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Model and toolkit for the formation of the production enterprise digital platform

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Abstract. The relevance of this topic is determined by the necessary to develop and study the model and mathematical toolkit for the production enterprise digital platform. The model of ecosystem is the territory where enterprises manufacture products and form the life services balanced with the production. This balance is fundamental for the digital platform of production enterprise controlling system. In its turn, the controlling system includes production organization, management and accounting systems and innovation activity which continuously increase market added value of manufactured and sold products and life services of the territory. Digital platform of a manufacturing-technological system includes the model of production and its graphical and digital mathematical toolkit. We suggest that the model of production can be presented as a closed operation cycle converting manufacturing capital into monetary capital in the form of expenses and added market value of products. Mathematical toolkit of this model is the system of two vector equations including the vector equation of manufacturing capital and of monetary capital. We identified the regularities of changing operation cycle parameters and their proportions. The main condition of territory strategic planning should be oriented on the equality of sales value of manufactured products and sales value of life activity services. Physical basis of technological processes should correspond to products consumer properties. Further research will be devoted to the improvement of the digital platform mathematical toolkit ensuring efficient management accounting and innovation activity of enterprises.

1. Introduction

Modern innovation market economy is a dynamic system [1]. The ecosystem of the territory includes the subjects of engineering business economic activity manufacturing and selling products outside the territory and assisting in forming the budget; municipal and commercial enterprises providing services; municipal executive bodies and state government bodies realizing strategic planning and operation management of the territory economy.

Figure 1 presents the model of territory ecosystem for the formation of production enterprise digital platform.

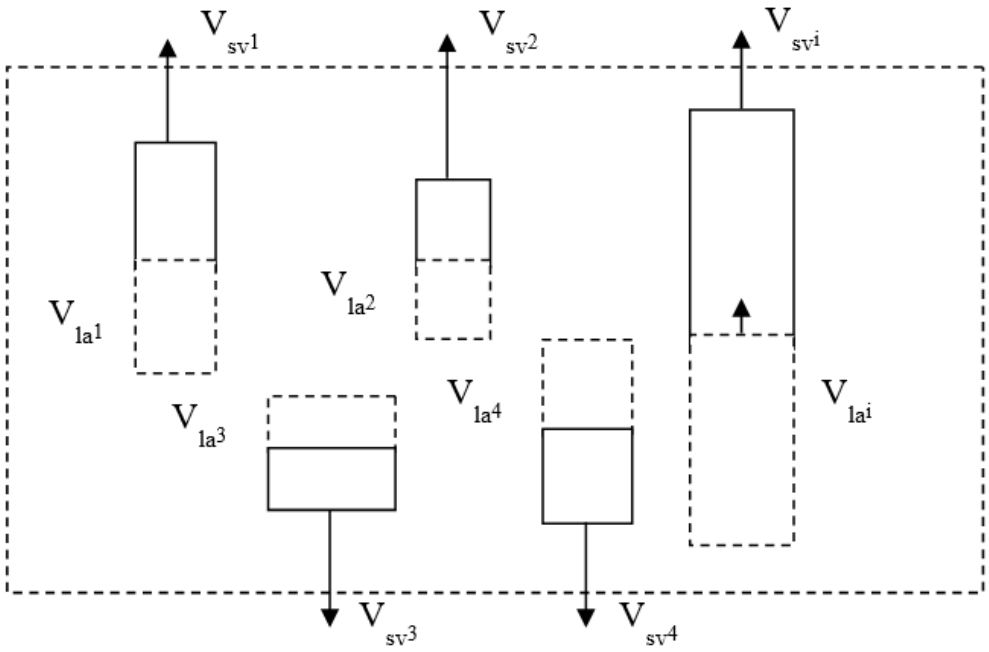

Figure 1. Production-economic model of the mathematical toolkit for the digital platform of strategic planning and operation management accounting of economic processes in the territory.

Enterprises manufacturing and realizing products V_{svi} (sales value) outside the territory are united in complexes with other enterprises (including municipal ones) providing the life activity services to production enterprises in monetary equivalent V_{lai} (life activity). This approach will form a reasonable amount of services to each enterprise and the territory as a whole. In addition, the enterprises providing services, from the point of view of the quality management system [2] are suppliers of services to manufacturing enterprises, which is mentioned in relevant standards. In this case, production enterprises can invest in payment for the services of simple and extended reproduction of service providers from the depreciation fund formed from tangible and intangible assets. Further research will explain the proportions of these costs.

