CONCEPT OF SUSTAINABLE TREND WITHIN LARGE INFRASTRUCTURE INVESTMENT PROJECTS

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ABSTRACT

Acceleration of economic growth of many countries, including Russia, through formation of a multiplier effect is largely based on successful implementation of investment programs of transport companies. At the same time, a positive trend should be ensured at all stages of the life cycle of each project. To make conceptually verified management decisions that are clearly oriented by economic theory, it is proposed to use dynamic economic and mathematical models for substantiating large investment projects aimed at developing transport infrastructure. The article considers options to ensure sustainability of a financial result, depending on implementation of the project with different amounts of financing and different degrees of approach of companies to the conditions of investment equilibrium.

Keywords: transport infrastructure, sustainable development, United Nations Commission on Sustainable Development, indicators, Organization for Economic Cooperation and Development, investment project, economic and mathematical modeling, Königs-Lamerey diagrams, Hicks–Lindahl concept.

Background. *The implementation of major investment projects aimed at formation of transport infrastructure is associated with integrated development of the territory. Sources of financing can be different: railway company's own funds, third-party investors, funds of public bodies of various levels, etc. The Russian example of the federal-level project is «Modernization of the railway infrastructure of Baikal-Amur and Trans-Siberian railway lines with development of throughput and carrying capacity» [1], due to which in the region, besides achievements of the railway industry, new automobile roads will appear, modernization of pre-port and port stations will take place, additional power capacities for growing industrial enterprises will be provided [2]. The creation and operation of the new object «Bovanenkovo–Sabetta new non-public railway line», in turn, is a regional-level project initiated by Yamal-Nenets Autonomous District [3].*

In development of such projects, specific problems arise, one of which is some uncertainty in estimating the horizon of the complete end of all associated activities for development of the gravity areas of the main line. Another peculiarity is caused by high risks of negative influence of various factors: economic, social, ecological, political, technological, any of them can delay for some time not only the implementation of related projects, but also to suspend the forcing of the main one [4]. And here again instability appears, although the question is not so much in fullness or incompleteness of the opening horizon, but in confidence of the movement itself towards the goal.

Objective. *The objective of the author is to consider concept of sustainable trend within large infrastructure investment projects.*

Methods. *The author uses general scientific methods, comparative analysis, evaluation approach, mathematical methods, graph construction.*

Results.

I

The problem of overcoming instability and finding sustainable development in economic theory is based on the theory of the maximum flow of the aggregate income of Hicks–Lindahl. It affirms the necessity, at least, of preserving the aggregate capital on the basis of which this income is generated.

Wide recognition in the world was received in this direction by the system of eco-indicators of the Organization for Economic Cooperation and Development (OECD). The United Nations Commission on Sustainable Development (UNCSD) system of indicators is also quite common, using which one can determine sustainability of development of large projects and large companies and corporations [5].

To assess sustainability of development of complex projects, it is expedient to use dynamic mathematical models in conjunction with the theory of optimal allocation of resources, since now all types of resources (financial, material, labor, information) directed to large-scale projects are limited [6].

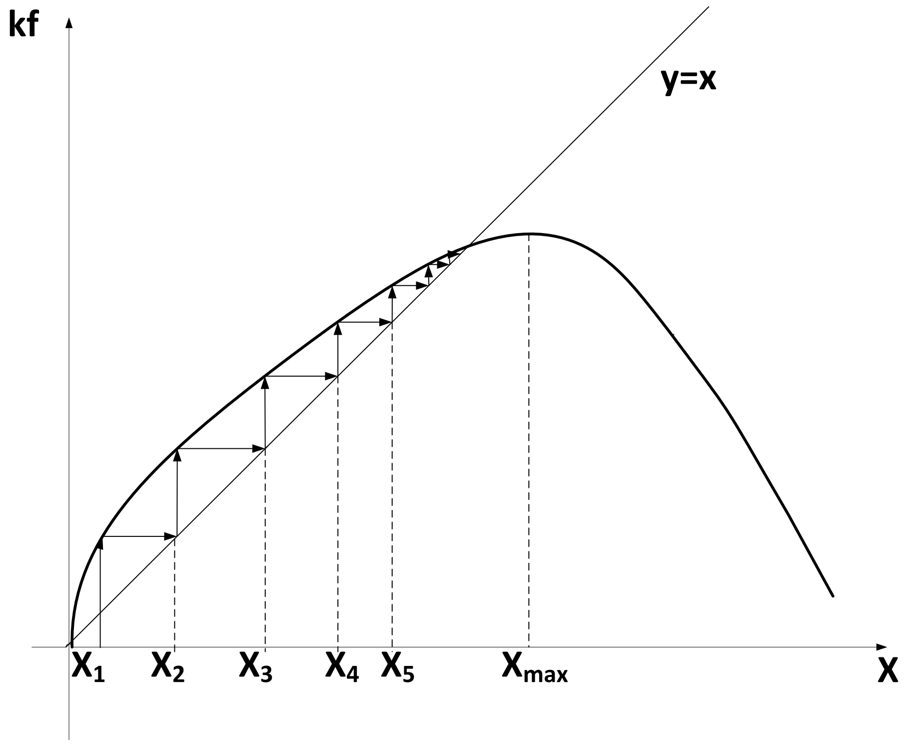
When compiling a mathematical model for finding the best investment plans, one of the ways to solve the problem of resource allocation can be involved. Within the framework of the classical problem of optimal distribution of investment resources (projects), the situation is considered in which the total amount of financing between m projects with convex functions [7] of economic effects $f_i(x_i)$ was represented in such a way that the total function of the economic effect was the greatest:

