Measuring Efficiency of Organizational Units in Forestry by Nonparametric Model

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Abstract – Nacrtak

This paper assesses the efficiency of basic organizational units in the Croatian forestry, forest offices, by applying Data Envelopment Analysis (DEA). DEA is a nonparametric methodology for measuring relative efficiency of comparable decision making units with more inputs and outputs. The relative efficiency of compared forest offices is calculated with the most frequently used DEA models – CCR and BCC model. According to the results of global technical efficiency, obtained by CCR model, average relative efficiency amounts to 0.829. Local pure technical efficiency, obtained by BCC model is 0.904, and scale efficiency is 0.919. The results also include the calculation of efficiency frontier, frequency of efficient units in reference set of inefficient units, determination of sources and values of inefficiencies, influence of the forest offices' structural characteristics on their efficiency and the average efficiency of forest offices grouped with respect to the forest administrations and regions they belong to. The research reveals DEA as a powerful multi criteria decision making tool and a possible, very valuable support in forest management.

Key words: forestry, forest management, efficiency, Data Envelopment Analysis (DEA)

1. Introduction – *Uvod*

Determination of efficiency has become increasingly important in many areas of human activity. Approach to this problem is particularly interesting when there are no clear success parameters, and when the efficiency of using several different resources/inputs is measured for achieving several different outputs. In such measurements, we are always interested in determining the degree of efficiency of individual organizations, institutions, associations, etc. in relation to others acting under similar conditions. In doing so, the compared objects are presented through data on used resources/inputs and data on achieved outputs.

In forestry, the determination of efficiency of forestry companies is extremely complex because of multiple goals of forest management. The principle of sustainable development represents the management and use of forests and forest land in the way to preserve their biological diversity, productivity, regeneration capability, vitality and potential in order to enable forests to fulfill now and in future their key economic, ecological and social functions. The above stated makes the conditions of forest management increasingly demanding and imposes the necessity of continuous analyses of all relevant efficiency indicators.

In the last few decades, forest management has been focused on multifunctional use and general benefits of forests. Due to multiple benefits and advantages offered by forests, as well as the non-market nature of a part of these outputs, the measurement of efficiency in forestry is highly demanding. In such conditions, it is pretty difficult to apply conventional economic methods, such as cost-benefit analysis, internal rate of return and others for determining efficiency. The right evaluation method must be selected in order to determine whether the resources are used efficiently.

Taking into consideration multiple inputs and multiple outputs of forest management, in this paper Data Envelopment Analysis (DEA) was applied for determining the efficiency of forest management units. DEA represents a methodology suitable for the efficiency analysis of numerous production units, but not traditionally used in forestry. Although it was first applied in the forestry sector in 1986 (Rhodes), the number of papers based on measuring the efficiency by non-parametric techniques, such as DEA, is still very limited in forestry literature. The basic idea is to determine the efficiency level of individual DMUs[1] based on the relationship between a complex input and a complex output.

Data Envelopment Analysis, as the technique for measuring productivity and efficiency, is widely applied in many areas. It was used, for example, for making comparisons between organizations (Sheldon 2003), companies (Galanopoulos et al. 2005), regions and countries (Vennesland 2005). For determining business efficiency it was applied in banking (Davosir 2006), agriculture (Bahovec and Neralić 2001), wood industry (Diaz-Balteiro et al. 2006), schooling (Glass et al. 1999), etc. In DEA bibliography (Tavares 2002) there are approximately 3,200 published DEA papers. However, in the area of management of renewable natural resources, it is still not sufficiently present. In forestry literature there is only a limited number of DEA papers (LeBel 1998, Kao 2000, Lee 2005, Šporčić 2007), and it yet has to be introduced and accepted in forestry as a management tool at a strategic and operating level of decision making.

2. Material and methods – *Materijal i metode*

2.1 DEA methodology – *Metodologija analize omeđivanja podataka (AOMP)*

DEA models are linear programming methods that calculate the efficiency frontier of a set of DMUs and evaluate the relative efficiency of each unit, therby allowing a distinction to be made between efficient and inefficient DMUs. Those identified as »best practice units« (i.e., those determining the frontier) are given a rating of one, whereas the degree of inefficiency of the rest is calculated on the basis of the Euclidian distance of their input-output ratio from the frontier (Coelli et al. 1998).

Compared to regression or stochastic frontier analysis methods, DEA shows several advantages. First, DEA allows handling multiple inputs and outputs (with different units) in a noncomplex way. Second, DEA does not require any initial assumption about a specific functional form linking inputs and outputs. The heart of the analysis lies in finding the »best« virtual producer for each real producer. If the virtual producer is better than the original producer by either making more output with the same input, or making the same output with less input then the original, producer is inefficient. While a typical statistical approach (regression analysis) is based on average values, DEA is an extreme point method and compares each producer with only the »best« producers. Efficiency is determined relatively with respect to other production units in the observed group.

Since DEA was introduced by Charner, Cooper and Rhodes (Charnes et al. 1978) several analytical models have been developed depending on the assumptions underlying the approach. For instance, the orientation of the analysis toward inputs or outputs, the existence of constant or variable (increasing or decreasing) returns to scale and the possibility of controlling inputs. According to Farrell (1957), technical efficiency represents the ability of a DMU to produce maximum output given a set of inputs and technology (output oriented) or, alternatively, to achieve maximum feasible reductions in input quantities while maintaining its current levels of outputs (input oriented). In this study, output oriented DEA seems more appropriate, since it is more reasonable to argue that forest area, growing stock and other inputs should not be decreased. Instead, the goal of forest sector should be increased outputs of forest management, and improved general state of forests.

Given the selected orientation and the diversity of units characterizing our example, we first applied CCR model proposed by Charnes et al. (1978). This model assumes constant returns to scale. Following Cooper et al. (2003), we begin by the commonly used measure of efficiency (output/input ratio) and we try to find out the corresponding weights by using linear programming in order to maximize the ratio. To determine the efficiency of n units (forest offices) n linear programming problems must be solved to obtain the value of weights (v_i) associated with inputs (x_i), as well as the value of weights (u_r) associated with the outputs (y_r). Assuming m inputs and s outputs and transforming the fractional programming model into a linear programming model, the CCR (Charnes–Cooper–Rhodes) model can be formulated as (Cooper et al. 2003):

$$\text{Max} \quad \Theta = u_1 y_{10} + \ldots + us\, y_{s0}$$

$$\text{Subject to:} \quad v_1 x_{10} + \ldots + v_m x_{m0} = 1$$

$$u_1 y_{1j} + \ldots + u_s y_{sj} - v_1 x_{1j} - \ldots - v_m x_{mj} \le 0 \quad (j = 1, 2, \ldots, n)$$

$$v_1, v_2, \ldots, v_m \ge 0$$

$$u_1, u_2, \ldots, u_s \ge 0 \qquad (1)$$

[1] DMU is any production or non-production unit that uses certain inputs so as to achieve certain outputs.

