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Economic and mathematical modeling of innovative development of the agglomeration on the basis of information technologies

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Abstract

Management of innovation processes is one of the functions of local governments and, therefore, they should be the initiators and moderators of communication between research organizations and enterprises. The program formation of agglomeration innovative development involves the creation of promoting innovation body, which allows to achieve the

maximum involvement degree of all the participants in the innovation process. The article is devoted to the research of urban agglomeration innovative development, the need to create a special body or center for innovation, which will form a set and interconnected, and will be integrated into the urban agglomeration and carry out innovation and technological activities as part of research and production infrastructure. The article develops a method for predicting the effectiveness of the advancement of this body through the digital space using trend models. It is expected to receive three forecasts: optimistic, realistic and pessimistic. This will accelerate the establishment of links between the players of the regional innovation market and contribute to a qualitative change in the spatial and functional structure of urban agglomerations. The development of information and communication technologies allows to create effective systems that will stimulate the agglomerations innovative development . Therefore, the communicative activities of regional governments should be carried out through the use of information and communication technologies. Thus, the urgency of developing a methodology for assessing the increase of the innovative component of agglomeration economic development is due to the low percentage of implementation research results, low science-intensive gross value added in the Ukrainian regions, the possibility of using information and communication technologies. Increasing the number of targeted visits will simplify and speed up the process of establishing links between innovation market players at the agglomeration spatial level in both the short and long term.

Keywords: Urban agglomeration, Innovation, Innovative development, Region, Information and communication technologies

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Introduction

Focusing on innovative development should lead to a change in the entire system of regional economic relations, influencing the transformation of urban agglomeration processes. Currently, urban agglomerations are considered as a tool for managing socio-economic processes in the regions. Urban agglomerations have a huge potential for economic, social, innovative and technological development, due to the wide concentration of resources and opportunities. In essence, urban agglomerations are on the one hand: a spatial system, and on the other - a form of organization of the regional economy. Scientists, research agglomeration processes, characterize this form of spatial organization as a multi-sectoral, multifunctional

center of national importance with specialization in the most advanced economic sectors, as well as a subsystem of the general economic system of production and resettlement.

The territory of the urban agglomeration, i.e the city and its environs, is a single territorial complex united by stable labor, cultural and industrial ties, common social and technical infrastructure, together with the used land resources, it is a qualitatively new form of settlement, which is a special product of modern urbanization.

Innovative agglomerations are a set of structures that develop on an innovative basis. All institutions of the agglomeration must be innovative, if not in structure, then at least in activities, so they can ensure sustainable development, be competitive in both domestic and foreign markets.

Management of innovation activities of the agglomeration is carried out in the direction of:

— organization of the introduction the latest knowledge-intensive technologies;

— creation of infrastructure and databases of scientific developments, patents, expertise and innovations;

— organization and management of courses, seminars, conferences, congresses and symposiums, permanent and temporary exhibitions and fairs;

— organization and conduct of scientific and technological, environmental, economic and other types of expertise of scientific and technical activities, investment and innovation projects;

— promoting the development of joint enterprises, associations, innovation structures such as technology parks, technology cities, small and medium-sized innovation structures, temporary teams to implement innovations;

— providing assistance in finding potential partners, assessing their capabilities in order to create conditions for economic and scientific-technological cooperation;

— representing the interests of the agglomeration and the region in the development and implementation of joint resource-saving and knowledge-intensive projects, programs of scientific and technical, economic and other types of internal and external cooperation, including international;

— organization and conduct of investment activities, attracting investments for the preparation and implementation of innovative projects.

Literature Review

Innovation is an important driver of economic growth. In particular, to acquire global competitiveness, the quality of innovation matters more than the quantity. Although innovative outcomes rest on individual efforts in research and development in firms and scientific organisations (Hamaguchi N., et al., 2016).

In essence, agglomerations with an innovative component are formed by enterprises with an innovative focus.

Innovation agglomeration is a spatial integration of administrative-territorial groups that have objects of innovative production, social, environmental and engineering infrastructure united by a set of links, creating a single spatial system.

In general, it can be argued that the innovation component of agglomerations should include a number of factors regarding the availability of: enterprises that have an innovative vector of development of resource, production, technological potential, perform research and development, have highly qualified research staff, innovation infrastructure, including higher education institutions, centers innovative development.