In digital economy it is possible to take management decisions in complex dynamic ecosystems only based on digital technologies of processing information. The Russian state programme "The strategies of developing a digital society in Russia in 2017-2030" defines the term "digital economy" as "an activity in which the key factors of production are digital data, processing big data and using analysis results" [3].

That is why we suggest that the digital platform of an enterprise in a territory ecosystem is an integrated set of an enterprise production cycle and a digital mathematical toolkit that allows taking management decisions in multi parameter production systems.

The analysis of publications on this research topic in the field of production organization [4], management accounting and innovation activity [5], modeling of innovation processes [6–8], methods and tools of innovative development of production enterprises [9], evaluation of innovation activities of economic entities of the region [10], as well as the development of mathematical models of management [11] showed that they are not capable of planning strategically and manage multi parametric systems by continuously implementing productive and technological innovations.

2. The aims and objectives of the research

The aim of the research is to develop a mathematical toolkit for strategic planning and operational management of the ecosystem in the territory ensuring the continuous growth of produced and sold products with added market value. Nowadays information and analytical capabilities of digital assets allow us to implement management accounting [12–14] in complex multi parametric ecosystems.

Thus, our primary aim is to identify the regulations of developing engineering business in territorial ecosystems.

3. Research methods

The production process in manufacturing-technological systems (MTS) of an enterprise from the mathematical point of view is a closed operation cycle converting manufacturing capital Q_{mc} (manufacturing capital), which includes technological costs C_{tc} (technological costs) and U_{mf} (main funds) into monetary capital in the form of manufactured and sold products V_{sv} (sales value), which is the sum of the expenses internal value V_{ev} (expenses value) and added market value V_{av} (added value) [15–18].

The system of vector equations describing the operation cycle of conversion in MTS of a production enterprises has the form:

$$\begin{cases} \vec{Q}_{mc} = \sum_{i=1}^{n} \vec{C}_{tci} + \sum_{i=1}^{n} \vec{U}_{mfi} = \vec{C}_{tc} + \vec{U}_{mf} & (1) \\ \vec{V}_{sv} = \sum_{i=1}^{n} \vec{V}_{evi} + \sum_{i=1}^{n} \vec{V}_{avi} = \vec{V}_{ev} + \vec{V}_{av} \quad , & (2) \end{cases}$$

where i is the number of enterprise complexes. The sums of eponymous vectors are collinear and the sums of opposite vectors are orthogonal.

The module of the vector of technological costs of the production enterprise includes material operational costs C_{mc}, other operational costs C_{oc}, labor payment costs with tax and charges for social insurance C_{lp} and business waste C_{bw}:

$$\left|\mathrm{C}_{\mathrm{tci}}\right| = \mathrm{C}_{\mathrm{mci}} + \mathrm{C}_{\mathrm{oci}} + \mathrm{C}_{\mathrm{lpi}} + \mathrm{C}_{\mathrm{bwi}} . \quad (3)$$

The vector of main funds is the sum of collinear vectors, each of which is the sum of collinear vectors of fixed assets (tangible assets) and intangible assets:

$$\vec{U}_{mf} = \sum_{i=1}^{n} \vec{U}_{mfi} = \sum_{i=1}^{n} (\vec{U}_{fai} + \vec{U}_{iai}) . \quad (4)$$

The module of the vector of the expenses value of product is equal to the module of the vector of technological costs:

$$\left|V_{evi}\right| = \left|C_{tci}\right| . \quad (5)$$

Added value module vector includes:

$$\left|V_{avi}\right| = (N_{vat} + N_{fat} + N_{opt} + P_0 + C_{dfa} + C_{aia} + C_{bw})_i , \quad (6)$$

where N_{vat} is added value tax, N_{fat} tax on fixed assets, N_{opt} – tax on operational profit, business owner's operational profit P_0, depreciation of fixed assets C_{dfa}, amortization of intangible assets C_{aia}, business waste C_{bw}.

