The relevance of the issue, related to building an information infrastructure of technology transfer, is predetermined by the transformation of information into the most important resource of technological cooperation. At the same time, its effective functioning requires investment support on a regular basis. This paper addresses the establishment of regularities in the process of investing in the development of the information infrastructure of technology transfer and determining the rational volumes of these investments. This study was carried out in the context of the regional market, which is due to the territorial specificity of market processes, the peculiarity of information interaction among economic agents in a separate market.

The study results have identified the following patterns: the lower the transaction costs of technology transfer participants, the more productive the functioning of the information infrastructure; the more active the cooperation between the participants of technology transfer, the more investment revenues in the development of this infrastructure. Taking into consideration these patterns, a simulation model of the process of investing in the development of the information infrastructure of technology transfer has been built.

The proposed model was tested using an example of the real estate market in the Prydniprovskyi economic region of Ukraine. As a result of the simulation experiment, the optimal level of costs for the development of the information infrastructure for technology transfer has been established. It makes up 20 % of all available investment funds in this market. The proposed model could be adapted for other regional markets.

The results of this study could be useful for the system of state and regional management since they substantiate the directions of innovation policy formation and promote the development of technology transfer under the conditions of certain territorial systems

Keywords: market, technology transfer, investment, information infrastructure, transaction costs, simulation model

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INVESTING IN THE DEVELOPMENT OF INFORMATION INFRASTRUCTURE FOR TECHNOLOGY TRANSFER UNDER THE CONDITIONS OF A REGIONAL MARKET

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1. Introduction

An important component of the economic complex of the state is the system of markets. The mechanism of formation and functioning of markets represents an interaction of objectively active factors, phenomena, and processes in the production, distribution, exchange, and consumption of goods and services specific to a given territory. Regional markets are inherently primary since this is where the product is created, tested, the volume of its supply and demand for it is formed, as well as the price, conditions, and principles of implementation [1]. Therefore, the degree of development of these markets affects the nature and characteristics of the regional and state market economy, the success of information and technological progress, knowledge management and updating.

Special changes in the evolution of regional markets occur due to innovative progress, the accumulation of innovative potential, the expansion of boundaries, and the activation of the technology transfer institute. In the innovative economy, its scientific principles, technology transfer is recognized as one of the effective tools for promoting knowledge, commercializing technological and scientific advances. Stimulating markets by attracting technology transfers is an appropriate tool for innovative progress.

It is also obvious that the key to effective technology transfer is the sustainable development of its infrastructure as a single network of information exchange between its participants. It consists of innovation and technology centers, technology transfer centers, information agencies, consulting firms, information funds of libraries and scientific institutions, statistics bodies, centers for the commercialization of innovations, as well as means of information exchange service.

Information flows circulating between market participants are carriers of their relations in a certain economic environment. They permeate the entire system of market relations and unite economic agents both within a certain market and in a system of different types of markets. Thus, various regional markets are integrated into a single information space, as a modern integrated platform with a targeted circulation of information flows and technology transfer.

The development of information infrastructure clearly has a territorial character since the institutions that make up its composition function mainly within the same region (although there may be exceptions). They serve the business entities and population of a certain territory (city, district, region). Therefore, it is advisable and logical to analyze the information infrastructure of technology transfer as a regional system.

The development of the information infrastructure of technology transfer requires the involvement of significant material and financial resources. However, at the same time, it poses an important question: what share should constitute investments in the development of information infrastructure in the total volume of regional investments? Therefore, justifying the volume of investment support for the development of the information infrastructure of technology transfer is a relevant task both from the point of the theory of innovative economy and from the point of the practice of state and regional management. Devising a model that would make it possible to determine these volumes could contribute to a more effective targeted use of investment funds to support the transfer of technologies in certain sectors of the economy and in specific regional markets.

2. Literature review and problem statement

The issue of information support for technological cooperation, both at micro and macro- and meso-levels, is of great interest to modern scientists. Paper [2] investigates the forms of cooperation between universities and businesses, it was proven that the close relationship between universities and the country's production system stimulates the process of technology transfer and commercial use of research results. The authors of the cited paper reveal the role of infrastructure support for innovative projects through the analysis of the network of the technology transfer bureau and offer a model for evaluating the interaction among its participants. However, the authors failed to consider investments in the creation and development of such a network. This can be explained by the complexity of accounting for project financing in flat network structures, which include a large number of small spin-off companies.

An option to overcome such difficulties may be the creation of a coordinating structure – a single center for supporting innovative activity at the level of a certain territory (region). In this context, work [3] is interesting, which tackles creating an integrated platform of knowledge and attracting technology transfers. However, the cited work does not take into consideration the regional contexts of technology transfer.

More fully, these contexts are disclosed in article [4], which reports a transnational analysis of various regional forms of cooperation in technology transfer processes. However, the cited article focuses on the organizational aspects of such interaction while not revealing the specifics of investing in these processes.

Scientists consider the significance and prospects of studying technology transfer issues and promoting open innovations from the point of view of the accumulation of national experience. The most indicative in this regard are the results reported in work [5], which systematizes the output from 249 researchers at a scientific center in Italy. These studies indicate that specific forms of technology transfer are associated with specific configurations of regional innovation systems, academic organizations, and the motivation of researchers. Thus, the importance of the infrastructure component of technology transfer is emphasized. However, at the same time, the issues of effective investment in the development of such infrastructure remain open.

The issues related to attracting investments to support technology transfer are addressed in the work by scientists at King's College London [6, 7]. Using an example of this institution, the scientists reveal the mechanism for stimulating academic entrepreneurship and technology transfer, outline actual strategies for the commercialization of the results of such interaction [6]. By outlining the synthesis of micro- and macro-levels, the authors provide a broader conceptualization of academic entrepreneurship and an assessment of its contextual heterogeneity [7]. At the same time, the emphasis is on the micro-level and concerns how firms organize their resources and opportunities to combine and configure them to obtain a steady return on technological cooperation. The macro-level analyzes four different dimensions of context: time, institutional, social, and spatial. Issues of attracting investments in the transfer of technologies are completely transferred to the micro-level, which significantly limits the possibilities of state support for innovative entrepreneurship.

The macroeconomic aspect of attracting investments to support technology transfer is revealed in work [8]. Its authors prove the relationship between variables of foreign direct investment into innovative infrastructure, technology diffusion, trade promotion, knowledge management, technology transfer, and economic growth. However, the cited work does not reveal how this interdependence can be measured and how to take that into consideration when developing programs to support the innovation field.

