

Geoecological Approaches to the Recreational Development of Avalanche Mountain Territories

Elena V. Kyul

Federal scientific center "Kabardin-Balkar scientific center of the Russian Academy of Sciences",
center of geographical research, Nalchik, Russian Federation;
Email: elenakyul@mail.ru

ABSTRACT

The article describes the principles of building a "simulation model" of mountain avalanche recreational region on the example of the Central Caucasus: the Northern slope, the ski resort "Prielbrusye", Russia. Its construction is based on the geo-ecological approach, i.e. assessment of not only geographical but also ecological component of the natural environment. The model is done based on the principles developed by the International Institute of applied systems analysis. The model has a block structure-4 blocks: 1) demand for recreational facilities, 2) population growth and economic development, 3) changes in the environment and the national economy; 4) control over the development and use of the territory. Moreover, in the first block the demand is limited by the presence of particularly protected natural areas (National Park "Prielbrusye"), and in 2-nd and 4-nd – by activation of avalanche activity. In General, the main limiting factors are ecological problems, arising from the development of high vulnerability and low resistance to anthropogenic impact of mountain areas. To maintain the positive trends in the development of this mountain region, it is necessary to solve a number of socio-economic and environmental problems. We have considered two of them, the most relevant for the region: alternative energy and anti-avalanche measures.

Keywords: Geosystem, territorial system of mountain type, avalanche system, avalanche activity, recreational object, recreational resources, simulation model, thermal station, semi-automatic module.

Journal of Economic Literature (JEL) Classification: Q01, Q26, Q42, Q5

1. INTRODUCTION

In the comparative analysis of the development of natural resources of mountain areas, held in the framework of international geographical field symposia [1-2], it was found that due to the peculiarities of the natural environment and the peculiar nature of the settlement, a unique socio-economic territorial system of the mountain type is formed here: in the study of the processes of development of the mountain territory, legally arising regional differences in the nature of the use of the territory and different levels of its development, directly subordinated to the law of vertical differentiation of the natural environment are revealed. The object of research-the Central Caucasus (Northern slope) - faces problems typical for many mountain avalanche-prone areas of the modern world. Since about

the 1970s, this region and, in particular, the ski resort of international importance "Elbrus" began to experience a period of economic recovery caused by the apparently unlimited possibilities the development of tourism. This economic recovery, most sharply manifested in the construction of recreational facilities (hotels, boarding houses, camp sites, Alpine camps, etc.) began to have a significant impact on the fragile mountain geosystem and should soon be limited due to the lack of free territories suitable for the construction. Since such facilities are most convenient for building in the valley, this fertile area has lost the role of agricultural land, and with it the main economic value for local residents. The pace of the development of recreational infrastructure should also be limited by the rate of growth of the local population, as it determines the labor resources. Thus, here we see the most important problem of global significance — the problem of the ratio of demographic and economic growth with the reduction of resources.

One of the main regulatory components in this system, as it turned out as a result of the analysis of scientific literature, is the "avalanche system", consisting of an avalanche territory and avalanches actually descending there [3]. It is the avalanche activity, the intensity of which depends on the scale and pace of economic construction, that is the main regulator in the development and development of mountain avalanche-recreational areas. For the avalanche-safe development of such a territory, it is also necessary to solve a number of problems: socio-economic, environmental and legal.

So, the aim of the research is to develop new geocological approaches to the development of avalanche recreational areas, i.e. the creation of the so-called "simulation model" of the development of mountain avalanche region [4]. The development of such a model will be of great practical importance, as it will reduce the impact of snow avalanches on the mountain area to a minimum and , as a result, it will make this area potentially safe.

2. METHODS AND MATERIALS OF RESEARCH

The region chosen by us for the development of the model – Prielbrusye -was subjected to intensive study during the period of research of dangerous natural processes: both the features of the natural structure of the territory and the human impact on the ecosystem were studied [5,6]. We are faced with the task of creating a preliminary dynamic model that describes not only the human impact on the geosystem, but also the development of recreational resources.

