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The Scenario Approach to the Development of Regional Waste Management Systems (Implementation Experience in the Regions of Russia)

Eugene P. Fomin[a], Andrey A. Alekseev[b], Natalia E. Fomina[c] and Vladimir E. Dorozhkin[d]

[a]Samara State Economic University, Samara, RUSSIA; [b]St. Petersburg State University of Economics, Russia; [c]Institute for Applied Ecology and Health, St. Petersburg, RUSSIA; [d]Russian State Vocational Pedagogical University, Ekaterinburg, RUSSIA

ABSTRACT

The article illustrates a theoretical approach to scenario modeling of economic indicators of regional waste management system. The method includes a three-iterative algorithm that allows the executive authorities and investors to take a decision on logistics, bulk, technological and economic parameters of the formation of the regional long-term (10-25 years) waste management program.

KEYWORDS
Waste management system, economy, regional economy

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Introduction

The main task which determines the enterprise movement to the defined aim is its social and economic development. The direction for movement is defined by the enterprise itself which takes the chosen strategy as the main guideline for it. So the aim is one of the main driving force motivating the enterprise for progressive development. The concept of sustainable economic development was studied thoroughly and the result of the study was the idea that the aims of environment protection and economic development do not contradict. Some research work has been done in order to find out how the corporation can achieve sustainability and what changes should be implemented in it for this aim.

CORRESPONDENCE Eugene P. Fomin ✉ fomin@sseu.ru

Waste management is defined as one of key issues of modern cities. And the effective waste management system is the most important factor to optimize the housing and utilities infrastructure, conditions for the territory development, and the prerequisite for the life quality improvement. From the organizational point of view, waste recycling is a system component of the city's socio-economic development, providing a long-term investment in collection, transmission, processing, recycling and burying, construction of infrastructure, social and ethical behavior of residents. The economy of the system has a complex structure from the standpoint of funding operating costs and investment. It is a component of the city's economy, its investment processes, projects to develop territories, various federal and international programs, processes of public-private partnerships, etc.

The quality improvement of the regional budget planning is expressed both in the accuracy of operational planning, and in medium- and long-term prospects for the region's economic development. Currently, there is an objective positive tendency: executive bodies form regional strategic concepts of the waste management system. The "linear", "utilization" waste recycling model: "accumulation point - transportation - dumping at the landfill" becomes a thing of the past. Its economic and ecological irrationality has been proven at the theoretical level of the issue understanding and has been confirmed by the practice of European waste recycling (Alekseev, Dwarf & Makhnadze, 2013; Alekseev, 2014). The modern model – is a complex regional waste management system (see Figure 1) that has the following features:

1. The formation of single logistic, economic and technological space of waste management in the region;

2. The transition from subsidized to the operational and effective waste management model by integration of the processing segment and sale of secondary raw materials;

3. The use of innovative technologies for increasing the "depth" of waste processing in order to achieve a positive operating result of recycling (Figure 1, mark ★);

4. Economic balancing of operational efficiency of the management system and investment in forming recycling facilities.

Current management models are described as "complex": integrated into the network of a number of institutional actors belonging to different spheres of activity - waste-producers of production and consumption, transport companies, the processing industry and industrial users of secondary resources.