An interesting perspective on the relationship between direct foreign investments and the intensification of technology transfer is given in work [9]. International technology transfer through foreign direct investment appears as an endogenous equilibrium phenomenon, which is the result of

strategic interaction between subsidiaries of multinational corporations and host country firms. This takes into consideration two types of costs the cost of transnational technology transfer to branches and the cost of training domestic firms. However, other transaction costs accompanying the transfer of technologies remain beyond the attention of the authors, the possibility of their changes is not taken into consideration depending on the region of technological cooperation.

All this suggests that it is expedient to conduct a study addressing the actualization of investments into providing information support for the transfer of technologies at the regional level based on reducing the transaction costs of participants in these processes.

3. The aim and objectives of the study

The purpose of this research is to substantiate the regularities of investment processes in the development of the information infrastructure of technology transfer, which could determine the rational volumes and priorities of investment support for technological cooperation in specific regional markets.

To accomplish the aim, the following tasks have been set:

– to define the role and regularities of the functioning of the information infrastructure of technology transfer in the development of the regional market;

– to build a model of investment processes in the development of technology transfer information infrastructure in the regional market;

– to conduct an imitation experiment to determine the amount of investment in the development of the information infrastructure of technology transfer using an example of a particular regional market.

4. The study materials and methods

The hypothesis of our study was as follows: the development of the information infrastructure of technology transfer has a clearly defined regional nature and is influenced by the level and structure of transaction costs of participants in specific regional markets. To reduce these costs, investment in the development of the information infrastructure of technology transfer is aimed. It was assumed that there are certain patterns related to investment processes. They were taken into consideration when building a model that interprets a simplified idea of the processes of investing into the development of the information infrastructure of technology transfer and makes it possible to establish the most rational level of investment costs. The simulation experiment involving our model was carried out using an example of the real estate market in the Prydniprovskyi economic region of Ukraine. However, according to assumptions made, it was expected that the would-be results could be extended to other regional markets. This is due to the fact that the components of the model and their relationship are universal for any market system. The specificity is only the dynamics of their changes under the specific conditions of information exchange between participants in the transfer of technologies, as well as various manifestations of the influence of the institutions of regulation of such interaction.

The methodological basis of this study is a dialectical method of knowledge of reality, a systematic approach to the study of technology transfer processes, fundamental positions of the knowledge economy, and information economy.

The research was conducted at the theoretical and empirical levels using the following methods. In the study of the essences and regularities of the development of the information infrastructure of technology transfer, methods of abstract-logical and system analysis were used. The research into the processes of developing the information infrastructure of technology transfer in the context of regional economy was carried out by methods of mean and relative values and dynamic series. The construction of a model of processes of investing into the development of the information infrastructure of technology transfer and its approbation in the regional market was carried out using a method of simulation. Correlation-regression analysis was used to identify the relationship between the model parameters.

To analyze the dynamics of the model's variables, as well as to establish the relationship between investments and the level of transaction costs as a result of technology transfer, the power of the MS Excel statistical data analysis package (USA) was used. PowerSim Studio (Norway) software package was used to implement an imitation experiment on investments in the development of technology transfer infrastructure in the regional real estate market. The information base of our research is made up of official statistics on the development of regional markets in Ukraine.

5. The results of studying the role of technology transfer information infrastructure and the justification of investments in its development

5. 1. An information technology transfer infrastructure: its role in the development of the regional market and the need for investment support

The information infrastructure of the regional market is one of the most important factors that create conditions for the effective transfer of technologies, so it is in the context of the development of regional markets that it is worth investigating the processes of its functioning.

An example of the regional real estate market is especially representative, which reflects all the issues of the economy, social life of the region, public administration. The market is characterized by the uneven development of its individual segments, imperfect legislative framework, and low investment liquidity of the product, by the constant need for the introduction of new construction technologies, innovative products for servicing market agents.

The role of information infrastructure is largely due to the existing issues related to information support for regional markets, the presence and efficiency of attracting innovative technologies and products. As regards the real estate market, a rather significant issue is the lack of awareness of market participants, which is due to the concealment of actual prices for the sale of objects, poorly developed information infrastructure, the low level of attracting intelligent products. That leads to the need for additional costs for collecting and verifying data when analyzing investment projects.

A negative factor in the development of the real estate market is the difficulty in obtaining reliable information about real estate objects, prices, and conditions for the sale

of these objects. The information contained in the published information sources of various real estate agencies is often repeated, is outdated, and unreliable, it does not meet the qualitative and quantitative parameters of evaluation models. Therefore, it seems that there are more offers in the real estate market than there really are.

Information support of technology transfer in the real estate market contains provisions of the regulatory and legislative framework of Ukraine, information resources of companies and scientific institutions on innovative projects in this area. A significant issue is the lack of statistical databases that would allow for the quantitative and qualitative assessment of technological flows in this market.

Most frequently, the information about the real estate market, which is published in the press, is repeated, the regulatory framework often changes. Information exchange between market participants is fragmented, inconsistent, and often unsystematic. That is due to the disconnection and incompatibility of information systems for collecting and processing data from various market participants, which gives rise to significant difficulties in the transfer of technologies. Therefore, the development of all segments of the regional real estate market is hampered by the issues of information supply, the low quality of intellectual products due to imperfection of the information infrastructure of technological exchange.

In the development of regional markets of Ukraine, there is no single information network that would connect all participants in the transfer of technologies. Participants in such an information network may include innovation and technology centers, technology transfer centers in construction and development, information databases of leading market agents. It could also be joined by consulting companies serving the real estate market, scientific institutions, and scientific parks engaged in developments in the field of construction, landscaping, and real estate management.

The creation of such a network would ensure the adoption of more informed management decisions on technological exchange implementation. And its functionality and resources could be involved in the analysis and implementation of innovative projects in the real estate market. Creating a network should be a priority for investment support of technology transfer at the regional level. That will contribute to the protection of property rights to real estate, effective assessment of its value, active exchange of technological information, protection of investors' rights, and, in general, the involvement of innovative technologies in the construction sector [10].

