Control of Natural Management on Marine Coasts by Simulation Modeling

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***Abstract*—**Control of natural management is a complex process where major things depend on adoption of a correct administrative decision. Subjectivity in certain regional development strategy may be eliminated by informational simulation models. The study represents the calculations of the relative tax value allowing natural management with unexhausted resources in the coastal zones and stable social and economic development of the coastal areas. All calculations are made by "CoMPAS" imitative software allowing calculations of a number of indices characterizing level and quality of life of the population within the coastal areas. This software allows simulating effects after investments into the extracting and recycling branches of economy, the recreational-and-tourist system, and nature protection measures as well. Specificity of marine coasts causes its own corrective amendments in the calculations of strategies. We consider specificity of choice among strategies of development in the contact zone of global level, such as marine coasts in the Far East of Russia.

***Keywords*—**Stable natural management, simulation model, development strategies of a region, environmental quality index, index of human development, budget value of the territory, quantity of marine biological resources.

I. Introduction

THE concept of stable development required the mechanism for its implementation, i.e. stable natural management. Problems of stable development are considered well enough in numerous studies [1] - [4]. Stable natural management should base on renewable natural resources and up-to-date information technologies [5]. Key aspects of the problem are as follows: application of certain models of natural management, and system of investments and taxation. Application of modeling in order to provide stable natural management was considered in studies of researchers all over the world [6] - [9]. There are some examples of the applied simulation models [10]. Specificity of our approach is in the nature-centered model of natural management (ensuring safety of biological diversity) and adoption of scientifically reasonable green administrative decisions on stable natural management in the region (based on biologically informational analysis). The nature-centered model makes the nature protection system a priority. Its purpose is to protect and restore the biodiversity presenting a paramount economic interest (a gene pool and protection of the resources from all sorts of violations of the legislation, such as poachers and consumers of natural resources with the legal licenses infringing the rules of lumbering and/or development of the earth interior) as the basis for stable prosperity. On the second place is creation of bumper zones and recreational systems (recreational natural management in order to separate nature protection systems from the regions with intensive natural management and to decrease anthropogenic pressure). In our opinion, the resource and branch natural management accepted in ordinary schemes of managing should take place at the very end of the schemes of natural management [5].

In the concept of stable natural management offered by us high-scientific ecophilous and information technologies will be claimed for registration and protection of biodiversity and bioresources. Hence, now ecological and biogeographical knowledge will be claimed by the consumers of natural resources, i.e. by those who were earlier prevented by such knowledge from developing natural resources.

As real behavior and rates of evolution of ecumene and human society strongly differ from each other, actually it is a question of radical change of human behavior in relation to nature, subordination of society to the ecological imperative. Territories with the intensive natural management should be placed within the landscapes most resistant to physical destruction. Territories of river basins with rather resistant visual environments may be used as zones for selective-local development, which mission includes compensation of "ecological inferiority" of the first zone, i.e. it should be recreational. But the basis of the bases is the nature protection system.

In the contact zone of the global level (on marine coasts of the Far East) a main obstacle for stable natural management is anthropogenic pollution of the environment. As a consequence, the biological variety decreases and the agricultural lands degrade [5], [11]. However, the degree of anthropogenic pressure on the environment may be controlled.

In order to define possibilities of stable development, it is necessary to accept a number of the assumptions, allowing regulating economic, ecological and social-and-economic development of the territories. In the study, they are as follows: a business factor of management of a degree of

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anthropogenic pressure on the environment; a measure of stability of social-and-economic development; and a degree of the environmental degradation.

II. Methods

The tax for the businessmen polluting the natural environment was offered by A. Pigou [12] and named in his honor. It is accepted in the study as a business factor of control of the extent of anthropogenic pressure on the environment. Calculations of its relative value allow supplying of inexhaustible natural management in the coastal areas and stable social and economic development of the coastal territories.