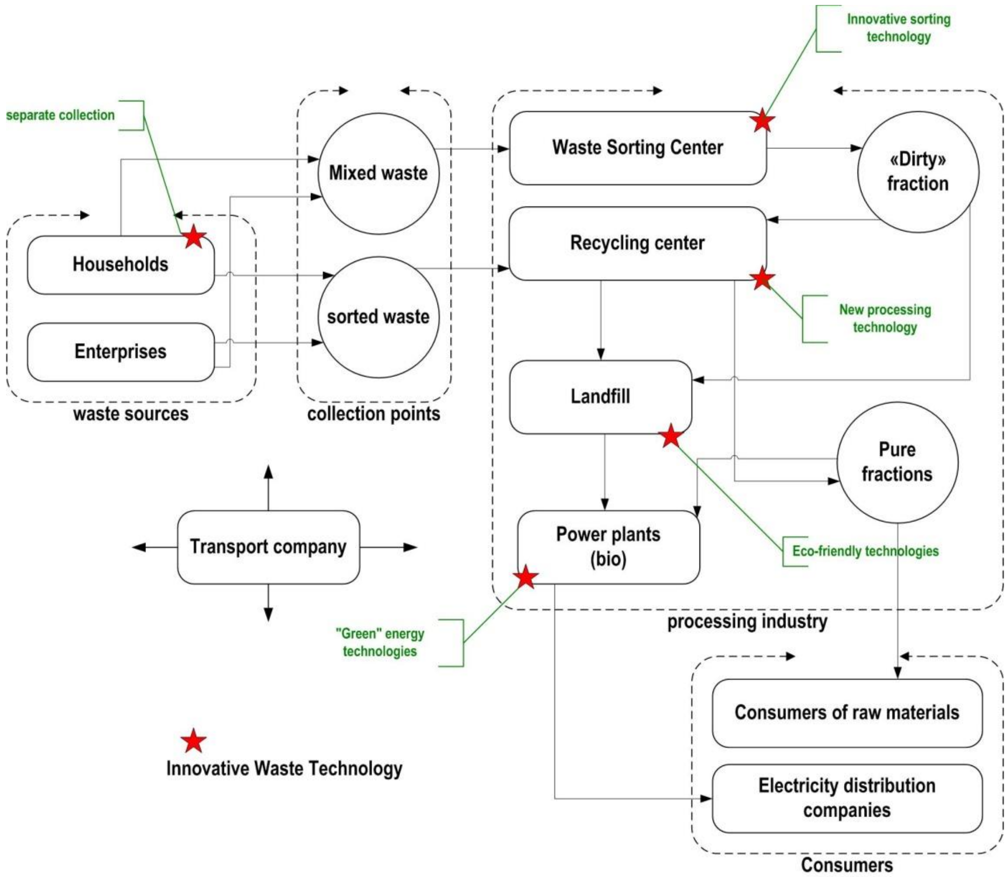

Figure 1. A modern model of the regional waste management system

In this context there is the issue - the synthesis of effectiveness evaluation models with regional waste management systems. Models and methods must meet the stated grounds, take into account the perspective (Figure 1) structure of its subjects and have the potential of direct and (or) comparative assessment of the economic attractiveness of the planned waste management system.

Theoretical aspects of economic and spatial design of regional waste management systems are considered by A. Scheinberg (2011), Z. Minghua, F. Xiumin & H. Rovetta (2009), C. Zurbrügg, S. Drescher & I. Rytz (2005), K. Berninger, L. Heikkilä & Z. Kolev (2010) , O.M. Eriksson, R. Carlsson & B. Frostell (2005), N.E. Fomina (2009), F. Cherubini & S. Bargigli (2009), A. Spoerri, D.J. Lang & C.R. Binder (2009), L. Rigamonti, A. Falbo & M. Grosso (2013), G. Meylan, H. Ami & A. Spoerri (2014). Geo-economic specifics of the development of regional waste management systems in the Russian Federation was considered by such scientists as: A.N. Kosarikov & P.V. Makarov (2014), V.A. Tarakanov (2012), L.N. Gorina, N.E. Danilina & T.Y. Mill (2015), K.G. Pugin (2014), P.N. Chepiga (2010), M.G. Eremina & B.B. Savinykh (2015), A.V. Albegova, A.M. Gonopolsky & V.A. Mariev (2015), M.Y. Shabalov (2014), A.M. Malinin, E.M. Bodenko & M.A. Rukomoynikova (2010), I.V. Minakova & O.G. Timofeeva (2015). However, there is no a holistic algorithmic approach while selecting the cost effective concept of regional waste management systems. The designing organizations of Russia, as a rule, use situational pricing procedures that do not have the objective academic basis and the possibility to replicate solutions in subsequent projects. That is why the authors have developed and tested a theoretical algorithm of scenario modeling, which allows regional executive services to make decisions on logistics, bulk, technological and economic parameters of the formation of long-term (10-25 years) waste management programs. The theoretical principles of the algorithm have been formed within the framework of the European grant SE-500 "Waste management" and tested in the waste management project of the Krasnodar Territory (Russia).

Methodological Framework

The algorithm of scenario modeling of the regional waste management system is proposed by the authors as a sequence of 3 iterations:

Creation of alternative scenarios of collection, transportation, processing and disposal of waste;

Evaluation of economic scenario indicators - investment and operating balance;

Comparison and selection of scenarios of the regional waste management system.

Let us consider the content of iterations of the algorithm.