Investments in the development of information infrastructure could contribute not only to the combination of market agents in a single technology transfer network but also would create a database of innovative projects of the regional market. They could cover the cost of technological audit (verification of technical capacity and readiness for transfer), information support of network members (creation of a website, organization of information events, consultations). Financing of the creation of a communication platform for job search, exchange of experience, interaction in solving business issues in the real estate market is positive.

Disclosure of the peculiarities of the functioning of the information infrastructure of technology transfer could be carried out in the context of the conditions of individual regions. It is important that these regions have the most pronounced prerequisites for the development of market potential in the context of regional informatization, stimulation of digital technologies, and targeted involvement of technology transfers in the information support sector.

To reveal the specifics of the impact of regional market information infrastructure on entrepreneurial activity, an example of the Prydniprovskyi economic region within the Dnipropetrovsk and Zaporizhia oblasts is relevant. These administrative units are similar in terms of economic activity, social development, and cultural traditions. All this predetermines the homogeneity of market development issues, outlines the interest of business in stimulating innovations, and fruitful cooperation of entrepreneurial structures forms a single information space of business activities.

Despite the active innovative activity of enterprises in the region (and this region ranks third in the rating of innovative activity of Ukrainian enterprises) [11], network forms of support for innovations are still underdeveloped. This creates the need for significant investment resources and targeted technology transfers. At the same time, the sources of funding should be not only the regional budget but, primarily, a private investor. It is the effective organization of information transactions in the process of technology transfer that provides significant advantages to economic agents in increasing their competitiveness in the regional market.

To resolve this issue, it is necessary to conduct an experiment and define the features and most effective trajectory of the development of the regional economic system at different values of the indicator of investments in the development into the information infrastructure of technology transfer. To this end, it is advisable to use the methods of economic and mathematical modeling, namely to build a mathematical model of the processes of investing into the development of regional information infrastructure and conduct an imitation experiment involving it, to determine the optimal value of the required parameter. At the same time, the most appropriate is the use of system dynamics methods.

Information infrastructure is nothing more than a specific area of interaction, which is a projection of the real space of contacts of technology transfer participants (that is, information infrastructures of individual regional markets) onto a new more stable coordinate system. The formation of such a system is influenced by the level of change in information images of market entities, which, in turn, constitute an information image of the regional market.

5. 2. Modeling the processes of investment into the development of information infrastructure of technology transfer in the regional market

The information image of the regional market gives an idea of its specific state, information connections among its participants. However, by its nature, this image is static and does not reflect the movement of information flows in the market system. Therefore, in order to understand the level of development of information support of a particular regional market and the possibility of its integration into a single regional system, a model has been built for the processes of investing in the development of regional information infrastructure of technology transfer.

It is proposed to carry out this experiment for the real estate market of the Prydniprovskyi region. This market is characterized by stable economic ties among entities, a rather complete list of elements of information infrastructure, but the lack of a unified system of information support for innovation activities, which complicates the transfer of technologies.

To build this model, the theory of transaction costs was used, since it most fully makes it possible to analyze the costs of enterprises for transactions, whose element is the cost of finding the information necessary for the transfer of technologies.

The structure and volume of these costs are associated with the development of the information infrastructure of the market. Effective channels of technological interaction provided by developed infrastructure contribute to their reduction and stimulate the attraction of technology transfers according to the parameters of the needs of market agents. Therefore, there is a relationship between transaction costs and the level of development of information infrastructure, which is the basis for building a model.

Resolving the task of forecasting the information interaction of technology transfer entities should begin with the construction of a scheme of causal relationships between variables – factors of information processes at the regional level (Fig. 1).

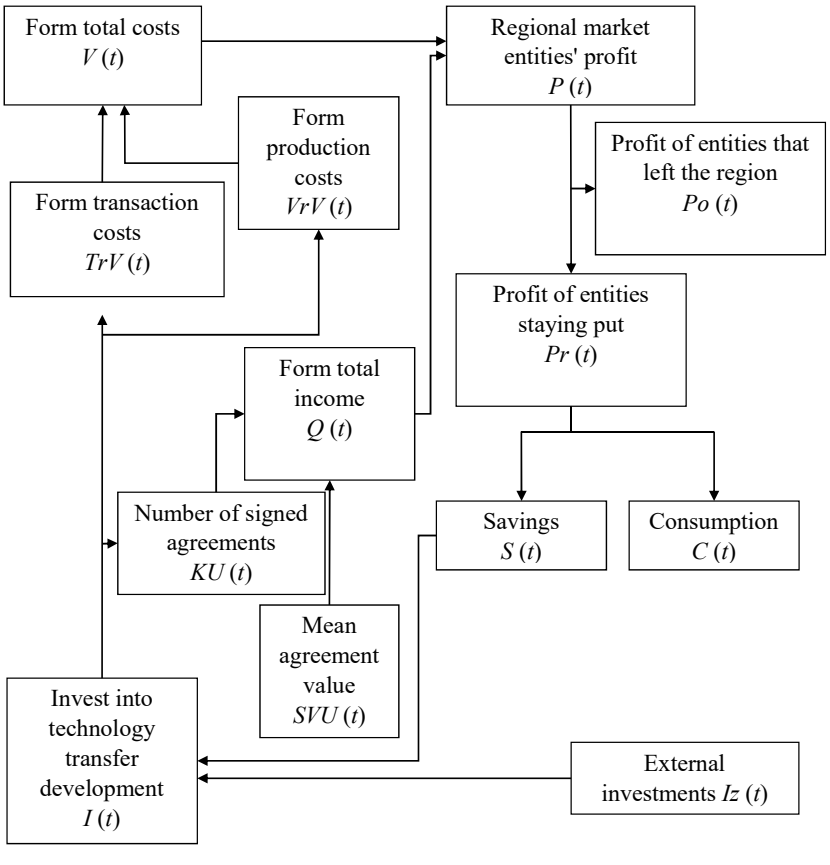


Fig. 1. Scheme of a simulation model of the processes of investing into the development of regional information infrastructure of technology transfer

The model's variables are:

Q (t) – income of regional real estate market entities in the period *t*;

KU (t) – the number of technological interaction agreements concluded during the period *t*;

SVU (t) – the average transaction value during the period *t*;

V (t) – expenses of the entities of the regional real estate market for the transfer of technologies in the period *t*;

VrV (t) – production costs of market entities during the period *t*;

TrV (t) – transaction costs of market entities during the period *t*;

Vi (t) – the cost of searching for information during the period *t*;

Vp (t) – negotiation costs during the period *t*;

Vk (t) – costs of drafting contracts during the period *t*;

Vm (t) – monitoring costs during the period *t*;

Vik (t) – the cost of enforcement of contracts during the period *t*;

Vz (t) – third-party protection costs during the period *t*;

P (t) – profit of the entities of the regional real estate market in the period *t*;

Pr (t) – part of the profits of regional market entities during the period *t* remaining in the region;

Po (t) – part of the profits of regional market entities during the period *t* that does not remain in the region;

C (t) – part of the profit remaining in the region, aimed for consumption in the period *t*;

S (t) – part of the remaining profit in the region, aimed for accumulation in the period *t*;

I (t) – the amount of investments to support technology transfer in the regional market in the period *t*;

Iz (t) – external, in relation to the regional market system, investment in the period *t*.