Due to lack of information concerning the form of the production frontier, an extension of CCR model, Banker–Charnes–Cooper model was also used. This model incorporates the property of variable returns to scale. The basic formulation of the model, best known as the BCC model is as follows:

$$\text{Max} \quad \Theta = u_1 y_{10} + ... + u_s y_{s0} - u_0$$

$$\text{Subject to:} \quad v_1 x_{10} + ... + v_m x_{m0} = 1$$

$$u_1 y_{1j} + ... + u_s y_{sj} - v_1 x_{1j} - ... - v_m x_{mj} - u_0 \leq 0 \quad (j = 1, 2,..., n)$$

$$v_1, v_2,..., v_m \geq 0$$

$$u_1, u_2,..., u_s \geq 0 \quad (2)$$

Where u_0 is the variable allowing identification of the nature of the returns to scale. This model does not predetermine if the value of this variable is positive (increasing returns) or is negative (decreasing returns). The formulation of the output oriented models can be derived directly from models described in (1) and (2), see Cooper et al. (2003).

In this study, two measures of efficiency are applied – technical and scale efficiency (SE). Scale efficiency is the ratio between CCR and BCC efficiencies. Measurement of allocative efficiency requires data on production costs which were not available in our data set. For computing the applied models, DEA Excel Solver software was used.

2.2 Sample selection and data description – *Izbor uzorka i opis podataka*

State forests in the Republic of Croatia (RC) are mostly managed by the company Hrvatske šume d.o.o. Zagreb (Croatian forests Ltd.) – they account for approximately 80% of the total forest-covered area or 1,991,537 ha. The company Croatian forests consists of: headquarters in Zagreb, 16 regional forest administrations (FA) and a total of 169 forest offices (FO). In the current three-layer organization of the Croatian forestry, forest office is the organizational unit in which the basic tasks of forestry activities are carried out and most income and direct costs of forest management are incurred in.

The efficiency analysis of selected forest offices is carried out based on the information adopted from the Croatian forests' Ltd. reports for the year 2006. Additional applications and more robust data may provide additional insights for the evaluation of forest management.

The research includes 48 forest offices. The selected forest offices are the representatives of four main regions in the Croatian forestry: lowland flood-prone forests (I), hilly forests of the central part (II), mountainous forests (III) and Karst/Mediterranean forests (IV). Each region is represented by two forest administrations i.e. by six forest offices from each forest administration. The sample of organizational units and data involved in this research is shown in Table 1.

Inputs and outputs were selected so as to reflect business activities of the investigated decision making units – forest offices as the basic organizational units of the Croatian forestry, which perform the basic professional and technical operations in forest management (regeneration and silviculture of forests, wood harvesting) in a certain part of the forest economic area of RC, and where most income is achieved and direct costs incurred from the core business activity of forest management.

According to the *Forest Act*, along with conventional production of wood, forest management must also provide additional outputs. They are related to silviculture, protection and use of forests and forest land for construction and maintenance of forest infrastructure, all in accordance with general European criteria for ensuring sustainable forest management. Also, the goal of Croatian forests ltd. and its administrations and offices is business profitability. Most income comes from sold wood and hence the segment related to maintaining and enhancing the production function of forests (increment of growing stock) becomes increasingly important. Accordingly, the inputs and outputs considered in this example are:

Inputs:

⇒ Land, I1 – forest area in thousand hectares

⇒ Growing stock, I2 – volume of forest stock in cubic meters per hectare

⇒ Expenditures, I3 – money spent in hundred-thousand Croatian kunas (HRK 7.4 ≈ EUR 1)

⇒ Labor, I4 – number of employees in persons

Outputs:

⇒ Revenues, O1 – yearly income in hundred-thousand Croatian kunas (HRK 7.4 ≈ EUR 1)

⇒ Removal, O2 – timber harvested in cubic meters per hectare

⇒ Investments in infrastructure, O3 – forest roads built in kilometers

⇒ Biological renewal of forests, O4 – area of conducted silvicultural and protection works in hectares.

There are 48 forest offices evaluated in this model. For the basic DEA models, the number of offices (units under consideration) should be a minimum of 3 to 5 times the total number of input and output fac-

Table 1 Input and output data of DMUs selected for efficiency measurement
Tablica 1. *Podaci za input i output varijable promatranih donositelja odluke*