$$\begin{cases} F(x_1,\ldots,x_m)=\sum_{i=1}^{m} f_i(x_i)\to max \\ x_1+x_2+\ldots+x_m=x>0 \\ x_i\ge 0, i=1,\ldots,m. \end{cases} \quad (1)$$

In the system (1) $F(x_1, x_2, \ldots, x_m)$ is the total function of the economic effect; x_i, i = 1,...m – volume of investment in projects; x – total funding for all projects. At the same time, it is possible that some projects cannot be financed. In this case, it turns out that $x_i = 0$ for some, but not for all i.

When constructing dynamic economic models or models of development, the functions of the economic effect can be used.

First, let's consider the development model of a single isolated project of the company. We denote by x_n the investment in the project at the n-th stage. Then $f(x_n)$ if positive, will represent a positive financial result from the project at the n-th stage. Let some part of these funds, with a coefficient k, be put into the project at its next stage. In this case, x_{n+1} is formed which is the amount of investment at the next stage. Of course, in the case of negative economic effect ($f(x_n) < 0$)) investments from it are inexpedient. From these considerations and



Pic. 1. The Königs–Lamerey diagram for the recurrence equation (2) when inequation (18) is satisfied.

assumptions, we obtain a mathematical model of the project implementation process in time:

$x_{n+1} = kf(x_n)$ *when* $f(x_n) \geq 0,\ 0 \leq k \leq 1.$ (2)

In doing so, we will assume that the remaining part of the profit $(1 - k)f(x_n)$ *will be spent on implementation of other projects, or on financing other needs of the company, or on dividends of shareholders. The case of negativity of the economic effect will not be considered for the time being.*

Equation (1) is a nonlinear recurrent of the first order [8]. Its analytic and numerical study in the case of convex functions $f(x_n)$ *may be of interest for study and management of the economic process. In this case, it is possible to consider the occurrence of a stationary process*

$x_n = x_1 = x_0 = const,$ (3)

and also its stability, efficiency, oscillation and other properties. The order of study of such autonomous models consists in the initial finding of the number of equilibrium positions and their parameters, then the stability of Lyapunov's equilibrium positions is evaluated, and then stability in the whole of the entire system is checked if the stable equilibrium position is unique. In the future, the quality of the transient processes of tuning the system to a stable equilibrium position, the conditions for monotonicity of transient processes are studied. To find the stationary process (3), it is sufficient to use equalities (3) in the equation (2), thus obtaining the following condition for the equilibrium position:

$x_0 = k\,f(x_0).$ (4)

From equality (4), the economic meaning of the coefficient k becomes clear. It is equal to the reciprocal of the economic efficiency in the steady state if this mode is stable. Equation (4) always has an obvious solution:

$x_{01} = 0 = k\,f(x_{01}).$ (5)

On the other hand, equation (5) for an upward convex function f(x) cannot have more than two roots. An example, when there are exactly two roots, is given by the equation

$kf(x_0) = 3(1 - e^{-x0}) - x_0 = x_0.$ (6)

This situation is typical of most economic processes. However, cases are possible where there is only one equilibrium position of equation (2). Note that the variable x in the equation (4) must be positive. Therefore, the equation

$kf(x_0) = 0{,}5\,x_0 - 2\,x_0^2 = x_0$ (7)

