DOI: 10.17323/2587-814X.2022.3.53.67

# High-level simulation model of tourism industry dynamics*

**Aleksei M. Gintciak**
E-mail: aleksei.gintciak@spbpu.com

**Marina V. Bolsunovskaya**
E-mail: marina.bolsunovskaia@spbpu.com

**Zhanna V. Burlutskaya**
E-mail: zhanna.burlutskaya@spbpu.com

**Alexandra A. Petryaeva**
E-mail: alexandra.petryaeva@spbpu.com

Peter the Great St. Petersburg Polytechnic University, St.Petersburg, Russian Federation
Address: 29 Politechnicheskaya str., St.Petersburg 195251, Russia

**Abstract**

This article is devoted to the development of a high-level simulation model of tourism industry dynamics. The purpose of this study is to form recommendations for the recovery of the tourism industry from the effects of the pandemic. The resulting model considers domestic tourism from the point of view of the interdependence of the economic condition of the state, the contribution of the tourism industry to gross domestic product, the size of the tourist flow and the average income per tourist. In addition to describing the functional dependencies of the model elements, several experiments are proposed to test the logic of the elements' relationships. System dynamics tools are used to develop the model. The study also examines the class of computable general equilibrium models as a tool for analyzing supply and demand in the market of tourist products.

**Keywords:** system dynamics, simulation modeling, tourism, model of domestic tourism, tourism industry, economy

**Citation:** Gintciak A.M., Bolsunovskaya M.V., Burlutskaya Zh.V., Petryaeva A.A. (2022) High-level simulation model of tourism industry dynamics. *Business Informatics*, vol. 16, no. 3, pp. 53–67. DOI: 10.17323/2587-814X.2022.3.53.67

* The article is published with the support of the HSE University Partnership Programme

## Introduction

We have been living in an unfavorable epidemiological situation for the last three years. The pandemic dealt a significant blow both to the health of the population and to the economies of countries [1–3]. The largest rating agencies update monthly reports with an assessment of the losses of national economies. Countries with "emerging" economies and high debt loads were particularly affected. The UN report of January 25, 2021 indicates that in 2020 the world economy lost about 5%, which significantly exceeds the consequences of the financial crisis of 2009. The UN calls for joint financing of certain industries by states to restore the economy. The most affected industry in need of support is the tourism industry [4].

The tourism industry is a vital part of the economy of countries. On average it accounts for 5–15% of gross domestic product (GDP) for developed countries and more than 40% for some individual states. The role of tourism in the well-being of the population is revealed through millions of jobs and enterprises. Tourism is also a driving force in the protection of natural and cultural heritage, being an additional source of funding. Moreover, the researchers note that economic growth is directly related to the development of tourism infrastructure, which in some cases can serve as a tool to overcome the economic crisis [5].

Taking into account all the new waves of morbidity, the recovery of the tourism sector should begin with the development of domestic tourism. This strategy will reduce the risk of morbidity of citizens, increase the investment attractiveness of the country for foreign investment, and will also stimulate the development of entrepreneurial activity not only in the main cities but also throughout the country [6].

However, uncontrolled development of the tourism industry within one country can lead to a sharp imbalance of cash flows between regions, depletion of resources, monopolization of individual enterprises and deterioration of historical sites [7, 8]. Each region is unique in its way, and it is necessary to provide investment support by their characteristics [9]. Such important management decisions cannot be made without full information and analytical support, which can be provided by the domestic tourism model and the data model, respectively [10, 11].

Modeling of socio-economic systems is associated with several difficulties, expressed in a decrease in the level of determinism of the system. To solve this problem, it is necessary to develop an approach that ensures the integration of the following modeling tools for technical systems.

At the first stage of the model development, it is necessary to focus on the development of a system-dynamic model that describes the interrelationships of key elements and facilitates assessing the mutual impact of economic growth [12–14]. Within the framework of this work, a high-level simulation model of tourism industry dynamics has been developed. In addition, we consider the computable general equilibrium (CGE) model applicable to the tourism industry as a possible extension of the model [15–21].

## 1. Materials and methods

### 1.1. Analysis of the existing approach

Simulation models are used to replace the studied subject area with a model which describes its key indicators and connections between them. This approach ensures transparency of the processes taking place inside the system, so it allows us to predict the behavior of the system. System dynamics as a method of simulation modeling considers the interaction of the following objects: stocks (accumulated values of indicators), flows (numerical equivalents of values of indicators of a given period), converters (auxiliary quantities for calculating flows and similar converters) [22]. Visualization of models in system dynamics is based on a static combination of elements of all three types connected in a certain way. An important feature of models in system dynamics is the ability to qualitatively predict the behavior of the system without conducting a simulation experiment based on cause-and-effect relationships, which are presented and visualized in the model [23–25].

The system dynamic modeling is used as an alternative to forecasting models for scenario planning of tourist destinations [26]. The advantage of system dynamics models is the ability to take into account the natural limitations of the system [27]. Simulation models are ideal for analyzing the risks and prospects of certain management decisions. The use of a CGE model adapted to the tourism sector makes it possible to assess the most promising areas of investment in terms of the subsequent impact on the country's economy and the durability of the results [9]. The model used allows economic agents to perfectly anticipate the demand for tourism so that they can fully adapt to future conditions.

The CGE model is a computable general equilibrium model and is used to ensure equilibrium between industries in economic modeling. The more industries, regions, types of consumers appear in the model, the more difficult it is to solve such a model analytically; therefore numerical methods processed by computer capacities are used.