Iteration 1. Creation of alternative scenarios. A scenario is a quantitative and qualitative variant of implementation of a waste management system, determined by logistics, bulk, technology and investment parameters. Scenarios are primarily formed on the basis of possible variability of logistics and technological parameters (Figure 2): routes of waste transportation, distribution of accumulation and transfer points, the reference to routes and capacity of sorting, processing and burning entities, location, number and cubical contents of waste landfills. All declared parameters should be designed in complex, then forming a single regional network. In the most crucial form the variability can be depicted as an alternative of the transport route distance to the primary object transfer, sorting or recycling. In this premise, the authors proceed from the existing practice; 60-80% of the budget of operating expenses is accounted for waste transmission (Alekseev, 2014). It means that the distance of transportation is opposed to the number and capacity of processing entities. We can distinguish two alternative scenarios (Figure 2) "transport" - high concentration of processing objects (with high capacity) under long-range transportation; "bushy" - a large number of processing objects (with relatively low capacity) with short distance transportation. It is clear that designing intermediate scenarios is also possible. These scenarios are optimal in subsequent economic assessment.

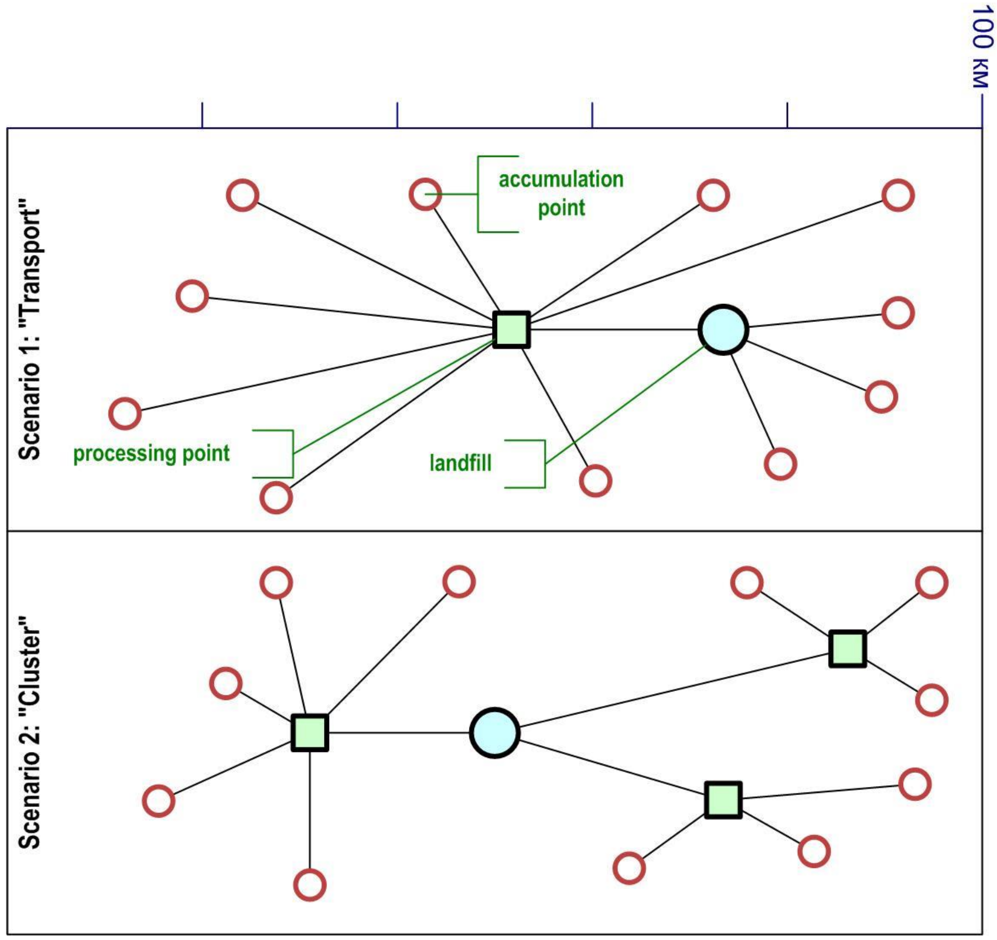

Figure 2. Logics of scenario formation of the regional waste management system

Then the chosen variation scenarios are superimposed on the primary logical scheme of the region with cartographic form (Figure 3), and representing the current points of waste formation and disposal. Consequently, the conceptual, fundamental approaches (Figure 2) are interpreted in specific scenarios, connected with the geography of objects of the projection region (Figure 3) The formed scenarios reflect variations of logistics, the number and processing capacity of recycling objects.