Innovation agglomeration leads to changes in the hierarchical structure of innovation, driving regional economic development (Fei Fan, et al.,2021).

Agglomeration innovative structures should use and develop the existing scientific and technological potential of the region and the country as a whole, attract investment for the development of the scientific component, develop a sustainable environmental component, adhere to innovative modernization of enterprises, intensify production and sales of competitive products.

Attention should be paid not only to the scale of the innovation agglomeration, but also to the structure of innovation entities of the agglomeration territory, so that innovation entities can effectively cooperate and jointly contribute to increasing the innovation potential of the region (Jing Li, Jialong Xing,2020).

Economic activity, expressed in economic entities, concentrated in the urban agglomeration, most effectively operate in the territorial cooperation of close to each other enterprises with similar or related specialization, understood as clusters. Innovation centers or bodies that are integrated into the urban agglomeration system and carry out innovation and technological activities as an element of research and production infrastructure are also effective.

The proposed structure in relation to the center or body to promote innovation gives new impetus to the development of the agglomeration creates a competitive, investment-attractive

environment, combining research and business ties, development of innovative products and industries, as well as transport and logistics, infrastructure, social ties. The effect of the work of the innovation promotion body is the profit from the implementation of innovations, patents, inventions, solvency of enterprises and their financial stability, promising opportunities for small and medium businesses, capacity building, improving working conditions and providing jobs in environmentally sustainable enterprises. reduction of ecological load on the environment.

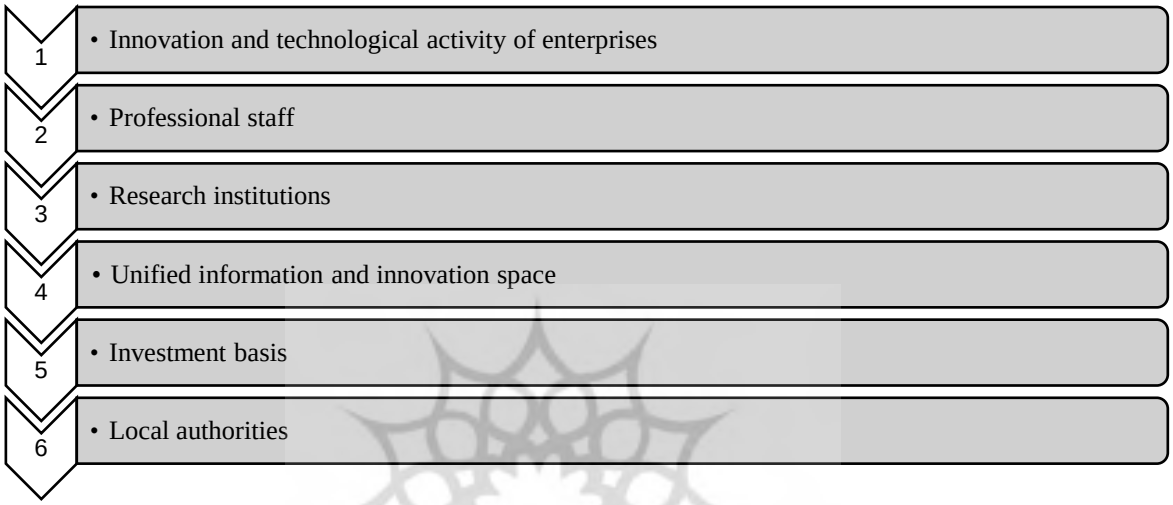

Fig. 1. Key elements of the center or body to promote innovation in the urban agglomeration

Source: developed by the authors.

Methodology

To assess the communicative and economic effects of measures aimed at increasing the agglomeration innovative component, we use economic and mathematical modeling.

Communicative Effect: First, let us assess the communicative effect of the activity the innovation management body by means of the dynamic models of economic processes. Forecasting based on time series, or trends, assumes that the indicator being studied is influenced by a large number of factors that are impossible to identify or no information on them. In this case, it is believed that the indicator is influenced by one factor - time. The communicative effect can be determined by the share of entrepreneurs working in the agglomeration who take part in the proposed communication activities. The number of innovative enterprises is closely correlated with the number of entrepreneurs who are informed about the activities of the center for forecasting scientific and technological development and the centre or body to promote innovation in the regional administration, attend exhibitions, participate in conferences, familiar with scientific developments of agglomeration scientists. And are also active users of the innovation portal, which is proposed to create.

