НАЦИОНАЛЬНЫЙ ИССЛЕДОВАТЕЛЬСКИЙ УНИВЕРСИТЕТ

Ranking Journals Using Social Choice Theory Methods: A Novel Approach in Bibliometrics

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Motivation

Emergence of more and more indicators poses the problem:

What a decision-maker can do if there are several rankings but he/she needs **just one**?

Indicators and journals used to make rankings

	Database	Year	Publication window, years	Weighted	Field-normalized
2-year IF	WoS/JCR	2011	2	No	No
5-year IF	WoS/JCR	2011	5	No	No
immediacy index	WoS/JCR	2011	1	No	No
article influence	WoS/JCR	2011	5	Yes	No
h-index	WoS	2007–2011 (papers and citations)	5	No	No
SNIP	Scopus	2011	3	No	Yes
SJR	Scopus	2011	3	Yes	No

- Economics: 212 journals
- Management: 93
- Political Science: 99

Rank correlations

Share of inversions, % (economic journals)

	impact factor	5-year impact factor	immediacy index	article influence	Hirsch index	SNIP	SJR
impact factor		8,46	24,59	18,13	15,45	15,09	14,23
5-year impact factor	8,46		24,25	13,72	13,15	13,66	12,20
immediacy index	24,59	24,25		26,00	25,57	27,01	25,25
article influence	18,13	13,72	26,00		17,15	16,31	15,50
Hirsch index	15,45	13,15	25,57	17,15		18,47	15,05
SNIP	15,09	13,66	27,01	16,31	18,47		17,28
SJR	14,23	12,20	25,25	15,50	15,05	17,28	

Rank correlations

Kendall τ_b (economic journals)

	impact factor	5-year impact factor	immediacy index	article influence	Hirsch index	SNIP	SJR
impact factor		0,830	0,503	0,637	0,654	0,698	0,700
5-year impact factor	0,830		0,510	0,725	0,702	0,726	0,741
immediacy index	0,503	0,510		0,475	0,442	0,454	0,472
article influence	0,637	0,725	0,475		0,620	0,673	0,674
Hirsch index	0,654	0,702	0,442	0,620		0,592	0,650
SNIP	0,698	0,726	0,454	0,673	0,592		0,638
SJR	0,700	0,741	0,472	0,674	0,650	0,638	

Rank correlations

Share of inversions, % (Russian economic journals)

	Muravyev	HSE	Balatsky	IF RSCI	Science Index	5-IF RSCI
Muravyev (2012)		10,8	26,1	29,2	27,8	25,3
HSE (2015)	10,8		12,3	17,7	16,8	15,6
Balatsky (2015)	26,1	12,3		35,6	29,0	32,1
IF RSCI	29,2	17,7	35,6		28,2	11,4
Science Index	27,8	16,8	29,0	28,2		23,1
5-IF RSCI	25,3	15,6	32,1	11,4	23,1	

Rank correlations

Kendall τ_b (Russian economic journals)

	Muravyev	HSE	Balatsky	IF RSCI	Science Index	5-IF RSCI
Muravyev (2012)		0,270	0,169	0,157	0,193	0,249
HSE (2015)	0,270		0,308	0,185	0,212	0,244
Balatsky (2015)	0,169	0,308		0,191	0,334	0,265
IF RSCI	0,157	0,185	0,191		0,431	0,770
Science Index	0,193	0,212	0,334	0,431		0,533
5-IF RSCI	0,249	0,244	0,265	0,770	0,533	

To choose or to aggregate?

To make decisions, there should be just one ranking. Two possible solutions.

1. One may try to choose the best indicator.

Unfortunately, the academic discussion concerning relative advantages of various indicators has been so far inconclusive; since there is no compelling reason to presume that any indicator is somehow inferior to others, it is quite problematic to make the choice *rationally*.

2. One may use all the rankings simultaneously by aggregating them in a single ranking.

The theory of aggregation is a well-developed area of knowledge, and it allows for making quite definite conclusions regarding the appropriateness of a choice.

Making an aggregate ranking is to rank on a basis of multiple criteria. There is a formal analogy between multicriteria choice and social choice. Consequently, one may consider whole panoply of extensively studied and well-behaved social choice rules.

