Tourism Industry Perspectives in the Context of the COVID-19 Pandemic Based on the Sustainable Development Concept

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Abstract: The relevance of this study is in the growing popularity of the concept of sustainable development in the tourism sector. The purpose of the article is to determine a systematic basis for the assessment of the possibility of sustainable tourism development at the regional level, as well as determining relevant vectors. In addition, the study considers a number of studies that allow for defining sustainable tourism, as well as determining groups of indicators affecting it. The leading method of studying tourism structure as part of a regional socio-economic system is topological analysis, which allows for identifying functionally significant combinations of factors. Incidence matrices of the structure of indicators with included weighting factors influencing the sustainable development of tourism, analysis of their q-connectivity, the results of the dimension of simplexes, the number of connected components and communication chains, the structural vectors of the complexes were determined and presented. The study proved the presence of simplexes in the complexes. The effects on simplexes can bring the desired result in the quickest and most efficient way. Since tourism is an integral part of environmental, social and economic sectors, and the sustainable development itself can be regarded as a unified system of interaction between them, it is possible to use the above factors in each of the sectors on a case-by-case basis in any territory or enterprise to conserve resources, eradicate poverty and ensure well-being. This research attempts to formalize the factors that determine the sustainable development of tourist destination that gives the full basis for a systematic study of the territory to assess the sustainability of tourism development. The topological analysis shows the mutual influence of simplicial complexes by means of a chain of connections leading to sustainable development.

Keywords: tourism Industry, COVID-19 pandemic, topological analysis, simplicial complexes, Q-connected systems.

INTRODUCTION

In recent years, the impact of tourism and related events on the environment of tourist destinations became a popular topic of study. The growing popularity of the concept of sustainable development resulted in the fact that tourism is seen as an activity that can be easily developed in accordance with the principles of sustainable development (Sunardi, Roedjinandari, and Estikowati, 2019). Tourist destinations develop and change over time, both in response to changes in tourism and under their influence (Mathew and Sreejesh, 2017; Dwyer, 2018; Goffi, Cucculelli, and Masiero, 2019; Dudetsky, 2014, 2015). They are not static environments and require responsible and proactive planning and management (Hidayat, Anduarima, Wesnina, Budiaman, and Possumah, 2019).

The concept of sustainable tourism arose from the merger of two separate areas of thought, developing simultaneously, but separately and ultimately converged in the late 1980s (Mihalic, 2016; Klarin, 2018). One direction is the increase of social attention to tourism and its economic consequences. According to the second, economic development was increasingly puzzling, especially in countries and regions characterized by high levels of poverty, limited access to health care and education, and limited opportunities to participate in the global economic system (Caraka, Hafianti, Hidayati, Wilie, and Muztahid, 2019). In the framework of these areas, ultimately there is a set of problems associated with the future, environmental and social consequences of tourism development, the institutional goals, and structures of economic development (Hartman, 2016; Scott, Gössling, Hall, and Peeters, 2016).

Thus, tourism continues to face a number of key unsolved issues related to the concept of sustainable development, including its link to acceptance rate, development and functioning control, as well as to mass or traditional tourism (Cuculeski and Petrovska, 2016; Hall, 2016; Amore and Hall, 2017). These issues are clearly interrelated arising from the nature of tourism development, the nature of the tourism industry and the role of the public sector in tourism along numerous lines (Buckley, 2012). In addition, measurement and monitoring challenges are also linked to the vague nature of the framework itself. The key challenge to sustainable development in the context of tourism is not to ensure the ongoing adoption of small, environmentally and culturally

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appropriate forms of tourism, but to make existing mass tourism developments as sustainable as possible (Budeanu, Miller, Moscardo, and Ooi, 2016; Higuchi and Yamanaka, 2017).

The sustainability of tourism can be assessed through its contribution to five Ps (global social phenomena) that are population, peace, prosperity, pollution and protection (Liu and Stephens, 2019; Caraka, Chen, Toharudin, Pardamean, Yasin, and Wu, 2019). In terms of global sustainability, the most important link between tourism and the environment is clearly the use of tourism as a financial and policy support tool for conservation of biodiversity (Shafiee, Rajabzadeh Ghatari, Hasanzadeh, and Jahanyan, 2019; Orlova, Afonin, Voronin, and Akopyan, 2015).

Sustainable development of tourist destinations is understood as striving to achieve target industry-specific indicators within the framework of maintaining a certain dynamic balance with the development of the internal and external environment. While dynamic equilibrium is regarded as a holding of the trajectory of destination development on a predicted time interval within a set of steady and safe conditions. Safe condition of the system is defined as its staying in the framework of its development within the limits of acceptable load on resources, and economic, socio-cultural and political environment of the territory (Fedorenko, Zaychikova, Abramov, and Vlasova, 2016). It should be noted that at present in tourist destinations economic and social instruments are weakly structured, neither having systematic bases, nor correlating with each other in terms of sustainable development (Gorelova, 2011).

Today, tourism, being one of the most labor-intensive sectors of the economy, is among those that are most affected by the COVID-19 pandemic (Caraka, Lee, Kurniawan, Herliansyah, Kaban, Nasution, Gio, Chen, Toharudin, and Pardamean, 2020; Vasiljeva, Neskorodieva, Ponkratov, Kuznetsov, Ivlev, Ivleva, Maramygin, and Zekiy, 2020). According to the World Tourism Organization (2020), the COVID-19 pandemic caused a 27.8% decline in international tourist arrivals in the first quarter of 2020 and a 95.2% decline in the second quarter. This puts millions of sources of funds at risk and threatens to reverse the progress made in achieving sustainable development goals. According to a review by the World Tourism Organization's Group of Experts, the evidence of recovery is expected in the last quarter of 2020, but mostly in 2021, with domestic demand recovering faster than international one.