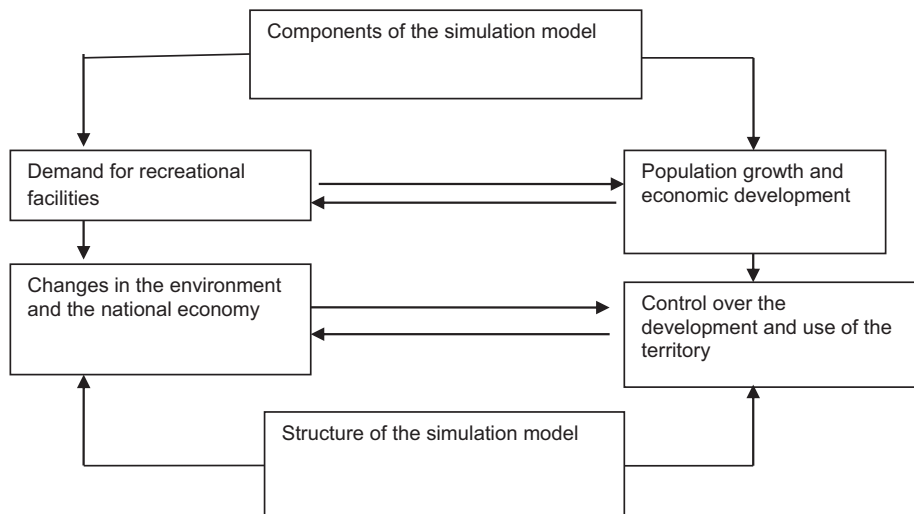
Principles of the creation of imitating models of development of mountain avalanche and recreation system. In our modeling work, we set the following tasks: a) on the base of the information needs of the model to determine the main directions of the research; b) to make alternative long-term forecasts for the residents of the district (for the next 20-30 years) about the possible consequences of using those development strategies that they considered to be practically applicable.

The model will be implemented according to the methodology developed by the International Institute of applied systems analysis [4]. Components of the model: assumptions, their confirmation and

priorities of future options: 1) the most possible of the natural limiting factors are: the widespread development of avalanche activity and, as a result, the limited availability of free land suitable for development, in particular for the construction of recreational facilities, the necessity to invest funds to combat avalanches; 2) population growth in conjunction with restrictions on the development of the region will cause unemployment with its attendant social problems; 3) measures to limit and regulate the growth of the mountain recreational area should be under territorial and financial control.

Based on these assumptions, components and internal connections of the model are identified as a set of minima required for a reliable forecast for the next 30-40 years. They consist of 4 blocks: demand for recreational facilities, population growth and economic development, changes in the environment and national economy; control over the development and use of the territory.

These four blocks are combined into a single structure, shown in Figure 1.



Figur.1.Block structure of "simulation model"

3.RESEARCH RESULTS AND DISCUSSION

Let's consider the results of the development of "simulation model" for the selected region. Prielbrusye is the oldest ski resort in Russia and in the world. Geomorphologically, it is located within the Main Caucasian and Lateral ridges (with the top of Elbrus). Hydrographically, it is in the upper reaches of the Baksan river. In of defending of nature terms, this area is located within the National Park "Prielbrusye". In socio-economic terms, Prielbrusye is part of the Kabardin - Balkar Republic (North Caucasus Federal District of the Russian Federation) (Fig.2) [1].



Figur.2.Location of avalanche-prone recreational system "Prielbrusye»

Let's consider each block of the "simulation model" (see Fig.1) in detail.

3.1. Block 1.Prediction of demand for recreational facilities

The demand for recreational facilities depends on three main factors: the General state of the economy outside the area, the ability of the area to receive tourists (usually determined by the number of beds, but also by the restrictive lack of other services — water, electricity, etc.), the recreational features of the area, which in summer are estimated by the degree of diversity of landscapes, in winter — by safety and time of lifting on the cable car. Little is known about the potential demand for recreational facilities. Since late 80 the rate of settlement of recreational facilities in Russia has fallen sharply, especially in 1991-1995. This was due to the General crisis in the country .Currently, the demand, especially for winter tourism and recreation, is growing; taking into consideration the growing popularity of ski sports and the lack of other such ski resorts in the country, the potential demand in the winter can be considered unlimited. On the other hand, the average level of population of recreational facilities in the summer has fallen, which can be directly related to changes in environmental quality in the last few years.

