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TIME DOMINANCE IN CLASSIFICATION OF DYNAMIC STRUCTURE

ABSTRACT. The idea of time dominance was formulated about twenty years ago and this term means the greater utility value of one „fact" over the other in every moment of strictly defined period of time. The dominance ranking methods are a direct adaptation of the stochastic dominance ranking methods which are used for choice between two statistical distributions. The first application of time dominance was evaluation of investment projects and then – according to the appropriate utility function – selection of one project of the group of others. But there are also other potential fields of application of time dominance methodology – almost all situations where problems of ranking take place. The simplicity and intelligibility of this method is presented through the example of its application to data connected with the sphere of preservation of environment.

Key words: stochastic dominance, time dominance, dynamic structure, preservation of environment

I. STOCHASTIC DOMINANCE

The stochastic dominance methodology is used for comparing various decision alternatives and then for choosing the one, which seems to be the best in the sense of earlier assumed criterion. The way of this comparison is generation of relations between cumulative probability density functions of analysed random variables, presenting the above mentioned alternatives. So, terms of basic importance in this methodology are: the utility function, determined by an aim of just solving problem and probability distribution or probability density function connected with „competing" random variables.

Let us suppose we have to do with two decision alternatives, represented by two probability density functions $f(x)$ and $g(x)$, where $x \in [a, b]$. The utility

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function is denoted as $U(x)$. The main criterion for any decision maker is the expected utility value of each alternative. These expected utilities are as follows:

– expected „income” of first variant $E_f(U)$:

$$E_f(U) = \int_a^b U(x) f(x) dx = U(b) - \int_a^b U'(x) F(x) dx, \tag{1}$$

and

– expected „income” of the second variant $E_g(U)$:

$$E_g(U) = \int_a^b U(x) f(x) dx = U(b) - \int_a^b U'(x) F(x) dx, \tag{2}$$

The difference between (1) and (2) is:

$$E_f(U) - E_g(U) = -\int_a^b U'(x)[F(x) - G(x)]dx \tag{3}$$

Under the assumption that $U'(x) > 0$ (which is the result of the assumed class of utility function) the expected utility value of the first alternative is at least the same as the expected utility value of the second if the condition below is satisfied:

$$\mathbf{F(x) \le G(x) \text{ for all } x \in [a, b]} \tag{4}$$

Condition (4) can be written in a little different form and, in consequence, we obtain stochastic dominance tests:

If:

$$\mathbf{H_1(x) = F(x) - G(x) \le 0 \text{ for all } x \in [a, b],} \tag{5}$$

there exists **STOCHASTIC DOMINANCE OF THE FIRST DEGREE**. That means that the variable with cumulative distribution $F(x)$ dominates the variable with cumulative distribution $G(x)$ at the first level.

If:

$$\mathbf{H_2(x) = \int_a^x H_1(y)dy \le 0 \quad for \quad all \quad x \in [a, b]} \qquad (6)$$

there exists **STOCHASTIC DOMINANCE OF THE SECOND DEGREE**. That means that the variable with cumulative distribution $F(x)$ dominates the variable with cumulative distribution $G(x)$ at the second level.

If:

$$\mathbf{H_3(x) = \int_a^x H_2(y)dy \le 0 \quad for \quad all \quad x \in [a, b]} \qquad (7)$$

there exists **STOCHASTIC DOMINANCE OF THE THIRD DEGREE**. That means that the variable with cumulative distribution F(x) dominates the variable with cumulative distribution G(x) at the third level.

Stochastic dominance relations are unidirectional: the relation of the first degree stands at the same time for all relations of higher degrees but there is no reason to say in the situation of, e.g. fourth degree relation, that it stands for relations of first, second or third degree. Naturally, the lower degree relation is observed between variables the clearer superiority exists there.

Example 1. We have two discrete variables described by probability distributions P_1 and P_2.

Table 1

Examination of stochastic dominance

P_1	P_2	F(x)	G(x)	$H_1(x)$
0.1	0.2	0.1	0.2	–0.1
0.2	0.3	0.3	0.5	–0.2
0.2	0.2	0.5	0.7	–0.2
0.3	0.2	0.8	0.9	–0.1
0.2	0.1	1.0	1.0	0.0

Variables presented in Table 1 are connected by the relation of the first degree stochastic dominance: the $H_1(x)$ function is nonpositive in all points. The first variable dominates the second one, described by probability function P_2. Automatically, we can say that the second variable is dominated by the first one at the second, third and so on, levels of domination.

Example 2. We observe two probability distributions once more.

