Role of time in implementation of innovative technologies

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Abstract. Time is considered as production resource, which determines the need for its effective use in connection with other production resources. The problem consists in the inconsistency of the results of the existing forecasting system of production which are founded on modern concepts of space and time. The theoretical positions of Galilean, A. Lorentz and G. Minkowski were analyzed. A. Einstein's explanations regarding the use of the velocity of light in vacuum as a constant in the well-known dependency for the generalized four-dimensional space were studied. An attempt is made to solve the applied problem in space and time, taking as a constant, for example, standard or maximum possible, (calculated) productivity.

1 Introduction

Time in the road construction industry is a resource and its efficient use is an extremely urgent task. The analysis of the concepts of time which are realized within scientific knowledge shows that in the understanding of time, various components of the reality's perception are organically intertwined. As a rule, each fundamental discovery in physics was accompanied by the development of a new model of time [1, 2].

Resources are analyzed in the form of capital, as a material factor (fixed and working assets) and human labor (which of course also includes non-material factors) [2]. It is suggested to use the production function as a digital model for the most universal analysis type of production systems [3]. Any savings ultimately leads to saving time, which increases the economic efficiency of business entities. In modern conditions, time as an economic category acts as a resource that follows the laws of market relations and largely

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forms the basis of economic laws, largely determining the motives and goals of economic activity of enterprises [2 - 4].

In the practice of introduction of innovative technologies the basic index of growth and average annual growth rate are usually used for a quantitative assessment of the dynamics of production. It is assumed that the growth of the volume of production over time occurs with unchanged parameters of the equations $X_t = X_0(1+x)^t$ or $X_t = X_0 e^{xt}$, where X – production volume, x – average annual growth rate, t – time. This approach shows quite precisely the real economic dynamics if the production expands equally. In real conditions of modern production development, such an assumption would be an escape from the truth. The task of variability assessment of the influence of factors over time which is associated with the dynamics of average values is complex. It is necessary to make a quantitative and qualitative description of this part of the variability not only in connection with each of the factors under consideration, but also with the combinations of the factors under analysis, and the variability of their values in time is interrelated [3, 5 -7]. The problem lies in the inconsistency of the existing system of result forecasting of innovative activities in the road construction industry with the opportunities based on the modern concept of space and time.

2 Research background

Let us consider a generalized case. Let a certain amount of work for the period of time ΔT is performed during the time ΔV with the productivity $Q(t)$. Then one of the economic relations can be presented as follows:

$$\Delta V = Q(t) \cdot \Delta T \tag{1}$$

Where ΔV is the increment in the volume of work performed over period of time ΔT. We will consider ΔT as a small quantity in order to avoid the differential calculus. Let us pay attention to the fact that if we fix all the material factors of production, then it follows from formula (1) that the amount of work performed ΔV is only a function of time.

For a fixed value of ΔV, equation (1) is an equation with two unknowns, namely $Q(t)$ and ΔT. As it is known, such an equation admits an infinite number of solutions $(Q_i(t); \Delta T_i)$ $i \in N$; none of them is complete without ΔT. If $\Delta V = const$, then the mutual, practically unlimited influence on each other becomes obvious. This fact is confirmed by the practice of introduction of innovations in organizational and economic systems.

Hence, we can make a conclusion. If $Q(t)$ is determined by the power of physical factors' use, then, influencing on ΔV through (1), it behaves exactly like a physical factors, i.e. it is a production factor. If time is a factor in production, then it should be taken into account during the planning of works. Time should be seen not only as "length" in the fourth dimension, but also as a factor that has a decisive influence on productivity.

Let us consider in more detail the consequences drawn form this conclusion.

It is required during the time T to perform the following volumes of various works: $V_1, V_2, \ldots V_k$ with the use of machines $M_1, M_2 \ldots M_n$. We indicate the productivity of the machines $M_1, M_2 \ldots M_n$ when performing various works q_{ij} (the i -th machine at the j - th type of work). Working hours of each machine in different jobs here are t_{ij}. The costs in conventional monetary units caused by the use of the i -th machine at works of the j- th type per unit of time will be indicated as p_{ij}.

Then at q_{ij} ; p_{ij} = const we get the following linear problem:

$$\begin{cases} \sum\limits_{j=1}^{k} t_{ij} \le T; \quad i=1,\overline{n}. \\ \sum\limits_{j=1}^{k} q_{ij} \cdot t_{ij} = A_i; \quad i=1,\overline{n} \\ q_{ij} \ge 0; \quad t_{ij} \ge 0 \quad \forall ij \in \{I;J\} \\ \sum\limits_{\forall i;j \in \{I;J\}}^{k} p_{ij} \cdot t_{ij} \to \min. \end{cases}, \tag{2}$$

This problem is set and solved under the assumption that the values of *p; q; t* are constants during the performance of the volume of work.