The index of human development [1] is accepted in the study as a measure of stable social-and-economic development of the territory. It is calculated from the base indicators characterizing one of directions of human development each.

The concept of human development [13] shows that the society development cannot be considered only as the increasing material benefits and services. That is the criterion for an assessment of the territory development may not include economic indices only. The given concept defines a central place for the human both in social and public life, and in creation of reproductive chains.

At any stage of the human development three groups of possibilities should be fulfilled: to live a long and healthy life; to acquire knowledge; and to have access to the resources necessary for a healthy way of life.

Generalizing indicator of an assessment of human development is the index of human development. It is calculated on the basis of the basic indicators characterizing directions of human development: longevity is an indicator of an expected life at birth; an educational level is an indicator of the adult literacy and involvement of the population into educational process; a standard of living is gross national product indicator per capita.

The qualitative characteristic of human development level depending on value of the human development index is represented in Table I.

Table I. The qualitative characteristic of human development level [14]

Level of the human capital development in the region	Index of human development in the region
High	0.8 and more
Middle	0.5 - 0.8
Low	0.5 and less

Extent of the environment degradation is estimated by an index of environmental quality represented by the relation of not degrading territories and water areas to a total territory and water area [2]. It varies from 0 to 1. With the higher indicator the environmental quality is better and the area of the degrading resource is lower. It is necessary to specify that this indicator is integrated, and its favorable value does not guarantee that there is no essential degradation in any local district.

In order to solve the task of stable development on marine coasts of the Far East of the Russian Federation the following was used:

- specific use of lands and water areas in the Far-Eastern region [11] as the basis for general schemes of natural management that serve to provide a maximum of planed territorial organization of an economic system with the important features of the natural environment;
- intrinsic zoning [5] of the coastal territories in the Far East of Russia in order to ensure stable social and economic regional development.

In the process of functional zoning within the area of natural-and-economic zoning, general economic system is defined, which depends on combination of natural resources less than on environmental factors influencing on the type of economic activity. First of all, such factors include zonal (the hydroclimatic indices determining severity of natural conditions and localizing regions with typhoon paths) and azonal factors (tsunami-dangerous places, areas with the increased seismicity, or with large wind-wave surges). With the benefit of the above, the assessment of natural-economic conditions is carried out separately for overland, marine and coastal zones, and last has the most complex conditions for economic management. Basing on these common reasons, four natural-economic areas [11] are revealed in the considered region:

- rather favorable,
- complex,
- especially complex,
- extreme.

Arctic regions are considered the area of extreme natural-economic conditions. It is characterized by subarctic or Arctic climate, mountainous topography, continuous permafrost everywhere, short vegetative period; natural systems here are low-resistant, and ecosystems are easily vulnerable. The domain boundary overland coincides with a divide between the Sea of Okhotsk and the East Siberian Sea, and approaching the coast of the Bering Sea (near Cape Dezhnev) it sharply deviates southward along east shore of Kamchatka and embraces the Kuriles. In the southward direction, the factors determining extremeness of natural-economic conditions change as follows: complex ice conditions in the north of the Bering Sea and hazard of icing of ships decrease southwards, but a large hazard of tsunami starts to emerge. Besides, flotation of small ships is extremely difficult here in the straits between the Kurile Islands.

The southern domain boundary of special complex natural-economic conditions overland passes between Ayano-Maysky and Tuguro-Chumikansky regions. Approaching the coast of the Sea of Okhotsk it sharply turns southward and follows along the eastern edge of the continent approximately to

Rudnaya Bay (Primorye Territory), where it turns up to the northeast crossing the Sea of Japan along the contour of maximum ice-covering, and comes to the coast of Sakhalin Island northward of Moneron Island. Hence, the entire northern coast and the water area of the Sea of Okhotsk, the northern Sea of Japan, Sakhalin Island, and Kamchatka can be defined as areas with complex natural-economic conditions [11].