Availability of a significant number of indicators allowing to study the sustainability of development of tourist destinations within a particular territory is associated with the fact that the resource potential and the impact of tourism on the economic, socio-cultural and ecological condition is quite difficult to differentiate from all the processes taking place, therefore, mainly various expert methods are used. In general, it is possible to say that indicators of sustainable development of any complex system should be the ones having functional and significant links between them, while their failure leads to the failure of the whole system.

LITERATURE REVIEW

Sustainable tourism as a development paradigm followed the idea “the less the better”, but there are significant questions about the significance of this topic in the modern world, characterized by changes, disputes, conflicts, and uncertainty. Today there is a significant number of studies of sustainability in tourism, and even listing only the directions of the raised issues is a difficult task (Lane, 2018; Ryan, 2018).

Sustainable tourism is often associated with ecotourism and environmental dependence as the main resource providing the basis for an empirical product. The growth of systems thinking has led to a new and perhaps more useful understanding of tourism as a strategy for economic development. The term “sustainable tourism” appeared in the studies just two decades ago.

Tourism researchers first turned their attention to social and environmental issues almost four decades ago. In the first decade, works were obtained (Allen, Long, Perdue, and Kieselbach, 1988; Brougham and Butler, 1981; Cater, 1987; Cohen, 1978; Ioannides, 1995) and basic foundations from experience in tourism (Kavallinis and Pizam, 1994; Butler, 1999; Berry and Ladkin, 1997; Hughes, 1995), economics (Driml and Common, 1996; Garrod and Fyall, 1998; Ivlev, Ivleva, and Ivleva, 2019), and environmental management (Buckley, 1996).

Sustainable tourism depends on meeting the needs of the host population in terms of improving living standards in the short and long term, meeting the needs for increasing the number of tourists and their further attraction to achieve this goal, as well as the environment to achieve the two above-mentioned goals (Laws, 1995).

Cronin (1990) points out the principles of sustainable development of tourism that make tourism a recognized option for sustainable economic development, considered on an equal basis with other economic activities. This includes the certain database of tourist information that would allow for the recognition, analysis and monitoring of the tourism industry in relation to other sectors of the economy. The development of tourism should be also carried out in accordance with the principles of sustainable development.

Conditions as "resource management", "waste reduction" and "biodiversity conservation" reflect the environmental prerequisites for sustainable development articulated in Rio de Janeiro (United Nations, 1992). The different sets of principles relating to sustainable tourism cannot be explicitly addressed in these formulations, but can be summarized as follows (World Tourism Organisation, 1993; World Tourism Organisation and World Travel and Tourism Council, 1996):

1. The conservation and sustainable use of natural, social and cultural resources is of crucial importance. Tourism must therefore be planned and managed within environmental constraints and with due regard for the long-term proper use of natural and human resources.

2. Tourism planning, development and operation should be integrated into national and local strategies for sustainable development of the destination. In particular, the different types of tourism, their relationship to existing resource use and socio-cultural factors should be taken into account.

3. Tourism is supposed to support a wide range of local economic activities, taking into account overall costs and benefits.

4. Local communities should be encouraged and involved in the planning, development and control of tourism with government and industry support. Special attention should be paid to the involvement of indigenous peoples, women and minors. These groups ensure an equitable distribution of benefits from tourism.

5. All organizations and individuals should respect the culture, economy, way of life, environment and political structures in the destination.

6. All tourism stakeholders should be made aware of the need to develop sustainable forms of tourism through staff training, as well as to raise awareness through education and tourism marketing, sustainability issues among host communities and tourists themselves.

7. Research should be carried out at all stages of tourism development, including studies on monitoring the impact of tourism, problem solving and providing local residents with participation in solving them.

8. All organizations and individuals ought to cooperate to avoid potential conflicts and streamline benefits for all actors involved in tourism development and management.

The second decade has provided a number of rethinking as well as criticisms, including Brysse (2012), Berg and Ostry (2011), Barnosky (2012), Grübler (2012), Lobell, Wolfram, and Costa-Roberts (2011), Ravallion (2012), Buckley (2012) and Lin, Li, and Ji (2020). The definitions reflect the social, cultural, economic, and environmental conditions of sustainable development. As a rule, the authors' definitions of "sustainable tourism" are based on the principle of equality between generations. However, the authors have different ideological points of view.

Existing discussions in the field of sustainable tourism development can be reduced to the conclusion reached by Webster (2017) that all definitions fall into the framework of two categories: tourism-oriented and considering its maintenance as an economic activity and determining tourism as an element of sustainable development policy. As the author notes, sustainable tourism should be considered as a potential means of achieving sustainable development, that is, any form of tourism itself must be environmentally sustainable, be able to make an unlimited contribution to the policies and goals of sustainable development.

For Lélé (2013), the sustainable development process is a broader concept than the mere conservation or protection of natural resources. Rather, sustainable development is a function of the complex interrelationships between society and natural resources, the multitude of socio-economic and political structures and local governance decisions. In particular, it provides a framework for recognizing and taking into account the environment, social, economic and political structures, and defines their interconnections.

McCool, Butler, Buckley, Weaver, and Wheeller (2013) argue that the modern view of sustainable tourism is characterized by conceptual uncertainty and pretentiousness, while certainty and practical expression are required.