Table 2

Examination of stochastic dominance

P_1	P_2	$F(x)$	$G(x)$	$H_1(x)$	$H_2(x)$	$H_3(x)$	$H_4(x)$	$H_5(x)$
0.2	0.3	0.2	0.3	–0.1	–0.1	–0.1	–0.1	–0.1
0.3	0.2	0.5	0.5	0	–0.1	–0.2	–0.3	–0.4
0.3	0.1	0.8	0.6	0.2	0.1	–0.1	–0.4	–0.8
0.2	0.4	1	1	0	0.1	0	–0.4	–1.2

This time, differences in cumulative probabilities $H_1(x)$ are of different signs. The same situation happens in the case of $H_2(x)$ function. $H_3(x)$ function satisfies the stochastic dominance test at last, so we have reasons to choose the first variable as the better in the meaning of the third degree stochastic dominance. If the $H_3(x)$ function is nonpositive, the $H_4(x)$ function must be of the same sign and $H_5(x)$ as well. ($H_4(x)$ and $H_5(x)$ functions are built in the same way as functions in conditions (2) and (3) that is as succeeding integrals of $H_3(x)$ function). It is the clearly consequence of unidirectional character of stochastic dominance relations.

II. TIME DOMINANCE

The basic applications of stochastic domination are decision problems in static context but in 1980 there appeared the term of time dominance created by Boren and Hansen (1980; 2; p. 48) and advanced later by Ekern (1981; 3), Jean (1989; 6) and Hajdasinski (1991; 7). In this conception random variables with concrete probabilities are replaced by mutually exclusive investment projects with the same time of duration. Each of the considered projects is described by its cash flow function $x(t)$, discrete or continuous, being the „equivalent" of probability density function of random variable and by chosen by the decision maker utility function $v(t)$, with strictly defined time of realisation $t \in [0, T]$. Succeeding cumulations or integrations of differences in cash flow functions correspond to succeeding cumulations or integrations of differences in cumulative probabilities of random variables.

So, let us assume that:

$A(t)$ – cash flow function of project A,

$B(t)$ – cash flow function of project B,

$v(t) = e^{-rt}$ – utility function of decision maker.

Our way of setting time dominance is the comparison of the expected utility values for each project. This net present value $NPV(r)$, for definite interest rate $r > 0$ is the following:

$$NPV(r) = \int_0^T e^{-rt} A(t)dt - \int_0^T e^{-rt} B(t)dt = \int_0^T e^{-rt} C_0(t)dt \qquad (8)$$

Condition (8) is the equivalent of condition (3) connected with stochastic dominance. $C_0(t)$ is a simple difference between $A(t)$ and $B(t)$. It is intuitively obvious that for any definite r project A is better than project B if the $NPV(r)$ value is positive. If this value is negative we should choose project B. In the situation when $NPV(r)$ value is equal to zero, we could not indicate a better choice. So, in order to answer the question of dominating project, we must execute the indicated integration. As the result of it we get a formula below, where $C_1(t)$ and $C_1(T)$ are equivalent to cumulative probabilities in random variables:

$$\mathbf{NPV(r) = e^{-rT}C_1(T) + r\int_0^T e^{-rt}C_1(t)dt} \qquad (9)$$

So consequently, if:

$$\mathbf{C_1(t) \geq 0 \text{ for all } t \in [0, T]} \qquad (10)$$

the $NPV(r)$ value is positive, and we have reasons to indicate project A as dominating over project B. Condition (10) constitutes **TIME DOMINANCE OF THE FIRST DEGREE.**

Analogously to stochastic dominance methodology we are able to construct tests for higher degrees time dominance relations. General conditions for k-th degree time dominance relation were given by J e a n (1989; 6; p. 141) and are written below:

$$\mathbf{C_i(T) \geq 0 \quad \text{for} \quad i = 1, 2, ..., k-1} \qquad (11)$$

and

$$\mathbf{C_k(t) \geq 0 \quad \text{for all} \quad t \in [0, T].} \qquad (12)$$

The two above formulas constitute **TIME DOMINANCE OF K-TH DEGREE.**

Thus we can see that in time domination method the choice of investment project is quite independent of interest rate r, contrary to other methods. It is a fundamental advantage of it, apart from its simplicity. The problem of continuous model of time and of continuous cash flow function was examined by J e a n (1989; 6), while H a j d a s i n s k i (1991; 7) considered models of discrete character, as well.

Example 3. We examine two investment projects A and B with discrete cash flow functions observed in time t = 0,1,2,3. In order to set time dominance we observed cumulated differences in cash flows.

T a b l e 3

Examination of time dominance

T	$A(t)$	$B(t)$	$C_0(t)$	$C_1(t)$	$C_2(t)$
0	–80	–100	20	20	20
1	5	–5	10	30	50
2	55	70	–25	5	55
3	90	125	–35	–30	25
4	180	130	50	20	45

As the effect of the second cumulation we get positive values of $C_2(t)$ for all observed points of time. So we can talk about time dominance of the second degree and we should take project A for realization.

Hitherto existing applications of time dominance methodology are from the sphere of investment efficiency analysis. But there are other possibilities as well. They appear in all situations where we have a problem of choice and a problem of classification and these problems are connected with time. „Potential application of the time dominance methodology include important decision-making situations, like comparing competitive technologies, ranking alternative financial management policies, selecting geographic locations, designing marketing strategies and evaluating public projects" (1981; 3; p. 1024). It seems possible to apply time dominance methodology as a part of the complex dynamic statistical comparative analysis. Its result can be concerned with the choice of future path of development or can deal with examining phenomena from the past. Other possibility of application could be the classification of dynamic structure of multidimensional feature. The following examination will be an attempt of demonstration of this last possibility.