CGE models are used for various sectors of the economy, in particular, to assess the impact of investments on individual economic products [28, 29]. Among the most significant models based on the concept of calculated general equilibrium models, we can single out the MONASH model of the Australian economy, as well as a similar model for the US economy – USAGE and RUSEC – the model of Russian economy [17, 18]. The RUSEC model is an example of the applicability of the CGE model to describe the impact of a particular industry on the main macroeconomic indicators of the country [19, 20], so RUSEC-GAZPROM links changes in gas tariffs with the economic situation in the Russian Federation [21].

The basic structure of the CGE model contains four economic agents:

♦ household;

♦ company;

♦ state;

♦ the outside world.

Each of the agents is connected to the others and is both a source and a supplier. Thus, households are consumers of goods and financial support, but also suppliers of labor and tax payments. Firms receive income from goods, but also are consumers of labor. The state is responsible for investments and receives taxes. In this case, the outside world is an additional source of investment that consumes goods.

Each type of agent is guided by certain rules in decision-making. These rules are described by mathematical functions.

It is worth noting that the use of all four economic agents is not mandatory. In some works, one can find a description of only three agents as the basis of the CGE model, and this allows us to conclude that such an approach is acceptable.

By analogy with the basic structure of the CGE model, the dynamics of the tourism industry can be represented by the following elements:

♦ tourist profile (household);

♦ infrastructure of tourist products (firms);

♦ outflow of tourist flow (the outside world).

In this case, the tourist profile should be understood as an economic agent with its characteristics and needs, the main consumer of tourist products.

Under the infrastructure of tourist products, many companies source consumer products. This indicator includes accommodation, food, transport, events and much more.

The outflow of tourist flow in this case is equivalent to the outflow of income from tourists. It is worth noting that it will be compensated to some extent by inbound tourism.

It is necessary to keep the structure of the CGE model to further enable the model to include indicators of supply and demand in the tourism products market. Thus, the task of this work is to develop a high-level model, which will be finalized in the framework of further research according to the CGE concept [30–36].

### 1.2. Initial data

To develop the model and test it, it was decided to independently find and select the data. When selecting data sources, emphasis was placed on their openness and reliability. In the end, all the data used in the model were taken from the website of the World Tourism Organization.

It is worth noting that as part of the development and testing of the model, no emphasis was placed on the use of data about the Russian Federation. In this case, it was necessary to focus on a developed country with stable economic indicators and with a minimum number of tourist zones. The latter requirement is due to the inability to obtain reliable results based on the average for several different points of attraction. Based on the stated requirements, the choice of the country for the study settled on Austria, for a number of the following reasons:

- relative completeness of data in comparison with other countries;
- stable contribution of the tourism industry to the country's GDP (about 6%);
- developed domestic tourism (at least 40% of the tourist flow);
- stability of economic indicators;
- the country is included in the list of developed countries;
- relative limitations of tourist points of attraction.

It was important to identify and provide at least a few necessary indicators [22–25]. Below is a list of indicators that could be found in open sources; the time range is 2008–2018:

- tourists, thousand people (inbound tourism);
- tourism expenses in the country in millions of USD (inbound tourism);
- tourists, thousand people (outbound tourism);
- tourism expenses in the country in millions of USD (outbound tourism);
- tourists, thousand people (domestic tourism);
- tourism expenses in the country in millions of USD (inbound tourism);
- GDP;
- the contribution of tourism to GDP.

## 2. Model description

Within the framework of the study, a simplified model of the dynamics of the tourism industry has been developed. The main purpose of the model is to analyze the connection between the tourism industry and the well-being of the country's population. Such simplification will allow us to refine the model in the future, considering the specifics of pricing policy, production, the economic situation and measures to contain the epidemic of each country separately.

The elements of the model being developed can be divided into three groups according to the purposes of the calculation:

- calculation of the contribution of the tourism industry to GDP;
- calculation of profit from consumption of tourist products within the framework of domestic tourism;
- calculation of the tourist flow within the framework of domestic tourism.

The model we developed is presented below (*Fig. 1*).

The model presents two indicators containing the accumulated values of existing flows.

*Total tourist flow* (*T.t.f.*) – the accumulated value of the tourist flow, reflecting the number of tourist trips of citizens of a given country for a specified period. This indicator directly depends on the growth rate of the number of tourists (*Tourist flow growth, T.f.g.*):

$$T.t.f.(t) = T.t.f.(t - dt) + (T.f.g.) \cdot dt \qquad (1)$$

*Total income* (*T.i.*) – the accumulated value of profit from tourist products. This indicator depends on the level of annual profit from tourist products (*Yearly income, Y.i.*):