These observations and assumptions form the basis of our *submodel of potential demand*. Tourist demand in winter is considered as a function of waiting time on the cable car, calculated by the number of tourists in the winter and available cable cars. Over the last 5 years, 2 stages of the gondola cable car to mount of Elbrus, more than 20 km of ski slopes have been put into operation. Tourist demand in the summer is considered as a function of the indicator of diversity of the natural

environment, calculated by the size of undeveloped and untouched by erosion area. In the first case, it will be regulated by the number of cable cars, in the second one – by the number of natural, not changed by humans landscapes. The real demand, calculated taking into account the potential demand and the quality of the environment, the existing recreational and economic infrastructure (availability of free places, electricity, water, gas, etc.), and the development of infrastructure, in turn, is limited by the availability of suitable territory safe for the development. Nowadays, on the one hand, the area of territories safe for development increases (the complex of anti-avalanche constructions was introduced entered), on the other hand, the area of natural landscapes is sharply decreasing.

3.2. Block 2. Population growth and economic development

The economic growth of the district is based on the growth of its population. In the construction of the model, population growth will be a function of fertility, mortality, migration of the population of four age groups (0-15, 15-30, 30-60 and more than 60 years). Economic development is considered from the point of view of the construction of recreational facilities and from the point of view of four types of employment (tourist services, agricultural production, construction, services). A model of population dynamics which will be applied by us is quite simple: the change in population is taken into account by annual monitoring of fertility, mortality and migration – thus the qualitative composition of the age groups is determined. The most important variable for the development of the economy in our *submodel* will be the intensity of construction of recreational facilities; this intensity, in turn, depends on the number of able to work population, financial investments and the cost of objects that are a function of the size of the territory suitable for use; this also includes the profitability from the of existing recreational facilities. Currently, the increase in fertility in the region exceeds the mortality rate. Life period has also increased: women to 85, men to 75, on average. The level of migration is also high. During the tourist season, the population of Prielbrusie increases several times. The pace of construction of new recreational facilities is also very high. So, in this case, the limiting factor affecting the development of the economy and population growth is the size of the territory suitable for development.

3.3. Block 3. Changes in the environment and the national economy

The *ecological submodel* will consider three groups of phenomena: topography disturbance; the state of the biological component (populations of wild and domestic animals, food they need, vegetation, in particular forest); changes in land use caused by erosion and other factors.

In the biotic part, the submodels should take into account the main types of domestic animals (the original number of cows, sheep, horses) and those species of wild animals that can be the object of sports hunting and rare endemic species protected by law and increasing the attractiveness of the landscape for tourists (chamois, tour, birds of prey, etc.). In the process of simulation of population dynamics, it is necessary to establish the dependence of their number on the habitat conditions (state of vegetation) and to determine how the size of populations changes. Domestic animals are also very important to the tourism industry for two reasons: providing food and giving the landscape a

picturesque view. The submodel should take into account not only the number of herds, but also the warrant feeding stuff (summer pastures and hayfields), in which vegetation plays an important role. Vegetation in the mountains, in addition to aesthetic, also plays a protective role, limiting and preventing erosion and, as a result, such dangerous processes as landslides, scree, mudflows, avalanches. So, the submodel should simulate the composition and condition of the vegetation and obligatorily to take into account its impact on the land subjected to erosion. To do this, the model introduces a variable that determines the restoration (regeneration) of vegetation, which will allow to include this area in the category suitable for development. Unfortunately, all these groups have a negative trend in their development: on the background of increasing land with disturbed terrain there is the activation of dangerous processes. This, in turn, leads to a reduction in wildlife habitats. Also, the number of hayfields and pastures is reduced: primary vegetation is replaced by "secondary"(ruderal).

The most important biome of the ecological submodel is the change of land-use, i.e. the transfer of land from one category of use to another due to erosion processes. Areas affected by erosion are affected by cattle breeding (sheep grazing) and tourism (trampling). The development of erosion leads to the emergence of dangerous processes, including avalanches. In the ecological submodel in the erosion biome, an erosion coefficient equal to the ratio of the eroded area to the whole area is calculated. Elimination of erosion processes, including its avalanche component, can be demonstrated by introducing parameters that control the restoration of erosion lands (reclamation).The amount of land affected by erosion is also growing here.