III. THE QUALITY OF PRESERVATION OF ENVIRONMENT IN CHOSEN CITIES OF POLAND IN YEARS 1992–1996

In order to show the possibility of application of time dominance to the classification of dynamic structure we examined the quality of preservation of environment in some chosen cities in Poland in years 1992–1996. The criterion for selecting these cities was the number of their population in the analysed period. In the examined group there were 42 cities which have the population of 100 thousand or more. The three examined attributes were: the proportional share of dust pollution kept in devices of specified types in the whole of generated dust pollution, the proportional share of cleared industrial and communal sewage in the whole of all generated sewage of these types and the size of industrial waste materials harmful for environment stored at the end of definite year on the ground of works. The obvious utility function in this examination is the subjective opinion that the more generated pollution we neutralize the better the situation is, and the more waste materials we store the vorse the situation is. The initial data were obtained as the result of calculations on the basis of information presented in Statistical Yearbooks of Poland published by GUS in years 1993–1997. The basic characteristics which will be analysed are presented in Tables 4, 5 and 6.

Table 4

Dust pollution kept in devices of specified types (in percentages of whole generated dust pollution)

No	Cities	1992	1993	1994	1995	1996
1	2	3	4	5	6	7
1	Białystok	96.4	94.6	95.5	96.8	97.6
2	Bielsko-Biała	97.7	98.4	98.5	98.4	98.6
3	Bydgoszcz	95.9	95.7	95.3	96.3	96.4
4	Bytom	89.9	86.5	89.2	92.6	95.9
5	Chorzów	89.8	92.9	94.7	97.4	97.9
6	Częstochowa	83.9	84.2	85.1	87.6	90.1
7	Dąbrowa Górnicza	97.4	98.0	97.6	98.3	98.4
8	Elbląg	87.9	89.8	89.6	93.9	94.2
9	Gdańsk	96.7	96.1	96.6	97.6	97.9
10	Gdynia	96.2	96.9	97.1	98.0	97.0
11	Gliwice	93.9	93.9	95.0	96.8	96.1
12	Gorzów Wielkopolski	86.8	89.0	88.0	87.0	87.3
13	Grudziądz	75.7	80.6	71.9	77.2	80.7
14	Jastrzębie Zdrój	98.5	98.3	98.7	98.5	98.4
15	Kalisz	78.1	76.3	79.7	80.3	80.8
16	Katowice	94.0	94.3	94.1	94.3	92.6

Table 4 (contd.)

1	2	3	4	5	6	7
17	Kielce	86.4	93.1	92.3	93.5	95.4
18	Koszalin	78,1	57,4	68,3	69,4	84,2
19	Kraków	94.5	96.0	96.3	96.6	97.3
20	Legnica	88.8	95.0	98.5	98.4	99.0
21	Lublin	95.0	94.0	90.7	92.9	94.2
22	Łódź	93.8	92.2	96.9	98.1	98.3
23	Olsztyn	97.0	96.9	95.9	96.3	96.1
24	Opole	98.4	98.5	98.8	98.6	98.8
25	Płock	93.5	95.0	95.6	94.7	94.7
26	Poznań	93.1	93.7	94.5	95.7	95.3
27	Radom	93.9	96.2	97.5	98.4	91.3
28	Ruda Śląska	98.1	98.3	98.8	98.2	98.0
29	Rybnik	99.0	99.1	98.9	98.9	98.7
30	Rzeszów	94.4	96.1	97.1	97.4	97.8
31	Słupsk	69.8	54.2	27.0	54.1	75.2
32	Sosnowiec	84.4	87.0	87.9	83.2	81.9
33	Szczecin	91.7	94.7	93.8	95.7	95.9
34	Tarnów	96.2	96.8	96.8	95.7	93.2
35	Toruń	93.1	93.8	94.1	94.3	94.6
36	Tychy	95.2	94.9	95.1	94.8	96.3
37	Wałbrzych	82.3	83.0	83.0	87.1	91.0
38	Warszawa	96.1	96.8	96.1	96.9	98.1
39	Włocławek	72.2	77.2	79.8	81.0	75.4
40	Wrocław	94.0	94.2	95.1	95.8	96.2
41	Zabrze	85.0	89.8	91.8	95.0	96.8
42	Zielona Góra	82.6	80.8	82.1	80.1	82.2

S o u r c e: *Statistical Yearbooks of GUS 1993–1997.*

T a b l e 5

Industrial waste materials harmful for environment stored on the ground of works at the end of the year (in thousands tons / km sq.)

No	Cities	1992	1993	1994	1995	1996
1	2	3	4	5	6	7
1	Białystok	18	19	20	22	22
2	Bielsko-Biała	0	0	0	0	0
3	Bydgoszcz	10	10	10	10	10
4	Bytom	645	641	639	640	363
5	Chorzów	397	393	317	281	279
6	Częstochowa	14	14	13	13	12
7	Dąbrowa Górnicza	39	31	32	33	34
8	Elbląg	8	8	8	8	8
9	Gdańsk	55	55	61	58	59
10	Gdynia	0	9	0	9	10
11	Gliwice	653	661	680	695	702

Table (5 contd.)