Of course, natural conditions of all mentioned districts are different, but they are combined by the following: each of them has certain factors strictly complicating economic activities. Such factors include severe weather conditions, high (about 5 m) wind-wave water rise near coasts, areas with tsunami danger, and paths of strong typhoons. The area of complicated natural-economic conditions covers the most of the southern Far East of Russia, and only the southern part of Primorye Territory belongs to the area with favorable natural-economic conditions. Such area includes the warmest districts of the Far East of the Russian Federation with the monsoonal climate covering the forest-steppe territory and the southern spurs of Sikhote-Alin [11].

All calculations were made by "CoMPAS" (Coastal Management Practices to Achieve Sustainability) software created with the help of the European Union's TASIS "IBPP-support of civil company and aboriginal initiatives" software and Leonardo da Vinci (the Dutch Agency) software. It is a freely distributed software allowing calculating a number of indicators characterizing level and quality of life of the population in the coastal territories. A simulation model of natural management on marine coasts allows simulating consequences of investments into various branches of industry, such as

- extractive and recycling branches of economy (from fishing industry, timber industry, pulp-and-paper mills to chemical industry);
- recreational-tourist system (from from tourist routes, bases of rest to medical-balneal centers);
- environment protection measures (from limitation of kinds of activity, building of natural sanctuaries to national parks).

The software allows considering various natural-economic areas. The areas with extreme natural-economic conditions will correspond to "high-marine" computational model, the areas with special complicated natural-economic conditions will correspond to "middle-marine" and the areas with complicated natural-economic conditions will correspond to "low-marine".

The "CoMPAS" software uses a step by step principle of action that, on the whole, meets principles of budgetary process in the Russian Federation. Its creators included into the software the following indicators of social and economic development of the coastal territories: budget of a territory; marine bioresources; population in a territory; income per capita; an environmental quality index; an index of human development. Calculations specified the relative value of Pigou's tax (in relation to a profitable part of the territory budget) that may provide stable social and economic development of a territory and prevent an eco-catastrophe. Hence, stable development in certain territory or water area will be characterized by an index of human development and an environment index.

The decision of the given task was divided into two stages. At the first stage, basic strategy of the territory development providing stable social and economic development was chosen; the direction of investments (conditions of their increase or reduction) was determined; interference of the developed industries was estimated; value of Pigou's tax was set up under condition of stable high indices of human development and environmental quality.

At the second stage of the task decision, the chosen strategy for various natural-economic areas was modeled; the relative value of Pigou's tax for every area was calculated; and their values were compared.

Decisions of the given task allowed to specify the most typical features of strategy for stable social and economic development of the coastal territories; the relative value of Pigou's tax providing stability of social and economic development of the coastal territories at the present level of environmental capacity of industry; effect of ecological factor on value of the differential rent in various natural-economic areas.

III. Results And Discussion

Some strategies were considered in the process of calculations. At the first step of an algorithm selecting a strategy of stable development, an arbitrary strategy was calculated, and then the method of consecutive improvements allowed developing of such strategy of coastal territory development, which would make it stable. Separation of investments into various industries is reached experimentally.

The strategies were applied consecutively in that order, as shown in Table II.

Every next strategy is characterized by a positive fluctuation received by a method of minor improvements made in the previous strategy of development. The process continued until certain "Strategy 4" revealed. In our opinion, this certain strategy provided rather stable social-and-economic development of the territory. The received results are shown in a dimensionless (relative) form, in order to average the effect of ecological factor on economic indicators of computer model. Duration of a settlement period is 10 years. If a smaller period for calculations is accepted, the effects of economic wave dynamics may be "lost" caused by loss of main funds [15].

In case of "Strategy 0" (Fig. 1), no stable development may occur. Though the population increases in proportion to increase of marine bioresources, nevertheless, the index of human development steadily decreases. It is caused by almost monotone environmental impairment and more than prompt reduction of income per capita level which falls to zero from the seventh calendar year, i.e. the population comes to housekeeping predominantly.

