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Investments Attractiveness via Combinatorial Optimization Ranking

Ivan C. Mustakerov, Daniela I. Borissova

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***Abstract*—**The paper proposes an approach to ranking a set of potential countries to invest taking into account the investor point of view about importance of different economic indicators. For the goal, a ranking algorithm that contributes to rational decision making is proposed. The described algorithm is based on combinatorial optimization modeling and repeated multi-criteria tasks solution. The final result is list of countries ranked in respect of investor preferences about importance of economic indicators for investment attractiveness. Different scenarios are simulated conforming to different investors preferences. A numerical example with real dataset of indicators is solved. The numerical testing shows the applicability of the described algorithm. The proposed approach can be used with any sets of indicators as ranking criteria reflecting different points of view of investors.

***Keywords*—**Combinatorial optimization modeling, economics investment attractiveness, economics ranking algorithm, multi-criteria problems.

I. Introduction

THE decision making for investing in particular country depends largely on the current and anticipated economic situation but also depends on some political and social factors. An investment climate could be composed also of economics location-specific factors (incentives and opportunities) that determine if investors will risk their capital in financing a particular project [1]-[3].

Many countries liberalize and promote foreign investment in various industries and introduce proper regulatory and restrictive measures. They adjust entry policies for local and foreign investors. It could be said that mobilizing investments and ensuring that they contribute to sustainable development is a priority for all countries. More and more governments pursue a broader and more intricate development policy agenda, while building or maintaining a generally favorable investment climate [4].

With globalization the competitiveness of an economics (or country) is acquiring a very important role. When a particular economics is competitive it is also attractive for investments. In particular the investor will try to benefit from those assets and competencies that make the economics competitive. Such an economics attracts capital and knowledge and this implies comparison of local enterprises with other external realities [5]. As a result, this comparison stimulates local enterprises to improve and enhance their competitiveness and to take international investment decisions [6].

Well known approach for defining of investment attractiveness is ranking of the economics (countries) in accordance with different economic, political, social, etc., indicators. Most of the published results of ranking approaches rely on statistical averages, surveys of executives, and experts' estimations of key indicators used as input variables [7]-[13].

In current paper we take different approach – the problem of economics ranking is investigated from the perspective of combinatorial optimization. The main idea is that each investor could have his own preferences for the importance of particular key indicators that not necessarily coincide with the preferences of other investors. In the paper multi-objective decision making technique is used to develop a flexible approach for economics ranking. A ranking algorithm is proposed allowing compliance with various preferences of investors about the importance of individual economic indicators for investment attractiveness.

II. Problem Definition

There are different economic indicators that can be used to estimate the investment attraction. The described in the paper approach is illustrated by a set of indicators for easiness of doing business [14] but there is no limitation on using of other economic indicators. When a variety of indicators have to be considered as features that have to be selected this can be viewed as a problem to search for optimal features combination i.e. as a problem of combinatorial optimization. Each features combination can be regarded as an alternative for problem solution. For the investor the "best" alternative could be defined by considering the key indicators as criteria at their "best" values. From this perspective, the search for the "best" alternative may be viewed as a discrete multi-criteria decision problem. The solution of such problems is focused on considering of all criteria (indicators) simultaneously. It is known that in general, it is impossible to get solution of a multi-criteria problem where all criteria are simultaneously at their optimum. Instead this, Pareto-optimal solution is seek, when it is not possible to make one criterion better off without making other criterion worse off [15], [16]. In terms of multi-criteria optimization, the investor is regarded as decision maker (DM). He estimates the relative importance of each criterion (i.e. economic indicator) and looks for Pareto optimal solution that defines the most preferred by him alternative. The solution process is based on evaluation of the alternatives with respect to the set of relevant criteria. When no mathematical methods are used, the decision maker somehow

I. C. Mustakerov is with the Institute of Information and Communication Technology at the Bulgarian Academy of Sciences, Sofia – 1113, Bulgaria (phone: 3952 9793241; e-mail: mustakerov@iit.bas.bg)

D. I. Borissova is with the Institute of Information and Communication Technology at the Bulgarian Academy of Sciences, Sofia – 1113, Bulgaria (phone: 3952 9792055; e-mail: dborissova@iit.bas.bg).

estimates the relative value of each alternative in the choice set and then makes the optimal choice in a systematic manner. Some investigations show that simplified approaches are not quite suitable for drawing conclusions about the attractiveness of complex financial products [17]. The main problem is to rank the existing alternatives in terms of how attractive they are to DM, when all criteria (economic indicators) should be considered simultaneously.

