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OPERATIONS MANAGEMENT: CONVERTING MANUFACTURING CAPITAL IN MANUFACTURING-TECHNOLOGICAL SYSTEMS OF ENGINEERING BUSINESS

A.N. Shichkov

Vologda State University, Vologda, Russian Federation

The article is dedicated to rethinking Kondratyev's research of economic environment in countries having the developed market economy. The methodology and the results of his research allowed us to conclude that there is no national economy, but there are national economic models. The initial parameters in these models are the needs of people ensuring their life activity. These conclusions have been made by analyzing prior indicators of different countries and the improvement rate of technological and manufacturing assets. Kondratyev's waves are the results of human activity in an objective economic environment directed at fulfilling people's needs. Shumpeter also suggested improving economic models based on continuous human needs in innovative products, technologies and efficient manufacturing structures. To respond to these challenges, we offer to use the first and second laws of thermodynamics. Based on these laws we have developed a mathematical model for converting manufacturing capital into monetary capital in the form of produced and sold products and services. The studies of a conversion operating cycle in real engineering business have shown that the market cost of business on the stock market and its result in the form of sold products are determined by a criterial equation including five similarity criteria. The mathematical model of operations management has been created based on an operating cycle converting the manufacturing capital into monetary capital in the form of produced and sold products and services. Further research will be dedicated to extending this approach in evaluative technologies of tangible and intangible assets, estimation of business by the market capital method, designing innovative projects, organization of manufacturing processes based on transfer operating costs within technological stages being at the same time the zones financial responsibility, organization of management accounting.

Keywords: conversion operating cycle in engineering business; operations management; criterial equation of conversion operating cycle; similarity criteria of operating cycle.

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ОПЕРАЦИОННЫЙ МЕНЕДЖМЕНТ: КОНВЕРСИЯ ПРОИЗВОДСТВЕННОГО КАПИТАЛА В ПРОИЗВОДСТВЕННО-ТЕХНОЛОГИЧЕСКИХ СИСТЕМАХ ИНЖЕНЕРНОГО БИЗНЕСА

А.Н. Шичков

Вологодский государственный университет, г. Вологда, Российская Федерация

Статья посвящена переосмыслению исследований Н.Д. Кондратьева экономической среды стран, имеющих развитую рыночную экономику. Методология и результаты исследований Н.Д. Кондратьева позволили сделать вывод, что нет национальной

экономики, а есть национальные экономические модели, где исходными параметрами являются потребности людей, обеспечивающие их жизнедеятельность. Вывод сделан на основе анализа приоритетных индикаторов каждой страны и темпов совершенствования технологических и производственных активов. Волны Н.Д. Конратьева – это результат деятельности людей в объективной экономической среде, направленной на реализацию потребностей людей. В этой связи вполне объяснимо предложение Й. Шумпетера совершенствовать экономические модели на основе потребностей людей в новых продуктах, технологиях и организации производственных процессов. Для реализаций этих задач, как правило, используют объективные природные законы. В основе планетарной теории атома и химических элементов и технологий использован закон всемирного тяготения. Нами предложено использовать объективные законы термодинамики и теорию потенциального поля. На основе этих законов создан математический аппарат конверсии производственного капитала в денежный капитал в форме реализованной продукции. Исследования реального инженерного бизнеса показали, что стоимость бизнеса на фондовом рынке и его результат в форме реализованной продукции определяются критериальным уравнением, состоящим из пяти критериев. Разработана математическая модель операционного менеджмента на основе операционного цикла конверсии производственного капитала производственно-технологической системы в денежный капитал в форме произведенной и реализованной продукции. Дальнейшие исследования будут направлены на расширение использования этого подхода в оценочной инновационной деятельности.

Ключевые слова: конверсия операционного цикла инженерного бизнеса; операционный менеджмент; критериальное уравнение операционного цикла конверсии; критерии подобия операционного цикла

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Introduction

Kondratyev's research of an economic environment of countries with developed market economy. N.D. Kondratyev studied the dynamics of cyclic economic processes of the indicators of infrastructure subjects which generate the people's needs ensuring their life activity. Kondratyev considered the indicators from the late 18^{th} century up to the early 20^{th} century (about 150 years) in the following countries:

a) in the United Kingdom: prices; interest on capital; wages of agricultural and textile workers; production coal, iron and lead;

b) in France: prices; interest on capital; foreign trade; coal consumption; the planting area of oats; the portfolio of the French Bank; deposits in saving banks; consumption of cotton, coffee, sugar;

c) in Germany: the production of coal and steel;

d) in the United States of America: prices; the production of coal, iron and steel; the number of spindles in the cotton industry; cotton acreage;

e) indicators of production and consumption are not overall, but per capita.