$$T.i.(t) = T.i.(t - dt) + (Y.i.) \cdot dt \qquad (2)$$

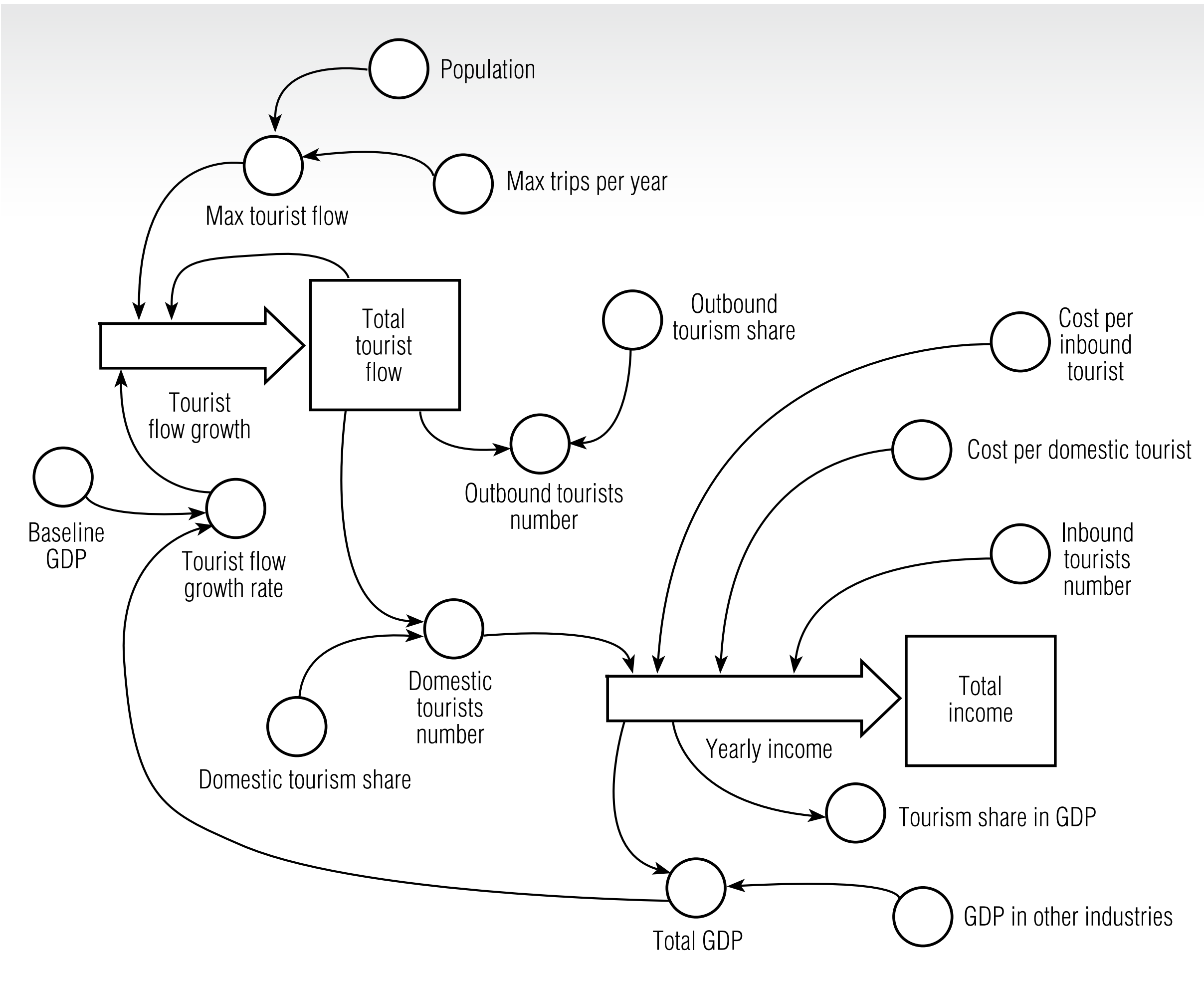


*Fig. 1.* Model of domestic tourism.

The model also includes two flows that precede changes in indicators containing accumulated values of existing flows:

*Tourist flow growth* (*T.f.g.)* – the growth rate of the tourist flow. This indicator depends on the level of growth of the tourism industry (*Tourist flow growth rate, T.f.g.r.)*, as well as on the maximum possible size of the tourist flow (*Max tourist flow, M.t.f.*), which is a limitation of the system:

$$T.f.g. = \left(M.\,t.\,f. - T.\,t.\,f.\right)\cdot 2^{\left(-\frac{1}{T.f.g.r.}\right)} \quad (3)$$

*Yearly income* (*Y.i.*) – the rate of annual profit growth from the tourist flow. This figure depends on the number of domestic tourists (*Domestic tourists number, D.t.n.*), the number of inbound tourists (*Inbound tourists number, I.t.n.*), the average revenue per domestic tourist (*Cost per domestic tourist, C.d.t.*), average income from inbound tourists (*Cost per inbound tourist, C.i.t.*):

$$Y.i. = C.d.t. \cdot D.t.n. + C.i.t. \cdot I.t.n. \quad (4)$$

In the model there are also fifteen converters required for the calculation of stream values:

*Baseline GDP* (*B. GDP*)– is the basic value of Austria's GDP. It is necessary to estimate the annual growth in GDP. A static value is set in the model:

$$B.\ GDP = 426000000000\ (USD). \quad (5)$$

*Cost per domestic tourist* (*C.d.t.*) – average income from domestic tourist. A static value is set in the model. However, this indicator is one of the main levers of influence on the model:

$$C.d.t. = 600\ (USD). \quad (6)$$

*Cost per inbound tourist* (*C.i.t.*) – the basic value of Austria's GDP. A constant value is set in the model:

$$C.i.t. = 800\ (USD). \quad (7)$$

*Domestic tourism share* (*D.t.s.*) – the share of tourists who prefer domestic tourism. A constant value is set in the model, but this indicator will be the lever of influence on the model:

$$D.t.s. = 0.5. \quad (8)$$

*Domestic tourists number* (*D.t.n.*) – the actual number of domestic tourists. It depends on the accumulated value of the tourist flow (*Total tourist flow, T.t.f.*) and the share of domestic tourism (*Domestic tourism share, D.t.s.*):

$$D.t.n. = D.t.s. \cdot T.t.f. \quad (9)$$

*GDP in other industries* (*GDP.o.i.*) – contribution to the GDP of other industries. A constant value is set in the model:

$$GDP.o.i. = 400000000000\ (USD). \quad (10)$$

*Inbound tourists number* (*I.t.n.*) – the actual number of incoming tourists. A constant value is set in the model:

$$I.t.n. = 25000000. \quad (11)$$

*Max tourist flow* (*M.t.f.*) – the maximum possible number of tourists. Depends on the maximum number of trips per tourist per year (*Max trips per year, M.t.y.*) and on the actual value of the population (*Population, P.*):