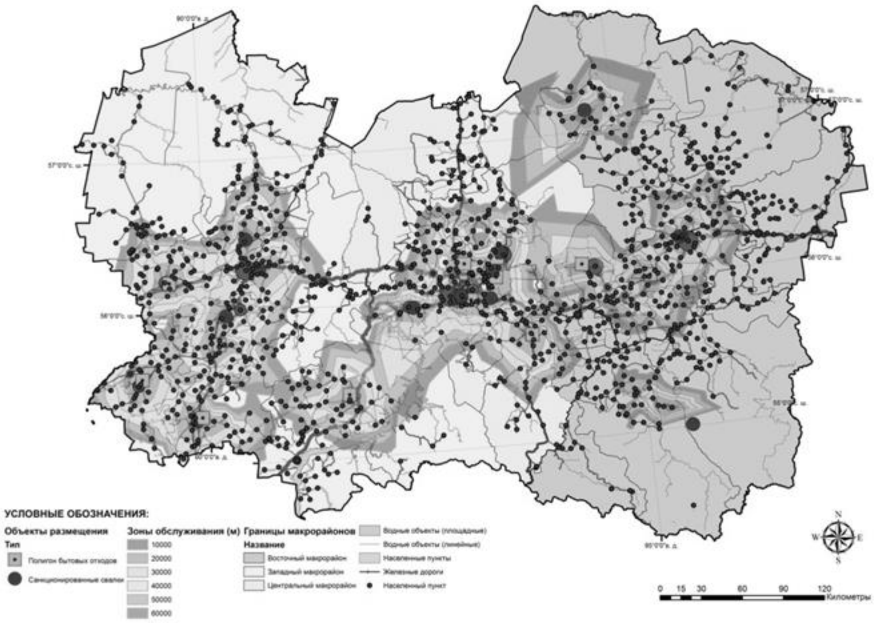

Figure 3. The primary logical scheme of hard domestic waste management of the Western, Central and Eastern macro districts of the Krasnoyarsk Region

Overlay on a cartographic form with the use of geographic information system, allows to calculate the natural quantitative parameters of scenarios:

1. The volume of transport wastes with regard to the forecast about its formation in the long term of the project (tons per year);

2. Transportation distances according to volumes and modes of transport (t/km, per year);

3. The number, capacity and location of processing stations of the following types: transfer, sorting, processing, burning (tons per year);

4. The number, capacity and location of waste landfills (tons, m3per year);

5. Duration of reconstruction and disposal of subjects of processing and burying (periods).

The obtained quantitative indicators allow to move to the second iteration – evaluation of economical parameters of alternative scenarios.

Iteration 2. Evaluation of economic scenario indicators. Like any economic system, the regional waste management system should obtain financial and investment practicality, efficiency. From the perspective of an investor, it is considered (minimum criterion) as a positive level of pure discounted revenue in the further operation of the waste management:

$$NPV = \sum^{T} \frac{CF_t}{(1+i)^t} - \sum^{T} \frac{IC_t}{(1+i)^t} \quad (1)$$

here	PV	- pure discounted revenue: economic effect from the waste management system functioning from the standpoint of an investor (rub.);

	- discounting rate;
	- project duration of the regional waste management system, years;
Ft	- positive transaction flow - operating balance of the economical activity;
Ct	- volume of investments in construction, reconstruction of buildings, installations and equipment of the regional waste management system.

In accordance with the investment logics (formula 1), it is necessary to evaluate each scenario in two vectors:

Investment value (ICt) is a set of costs on formation and development of capital objects of the regional waste management system throughout the duration of the functioning period (T);

Operating value (CFt) is the operating balance of the waste management system as an integrated economical system, which is interpreted as the difference between the operating revenue and expenses on its functioning. The indicator is calculated for each functioning period (year) of the regional waste system management.

In the relation to the selected vectors, the authors developed the structural models for evaluation of economic scenario indicators. Calculation of investment value (Table 1) is based on the project appraisal of capital investments in objects of the waste management system. It is connected with three logical stages: collection and transportation; recycling; utilization. When evaluating pure discounted revenue, capital expenses on construction and reconstruction are linked to the functioning period (years) of the waste management system. This allows to refer cash flows from investment activities to the current discounting rate.