DMU	Inputs – *Inputi*				Outputs – *Outputi*			
	Area – *Površina*	Growing stock – *Drvna zaliha*	Costs – *Troškovi*	Employees – *Zaposleni*	Income – *Prihod*	Removal – *Etat*	Investments – *Investicije*	Biological renewal – *Biološka obnova*
	I1, 10^3 ha	I2, m^3/ha	I3, 10^5 kn	I4, N	O1, 10^5 kn	O2, m^3/ha	O3, km	O4, ha
Lowland flood-prone forests (I) – *Ravnične poplavne šume (I)*								
Forest administration Vinkovci (A) – *Uprava šuma podružnica Vinkovci (A)*								
1. Gunja	5.84	234.00	300.10	68	315.51	4.30	1.80	547.34
2. Otok	10.72	418.00	470.31	100	538.41	7.13	0.00	3846.34
3. Strizivojna	4.31	294.00	149.90	40	160.61	4.42	0.00	510.00
4. Strošinci	4.84	394.00	141.83	40	141.04	4.28	1.21	493.87
5. Vinkovci	5.70	234.11	219.23	77	226.77	4.98	0.00	1748.59
6. Županja	6.54	364.00	177.64	61	393.10	8.78	0.00	583.70
Forest Administration Nova Gradiška (B) – *Uprava šuma podružnica Nova Gradiška (B)*								
7. N. Gradiška	12.39	242.95	320.47	85	288.71	5.12	3.10	1221.10
8. N. Kapela	8.40	218.75	151.21	71	130.73	3.61	0.00	229.98
9. Novska	11.73	263.02	289.54	64	320.66	4.04	0.70	649.10
10. Okučani	6.56	276.00	124.73	26	144.76	3.91	0.98	91.69
11. S. Brod	6.23	210.00	217.88	61	229.30	5.21	0.00	461.13
12. Trnjani	5.77	265.00	145.37	55	128.97	3.40	1.00	237.00
Hilly forests of the central part (II) – *Brdske šume središnjega dijela (II)*								
Forest Administration Zagreb (C) – *Uprava šuma podružnica Zagreb (C)*								
13. D. Stubica	2.60	239.04	23.24	12	21.12	2.47	0.00	51.00
14. Krapina	4.47	248.00	115.63	37	100.67	5.01	2.27	457.00
15. Novoselec	10.50	211.03	243.74	63	289.85	4.89	2.00	991.28
16. Popovača	7.64	201.00	158.69	52	168.71	3.24	3.00	829.00
17. Samobor	6.46	232.00	85.62	21	75.59	3.61	1.72	179.55
18. Zagreb	6.59	270.00	166.56	35	140.90	4.09	0.00	269.12
Forest Administration Koprivnica (D) – *Uprava šuma podružnica Koprivnica (D)*								
19. Čakovec	3.36	139.00	59.97	23	45.62	2.41	0.00	679.60
20. Ivanec	2.86	235.00	79.96	22	61.49	4.54	0.00	41.93
21. Koprivnica	6.53	331.00	219.34	65	215.91	5.05	0.00	556.06
22. Križevci	9.78	298.68	235.18	67	255.43	5.24	5.50	679.87
23. Ludbreg	5.00	271.00	129.40	35	123.20	4.30	0.50	380.00
24. Varaždin	5.12	187.00	108.90	37	85.73	1.71	0.00	119.82
Mountainous forests (III) – *Gorske šume(III)*								
Forest Administration Delnice (E) – *Uprava šuma podružnica Delnice (E)*								
25. Gerovo	7.04	316.13	181.84	53	202.73	6.21	0.00	118.17
26. Gomirje	5.43	297.30	119.95	39	118.33	4.58	0.00	55.92
27. Klana	6.81	251.12	96.88	38	79.79	2.82	3.50	59.08
28. Mrkopalj	9.25	314.00	179.28	50	190.23	4.92	0.00	894.00
29. Prezid	5.57	336.45	127.39	44	128.10	5.10	0.00	91.00
30. R. Gora	6.20	361.00	167.88	44	177.89	5.34	0.26	48.00
Forest Administration Gospić (F) – *Uprava šuma podružnica Gospić (F)*								
31. Brinje	17.25	208.00	215.07	43	212.38	2.55	7.10	390.85
32. D. Lapac	20.07	193.57	172.41	41	213.71	1.89	9.24	40.35
33. Gospić	34.95	142.00	268.40	59	225.58	0.99	6.00	389.00
34. Gračac	49.87	140.66	204.33	45	167.67	0.77	4.15	329.64
35. Korenica	25.05	171.92	299.38	50	289.70	1.60	15.73	190.59
36. Udbina	20.99	144.62	268.05	61	246.95	1.67	22.59	139.23
Karst/Mediterranean forests (IV) – Krške/mediteranske šume *(IV)*								
Forest Administration Buzet (G) – *Uprava šuma podružnica Buzet (G)*								
37. Buje	7.55	75.34	58.56	33	61.52	0.12	0.00	307.81
38. Buzet	2.63	129.98	49.26	15	47.09	1.02	0.00	97.70
39. Cres-Lošinj	9.36	82.91	40.04	13	39.74	0.21	0.00	205.00
40. Opatija	9.04	154.00	76.53	24	77.33	1.23	0.00	99.00
41. Poreč	7.05	77.17	42.50	19	45.32	0.10	0.00	118.59
42. Rovinj	6.55	76.53	39.70	16	44.00	0.03	0.00	120.00
Forest Administration Split (H) – *Uprava šuma podružnica Split (H)*								
43. Brač	9.61	81.54	27.67	8	27.72	0.00	0.00	30.21
44. Dubrovnik	19.51	108.16	44.09	9	45.45	0.00	0.00	115.94
45. Makarska	7.24	115.00	40.81	13	50.85	0.00	1.35	198.15
46. Sinj	44.14	51.85	67.19	27	71.95	0.01	7.30	113.86
47. Šibenik	28.14	91.57	53.01	19	60.69	0.00	0.00	105.00
48. Zadar	28.72	121.63	138.33	27	118.17	0.02	6.48	157.31

Table 2 Descriptive statistics of the variables used in the DEA model
Tablica 2. *Statistika inputa i outputa uključenih u model AOMP*

Variable *Varijabla*	Mean *Aritmetička sredina*	Minimum *Najmanja vrijednost*	Maximum *Najveća vrijednost*	Total *Ukupno*
Inputs – *Inputi*				
Area – *Površina*, 10^3 ha	11.42 ± 10.36	2.60	49.87	547.96
Growing stock – *Drvna zaliha*, m^3/ha	214.98 ± 91.94	51.85	418.00	-
Costs, – *Troškovi*, 10^5 kn	152.35 ± 93.61	23.24	470.31	7312.99
Employees – *Zaposleni, N*	42 ± 21	8	100	2007
Outputs – *Outputi*				
Income – *Prihod*, 10^5 kn	157.20 ± 106.40	21.12	538.41	7545.68
Removal – *Etat*, m^3/ha	3.06 ± 2.19	0.00	8.78	-
Investments – *Investicije*, km	2.24 ± 4.29	0.00	22.59	107.48
Biological renewal – *Biološka obnova*, ha	422.26 ± 606.34	30.21	3846.34	20268.4

tors. Thus, we have limited the total number of inputs and outputs to eight factors.

Table 2 presents the descriptive statistics of the variables used in the analysis. A wide variation in both inputs and outputs is noticeable. The input use is in some cases twenty times larger than that used by other offices, while variation in output variables is even higher. Such variation in the level of input and output implies that there are big differences between conditions under which individual forest offices operate. These differences are not unexpected, since the sample involves all representative areas managed by Croatian forests. However, it may also be a sign of bad management of resources in individual forest offices.

3. Results – *Rezultati*

3.1 Technical and scale efficiency – *Tehnička i efikasnost s obzirom na opseg djelovanja*

Technical and scale efficiency were determined individually for each forest office. Results obtained by the application of the output-oriented DEA are given in Table 3.