$$M.t.f. = P. \cdot M.t.y. \quad (12)$$

*Max trips per year* (*M.t.y.*) – the maximum number of trips per tourist:

$$M.t.y. = 4. \quad (13)$$

*Outbound tourism share* (*O.t.s.*) – the share of outbound tourists. A constant value is set in the model:

$$O.t.s. = 0.5. \quad (14)$$

*Outbound tourists number* (*O.t.n.*) – the actual value of outbound tourists. Depends on the accumulated value of the tourist flow (*Total* *tourism flow, T.t.f.*) and the share of outbound tourism (*Outbound tourism share, O.t.s.*):

$$O.t.n. = O.t.s. \cdot T.t.f. \qquad (15)$$

*Population* (*P.*) – the actual value of the population. A constant value is set in the model:

$$P. = 8900000. \qquad (16)$$

*Total GDP* (*T.GDP*) – the value of GDP. It depends on the profit from other industries (*GDP in other industries, GDP.o.i.*) and on the annual revenue from tourism products (*Yearly income, Y.i.*):

$$T.GDP = GDP.o.i. + Y.i. \qquad (17)$$

*Tourism share in GDP* (*T.s.GDP*) – the share of the tourism industry in GDP. It is assumed that the growth of this indicator will positively affect the dynamics of the model indicators. Calculated on the basis of annual income (*Yearly income, Y.i.*) from tourist products to the total value of GDP (*Total GDP, T.GDP*):

$$T.s.GDP = \frac{Y.i.}{T.GDP} \cdot 100. \qquad (18)$$

*Tourist flow growth rate* (*T.f.g.r.*) – increase in tourist flow. Depends on the total value of GDP (*Total GDP, T.GDP*) and the base value of GDP (*Baseline GDP, B. GDP*):

$$T.f.g.r. = \frac{T.GDP}{B.GDP} - 1. \qquad (19)$$

All static values are set based on the analysis of the initial data and represent the average figures for 11 years.

As part of one of the goals of modeling, the preparation of an analytical base for making informed management decisions, the goal will be to maximize the return on investment in tourism products, namely, to maximize the contribution of the tourism industry to GDP.

After the verification stage of the model on the available data, the model will be finalized considering the possible financing of individual tourist products (hotels, roads, events, and so on). The difficulty of this stage is the lack of data to test hypotheses about the impact of investments on increasing revenue from tourism products, which is why this stage is not considered in this work.

These values of indicators provide a static state of the model when the level of indicators remains stable except for accumulated values.

## 3. Simulation results and discussion

To test the operation of the model, it is necessary to conduct a series of experiments. Below is a table with a description of the experiment and the expected result. The extent to which the expected and actual results coincide determines the quality of the model (*Table 1*).

The proposed experiments are implemented in the software environment iThink.

Based on the experimental data, the logical component of the model and their interrelations are checked. Connections of the following indicators are being worked out:

- the impact of the share of domestic tourism on tourism revenues and GDP growth;
- dependence of GDP on income from tourism and income from other industries;
- the impact of income from one tourist on the annual income from tourism, the share of tourism in GDP.

We will conduct a test simulation for 10 years to check the stability of the model.

The increase in total income from tourism increases evenly since there is an equal annual increase, as can be seen from the graphs of total income from tourist products (*Fig. 2*).

The total tourist flow (*Fig. 3*) remains constant.

*Table 1.*

**Description of experiments**

| No. | Description of the experiment | Description of the expected results |
|---|---|---|
| 0 | Zero starts, the values are described above. | The model is in a static state; all indicators remain at the same level in all the periods under consideration. |
| 1 | We change the indicators of the share of the distribution of domestic tourism and outbound tourism: 0.65 and 0.35 respectively. | It is assumed that the annual income from tourism will increase and a slight increase in the tourist flow. |
| 2 | We are changing the contribution of other industries, increasing it to 500 000 000 000 (USD). | It is assumed that the share of the contribution of tourism will fall, and the tourist flow and GDP will grow. |
| 3 | We return the value for other industries and double the income from domestic tourism. | It is expected to increase the contribution of tourism to DP, as well as an increase in annual income. |

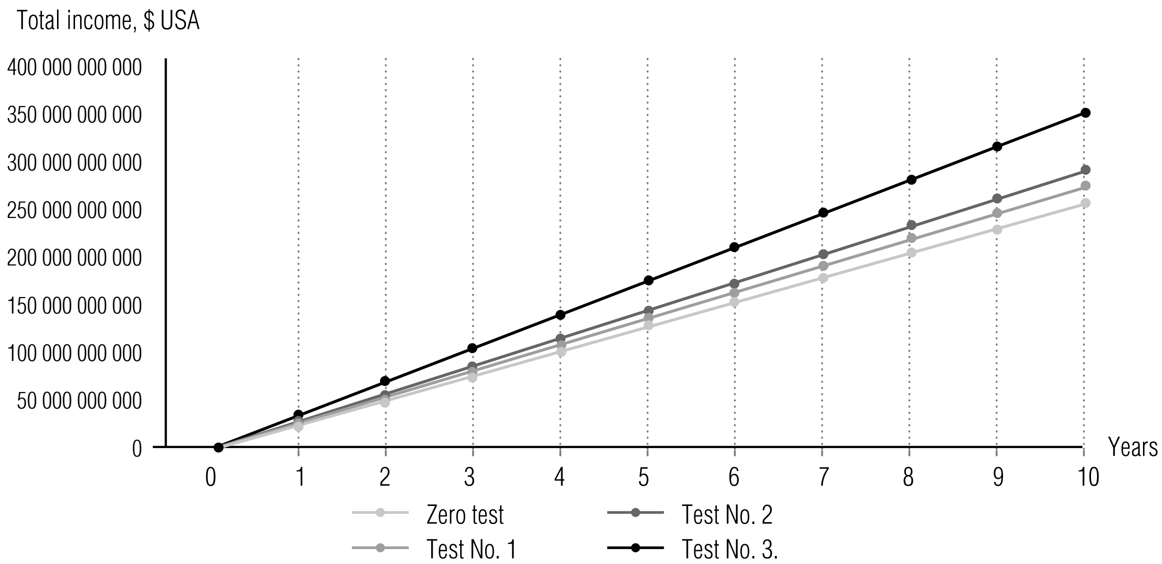


*Fig. 2.* Total income.