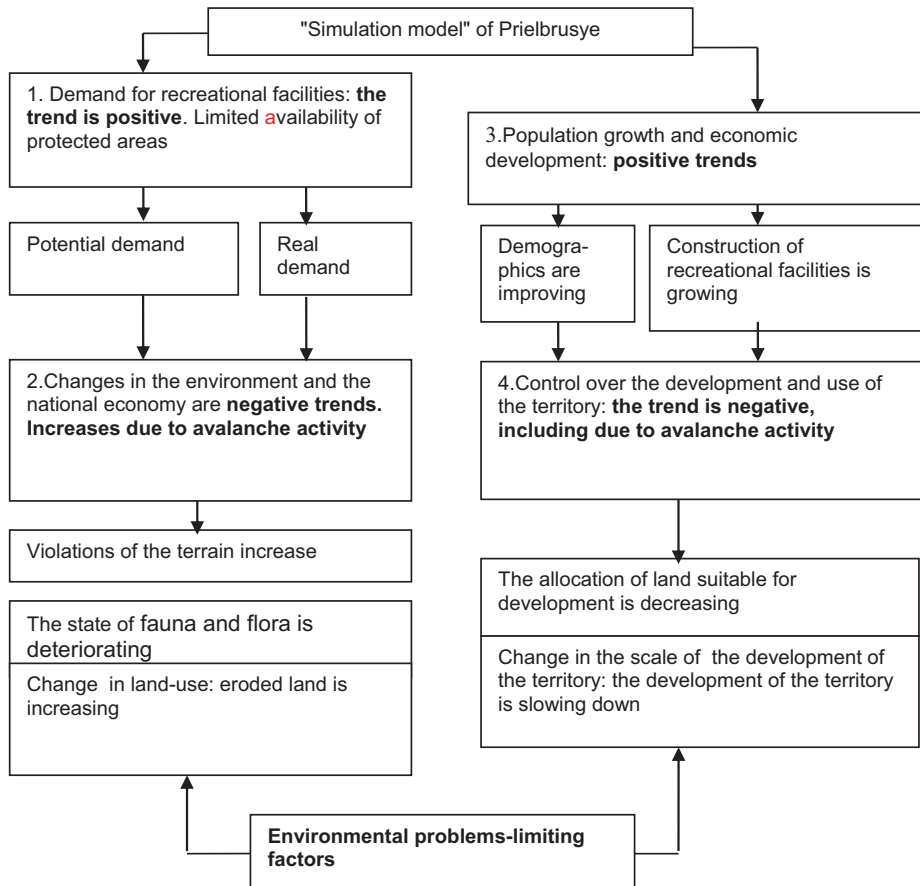
Despite the rather simplistic nature of the ecological submodel, it can identify some of the main areas of further research: (1)the processes of vegetation restoration and the main obstacles to it; in our case, it is the intensification of avalanche processes; (2)the perception of the environment how tourists take it and respond to its changes; (3) the processes that cause erosion and lead to rapid overcoming of its consequences; (4) a consistent picture of the evolution of the territory occupied by erosion lands.

These four directionse are of priority not only in terms of the environment, but also in terms of planning the development of the local economy.

3.4. Block 4. Control of the development of the territory

In this block of model there must be determined alternative schemes of the management of growth of the area . To do this, it is necessary to identify the variables available for control in the submodels described above. We distinguish the following classes of controlling actions: 1) the allocation of the territory suitable for the development ; 2) the change in the scale of development of the territory; 3) the provision of tourists, in addition to housing, by other related services. Control of the first two classes of actions in the model can be achieved sufficiently by regulating financial resources. The composition of basic services and leisure facilities should be determined, first of all, by demand.

Figure 3 shows a simulation model of Prielbrusye.



Figur.3.Full structure of the "simulation model" of Prielbrusye

The functioning of the model revealed the links between the submodels, first of all between environmental and socio-economic, ones all. It turned out that the limiting factors are unsolved environmental problems (3rd geoecological and 4th environmental blocks). In order to get a balanced picture of the complete system, it will be necessary to work more deeply on the ecological side and related issues.