The average CCR efficiency of the investigated forest offices is 0.829, which means that an average (assumed) forest office should only use 82.9% of the currently used quantity of inputs and produce the same quantity of the currently produced outputs, if it wishes to do business at the efficiency frontier. In other words, this average organizational unit, if it wishes to do business efficiently, should produce 20.6%[2] more output with the same input level.

According to the BCC model, the average efficiency is 0.904. This means that an average forest office should only use 90.4% of the current input and produce the same quantity of output, if it wishes to be efficient. In other words, to be BCC efficient it should produce 10.6%[3] more outputs with the same inputs.

In spite of a relatively high mean efficiency (83 or 90%) and regardless of the used model (CCR or BCC), the lowest level of relative efficiency ranges between 0.407 (CCR) and 0.524 (BCC). This implies firstly that individual units can reduce the level of used input up to 59.3% or 47.6%, without affecting the output level, and secondly that there are significant differences in production and business activities between the analyzed units.

According to the CCR model, 15 forest offices are relatively efficient (31%), while a total of 24 units (50%) are rated '1.000' according to the BCC model. Incompatibility between CCR and BCC efficiency is most conspicuous with forest offices with extremely low values of one or more input variables. According to the model with variable returns (BCC), the efficiency of such units is much higher than according to the model with constant returns (CCR). This may indicate the influence of size or volume of activities of the observed units on the level of their efficiency, but it can also mean that the BCC model with the se-

[2] It can be easily obtained that 20.6% = (1–0.829)/0.829

[3] It can be easily obtained that 10.6% = (1–0.904)/0.904

Table 3 Relative efficiency of forest offices
Tablica 3. *Relativna efikasnost organizacijskih jedinica*

Forest offices *Šumarije* (DMU)	Efficiency – *Efikasnost*			Forest offices *Šumarije* (DMU)	Efficiency – *Efikasnost*		
	CCR model	BCC model	SE model		CCR model	BCC model	SE model
1. Gunja	1.000	1.000	1.000	25. Gerovo	0.814	0.836	0.974
2. Otok	1.000	1.000	1.000	26. Gomirje	0.721	0.726	0.993
3. Strizivojna	0.831	0.926	0.897	27. Klana	0.807	0.820	0.984
4. Strošinci	0.826	0.865	0.955	28. Mrkopalj	0.810	0.827	0.979
5. Vinkovci	1.000	1.000	1.000	29. Prezid	0.738	0.762	0.969
6. Županja	1.000	1.000	1.000	30. R. Gora	0.755	0.782	0.965
7. Nova Gradiška	0.952	0.981	0.970	31. Brinje	0.866	0.883	0.981
8. Nova Kapela	0.677	0.723	0.936	32. Donji Lapac	0.990	1.000	0.990
9. Novska	0.924	0.929	0.995	33. Gospić	0.984	0.996	0.988
10. Okučani	1.000	1.000	1.000	34. Gračac	0.779	0.786	0.992
11. Slavonski Brod	1.000	1.000	1.000	35. Korenica	1.000	1.000	1.000
12. Trnjani	0.561	0.590	0.951	36. Udbina	1.000	1.000	1.000
13. Donja Stubica	1.000	1.000	1.000	37. Buje	0.745	1.000	0.745
14. Krapina	1.000	1.000	1.000	38. Buzet	0.501	1.000	0.501
15. Novoselec	1.000	1.000	1.000	39. Cres-Lošinj	0.695	1.000	0.695
16. Popovača	0.879	0.897	0.981	40. Opatija	0.500	0.593	0.844
17. Samobor	1.000	1.000	1.000	41. Poreč	0.568	1.000	0.568
18. Zagreb	0.756	0.769	0.984	42. Rovinj	0.595	1.000	0.595
19. Čakovec	1.000	1.000	1.000	43. Brač	0.538	1.000	0.538
20. Ivanec	1.000	1.000	1.000	44. Dubrovnik	0.813	1.000	0.813
21. Koprivnica	0.645	0.645	1.000	45. Makarska	0.956	1.000	0.956
22. Križevci	0.898	0.904	0.994	46. Sinj	1.000	1.000	1.000
23. Ludbreg	0.816	0.819	0.996	47. Šibenik	0.591	0.867	0.682
24. Varaždin	0.407	0.524	0.777	48. Zadar	0.843	0.924	0.913

lected input and output variables cannot make distinction between efficient and inefficient units. Such results may, however, also be useful if additional models of decision making are applied. The results of DEA analysis may then be used as the first filter of inefficient units. The survey of DEA results is given in Table 4.

The interpretation of scale efficiency scores allows for some interesting remarks. Scale efficiency shows how close or far the size of the observed unit is from its optimal size. The efficiency of 100% indicates that the size and volume of activities are well balanced. The values lower than 100% mean that the level of technical efficiency is at least partly under influence of size or volume of activities of the observed unit.

The scale efficiency of 0.919 means that the analyzed forest offices would increase their relative efficiency on average by 8% if they adapted their size or volume of activities to the optimal value. Relatively efficient are 16 (33%) units. Almost all of them (15) are also efficient according to the CCR model (Table 3). Forest offices that are efficient only according to the BCC model (Table 3) do not show the same efficiency level in case of determination of scale efficiency. This indicates their inadequate size or inadequate volume of activities expressed by the main parameters of their production and business performance. These are mostly the units with low values of one or more input and output variables – Karst/Mediterranean forest offices with low growing stock, number of employees, annual cut, etc.

3.2 Sources and values of inefficiency – *Izvori i iznosi neefikasnosti*

By selecting output-oriented models projection course of inefficient units against the efficiency frontier was determined. By comparing empirical and

Table 4 Results obtained with the base case DEA models

Tablica 4. *Rezultati osnovnih modela AOMP*

	CCR model	BCC model	SE model
Number of forest offices (DMU) *Broj šumarija (DMU)*	48	48	48
Relatively efficient DMUs *Relativno efikasne šumarije*	15	24	16
Relatively efficient DMUs (in %) *Relativno efikasne šumarije (u %)*	31%	50%	33%
Average relative efficiency, E *Prosječna relativna efikasnost, E*	0.829	0.904	0.919
Maximum – *Najveća vrijednost*	1.000	1.000	1.000
Minimum – *Najmanja vrijednost*	0.407	0.524	0.501
Standard deviation – *Standardna devijacija*	1.170	0.129	0.138
DMUs with efficiency lower than E *Šumarije s efikasnošću manjom od E*	23	18	12

projected data, it is possible to identify the sources of inefficiency as well as their value. The lower the percentage of projected input values in empirical input values, the higher is on average the source of inefficiency caused by this input. The higher the percentage of projected output values in empirical output values, the higher is the source of inefficiency caused by this output. Table 5 shows percentage shares of average projected values in total empirical input and output values of CCR and BCC model.