1	2	3	4	5	6	7
12	Gorzów Wielkopolski	22	23	24	25	26
13	Grudziądz	0	0	0	0	0
14	Jastrzębie Zdrój	1 422	1 541	1 572	1 621	1 669
15	Kalisz	0	0	1	1	1
16	Katowice	115	119	121	124	124
17	Kielce	0	0	0	0	0
18	Koszalin	0	0	0	0	1
19	Kraków	185	186	180	178	178
20	Legnica	69	67	67	68	67
21	Lublin	4	4	4	4	3
22	Łódź	0	1	1	1	1
23	Olsztyn	7	8	8	8	8
24	Opole	0	0	0	0	1
25	Płock	2	3	3	3	4
26	Poznań	3	3	3	3	3
27	Radom	0	0	1	1	1
28	Ruda Śląska	278	279	327	344	371
29	Rybnik	77	83	83	63	63
30	Rzeszów	3	2	2	3	3
31	Słupsk	0	0	0	0	0
32	Sosnowiec	4	3	3	3	3
33	Szczecin	13	13	14	14	14
34	Tarnów	29	29	30	32	34
35	Toruń	2	2	2	2	2
36	Tychy	3	3	3	3	3
37	Wałbrzych	1 016	1 023	1 029	1 034	1 037
38	Warszawa	11	11	11	10	10
39	Włocławek	1	1	1	2	2
40	Wrocław	13	13	14	15	15
41	Zabrze	290	295	299	304	308
42	Zielona Góra	0	0	0	0	0

S o u r c e: *Statistical Yearbooks of GUS 1993–1997.*

T a b l e 6

Cleared industrial and communal sewage carried to surface water (in percentages of generated sewage of thes types)

No	Cities	1992	1993	1994	1995	1996
1	2	3	4	5	6	7
1	Białystok	7.04	7.29	37.6	99.55	99.08
2	Bielsko-Biała	70.8	62.94	60.31	58.99	61.84
3	Bydgoszcz	22.76	20.85	20.22	21.16	20.56
4	Bytom	80.31	73.28	78.48	80.5	83.81
5	Chorzów	28.78	25.26	27.17	25.35	6.18
6	Częstochowa	99.63	99.22	96.28	99.1	100
7	Dąbrowa Górnicza	96.1	96.18	93.13	90.5	94.67

Table 6 (contd.)

1	2	3	4	5	6	7
8	Elbląg	99.14	99.06	100	100	98.15
9	Gdańsk	92.52	95.21	99.41	90.69	81.16
10	Gdynia	90.1	97.66	100	97.32	98.32
11	Gliwice	64.68	51.45	49.57	52.38	55.72
12	Gorzów Wielkopolski	100	93.96	98.33	99.11	99.09
13	Grudziądz	1.89	2.15	3	2.15	2.82
14	Jastrzębie Zdrój	97.64	100	96.9	90.83	100
15	Kalisz	7.5	7.63	7.89	8.93	7
16	Katowice	65.74	68.96	67.93	71.87	74.11
17	Kielce	74.19	77.73	71.22	70.31	98.91
18	Koszalin	95.83	96.49	100	100	100
19	Kraków	77.33	73.99	73.49	71.88	80.28
20	Legnica	99.36	100	99.01	98.94	100
21	Lublin	92.31	94.53	94.33	96.51	100
22	Łódź	0.2	0.2	0.21	0.35	0.37
23	Olsztyn	99.45	99.48	99.01	98.93	100
24	Opole	100	85.38	89.84	96.8	97.58
25	Płock	97.49	96.51	98.58	99.65	99.15
26	Poznań	47.82	72.97	72.12	88.3	99.28
27	Radom	99.61	99.6	99.57	100	96.53
28	Ruda Śląska	58.51	61.64	66.67	67	82.61
29	Rybnik	96.93	90.2	88.51	80.67	74.81
30	Rzeszów	78.43	82.89	88.55	82.78	67.59
31	Słupsk	100	100	100	100	98.86
32	Sosnowiec	70.16	72.82	64.71	65.98	71.69
33	Szczecin	37.58	34.9	35.62	37.7	38.82
34	Tarnów	84.69	78.23	77.12	76.31	74.3
35	Toruń	11.41	10.75	12.03	11.45	9.65
36	Tychy	100	100	97.5	97.94	98.66
37	Wałbrzych	100	100	100	100	100
38	Warszawa	27.15	36.21	45.45	45.24	47.98
39	Włocławek	83.1	84.88	84.88	82.76	79.59
40	Wrocław	97.99	98.04	98.04	98.67	97.57
41	Zabrze	79.46	85.22	85.22	86.74	85
42	Zielona Góra	0	0	0	0	0

S o u r c e: *Statistical Yearbooks of GUS 1993–1997.*

Between every pair of cities we examined time domination relations for each attribute. The way of their setting is shown in Examples 4 and 5.

Example 4. In this example we examine time domination relations between Tarnów and Zabrze. The needed information and all calculations are presented in Tables 7, 8 and 9.