The paper describes an approach to ranking a set of potential economics to invest considering the investor point of view about particular indicators. The proposed approach involves an algorithm for ranking that contributes to rational decision making. The described algorithm is based on multiple solutions of multi-criteria optimization tasks. Different scenarios could be simulated to get best conforming to the DM requirements economics ranked list.

III. Multi-Criteria Decision Model

A major part of decision making process involves the analysis of a finite set of alternatives described in terms of evaluative criteria. The multi-criteria techniques can help identify desired measures among a variety of alternatives through analyzing multiple criteria. This approach of decision making has attracted the interest of many researchers and practitioners [16].

From the mathematical point of view, solution of multi-objective optimization problem can define a set of Pareto optimal solutions and each of them is equally acceptable as solution to the problem. In practice, only one solution should be chosen by active involvement of DM. The decision maker assists in the selection of a solution by incorporating his preferences about the importance of each of the criteria. In this context the proposed multi-criteria optimization seeks a solution that is both Pareto optimal and also satisfies the decision maker.

A generalized definition of multi-criteria optimization problem to be used in ranking algorithm is:

$$\begin{aligned} &\text{minimize}(a_1, a_2, ..., a_j) \\ &\text{maximize}(b_1, b_2, ..., b_k) \end{aligned} \quad (1)$$

subject to

$$\forall j = 1, 2, ..., \mathrm{J} : a_j = \sum_{i=1}^{\mathrm{N}} a_j^i \, x_i \,, \quad (2)$$

$$\forall k = 1, 2, ..., \mathrm{K} : b_k = \sum_{i=1}^{\mathrm{N}} b_k^i \, x_i \,, \quad (3)$$

$$\sum_{i=1}^{\mathrm{N}} x_i = 1, \; x_i \in \{0, 1\} \quad (4)$$

where **J** is the number of objective functions (economic indicators) ***a*** that have to be minimized, **K** is the number of objective functions (economic indicators) ***b*** that have to be maximized, x_i are binary integer decision variables and **N** is number of economics (countries) that are to be ranked.

IV. Economics Ranking Algorithm

The solution of multi-criteria optimization problem (1) – (4) defines a single economics with Pareto optimal combination of indicators. The basic idea of the proposed ranking algorithm is to solve sequentially *n* multi-criteria optimization tasks. The first task solution gives the best Pareto optimal country and this country occupies the top of the ranking list. Then that country is excluded from the optimization task formulation, i. e. the number of countries to search for Pareto optimum is reduced from *n* to (*n* – 1). The modified multi-criteria optimization task is solved again to define the second Pareto-optimal country in the ranking list. This procedure is repeated as a cyclic loop **N**-times. It is evident that on the last step of the cycle when a single economy is left the choice is obvious but the solution of the last task will provide information about its objective function value that could be used for comparison with other objective functions values. The objective function values are used as estimation of how far from the best one is some particular economics. The multi-criteria optimization based algorithm for ranking of countries (economics) is illustrated on Fig. 1.

