 7452.80
Sales value, V_{sv}	1707	5380.00	1322	4468.73	1747	5055.17
$Q = U_{fa}+G_0W_0$	4296.33	11884.57	3090.4	6853.52	4274.1	9597.87
$\mathbf{v = V_{sv}/Q}$	**0.40**	**0.45**	**0.43**	**0.65**	**0.41**	**0.53**
G_0W_0	1334.33	3771.43	990.40	2411.85	1334.10	3046.45
Balance cost, U_{fa}	2962	8113.14	2160	5519.42	2940	6551.42
$\mathbf{k = G_0W_0/U_{fa}}$	**0.45**	**0.47**	**0.46**	**0.44**	**0.45**	**0.47**
Net income, D_0	242.2	1154.15	285.1	1578.52	293.8	1441.31
$\lambda = V_{sv}/G_0W_0$	1.28	1.43	1.42	1.85	1.31	1.66
$\gamma = (G_0W_0+D_0)/V_{sv}$	0.92	0.92	0.92	0.89	0.93	0.89
$\mu = D_0/G_0W_0$	0.18	0.30	0.30	0.65	0.22	0.47
$m = D_0/U_{fa}$	0.08	0.14	0.13	0.29	0.10	0.22
$v_p = (k+m)/(k+1)$	0.38	0.42	0.42	0.53	0.40	0.48
Unit costs, W, $/т	143.8		122.7		151.3	
Constant of business						
$k = G_0W_0/U_{fa}$	0.49		0.47		0.49	
$v = V_{sv}/Q$	0.42		0.43		0.37	
$m = D_0/U_{fa}$	0.10		0.13		0.10	

Eq. (19) in a dimensionless form is the following:

$$\frac{V_{sv}^2}{Q^2} = \frac{(G_0W_0)^2 + D_0^2}{U_{fa}^2 + (G_0W_0)^2}. \qquad (20)$$

If $V_{sv}/Q = \upsilon$ is the conversion coefficient, $k = G_0W_0/U_{fa}$ is the characteristic of business, $D_0/U_{fa} = m$ is the coefficient fixed assets maintenance, then the equation (24) will have the form:

$$\left[V_{asv}(Q)\right]^2 = (G_0W_0)^2 + \left[D_0(U)\right]^2$$
$$\textit{if} \quad (G_0W_0)^2 = \left[D_0(U)\right]^2 \qquad (25)$$
$$\textit{then} \quad 2\left[D_0(U)\right]^2 = \left[V_{sv}(Q)\right].$$

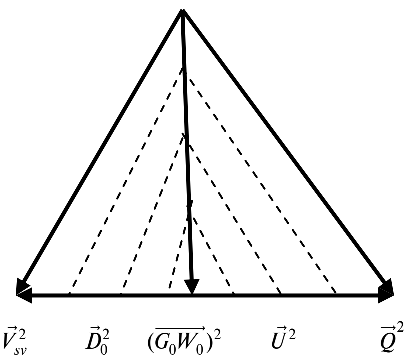

Fig. 3. Graphical interpretation of the operation cycle of the ideal manufacturing and technological system

Conclusion. Parametric analysis of the operation cycle of the ideal manufacturing and technological system allowed to formulate an integrated set of criteria for innovative tasks of an engineering business.

The integrated set of similarity criteria has the form:

1. $\vartheta = V_{sv} / Q \le 1$ is the **conversion criterion** of the operation cycle in the ideal manufacturing and technological system equal to the ratio between the sales value of products and services sold and the cost of manufacturing capital. The conversion criterion of a real operation cycle is less than 45 %.

2. $\lambda = \dfrac{V_{sv}}{G_0W_0} \le 2$ is the **criterion of capitalization** of the operation cycle equal to the ratio between the sales value of products and services sold and the direct technological costs. Its numerical value cannot be more than 2 in an ideal operation cycle. The criterion of capitalization of a real operation cycle reaches only 1.5.

3. $M = D_0 / U \le 1$ is the **criterion of capital maintenance adjustments** equal to the ratio between the net income and the balance cost of the summation of tangible and intangible assets. The numerical value of this criterion for the operation cycle in an ideal manufacturing and technological system equals one. As a rule, intangible assets do not exist in the structure of manufacturing capital or their amount is very small; therefore M << 1.

4. $\mu = \frac{D_0}{G_0 W_0} \le 1$ is the **criterion of net income** equal to the ratio between the net income and the direct technological costs. The criterion cannot be more than one for a real operation cycle in a manufacturing and technological system.

Every criterion in this integrated set may change simultaneously when any innovation is implemented in the manufacturing and technological system.

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