Table 7

Setting time domination in the sphere of clearing sewage

Years	Tarnów	Zabrze	$C_0(t)$	$C_1(t)$	$C_2(t)$	$C_3(t)$	$C_4(t)$	$C_5(t)$	$C_6(t)$
1992	84.69	79.46	5.23	5.23	5.23	5.23	5.23	5.23	5.23
1993	78.23	85.22	–6.99	–1.76	3.47	8.70	13.93	19.16	24.39
1994	77.12	85.22	–8.10	–9.86	–6.39	2.31	16.24	35.40	59.79
1995	76.31	86.74	–10.43	–20.29	–26.68	–24.37	–8.13	27.27	87.06
1996	74.30	85.00	–10.70	–30.99	–57.67	–82.04	–90.17	–62.90	24.16

Table 8

Setting time domination in the sphere of keeping dust pollution

Years	Tarnów	Zabrze	$C_0(t)$	$C_1(t)$
1992	96.20	85.00	11.20	11.20
1993	96.80	89.80	7.00	18.20
1994	96.80	91.80	5.00	23.20
1995	95.70	95.00	0.70	23.90
1996	93.20	96.80	–3.60	20.30

Table 9

Setting time domination in the sphere of storing waste materials

Years	Tarnów	Zabrze	$C_0(t)$
1992	29	290	–261
1993	29	295	–266
1994	30	299	–269
1995	32	304	–272
1996	34	308	–274

In the sphere of clearing sewage Tarnów dominates Zabrze by time domination relation of the sixth degree. Tarnów dominates Zabrze in the sphere of keeping dust pollution, as well. But in this case the relation is of the first degree, so is much more intelligible than in the previous situation.

Considering the amount of stored industrial waste materials the dominating city is this time Zabrze, and the relation is of implicit character. But with respect to the quality of preservation of the environment once again better in Tarnów.

Concluding: in all aspects the quality of preservation is better in Tarnów in confrontation with Zabrze, however, its superiority is of different power in each case.

Example 5. In this example we observe relations between Gdańsk and Lublin. Tables 10, 11 and 12 present all information connected with these two cities.

Table 10

Setting time domination in the sphere of clearing sewage

Years	Gdańsk	Lublin	$C_0(t)$	$C_1(t)$	$C_2(t)$	$C_3(t)$
1992	92.52	92.31	0.21	0.21	0.21	0.21
1993	95.21	94.53	0.68	0.89	1.10	1.31
1994	99.41	94.33	5.08	5.97	7.07	8.38
1995	90.69	96.51	–5.82	0.15	7.22	15.60
1996	81.16	100.00	–18.84	–18.69	–11.47	4.13

Table 11

Setting time domination in the sphere of keeping dust pollution

Years	Gdańsk	Lublin	$C_0(t)$
1992	96.70	95.00	1.70
1993	96.10	94.00	2.10
1994	96.60	90.70	5.90
1995	97.60	92.90	4.70
1996	97.90	94.20	3.70

Table 12

Setting time domination in the sphere of storing waste materials

Years	Gdańsk	Lublin	$C_0(t)$
1992	55	4	51
1993	55	4	51
1994	61	4	57
1995	58	4	54
1996	59	3	56

In all aspects Gdańsk dominates Lublin: in the sphere of clearing sewage by time dominance of third degree, in the sphere of keeping dust pollution and in the sphere of storing waste materials by the implicit domination relations. But considering the other utility function in the last situation we conclude: in two cases Gdańsk is in a better situation and in one case Lublin. So, this time we have some problems with saying in which of the two cities the quality of preservation of the environmental is better.

In the same way we examined all pairs and as a result we obtained three rankings, according to three considered attributes, presented in Table 13. In these orderings the higher the position of the city, the better the quality of preservation of the environment in it. The notation at one position means the same level of „quality" in indicated cities.

Table 13

Specification of rankings of cities

The ranking of cities according to the time dominance in the sphere of:		
Clearing sewage	Keeping dust pollution	Storing waste materials
1	2	3
Wałbrzych	Rybnik	Bielsko-Biała
Słupsk	Jastrzębie Zdrój	Grudziądz
Tychy	Opole	Kielce
Gorzów	Ruda Śląska	Słupsk
Opole	Bielsko Biała	Zielona Góra
Częstochowa	Dąbrowa Górnicza	Koszalin
Radom	Olsztyn	Opole
Olsztyn	Gdańsk	Kalisz
Legnica	Białystok	Radom
Elbląg	Gdynia	Łódź
Wrocław	Tarnów	Gdynia
Jastrzębie Zdrój	Warszawa	Włocławek
Płock	Bydgoszcz	Toruń
Rybnik	Tychy	Płock
Dąbrowa Górnicza	Lublin	Rzeszów
Koszalin	Kraków	Poznań
Gdańsk	Rzeszów	Tychy
Lublin	Katowice	Sosnowiec
Gdynia	Wrocław	Lublin
Tarnów	Radom	Olsztyn
Włocławek	Gliwice	Elbląg
Bytom	Łódź	Bydgoszcz
Zabrze	Płock	Warszawa
Rzeszów	Toruń	Szczecin
Kraków	Poznań	Wrocław
Kielce	Szczecin	Częstochowa
Bielsko-Biała	Bytom	Białystok

Table 13 (contd.)