The authors note that the traditional concept of sustainable tourism as a small-scale tourism at the interface of economic feasibility, environmental sensitivity and social acceptability no longer provides a constructive way to address these issues. Given the great uncertainty in the world, one of the goals of managing complex social and environmental systems would be to make them more resilient to outrages caused by domestic or broader factors such as economic restructuring requirements, global business competition, changing tourism markets or climate change (Triarchi and Kostas Karamanis, 2017; Sivesan, 2019; Caraka, Bakar, Tahmid, Yasin, and Kurniawan, 2019; Toharudin, Caraka, Darmawan, Iskandar, Somantri, Arnita, Soebagyo, Goldameir, and Asmawati, 2018). Sustainable tourism is more focused on creating and maintaining proper characteristics of systems, such as local community, than on the scale of an individual business or ensuring business survival over an extended period of time (Tretyakova, 2013).

Structural analysis is part of the study of complex systems, among which social, economic, political and environmental are a complex of various subsystems in a hierarchical representation and combine a large number of interconnected and interacting objects of various nature. At the same time, one of the most important characteristics of complex systems is its sensitivity to negative environmental influences. This problem has been little studied at present, and, therefore, is an actual area of the study (Almukhamedova, Yakimenko, and Goryainov, 2018; Yakimenko, Zhertovskaya, Pshenichnykh, Gorelova, Sukhov, and Almukhamedova, 2019). In addition, the features and laws of complex systems were purposefully studied by Golubkov (1982), Casti (1982), Klir and Elias (1990), Volkova and Denisov (1998), Evans (2012), Khokher, Ghafoor, and Siddiqui (2013). A large number of studies and works are based on their works. The works by Gorelova and Pankratova (2018a, 2018b), Gorelova, Gorelova, and Kolodenkova (2016), Gorelova, Lyabach, and Kuizheva (2017) provides a basis for analyzing the structure of the system under study, where it is necessary to identify its functionally significant elements in order to determine the conditions of structural stability.

MATERIALS AND METHODS

The Q-connectivity analysis allows for considering the connectedness of the system (Bozhenyuk and Ginis, 2013; Capitelli, 2016; Altmann, Bigdeli, Herzog, and Lu, 2016; Boissonnat and Mazauric, 2016; Seyed Fakhari, 2016; Chachólski, Scolamiero, and Vaccarino, 2017; Deo, 2018; Lubotzky, Luria, and Rosenthal, 2018; Luo and Tate, 2018) more deeply than traditional graph connectivity studies, and the presence of mutual influence of simplicial blocks of the system through a chain of connections between them (sets of vertices V and a family of nonempty subsets of these vertices - simplexes is established δ). The sets of vertices and their corresponding simplexes form simplicial complexes (Wheeler, 2017).

Therefore, for example, there are two finite sets X and Y whose elements are connected with the system Σ. These sets include many factors and indicators that affect the system. The authors apply the binary relation $\lambda \in$ X XY on the direct product X and Y to describe the relationships existing between the two elements (x,y), $x \in X$, $y \in Y$. A relationship λ exists between x_i and y_j if and only if there is a connection between x_i and y_j (Landi, Minoarivelo, Brännström, Hui, and Dieckmann, 2018). In that case, for example, $\lambda = \{(x_3, y_1), (x_1, y_2), (x_2, y_2), (x_1, y_4)\}$. It is graphically convenient to represent λ as the incidence matrix, moreover:

$$[\Lambda]_{ij} \begin{cases} \pm 1, (xi, yj) \in \lambda, \overset{them}{\Rightarrow} \\ 0 \ elsewise \end{cases}$$

$\Lambda =$

λ	y_1	y_2	y_3	y_4
x_1	0	1	0	0
x_2	0	1	0	0
x_3	1	0	0	0
x_4	0	0	0	1

From a geometric point of view, the relation λ is determined by the simplicial complex $K_x(Y;\lambda)$, where the elements of the set Y are considered as vertices and the elements of the set X are simplexes. If $K_x(Y;\lambda)$ does not contain r-simplexes, then it can be represented pointwise in the plane. It can be concluded that y_3 in the analysis of $K_x(Y;\lambda)$ does not play any role, this is a ghostly peak.

The field of definition of the sets X and Y and the relation λ can go to the relation λ generated by the conjugate relation λ^*. The latter is obtained by changing the roles of the sets X and Y, i.e. $\lambda^* \in$ YXX. The relation λ^* exists between x_i и yj and y_j if and only if there is a relation λ between x_i and y_j. It is convenient to represent graphically λ^* by the incidence matrix by transporting the incidence matrix for λ:

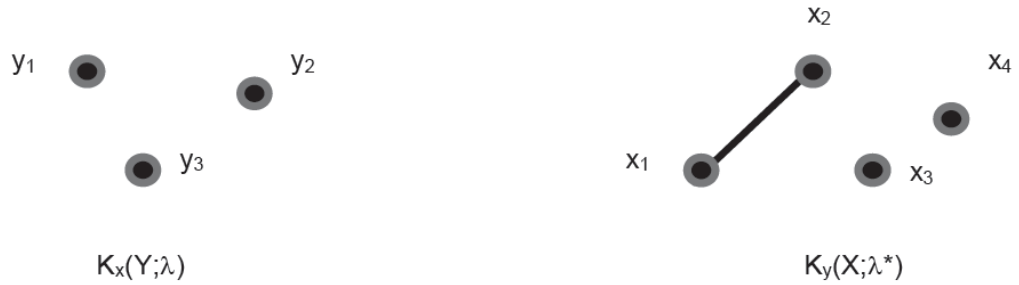

Figure 1: Geometric implementation of simplicial complexes $K_x(Y;\lambda)$ и $K_y(X;\lambda^*)$ (compiled by the author).

$$\Lambda^* = \Lambda \overset{them}{\Rightarrow} \quad \Lambda^* =$$

λ	x_1	x_2	x_3	x_4
y_1	0	0	1	0
y_2	1	1	0	0
y_3	0	0	0	0
y_4	0	0	0	1

The result is a simplicial complex $K_y(X;\lambda^*)$, in which: already X is the set of vertices, and Y is the set of simplexes. In most cases, the complex $K_y(X,\lambda^*)$ is more meaningful than $K_x(Y,\lambda)$. The topological space (geometric realization of simplicial complexes) of the complexes $K_x(Y;\lambda)$ and $K_y(X;\lambda^*)$ is shown in Figure **1**.