The analysis of the research results allows to formulate the main properties of every infrastructure subject in an economic environment.

1. Cyclic changes of the indicators are continuous; based on the property of self-organization, their oscillation amplitude takes an average value. Non-stationary oscillatory processes become stationary.

2. The synergic effect (2 + 2 = 5) in an integrated set of infrastructure subjects in an economic environment is achieved by the property of self-organization.

3. Economic environment as a result of manufacturing capital conversion is a vector field of monetary flows. A thermodynamic system has similar properties. In this system, the heat flow vectors arise based on a temperature gradient. Therefore, the economic environment is a field whose infrastructure subjects have cyclic, self-organization and synergetic properties.

Based on the mathematical analogy of thermodynamic and economic systems, we conclude that operation management considers economy as an objective law. According to the first and second thermodynamic laws, the infrastructure subjects in an economic environment convert manufacturing capital into monetary capital in the form of produced and sold products and services necessary and sufficient for ensuring the life activities of people.

The Carnot thermodynamic cycle converts heat energy into mechanical work. An ideal closed cycle consists of two isotherms and two adiabats. In this case a real conversion cycle is placed inside an ideal closed conversion cycle.

The mathematical analogy of converting the operating cycle in thermodynamic and manufacturing-technological systems (based on the first and second laws of thermodynamics) allowed to formulate and substantiate the theoretical and practical tools to design, plan and control the innovative development of manufacturing-technological systems of engineering business.

Research objectives. Our aim is to develop a mathematical model of operation management based on converting manufacturing capital into monetary capital in the form of produced and sold products. The mathematical models of the first and second thermodynamics laws have been used as paradigms for developing an operations management model. One of our main objectives is to study the operating cycle of real metallurgical enterprises on the basis of these models using the information from the stock market as initial data.

Research methods

The ideal operational cycle of converting manufacturing capital into monetary capital consists of five unit vectors:

Q is the manufacturing capital of the conversion operating cycle which is equal to the sum of technological costs $G_0W_0 = C_{mc} + C_{lp} + C_{oc}$, where C_{mc} are the material costs; C_{lp} are the labor payment costs; C_{oc} are the other costs (without amortization of intangible assets) and $U_{mf} = U_{ta} + U_{ia}$ are the main funds of a manufacturing-technological system, including the tangible assets U_{ta} and the intangible assets U_{ia}.

V_{sv} is the sales value of the manufactured products (services) which is equal to the sum of net income D0, including P_0 which is the net profit (property of business owners); C_{dta} which is the depreciation of tangible assets, C_{aia} which is the amortization of intangible assets. The monetary equivalent of products manufactured in a conversion operating cycle $(G_0W_0)_{sv}$ is numerically equal to technological costs (G_0W_0). In turn, the sum of amortization of intangible assets and depreciation of tangible assets $C_{dta} + C_{aia} = C_{ma}$ is the necessary and sufficient capital for simple and extended reproduction of the main funds in a manufacturing-technological system.

The balance equation for converting the manufacturing capital into monetary capital in the form of produced and sold products has the form:

$$\frac{Q}{U_{mf} + G_0W_0} = \frac{V_{sv}}{D_0 + (G_0W_0)_{sv}} \qquad (1)$$

by analogy with the adiabatic process $G_0W_0 = (G_0W_0)_{sv}$.

The level of conversion is equal to the relation of the sales value to the manufacturing capital. The parametric equation has the form:

$$\frac{V_{sv}}{Q} = \frac{(G_0W_0)_{sv} + D_0}{G_0W_0 + U_{mf}} = \leq 1. \qquad (2)$$

Our research shows that the conversion level for the ideal operating cycle is equal to one while for the real converting operating cycle (according to second thermodynamic law) it is less than one. The conversion level is more than one for the excise business.