Let us outline the range of particular problems that should be solved not in terms of the use of the resources, but in the environmental:

1. Block of economic problems: mountain mining, transport, energy, forestry, animal husbandry.
2. Block of social problems: historical and ethnographic.

3. Block of environmental problems: the fight against dangerous processes and protection against them.

Energy problem. Mountainous areas have large potential reserves of hydropower resources. The Central Caucasus is not an exception, and with their high quality, only 22 % of economically possible hydropower resources are used. On the territory the total capacity of hydroelectric power barely exceeds 35 m W. According to experts, this problem can be solved by the introduction of small (up to 10 m W) and micro hydropower (up to 1 m W), which will solve the problem of providing dispersed consumers with the use of "short networks", which is most convenient for the recreational type of the development of the territory [7,8]. As follows from the project "Scheme of placement of perspective hydroelectric stations in Kabardin-Balkar Republic ", developed a few years ago by S.I. Zhula design and survey and research Association "Hydroproject". There can be built in Kabardino - Balkaria in the next 15-20 years a hydroelectric station with a total capacity of 600 to 900 m W, in reality, taking into account the serious comments and limitations of hydropower and environmentalists of the Republic, which we consider quite justified, it is possible to build a hydroelectric station with a total capacity of not more than 250-300 m W, which will significantly improve the energy supply of the Republic [8].But here the aspect of ecological and economic planning becomes important, that is, taking into account, along with other factors, the territorial capacity of hydroelectric power (which does not play a significant role on the plain), as well as estimates of the industrial load on the natural ecosystem. It should be borne in mind that the area of land suitable for the construction of hydroelectric power plants is extremely limited, mainly by the wide spread of dangerous processes, in particular avalanches. This raises the question of the use of environmentally "clean" non-traditional forms of energy, such as hydrothermal. This is one of the possible rational approaches to the use of energy geothermal sources that can give a great economic and environmental effect.

One of the well - known geothermal regions of Russia is a significant part of the North Caucasus. In particular, in the area of Elbrus uplift there is a large underground pool of hot water. In Kabardino-Balkaria explored total reserves of underground thermal waters are 27 thousand m³ per day at a temperature of 70-75°C. Not too high temperature of these sources is connected with insufficient depth of available wells. Their depth usually does not exceed 1.5-2.0 km. However, wells with the depth of 3.5-4.0 km in the hydrothermal areas of the Kabardin-Balkar Republic can give gas-vapor mixture with a temperature of 120-140°C . Such thermal waters can be used in production both directly and after conversion of low-potential energy into high-temperature heat that is necessary for conducting technological processes requiring high temperature [7].

According to our estimates, to supply energy to an average enterprise, for example, for the production of building materials, it is necessary to select from rocks a thermal power equal to 100-150 m W. In the case of construction of a geothermal power plant with a capacity of 50 m W , the thermal power of the sources will need about 500 M W, since only 10-12 % of the thermal energy of the geothermal field can be converted into electricity. The forthcoming industrial development of geothermal deposits

raises the question-whether the work of a powerful geothermal station will cause an increase in seismic activity in the area of the station's location? For us, this issue is particularly relevant due to the fact that in the areas of geothermal deposits there are often located recreational facilities that are of economic importance for the region. Even a small increase in seismic activity can activate unwanted slope processes: landslides, mudflows, etc.

Our estimates show that the operation of a fairly large geothermal station with a thermal capacity of 500 m W, which produces the removal of thermal energy from the rock mass with an area of about 5 km² and a thickness of 100 m, located at a depth of 3-4 km, will not lead to any noticeable change in the temperature of this rock mass. This is due to the fact that the flow of heat from the depths of the Earth to its surface in areas of geothermal deposits is abnormally high and reaches a capacity of 100-120 m W/m². Therefore, at the specified volume of the used rock mass, its temperature in the area of the located station during the first year of exploration may decrease by no more than 3-40 C, after which the stationary temperature regime of work of the field will come.