RESULTS

Stability is a property of a system that coincides in terms of characteristics before and after changes caused by the action of both internal and external factors (Yu and Wu, 2014; Recuero Virto, 2018; Caraka, Chen, Lee, Toharudin, Rahmadi, Tahmid, and Achmadi, 2021). Each attribute of the system can be changed quantitatively, qualitatively, relationally, quantitatively-qualitatively, quantitatively-relatively, quantitatively-qualitatively-relatively, as well as in an identical way, meaning the absence of any changes, preservation in its original state (Li, Huang, Nie, Chen, and Qin, 2013). Thus, it is necessary to analyze the regional structure to identify significant and functionally significant compounds of factors, indicators in the socio-economic system of the region (Slesarev and Yanovskiy, 2014; Liu, Liu, Yang, Chen, and Ulgiati, 2016; Yakimenko, Zhertovskaya, Pshenichnykh, and Gorelova, 2019; Gebreegziabher Asmelash and Kumar, 2019), of which tourism is a part.

The group of social indicators includes:

V1. Employment growth rate

V2. Population growth rate, including the school-age population

V3. Percentage of the population exposed to harmful air pollution

V4. Urban settlements growth rate

V5. Population living in absolute poverty

V6. Population density

V7. The literacy rate in adults

V8. Life expectancy

V9. Percentage of urban population

V10. Rise in births

V11. Gross regional product share spent on education

V12. Gross regional product share spent on health care

V13. Infrastructural expenses per capita

The group of economic indicators includes:

V14. The growth rate of gross regional product per capita

V15. Share of resource sales in gross regional product

V16. Gross regional product per capita

V17. The share of investment in gross regional product

V18. Environmental protection share of gross regional product

The group of ecological indicators includes:

V19. Water consumption per capita

V20. Population growth in coastal zones

V21. Oil discharges in the coastal zones

V22. Wood consumption for heating per capita

V23. Rate of deforestation

V24. Rate of forest restoration

V25. Wood consumption

V26. Hazardous waste volume

V27. Groundwater reserves of land affected by desertification

V28. Number of threatened and extinct species

V29. Area of land contaminated with hazardous waste

V30. Wastewater treatment

V31. The costs for ecosystem restoration

V32. Area of conservation districts of the total territory

V33. Waste collection and treatment costs

V34. Share of recycled waste

In addition to assessing systemic indicators that affect the sustainable development of the region, it is also necessary to talk about the need to assess the sustainable development of tourism in the destination region. It is necessary to consider the stability assessment of such indicators as:

V35. The competitiveness of the destination

V36. Quality level of the destination

V37. The level of tourists satisfaction

V38. Tourist expenditures, including their additional expenditures

V39. The profit from the tourism sector

V40. Employment rate in the tourism sector

V41. Employer satisfaction rate in the tourism sector

V42. Impact of the tourism sector on the regional economy

V43. Sustainability of cooperation in the tourism sector

V44. Sustainability of the tourist destination

V45. Sustainability of foreign tour operators

V46. The stability of Russian tour operators

V47. Sustainability of airlines, including budget airlines

V48. Weather stability

V49. Sustainability of hotels in different categories, including boutique hotels

V50. Sustainability of alternative types of placement

V51. Sustainability theme parks

V52. Sustainability of beaches

V53. Sustainability of golf courses

V54. Sustainability of historical sites

V55. Sustainability of museums

V56. Sustainability of health

V57. Sustainability of security

V58. Sustainability of shopping centers

V59. Sustainability of the rural environment

V60. Sustainability of government management

Indicators can be used to assess the sustainability of tourism development at a certain point in time. In general, indicators are a collection, a database of the most important data that affect sustainable development and require constant monitoring (Agyeiwaah, McKercher, and Suntikul, 2017; Szopik-Depczyńska, Cheba, Bąk, Stajniak, Alberto Simboli, and Ioppolo, 2018; Szopik-Depczyńska, Kędzierska-Szczepaniak, Szczepaniak, Cheba, Gajda, and Ioppolo, 2018). Three fundamental groups that directly or indirectly affect sustainable development, including social, economic, and environmental indicators (Zakharova, Kerashev, Prokhorova, Gorelova, and Mokrushin, 2015; Dalevska, Khobta, Kwilinski, and Kravchenko, 2019), can represent the system of indicators. It is necessary to analyze its structure to determine the conditions for its structural stability to identify significant and functionally significant compounds of indicators in the socio-economic system (Trindade, Hinnig, Moreira da Costa, Marques, Bastos, and Yigitcanlar, 2017; Torres-Delgado and Palomeque, 2018).

For these purposes, there are the apparatus of algebraic topology, group theory, system theory, and binary relations, which allows for analyzing the structure of the complex, as a multidimensional geometric formation. A topological (or polyhedral) analysis of the structure of the system under study is an analysis of its Q-connectivity, consisting in the analysis of simplicial complexes proposed by Atkin, Barcelo, Kramer, Laubenbacher, and Weaver (Gates and Rocha, 2016; Lum, Singh, Lehman, Ishkanov, Vejdemo-Johansson, Alagappan, Carlsson, and Carlsson, 2013).

The incidence matrix of the structure of some indicators with included weighting factors affecting the sustainable development of tourism in the socio-economic system of the region and requiring constant monitoring is presented in Figure **2**.