We analyzed the scheme of a causal relationship in the model.

As a result of transactions, the income and expenses of regional market participants are formed. Income of subjects can be found from the following ratio:

$$Q(t)=KU(t)\times SVU(t). \quad (1)$$

The costs of regional market entities are divided into production and transactional:

$$V(t)=VrV(t)+TrV(t). \quad (2)$$

Traditionally, transaction costs are represented in accordance with the following formula:

$$TrV(t)=Vi(t)+Vp(t)+Vk(t)+ +Vm(t)+Vik(t)+Vz(t). \quad (3)$$

To determine the transactional and production costs of regional market entities, statistical reporting data [12] were used in our work. Table 1 illustrates the dynamics of expenditures of real estate market entities in the Prydniprovskyi region during 2013–2019.

By analyzing the data in the above table, we can conclude that during 2013– 2019 the expenses increased by USD 16.3 thousand per day, which is 18.4 % of the 2013 level. At the same time, the cost structure is as follows: depreciation deductions (41 %), followed by other expenses (20 %), material costs (17 %), employee remuneration (16 %), and deductions for social events (6 %).

Table 1

The dynamics of expenses by the real estate market entities in the Prydniprovskyi region

Year	Expenses, USD thousand per day	including (USD thousand per day)				
		Material	Depreciation	Wages	Social deductions	Other
2013	88.5	15.1	36.3	14.2	5.3	17.7
2014	91.2	15.5	37.4	14.6	5.5	18.2
2015	94.1	15.9	38.6	15.1	5.6	18.8
2016	96.9	16.5	39.7	15.5	5.8	19.4
2017	99.1	16.8	40.6	15.8	5.9	19.8
2018	102.6	17.4	42.5	16.4	6.2	20.5
2019	104.8	17.8	42.9	16.8	6.3	20.9

The production costs of the entities include depreciation deductions, material costs, employee remuneration, and deductions for social events; other expenses are defined as transaction costs.

The following is the dependence between costs and the amount of investment into the development of information infrastructure (Table 2). To this end, we use the following data [12]:

Table 2

Dynamics of the main indicators of the development of the real estate market in the Prydniprovskyi region

Year	Production costs, USD thousand per day	Transaction costs, USD thousand per day	Investments, USD thousand per day
2013	70.8	17.7	13.5
2014	72.9	18.2	17.2
2015	75.3	18.8	15.3
2016	77.5	19.4	16.5
2017	79.2	19.8	19.7
2018	82.1	20.5	25.9
2019	83.8	20.9	28.3

To identify the connection between these indicators, a correlation-regression analysis was carried out. To this end, a correlation model has been built that determines the dependence between investments and transactional costs, as well as production costs, respectively:

1. Transaction costs. To derive the dependence, the capabilities of the statistical data analysis package MS Excel were used. The following regression equation was built:

$$TrV(t)=0{,}19\times I(t)+423{,}52. \quad (4)$$

In this case, the derived values of the determinant coefficient (R^2=0.84) and the corrected determinant coefficient ($\overline{R^2}=0{,}81$) indicate a fairly close linear relationship between variables. The value of the σ rms deviation is 14.1 (2.3 %). The significance of the Student's *t*-test for the variable *I (t)* (0.26 %) and Fisher's *F*-test for the model (0.39 %) are less than 5 %, which indicates the statistical significance of the variable and the model as a whole.

Thus, based on the analysis of the obtained indicators, we can conclude about the informational suitability of the built model.

2. Production costs. Similarly, the regression equation is constructed:

$$VrV(t)=0{,}78\times I(t)+1694{,}07. \quad (5)$$

At the same time, the derived values of the determinant coefficient (R^2=0.85) and the corrected determinant coefficient ($\overline{R^2}=0{,}81$) indicate a rather close linear relationship between variables. The value of the σ rms deviation is 56.38 (2.6 %). The significance of the Student's *t*-test for the variable *I (t)* (0.31 %) and Fisher's *F*-test for the model (0.38 %) is less than 5 %, which indicates the statistical significance of the variable and the model as a whole.

Thus, based on the analysis of the obtained indicators, we can conclude about the informational suitability of the built model. The resulting regression equations are used in further simulation modeling.

The dynamics of profits received by regional market entities have been investigated. It is defined as the difference between the income and expenses:

$$P(t)=Q(t)-V(t). \quad (6)$$

According to Fig. 1, not all profits remain in the regional market, part of it leaves a given system. That is:

$$Pr(t)=P(t)-Po(t). \quad (7)$$

Part of the profits of the remaining market entities in the region, in turn, is used for consumption and accumulation, the attraction of technology transfers in order to further improve information support, eliminate information asymmetry, simplify commercial activities. That is, the accumulation process is as follows:

$$S(t)=Pr(t)-C(t). \quad (8)$$

The investments into regional market development *I (t)* are expressed through the following relation:

$$I(t)=S(t)+Iz(t). \quad (9)$$

The relationship between the volume of investments to support technology transfer in the real estate market and the number of transactions performed has been determined. For this purpose, a correlation-regression analysis of data (Table 3) on the statistical reporting of the region [12] was carried out:

Table 3

Dynamics of investments and number of transactions in the field of technology transfer in the real estate market of the Prydniprovskyi region

Year	Number of agreements, unit per day	Investments, USD thousand per day
2013	41.92	13.5
2014	47.18	17.2
2015	48.43	15.3
2016	51.52	16.5
2017	55.61	19.7
2018	60.97	25.9
2019	65.86	28.3

Similar to equations (8) and (9), the following regression equation has been constructed:

$$KU(t)=0{,}05\times I(t)+25{,}03. \quad (10)$$

At the same time, the derived values of the determinant coefficient (R^2=0.91) and the corrected determinant coefficient $\left(\overline{R^2}=0{,}87\right)$ indicate a rather close linear relationship between variables. The value of the σ rms deviation is 2.44 (3.7 %). The significance of the Student's *t*-test for the variable *I (t)* (0.09 %) and Fisher's *F*-test for the model (0.12 %) is less than 5 %, which indicates the statistical significance of the variable and the model as a whole. Thus, based on the analysis of the obtained indicators, a conclusion has been made about the information suitability of the constructed model.