Let us write Eq. (2) in a dimensionless form:

$$\frac{V_{sv}}{Q} = \frac{\frac{V_{sv}}{(G_0W_0)_{sv}}}{\frac{Q}{G_0W_0}} = \frac{\frac{(G_0W_0)_{sv}}{U_{mf}} + \frac{D_0}{U_{mf}}}{\frac{G_0W_0}{U_{mf}} + 1} = \vartheta. \qquad (3)$$

Let us introduce the notion of dimensionless complexes and write Eq. (3) in a dimensionless form:

$$\vartheta = \frac{\lambda}{\rho} = \frac{k_0 + M}{k_0 + 1} = \frac{k_0}{k_0 + 1} + \frac{M}{k_0 + 1} = \vartheta_{mts} + \vartheta_{bus}. \qquad (4)$$

The dimensionless complexes in Eq. (4) are similarity criteria and therefore Eq. (4) is a similarity equation, where:

$\vartheta = \frac{V_{sv}}{Q}$ is the conversion criterion of the operating cycle equal to the sum of conversion criteria: ϑ_{mts} is the manufacturing-technological system criterion and ϑ_{bus} is the criterion of the enterprise. This criterion has a very impotent property for engineering business. Namely,

the operations cycles are similar if the numerical values of their conversion criteria are equal. Theory of similarity is widely used for research in thermodynamic systems. Eq. (4) allows applying the methods of similarity theory for research of manufacturing-technological systems.

Similar processes take place in the Carnot cycle where the first part of conversion is a thermodynamic cycle and the second part is converting the thermodynamic cycle into mechanical work. Each conversion cycle is improved by self-innovations. Each part of the conversion cycle is improved by self-innovations.

Our research of the factors determining the level of conversion in a real engineering business has shown that it primarily depends on the physical fundamentals of the technological process. For example, if turning with a low material utilization coefficient is substituted by plastic deformation (forging, stamping, rolling, i.e., breakthrough technological innovations) with a much higher utilization coefficient, then the conversion level of the operating cycle will increase. Therefore, «incremental» improving technological innovations cannot increase the level of conversion.

$k_0 = \frac{G_0 W_0}{U_{mf}}$ is the criterion (characteristic) of an operational cycle. The value of this criterion for an ideal operating cycle is equal to $k_0 = 1$, while for a real operating cycle this is a constant $k_0 < 1$. Therefore, the variation range of the conversion criteria of the engineering business can be written in the form:

$$\vartheta \le \vartheta_{mts} + \vartheta_{bus} \le 0,5 + 0,5 \le 1. \qquad (5)$$

Our research has shown that the inequality $\vartheta_{mts} \le 0,5 \ge \vartheta_{bus}$ takes place. In this case, the design and subsequent adjustments should ensure equality $\vartheta_{mts} = \vartheta_{bus}$ of the conversion criteria of the manufacturing-technological system (mts) and of the business (bus).

$M = \frac{D_0}{U_{mf}}$ is the criterion of self-financing of simple and expanded reproduction of the main funds at the expense of the depreciation and amortization funds of the enterprise and financing dividends at the expense of the net operation profit. This criterion must be equal to or less than the conversion criterion of the manufacturing-technological system $\vartheta_{mts} \ge \vartheta_M$.

$\lambda = \frac{V_{sv}}{(G_0 W_0)_{sv}}$ is the conversion criterion of a marketing enterprise.

$\rho = \frac{Q}{G_0 W_0}$ is the conversion criterion of technological processing,

where $\vartheta = \frac{\lambda}{\rho}$.

Fig. 1 presents a block diagram of operations management based on the conversion operating cycle in a manufacturing-technological system (MTS).