Social choice

X – the *general set* of alternatives

A – the *feasible set* of alternatives: $A \subseteq X \wedge A \neq \varnothing$. The feasible set is a variable.

N – the *society* (a group of voters or a panel of experts)

$u_i(x)$ – the *utility* of alternative $x \in X$ for voter $i \in N$, $u_i(x)$: $X \rightarrow \mathbb{R}$

$$u_i(y) > u_i(x) \Leftrightarrow \text{voter } i \text{ strictly prefers } y \text{ to } x$$

$U = \{ u_i(x) \mid i \in N \}$ – the profile of utility functions

R – (*weak*) *social preferences*, $R \subseteq X \times X$

R is presumed to be complete: $\forall\, x \in X, \forall\, y \in X, (x, y) \in R \vee (y, x) \in R$

P – *strict social preferences*, $P \subseteq R$: $(x, y) \in P \Leftrightarrow ((x, y) \in R \wedge (y, x) \notin R)$

It is presumed that $R = R(P)$ and $P = P(U)$.

The majority rule

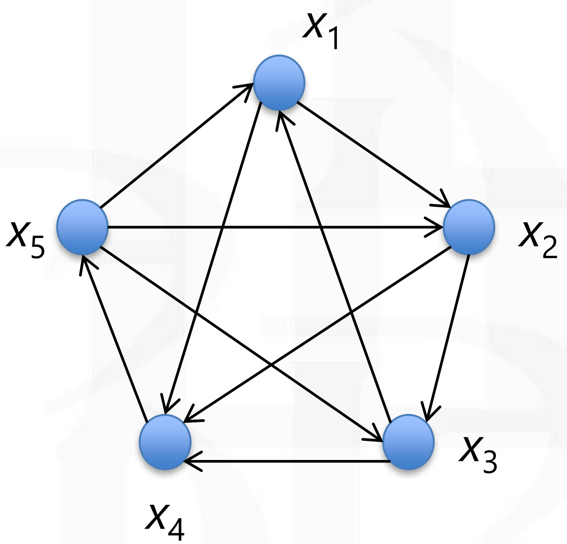
P – majority preference relation

$$(x, y) \in P \Leftrightarrow \#\{ i \in N \mid u_i(x) > u_i(y) \} > \#\{ i \in N \mid u_i(y) > u_i(x) \}$$

$\mathbf{M}=[m_{ij}]$ – matrix representing P $\quad m_{xy}=1 \Leftrightarrow (x, y) \in P,\ m_{xy}=0 \Leftrightarrow (x, y) \notin P$

	x_1	x_2	x_3	x_4	x_5
x_1	0	1	0	1	0
x_2	0	0	1	1	0
x_3	1	0	0	1	0
x_4	0	0	0	0	1
x_5	1	1	1	0	0

Majority matrix **M**



Majority digraph

Why the majority rule? An axiomatic argument

Majority rule $R(P)$ uniquely satisfies the set of natural conditions (May 1952).

- ***Full domain***: the rule can be applied in all cases, that is, to any utility profile U
- ***Neutrality***: the rule treats all alternatives equally
- ***Anonymity***: the rule treats all voters (in our case, indicators) equally
- ***Pareto principle***: if x Pareto-dominates y, then xPy
- ***Monotonicity***: if utility profiles U and U' are such that

  $\forall i \in N, u'_i(x) \geq u_i(x) \wedge u'_i(y) = u_i(y)$, then $xP(U)y \Rightarrow xP(U')y$ and $xR(U)y \Rightarrow xR(U')y$
- ***Positive responsiveness***: if utility profiles U and U' are such that

  $\exists j \in N$: $(u_j(x) < u_i(y) \wedge u'_j(x) \geq u'_j(y)) \vee (u_j(x) = u_j(y) \wedge u'_j(x) > u'_j(y))$ and

  $\forall i \in N \setminus \{j\}, u'_i(x) = u_i(x) \wedge u'_i(y) = u_i(y)$ and $xR(U)y$ and $yR(U)x$ then $xP(U')y$
- ***Independence of irrelevant utilities***: $\forall A \subseteq X, P(U)|_A = P(U|_A)$
- ***Ordinality***

Ordinality versus Cardinality

Ordinality

If utility profiles U and U' are such that $\forall x \in X$, $\forall i \in N$, $u'_i(x) = g_i(u_i(x))$, where all g_i are strictly increasing real-valued functions of a real variable, then $P(U)=P(U')$.