The AG incident matrix (Figure **2**) is a square one. There are units (-1,1) at the intersections if there is a relationship between elements V_i and V_j (0 otherwise). The matrix has +1 if the growth (fall) of x_i implies the growth (fall) of x_j; or it has -1 if the growth (fall) of x_i implies the growth (fall) of x_j

Since the purpose of the article is to define a systematic basis for assessing sustainability of tourism development at the regional level, it is important to define groups of indicators that affect sustainable development, rather than assess the sustainability of a particular area. Therefore, a list of indicators from the general group was chosen at random as a visual representation of the use of Q-analysis methodology.

$A_G =$

	V1	V6	V16	V23	V26	V31	V39	V40	V42	V57
V1	0	1	1	−1	−1	1	1	1	1	0
V6	1	0	1	−1	−1	0	1	0	1	1
V16	1	1	0	−1	−1	0	1	1	1	1
V23	0	1	1	0	0	1	−1	0	−1	0
V26	0	−1	−1	−1	0	1	0	0	0	0
V31	0	1	0	−1	−1	0	−1	0	1	0
V39	1	1	1	1	−1	1	0	1	1	1
V40	1	1	0	0	0	1	1	0	1	1
V42	1	0	0	−1	−1	1	1	1	0	1
V57	1	0	0	0	0	0	1	1	1	0

Figure 2: The incidence matrix.

The authors analyze q-connectivity to identify significant, functionally significant relationships between indicators.

X 1: $\sigma^{(1)}_7$; **X 6**: $\sigma^{(6)}_6$; **X 16**: $\sigma^{(16)}_7$; **X 23**: $\sigma^{(23)}_4$; **X 26**: $\sigma^{(26)}_3$; **X 31**: $\sigma^{(31)}_4$; **X 39**: $\sigma^{(39)}_8$; **X40**: $\sigma^{(40)}_8$; **X 42**: $\sigma^{(42)}_6$; **X 57**: $\sigma^{(57)}_3$.

The results of the dimension of simplexes of the indicators' complex structure:

Y 1: $\sigma^{(1)}_5$; **Y 6**: $\sigma^{(6)}_6$; **Y 16**: $\sigma^{(16)}_4$; **Y 23**: $\sigma^{(23)}_6$; **Y 26**: $\sigma^{(26)}_5$; **Y 31**: $\sigma^{(31)}_5$; **Y 39**: $\sigma^{(39)}_7$; **Y 40**: $\sigma^{(40)}_4$; **Y 42**: $\sigma^{(42)}_7$; **Y 57**: $\sigma^{(57)}_4$.

Matrix A_G is transformed to matrix ${}^{(1)}\Lambda$ (Figure **3**) by sorting the lines from top to bottom in order of decreasing the geometric dimensional value of simplex q^i.

Matrix ${}^{(1)}\Lambda$ is transformed into matrix ${}^{(2)}\Lambda$ (Figure **4**) by sorting the columns from left to right in the order of geometric dimensional decrease of simplex q^j.

The results of the converted matrix A_G в ${}^{(1)}\Lambda$, and then ${}^{(1)}\Lambda$ in ${}^{(2)}\Lambda$ are shown in Figures **3** and **4**.

${}^{(1)}\Lambda =$

	V1	V6	V16	V23	V26	V31	V39	V40	V42	V57	$q^{(i)}$
V39	1	1	1	1	1	1	0	1	1	1	8
V1	0	1	1	1	1	1	1	1	1	0	7
V16	1	1	0	1	1	0	1	1	1	1	7
V6	1	0	1	1	1	0	1	0	1	1	6
V42	1	0	0	1	1	1	1	1	0	1	6
V40	1	1	0	0	0	1	1	0	1	1	5
V23	0	1	1	0	0	1	1	0	1	0	4
V31	0	1	0	1	1	0	1	0	1	0	4
V26	0	1	1	1	0	1	0	0	0	0	3
V57	1	0	0	0	0	0	1	1	1	0	3

Figure 3: Results of matrix conversion to ${}^{(1)}\Lambda$.

${}^{(2)}\Lambda =$

	V39	V42	V6	V23	V1	V26	V31	V16	V40	V57	$q^{(i)}$
V39	0	1	1	1	1	1	1	1	1	1	8
V1	1	1	1	1	0	1	1	1	1	0	7
V16	1	1	1	1	1	1	0	0	1	1	7
V6	1	1	0	1	1	1	0	1	0	1	6
V42	1	0	0	1	1	1	1	0	1	1	6
V40	1	1	1	0	1	0	1	0	0	1	5
V23	1	1	1	0	0	0	1	1	0	0	4
V31	1	1	1	1	0	1	0	0	0	0	4
V26	0	0	1	1	0	0	1	1	0	0	3
V57	1	1	0	0	1	0	0	0	1	0	3
$q^{(j)}$	7	7	6	6	5	5	5	4	4	4	

Figure 4: Results of matrix conversion to ${}^{(2)}\Lambda$.

The simplicial complex $K_x(Y;\lambda)$={ $\sigma^{(39)}_8$; $\sigma^{(1)}_7$; $\sigma^{(16)}_7$; $\sigma^{(6)}_6$; $\sigma^{(42)}_6$; $\sigma^{(40)}_5$; $\sigma^{(23)}_4$; $\sigma^{(31)}_4$; $\sigma^{(26)}_3$; $\sigma^{(57)}_3$ } contains ten connected components. The simplicial complex $K_x(Y;\lambda)$ contains the simplex $\delta^{(39)}_8$ (profit of the tourism sector). This simplex connects nine vertices. In total, the $K_x(Y;\lambda)$ complex has 53 communication chains.