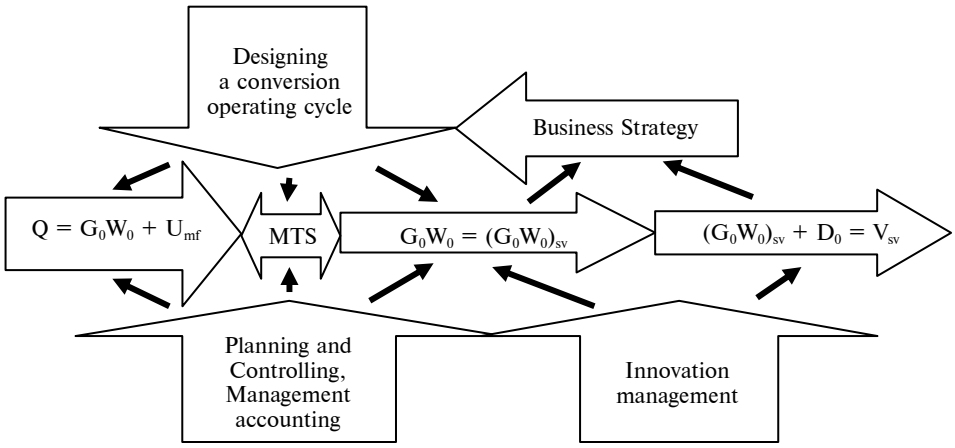

Fig. 1. Block-diagram of an operations management infrastructure based on the conversion operating cycle in a manufacturing-technological system (MTS)

Operations management is an economic system whose infrastructure is implemented by self-managed engineering business in an economic environment. To continuously manufacture products with competitive advantages in the domestic and foreign markets, the work cycle should be supplemented by creating the **strategy** based on marketing information about the demand and supply of innovative products and technologies. The algorithm for developing the strategy is as follows. After the function of operations has understood its role in business and after it has formulated its efficiency goals, it needs to formulate a set of general principles that will determine its decision-making.

The first stage: enterprises should understand their main role (mission) in a municipal territory. Labor market ensures the workplaces of a municipal territory, and that is the main need of humans for their life activity.

The second stage: enterprises should articulate the performance objectives. They increase the conversion level of the manufacturing capital by continuous implementation of innovation-investment projects, and on this basis they increase their sales value.

The third stage: enterprises should formulate a set of general principles which will guide their decision-making. The organization of production should ensure the competitive advantages of consumer properties of each technological stage being the zone of financial responsibility. It means the manufacturing technological system of an enterprise should ensure the transfer of technological costs and consumer properties within technological stages. In this case management accounting or controlling are applied.

This information is initial for **designing** an organization production by transferring technological costs and consumer properties (market cost) of products or technological stages within the zones of financial responsibility. In this case **management accounting** will allow implementing the main condition of an innovative organization production ensuring the market cost in each technological stage. By using **innovative management tools**, enterprises continuously improve the parameters of conversion operating cycles and conversion marketing tools.

The manufacturing capital Q is converted into monetary capital in the form of sales value V_{sv} in an operating cycle of conversion consisting of two stages. The first stage is a manufacturing-technological stage with the following condition: technological costs are equal to the market value of the manufactured products:

$$G_0W_0 = (G_0W_0)_{sv}. \quad (6)$$

The second stage of conversion is the marketing conversion where net income D_0 is added to the market value of products $(G_0W_0)_{sv}$, which is necessary and sufficient for paying taxes of all levels, dividends in the form of net profit P_0 and capital maintenance adjustments $C_{mac} = C_{dtc} + C_{aic}$.

Designing management accounting in a conversion operating cycle

Competitive advantages of products and technologies of engineering business are implemented on the basis of «incremental» and «breakthrough» innovative projects. In this case managers of engineering enterprises obtain the required consumer properties of products by management accounting using the transfer of technological costs and market cost within technological stages being zones of financial responsibility. The organization of a conversion operating cycle based on management accounting is the necessary condition for implementing any innovative projects. In this case, the competitive advantages of end products are formed by the transfer of technological costs and the cost of consumer properties in each technological stage, considering the parameters of an innovation project.

The mathematical model for management accounting ensures the competitive advantages based on the transfer of the set of cumulative properties of a conversion operating cycle.

Balance equation of the sales value V_{sv} for four technological stages:

$$V_{sv} = V_{sv1} \to V_{sv2} = \sum_{n=1}^{n=2} V_{svn} \to V_{sv3} = \sum_{n=1}^{n=3} V_{svn} \to V_{sv4} = \sum_{n=1}^{n=4} V_{svn}.$$