Now let us suppose that in this model *p* and *q* are functions of *t*, what is an absolute requirement for innovative development. This circumstance changes the model qualitatively. First, it is not linear any longer and therefore it cannot be solved by widely used methods. Secondly, the efficiency of planning will be completely different, because now $\min(\sum\limits_{\forall p_{ij=const}} p_{ij} \cdot t_{ij}) \ne \min(\sum\limits_{\forall p_{ij(t)}} p_{ij} \cdot t_{ij})$. There is no doubt that in mathematical terms, the study of such a model is important for sufficiently accurate forecasting, since it meets the real conditions of the innovation process to a much greater extent. It is also clear that such a study is much more complicated than the research presented in the linear form [8 - 10].

The purpose of the study is to show the opportunities of assessment of time influence on the innovation process in interdependence with the main production resources (in space and time).

3 Materials and methods

Let us study one of the simplest examples of the use of time as a factor of production.

Let us suppose that the productivity (the amount of work performed per unit of time) is known, which is a variable in time:

$$Q_0(t) = a_0 t^2 + b_0 , \tag{3}$$

where b_0 - productivity in moment in time $t = t_0 = 0$, and a_0 characterizes the speed of productivity changes (i.e. the curve gradient $Q_0(t)$). Let the amount of work be carried out over time T_0 . Then the amount of work performed is determined by the integral:

$$V = \int\limits_0^{T_0} Q_0(t)dt = \int\limits_0^{T_0} (a_0 t^2 + b_0)dt = \frac{a_0 T_0^3}{3} + b_0 T_0. \tag{4}$$

Let us set the problem. We need to perform the same work in time $T_1 \prec T_0$ by means of changing the productivity. How can we determine the coefficients of the productivity equation?

We will present this equation in the form $Q_1(t) = a_1 t^2 + b_1$. Since the change in productivity begins with the change in the material and intellectual basis, we will assume that b_1 in equation $Q_1(t) = a_1 t^2 + b_1$ we already know: $b_1 = Q_1(0)$. Let's note that there is a lot of freedom in choice, because the productivity of work in time can be determined not only by the magnitude b_1, but by the magnitude $a_1 \succ 0$.

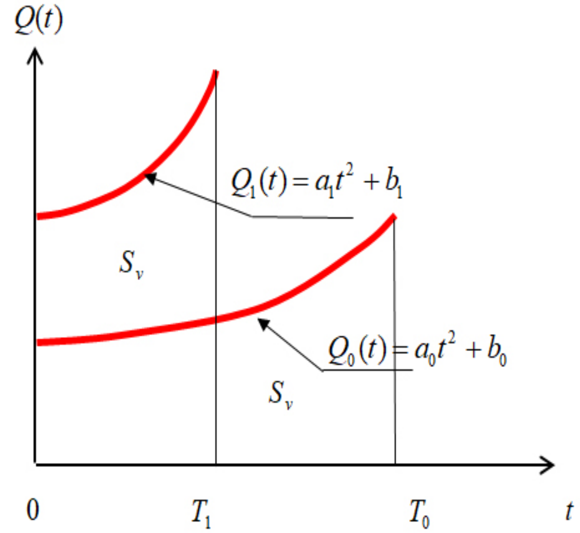

Fig. 1. Presentation of equal areas of curved trapezoids S_v.

Let us show how you can determine the coefficient a_1. Let us have two productivities: $Q_0(t)$ and $Q_1(t)$. $Q_0(t) = a_0 t^2 + b_0$ - initial productivity. The coefficients of this equation are easily determined, for example, by the least squares method $Q_1(t)$ - new performance.

In Figure 1 S_v is the area of curvilinear trapezoids, which in our case are equal, since their area coincides with the volume of work performed during the times T_0 and T_1, although in our research we do not always assume their equality. The amount of work done with productivity $Q_0(t)$ is determined by means of the integral

$$V = \int_0^{T_0} (a_0 t^2 + b_0) dt = \frac{a_0 T_0{}^3}{3} + b_0 T_0; \text{ Similarly}$$

$$V = \frac{a_1 T_1^3}{3} + b_1 T_1 \Rightarrow \frac{a_1 T_1^3}{3} + b_1 T = \frac{a_0 T^3{}_0}{3} + b_0 T_0 , \qquad (5)$$

since the areas of the trapezoids (volumes of work) are equal.

