



712CD

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If the title was revised please list the original title above and the revised title here:

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Report Documentation Page

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The Resource Allocation Strategy Evaluator (RASE)

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Decision Support and Analysis Center



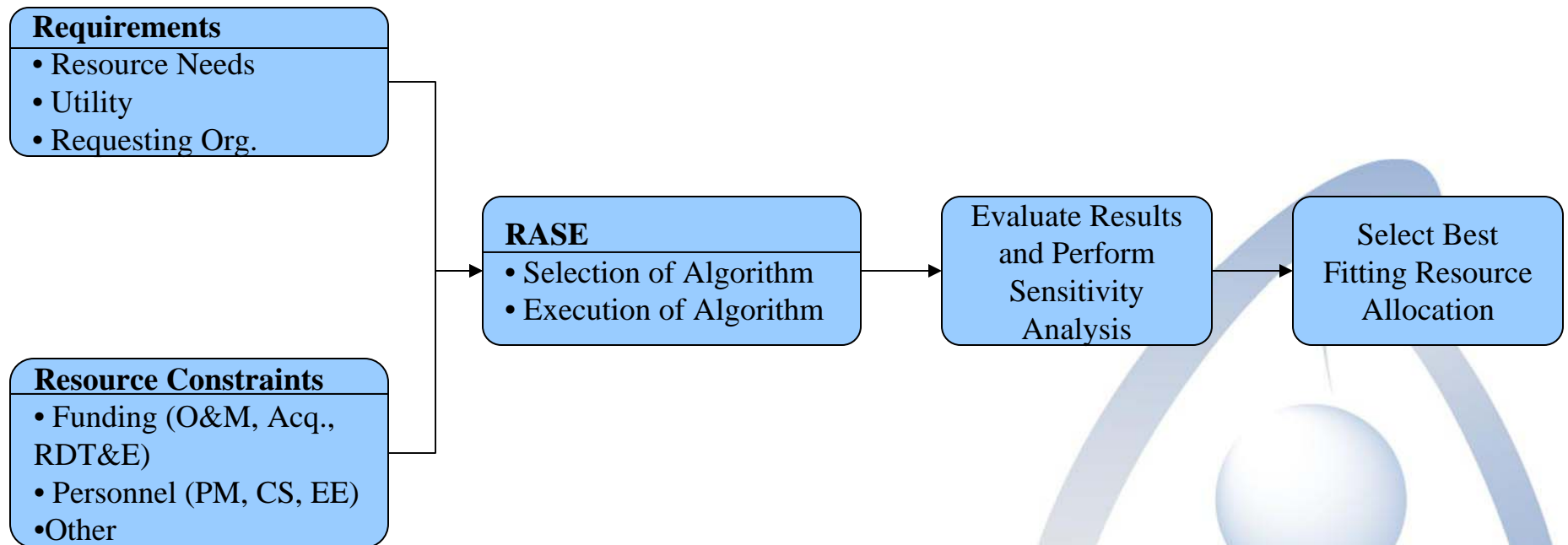
From Science to Solutions™

RASE – What is it?

- A decision support tool developed in 2006 to:
 - Highlight the implications of different strategies available for resourcing requirements
 - Automate resource allocation

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RASE – Methodology



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RASE – Algorithms

- Heuristics
 - Minimum Loading
 - Binding Resource
 - Proportional Impact
 - Maximum Loading
 - Binding Resource
 - Proportional Impact
 - Balanced Loading

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RASE – Algorithms (cont.)

- Heuristics (cont.)
 - Utility Loading
 - Equity Based Loading
- Optimal Search
 - Maximize Number Resourced
 - Maximize Aggregate Utility

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RASE – Features

- Manual override allocation
- Run and compare performance of all algorithms
- Select the number of constraints to consider
- Choice of optimization engine (LINGO, Excel Solver)
- Basic sorting

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RASE – Future Additions

- Optimal Equity Algorithm (Nonlinear)
- Consider Ancillary Constraints
 - “If requirement X is resourced, requirement Y must be resourced”
- Formal sensitivity analysis capability
- Display multiple optimal solutions when present
- Allow user to stop optimal search at “close enough” solution
- Highlight binding constraint
- Advanced Sorting

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RASE – Screenshots

Resource Allocation Strategy Evaluator - (RASE)

Add Requirement Edit Requirement Delete Requirement Clear All Requirements

Resources							Edit Resources	Change Constraints
	O&M Funds (\$M)	Acq. Funds (\$M)	RDT&E Funds (\$M)	Comp. Sci. FTE	Elec. Eng. FTE	Comms. Eng. FTE		
Total	500.0	500.0	500.0	100.0	100.0	100.0		
Allocated	456.3	493.7	493.7	72.0	72.0	46.0		
Available	43.7	3.7	6.3	28.0	28.0	54.0		