Thus, having summarized equations (1) to (10), the model of processes of investing into the development of information infrastructure of technology transfer in the regional real estate market has been represented:

$$\begin{cases} Q(t)=KU(t)\times SVU(t), \\ V(t)=VrV(t)+TrV(t), \\ TrV(t)=0{,}19\times I(t)+423{,}52, \\ VrV(t)=0{,}78\times I(t)+1694{,}07, \\ P(t)=Q(t)-V(t), \\ \Pr(t)=P(t)-Po(t), \\ S(t)=\Pr(t)-C(t), \\ I(t)=S(t)+Iz(t), \\ KU(t)=0{,}05\times I(t)+25{,}03. \end{cases} \quad (11)$$

The proposed simulation model makes it possible to assess the investment support to technology transfer in the regional market. It could be the basis for the adoption and implementation of adequate management decisions aimed at increasing technological cooperation, stimulating an expanded investment model for the development of territories with elements of attracting technology transfers. The formation of effective infrastructure requires the development of new methods for organizing planned measures in the formation of income that contribute to the additional flow of resources into the economy of each region, in particular on the basis of the use of methods of economic and mathematical modeling [13].

5. 3. Implementing a simulation model of investing into the information infrastructure of technology transfer in the regional market

PowerSim Studio software package was used to implement our economic and mathematical model of the processes of investing into the development of the information infrastructure of the transfer of technologies of the regional market. The software is based on the corresponding theory of system dynamics [14, 15]. Underlying this theory are the general structural elements suitable for modeling almost any economic system:

– pace – the parameters of flows that come from one integrating link and enter others, as well as cause corresponding changes in both groups;

– levels – the adjustable objects that formally reflect the variables that appear in the system, whose parameters are obtained by the integration of the corresponding characteristics of streams;

– solution functions – the ratios that reflect the functional dependences available in the system that determine the intensity of incoming and output streams;

– auxiliary values and parameters of the model that are actively involved in determining the general characteristics.

Actual systems are represented in the models of system dynamics in the form of a set of difference equations, defined in terms of discrete moments of time of equal length.

When stating the problem of simulation modeling, the following restrictions were introduced, which could be removed subsequently:

– first, within the framework of the modeling object, the regional real estate market is considered since this makes it possible to more fully reveal the extent of the impact of transactional costs on the development of the information infrastructure of technology transfer. At the same time, the inclusion of other markets in this model could significantly complicate its implementation;

– second, external income and investments in the region, as well as the average value of the transaction, are taken into consideration via a time factor; they are random values with normal distribution laws;

– third, the modeling step is taken equal to one day, and the modeling horizon is one year.

To implement the proposed model in the PowerSim system-dynamic modeling environment, the following designations were introduced:

Level variables:

Pref_Trans – the number of transactions in the field of technology transfer over the entire modeling period; *Investing* is the volume of a regional investment fund.

Flow variables:

– *Inv_Enter* and *Inv_Exit* – the volumes of resources entering or leaving the investment fund.

– *Transactions* – the number of technological interaction agreements over a period *t*.

– *Av_Cost_Trans* – an agreement mean value.

– *Expenses* – the costs of regional market entities for technology transfer.

– *Prod_Expenses* – production costs of regional market entities.

– *Trans_Expenses* – transaction expenses of regional market entities.

– *Ud_ Trans_Expenses* – specific transaction expenses.

– *Income* – the income of regional market entities.

– *Profit* – the profit of regional market entities.

– *Profit_Reg* – the profit of market entities staying in the region.

– *Consumption* – remaining profit in the region, which is aimed at consumption.

– *Economy* – a part of the remaining profit in the region, aimed at use and accumulation.

– *External_Inv* – the amount of external investment into innovation activity.

Constants:

– *Sh_Profit_Reg* – the share of profits of market participants remaining in the region.

– *Sh_Consumption* – the share of profit for consumption.

– *Inv_Inf* – a governing parameter that determines the share of investments for the development of the information infrastructure of technology transfer.

– *ACT_Mean* і *ACT_Dev* – the constants that determine the mean value and standard deviation of a random variable *Av_Cost_Trans*.

– *EI_Mean* і *EI_Dev* – the constants that determine the mean value and the standard deviation of a random variable *External_Inv*.

– *Inv_Delay_Time* – a constant that determines the period of delay of the variable *Inv_Exit*.

The flow diagram of the simulation model, implemented in the software package PowerSim, is shown in Fig. 2. Decoding the calculation of values for the main variables in the model is given in Table 4.

Based on the proposed model, an imitation experiment was carried out for the real estate market of the Prydniprovskyi region with certain input conditions. The mathematical expectations and rms deviations of random variables in the model were determined on the basis of statistical reporting data [12].

The following values were derived: the mathematical expectation of external investments is USD 18,390 per day (the rms deviation is USD 59.84). The mathematical expectation of the average transaction value is USD 2,603 per day (the rms deviation is USD 86.27).

The values of constants are as follows (statistical reporting data [12]) were used to determine them): *Sh_Income_Reg*=0.67; =0.72; =30 days. The value of the governing parameter that determines the share of investments for the development of regional market information infrastructure is 20 %, that is, =0.2.