It can be concluded from the Table 5 that the second and third output – annual cut and investments – affect the inefficiency of forest offices most seriously. Then follow the activities of forest regeneration and achieved income with a somewhat lower impact on inefficiency of forest offices.

Table 5 Sources and average amounts of inefficiency, CCR and BCC model

Tablica 5. *Izvori i prosječni iznosi neefikasnosti, model CCR i BCC*

		CCR	BCC
Inputs *Inputi*	Area, I1 – *Površina, I1*	85.48	93.85
	Growing stock, I2 – *Drvna zaliha, I2*	93.47	98.06
	Costs, I3 – *Troškovi, I3*	96.60	96.64
	Employees, I4 – *Zaposleni, I4*	96.94	97.37
Outputs *Outputi*	Income, O1 – *Prihod, O1*	125.64	118.68
	Removal, O2 – *Etat, O2*	268.04	158.94
	Investments, O3 – *Investicije, O3*	219.45	207.23
	Biological renewal, O4 *Biološka obnova, O4*	167.61	156.03

In the period concerned the observed units should have produced on average 25.64% more than the produced quantity of output O1, 168.04% more than the produced quantity of the second output O2, 119.45% more than output O3 and 67.61% % more than the produced quantity of output O4. Similarly, they should have used 85.48% of the used quantity of the first input I1, 93.47% of the quantity of output I2, 96.60% of the third input I3 and 96.94% of the used quantity of input I4. Then they would be CCR-efficient.

For achieving BCC efficiency, it was necessary to produce on average 18.68% more than the produced quantity of the first output I1, 58.94% more than the second output O2, 107.23% more than output O3 and 56.03% more than output O4. With such an average increase of output, the observed forest offices would do business efficiently according to the BCC model.

It should be noted that the projected values are achievable because some forest offices involved in the analysis achieved them successfully.

3.3 Structural characteristics and efficiency of forest offices – *Strukturne karakteristike i efikasnost šumarija*

Forest offices differ among themselves in a series of structural characteristics and hence professional and technical operations are carried out in different conditions with respect to the surface area, number of employees, means of work, growing stock, etc. Differences between the basic structural characteristics of the analyzed forest offices are shown in Table 1 and 2. Based on the efficiency results of forest offices grouped according to the values of their basic structural characteristics – surface area, growing stock and number of employees, it has been determined to what extent the given environment affects the efficiency of specific units.

The average efficiency with respect to surface area was determined as the arithmetic mean of the efficiency of forest offices that belong to a certain surface area class (Fig. 1). The highest levels of efficiency according to all three models were recorded for forest offices that manage a surface area ranging between 10 and 15,000 hectares (the average efficiency is 0.969 according to the CCR model, 0.977 according to the BCC model and 0.991 according to the SE model). The lowest levels of efficiency were determined for the group of forest offices with a surface area from 5 to 10,000 hectares.

The volume of the managed growing stock was taken as the second criteria for grouping the analysed units. Forest offices are divided into classes with respect to the growing stock expressed in m^3

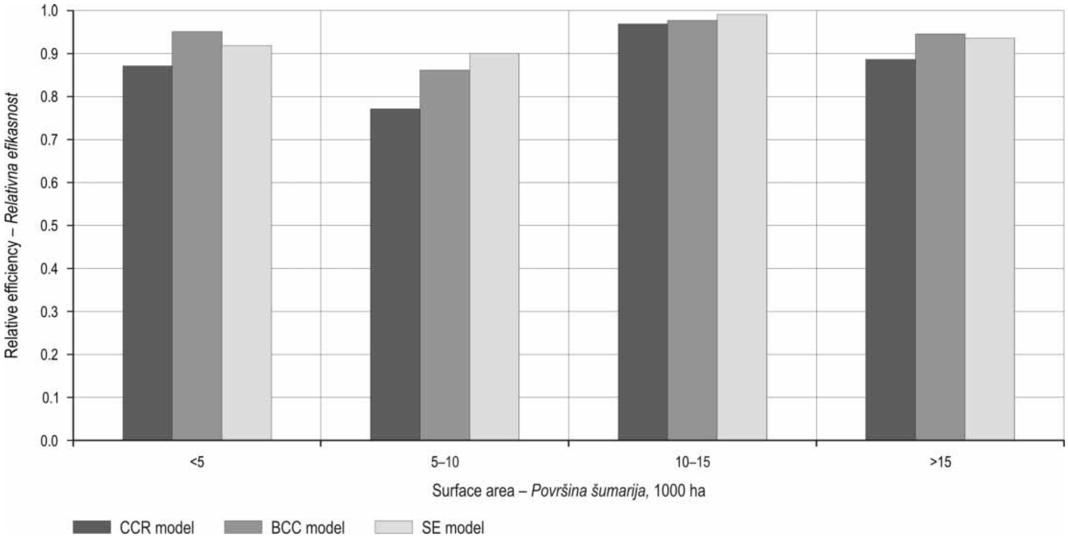

Fig. 1 Average relative efficiency of forest offices grouped with respect to surface area
Slika 1. *Relativna efikasnost šumarija grupiranih prema površini*

per hectare, and the average efficiency of individual classes is presented in Fig. 2.

Forest offices that manage the lowest growing stock volume (less than 100 m^3/ha) also have the lowest average relative efficiency, according to the CCR and SE model (0.676 and 0.689, respectively). According to these models the highest level of efficiency is recorded for forest offices with growing stock ranging between 200 and 300 m^3/ha i.e. over 300 m^3/ha – 0.890 (CCR) and 0.984 (SE) for the group III (200–300 m^3/ha) and 0.824 (CCR) and 0.980 (SE) for the group IV of forest offices (>300 m^3/ha). Only one forest office manages the growing stock exceeding 400 m^3/ha and it was not separated in a special class but was included in the group IV.