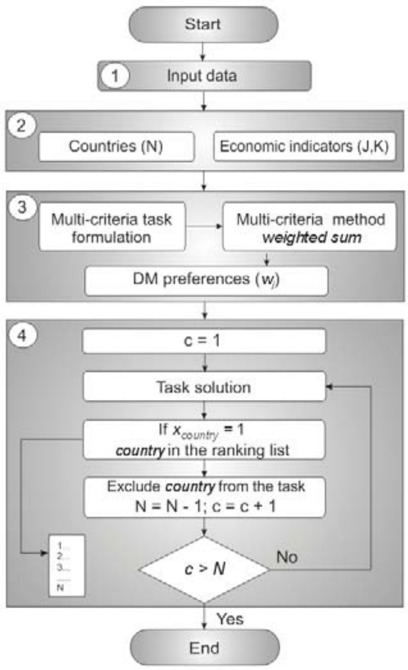

Fig. 1 Economics ranking algorithm

On the 1-st step input data are collected and processed. On the 2-nd step, a set of **N** economics that have to be ranked is defined. Each economics is described by a set of economic indicators. Then on the 3-rd step a multi-criteria task is formulated and multi-criteria solution method is chosen. The DM point of view about the importance of different economic attributes is expressed accordingly to the chosen solution method. The economics ranking list is created by multi-criteria task solution on the step 4 following the loop: a) set a counter c = 1; b) solve the multi-criteria task and include the defined Pareto optimal economics conforming to decision variable $x_{country}$ = 1 on the top of the ranking list; c) remove this country and the corresponding decision variable $x_{country}$ and restrictions from the task formulation. That operation decreases the number of economics from **N** to (**N** – 1). Increment the counter $c = c + 1$; d) check if c > **N** and if *NO* – go to b) or if *YES* – go to END. The economics ranking list is available on exit of step 4.

Some possible scenarios for adjusting the algorithm for different investment conditions could be: add or remove some economic indicators; change the definition of multi-criteria optimization task; choice of other multi-criteria solution method; change the preferences about the indicators relative importance; look for another set of countries (economics).

Thus, the proposed algorithm can be used as a simulation tool based on Pareto optimization for reasonable decision making about the economics attractiveness.

V. Numerical Illustration of the Ranking Algorithm

To prove the applicability of the proposed algorithm it is applied to a case study published by the International Finance Corporation, a member of the World Bank Group, for benchmarking in the sense of doing business in countries from the East Europe and Central Asia [14]. The 24 economics are ranked on the basis of indicators for ease of doing business with values from 1 to 24. These indicators estimate regulations for: *starting a business*, *dealing with construction permits*, *getting electricity*, *registering property*, *getting credit*, *protecting investors*, *paying taxes*, *trading across borders*, *enforcing contracts and resolving insolvency*. The low value of indicator for the ease of doing business means the regulatory environment is more conducive to the starting and operation of an enterprise. The numerical data of indicators for countries of Eastern Europe and Central Asia in alphabetical order for June 2012 are shown in Table I.

TABLE I
Economic Indicators for Eastern Europe and Central Asia Countries

lphabetical order	*Country (economy)*	*Starting a Business*	*Dealing with Construction Permits*	*Getting Electricity*	*Registering Property*	*Getting Credit*	*Protecting Investors*	*Paying Taxes*	*Trading Across Borders*	*Enforcing Contracts*	*Resolving Insolvency*
No	*indicators*	a_1	a_2	a_3	a_4	a_5	a_6	a_7	a_8	a_9	a_{10}
1	Albania	14	24	14	22	6	3	20	9	17	10
2	Armenia	4	3	10	3	10	6	14	14	19	9
3	Azerbaijan	6	19	21	5	15	6	10	20	5	18
4	Belarus	3	2	20	2	21	16	17	18	2	7
5	Bosnia and Herzegovina	24	16	15	18	18	19	16	12	22	14
6	Bulgaria	11	9	13	14	10	11	13	10	18	17
7	Croatia	18	12	2	20	10	23	5	13	14	19
8	Cyprus	8	7	9	19	15	9	3	2	21	1
9	Georgia	2	1	1	1	1	4	4	4	8	13
10	Kazakhstan	7	15	7	8	19	1	1	22	7	6
11	Kosovo	23	13	12	16	6	19	6	15	24	15
12	Kyrgyz Republic	5	6	22	6	4	2	23	21	13	23
13	Latvia	13	8	8	9	1	13	7	1	4	2
14	Lithuania	22	4	5	4	15	13	8	3	3	3
15	Macedonia	1	5	10	13	6	4	2	7	15	8
16	Moldova	20	17	16	7	10	16	15	16	6	16
17	Montenegro	12	18	4	21	1	9	12	5	23	4
18	Romania	15	10	19	15	4	11	18	6	16	20
19	Russian Federation	21	20	24	12	21	21	9	19	1	5
20	Serbia	9	21	6	10	10	16	19	11	20	21
21	Tajikistan	17	22	23	17	24	6	24	23	11	12
22	Turkey	16	11	3	11	19	13	11	8	9	22
23	Ukraine	10	23	17	24	6	21	22	17	10	24
24	Uzbekistan	19	14	18	23	23	23	21	24	12	11