Table II. Characteristics of strategies of stable social-and-economic development in the coastal territories ("CoMPAS" software)

Code name	Short characteristics
"Strategy 0"	Budgetary funds are not invested anywhere.
"Strategy 1"	All budgetary funds are invested in a recreational-tourist complex only.
"Strategy 2"	All budgetary funds are invested in a recreational-tourist complex (50 %) and in nature protection measures (50 %).
"Strategy 3"	All budgetary funds are invested as follows: a recreational-tourist complex (20 %), fishing (10 %), agriculture (10 %), fish-farming (5 %), timber industry (5 %) and environment protection measures (50 %).
"Strategy 4"	All budgetary funds are invested as follows: a recreational-tourist complex (10 %), fishing (10 %), agriculture (10 %), fish farming (10 %), timber the industry (10 %) and nature protection measures (50 %). In case of a sharply deteriorating environmental quality index or retarding increase of the indicators rates, the investments are withdrawn from the corresponding industry and directed to the environment protection measures.

Value of the territory budget is enlarged till the fifth calendar year. Then, it starts to monotonically decrease with the increasing loss of the capital not offset by incomes decreased with environmental impairment and lack of financing of industries. It is obvious that in order to maintain the budget value up to the mark and, hence, to provide a high index of human development, the investments into the industry are necessary.

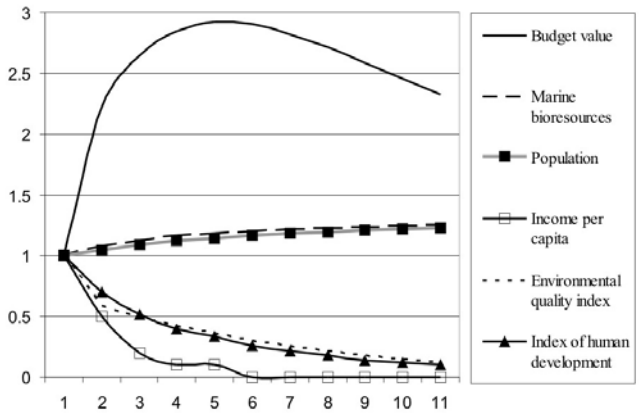

Fig. 1 relative indices of social-and-economic development for "Strategy 0"

In "Strategy 1" (Fig. 2), the recreational-tourist branch (the leading industry of coastal territories of the Far-Eastern seas) is chosen as the object for investments.

In "Strategy 1" fulfillment, the budget value is maximal in the second calendar year, however then it drops very sharply. Only quantity of the fish stores and quantity of the population are stable in development that is caused by lack of investments into the fishing industry. "Strategy 1" is also impossible to reach stable social and economic development of the territory.

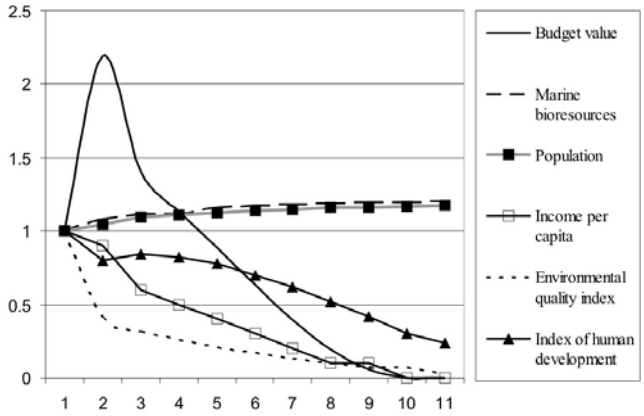

Fig. 2 relative indices of social-and-economic development for "Strategy 1"

"Strategy 2" (Fig. 3) includes the investments into environment protection activity that helps to assimilate consequences of pollution caused by anthropogenic pressure from recreational-tourist system of the territory. In this case, the budget maximum is reached in the second calendar year. Further, the slump of the budget occurs (rather than during "Strategy 1" fulfillment) because of insufficient investments into the recreational-tourist system development. Remaining indicators also rapidly fall, approximately in the third-fourth calendar years. Then they monotonically decrease and fall down to zero by the end of the calculation period. Only reserves of marine bioresources and quantity of the population develop stably that is also caused by lack of investments into fishery.