1	2	3
Sosnowiec	Chorzów	Gorzów
Katowice	Legnica	Tarnów
Gliwice	Elbląg	Dąbrowa Górnicza
Ruda Śląska	Gorzów	Gdańsk
Poznań	Kielce	Legnica
Szczecin	Zabrze	Rybnik
Chorzów	Sosnowiec	Katowice
Warszawa	Częstochowa	Kraków
Bydgoszcz	Zielona Góra	Ruda Śląska
Toruń	Wałbrzych	Zabrze
Kalisz	Kalisz	Chorzów
Białystok	Koszalin	Bytom
Grudziądz	Grudziądz	Gliwice
Łódź	Włocławek	Wałbrzych
Zielona Góra	Słupsk	Jastrzębie Zdrój

In none of the constructed orderings the sequence of cities was the same. Therefore, we verified with the test of signs at level $\alpha = 0.05$ the hypothesis that these orderings describe the same population of cities. Numbers in Table 14 are the succeeding numbers of cities from Tables 4, 5 and 6.

At the level $\alpha = 0.05$ the critical value is $r_{0.05,42} = 12$ so there are no reasons to reject the analysed hypothesis that all three rankings describe the same population of cities. But the problem is that these orderings describe – *de facto* – only the situation in the first year of our period. The reason for this is that the direction of time dominance relation is determined by the first difference in the series. That means that rankings in Tables 13 and 14, with no information about degrees of dominance relations, are a description of static situation in the year 1992. Our notation requires some broadening. Comprehensive descriptions of time dominance relations are written in Tables 15, 16 and 17.

Tables 15, 16 and 17 are symmetrical, so for more convenience only one half is marked. We could read domination relations vertically or horizontally. The vertical way of reading means that below the main diagonal there are cities which are dominated by the city at the top of the column (so cities are presented beginning with the „best" finishing with the „worst"). The lack of notation means the implicit dominance, notation „1" means time dominance of the first degree, „2" – time dominance of the second degree and so on till the notation „9" which means the ninth degree time dominance. The sign „?" appears, when the relation is of the tenth or higher degree. Considering troubles connected with so high domination we marked them as dominations „under the sign of question mark". The sign „x" means the lack of any domination relation. In order to collect all information from three rankings we used the system of points.: for the implicit dominance a city was aworded by 10 points, for the first degree time dominance – 9 points, ..., for ninth degree time dominance – 1 point; for „?" and „x" – 0 points. The total score of all cities is presented in Table 18.

In the context of the assumed utility function the first location in the total score ranking takes Opole: it has 1003 points (1230 points was the upper limit). So during the five examined years in this city the quality of preservation of the environment was the best in Poland (in the sense of our examination of course). The last and the least location at the same time belongs to Chorzów with only 236 points. The median value in constructed series is 553. This value is characteristic in this time for Legnica and Gorzów. Next, the obtained information could be analysed with simple statistical tools. The data prepared in such a way should be then examined by experts in problems of preservation of the environment and by experts of communal policy.

V. CONCLUSION

As a result of application of time dominance methodology to problems of the sphere of preservation of the environment we get the dynamic structure of examined phenomenon. In the first stage we obtained information about relations during a definite period between all interesting for us cities according to each interesting to us attribute. In the second step this information led us for construction of some rankings, which describe only the direction of dominance. The next step led us to building comprehensive tables of domination, showing not only directions but also degrees of domination. And finally, by „system of points" we created a total ranking system of cities, being the global a dynamic description of a group of cities in three aspects during five years. This alternative way of building a dynamic structure of the phenomenon was conducted in a very simple way and its result seems to be rather reliable. The time dominance methodology in other application than in investment project efficiency analysis demands more theoretical studies but they it seem to be worth doing.

T a b l e 14

Examination of population with the test of signs at level $\alpha = \mathbf{0.05}$

Ranking in the sphere of clearing sewage *A*	Ranking in the sphere of keeping dust pollution *B*	Ranking in the sphere of storing waste materials *C*	*A – B*	*A – C*	*B – C*
1	2	3	4	5	6
37	29	2			+
31	14	13			+
36	24	17			+
12	28	31			–
24	2	42			–
6	7	18			–
27	23	24			–
23	9	15			–
20	1	27			–
8	10	22			–
40	34	10			+
14	38	39			–
25	3	35			–
29	36	25			+
7	21	30			–
18	19	26			–
9	30	36	–	–	–
21	16	32	+	–	–
10	40	21	–	–	+
34	27	23	+	+	+
39	11	8	+	+	+
4	22	3	–	+	+
41	25	38	+	+	–
30	35	33	–	–	+
19	26	40	–	–	–
17	33	6	–	+	+
2	4	1	–	+	+
32	5	12	+	+	–
16	20	34	–	–	–
11	8	7	+	+	+
28	12	9	+	+	+
26	17	20	+	+	–
33	41	29	–	+	+
5	32	16	–	–	+
38	6	19	+	+	–
3	42	28	–	–	+
35	37	41	–	–	–
15	15	5	x	+	+
1	18	4	–	–	+
13	13	11	x	+	+
22	39	37	–	–	+
42	31	14	+	+	+
			$r^+ = 19$ $r^- = 21$	$r^- = 20$ $r^+ = 22$	$r^- = 20$ $r^+ = 22$