Using the data from Table I, the multi-criteria optimization task included in the proposed ranking algorithm is formulated as follows:

$$\min(a_1, a_2, a_3, a_4, a_5, a_6, a_7, a_8, a_9, a_{10}) \quad (4)$$

subject to

$$\forall j = 1,2,...,10 : a_j = \sum_{i=1}^{24} a_j^i x_i \quad (5)$$

$$\sum_{i=1}^{24} x_i = 1, \; x_i \in \{0,1\} \quad (6)$$

The widely used and easy to understand and implement *weighted sum* method is performed to solve the task (4) – (6). This method transforms the original multi-criteria problem into problem with a single scalar evaluation criterion [18]–[20]. The required for implementation of the *weighted sum* method normalization of criteria is done by the normalization scheme [21]:

$$a^* = \frac{a_{\max} - a_j}{a_{\max} - a_{\min}} \qquad (7)$$

The *weighted sum* method transforms multiple objectives into an aggregated maximized objective function by using normalized objectives and weighting coefficient for each of normalized objectives given by the DM. This objective function is used to formulate single objective mixed integer linear programming optimization task:

$$\max(w_1(a_1)^* + w_2(a_2)^* + w_3(a_3)^* + w_4(a_4)^* + w_5(a_5)^* + w_6(a_6)^* + w_7(a_7)^* + w_8(a_8)^* + w_9(a_9)^* + w_{10}(a_{10})^*) \qquad (8)$$

subject to (5), (6) and

$$\sum_{i=1}^{10} w_i = 1 \qquad (9)$$

where w_1, ..., w_{10} are non-negative weight coefficients and $(a_j)^*$ are normalized criteria.

The weight coefficients w_i in Table II reflect *a priory* preference information of the DM point of view about the relative importance of the economic indicators regarded as criteria. Three examples of weight coefficients sets are tested.

TABLE II
SAMPLE SETS OF CRITERIA'S WEIGHT COEFFICIENTS

w_i	w_1	w_2	w_3	w_4	w_5	w_6	w_7	w_8	w_9	w_{10}
set (a)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
set (b)	**0.15**	0.05	0.05	0.05	0.05	0.1	**0.15**	0.1	0.05	**0.25**
set (c)	0.05	**0.25**	0.05	**0.25**	0.05	0.05	**0.1**	0.05	0.1	0.05

The set (a) of weight coefficients corresponds to equivalent importance of the all economic indicators. The set (b) of weight coefficients illustrates the dominant importance of *Resolving Insolvency* (***w*₁₀**) indicator. The indicators *Starting a Business* (***w*₁**) and *Paying Taxes* (***w*₇**) are not so much important but also are prevailing over other indicators. The rest of indicators are approximately of equal importantance. The set (c) reflects the DM strong preferences about the indicators *Dealing with Construction Permits* (***w*₂**) and *Registering Property* (***w*₄**), and some preference about *Paying Taxes* (***w*₇**).

As a result of algorithm execution three ranking lists of countries reflecting the given sets of weight coefficients are defined (Table III).

TABLE III
RANKED LISTS OF COUNTRIES

Ranking	*set (a) of w_i*		*Ranking*	*set (b) of w_i*		*Ranking*	*set (c) of w_i*	
	Countries	*Objective function*		*Countries*	*Objective function*		*Countries*	*Objective function*
1	Georgia	0.1260870	1	Georgia	0.1978261	1	Georgia	0.0847826
2	Latvia	0.2434783	2	Macedonia	0.2173913	2	Lithuania	0.2239130
3	Macedonia	0.2652174	3	Latvia	0.2347826	3	Belarus	0.2673913
4	Lithuania	0.3043478	4	Cyprus	0.2413034	4	Latvia	0.2717391
5	Kazakhstan	0.3608696	5	Kazakhstan	0.2956522	5	Macedonia	0.3043478
6	Cyprus	0.3652174	6	Lithuania	0.3217391	6	Armenia	0.3347826
7	Armenia	0.3782609	7	Montenegro	0.3565217	7	Kazakhstan	0.3760870
8	Montenegro	0.4173913	8	Armenia	0.3673913	8	Kyrgyz Republic	0.4108696
9	Belarus	0.4260870	9	Belarus	0.4130435	9	Cyprus	0.4391304
10	Turkey	0.4913043	10	Azerbaijan	0.5108696	10	Turkey	0.4586957
11- 12	Azerbaijan	0.5000000	11	Albania	0.5195652	11	Azerbaijan	0.4695652
	Kyrgyz Republic	0.5000000	12	Bulgaria	0.5282609	12	Bulgaria	0.4978261
13	Bulgaria	0.5043478	13	Russian Federation	0.5500000	13	Moldova	0.5130435
14	Romania	0.5391304	14	Turkey	0.5782609	14	Romania	0.5391304
15	Croatia	0.5478261	15	Croatia	0.5956522	15	Croatia	0.5717391
16 - 17	Albania	0.5608696	16	Kyrgyz Republic	0.6000000	16	Russian Federation	0.5891304
	Moldova	0.5608696	17	Romania	0.6021739	17	Kosovo	0.5978261
18	Serbia	0.5782609	18	Kosovo	0.6108696	18	Belarus	0.6021739
19	Kosovo	0.6043478	19	Moldova	0.6195652	19	Serbia	0.6217391
20	Russian Federation	0.6217391	20	Serbia	0.6304348	20	Bosnia and Herzegovina	0.7130435
21 - 22	Bosnia and Herzegovina	0.7130435	21	Tajikistan	0.6913043	21	Albania	0.7391304
	Ukraine	0.7130435	22	Bosnia and Herzegovina	0.6978261	22	Uzbekistan	0.7586957
23	Tajikistan	0.7347826	23	Uzbekistan	0.7369565	23	Tajikistan	0.7608696
24	Uzbekistan	0.7739130	24	Ukraine	0.7652174	24	Ukraine	0.8130435