If this were not so, then in equation (3) there would appear an additional numerical coefficient, which does not lead to a complication of the solution. From equation (3) we get:

$$a_1 = \frac{3}{T_1^3} \left(\frac{a_0 T_0^3}{3} + b_0 T_0 - b_1 T_1 \right). \qquad (6)$$

Therefore, the equation of the "new" productivity will be presented as follows:

$$Q_1(t) = \frac{3t^2}{T_1^3} \left(\frac{a_0 T_0^3}{3} - b_0 T_0 - b_1 T_1 \right) + b_{1.}. \qquad (7)$$

This productivity allows us completing the same amount of work for the period of time $T_1 \prec T_0$

4 Discussion

Taking into account the fact that spatial and temporal characteristics are mutually dependent [11, 12, 13, 14], let us first of all consider the Galilean coordinate system of space and time, in which the four-dimensional pseudo-Euclidean space is presented by a linear element [12]:

$$ds^2 = c^2 dt^2 - dx^2 - dy^2 - dz^2, \tag{8}$$

where $x, y, z -$ spatial coordinates, and t temporal coordinate, c – velocity of light. In the special theory of relativity, inertial reference systems, as a rule, are specified by the Galilean coordinate system, in classical mechanics they are specified by the Cartesian coordinate system [12]. The transition between different Galilean coordinate systems is carried out by means of the Lorentz transformation [13]. It should be noted that the Lorentz transformation is an analogue of orthogonal transformations in Euclidean space.

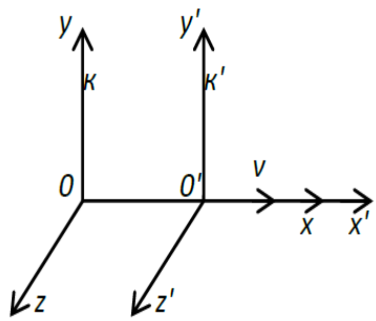

Fig. 2. Geometric interpretation of Lorentz transformation

According to Minkowski theory, the location of an event is also specified by four coordinates: three spatial and one temporal [14, 15]. The following coordinates are commonly used: $x_1 = x, x_2 = y, x_3 = z$, where *x, y, z* are rectangular Cartesian coordinates of the event in some inertial system and $x^\circ = ct$, where t – time of event, c – velocity of light in vacuum. The geometric properties of four-dimensional space are determined by the expression of the squared distance between two events (intervals) s^2 :

$$s^2 = (dx^\circ)^2 - dx^2 - dy^2 - dz^2, \tag{9}$$

It can be seen from the given dependences that for the solution of applied problems in space and time it is very important to explain the role of the factor *c,* i.e. the velocity of light. It is advisable to refer to the remark of A. Einstein. “In order to give the concept of time a physical meaning, we need some kind of processes that would make it possible to establish a connection between different points in space. The issue about the type of processes that are chosen with this definition of time is insignificant. It is beneficial for theory, of course, to choose only those processes for which we know something definite. The propagation of light in emptiness is suitable for this purpose to a much greater extent than any other process that could become an object of consideration thanks to the research of Maxwell and Lorentz "[16].

In system (6), *c,* the velocity of light in vacuum is a constant. Consequently, in order to solve the applied problems, it can be replaced by a constant that satisfies most the requirements of the process under analysis [12]. For example, in our problem, you can take the standard one, or maximum possible, (or calculated) productivity.

Then in order to solve the problem of modeling the production process in a generalized four-dimensional space, expression (7) can be presented as:

$$s^2 = (dx^\circ)^2 - dx_1^2 - dx_2^2 - dy^2 , \tag{10}$$

where x_1 – fixed assets; x_2 – working capital (labour and materials); y – amount of work. Then $x^\circ = Q_i t$, where Q_i – productivity at ideal (or, for instance, normative one) conditions, t – time, q – productivity, characterizing the system in the planned process.

The Lorentz transformations are an analogue for the Minkowski metric of orthogonal transformations that change from one orthonormal basis (a basis consisting of mutually orthogonal vectors) to another or a generalization of motion concept in Euclidean space.

The general transformation group consists of combinations of spatial reflections in time and transformations, which, from a physical point of view are the transformations of the transition from one inertial system to another one [13].

The transformations in the plane of pseudo-Euclidean metric are a specific feature of the transformation, which is very important for our study. The zero of coordinate system coincides at the initial moment of time in both systems [13]. Then the direct quasi Lorentz transformations for the solution of the problem in three-dimensional space and time will look as follows:

$$x_1^/ = \frac{x_1 q t}{\sqrt{1 - \dfrac{q^2}{Q^2}}}, \qquad x_2^/ = x_2 , \qquad y^/ = y, \qquad t^/ = \frac{t - \left(\dfrac{q}{Q^2}\right) x_1}{\sqrt{1 - \dfrac{q^2}{Q^2}}}. \tag{11}$$

The obtained mathematical expressions allow us to proceed to prediction calculations of a process in space and time [17, 18].