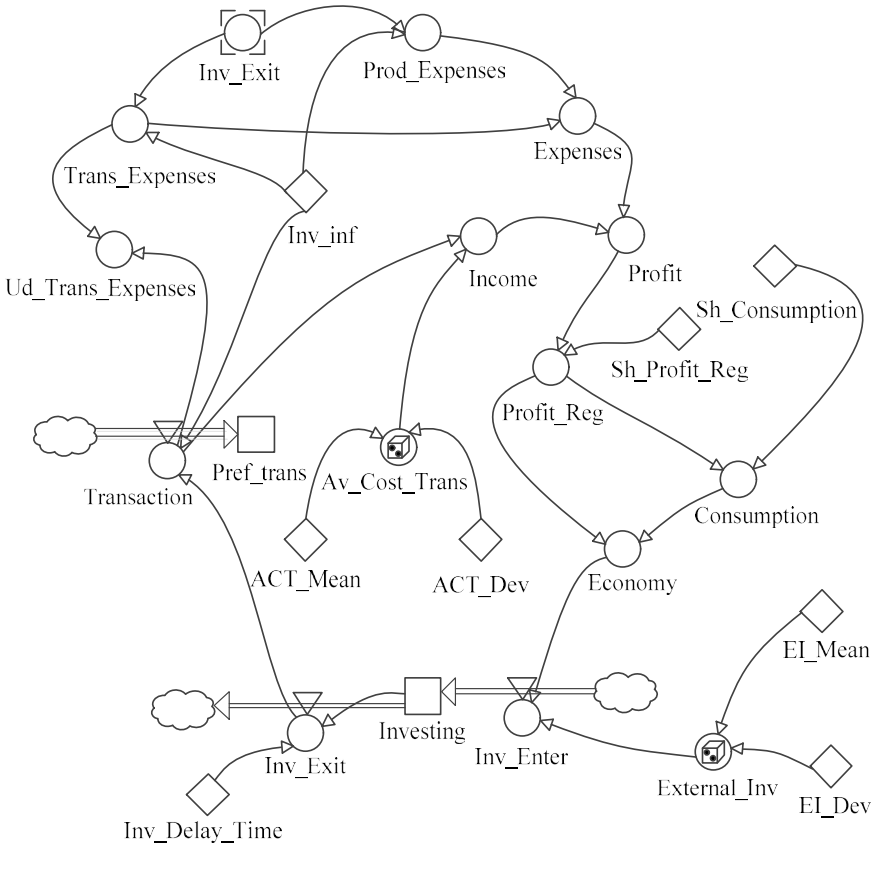


Fig. 2. Flow diagram of the simulation model implemented the software package PowerSim Studio

Table 4

Calculating the values for the model's variables

Variable	System dynamics equation
Inv_Enter	*Economy+External_Inv*
Inv_Exit	*DELAYPPL(Investing,Inv_Delay_Time,0)*
Transactions	*(Inv_Exit×0,05+25,03)×Inv_Inf*
Av_Cost_Trans	*NORMAL(ACT_Mean,ACT_Dev)*
Trans_Expenses	*(0,19×Inv_Exit+423,52)×Inv_Inf*
Ud_Trans_Expenses	*Trans_Expenses/Transactions*
Prod_Expenses	*(0,78×Inv_Exit+1694,07)×(1-Inv_Inf)*
Expenses	*Prod_Expenses+Trans_Expenses*
Income	*Transactions×Av_Cost_Trans*
Profit	*IncomeExpenses*
Profit _Reg	*Profit×Sh_Profit_Reg*
Consumtion	*Profit_Reg×Sh_Consumtion*
Economy	*Profit_Reg-Consumtion*
External_Inv	*NORMAL(VI_Mean,VI_Dev)*

The results of one of our simulation experiments are shown in Fig. 3, 4.

When analyzing the results shown in the figure, we have generalized them and drew the following conclusion. In the current economic situation, the number of transactions between the entities of the regional real estate market in the field of technology transfer is increasing (Fig. 4, *b*). At the same time, transaction costs for transaction implementation are also increasing; however, their growth rate is lower than the rate of income growth, which leads to a decrease in unit transaction costs (Fig. 4, *a*). In addition, the profit of regional market entities (Fig. 3), 67 % of which remains in the region, is also growing. Part of this profit (72 %) in the form of savings, together with external financing, is invested in the development of the information infrastructure of technology transfer (Fig. 4, *c*). That contributes to the further increase in the number of transactions on it and further targeted attraction of innovations. A given situation indicates the stable economic growth of the regional real estate market.

However, our experiment characterizes the dynamics of the regional market system provided that 20 % of all regional investments in the field of promoting innovative activity of the region are invested in the development of information infrastructure. However, it is also obvious that other values of this parameter are possible, so it is advisable to consider the performance of the model for other cases. At the same time, for the convenience of modeling, the discrete change in the parameter was taken at the level of 5 %. The results of simulation experiments are given in Table 5.

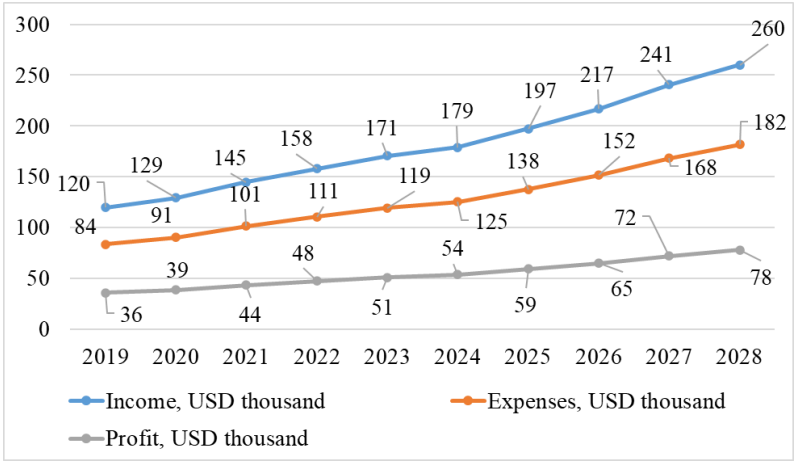


Fig. 3. Predicted dynamics in the main indicators of real estate market development according to the results of the imitation experiment