Why ordinality? It removes the problem of non-comparability of individual utilities.

Individual utilities can be incomparable. Roughly speaking, we may not know the utility substitution rates; consequently, if the utility of person *i* decreases, we are unable to keep the social welfare constant by increasing the utility of person *j*.

Cardinal procedures are over-demanding from the informational point of view.

Their application may lead to meaningless results.


TOWN OF
SNOWMASS VILLAGE
ESTABLISHED 1967
ELEVATION 8388
POPULATION 2826
TOTAL 13,181

Why the majority rule? An epistemic argument

If individual preferences are not subjective tastes but rather objective judgments concerning the state of affairs *Q*, the Condorcet Jury Theorem applies.

The Condorcet jury theorem (Condorcet 1785)

- If a binary judgment of each voter is more likely to be correct than otherwise, that is, if the conditional probability $p(xQy \mid u_i(x) > u_i(y))$ is greater than 0.5,
- and if judgments of different individuals are statistically independent,

then the judgment *xPy* obtained by the majority rule is likely to be true with the probability higher than that of any individual judgment:

$$\forall\ i \in N,\ p(xQy \mid xPy) > p(xQy \mid u_i(x) > u_i(y)).$$

Moreover, the probability $p(xQy \mid xPy)$ tends to 1 with number of voters $|N|$ increasing.

The Condorcet paradox

But the majority rule violates the axiom *Transitivity*, since the majority relation P may contain cycles. This result is known as the Condorcet paradox (Condorcet 1785).

In order to evaluate how nontransitive the majority relation is in our case, we calculate the number of 3-step, 4-step and 5-step P-cycles for three sets of journals.

Numbers of 3-, 4- and 5-step *P*-cycles for three sets of journals

	3-step cycles	*4-step cycles*	*5-step cycles*
Economics	2446	22427	226103
Management	203	787	3254
Political Science	149	430	1344

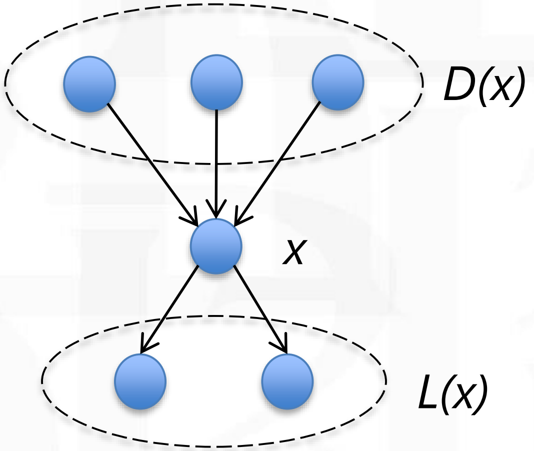
The Copeland rule (Copeland 1951)

In order to get transitivity, which we need since we need a ranking, we sacrifice the independence of irrelevant utilities but keep the ordinality.

<u>The idea is to mend the majority relation, when it is nontransitive.</u>

The Copeland rule: when $|X| < \infty$, rank the alternatives by their score $s(x)$, determined in either of the following ways:

- Version 1. $s_1(x) = |\{y \in X \mid xPy\}| - |\{y \in X \mid yPx\}|$
- Version 2. $s_2(x) = |\{y \in X \mid xPy\}|$
- Version 3. $s_3(x) = |X| - |\{y \in X \mid yPx\}|$



Tournament solutions

A *social choice rule* is a correspondence S with arguments A and P and values in the set of subsets of A.

It is presumed that S depends on A and P only through restriction of P on A: $S=S(A, P)=S(P|_A) \subseteq A$, i.e. social choices are dependent on social preferences for available alternatives only.