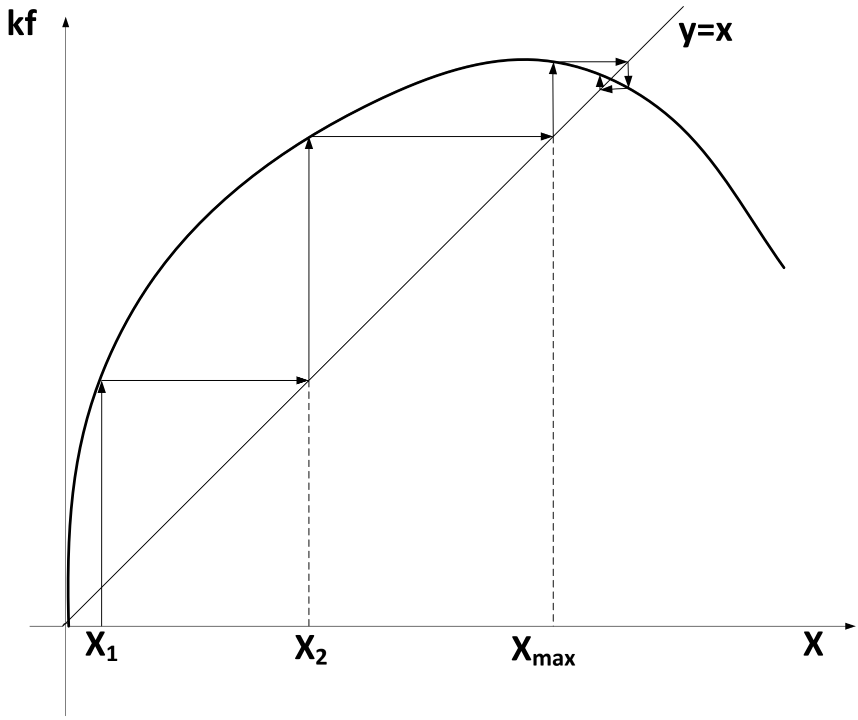
will have a single zero equilibrium position that preserves the economic meaning. The second position of equilibrium here is negative and is beyond the existence of a correct mathematical model of the economic process. This situation is created in those cases when the initial economic efficiency is less than one, but greater than zero:

$0 < kf'(0+) < 1.$ (8)

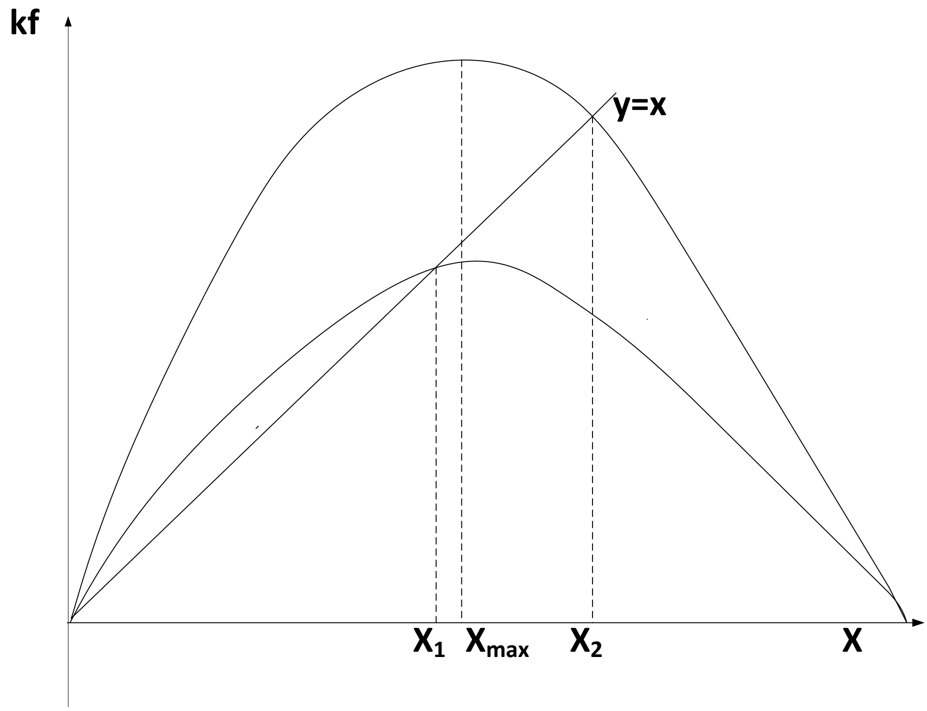
With a negative initial efficiency for convex functions, the economic reason in this work is not envisaged because of their global non-profitability. And then the undesirable stability of the zero position of equilibrium, leading to ruin, manifests itself. This situation can be changed in some cases, increasing financing of the project, which leads to an increase in the parameter k in the model (2). If the condition $kf'(0+) = 1$ *is satisfied, then the straight line* $y = x$ *is tangent to the graph of the convex function* $y = f(x)$*, and in this variant equation (4) also has exactly one zero root. The corresponding equilibrium position is also unstable, but is at the stability boundary. When*