The annual income is stable, so the graph is a straight line parallel to the ordinate axis (*Fig. 4*).

Another important indicator that makes sense; displayed on the graph is the contribution of the tourism industry to GDP (*Fig. 5*).

At the zero-modeling stage, the contribution is stable and amounts to just over 6%.

We will conduct a test simulation for 10 years, taking into account the increase in the share of domestic tourism to 65%. This result can be achieved by increasing the level of attractiveness of the country in comparison

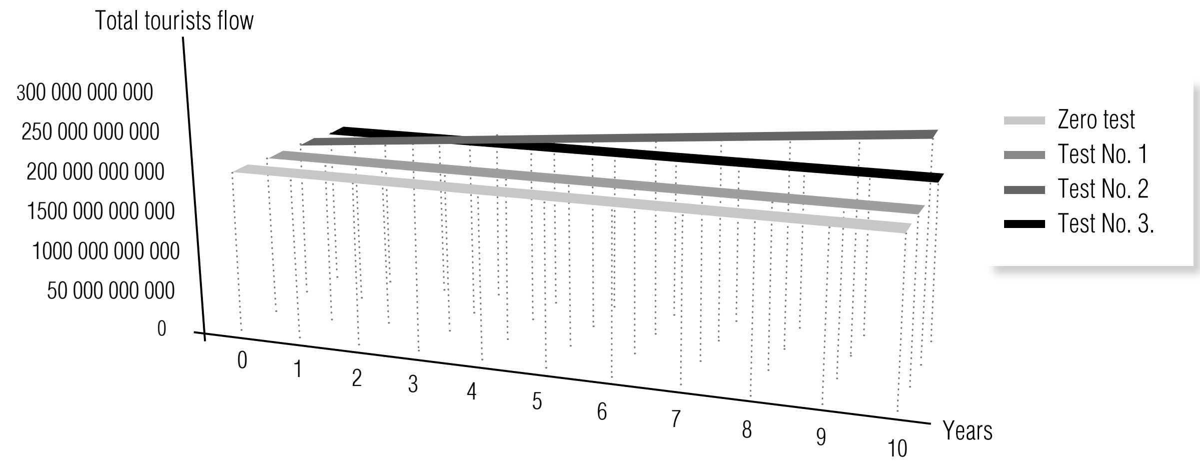


*Fig. 3.* Total tourists flow.

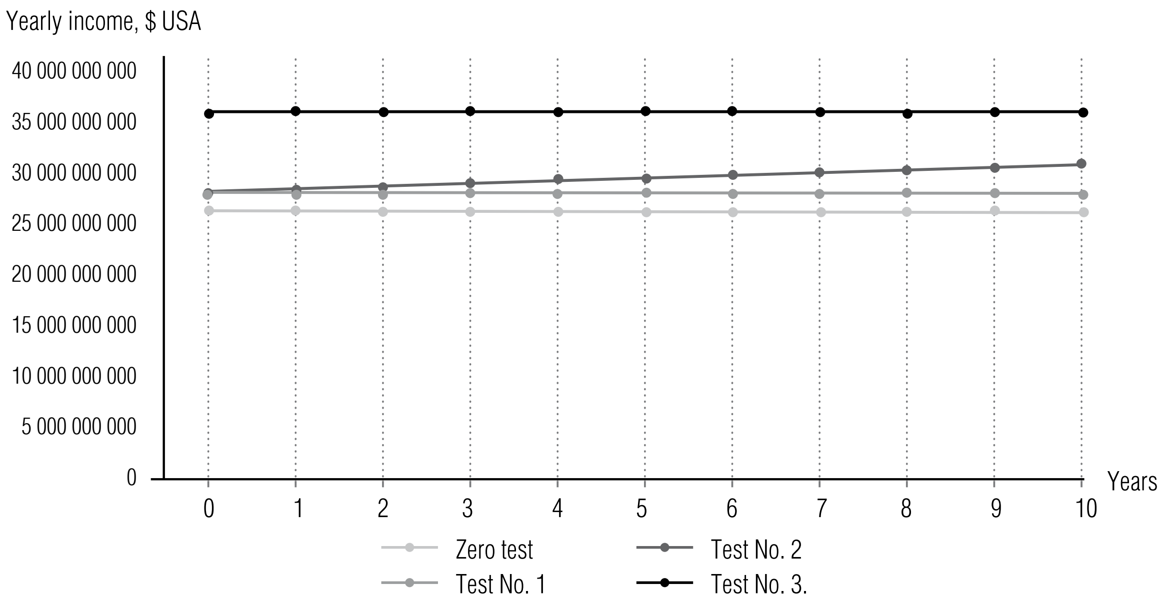


*Fig. 4.* Yearly income.

with other places. Let's see how the income from tourism will change after the result of the experiments.

The graph shows that the test gave similar values of the tourist flow in comparison with the zero tests. This is due to the slow growth of the tourist flow because of the relatively small contribution of the tourism industry to GDP (*Fig. 2*).