The simplicial complex $K_y(X,\lambda^*)$ = { $\sigma^{(39)}_7$; $\sigma^{(42)}_7$; $\sigma^{(6)}_6$; $\sigma^{(23)}_6$; $\sigma^{(1)}_5$; $\sigma^{(26)}_5$; $\sigma^{(31)}_5$; $\sigma^{(16)}_4$; $\sigma^{(40)}_4$; $\sigma^{(57)}_4$ }

contains ten connected components. The simplicial complex $K_y(X;\lambda)$ contains the simplex $\delta^{(39)}{}_7$ (profit of the tourism sector) and $\delta^{(42)}{}_7$ (the impact of the tourism sector on the economy of the region). Each of the simplexes connects eight vertices. In total, the $K_y(X,\lambda^*)$ complex, like $K_x(Y;\lambda)$ has 53 communication chains. Connectivity values for $K_x(Y;\lambda)$ are shown in the table below:

Table 1: Connectivity Values for $K_x(Y;\lambda)$

q=8	Q_8 =1	$\{X_{39}\}$
q=7	Q_7 =2	$\{X_1\}\{X_{16}\}$
q=6	Q_6 =5	$\{X_{39}\}\{X_1\}\{X_{16}\}\{X_6\}\{X_{42}\}$
q=5	Q_5 =6	$\{X_{39}\}\{X_1\}\{X_{16}\}\{X_6\}\{X_{42}\}\{X_{40}\}$
q=4	Q_4 =8	$\{X_{39}\}\{X_1\}\{X_{16}\}\{X_6\}\{X_{42}\}\{X_{40}\}\{X_{23}\}\{X_{31}\}$
q=3	Q_3 =10	$\{X_{39}\}\{X_1\}\{X_{16}\}\{X_6\}\{X_{42}\}\{X_{40}\}\{X_{23}\}\{X_{31}\}\{X_{26}\}\{X_{57}\}$

Note: Structural vector of the complex $K_x(Y;\lambda)$ equals to: Q_x*={ 1 2 5 6 8 10 }*.

Connectivity values for $K_y(X,\lambda)$ are shown in the table:

Table 2: Connectivity Values for $K_y(X,\lambda)$

q=7	Q_7 =2	$\{Y_{39}\}\{Y_{42}\}$
q=6	Q_6 =4	$\{Y_{39}\}\{Y_{42}\}\{Y_6\}\{Y_{23}\}$
q=5	Q_5 =7	$\{Y_{39}\}\{Y_{42}\}\{Y_6\}\{Y_{23}\}\{Y_1\}\{Y_{26}\}\{Y_{31}\}$
q=4	Q_4 =10	$\{Y_{39}\}\{Y_{42}\}\{Y_6\}\{Y_{23}\}\{Y_1\}\{Y_{26}\}\{Y_{31}\}\{Y_{16}\}\{Y_{40}\}\{Y_{57}\}$

Note: The structural vector of the complex $K_y(X,\lambda)$ equals Q_y*={ 2 7 7 10 }*.

Accordingly, q is a geometric dimensionality of simplexes in complexes $K_x(Y;\lambda)$ и $K_y(X,\lambda^*)$. The number q is less by one than the number of units "1" of each individual i-string of the matrix ${}^{(1)}\Lambda$, and each individual column j of the matrix:

$$q = q^{(i)} = \sum_{j=1}^{m} \lambda_{ij} - 1 \text{ and } q = q^{(j)} = \sum_{i=1}^{m} \lambda_{ij} - 1 .$$

Q is a structural vector of complexes $K_x(Y;\lambda)$ and $K_y(X,\lambda^*)$.

Q is set by the rule: if at least one peak of a simplex is not included in the previous simplex of greater dimension, it is a separate class. For Q_x: if at least one unit of the i line of ${}^{(1)}\Lambda$ matrix is not included in the previous lines i-1, i-2,...1 then the simplex corresponding to this line forms a separate equivalence class. For Q_y: if at least one unit of the j column of ${}^{(2)}\Lambda$ matrix is not included in the previous columns j-1, j-2,...1 then the simplex corresponding to this column forms a separate equivalence class.

DISCUSSION

The set of factors and indicators presented by the author can be roughly divided into such groups as dominants, determinants (Bornhorst, Ritchie, and Sheehan, 2010) and resistants. Attribution of factors and indicators to this or that category is artificial, as factors that at a certain point of time were determinants can become dominants, i.e. basic conditions for tourism development in the next time interval. The presented determinant, dominant and resistant factors, indicators of internal and external environment that determine the conditions for sustainable development of tourist destination are of primary importance (Yakimenko and Almukhamedova, 2019).

The dominating factors are not only the factors that have a major impact on the sustainable development of the tourist destination, but also those that largely determine the very fact of its tourist nature. For example, the lack of attractions or minimum necessary infrastructure facilities, most often, does not allow the development of tourism.

The determinants include factors that are formed first of all under the influence of changes in the consumers' needs and forms of public consciousness that form within a certain time interval the guidelines for the development of tourist destinations.

The resistants are the limiting factors that lead to a steady state of destination.

This formalization of the factors that determine sustainable development and their study is essential as, on the one hand, it becomes possible to study the territory in depth and, on the other hand, it presents a very complex process based on the analysis of a large number of factors of different levels and character often having uncertain meanings. Among other things, it allows to describe correctly the introductory guidelines for making forecasts of tourist destination development on the way to sustainable development, which in its turn will contribute to making effective managerial decisions.

It is important to note that it is not the factors and indicators acting as a system of sustainability indicators that matter most, but their threshold values, which need to be consistently clarified at certain intervals.