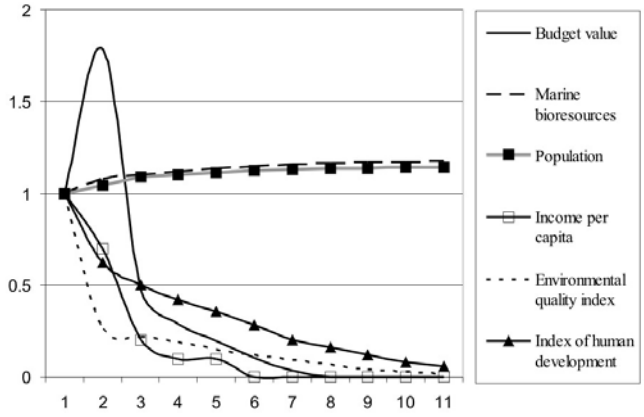

Fig. 3 relative indices of social-and-economic development for "Strategy 2"

We should note that allocation of a leading branch of economy and priority for its investments does not bring notable benefits. The situation similar to "Strategy 2" indicators is observed during priority development of fishing and timber industry. As we can see, the stable natural management in the coastal territory is not reached on fulfillment of the aforementioned strategies of social and economic development.

Though paradoxical, "Strategy 0" with zero budget of development is the best of the considered strategies. In the following strategies the sum of investments into environmental protection measures will not be less than the budget of territory development. Investments will be made into various industries, and not just in the leading industry, as in the two previous strategies.

Implementation of "Strategy 3" (Fig. 4), apparently, comes to stable natural management. Really, the budget increases, the income per capita achieves a local minimum in the third calendar year, however then it starts to increase and "pulls" the index of human development. The environmental quality index achieves a stable level by the tenth calendar year.

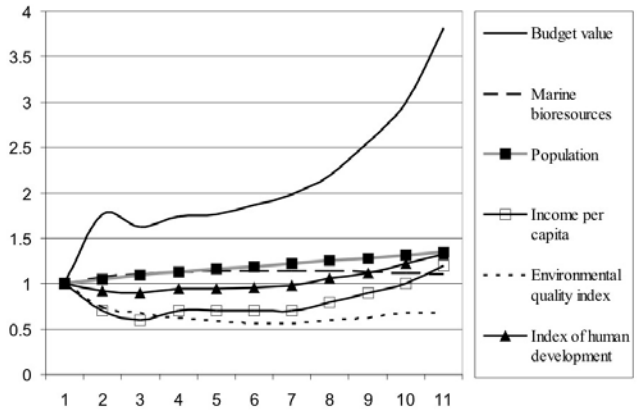

Fig. 4 relative indices of social-and-economic development for "Strategy 3"

But such situation cannot continue for a long time. The reserves of marine bioresources are maximal in the sixth calendar year and then start to monotonically decrease. The effect from it should follow after the tenth year that is beyond the calculation period. Consequently, the environmental quality index and the budget value should decrease. That will cause a "slump" of other indicators excluding population that only aggravates a situation. Thus, the stable natural management is unattainable in case of "rigidly" limited investments into the environment protection measures.

Rather stable social-and-economic development may be reached only in "Strategy 4" (Fig. 5). Its features are as follows:

- the budget in the first calendar year (designed to environment protection measures) is equal to the development budget;
- in case of sharp reduction of growth rates in any industry (or sharp increase of pollution from an industry), less investments are made into such industry;
- the funds withdrawn from the budget of development are invested into environment protection measures (directed to the advancing assimilation of environmental pollution).