Particular attention should be paid to the values of the following indicator (*Fig. 4*). The increase in annual income from tourism products should have caused an increase in the contribution of the tourism industry to GDP (*Fig. 5*). The indicator of the contribution of the tourism industry increased by almost a percentage point, which corresponds to the expected results.

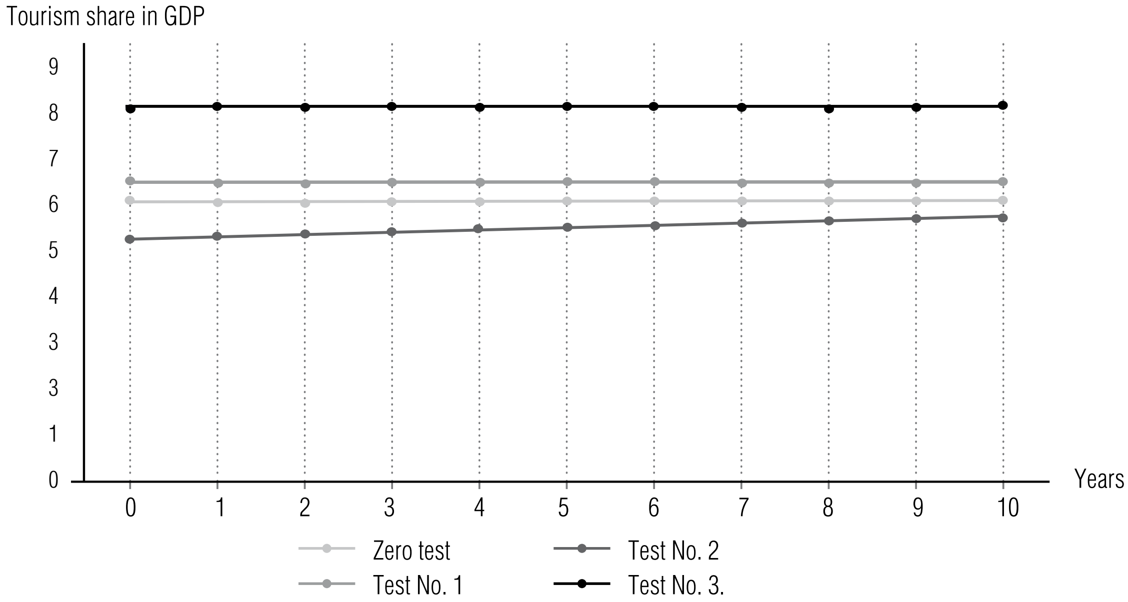


*Fig. 5.* Tourism share in GDP.

Since the share of tourism is about 6% of the total GDP, it is difficult to trace the change in tourist flow from GDP growth. Therefore, as part of the verification of the work of the model, we will increase the contribution of other industries to trace the dependence of the tourist flow on the level of well-being.

The graph shows a change in the trend of income growth from tourist products. In comparison with the results of the first experiments, significant nonlinear growth of the indicator is observed.

The tourist flow, taking into account recent changes, has acquired a tendency to a non-linear increase in the values of the indicator.

Annual income has acquired an upward trend. The graph shows the nonlinearity of growth (*Fig. 4*).

The graph shows the change in the share of the tourism industry, which is explained by the change in the share of other industries (*Fig. 5*). Interestingly, the share of the tourism industry has acquired a tendency to non-linear, but tangible growth, which once again proves the mutual influence of the development of economic sectors on each other.

Let's conduct a third experiment. Let's return the contribution values of other industries and return to modeling the tourism industry. Suppose that the increase in the attractiveness of the country affected the share of domestic tourism, which led some of the category of "expensive" tourists to the desire to relax in their native country. This caused a sharp increase in the average income per tourist – twice.

Consider the change in total income (*Fig. 2*). The graph shows that the total revenue from an increase in income from one tourist is growing significantly better than with an increase in total revenue from other industries.

The tourist flow is leveling off again to the previous values (*Fig. 3*).

The graph shows that the total income from an increase in income from one tourist is growing significantly better than with an increase in total revenue from other industries.

The annual income returned to a stable level but exceeded it significantly in comparison with the results of previous experiments.

*Table 2.*

**Description of results**

| No. | Description of the experiment | Description of the expected results | Compliance with the results |
|---|---|---|---|
| 0 | Zero starts; the values are described above. | The model is in a static state; all indicators remain at the same level in all the periods under consideration. | Successfully, all indicators remain unchanged at all intervals. |
| 1 | We change the indicators of the share of the distribution of domestic tourism and outbound tourism: 0.65 and 0.35 respectively. | It is assumed that the annual income from tourism will increase and there is a slight increase in the tourist flow. | Successfully, the increase in annual income and contribution of the tourism industry to the stable values of the tourist flow. |
| 2 | We are changing the contribution of other industries, increasing it to 500 000 000 000 (USD). | It is assumed that the share of the contribution of tourism will fall; the tourist flow and GDP will grow. | Successfully, the share of the tourism industry fell but showed growth trends due to an increase in the accumulated value of income. The tourist flow schedule also showed a significant increase. The limitations of the model also work and have shown themselves in a drop in the growth rate of the tourist flow after reaching a maximum. |
| 3 | We return the value for other industries and double the income from domestic tourism. | It is expected to increase the contribution of tourism to GDP, as well as an increase in annual income. | Successfully, the contribution of the tourism industry has increased, as has the total income. |

The increase in the value of one tourist caused a significant increase in the share of the tourism industry in the country's GDP; now this figure is more than 8%.

As part of this work, a series of experiments were carried out. At this stage, it is necessary to compare the expected results from the actual results of the model.

A comparative analysis is presented below (*Table 2*).