Table 15

Ranking of cities according to time dominance in the sphere of clearing industrial and communal sewage

Cities	Wa	Słu	Ty	Go	Op	Cz	Ra	Ol	Le	Elb	Wr	Ja	Pło	Ry	Dą	Ko	Gd	Lu	Gd	Tar	Wł	Byt	Za	Rz	Kr	Kie	Bie	Sos	Kat	Gli	Ru	Po	Szc	Ch	Wa	By	Tor	Kal	Bia	Gr	Łó	Zie
Wałbrzych	x																																									
Słupsk		x																																								
Tychy			x																																							
Gorzów		1	1	x																																						
Opole					x																																					
Częstochowa		1	2	?	?	x																																				
Radom			5	?	?	?	x																																			
Olsztyn			1	3	?	?	?	x																																		
Legnica			4	?	?	?	2	?	x																																	
Elbląg					?		2	3	2	x																																
Wrocław			2		?	1	1				x																															
Jastrzębie Z.		1	1	4	?	1	1	1		1	?	x																														
Płock		1	1	3	?	1	1	1	1	1	2	3	x																													
Rybnik					2									x																												
Dąbrowa G.					9									?	x																											
Koszalin		1	1	2	2	1	1	1	1	1	2	3	2	?	5	x																										
Gdańsk			1	1	?	1		1	1		1	1	1	7	1		x																									
Lublin			1	1	4		1			1	1	1	1	6	2		3	x																								
Gdynia			1	2		1	1	1	1	1	1	1	1	6	3	1	?	7	x																							
Tarnów																				x																						
Włocławek														1						?	x																					
Bytom														1						2	1	x																				
Zabrze														1			1			6	2	?	x																			
Rzeszów														1						5	1	?	1	x																		
Kraków														1						1	1	1		1	x																	
Kielce		1	1		1		1			1	1			1	1		1		1	2	1	1	1	1	3	x																
Bielsko B.																											x															
Sosnowiec																								1			?	x														
Katowice																								1		1	6	2	x													
Gliwice																														x												
Ruda Śl.														1						1	1			1	1		2	1	1	8	x											
Poznań		1	1	1	1		1			2	1	1		1	1		1		1	1	1	1	1	1	2	1	3	2	2	6	5	x										
Szczecin																																	x									
Chorzów																																		x								
Warszawa																																	3	?	x							
Bydgoszcz																																		1		x						
Toruń																																		1			x					
Kalisz																																						x				
Białystok		1	1		1		1			1		1		1	1		1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	?	?	x			
Grudziądz																																								x		
Łódź																																									X	
Zielona G.																																										x

Table 16

Ranking of cities according to time dominance in the sphere of keeping dust pollution

Cities	Ry	Ja	Op	Ru	Bi	Dą	Ol	Gd	Bi	Gd	Ta	Wa	By	Ty	Lu	Kr	Rz	Ka	Wr	Ra	Gl	Łó	Pł	To	Po	Sz	By	Ch	Le	El	Go	Ki	Za	So	Cz	Zi	Wa	Ka	Ko	Gr	Wł	Sł
Rybnik	X																																									
Jastrzębie Z.		x																																								
Opole	1	7	x																																							
Ruda Śl.		1		x																																						
Bielsko B.		1		1	x																																					
Dąbrowa G.				1		x																																				
Olsztyn							x																																			
Gdańsk							3	x																																		
Białystok							1		x																																	
Gdynia							5	6	?	x																																
Tarnów											x																															
Warszawa							2	2	?			x																														
Bydgoszcz							1		8		2		x																													
Tychy							1		1		1			x																												
Lublin															x																											
Kraków							1		2	1	2		2	7	?	x																										
Rzeszów							2	1	3		2	1	3	8	?	?	x																									
Katowice															6			x																								
Wrocław							1				1			1	7			?	x																							
Radom						1	1	1	3	1	2	2	2	6	5	4	6		?	x																						
Gliwice											1		1	4	5	1		7	2	1	x																					
Łódź				1			1	1	1	1	2	1	1	2	5	1	1	4	3	2	3	x																				
Płock									1		1		1	1	6			8	4	1	?	?	x																			
Toruń											1				3			2				2		x																		
Poznań											1			1	4			2		1		3	1	?	x																	
Szczecin									1		1			1	3			2	1	1	1	1	1	2	1	x																
Bytom											1				1			1		1			1	1	1		x															
Chorzów							1		1	1	1	1	1	1	2	1	1	2	1	1	1	1	1	2	2	2	?	x														
Legnica		1	1	1	1	1	1	1	1	1	2	1	2	2	3	1	1	3	2	2	2	2	2	3	3	3	?	?	x													
Elbląg											1				1			1									4			x												
Gorzów																											1				x											
Kielce											1				1			1		1		1	1	1	1		6	1		1	?	x										
Zabrze											1				1			1		1			1	1	1		3						x									
Sosnowiec																											1							x								
Częstochowa																															1			2	x							
Zielona G.																																		1		x						
Wałbrzych																															1			2	1		x					
Kalisz																																				1		x				
Koszalin																																		1		1		1	X			
Grudziądz																																						2	?	x		
Włocławek																																				1		1	?	2	x	
Słupsk																																										x