Table 1. The structural model of calculation of capital expenditures and investment outlay of the waste management system

Reference	Indicators	Calculation formula	Estimation of the average volume in the waste management structure
Capital input		A+B+C	100,00%
A	Collection and transportation	A1+A2+A3	0,38%
A1	Arrangement of container yards		0,05%
A2	Arrangement of dangerous waste dropoff points		0,00%
A3	Construction of transfer stations		0,33%
B	Recycling	B1+B2	26,45%
B1	Construction of sorting stations		8,00%
B2	Construction of processing stations		18,44%
C	Utilization	C1+C2+C3	73,17%
C1	Construction of waste dumps		3,13%
C2	Rehabilitation of waste landfilling (dumps)		23,71%
C3	Construction waste-to-energy facilities		46,33%

The operating balance is considered as a difference of profitable and expensive positions which are recalculated proceeding from natural indexes (iteration 1) and the forecast of prices and tariffs. The transition to the modern models of the organization of waste management system assumes a significant growth in a revenue structure from selling secondary raw materials (Table 2, the B1 block). In the developed countries its volume reaches 90% from the volume of a positive operating flow (Sonesson, 2000). At the same time tariffs for waste service and level of grants from regional budgets naturally decrease. It is necessary to tend to such model when forming design scenarios (structural balance of Table 2) revenues of the regional waste management system.

Table 2. The structural model of calculation of operating balance of the waste management system

Reference	Indicator	Calculation formula	Estimate of average volume in the waste management structure
Operating balance of waste management system		B-A	
A	Operating expenses of a waste management system	A1+A2+A3	100,000%
A1	Fee	A11+…+A15	8,821%
A11	Operating costs on purchasing containers and bags		5,224%
A12	Operating costs on containers maintenance		2,608%
A13	Operating costs on the maintenance of container platforms		0,914%
A14	Operating costs on purchasing containers for collecting dangerous wastes		0,025%
A15	Operating costs on containers maintenance for collecting dangerous wastes (without disposal)		0,051%
A2	Transportation	A21+A22+A23	35,077%
A21	First stage (waste collecting)		34,644%
A22	Second stage (transportation, overload processing, processing ground)		0,180%
A23	Wastage transportation of 1-3 classes of danger which are formed as a part of MSW and collected separately		0,254%
A3	Objects functioning of capital construction	A31+A32+A33	56,102%
A31	Operating costs of functioning of transfer stations		0,210%
A32	Operating costs of functioning of the waste-processing enterprises*		55,889%
A33	Operating costs of grounds functioning		0,002%
B	Revenue of waste management system	B1+B2+B3	100,0%
B1	Secondary raw materials	B11+…+B22	94,6%

B11	Card board	8,2%
B12	Paper	8,2%
B13	PETF	16,3%
B14	LDPE	8,3%
B15	HDPE	2,4%
B16	Polypropylene	5,9%
B17	Broken glass	5,3%
B18	Ferrous metal	3,8%
B19	Nonferrous metal	30,9%
B20	Aluminum	5,4%
B21	Fuel RDF	4,7%
B22	Compost	0,7%
B2	Payments of litter formers for waste disposal	2,0%
B3	Subsidies from regional budget	1,0%

Note: * - Including all elements of transformation of secondary raw materials (sorting, drying, packing, processing, etc

The expenditure section of waste management system is constructed as a sum of operating costs of collecting, transportation and functioning of capital construction projects. Operating expenses are considered as annual expenses in relation to a forecast volume of waste formation.

Thus, 1-2 algorithms allow creating scenarios economy of regional waste management system which comparison is the result of projection, the basis of administrative decision.

Results

The comparison and the choice of the scenario (iteration 3), apparently, can be constructed on the quantitative assessment of net discounted income level. From the formal point of view, most of income (a minimum of losses) of waste management system is a single preference criterion. But as practice of economic projection shows, often there is a situation of low level of distancing of economic scenarios assessments: dispersion of values less than 20%. And at a 15-25-year projection log such distance of the quantitative values does not allow approving the advantage of the scenario with highest assessment. In this context authors created the additional tool that allow an investor and regional executive bodies to discuss and choose the scenario from a position of investment balance and operating results of waste management system.