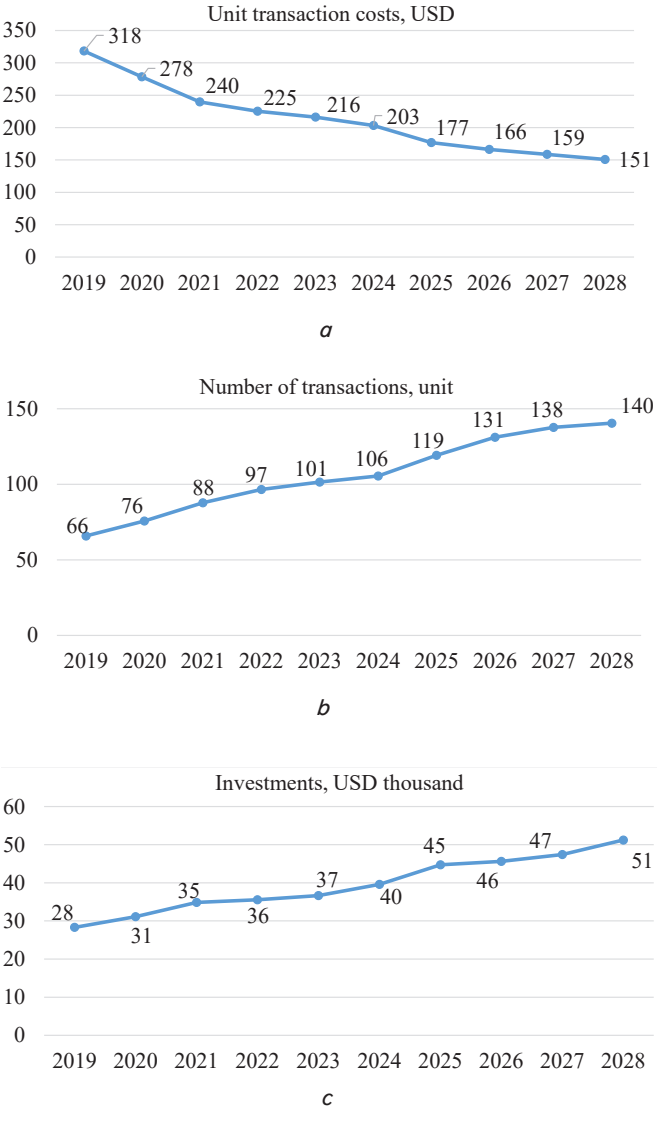


Fig. 4. Results of the simulation experiment for the regional real estate market: *a* — unit transaction costs of market entities, USD; *b* — number of transactions on technology transfer, unit; *c* — investments in information infrastructure, USD thousand

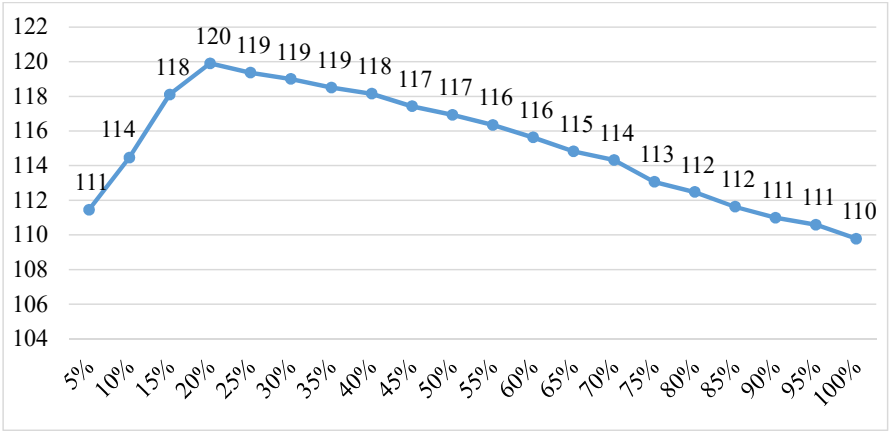
Analyzing the data in the table allowed us to conclude that the largest number of transactions in the real estate market is observed with the full investment of all regional investment resources in the development of the information infrastructure of technology transfer. However, the resulting solution is not optimal, since there is a significant increase in unit transaction costs (Fig. 5, *a*) and a decrease in the profits of regional market entities (Fig. 5, *b*).

The largest profit by entities in the regional real estate market is obtained provided that the share of investments in the development of information infrastructure in the total investment structure is 20 %. At the same time, the unit transaction costs are USD 319, which is a minimum of all acquired values. That is, in order to obtain the highest indicators of economic growth of the regional real estate market, it is necessary to invest in the development of information support for the transfer of technologies of 20 % of all available investment means.

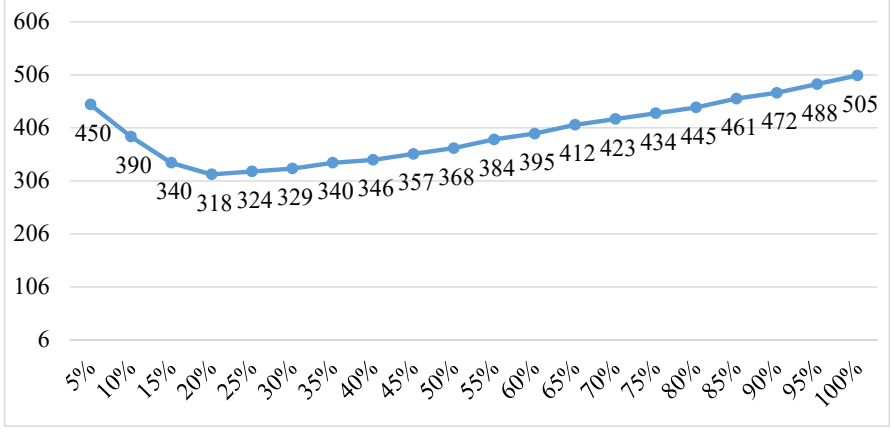
Table 5

Results of simulation experiments involving the model

Share of investments in the development of technology transfer infrastructure in the total investment structure, %	Number of transactions in the market, unit	Unit transaction costs, USD	Profit of market participants, USD thousand
5 %	50	450	111
10 %	56	390	114
15 %	61	340	118
20 %	66	318	120
25 %	70	324	119
30 %	70	329	119
35 %	71	340	119
40 %	72	346	118
45 %	73	357	117
50 %	73	368	117
55 %	73	384	116
60 %	75	395	116
65 %	76	412	115
70 %	77	423	114
75 %	77	434	113
80 %	79	445	112
85 %	79	461	112
90 %	81	472	111
95 %	83	488	111
100 %	83	505	110



a



b

Fig. 5. Results of simulation experiments:
a — profit of regional real estate market entities, USD thousand;
b — unit transaction costs of regional real estate market entities, USD

6. Discussion of results of modeling the processes of investment into the information infrastructure of technology transfer

The results from our simulation experiment make it possible to establish a close relationship between the level of transaction costs by the regional market entities and investments into the development of the information infrastructure of technology transfer (Fig. 1, 2). With the proposed model (11), it is possible to establish the optimal amount of investment into effective infrastructure support for technological exchange in a particular regional market, taking into consideration its specificity and level of development.