The experimental results confirmed the applicability of the model for assessing the economic dependence of the level of well-being of citizens, the size of the tourist flow and the contribution of the tourism industry to GDP. The relevance of investing in the tourism industry as a way to restore the economy and increase profits for business and the state is confirmed.

Based on the experiments, we can conclude about the stability of the model and the logically correct relationship of the indicators.

The results of the experiments do not contradict logic and fit into the general concept of the interrelation of elements in the model of domestic tourism. Accordingly, the results of the first high-level model can be considered successful.

The resulting model is a high-level simulation model of the dynamics of the tourism industry. There are plans to develop the model considering the analysis of intersectoral relations, the contribution of various tourist products and the seasonality of demand. It is also necessary to integrate into the model elements of the impact of Covid-19 restrictions and changes at the macroeconomic level on the tourist flow.

## Conclusion

This article is devoted to the development of a model based on data available in open sources. The purpose of this is to model the dependence of the economic condition of the state on the development of the tourism sector. As part of the work, a high-level model of domestic tourism was developed with a description of the functional dependencies of the model elements. The resulting model was tested for compliance with the logic of functional dependencies between elements determined as a result of the analysis of international experience in modeling tourist processes. The results obtained link the indicators of the contribution of the tourism industry to the country's GDP, the tourist flow and revenue from the consumption of tourist products. This study is the first stage in a project to develop a model of domestic tourism that considers the natural limitations of the system, such as the environmental situation, available labor resources and the condition of historical heritage monuments, also taking into account functional descriptions of the propensity of tourists to save and spend for different groups of profitability, the division of tourist products by type and other economic indicators. ■

## Acknowledgements

The research is funded by the Ministry of Science and Higher Education of the Russian Federation (contract No. 075-03-2021-050 dated 29.12.2020).

## References

1. Smith R.D., Keogh-Brown M.R. (2013) Macroeconomic impact of pandemic influenza and associated policies in Thailand, South Africa and Uganda. *Influenza and other Respiratory Viruses*, vol. 7, pp. 64–71. https://doi.org/10.1111/irv.12083

2. Beckman J., Countryman A.M. (2021) The importance of agriculture in the economy: Impacts from COVID-19. *American Journal of Agricultural Economics*, vol. 103, no. 5, pp. 1595–1611. https://doi.org/10.1111/ajae.12212

3. Deriu S., Cassar I.P., Pretaroli R., Socci C. (2021) The economic impact of Covid-19 pandemic in Sardinia. *Research in Transportation Economics*, vol. 93, 101090. https://doi.org/10.1016/j.retrec.2021.101090

4. Pham T.D., Dwyer L., Su J.-J., Ngo T. (2021) COVID-19 impacts of inbound tourism on Australian economy. *Annals of Tourism Research*, vol. 88, 103179. https://doi.org/10.1016/j.annals.2021.103179

5. Dogru T., Bulut U. (2018) Is tourism an engine for economic recovery? Theory and empirical evidence. *Tourism Management*, vol. 67, pp. 425–334. https://doi.org/10.1016/j.tourman.2017.06.014

6. Esfandiar K. [et al.] (2019) Understanding entrepreneurial intentions: A developed integrated structural model approach. *Journal of Business Research*, vol. 94, pp. 172–182. https://doi.org/10.1016/j.jbusres.2017.10.045

7. Berawi M.A. (2016) Accelerating sustainable infrastructure development: Assuring well-being and ensuring environmental sustainability. *International Journal of Technology*, vol. 7, no. 4, pp. 527–529. https://doi.org/10.14716/ijtech.v7i4.3829

8. Widaningrum D.L., Surjandari I., Sudiana D. (2020) Analyzing land use changes in tourism development areas: A case study of cultural world heritage sites on Java Island, Indonesia. *International Journal of Technology*, vol. 11, no. 4, pp. 688–697. https://doi.org/10.14716/ijtech.v11i4.4097

9. Blake A. (2009) The dynamics of tourisms economic impact. *Tourism Economics*, vol. 15, pp. 615–628. https://doi.org/10.5367/000000009789036576

10. Makaro V. [et al.] (2016) Modeling the development of regional economy and an innovation space efficiency. *Foresight and STI Governance*, vol. 10, no. 3, pp. 76–90. https://doi.org/10.17323/1995-459X.2016.3.76.90

11. Miao K., Vinter R. (2021) Optimal control of a growth/consumption model. *Optimal Control Applications and Methods*, vol. 42, no. 6, pp. 1672–1688. https://doi.org/10.1002/oca.2754

12. Laffargue J.-P. (2011) Computable general equilibrium (CGE) models and tourism economics. In *Tourism, Trade and Welfare*, Nova Science Publishers, Inc., pp. 117–138.

13. Blake A. [et al.] (2006) Integrating forecasting and CGE models: The case of tourism in Scotland. *Tourism Management*, vol. 27, no. 2, pp. 292–305. https://doi.org/10.1016/j.tourman.2004.11.005

14. Ilyash O. (2021) Models of efficiency of functioning in trading enterprises under conditions of economic growth. *Bulletin of Geography*, vol. 51, pp. 7–24.

15. Meng X., Siriwardana M., Pham T. (2013) A CGE assessment of Singapore's tourism policies. *Tourism Management*, vol. 34, pp. 25–36. https://doi.org/10.1016/j.tourman.2012.03.006

16. Van Heerden J., Roos E.L. (2021) The possible effects of the extended lockdown period on the South African economy: A CGE analysis. *South African Journal of Economics*, vol. 89, no. 1, pp. 95–111. https://doi.org/10.1111/saje.12273

17. Makarov V.L. (1999) *Computable model of the Russian economy (RUSEC)*. Preprint WP/99/069. Moscow: CEMI of the Russian Academy of Sciences (in Russian).