The number of entrepreneurs working in the agglomeration is limited, so in the case under consideration, it is proposed to choose curves with saturation. Such curves include S-shaped curves: the Gompertz curve and the logistic curve or the Pearl-Reed curve.

The Gompertz curve is analytically expressed by the following formula:

$$\hat{y} = ka^{b^t} \quad (1)$$

a, b - positive parameters, moreover $b < 1$;

k - asymptote of the function.

There are four segments in the Gompertz curve: on the first - the increment of the function is insignificant, on the second - the increment increases, on the third - the increment is constant, on the fourth - the growth rate slows down and the function approaches the value indefinitely (Fig. 2).

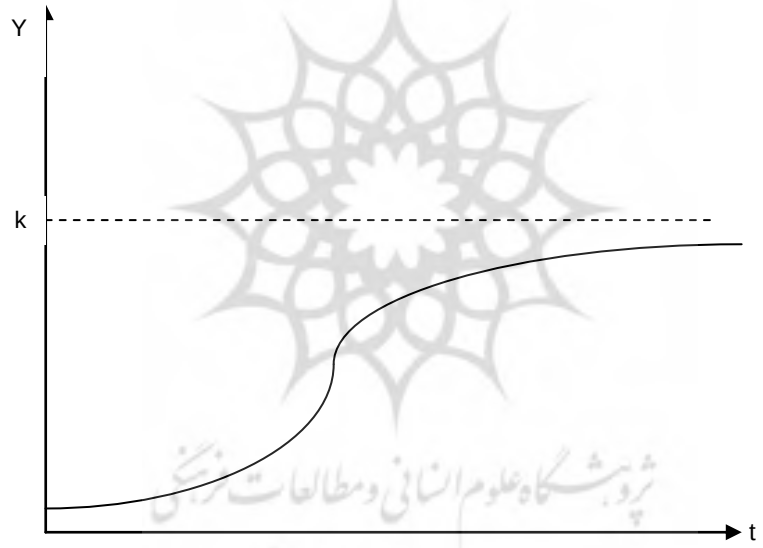

Fig. 2. Graph of the Gompertz curve

Source: developed by the authors.

The logistic curve or the Pearl Reed curve is an increasing function, most often given by the following formula:

$$\hat{y} = \frac{k}{1+ae^{-bt}} \quad (2)$$

a, b - positive parameters;

k - asymptote of the function.

The configuration of the logistic curve graph is close to the Gompertz curve graph, but the logistic curve has a point of symmetry that coincides with the inflection point. The

Gompertz curve is suitable for modeling the share of entrepreneurs who take part in innovation-oriented activities.

It is proposed to obtain three forecasts: optimistic, realistic and pessimistic. Depending on the funding of the communication program, how the share of innovation-active entrepreneurs will increase depends on the active or passive activity of the body promoting innovation. The asymptote of the Gompertz function – $k = 1$, as we plan to cover 100% of entrepreneurs with communicative measures on innovation activity.

To determine the parameters of the model and build its graph, we set the initial conditions:

1. Optimistic forecast. In this case, it is planned to obtain sufficient funding for the implementation of all planned communications activities and the maximum effect is expected to be achieved, i.e about 100% coverage of entrepreneurs with innovative communications during the year. Suppose that in six months 50% of entrepreneurs will be covered by the activities of the body to promote innovation, and in a year - 90%.

Then to determine the parameters of the model $\hat{y} = ka^{b^t}$ we obtain a system with two unknowns ($k = 1$ discussed above):

$$\begin{cases} 0{,}5 = a^{b^6} \\ 0{,}9 = a^{b^{12}}. \end{cases}$$

To solve the system, take the logarithm both equations:

$$\begin{cases} \ln 0{,}5 = b^6 \ln a \\ \ln 0{,}9 = b^{12} \ln a, \end{cases}$$

Or

$$\begin{cases} -0{,}69 = b^6 \ln a \\ -0{,}105 = b^{12} \ln a. \end{cases}$$

From the last system we receive $b^6 = 0{,}152$. Hence $b = 0{,}73$. Substitute b into the first equation of the last system and receive $\grave{a} = 0{,}011$. In Fig. 3 shows the graph of the Gompertz curve $\hat{y} = 0{,}011^{0{,}73^t}$ for the optimistic development of the communicative activity of the body promoting innovation.