A *tournament solution* is a social choice rule S that has the following properties:

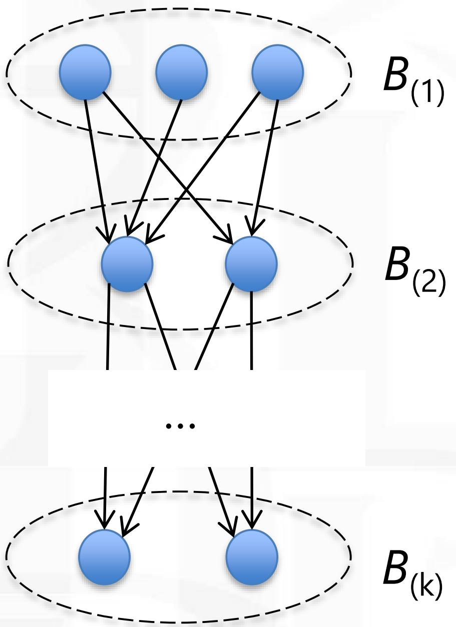
1. *Nonemptiness*: $\forall A, \forall P, \; S(P|_A) \neq \varnothing$;
2. *Neutrality*: permutation of alternatives' names and social choice commute;
3. *Condorcet consistency*:

if there is the Condorcet winner (P-maximal element) w for $P|_A$ then $S(P|_A) =\{w\}$.

A sorting based on a tournament solution

Let us consider the following sorting procedure:

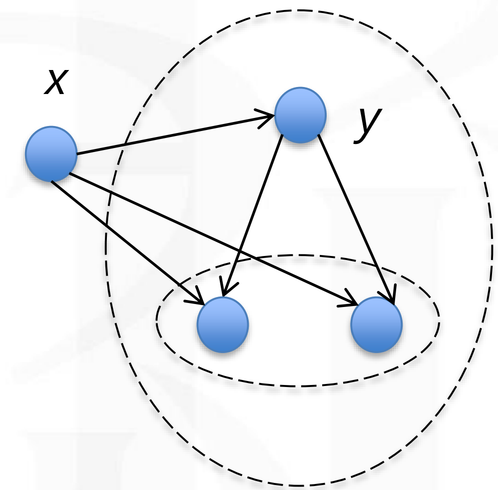
- Tournament solution S determines the set $B_{(1)}$ of social optima in A, $B_{(1)}=S(A)$.
- Let us exclude them and repeat the procedure for the set $A \backslash B_{(1)}$. The set $B_{(2)}=S(A \backslash B_{(1)})=S(A \backslash S(A))$ contains second best choices.
- After a finite number of selections and exclusions, all alternatives from A will be separated by classes $B_{(k)}=S(A \backslash (B_{(k-1)} \cup B_{(k-2)} \cup \ldots \cup B_{(2)} \cup B_{(1)}))$ according to their "quality", and these classes constitute a ranking.



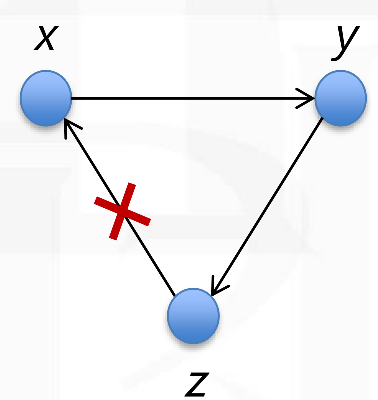
The uncovered set (Fishburn 1977, Miller 1980)

An alternative *x* **covers** an alternative *y*, if *x* is strictly more preferable (socially) than *y*, and all the alternatives, which are strictly less preferable than *y*, are also strictly less preferable than *x*:

$$xPy \wedge \forall z \in X, yPz \Rightarrow xPz.$$



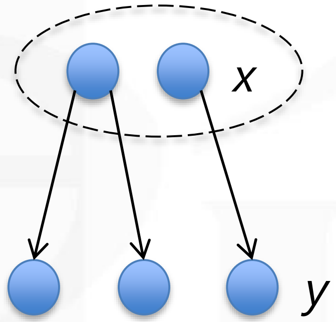
The best alternatives according to this solution concept are those that are not covered by any other alternative. The set of such alternatives is called the *uncovered set UC* (Fishburn 1977, Miller 1980).