Thus, the study of $K_x(Y;\lambda)$ and $K_y(X,\lambda)$ showed that with respect to the vertices V or X (Y) of the "inputs" of the system (control factors), the complex is connected

only for small q values, and for large and intermediate values splits into 10 components. So, for example, at the level q = 4 for $K_x(Y;\lambda)$, there are six simplexes, each of which affects the components of the system under study, but there is an obstacle between them for effective interaction. Therefore, we can talk about a geometric obstacle to the free flow of information aimed at changing a particular situation at each level of dimension. Since the complexes break up into disconnected components, which make it difficult to transfer control actions, it is, therefore, necessary to introduce additional vertices that will serve as a connecting link between these components. This requires further study.

The totality of positive and negative combinations of the spreading of control influences on the tops (Yun, Jung, and Yang, 2015), instability to external influences allow to speak about possible variants of modeling at which, taking into account basic conditions of the investigated environment, there are scenarios of both favorable and unfavorable development of a situation.

So at the moment there are a lot of different models and scenarios of achieving the stability of destinations (Slesarev and Yanovskiy, 2014). These include sustainable development of territories, determined by development priorities in the short term based on maximization of performance indicators; sustainable development of territories, determined by the current state with minimal risks; sustainable development, implying growth of the value of material assets of tourist enterprises, aimed at economic modernization; dominance of sustainable development strategy in environmental, economic and social directions.

As an example of the processes of managing tourist destinations and identifying their impact on the sustainable development of the region, as well as its sustainable development itself, designed to select a mechanism for managing the sustainable development of these systems, we can cite the simplest development scenarios, based on a simulation experiment (Morales-Matamoros, Tejeida-Padilla, and Badillo-Pina, 2010; Gorelova, 2011; Kalmar-Nagy and Stanciulescu, 2014; Gorelova and Pankratova, 2018a, 2018b).

The plan of the model experiment based on the structural vector of the complex $K_y(X, \lambda)$ is presented in the table below.

Since it is important to see the results of the experiment in the form of node behavior as a result of perturbation, absolutely all nodes of the obtained $K_y(X, \lambda)$ complex were involved in the scenarios. Thus, in order to obtain information, perturbations (control actions) were set at the moment t, i.e. there was a growth of target factors (pulse +1) or a fall of target factors (pulse -1). Then, the propagation of this perturbation at time t+1 will lead to the results shown below, which allow us to conclude about the relationship between the factors (rise or fall). This is what is needed to assess sustainability. In general, the scenarios show general trends of situation development taking into account modeling of control actions.

The basic results of the impulse modeling are given below.

With an impulse at the top point V39 that increases the profit of tourist sector, positive dynamics of influence of sphere of tourism on economy of region is evident already after the first cycle, while after the second cycle there is a growth of a level of employment in tourism and growth of a total regional product per capita, as well as the stability of safety of tourist destinations. After the fourth cycle, there is a particularly rapid growth of these indicators.

With an impulse at the top point V42 that increases the impact of tourism on the economy of the region, the profit of the tourism sector, population density, employment growth rate increases. At the same time, the rate of deforestation drops already on the second cycle, and, starting from the fourth cycle, the drop is greater.

As results of the simulation experiment show, when managing factors V39 (profit of tourist sector) and V42

Table 3: The Basic Results of the Impulse Modeling

Scenario	Impulse	V_{39}	V_{42}	V_6	V_{23}	V_1	V_{26}	V_{31}	V_{16}	V_{40}	V_{57}
№1	q_{V39}	+1	?						?	?	?
№2	q_{V42}	?	+1	?	?	?					
№3	q_{V26}				?		-1	?	?		

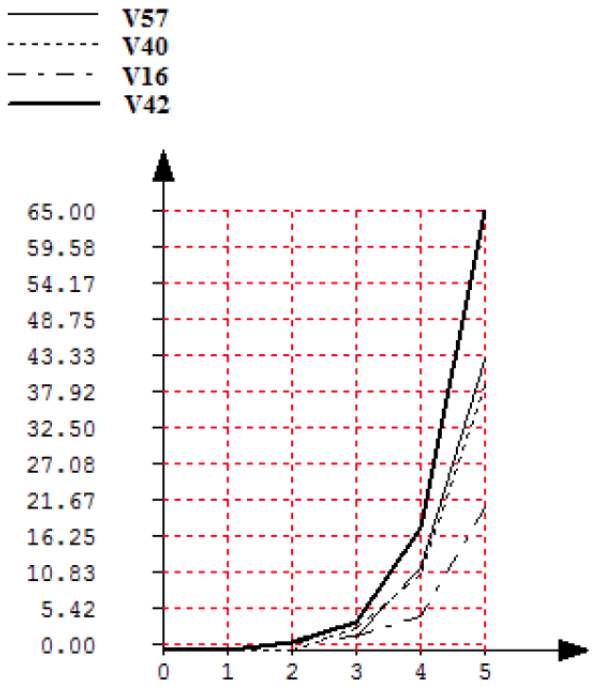

Figure 5: Destination development scenario, if tourism sector profit starts to boost q_{V39}=+1 (compiled by the author).