5 Conclusion

It was specified that in mathematical terms the study of a model, including costs, productivity and time, is a necessary condition for sufficiently accurate forecasting, since it meets to a much greater extent the real conditions of the innovation process. It is shown that time can be considered as an production resource, which causes its effective use in interdependence with other production resources. On the basis of research of theoretical provisions of the works of Galilean, G. Lorentz and G. Minkowski, as well as A. Einstein's explanation about the constant, i.e. the velocity of light in a vacuum in a generalized four-dimensional space, the assessment of the influence of the innovation process in space and time is suggested. At the same time, the authors suggest using the standard or maximum possible (calculated) performance as a constant. As a result, it was found that the quasi-Lorentz transformation and the generalized Minkowski space make it possible to simulate the management of an innovative process in a four-dimensional space that combines a physical three-dimensional space of resources with the time factor.

References

1. V.P. Kazaryan, *The concept of time in the structure of scientific knowledge*. Moscow, Moscow State University Publishing House (1980)
2. J. Whitrow, *Natural philosophy of time*. Transl. from English. Edition **2**, stereotyped. 398 P. (2003)
3. N.V. Kozhevnikova, *Time factor in the system of economic stability of business entities*. Dissertation of Candidate of economic sciences. Moscow (2005)
4. V.B. Daskovsky, V.B. Kiselev, *Time factor in assessing the effectiveness of investment projects*. Electronic resource. Available at: https://www.youtube.com/watch?v=9MURHs7CwJ0 Reference date 01.02. 2021
5. A.I. Anchishkin, L.D. Dmitrieva, *Simple quantitative characteristics of the dynamics of social production* / Statistical analysis of economic time series and forecasting. M .: Science. 233 P. (1973)
6. L.M. Shnaidman, *Analysis of dynamics and forecasting of labor productivity* / Statistical analysis of economic time series and forecasting. M .: Science. P. 248. (1973)
7. J. Schumpeter, *History of Economic Analysis.* In three volumes. St. Petersburg: School of Economics, 1353 P. (2004)
8. N.S. Chetverikov, *Time series smoothing* // Statistical analysis of economic time series and forecasting. M .: Science. 106 P. (1973)
9. V.M.Polterovich, *Hypothesis about the innovation pause and modernization strategy* // Problems of Economics.. No. **6**. 12 P. (2009)
10. V.A.Yarmolinsky, A.M. Khakimov, *Increasing the efficiency of the use of production resources in conditions of uncertainty in financing road facilities* // Bulletin of Pacific Ocean State University. No. **1**. pp. 11–19 (2011)
11. Sakai Yukihito, *Four-dimensional Mathematical Data Visualization via* "Embodied Four-dimensional Space Display System" Faculty 2 Research of Information Sciences and Arts, Toyo University, 2100 Kujirai, Kawagoe, Saitama [Electronic resource] / Sakai Yukihito, Shuji Hashimoto. Available at: http://www.scipress.org/journals/forma/pdf/2601/26010011.pdf. Reference date 30.01.2021.
12. A. Einstein, *Basic ideas and problems of relativity theory* // Collected scientific works, Vol. II. M., 120 P. (1966)
13. Moshe Carmeli, *Group Theory and General Relativity*, Representations of the Lorentz Group and Their Applications to the Gravitational Field / Moshe Carmeli. McGraw-Hill, New York, 311 p. (1977)
14. Hermann Minkowski, *Geometrie der Zahlen* / Hermann Minkowski. eipzig-Berlin: R. G. Teubner, 320p. (1910)
15. *Raum und Ziet*, Report made on September 21, 1908 at the meeting of German naturalists and doctors in Cologne. Phys, ZS. 10. 104. (1909)
16. A. Einstein, *Theory of relativity*. Foreign literature publishing house. M., P. 28. (1955)
17. V.S. Borovik, V.V. Borovik, *The Development of the Innovation Process in Road Construction in Minkowski Space.* Advances in Economics, Business and Management Research, Volume 47. International Scientific Conference "Far East Con" (ISCFEC 2018). Part of series Publication, date 2019/01/27. ISBN 978-94-6252-656-3. ISSN 2352-542. DOI: 10.2991 / iscfec-18.2019.12/
18. V.S. Borovik, V.V. Borovik & V.V. Lukin, *Modeling in Space and Time of Management Level for Road Safety* // Transportation Research Procedia. Volume 20, 2017, Pages 74–79. Oxford, OX5 1GB, United Kingdom. https://authors.elsevier.com/sd/article/S2352-1465(17)30017-0