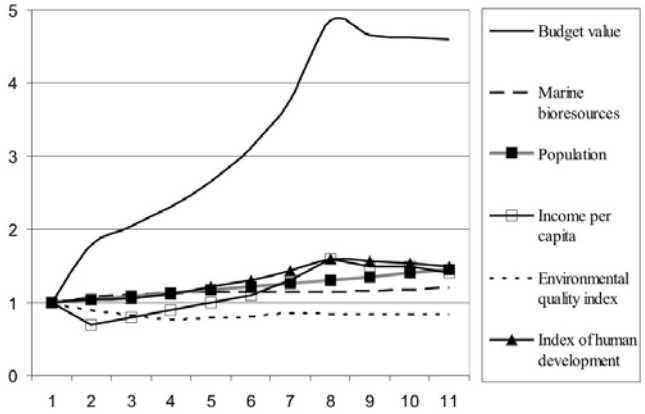

Fig. 5 relative indices of social-and-economic development for "Strategy 4"

Fig. 5 shows that all parameters of social-and-economic development become stable in the eighth or the ninth calendar year.

As we can see from Figs. 6-8, the best strategy of social-and-economic development is "Strategy 4" characterized by leading growth of the budget of environment protection measures by means of the budget of development.

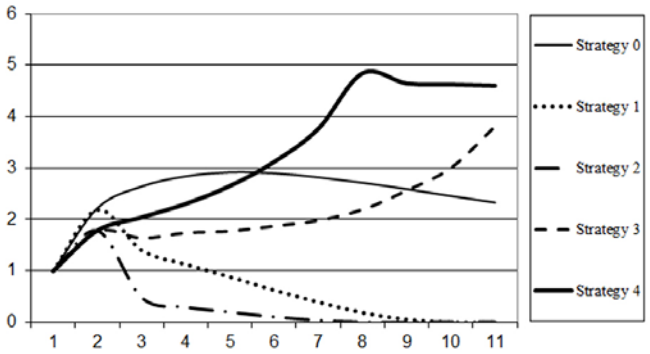

Fig. 6 the comparative graph of the relative budget value on implementation of development strategies

The worst is "Strategy 2" providing one-sided development of any industry, if the budget of development is equal to the budget of environment protection measures.

Fig. 9 shows fluctuation of a relative index of human development depending on a choice of economic development strategies in the coastal areas.

Analysis of the abovementioned results shows that the similar simulation model may be used in design of ecological-economic policy of coastal development in the Far-Eastern Russia.

Among the described strategies, "Strategy 4" was chosen as the best strategy of coastal development (i.e. the strategy allowing achievement of a stable natural management within 10-year time diversity) with the following features. All budgetary funds are invested in the following proportion: a recreational-tourist system (10 %), fishing (10 %), agriculture (10 %), fish farming (10 %), timber industry (10 %), and environment protection measures (50 %). In case of deterioration of the environmental quality index or retardation of growth rates of the indicators, the investments are withdrawn from the conforming industry and forwarded to the environment protection measures. Here the stable development is understood as "soft" definition of stability. It means stabilization of the environmental quality index on any level high enough. A return to "wild nature" is not considered.

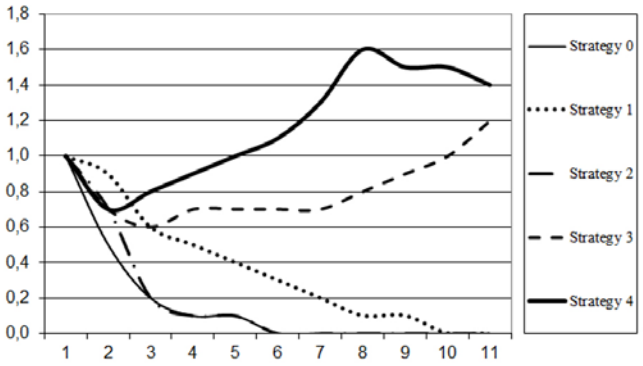

Fig. 7 the comparative graph of the relative income per capita on implementation of development strategies