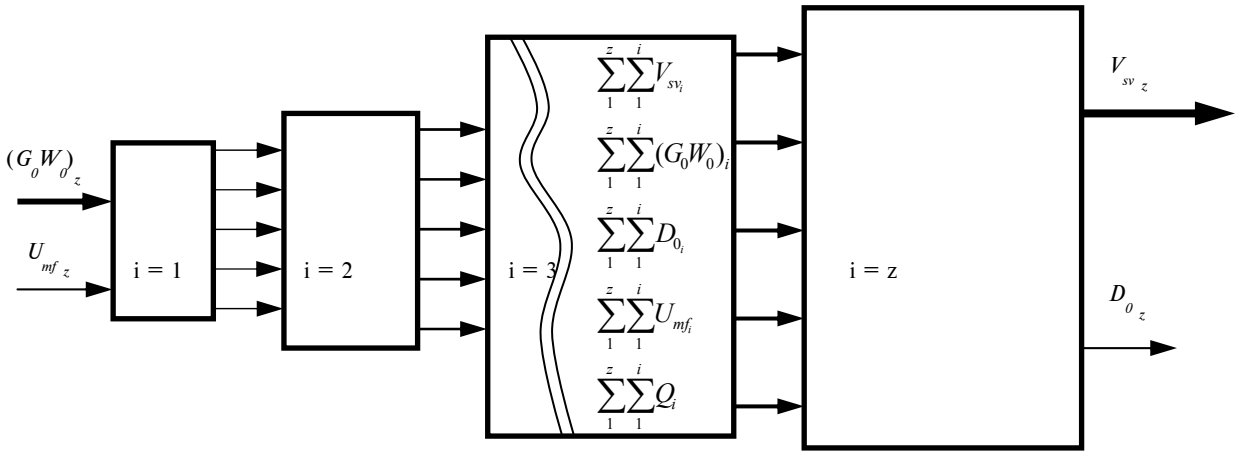

Fig. 2. Block diagram of trasferring parameters of a conversion operating cycle

Balance equation of manufacturing costs:

$$(G_0W_0) = (G_0W_0)_1 \to (G_0W_0)_2 = \\ = \sum_{n=1}^{n=2}(G_0W_0)_n \to (G_0W_0)_3 = \\ = \sum_{n=1}^{n=3}(G_0W_0)_n \to (G_0W_0)_4 = \sum_{n=1}^{n=4}(G_0W_0)_n.$$

Balance equation of net income:

$$D_0 = D_{01} \to D_{02} = \sum_{n=1}^{n=2} D_{0n} \to D_{03} = \\ = \sum_{n=1}^{n=3} D_{0n} \to D_{04} = \sum_{n=1}^{n=4} D_{0n}.$$

Balance equation of manufacturing capital:

$$Q = Q_1 \to Q_2 = \sum_{n=1}^{n=2} Q_n \to Q_3 = \\ = \sum_{n=1}^{n=3} Q_n \to Q_4 = \sum_{n=1}^{n=4} Q_n.$$

Graphical interpretation of the conversion operating cycle in manufacturing-technological systems of engineering business. The sum of collinear vectors is a single vector, while the sum of two orthogonal vectors is a right-angled triangle.

Therefore, the ideal converting operating cycle of manufacturing-technological system is an equilateral triangle consisting of five unit vectors of monetary flows. In this case, the graphical interpretation of the criterial Eq. (4) for a conversion operating cycle in vector form is the following:

$$\frac{\vec{V}_{sv}}{\vec{Q}} = \frac{k_0\left(\overrightarrow{G_0W_0}\right)_{sv} + M\overrightarrow{D_0}}{k_0\left(\overrightarrow{G_0W_0}\right) + 1\vec{U}_{mf}}. \qquad (7)$$

An ideal conversion operating cycle is presented in Fig. 3.

The operating cycle of converting manufacturing capital into monetary capital in the form of the sales value of products and services consists of two closed cycles. The first closed operating cycle of converting manufacturing capital into products 1-3-4 consists of three vectors of monetary flows $\vec{Q} = \overrightarrow{G_0W_0} + \vec{U}_{mf}$. This contour is a manufacturing cycle, where the end product (or technological stage) with the market cost that is equal to the technological costs $\left(\overrightarrow{G_0W_0}\right)_{mf} = \overrightarrow{G_0W_0}$ is manufactured as a result of converting the manufacturing capital. The second cycle 1-2-3 consists of three unit vectors $\vec{V}_{sv} = \left(\overrightarrow{G_0W_0}\right)_{sv} + \vec{D}_0$ of monetary flows. This is a marketing cycle. A real operating cycle of converting the manufacturing capital is placed inside an ideal operating cycle. The criteria k_0-M are a coordinate system for the real operating cycle of conversion. For example, the criterion of conversion in a real operating cycle 1^1-2^1-4 at $k_0 = 0.40$ and $M = 0{,}35$, $\vartheta = \frac{0.40 + 0.35}{0.40 + 1} = 0.54$.