We divide the module of equation 2 by the module of equation 1, and as a result, we obtain a criterial equation of the closed operation cycle converting manufacturing capital into monetary capital:

$$\vartheta_{me} = \frac{V_{sv}}{Q_{mc}} = \frac{\frac{V_{ev}}{U_{mf}} + \frac{V_{av}}{U_{mf}}}{\frac{C_{tc}}{U_{mf}} + 1} = \frac{k+M}{k+1} = \frac{k}{k+1} + \frac{M}{k+1} = \vartheta_{mc} + \vartheta_{av} \quad , \quad (7)$$

where ϑ_{mc} – the criterion (level) of the converting manufacturing capital into monetary capital, k – the equilibrium criterion of the manufacturing capital, and M – the criterion (marketing) equilibrium of monetary capital. Criterion ϑ_{mc} of the manufacturing capital conversion and criterion ϑ_{av} of the monetary capital in the equilibrium conversion operation cycle is equal to 0.5.

The system of vector equations of a closed operation cycle converts manufacturing capital Q_{smc} into monetary capital V_{smc} in the form of produced and sold services. Manufacturing capital includes technological costs in monetary equivalent not exceeding the added value of the production enterprise V_{av}, and fixed assets U_{smf}, necessary and sufficient for the formation of services.

In an equilibrium conversion operation cycle, they should be equal to technological costs. Monetary capital includes the value of V_{sv} services and the added value of V_{as} [15–18], where i is the number of enterprises:

$$\begin{cases} \vec{Q}_{smc} = \sum_{i=1}^{n} \vec{V}_{avi} + \sum_{i=1}^{n} \vec{U}_{smfi} = \vec{V}_{av} + \vec{U}_{smf} \end{cases} \quad (8)$$

$$\begin{cases} \vec{V}_{smc} = \sum_{i=1}^{n} \vec{V}_{avi} + \sum_{i=1}^{n} \vec{V}_{asi} = \vec{V}_{av} + \vec{V}_{as} \end{cases}, \quad (9)$$

Figure 2 shows a plot of the monetary flows vectors in an equilibrium operation conversion cycle in a manufacturing enterprise and a service provider.

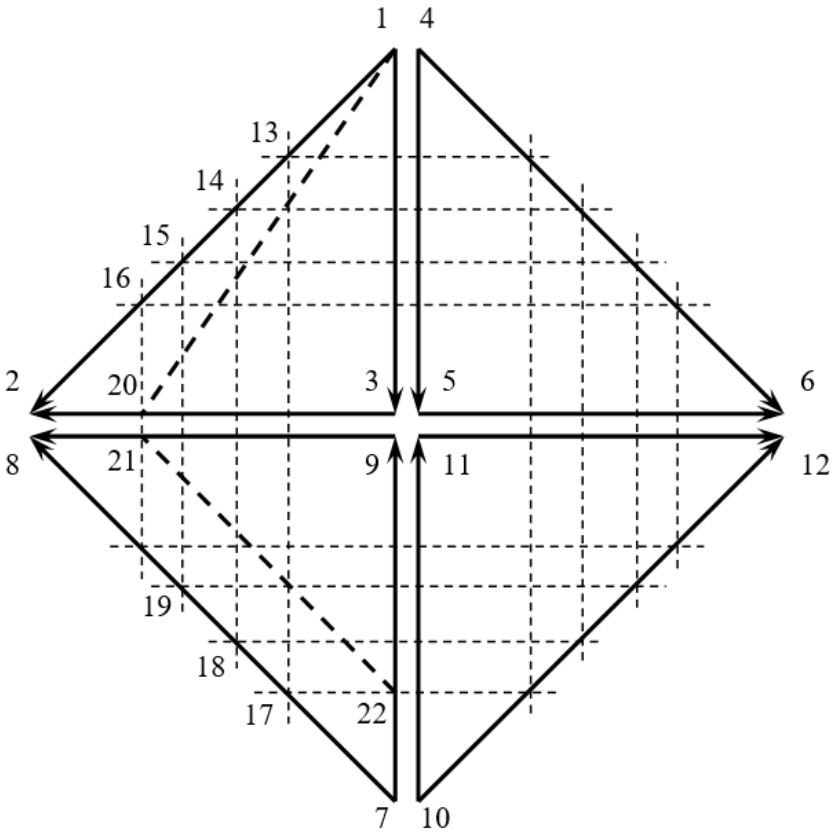

Figure 2. Vector plot of the closed cycle of an annual equilibrium operation cycle converting manufacturing capital of manufacturing technological complexes of territory enterprises into monetary capital in the form of manufactured and sold products having the added market value and the operation cycle converting manufacturing capital of enterprises providing services to production enterprises.