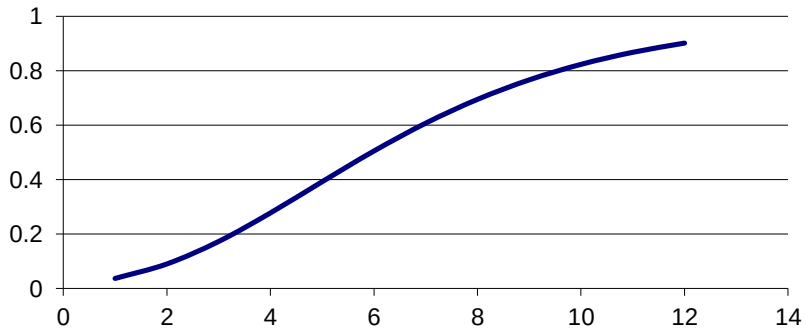

Fig. 3. The Gompertz curve in the optimistic case of communications

Source: developed by the authors.

2. Realistic forecast. In this case, we expect that the period of communications maximum coverage of the body to promote innovation of agglomeration entrepreneurs will be two years. To determine the parameters of the model, we set the initial conditions: 50% of entrepreneurs of the agglomeration will be covered in a year, and 90% in two years. Then the system of equations has the following form:

$$\begin{cases} \ln 0{,}5 = b^{12} \ln a \\ \ln 0{,}9 = b^{24} \ln a \end{cases}.$$

Solve the system as in the previous example and receive the values of the model parameters $b = 0{,}85$, $à = 0{,}011$ In Fig. 4 shows a graph of the Gompertz curve $\hat{y} = 0{,}011^{0{,}85^t}$ for the realistic development of the communicative activity of the body promoting innovation.

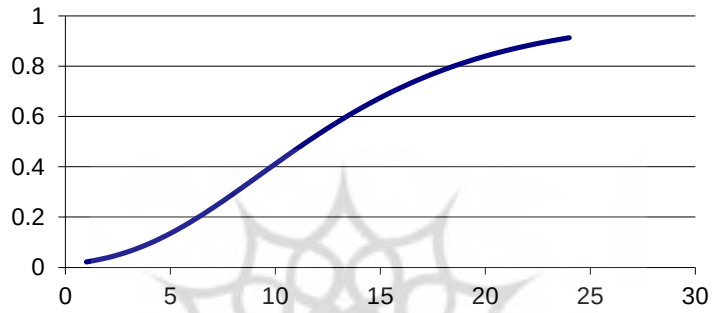

Fig. 4. Gompertz curve for the pessimistic case of communications

Source: developed by the author.

3. Pessimistic forecast. We hope for insufficient funding and passive communication activities of the body to promote innovation. To determine the parameters of the Gompertz curve, we assume that 50% of entrepreneurs will be covered by innovative measures in 1.5 years, and 90% in 3 years. Then the system for determining the parameters of the model will be as follows:

$$\begin{cases} \ln 0{,}5 = b^{18} \ln a \\ \ln 0{,}9 = b^{36} \ln a \end{cases}.$$

The solution of the system $b = 0{,}9$, $à = 0{,}011$. In Fig. 5 shows a graph of the obtained model $\hat{y} = 0{,}011^{0{,}9^t}$ for a pessimistic case.

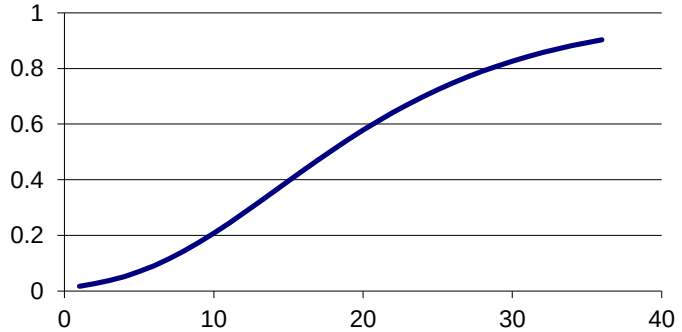

Fig. 5. Gompertz curve for the pessimistic case of communications

Source: developed by the authors.