The offered tool looks as the matrix constructed in two vectors (Figure 4): operating and investment cost. The calculated indicators of scenarios (Tables 1, 2) are located in the data assessments (for example, A, B, C). At the same time it is possible to allocate 4 quadrants of a matrix allowing defining key characteristic of the considered scenario.

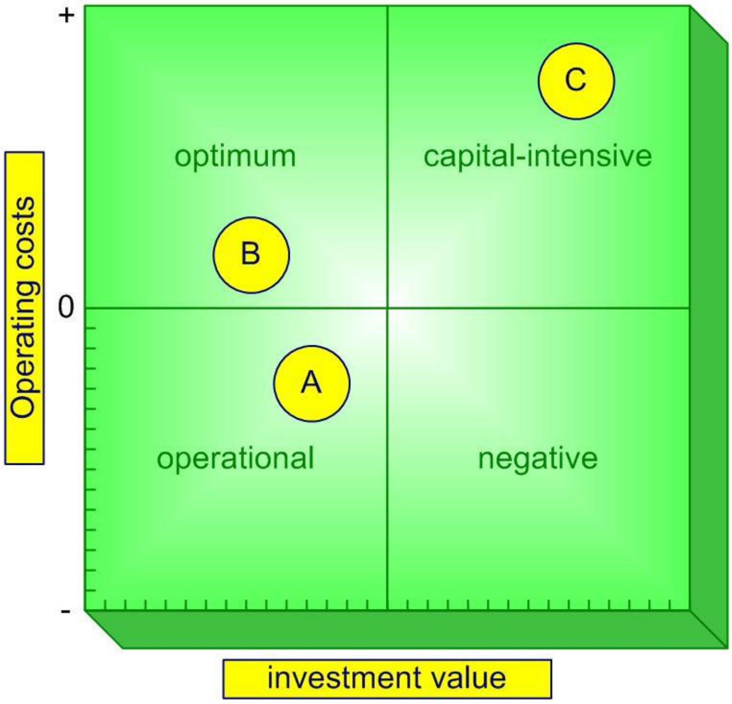

Figure 4. Matrix of comparison of scenarios of the regional waste management system

It is apparent that scenarios in a quadrant "negative" cannot be accepted as they have high investment cost which is not supported with a positive result of operating balance of waste management system. Contrary to it the quadrant “optimum” reflects scenarios with a positive level of operating balance at low investment level. But as practice of economic projection shows and it is obvious, the emergence of such scenario is doubtful: high level of starting investment into high innovative processing technologies provides low level of operating expenses and, respectively, high profitability. Such scenarios have to be in a quadrant “capital-intensive”. Nevertheless, authors do not deny, and practice shows (Zamyatina & Fesenko, 2011) relevance of scenarios introduction from a quadrant “operational”. They are characterized by rather low loss of waste management system at the minimum investments level. The “operational” scenario is “planned unprofitable” from a position of an executive authority that makes a decision regarding its realization. As a rule, in a decision making practice concerning the concept of formation of regional waste management system there is such alternative: between the scenarios from quadrants “operational” and “capital-intensive”. At high investment appeal of the region the "capital-intensive" scenario is adopted, otherwise – “operational”.

A set of alternate scenarios and matrix of their comparison can be considered as the basis for decision making on creating economically optimum regional waste management.

Conclusion

So, in the article the methodical approach to scenario modeling of regional waste management systems considering space and investment aspects is revealed. The offered algorithm is addressed to design organizations and regional authorities which form assignment specification on the projection of regional waste management system. Authors believe that suggested approach can be considered as a theoretical platform for further specification of methods and algorithms of economic projection of regional waste management system in the Russian Federation and the countries with similar space and geo-economic structure.

Disclosure statement

No potential conflict of interest was reported by the authors.

Notes on contributors

Eugene P. Fomin is Doctor of Economics, Professor of Samara State University of Economics, Samara, Russia.

Andrey A. Alekseev is Doctor of Economics, Professor of St. Petersburg State University of Economics, St. Petersburg, Russia.

Natalia E. Fomina is Doctor of Economics, Associate professor, scientific consultant of Institute for Applied Ecology and Health, St. Petersburg, Russia.

Vladimir E. Dorozhkin is graduate student of Russian State Vocational Pedagogical University, Ekaterinburg, Russia.

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