According to the BCC model, the average efficiency of all groups is assessed as relatively high. The highest average efficiency of forest offices with low growing stocks in the Karst and Mediterranean areas is the effect of increasing returns to scale, where it is considered that little increase of input (growing stock, etc.) would result in more than pro-

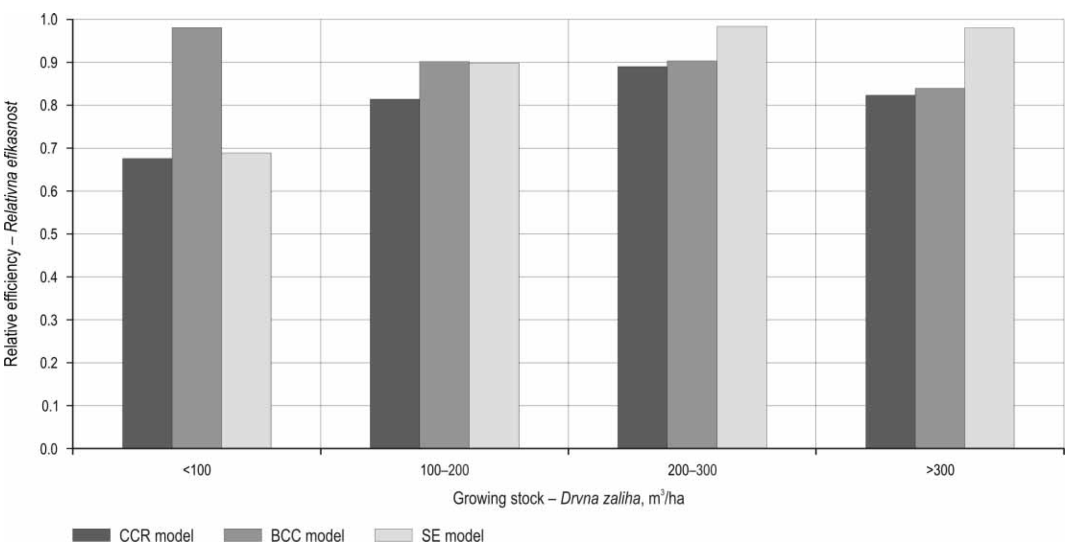

Fig. 2 Average relative efficiency of forest offices grouped with respect to growing stock
Slika 2. *Relativna efikasnost šumarija grupiranih prema drvnoj zalihi*

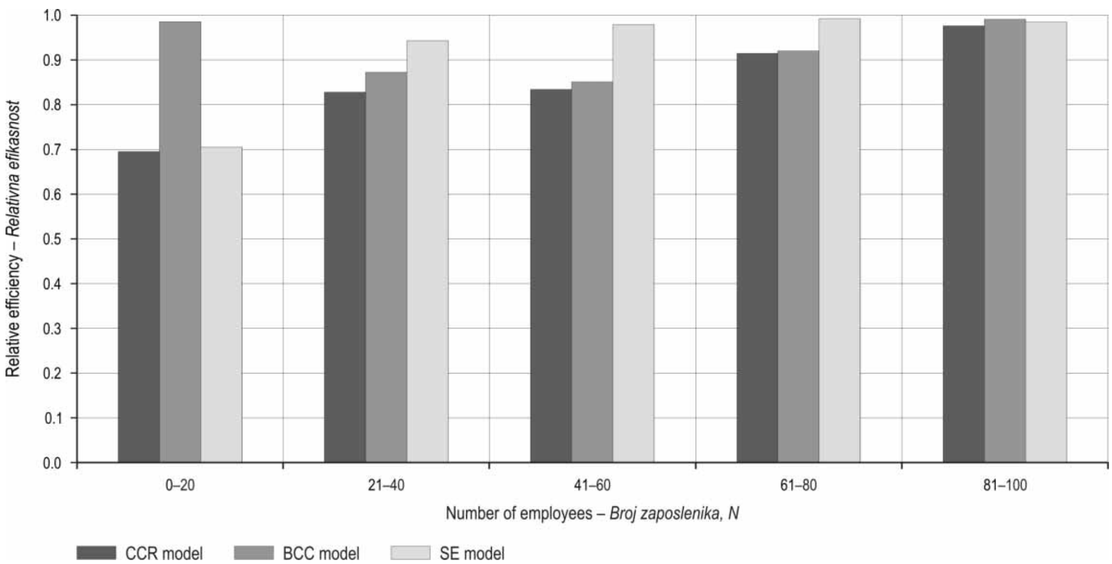

Fig. 3 Average relative efficiency of forest offices according to the number of employees
Slika 3. *Relativna efikasnost šumarija grupiranih prema broju zaposlenika*

portional increase of output (income, allowable cut, etc.). This assumption may be considered wrong for the said forest offices, if bad structure and poor quality of growing stock in the Karst and Mediterranean area are taken into account.

The observed forest offices employ 2,007 workers. Their number ranges from a minimum of 8 workers to a maximum of 100 workers per forest office. The number of workers in individual forest offices is mainly connected with the quantity and volume of production tasks. The average efficiency of forest offices with respect to the number of employees is presented in Fig. 3.

It can be seen that the highest level of CCR and SE efficiency is achieved by forest offices with the highest number of employees (group IV and V). For forest offices with 61 to 80 employees, the determined BCC, CCR and scale efficiency is 0.914, 0.920 and 0.992, respectively. In the group with more than 80 employees there are only two forest offices and their efficiency is approximately 0.985 regardless of the applied model.