Economic effect. Secondly, we will determine the economic effect of measures aimed at increasing the innovation component of agglomerations by the share of innovation-active enterprises. For example, in the Odessa agglomeration in 2020 the share of enterprises engaged in innovation was 14.2%, this level will be considered the starting point for forecasting - we hope that it will not decrease.

To model and forecast the share of innovative enterprises, we apply the modification of the logistics curve in the form of:

$$\hat{y} = \frac{k}{1+ae^{-bt}} \quad (3)$$

The logistic curve should be used in this case because it determines slower processes than the Gompertz curve.

Results

We will build three models of coverage of enterprises of the Odessa agglomeration with innovative activity: optimistic, realistic and pessimistic.

1. Optimistic forecast. We hope to reach 65% of the share of innovation-active enterprises in the agglomeration in six years. Define the parameters of the model and build its graph. In all cases $k = 0{,}7$ (the optimal share of innovation-active enterprises of the agglomeration). To determine the parameters of the model we will make a system:

$t = 0$: in 2020 there were 14.2 innovation-active enterprises, therefore $y = 0{,}142$, $b^0 = 1$, hence $0{,}142 = \frac{0{,}7}{1+a}$;

$t = 6$: in six years, we expect 65% of innovation-active enterprises, therefore $y = 0{,}65$, hence $0{,}65 = \frac{0{,}7}{1+ab^{-6}}$. We will solve the system:

$$\begin{cases} 0{,}142 = \frac{0{,}7}{1+a} \\ 0{,}65 = \frac{0{,}7}{1+ab^{-6}} \end{cases} \quad (4)$$

From the first equation $a = 3{,}93$ substitute a in the second equation and receive $b = 1{,}93$. We will plot a graph of the logistics curve

$\hat{y} = \frac{0{,}7}{1+3{,}93\times 1{,}93^{-t}}$ (Fig. 6).

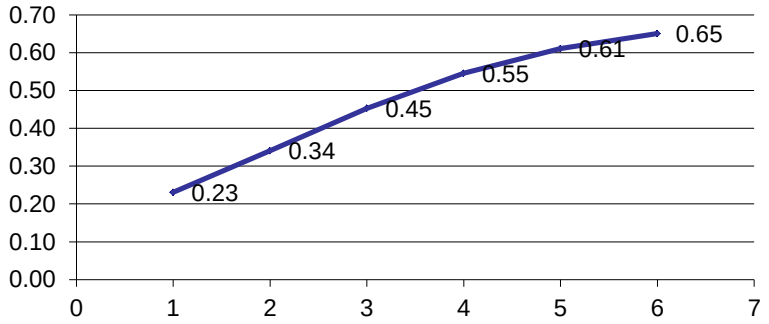

Fig. 6. Logistic curve for the optimistic case of enterprises innovation activity of Odessa agglomeration

Source: developed by the author.

2. Realistic forecast. We hope to reach 65% of innovation-active enterprises in the Odessa agglomeration in 10 years. Then the initial data to obtain a forecast:

t = 0: in 2020 there were 14.2 innovation-active enterprises, therefore y = 0,142, hence $0{,}142 = \frac{0{,}7}{1+a}$;

t = 10: in ten years we expect 65% of innovation-active enterprises, therefore y = 0,65, hence $0{,}65 = \frac{0{,}7}{1+ab^{-10}}$;

We will solve the system:

$$\begin{cases} 0{,}142 = \frac{0{,}7}{1+a} \\ 0{,}65 = \frac{0{,}7}{1+ab^{-10}} \end{cases} \quad (5)$$