The equilibrium operation cycle plot consists of four orthogonal sums of the resulting collinear sums of vectors, where 1-2-3 is the equation plot (2), 4-5-6 is the equation plot (1), 7-8-9 is the equation plot (9) and 10-11-12 is the equation plot (8). Dotted lines 13-19 indicate the bound areas of production and related enterprises providing services. Plot 1-20-3 describes the real (non-equilibrium) conversion of industrial capital into monetary capital. In this case, the added value of 3-20 is less, therefore, the required (produced) volume of services 21-22 will be less. The conversion criterion in production and technology systems will be lower than in an equilibrium cycle.

4. The results of the research

It allow us to formulate the tasks of innovative activity aimed at improving the parameters of the operation cycles converting manufacturing capital into the monetary capital of engineering business enterprises.

For example, Table 1 shows the criterion conversion of "Novolipetsk", "Magnitogorsk" and "Severstal". The innovative activity of these enterprises should be aimed at increasing the criterion determining the share of the added market value of products, and increasing the criterion *K*, characterizing the ability of main funds of enterprises MTS to process technological costs.

Table 1. The conversion parameters of manufacturing capital in an operation cycle of analogical (sheet) metallurgical enterprises.

Enterprises	JSC "MMC"	JSC "NMC"	JSC "Severstal"
Stock market parameters of analogical metallurgical enterprises manufacturing steel sheet in billion $ USA[a-c]			
Sales value of products, V_{sv}	5380.00	4468.73	5055.17
Return on sales, $r=P/V_{sv}$	24.6%	41.6%	35.2%
Net profit, P_0	947.00	1385.34	1212.00
Operation profit, P	1323.48	1859.00	1779.42
Conversion criteria			
Monetary capital conversion criterion, M	0.17	0.25	0.12 (0.25)
Manufacturing capital conversion criterion, k	0.55	0.39	0.22
Conversion criterion $\vartheta = \frac{V_{sv}}{Q} = \frac{k+M}{k+1}$	0.46	0.46	0.28 (0.46)

[a] Severstal', https://www.severstal.com/rus/ir/results_reports/annual_reports/index.phtml
[b] NLMK, http://nlmk.ru/investor-relations/reporting-center/annual-reports/
[c] Magnitogorskij metallurgicheskij kombinat, http://mmk.ru/for_investor/annual_reports/

5. Conclusions

The model and mathematical toolkit for the territory ecosystem digital platform have been created. This toolkit allows developing the strategic plan and operation management at reasonable costs in order to provide for people's life activity.

The results of the research present the main characteristics of the territory ecosystems.

1. Territory ecosystem consists of two balanced manufacturing-technological systems including engineering business that manufactures and sells products (having market added value) outside the territory and on this basis forms the territory budget which is necessary and sufficient for the manufacturing-technological system to function and ensure the life activity of the territory.

2. Market value of engineering business products consists of the exposes (internal) value and added market (innovative) value. The added market value may be more or less than the expenses value. The excise product added market value is more than expenses value. Innovation activity should

be aimed at increasing the share of added market value by decreasing the expenses value by implementing technological innovations or increasing an added market value based on productive innovations.

3. It is necessary to reduce the product expenses value primarily by decreasing the business waste.
4. As a model of mathematical toolkit of management accounting of production activities in an engineering business enterprise it is important to introduce the equilibrium operation cycle converting manufacturing capital into monetary capital in the form of manufactured and sold products having added market value.

Other characteristics might be necessary for planning the strategic development of a municipality and subjects of the Federation.

6. Further research

Further research will be aimed at improving the mathematical toolkit that enables planning and operational management of multi parameter systems in the conditions of continuous development of product and technological innovations that provide the required added market value of products.

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