A special feature of the proposed model is that it takes into consideration the parameter of transaction costs as an assessment of the effectiveness of the interaction among technology transfer participants. The following pattern has been identified: the lower the transaction costs, the more productive the functioning of the information infrastructure of technological exchange. Transaction costs have a reverse impact on the development of information infrastructure: high transaction costs are an incentive for the development of information infrastructure, and a developed information infrastructure contributes to more efficient use of transaction costs. This demonstrates the institutional connection between these economic categories. This approach differs from the research by other scientists [7–9], who, when assessing the effectiveness of investments into the development of technology transfer infrastructure, did not take into consideration the specifics of information exchange and the costs associated with it.

However, such a model's dependence on the transaction costs parameter can be a significant limitation of its application. This is explained by the fact that transaction costs, despite their significance, are not separately taken into consideration in the reporting process (they are not separately accumulated in a special account). In addition, their monitoring is not carried out, which complicates the analysis of the degree of their impact on profit from technological cooperation. It is quite difficult to quantify the level of transaction costs, since, first, there is no single understanding of what to classify as transaction costs, and, second, most of them are carried out in the field of informal relations.

When stating the problem of simulation modeling, a restriction was adopted: the experiment was carried out using an example of a particular regional market. That has made it possible to more fully reveal the interdependence of transaction costs and investments into the development of information infrastructure, as well as to avoid complicating the implementation of the model in case of its integration with other markets. At the same time, regional investments and an average value of the transaction were taken into consideration through a time factor as random variables with normal distribution laws. The simulation step was one day, and the modeling horizon was one year.

Verifying the model by using an example of the real estate market of the Prydniprovskyi economic region in Ukraine has shown that the growth of investments in the development of information infrastructure contributes to an increase in the number of transactions in the field of technology transfer (Fig. 4). At the same time, the growth rate of transaction costs is lower than the growth rate of income for market entities (Fig. 3, 4). The profit of regional market entities is also growing (Fig. 3). Part of this profit (72 %) in the form of savings, together with external financing, is invested into the development of the information infrastructure of technology transfer. That is, there is a pattern – the more active cooperation between the participants of the technology transfer, which is achieved due to the developed information infrastructure, the more investment revenues in the development of this infrastructure. We have also established the optimal level of expenses for the development of information infrastructure of technology transfer (Table 5

and Fig. 5). In the regional real estate market, it makes up 20 % of all available investment funds.

The model built is universal because it operates on parameters that are typical of any market (investments, profits, production and transaction costs). It should be recognized as relevant for markets – information, real estate, agricultural sector, food products, services, etc. However, there is a certain specificity of its application, due to the different state of development of information infrastructure components of each individual regional market, as well as the heterogeneity of transaction costs. Restrictions may also include business traditions characteristic of a particular market and region. They act as institutions for regulating the interaction of technology transfer participants, which could significantly affect the level and dynamics of transaction costs. Therefore, the proposed model could and should be adapted for the conditions of a particular market.

The regional aspect of the research should be recognized as both an idealized approach to information processing and the possibility of adaptation to more complex market systems. It is possible to further conduct similar research at the level of macro-economies – national and world markets.

The results of our study have a clear focus on justifying the volume of investment support for the development of the information infrastructure of technology transfer for the effective cooperation of business in the technological field. They update the issue of successful investments in the technological development of the market environment, which is the most painful and risky in terms of information quality.

The disadvantages of the proposed approach are the lack of taking into consideration the risks of information exchange that arise during the transfer of technologies. It could be eliminated by supplementing the model with components for assessing the degree of information entropy and its impact on the level of transaction costs of technological cooperation.

A promising direction of further research into this topic is the development of a methodology for assessing the transfer potential of enterprises to attract investments in the field of technological exchange. That could complement the proposed advancement with new content and would expand the understanding of the effectiveness of technological cooperation support by ranking enterprises according to the level of their transfer potential and information support needs of these processes. Among the difficulties that researchers may face along the way is the level of information asymmetry in the development of individual markets, as well as the lack of information transparency in the technological interaction processes between their participants. This complicates the objective assessment of the prospects for technology transfer and the need for its information support at both micro and macro levels.

7. Conclusions

1. Technology transfer requires systematic information support from both its participants and market regulators – the state and local authorities, social organizations, and business associations. This information support is carried out on the basis of extensive infrastructure that combines information resources of businesses, scientific and educational institutions, consulting, news agencies, state statistical bodies. An important issue is the creation of technology transfer centers and innovation and technology centers that would provide such support within certain regional markets.

The regional aspect of the development of such infrastructure is due to the specifics of market processes, the peculiarity of information interaction between economic agents of the individual market. Information infrastructure as a component of the market infrastructure system is characterized by a high degree of branching within a certain region, is distinguished by a variety of its components (information resources, infocommunication technologies, communications, institutes of information exchange regulation). At the same time, its effective functioning requires the involvement of significant material and financial resources, innovative products and technologies on a commercial basis.

2. Based on the simulation modeling methodology, a model of processes of investing in the development of information infrastructure of the transfer of technologies of the regional market has been built. The theoretical basis of this model is the theory of transaction costs since it most fully makes it possible to analyze the costs of enterprises for transactions, whose element is the cost of finding the information necessary for the transfer of technologies.

The proposed simulation model establishes the dependence of the level of transaction costs of enterprises on the volume of investments in the development of information infrastructure and makes it possible to assess the investment support to technology transfer under the conditions of a particular regional market. It could be the basis for the adoption and implementation of adequate management decisions aimed at increasing technological cooperation between regional market actors.

3. Based on the proposed model, an imitation experiment was conducted to determine the amount of investment in the development of the information infrastructure of technology transfer using an example of the real estate market in the Prydniprovskyi economic region of Ukraine. Our experiment has made it possible to establish that the largest profit of market entities would be obtained if 20 % of the total regional market investments were invested in the development of information infrastructure.

Based on the proposed approach, it is promising to devise similar models for other regional markets. Thus, it becomes possible to streamline the system of information support for innovation activities, additionally stimulate the attraction of targeted technology transfers, and build a stable information image of these markets. And this, in turn, creates favorable conditions for the integration of information infrastructures of different markets into a single information system as innovatively oriented.

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