$kf'(0+) > 1,$ (9)

it is also possible that equation (2) has only one root. Such a situation is probable only if the function f(x) increases monotonically [9].



Pic. 2. The Königs–Lamerey diagram for the recurrence equation (2) when inequation (19) is satisfied.

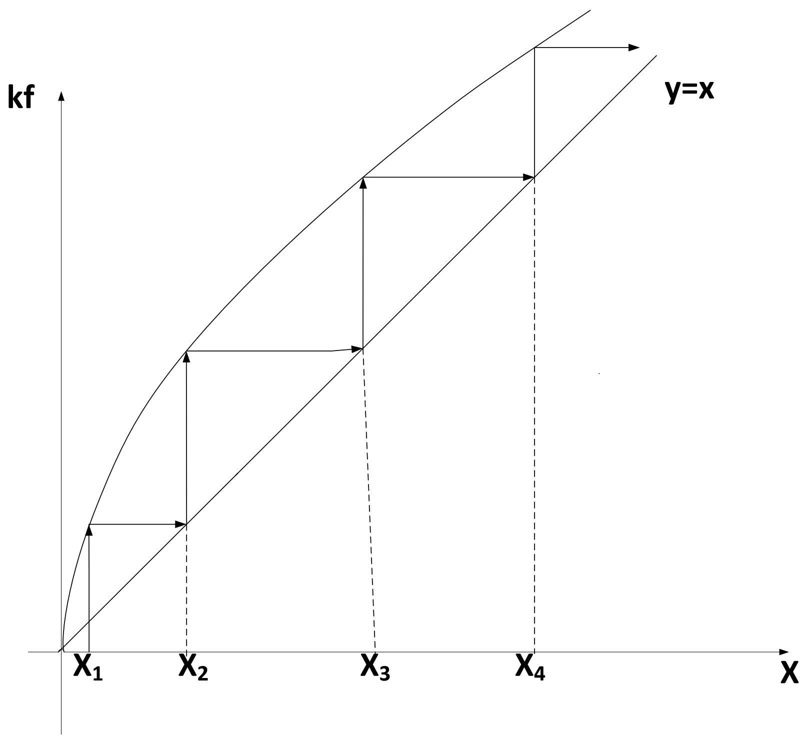


Pic. 3. Dynamic process on the Königs–Lamerey diagram in overcoming excess financing.

Let us study this case in more detail. It follows from conditions (9) and (6) that for sufficiently small positive values of the unknown the condition is satisfied

$kf(x) > x$. (10)

If, under condition (10), the convex function kf(x) is not monotonically increasing, then there is a number x_1 for which condition (4) is satisfied, and x_1 itself is the equilibrium position of the recurrence equation (2). If the condition (9) and the increasing



Pic. 4. The Königs–Lamerey diagram for the increasing function of the economic effect and in the absence of the second equilibrium position for the recurrence equation (2).

function kf (x) are satisfied according to the property of decreasing positive function of economic efficiency

$$d(x)=\frac{kf(x)}{x} \quad (11)$$

and from the classical Weierstrass theorem the existence of the following limit implies:

$$\lim_{x\to+\infty}\frac{kf(x)}{x}=s\geq 0. \quad (12)$$

If the limiting efficiency s < 1, then equation (4) certainly has a non-zero positive root – the equilibrium situation of the recurrence equation (2). For s ≥ 1, equation (4) has no positive roots.