Find the solution, as in the previous example, and receive it a = 3,93, b = 1,48. We will build a graph of the logistics curve

$$\hat{y} = \frac{0{,}7}{1 + 3{,}93 \times 1{,}48^{-t}}$$

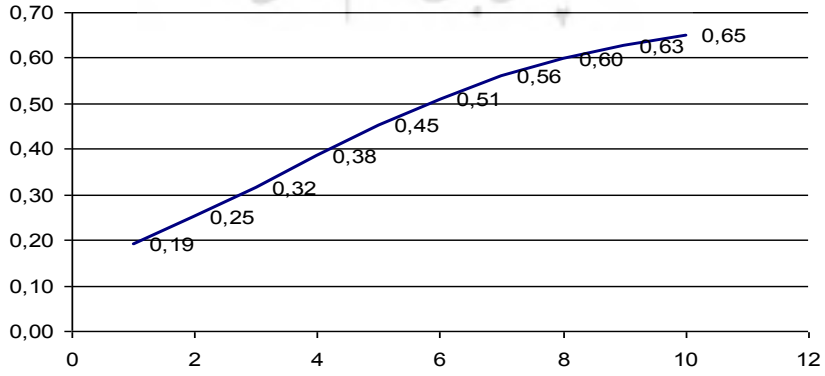

Fig. 7. Logistic curve for the optimistic case of enterprises innovation activity of Odessa agglomeration

3. Pessimistic forecast. We hope that 65% of innovation-active enterprises in the agglomeration will be no earlier than 15 years. Then the initial data to obtain a forecast:

t = 0: in 2020 there were 14.2 innovation-active enterprises, therefore y = 0,142, hence $0{,}142 = \frac{0{,}7}{1+a}$;

t = 15: in fifteen years we expect 65% of innovation-active enterprises, therefore y = 0,65, hence $0{,}65 = \frac{0{,}7}{1+ab^{-15}}$;

We will solve the system:

$$\begin{cases} 0{,}142 = \frac{0{,}7}{1+a} \\ 0{,}65 = \frac{0{,}7}{1+ab^{-15}} \end{cases} \quad (6)$$

Find the solution, as in the previous example, and receive it a = 3,93, b = 1,3. We will build a graph of the logistics curve

$$\hat{y} = \frac{0{,}7}{1 + 3{,}93 \times 1{,}3^{-t}}$$

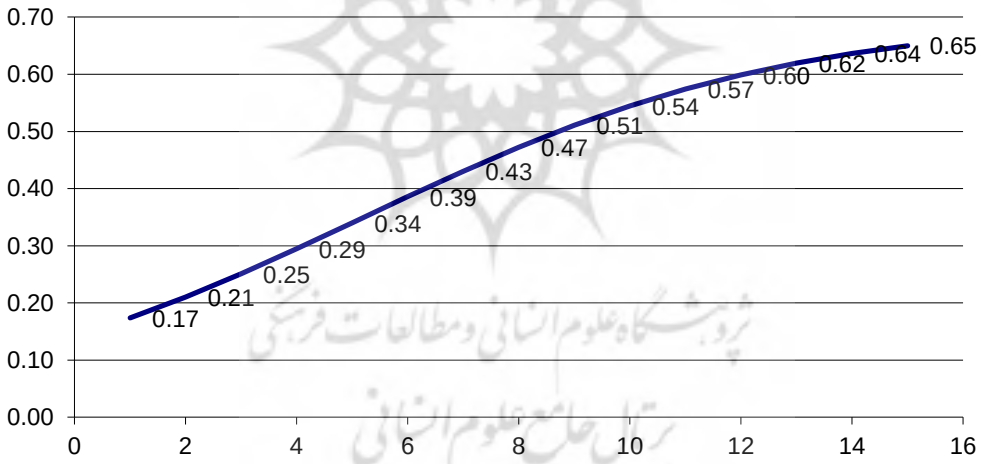

Fig. 8. Logistic curve for the pessimistic case of innovation activity of enterprises of Odessa agglomeration

The need to form an innovation orientation in urban agglomerations is related to the trends of modern society, when the innovative and socio-economic potential of spatial structures can be effectively used and implemented on the basis of innovative technologies involving creative and intellectual communities.

Conclusion

The proposed methodological approach allows to develop urban agglomerations through the information and digital space, as well as due to the relationship between economic entities to develop an innovative component in peripheral areas, which allows to create a comfortable urban environment based on the principle of sustainable development.

Conflict of interest

The authors declare no potential conflict of interest regarding the publication of this work. In addition, the ethical issues including plagiarism, informed consent, misconduct, data fabrication and, or falsification, double publication and, or submission, and redundancy have been completely witnessed by the authors.

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