In General, it is important to note that during the first year of exploration of the station, all its thermal power can be provided only due to the huge heat content of the rock mass without additional heat inflow from the underlying rocks. In this case, the temperature of rocks during the year will decrease by no more than a few degrees. The reason for not being afraid of a relatively small violation of the thermal equilibrium of rocks is that when the temperature drops by a few degrees, the thermal deformation of the mass will be relatively small. This is connected with the fact that due to the characteristic for sedimentary rocks poor connectivity and, accordingly, low strength, especially at break and shear, they are not prone to large accumulation of elastic energy in the rock mass, the discharge of which could lead to a noticeable seismic shock due as a result of elastic recoil. A more significant and less unambiguous reason that can affect the seismic situation in the area of the geothermal station is that the change in the degree of flooding of rocks affects their behavior in conditions of high compressive or shear stresses. When regional tectonic stresses reach the ultimate rock strength, the finest cracks begin to form and the rocks experience dilatancy (volume change). In this state, they can withstand higher stresses, but as the fluid flows to the dilatancy site, the strength of the rocks falls. Since the deformations at this point may exceed the normal value, the loss of strength leads to the destruction of the rock.

Prediction of seismic events is the most difficult section of seismology. Let's refer to the world experience. As you know, New Zealand, like some other countries (Iceland, Italy, etc.) widely uses geothermal energy. In areas where there are active or extinct volcanoes, such as separate regions of Japan or the North island in New Zealand, there are often series of earthquakes. They represent sequences of weak or moderate seismic shocks. In New Zealand, geothermal power plants now produce up to 50% of all energy consumed in the country. At one of these New Zealand stations in Wairaki seismographs record about 5 tremors per month, but during the peak period of the series of earthquakes their number increases to 900 per day. Local observers tend to blame the exploration of

the geothermal field for the occurrence of earthquakes, but the geothermal power plant workers did not note significant changes either in qualitative or quantitative characteristics of steam, which could indicate the contribution of geothermal To the activation of tectonic processes .

Thus, taking into account the analysis of the seismic situation in the area of geothermal water deposits and orographic features of the surrounding area for the development of dangerous processes (avalanches, mudflows, landslides, etc.), we can consider the construction of geothermal stations. The commissioning of only one such station will fully provide electricity to the entire territory of Kabardino-Balkaria and save the most scarce land resources in mountainous conditions.

Avalanche control. The most reliable method for the development of avalanche territory is the placement of national economic objects outside the avalanche areas, but in reality this condition, especially for communication facilities (roads, power lines and gas pipelines), is almost impossible to observe. In this case, effective measures may be the regulation of the operation mode of avalanche-prone objects with the help of artificial (preventive avalanche descent), which will be carried out by a specially created predictive and preventive service [3,9].The choice of such means of struggling against avalanches for the territorial and recreational system is justified for many reasons. To protect transport communications and recreational areas that may be here, it is necessary to work off a great number of snow-avalanche centers for a limited time. The solution of such a problem with the help of already appropriated methods of preventive avalanche descent with the use of artillery systems depends on the availability of mobile forces and means of the mining service, which, as a rule, are not too large.

The estimation of existing methods of preventive avalanche descent and the analysis of new methods studied in the course of exploratory research shows that the methods of avalanche collapse with the help of art systems remain the most effective and irreplaceable for the working up of hard-to-reach slopes [3]. However, everywhere, the where conditions allow, in the future it is possible to use various semi-automatic radio command modules installed above avalanche centers for a long time.

Let's formulate the basic requirements for such modules, taking into account the warriant provision of their multiple operation during the season on the radio commands of the operators:

1. The modules should allow to be transported to the mountainous area during the snowless period on several human packs, as well as in the fuselage of the helicopter or on its external suspension. The design of the module should be vandal-resistant. This is especially true for modules installed on accessible slopes.

2. The operation of modules is based: a) on the basis of the issuance of metered charges of fuel-air mixture and exploding them in the specified region of the avalanche center, with the delivery of the fuel-air charge to a distance of 50-300 m from the module to the place of the explosion is deserted by different ways in a single inflatable or folding casings with capacities from 3 to 10 m³ made of a thin rubber or polymer film, and the use of folding shells of corrugated Kraft paper with a

capacity up to 3 m³; b) on the basis of self-rotating under pressure fuel-air mixture of polyethylene or paper sleeves with a diameter of 0.2-0.5 m and a length of 10 to 50 m, undermined by built-in igniters in each sleeve. Rolled sleeves are in clips, 20-50 m away from the module. They are connected to the fan gas network module with built-in check valves.