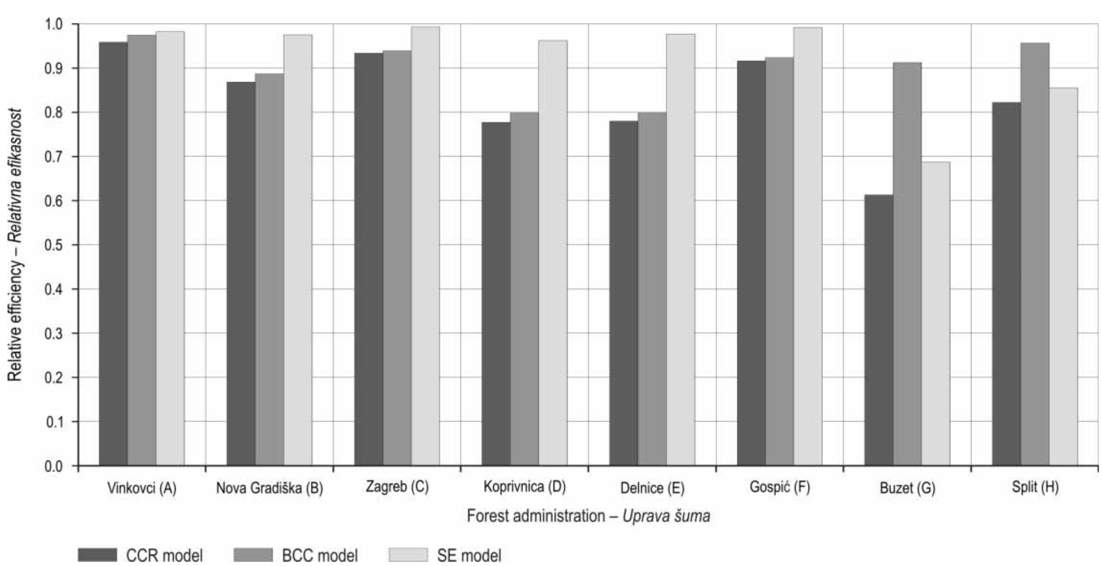

Fig. 4 Average relative efficiency of forest administrations
Slika 4. *Prosječna relativna efikasnost uprava šuma*

3.4 Relative efficiency of forest administrations and regions – *Relativna efikasnost uprava šuma i regija*

The sample of forest offices included in the analysis comes from eight forest administrations. Six forest offices from each selected forest administration account for 35% (FA Split) to 67% (FA Nova Gradiška and Buzet) of the total number of offices that make individual forest administrations. The efficiency level of individual forest administrations is calculated as the weighted arithmetic mean of the pertaining forest offices' relative efficiency (Fig. 4). Surface areas of forest offices are taken as weights.

On average forest administrations A (0.959), C (0.934) and F (0.916) have the highest relative efficiency according to the CCR model. FA G has the lowest average efficiency (0.613), while the Forest Administrations D, E and H are assessed better with average values between 0.778, and 0.822. FA B (0.868) gets closer to the average efficiency of 90%.

According to the scale efficiency, the forest administrations A, B, C, D, E and F are assessed similarly, and the level of their average efficiency ranges between 0.963 and 0.993. Like in CCR model, FA G and FA H represent the 'worst' units with average scale efficiency 0.687 and 0.855, respectively.

The average efficiency of the most successful forest administration according to the BCC model is 0.974 (A). Then follow forest administrations H (0.957), C (0.939), F (0.924) and G (0.913). Forest administrations B, D and E have the lowest BCC efficiency.

For success assessment of a forest administrations, besides their average efficiency, it is also important to take into account the number of forest offices that define the efficiency frontier. In this way it was determined that the efficiency frontier was on average most frequently determined by forest offices of forest administrations A and C (CCR and SE model) i.e. forest administrations G and H according to the BCC model (Table 3).

The average relative efficiency of forest management in different geographical regions is also calculated as the weighted (by areas) mean efficiency of forest offices situated in individual regions. The highest average efficiency was achieved in the area (I) lowland flood-prone forests – 0.907, somewhat lower in the area (II) hilly forests of the central part and area (III) mountainous forest – 0.862 and 0.890, and the lowest in the area (IV) Karst/Mediterranean area – 0.773, according to the CCR model. According to the BCC model, the average efficiency of lowland, hilly and mountainous forest offices is 0.924, 0.874 and 0.899, respectively, while the average efficiency of Karst/Mediterranean forest offices is somewhat higher and namely 0.946. The average scale efficiency of continental regions is relatively uniform and it ranges around 0.980, while in the Karst/Mediterranean area it is much lower and namely 0.816. The average relative efficiency of organizational units grouped by regions is shown in Fig. 5.

4. Discussion and Conclusions – *Rasprava i zaključci*

In this very dynamic period of management of natural resources, when forest experts face the chal-

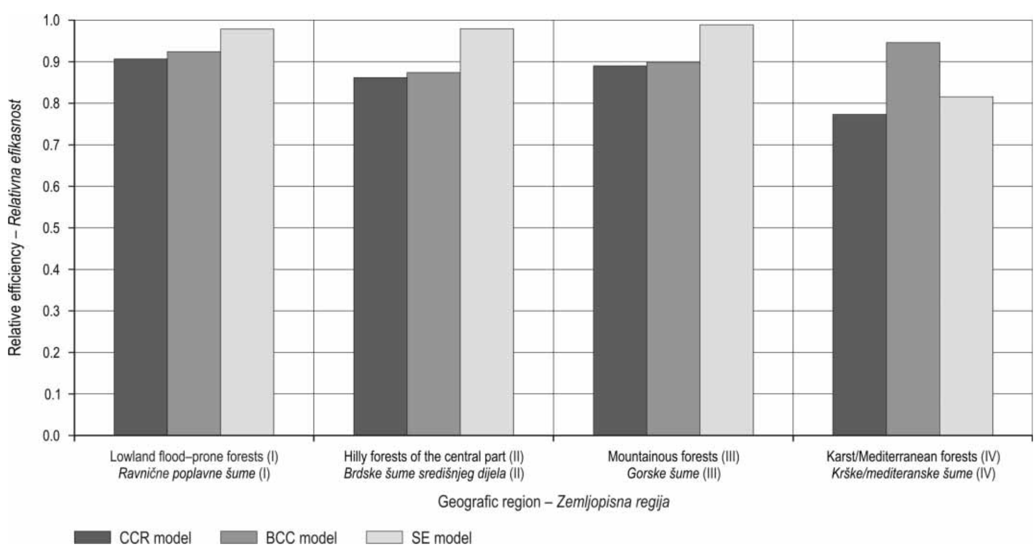

Fig. 5 Average relative efficiency by geographic regions
Slika 5. *Prosječna relativna efikasnost po regijama*

lenges of professional and responsible management of forests and forest land, having to observe at the same time the protection requirements of their ecological, social and economic functions, as well as challenges of profitable management of forestry companies, managers need different models for converting the accounting and financial data into useful information. In this paper the models of Data Envelopment Analysis were applied for the assessment and comparison of organizational units in Croatian forestry. In applying these models, a number of variables can be taken into consideration, so as to obtain a more comprehensive indicator for judging business activities of organizational units in forestry.