VI. Results and Discussion

There exist different software systems to be used for formulated tasks solution [16], [18]. LINGO solver [21] is used for numeric illustration of the described approach. The solution times are about few seconds on PC with 2.93 GHz Intel i3 CPU and 4 GB RAM. The advantage of proposed approach is that after execution of each step of the loop on step 4 of algorithm the task dimension is reduced. Further numerical testing with different tasks dimensions is needed to get the functional dependence between solution times and tasks dimensions.

As it is seen from Table III the different DM preferences lead to different ranking lists of countries. The ranking of the countries is on the basis of the values of objective functions. In most cases the objective function values are different but sometimes it is possible to have equal values for some countries. This is the case with Azerbaijan and Kyrgyz Republic, Albania and Moldova, Bosnia-Herzegovina and Ukraine in the ranking list for w_i of set (a) – equal weights for all indicators. In cases like this the countries with same values of objective function are ranked equally.

The ranking of the countries as a result of execution of the described algorithm for set (a) of weightings is compared with ranking shown in [14]. The graphical illustration of this comparison (Fig. 2) shows some differences in countries ranking.

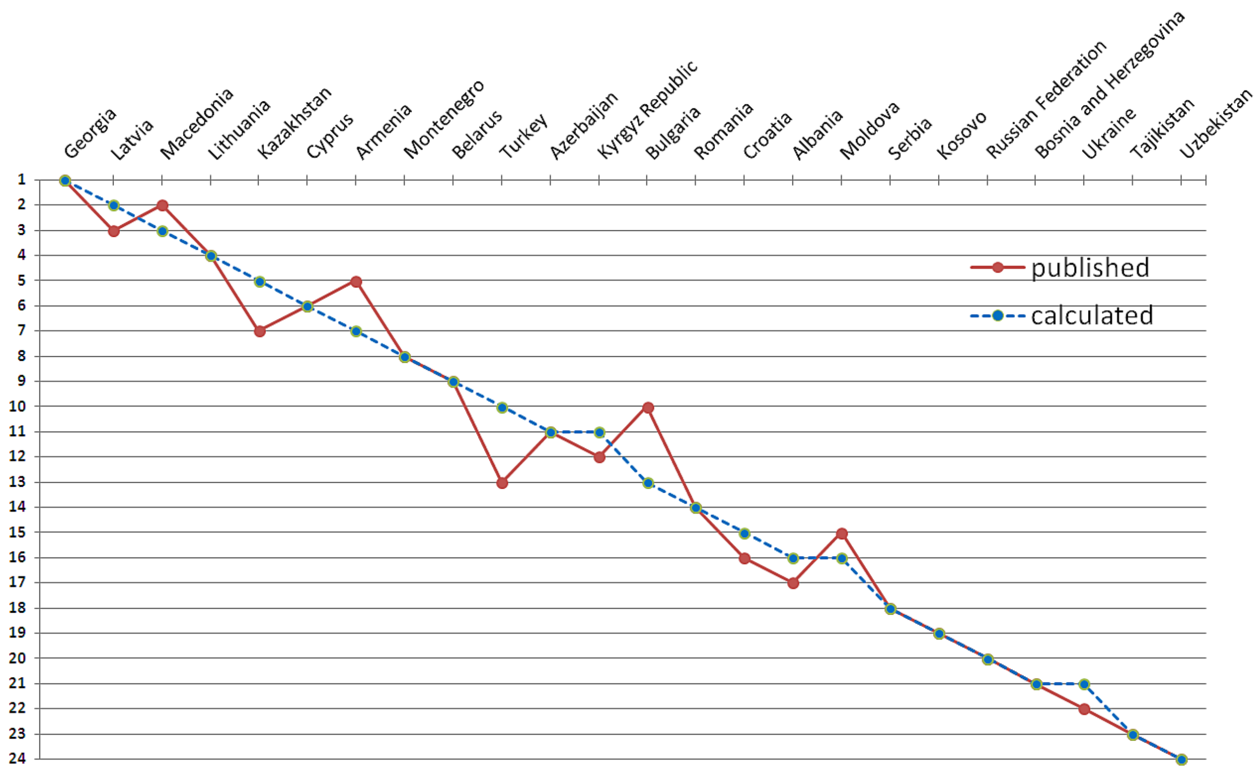

Fig. 2 Comparison of results for equal weights of all indicators

The explanation of these differences is that ranking in [14] averages the country's percentile rankings on all 10 indicators, while giving equal weight to each topic. In general, the average results of each country are fractions and they are rounded to get the index (position in the list) of that country. For example, the averages for Macedonia and Latvia are 7.1 and 6.6. When these averages are rounded both countries have index equal to 7 and they can be ranked as Macedonia positioned above Latvia or vice-versa on equal basis. The solution of the formulated multi-criteria optimization task defines values of aggregated objective function equal to 0.2434783 for Latvia and 0.2652174 for Macedonia. This means Latvia has better objective function value and should be ranked above Macedonia.

Different scenarios of the proposed algorithm could be applied: the DM makes a choice of the "best" country using the preferred ranked list; the DM evaluates a preliminary chosen country accordingly to its position in the ranked list; the DM plays with different sets of weighting coefficients (different preferences) to get preliminary estimation about investment climate in some country. For example, Georgia is on the top of all lists in the described numerical testing and for this example could be considered as the best place to invest. In other words, the proposed approach can be used as investor's tool to simulate different environment conditions helping the investor to make an informed and rational choice.