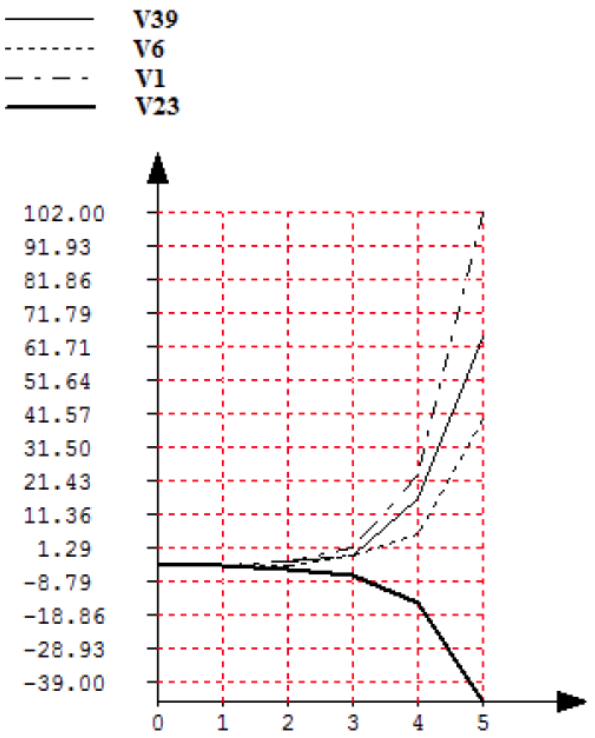

Figure 6: Destination scenario, if tourism's impact on the region's economy starts to increase q_{V42}=+1 (compiled by the author).

(influence of sphere of tourism on economy of region) are affected, the positive impulse triggers both growth of employment in sphere of tourism, and growth of employment in adjacent branches, encouraging an increase in density of the population, as well as the stability of safety of tourist destinations, including the drop in rates of deforestation. This confirms the fact that it is appropriate to manage the region as a whole or tourist destinations through factors V39 and V42.

Provided that factor V26 has a negative management impact, the subsequent reaction of factors such as the rate of deforestation, the cost of restoring ecosystems and the gross regional product per capita can be observed.

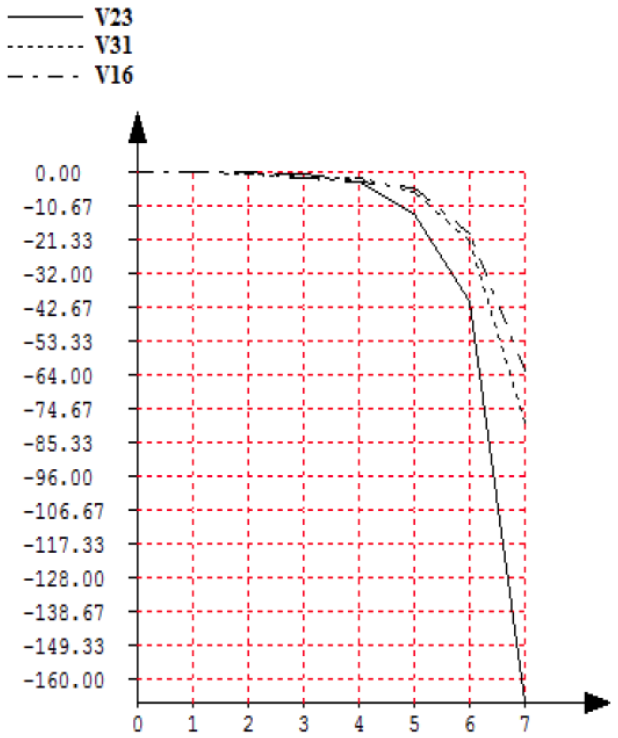

Figure 7: Destination scenario, if hazardous waste volumes begin to increase q_{V26}=-1 (compiled by the author).

It is important to note that each individual region needs its own system of indicators to assess the state of the region and its sustainable development, as well as the most sustainable development of the tourism sector, which will take into account the specifics of the available resources (history, geography, culture, life, traditions, etc.) (Abramova, Ageeva, Shapoval, Lysenko, and Samofalova, 2018).

Thus, in order to assess the sustainable development of tourism in the destination or region, it is necessary to use a system of factors and indicators applicable to the conditions of a particular territory, which do not exist by themselves, but are a tool for achieving sustainable tourism development goals.

CONCLUSION

The study considered a systematic basis for assessing the sustainable development of tourism at the regional level based on the simplicial complexes analysis method. The authors analyzed the q-connectivity for the structure of indicators, affecting the sustainable development of tourism in the socio-economic system of the region and requiring constant monitoring. It was found that the components of the analyzed symptomatic complexes are substantial and, therefore, bind many nodes. This allows us to conclude that within the framework of the factors taken for consideration, the most substantial are such simplexes as the profit of the tourist sector and the impact of tourism on the economy of the region. That is, they can be chosen as control ones for the region's taking the path of sustainable development, as evidenced by the fragments of the scenario analysis. The possibility to consider other significant and functionally significant compounds of factors from the above list allows the author to continue the research.

LIMITATIONS AND STUDY FORWARD

The results of this study should be considered in light of some limitations. When constructing the incident matrix of the structure of indicators affecting the sustainable development of tourism in the socio-economic system of the region, the weight coefficients were determined using expert methods. The main purpose was to determine the impact (positive, negative or lack thereof) of certain factors on each other. It is necessary to take into account that the interrelation of the considered factors (top points) was not connected with a certain tourist destination.

Presentation of a systematic basis for evaluation of sustainable tourism development at the destination level on the basis of the method of symptomatic complexes analysis in current materials can be considered in future studies. A question for further research is the inclusion of cognitive modeling. This could be the subject of further research. It is important that further research be focused on the analysis of the stability of cognitive model cycles in the studied structure, on the example of a specific territory, where pathways and cycles will be highlighted by software.

This paper has systematized existing studies on sustainable development of territories, including sustainable tourism. Factors and indicators influencing the sustainable development of tourism were formalized. With the help of polyhedral analysis the Q-connectivity of the factors of dominants, determinants and resistants was analyzed that allowed to determine the control ones, including their coherence. The author developed simulation models showing the result of the distribution system behavior from positive and negative behavior of sustainable development indicators.

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