This paper shows the relative efficiency of organizational units of »Croatian Forests« Ltd., based on calculation of CCR and BCC output-oriented DEA models. Shares have been determined of projected values of inputs and outputs in empirical values, as well as sources and amounts of inefficiency. Scale efficiency of forest offices has also been determined. The effect of structural characteristics on relative efficiency of forest offices is determined, and so is the average efficiency of forest administrations and geographic regions.

On the average, global technical efficiency obtained by CCR models amounts to 0.829. Local pure technical efficiency, obtained by BCC model is 0.904, and scale efficiency is 0.919. A higher level of efficiency is averagely achieved by forest offices with an area from 10 to 15,000 hectares and with the growing stock from 200 to 300 m^3/ha. A relatively higher efficiency is achieved by units in continental regions. The analysis of amounts and causes of inefficiency shows that inefficiency is more significantly affected by outputs O2 and O3 (allowable cut and investments).

DEA solutions of relative efficiency can be interesting for forestry experts, managers and researchers due to three properties of this method:

⇒ Characterization of each organizational unit by a single result of relative efficiency,

⇒ Improvements proposed by the model to inefficient units are based on achieved results of units that manage their business efficiently,

⇒ Considering the problem with DEA is an alternative and indirect approach to specifying abstract statistical models and decision making based on residual analysis or analysis with coefficients – parameters.

Further advantages are in the comparison of units with multiple inputs and outputs, whereby they can be expressed in different units of measure. Furthermore, the selected inputs and outputs are supposed to have a correlation and however it is not necessary to know the explicit form of this correlation. One of the main disadvantages of DEA method is its sensibility to extreme observations and random errors. The basic assumption is that there are no random errors and that all deviations from efficiency frontier represent inefficiency.

Undoubtly, additional research is required to generalize the evidence provided in this study, in particular regarding the explanation of the underlying differences in the use of particular inputs and the production of certain outputs that could improve efficiency of forest management units. Nevertheless, some interesting insights regarding the performance of the forest management units in Croatia may have been provided.

It is also considered that by the development and application of Data Development Analysis and other models of multi-criteria decision making, it is possible to enrich the forestry science and practice by an approach that should provide easier analysing, planning and predicting in forest management.

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Sažetak

Ocjena efikasnosti organizacijskih jedinica u šumarstvu neparametarskim modelom

Složenost današnjega poslovnoga okruženja i imperativ stalnoga povećanja uspješnosti poslovanja nalaže menadžmentu organizacijskih jedinica u šumarstvu stalnu analizu svih relevantnih pokazatelja efikasnosti poslovanja. U tome je nađen motiv da se istraživanjem prihvatljivosti novih modela i metoda unaprijedi ocjenjivanje poslovanja u šumarstvu.

U radu se primjenom analize omeđivanja podataka (AOMP) ocjenjuje uspješnost organizacijskih cjelina u hrvatskom šumarstvu. Analiza za omeđivanja podataka je deterministička, neparametarska metodologija za procjenu relativne efikasnosti usporedivih jedinica/donositelja odluke s više inputa i outputa. Modeli AOMP na temelju podataka o korištenim inputima i ostvarenim outputima svih jedinica linearnim programiranjem određuju empirijsku granicu efikasnosti. Pritom se izračunava razina efikasnosti svake proizvodne jedinice te omogućuje razlikovanje efikasnih i neefikasnih jedinica. Najuspješnije jedinice, one koji određuju granicu efikasnosti, dobivaju ocjenu »1«, a stupanj tehničke neefikasnosti ostalih jedinica računa se na osnovi udaljenosti njihova omjera inputa i outputa u odnosu na granicu efikasnosti. U istraživanjima su primijenjeni osnovni modeli analize omeđivanja podataka.

U istraživanja je uključeno 48 šumarija. Odabrane su šumarije predstavnici četiriju glavnih regija u hrvatskom šumarstvu: ravničnih poplavnih šuma, brdskih šuma središnjega dijela, gorskih šuma i krških/mediteranskih šuma. Svaka je od regija zastupljena u analizama s dvije uprave šuma podružnice, odnosno sa šest šumarija iz svake uprave šuma.

Inputi i outputi su izabrani tako da odražavaju poslovanje temeljnih organizacijskih jedinica hrvatskoga šumarstva, odnosno šumarija. Kao inputi u model su uključeni površina, drvna zaliha, ukupni troškovi i broj zaposlenika. Outputi su u istraživanjima predstavljeni ukupnim prihodima, etatom, investicijama u infrastrukturu i biološkom obnovom šuma.

U radu su prikazani rezultati relativne efikasnosti na temelju izračuna modela CCR i BCC usmjerenih outputima. Utvrđeni su udjeli projiciranih vrijednosti inputa i outputa u empirijskim vrijednostima te su utvrđeni izvori i iznosi neefikasnosti. Prikazan je utjecaj strukturnih karakteristika na relativnu efikasnost šumarija. Šumarije su grupirane prema upravama šuma i regijama kojima pripadaju i analizirane su razlike u efikasnosti tako formiranih skupina.

Prosječna relativna tehnička efikasnost analiziranih jedinica u 2006. godini iznosi 0,829 prema rezultatima globalne tehničke efikasnosti koji su dobiveni rješavanjem modela CCR. Čista lokalna tehnička efikasnost, dobivena modelom BCC, iznosi 0,904, a efikasnost s obzirom na opseg djelovanja iznosi 0,919. Mali udio jedinica u području varijabilnih prinosa i relativno visoka prosječna vrijednost efikasnosti s obzirom na opseg djelovanja upućuju da efekt obujma nije izražen i da model CCR dobro opisuje analizirano poslovanje. Najveću razinu efikasnosti imaju šumarije koje gospodare s 10 do 15 000 hektara obrasle šumske površine i drvnom zalihom od 200 do 300 ili preko 300 m^3/ha. Relativno veću razinu efikasnosti postižu jedinice u kontinentalnim regijama. Značajniji izvor neefikasnosti u odnosu na druge varijable predstavljaju etat i investicije.

Na temelju provedenih istraživanja i prikazanih rezultata zaključuje se da analiza omeđivanja podataka u šumarstvu, jednako kao u mnogim drugim poslovnim sustavima, može biti vrlo snažna podrška planiranju i odlučivanju.

Ključne riječi: šumarstvo, uspješnost poslovanja, analiza omeđivanja podataka (AOMP), efikasnost

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Received (*Primljeno*): December 8, 2008
Accepted (*Prihvaćeno*): April 8, 2009