Experimental study indicates that the proposed algorithm is more informatively efficient in respect of investment attractiveness than other published methods. Investor perception or preference, in the form of multivariate countries estimation is important and the proposed approach is consistent with this.

VII. Conclusion

The paper describes an approach to investment attractiveness estimation based on combinatorial optimization by modeling the investor's decision making behavior. A ranking algorithm based on repeatedly solving of multi-criteria optimization problem using *a priori* aggregation of preference information about the importance of particular indicators is developed. The result of the algorithm execution is list of economics (countries) ranked in respect of investment attractiveness indicators. The defined ranking list of economics could be used to help the investor to make an informed and reasonable choice. The proposed approach is numerically illustrated on the example of indicators data for economics of Eastern Europe and Central Asia. Three different scenarios of user preferences about the importance of economic indicators are tested. The results of numerical testing show the applicability of the proposed algorithm for investment attractiveness defining. Any other economic indicators can be used according to the requirements of different investors.

As a challenge for future work, other multi-criteria solution methods will be tested for effectiveness toward the proposed approach. The algorithm is to be coded as a software tool to help the investors to simulate and play with different economic conditions and indicators, to make a reasonable choice of country to invest.

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Dr. Ivan C. Mustakerov is Associated Professor in the Institute of Information and Communication Technologies of Bulgarian Academy of sciences. Office address: Sofia 1113, Acad. G. Bonchev St., Block 2. E-mail: mustakerov@iit.bas.bg.

Major fields of scientific research: operations research, modeling and optimization, engineering systems design, software systems for information processing.

Dr. Daniela I. Borissova is Associated Professor at the Institute of Information and Communication Technologies of Bulgarian Academy of sciences. Office address: Sofia 1113, Acad. G. Bonchev St., Block 2. E-mail: dborissova@iit.bas.bg.

Major fields of scientific research: decision support systems, modeling and optimization, night vision devices, software systems for information processing, Web-based applications.