Table 17

Ranking of cities according to time dominance in the sphere of storing industrial waste materials

Cities	Ja	Wa	Gl	By	Ch	Za	Ru	Kr	Ka	Ry	Le	Gd	Dą	Ta	Go	Bi	Cz	Wr	Sz	Wa	By	El	Ol	Lu	So	Po	Ty	Rz	Pł	To	Wł	Gd	Łó	Ka	Ra	Ko	Op	Bi	Gr	Ki	Sł	Zi
Jastrzębie Z.	X																																									
Wałbrzych		x																																								
Gliwice			x																																							
Bytom				x																																						
Chorzów					x																																					
Zabrze					1	x																																				
Ruda Śl.					1		x																																			
Kraków								x																																		
Katowice									x																																	
Rybnik										x																																
Legnica										1	x																															
Gdańsk												x																														
Dąbrowa G.													x																													
Tarnów														x																												
Gorzów															x																											
Białystok																x																										
Częstochowa																	x																									
Wrocław																	3	x																								
Szczecin																	2		x																							
Warszawa																				x																						
Bydgoszcz																					x																					
Elbląg																						x																				
Olsztyn																							x																			
Lublin																								x																		
Sosnowiec																									x																	
Poznań																										x																
Tychy																										x	x															
Rzeszów																												X														
Płock																								1	1	1	1	1	x													
Toruń																														x												
Włocławek																															x											
Gdynia																						1	1	3	4	5	5	6		?	?	x										
Łódź																																	x									
Kalisz																																		x								
Radom																																		x	x							
Koszalin																																				x						
Opole																																				x	x					
Bielsko B.																																						x				
Grudziądz																																						x	x			
Kielce																																						x	x	x		
Słupsk																																						x	x	x	x	
Zielona G.																																						x	x	x	x	x

Table 18

The total score of cities

Cities	Points for storing waste materials	Points for clearing sewage	Points for keeping dust pollution	Total score
1	2	3	4	5
Opole	350	264	389	1 003
Olsztyn	220	322	329	871
Tychy	250	366	253	869
Bielsko-Biała	370	128	369	867
Radom	330	327	208	865
Gdynia	265	227	315	807
Słupsk	370	392	0	762
Płock	275	285	183	742
Dąbrowa Górnicza	120	256	358	734
Rybnik	90	232	409	731
Rzeszów	270	173	250	693
Jastrzębie Zdrój	0	289	390	679
Gdańsk	110	233	328	671
Wrocław	167	291	207	665
Lublin	230	233	195	658
Elbląg	210	311	119	640
Kielce	370	157	100	627
Koszalin	350	259	10	619
Tarnów	130	191	286	607
Gorzów	140	337	98	575
Legnica	99	324	130	553
Częstochowa	160	324	69	553
Ruda Śląska	59	104	376	539
Bydgoszcz	200	59	277	536
Włocławek	300	201	10	511
Poznań	250	99	161	510
Łódź	320	10	180	510
Toruń	290	40	160	490
Kraków	70	163	242	475
Wałbrzych	10	410	50	470
Białystok	150	30	288	468
Sosnowiec	240	134	74	448
Zielona Góra	370	0	57	427
Szczecin	178	86	155	419
Grudziądz	370	20	18	408
Katowice	80	126	196	402
Kalisz	330	30	36	396
Zabrze	49	195	90	334
Bytom	30	176	115	321
Gliwice	20	105	193	318
Warszawa	190	69	294	288
Chorzów	40	67	129	236

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DOMINACJA CZASOWA W KLASYFIKACJI STRUKTURY DYNAMICZNEJ

Koncepcja dominacji czasowej opracowana została w latach osiemdziesiątych jako adaptacja coraz popularniejszej metody dominacji stochastycznych do kontekstu dynamicznego. Pojęcie dominacji czasowej oznacza większą użyteczność jednego zjawiska w porównaniu z innymi w każdym momencie ściśle określonego przedziału czasu. Pierwszym obszarem zastosowania dominacji czasowej była ocena projektów inwestycyjnych wraz ze wskazaniem – w myśl określonego kryterium – projektu najlepszego. Jednakże zastosowanie metodologii dominacji czasowej może mieć miejsce także w wielu innych sytuacjach – praktycznie wszędzie tam, gdzie pojawia się problem wskazania zjawiska rozwijającego się, zgodnie z założoną przez decydenta funkcją użyteczności, „najlepiej" w badanym czasie. Prostotę stosowania oraz czytelność wyników uzyskiwanych w toku badania dominacji czasowych prezentuje przykład zaczerpnięty z dziedziny ochrony środowiska.