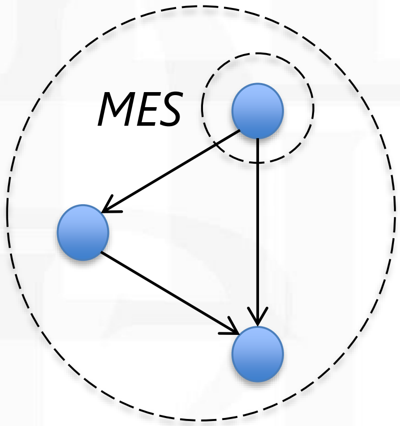
The minimal externally stable set

A nonempty subset *B* of a feasible set *A* is *externally stable* (von Neumann & Morgenstern 1944), if for any alternative *y* from *A* and outside *B*, there is an alternative *x* in *B*, that is strictly more preferable (socially) than *y*:

$$\forall y \in A \backslash B, \exists\, x \in B: xPy.$$

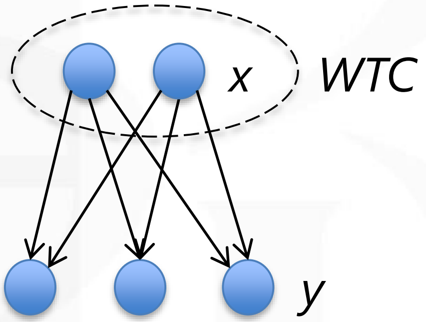


Externally stable set is called *minimal*, if none of its proper nonempty subsets is externally stable. The alternative is considered as "good" if it belongs at least to one minimal externally stable set. Thus the solution concept is a union of all such sets *MES* (Wuffl et al. 1989, Aleskerov & Kurbanov 1999, Subochev 2008, Aleskerov & Subochev 2013).



The weak top cycle (Ward 1961, Schwartz 1970, 1972, Smith 1973)

A set *D*, $D \subseteq A$, is called dominant in *A*, if every alternative from *D* is strictly more preferable (socially) than every alternative from $A \backslash D$: $\forall x \in D, \forall y \in A \backslash D, xPy$.



The weak top cycle WTC is a minimal dominant set.

The Markovian ranking (Daniels 1969, Ushakov 1971)

First, sort the alternatives by *WTC*. Then, consider a set B of all the alternatives of a given sort. Imagine that a digraph representing $P|_B$ is a labyrinth: vertices are rooms, arcs are one-way passages between the rooms. Time is discrete. A visitor in a certain moment of time k is in a certain room x. Then at random with equal probability another vertex $y \in B \backslash \{x\}$ is chosen. If y is at least as preferable as x (yRx), then the visitor moves to y.

Let us denote alternatives in B by numbers. Let $\mathbf{p}^{(k)}$ – the vector, its component $p_x^{(k)}$ is probability that the visitor is in a room number x at a time moment k. Let us consider the vector $\mathbf{p}=\lim_{k\to\infty} \mathbf{p}^{(k)}$. Its value does not depend on initial conditions (i.e. on the value of $\mathbf{p}^{(0)}$). The greater is the number of visits to a room number x, the better is the corresponding alternative x. The relative number of visits to a room number x over infinite time period is proportional p_x, so we rank alternatives by this value.

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Rank correlations (continued)

Kendall τ_b (economic journals)

	impact factor	5-year impact factor	immediacy index	article influence	Hirsch index	SNIP	SJR	Copeland (2)	Copeland (3)	*UC*	*MES*	Marcovian
impact factor		0,830	0,503	0,637	0,654	0,698	0,700	0,834	0,831	0,834	0,835	0,819
5-year impact factor	0,830		0,510	0,725	0,702	0,726	0,741	0,903	0,904	0,906	0,896	0,891
immediacy index	0,503	0,510		0,475	0,442	0,454	0,472	0,550	0,551	0,556	0,578	0,560
article influence	0,637	0,725	0,475		0,620	0,673	0,674	0,766	0,769	0,777	0,785	0,769
Hirsch index	0,654	0,702	0,442	0,620		0,592	0,650	0,738	0,737	0,737	0,747	0,729
SNIP	0,698	0,726	0,454	0,673	0,592		0,638	0,759	0,759	0,767	0,775	0,750
SJR	0,700	0,741	0,472	0,674	0,650	0,638		0,792	0,790	0,800	0,797	0,775
Copeland (2)	0,834	0,903	0,550	0,766	0,738	0,759	0,792		0,990	0,970	0,950	0,956
Copeland (3)	0,831	0,904	0,551	0,769	0,737	0,759	0,790	0,990		0,969	0,950	0,959
UC	0,834	0,906	0,556	0,777	0,737	0,767	0,800	0,970	0,969		0,955	0,954
MES	0,835	0,896	0,578	0,785	0,747	0,775	0,797	0,950	0,950	0,955		0,949
Markovian	0,819	0,891	0,560	0,769	0,729	0,750	0,775	0,956	0,959	0,954	0,949	