18. Bakhtizin A.R. (2008) *Agent-based models of the economy*. Moscow: Ekonomika (in Russian).

19. Akopov A.S., Beklaryan G.L. (2005) Analysis of efficiency of adjusting policy of the state by means of regional model CGE of behaviour of natural monopolies (on the example of electric power industry). *Economics of Contemporary Russia*, vol. 4, pp. 130–139 (in Russian).

20. Akopov A.S., Beklaryan G.L. (2014) Modelling the dynamics of the "Smarter Region". In *Proceedings of 2014 IEEE Conference on Computational Intelligence for Financial Engineering & Economics*. IEEE, pp. 203–209. https://doi.org/10.1109/CIFEr.2014.6924074

21. Akopov A.S. (2012) Designing of integrated system-dynamics models for an oil company. *International Journal of Computer Applications in Technology*, vol. 45, no. 4, pp. 220–230. https://doi.org/10.1504/IJCAT.2012.051122

22. Lychkina N.N., Gorbunov A.R. (2007) Simulation modeling paradigms: new in solving problems of strategic management (combined simulation-modeling logic). *Business informatics*, vol. 2, pp. 60–66 (in Russian).

23. Franco E.F., Hirama K., Carvalho M.M. (2018) Applying system dynamics approach in software and information system projects: A mapping study. *Information and Software Technology*, vol. 93, pp. 58–73.

24. Stadnicka D., Litwin P. (2019) Value stream mapping and system dynamics integration for manufacturing line modelling and analysis. *International Journal of Production Economics*, vol. 208, pp. 400–411.

25. Castellacci F. (2018) Co-evolutionary growth: A system dynamics model. *Economic Modelling*, vol. 70. pp. 272–287.

26. Mai T., Smith C. (2018) Scenario-based planning for tourism development using system dynamic modelling: A case study of Cat Ba Island, Vietnam. *Tourism Management*, vol. 68. pp. 336–354.

27. Sidorenko V.N. (1998) *System Dynamics.* Moscow: TEIS (in Russian).

28. Zhang Q., Tong Q. (2021) The economic impacts of traffic consumption during the COVID-19 pandemic in China: A CGE analysis. *Transport Policy*, vol. 114, pp. 330–337. https://doi.org/10.1016/j.tranpol.2021.10.018

29. Timilsina G., Shrestha R. (2008) A general equilibrium analysis of potential demand side management programs in the household sector in Thailand. *International Journal of Energy Sector Management*, vol. 2, no. 4, pp. 570–593.

30. Romero C.A., Tarelli J.P., Mercatante, J.I. (2021) The economic impact of tourism in a small region: A general equilibrium analysis applied to Ushuaia. *International Journal of Tourism Policy*, vol. 11, no. 4, pp. 335–354.

31. Van Truong N., Shimizu T. (2017) The effect of transportation on tourism promotion: Literature review on application of the Computable General Equilibrium (CGE) Model. *Transportation Research Procedia*, vol. 25, pp. 3096–3115.

32. Deepak M., Taylor West C., Spreen T. (2001) Local government portfolios and regional growth: some combined dynamic CGE/optimal 320 control results. *Journal of Regional Science*, vol. 41, pp. 219–254.

33. Dwyer L., Forsyth P., Madden J., Spurr R. (2000) Economic impacts of inbound tourism under different assumptions regarding the macroeconomy. *Current Issues in Tourism*, vol. 3, no. 4, pp. 325–363. https://doi.org/10.1080/13683500008667877

34. Gül H. (2015) Effects of foreign demand increase in the tourism industry: a CGE approach to Turkey. *Anatolia*, vol. 26, no. 4, pp. 598–611. https://doi.org/10.1080/13032917.2015.1044016

35. Inchausti-Sintes F., Pérez-Granja U., Morales-Mohamed J.J. (2021) Analysing labour productivity and its economic consequences in the two Spanish tourist archipelagos. *Tourism Economics*, vol. 27, no. 5, pp. 1039–1059. https://doi.org/10.1177/1354816620917865

36. Attar M.A. (2021) Growth, distribution and dynamic inefficiency in Turkey: An analysis of the naïve neoclassical theory of capital. *Structural Change and Economic Dynamics*, vol. 59, pp. 20–30.

## About the authors

**Aleksei M. Gintciak**

Head of Laboratory of Digital modeling of Industrial systems, Peter the Great St.Petersburg Polytechnic University, 29 Politechnicheskaya str., St.Petersburg 195251, Russia.

E-mail: aleksei.gintciak@spbpu.com

ORCID: 0000-0002-9703-5079

**Marina V. Bolsunovskaya**

Cand. Sci. (Tech.);

Head of Laboratory of Industrial Systems for Streaming Data Processing, Peter the Great St.Petersburg

Polytechnic University, 29 Politechnicheskaya str., St.Petersburg 195251, Russia.

E-mail: marina.bolsunovskaia@spbpu.com

ORCID: 0000-0001-6650-6491

**Zhanna V. Burlutskaya**

Junior Researcher of Laboratory of Digital Modeling of Industrial Systems, Peter the Great St.Petersburg Polytechnic University, 29 Politechnicheskaya str., St.Petersburg 195251, Russia.

E-mail: zhanna.burlutskaya@spbpu.com

ORCID: 0000-0002-5680-1937

**Alexandra A. Petryaeva**

Junior Researcher of Laboratory of Digital Modeling of Industrial Systems, Peter the Great St.Petersburg Polytechnic University, 29 Politechnicheskaya str., St.Petersburg 195251, Russia.

E-mail: alexandra.petryaeva@spbpu.com

ORCID: 0000-0002-2028-7251