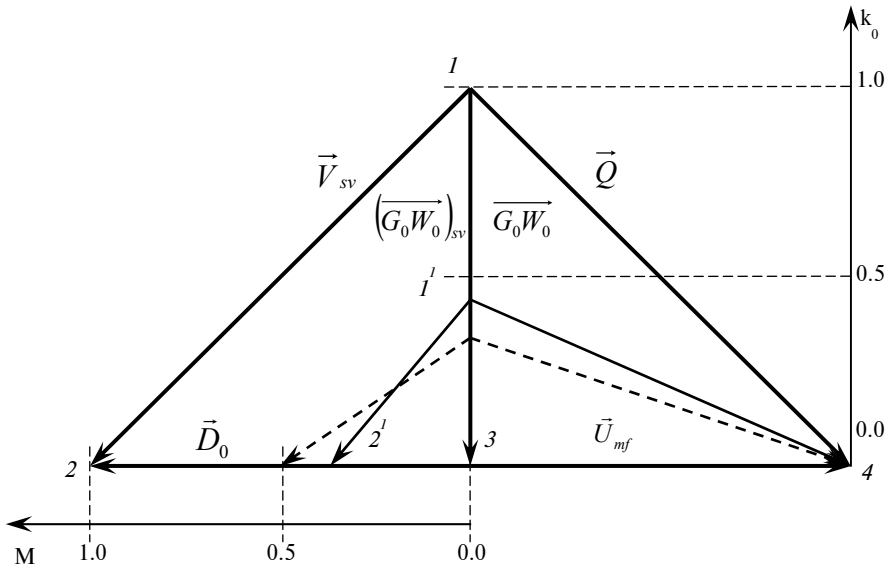

Fig. 3. Graphical interpretation of the conversion operating cycle in a manufacturing-technological system

Table 1

Conversion criteria for the operating cycles of similar metallurgical enterprises: «Magnitogorsk Metallurgical Company» (MMC), «Novolipetsk Metallurgical Company» (NLMC) and «Cherepovets Steel Mill» (ChMC)

Similar enterprises on stock market	JSC «MMC»	JSC «NLMC»	JSC «CHMC»
Stock market parameters, mln USD			
Sales value, V_{sv} Sales value without taxes and payment	5380.00 4983.37	4468.73 3996.36	5055.17 4617.31
Profitability of sales, $r = P/V_{sv}$	24.6%	41.6%	35.2%
Net profit, P_0	947.00	1385.34	1312.00
Operation profit, P	1323.48	1859.00	1779.42
Parameters of a conversion operating cycle			
Operation costs $C_{oc} = V_{sv}$-P	4056.52	2609.74	3275.75
Sum of tax fixed assets and tax of operating profit $\Delta P = P - P_0 = N_{fa} + N_p$	376.48	473.66	467.42
Tax on operating profit $N_p = P_0\psi_p/(1-\psi_p)$, where $\psi_p = 0.2$ is the tax rate on operating profit	236.75	348.34	328.00
Tax on fixed assets (tax on equity of entity) $N_{fa} = \Delta P - N_p$	139.73	125.32	139.42
Main funds U_{mf} for these enterprises are fixed assets (tangible assets) U_{mf}/ψ_{fa}, where $\psi_{fa} = 0.02$ is the tax rate for fixed assets	6986.50	6266.00	6971.00
Depreciation (amortization) of tangible assets $C_{dc} = \alpha_{dt}\, U_{fa} = 0.03 U_{fa}$, where α_{dt} is the rate of depreciation (amortization)	209.60	188.00	209.13
Technological costs $G_0W_0 = C_{oc}$-C_{dc}	3846.92	2421.74	3066.62
Net income $D_0 = P_0 + C_{dc}$	1156.60	1573.34	1521.12
Manufacturing capital $Q = G_0W_0 + U_{fa}$	10833.42	8687.74	10037.62
Criteria of a conversion operating cycle			
Capitalization criteria $\lambda = V_{sv}/G_0W_0$	1.30	1.65	1.51
Investment criteria $M = D_0/U_{mf}$	0.17	0.25	0.22
Resources criteria $\rho = Q/G_0W_0$	2.82	3.59	3.27
Characteristic of the manufacturing capital $k_0 = G_0W_0/U_{mf}$	0.55	0.39	0.44
Conversion criterion $\vartheta = \frac{V_{sv}}{Q} = \frac{\lambda}{\rho} = \frac{k_0 + M}{k_0 + 1}$	0.46	0.46	0.46
The cost of equity capital on 19.04.2006	7892.94	13964.22	7452.80