Rank correlations (continued)

Kendall τ_b (Russian economic journals)

	Muravyev	HSE	Balatsky	IF RSCI	Science Index	5-IF RSCI	Pareto	Core	*UC*	*MES*	Copeland (1)	Copeland (2)	Copeland (3)
Muravyev		0,270	0,169	0,157	0,193	0,249	0,590	0,471	0,602	0,629	0,477	0,432	0,529
HSE	0,270		0,308	0,185	0,212	0,244	0,596	0,545	0,568	0,554	0,528	0,474	0,547
Balatsky	0,169	0,308		0,191	0,334	0,265	0,465	0,637	0,500	0,489	0,628	0,731	0,571
IF RSCI	0,157	0,185	0,191		0,431	0,770	0,162	0,211	0,161	0,169	0,217	0,241	0,207
Science Index	0,193	0,212	0,334	0,431		0,533	0,222	0,291	0,246	0,250	0,302	0,354	0,275
5-IF RSCI	0,249	0,244	0,265	0,770	0,533		0,234	0,271	0,238	0,247	0,286	0,323	0,273
Pareto	0,590	0,596	0,465	0,162	0,222	0,234		0,810	0,950	0,954	0,813	0,710	0,887
Core	0,471	0,545	0,637	0,211	0,291	0,271	0,810		0,830	0,822	0,881	0,786	0,925
UC	0,602	0,568	0,500	0,161	0,246	0,238	0,950	0,830		0,978	0,829	0,751	0,892
MES	0,629	0,554	0,489	0,169	0,250	0,247	0,954	0,822	0,978		0,825	0,743	0,891
Copeland (1)	0,477	0,528	0,628	0,217	0,302	0,286	0,813	0,881	0,829	0,825		0,899	0,918
Copeland (2)	0,432	0,474	0,731	0,241	0,354	0,323	0,710	0,786	0,751	0,743	0,899		0,812
Copeland (3)	0,529	0,547	0,571	0,207	0,275	0,273	0,887	0,925	0,892	0,891	0,918	0,812	

Formal analysis of correlations

The problem of aggregation can be reformulated as a choice of a single object representing a given group of objects.

Let us again use the majority rule to determine the best representations.

Let us say that ranking R_1 represents a given set of rankings better than ranking R_2 if R_1 is better correlated with the majority of rankings from this set than R_2.

In our case, each ranking is characterized by the 7-component vector, its i-th component being the value of τ_b for this ranking and i-th single-indicator-based ranking.

We compare these vectors and define the majority relation on the set of the twelve rankings compared. Then we use the Copeland rule (version 2) to rank them.

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The rankings of rankings

rank	Economics	Man. Sc.	Pol. Sc.	All 3 sets combined	Previous results (2008)
1	*MES*	*MES*	*MES*	*MES*	*UC*
2	*UC*	*UC*	*UC*	*UC*	*MES*
3	Copeland 3	Copeland 2	Copeland 3	Copeland 3	Copeland 3
4	Copeland 2	Copeland 3	Copeland 2	Copeland 2	Copeland 2
5	Markovian	Markovian	Markovian	Markovian	Markovian
6	5-y.impact	5-y.impact	5-y.impact	5-y.impact	impact
7	impact	SNIP	Hirsch	impact	5-y.impact
8	SJR	Hirsch	AI/ impact/ SJR	AI/ SJR	SJR
9	AI	AI			AI/ Hirsch/ SNIP
10	SNIP	SJR		Hirsch/ SNIP	
11	Hirsch	impact	SNIP		
12	immediacy	immediacy	immediacy	immediacy	immediacy

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4. Subochev A. 2010. Dominating, weakly stable, and uncovered sets: Properties and generalizations. *Automation and Remote Control*, V. 71, P. 116-127.

5. Aleskerov F., Subochev A. 2009. On Stable Solutions to the Ordinal Social Choice Problem. *Doklady Mathematics*, V. 73, N. 3. P. 437-439.

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