3. As an energy carrier, it is supposed to use liquefied gas, the stock of which for the work is stored in replaceable cylinders of the module. The use of hydrogen and other energy carriers is also possible.

4. It is a chance to develop a nonvolatile long-term module that produces hydrogen by electrolysis from molten snow. Hydrogen is pumped by a microcompressor into the cylinder for subsequent preparation of charges of the fuel-air mixture. As an energy source for the electrolysis of water, a small wind generator with a capacity of 0.5-1 k W is used, that is installed at the top of the module. It should be borne in mind that the progress of microelectronics over the last 10-15 years allows at an affordable price to solve the problem of automation of the module and guaranteed receipt of radio commands from the operator.

4. CONCLUSIONS

Thus, from the analysis of the simulation model "Prielbrusye" it is possible to give the main forecasts for the development of the study area. Although the development of models takes into account many indicators and converse mechanisms, as it turned out, its main forecasts depend on several main links:

1. On the background of potential demand, the growth of the repose industry will be limited by the growth of the local population.
2. The area suitable for use, with the development of tourism will be rapidly reduced.
3. With the economic development of the territory will change the nature of land use and reduce the quality of the environment, including through the intensification of avalanches will change.
4. The reduction of resources and demand against the background of population growth and economic development can lead to a socio-economic crisis in the mountain recreational area.

The creation of such a model can serve as a basis for stabilizing the development of a mountain avalanche-prone recreational area, taking into account the correctly chosen environmental strategy. We propose a further strategy for the development and development of mining and recreational activities, based on the solution of the main problem — the problem of security of the territory. At the moment, in Prielbrusye there has been built a complex of avalanche structures in the Azau Meadow, which has greatly increased the avalanche safety of the territory. But at the same time the recreational complex "Cheget" remains without protection. Uncontrolled construction of recreational facilities has led to a sharp reduction in the area of forest landscapes. Then, due to the increase in the number of recreants, the condition of meadow vegetation, including land allocated for hayfields and pastures, has deteriorated sharply. To solve the problem of safety, a new "geo-ecological" approach

to the development of the territory, where the degree of impact on the environment will be minimal is necessary.

5. REFERENCES

Weir, P., Deadma, J., Bravar, I., and Gerasimov, I. P etc., 1980, The Alps- the Caucasus. Modern problems of constructive geography of mountain countries. The scientific results of the Franco-Soviet field symposia in 1974 and 1976. Moscow: Nauka, 325 . (in Russian)

Gerasimov, I. P., Lilienberg, D. A., Galibov, J. etc., 1984, The Greater Caucasus - the Stara Planina (Balkan) - The Greater Caucasus - the Stara-Planina (the Balkans): Comparative-geological analysis of natural resource potential and its role in the development and location of the economy and population in mountain countries. M.: Science, 123. (in Russian)

Kyul, E. V. 2012, Principles of geo-ecological mapping and zoning of avalanche activity. Nalchik. 227. (in Russian)

Holling, C. S. etc., 1978, Adaptive environmental assessment and management .A Wiley – Interscience Publication International Institute for Applied Systems Analysis . Chichester – New York – Brisbane – Toronto.

Razumov, V.V., Perekrest, V.V., Streshneva, N.P., Kyul, E.V. etc., 2001, Cadastre of avalanche-mudflow hazard Kabardin-Balkar Republic. SPb.: Hydrometeoizdat, 54 . (in Russian)

Ivanov, P. M., 1996, Regionalization of management and sustainable development. Nalchik. (in Russian)

Kyul, E. V., 1997, The use of geothermal deposits in the North Caucasus and seismic activity. *Scientific thought of Caucasus*, 4, 49-50. (in Russian)

Calov, R. O., 2016 The issue of unrealized hydropower potential of mountain-valley landscapes of KBR. *News Kabardin-Balkar scientific center of RAS*, 6 (74), 109-113. (in Russian)

Florian, R.-M., Sauermoser, S., Mears, A., 2014, The Technical Avalanche Protection Handbook. Wiley, 420 .