Research results and discussions. Based on the information taken from Table 1, we can come to the conclusion that the enterprises are similar in terms of the similarity criterion of the conversion level. Our research has shown that the similarity criterion of the conversion operating cycle is its property that depends only on physical fundamentals of technological processes. In this case all three enterprises manufacture sheet metal based on a similar technology.

Having considered the results of criterial assessment of conversion operating cycles in three enterprises, we may suggest the following research issues for a discussion:

1. The physical basis of the enterprises' technology is absolutely similar. Despite different equipment, the conversion criterion is equal and it does not depend on the production volume. Novolipetsk Metallurgical Company is relatively new and its products are in much demand, therefore the value of its stock capital is higher than the same value in other enterprises. Its criteria ρ and λ are higher. The first criterion demonstrates that the company has more modern technological equipment; the second one shows that marketing performs much more effectively. The higher value of the criterion M indicates that the enterprise has more revenue and the lower value of business characteristic indicates that it has lower technological costs.

2. The criterial analysis allows to formulate the aims and objectives of innovative projects ensuring the increase of business value on a stock market. As a rule, the strategic business objective is to increase the value of stock capital. In this case an enterprise receives investment resources from stock capital sales.

3. Magnitogorsk Metallurgical Company and Cherepovets Steel Mill should reduce the operation costs (reduce the criterion k_0) and improve the consumer properties of metal sheets (increase the criterion λ). In this case, the conversion criterion and the criterion M will increase.

Conclusions. The mathematical model of operations management has been created based on an operating cycle converting manufacturing capital into monetary capital in the form of produced and sold products and services. The main principle of market economy is realized by this approach. Namely, successful business is determined by the sales value of products and the cost of stock capital on a stock market. These parameters define the area of a mathematical model in an economic environment.

The criterial Eq. (4) and its vector form (5) including five unit vectors of monetary flows are the integrated set of similarity criteria ensuring the possibility to analyze, design and create conversion operating cycles in manufacturing technological systems with competitive advantages.

The graphical interpretation of a conversion operating cycle has been created in the form of two contours of closed right-angled triangles consisting of five unit vectors of monetary flows. The research of conversion operating cycles allows to conclude that the change of one of five criteria alters all the parameters. This fact is clearly illustrated by the graphical model of the conversion operating cycle. All five similarity criteria participate in the operating cycle simultaneously. It is not possible to improve the conversion operating cycle based on one or two parameters.

The analysis of the criterial equation demonstrates that the conversion criterion is the sum of conversion of manufacturing technological system and business marketing. The conversion criteria of business cannot be more than the conversion criteria of marketing business; they should be equal. The conversion criterion of a real operating cycle depends only on physical fundamentals of a technological process. For example, the conversion criterial of turning technological processing with the material utilization coefficient equal to 0.5 might be increased only by a breakthrough innovation based on replacing it by a technological process with a higher material utilization coefficient.

The manufacturing-technological system of each technological stage should be adjusted to the conversion criterion of the whole system, and in each stage $k_0 \geq M$. In this case, intangible assets appear in the main funds of the enterprise. The balance cost of intangible assets is determined on the basis of the criterial equation.

The directions of further research

Further research will be directed at expanding the areas of this approach in the assessment of innovative activity, such as:

a) using the theory of similarity criteria in the assessment of business activity;

b) the ways of improving the design methods in management accounting;

c) formulating the performance tasks for innovative projects in operations management.

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Shichkov A.N. E-mail: shichkov-an@yandex.ru

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Шичков А.Н. E-mail: shichkov-an@yandex.ru

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