Let us consider the questions connected with stability of the equilibrium positions of the recurrence equation (3) as a function of the convex function f(x) and the parameter k entering into it. The condition of asymptotic stability of the equilibrium position x_0 is achieved when the following inequality is satisfied:

$|kf'(0+)| < 1.$ *(13)*

If the inequation takes places

$|kf'(0+)| > 1,$ *(14)*

then the equilibrium position is unstable. Let us study the zero equilibrium position of the recurrence equation (2) for stability. Since case (9) is taken, instability of the zero equilibrium position takes place. The case $|kf'(0+)| = 1$ for convex functions f(x) also corresponds to an unstable zero position of equilibrium. This circumstance is connected with the fact that for convex functions under the condition of sufficiently small positive values of the unknown the inequation f(x) > x is satisfied, from which again instability follows. In this case, as in the case of condition (9), the sequence $\{x_n\}$ is increasing.

II.

We now turn to the study of stability of the second equilibrium position. It satisfies

$kf'(x_0) < 1,$ *(15)*

because the condition is satisfied

$$\frac{kf(x_0)}{x_0}=1. \quad (16)$$

But above for convex functions it was proved that

$$\frac{kf(x)}{x}>kf'(x),$$

from which and from (15) follows the inequation (16). It follows from (15) that instability of the equilibrium position is possible only if the condition is satisfied

$kf'(x_0) < -1.$ *(17)*

Such a situation is impossible for s ≥ 0. Hence the second equilibrium position is always stable, if it exists at all. If, however, the function kf(x) has a maximum, then for the equilibrium positions less than the abscissa of the maximum x_{max} of the function f(x) its derivative is positive. Therefore, the corresponding equilibrium positions are stable. At the maximum point (x_{max}, f_{max}), this derivative is zero and the equilibrium position x_{max} is also stable.

All cases

$1 > kf'(x_0) > 0$ *(18)*

correspond to the Königs–Lamerey diagram sketched in Pic. 1 [10]. From consideration of this diagram it is clear that the economic process has an asymptotically stable equilibrium position, to *which it converges monotonically. In such cases, we will speak about sustainable economic growth. With it, during growth, at every stage of the investment and profit process, conditions favorable for the company arise, which gradually end in a stable operation near the equilibrium position, when investments, profits and dividends become permanent.*

If the inequation is satisfied

$$0 > kf'(x_0) > -1, \qquad (19)$$

then the equilibrium position is also stable, but the Königs–Lamerey diagram in Pic. 2 shows the oscillatory process of solving the equation (1). This situation is acceptable in principle, but less comfortable for the company, because there is no monotony of development. In addition, the volume of investment is excessive. In the area of increasing the function of the economic effect in Pic. 2 there is a point in which the same profit is theoretically possible, which is available in its falling area, but with less investment. This suggests that investments are not being made with better efficiency.

The situation when the equilibrium position exceeds the maximum point of the function of the economic effect indicates that there is excess financing for the project. The very fact of excess can be detected when there are fluctuations in the economic process (Pic. 2). Accordingly, Pic. 3 shows that in this case it is expedient to reduce the value of k in the model (2). Then the curve $y = kf(x)$ decreases along the ordinate axis, and the equilibrium position changes in a similar way.

At the same time, it is possible to achieve sustainable growth with better efficiency, but also the steady-state value of the economic effect $f(x_{02})$ will decrease. Of particular interest is the dynamic economic process in the case of an increasing function of the economic effect and in the absence of a second equilibrium position. Here the condition is satisfied

$$kf(x) > x \text{ for all } x > 0. \qquad (20)$$

When condition (20) is satisfied, the sequence of economic effects increases year by year with exponential rate. This is shown in Pic. 4.

Note that in this version the project efficiency is lower than the initial one and decreases. Therefore, such a project may not be very profitable. In such cases, instead of examining the second equilibrium position, which is not here, you need to check the effectiveness at each stage, and find the marginal efficiency using the formula (12).

It should be borne in mind that after obtaining the value of the equilibrium position x_{02} of equation (1) it is necessary to find the economic effect $kf(x_{02})$ and the established efficiency:

$$s = \frac{kf(x_{02})}{x_{02}}.$$

Both these parameters are required to satisfy the requirements for the economic project. If there is a discrepancy between the requirements – a small amount of economic effect or a lack of efficiency – the value of k should be changed through the project financing system or the function of the economic effect $f(x)$ by changing the means of production or their volumes.

Conclusions. *In many cases, for normal development of companies and implementation of their projects, it is desirable to have time-increasing profit and production volumes. If these values are subject to fluctuations with recessions, then this situation is extremely undesirable for reliable and confident development of the company. At the same time, losses in recessions are not only of direct financial nature, besides image damage is also possible. Therefore, sustainable development is considered as an increasing process of the project's (and the entire company's) entrance to a stable equilibrium position.*

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