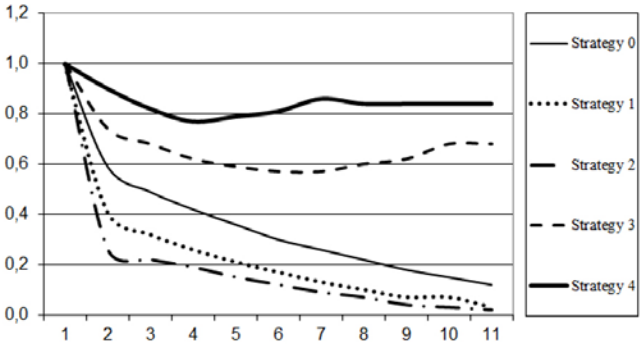

Fig. 8 the comparative graph of a relative index of environmental quality on implementation of development strategies

The next stage of the investigation is to define a tax levied from nature managers and directed to minimization of man's impact caused by land tenure. Such tax is directed to the following possible measures: land reclamation, chemical refining and bioscrubbling, breeding of certain kinds of animals, etc. Primary purpose of the calculations is to define a bite of the tax levied from land users in the territory budget, and to define the factors influencing the tax value. These calculations were carried out for the areas with extreme natural-economic conditions, special complicated natural-economic conditions, and the area with complicated natural-economic conditions as well. The calculations were carried out provided that the territory achieves stable development within 10 years of such strategy.

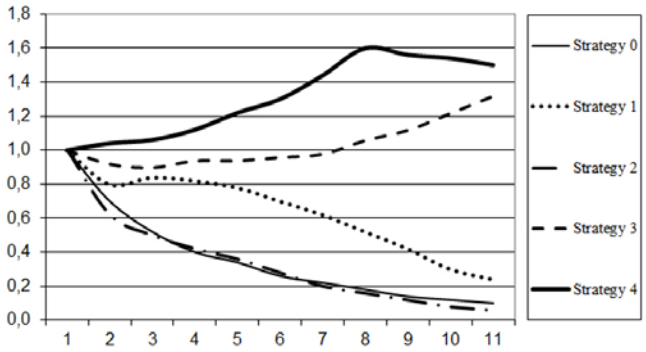

Fig. 9 the comparative graph of a relative index of human development on implementation of development strategies

Analysis of the indicators of the strategy of stable social-and-economic development of the territory shows that the growth tendency, as a whole, is determined by the population development in the territory. Fluctuations in the share of investments into environment protection measures are caused by administrative influence applied depending on a status of the environmental quality index.

IV. Conclusion

1. The mechanism of stable development implementation is considered as stable natural management based on renewable natural resources with application of ecophilous technologies.
2. Stability of natural management increases essentially, if nature-centered models of a natural management (ensuring biodiversity safety) are applied, and scientifically reasonable green administrative decisions on regional economic management are adopted.
3. The degree of anthropogenic pressure on the environment may be controlled, if the consequences of resistance of social-and-economic development and a degree of environmental degradation from developing priority industries are simulated.
4. Subjectivity in the development strategy of certain region may be removed by means of informational simulation models.
5. Stable social-and-economic development and maintaining of a high quality environment in a region in many respects depend on a direction of investments into promoted industries and on values of the taxes collected from the consumers of natural resources.
6. Adoption of administrative decisions is based on: long term (minimum 10 years); priority in funds allocation to environmental measures; strategy (definition of the regional development strategy); an assessment of correctness for a choice of the regional development strategy.
7. Analysis of indices of stable social-and-economic development strategy of the territory says that the growth trend, as a whole, is defined by growth of population within

the territory (variations of a share of investments into environmental measures are caused by the administrative effect applied depending on a status of an environmental quality index).

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