CNO Req. Number	Requirement Name	O&M Funds (\$M)	Acq. Funds (\$M)	RDT&E Funds (\$M)	Comp. Sci. FTE	Elec. Eng. FTE	Comms. Eng. FTE	Utility Score	Organization	Allocation Order
1	R1	102.7	114.3	95.9	26	4	6	87	Com1	
2	R2	26.3	25.4	32.8	2	4	6	9	Com1	
3	R3	42.6	54.0	52.4	12	5	0	49	Com1	1
4	R4	32.9	23.5	18.7	2	1	4	25	Com1	5
5	R5	41.8	49.1	56.9	2	5	12	75	Com1	
6	R6	21.5	27.8	26.0	2	4	2	1	Com2	
7	R7	94.1	108.2	99.9	22	30	9	74	Com2	
8	R8	91.2	111.1	88.8	16	4	17	76	Com2	
9	R9	101.6	86.4	97.9	26	14	11	98	Com2	
10	R10	92.8	105.4	90.4	23	11	9	75	Com3	
11	R11	26.6	27.8	30.3	3	4	6	32	Com3	7
12	R12	97.0	104.8	106.4	6	20	1	91	Com3	
13	R13	97.5	97.6	99.1	7	5	30	88	Com3	
14	R14	29.8	31.2	23.4	6	5	10	17	Com3	
15	R15	55.5	49.8	55.5	18	16	0	56	Com3	2
16	R16	45.7	52.9	56.3	0	11	8	48	Com4	
17	R17	45.9	46.9	57.2	14	6	7	40	Com4	
18	R18	120.7	91.7	98.4	1	12	6	99	Com4	
19	R19	40.4	56.0	62.5	8	2	12	36	Com4	
20	R20	27.2	16.9	20.3	2	4	9	44	Com4	
21	R21	51.3	46.0	54.0	16	10	8	74	Com5	
22	R22	76.6	102.7	96.4	4	0	16	73	Com5	
23	R23	14.6	20.1	20.2	2	0	3	9	Com5	3
24	R24	26.1	20.6	26.0	3	7	3	20	Com6	4
25	R25	107.6	93.7	121.3	23	1	18	100	Com6	
26	R26	40.5	60.2	54.3	13	11	8	69	Com6	
27	R27	105.1	85.5	93.5	23	30	6	73	Com6	
28	R28	46.2	59.3	47.8	4	14	10	70	Com6	
29	R29	91.3	120.2	77.7	20	11	24	76	Com6	
30	R30	21.0	16.6	19.3	1	1	6	9	Com7	
31	R31	96.8	106.5	101.5	26	31	10	75	Com7	
32	R32	84.0	116.6	117.3	20	20	24	85	Com7	
33	R33	66.8	94.3	99.7	17	15	6	100	Com7	
34	R34	19.1	25.8	27.6	1	2	6	29	Com7	
35	R35	88.9	109.0	104.5	26	21	6	94	Com8	
36	R36	24.0	26.2	29.2	8	3	8	20	Com8	
37	R37	48.3	43.5	50.8	11	4	5	52	Com8	
38	R38	22.0	31.3	36.6	6	7	4	30	Com8	6

Hueristic Based

Min Load-Bind.Con	Balanced Loading
Min Load-% Impact	Equitable Loading
Max Load-Bind.Con	Utility Loading
Max Load-%Impact	

Run All Strategies

Optimal Search

Maximize Requirements
Maximize Utility
Lingo Max. Reqs
Lingo Max. Utility

Manually Assign Resources

Clear RASE Selections

Clear Manual Selections

Clear All Selections

Measures of Effectiveness

Number of Reqs Resourced	11
Total Aggregate Utility Score	398.0
Std. Dev. of Org. Equity (\$M)	140.0

Sort Requirements

Key

	Manually Assigned
	RASE Selection
	Disabled Constraint

RASE – Screenshots

Return to RASE	Hueristics						Equitable Hueristics			Optimal Searches	
Measures of Performance	Min Load - Binding Constraint	Min Load - Proportional Impact	Max Load - Binding Constraint	Max Load - Proportional Impact	Balanced Loading	Utility Based Loading	Equitable - Min Loading	Equitable - Balanced Loading	Equitable - Utility Loading	Max Num Resourced	Maximize Utility
Leftover O&M Funds	43.7	50.5	75.2	83.2	76.7	62.3	14.0	14.0	33.1	42.7	51.8
Leftover Acq. Funds	3.7	22.0	13.2	7.7	0.4	26.0	18.9	18.9	2.4	22.2	6.0
Leftover RDT&E Funds	6.3	17.7	69.2	27.2	14.6	4.7	13.2	13.2	21.9	30.9	9.0
Leftover Comp. Sci.	28	46	47	28	36	32	35	35	19	46	46
Leftover Elec. Eng.	28	39	52	17	32	48	37	37	46	41	29
Leftover Comm. Eng.	54	25	20	40	24	41	32	32	51	19	23
Number of Reqs Resourced	11	13	6	6	9	7	11	11	7	13	10
Total Aggregate Utility Score	398.0	395.0	341.0	337.0	393.0	421.0	414.0	414.0	394.0	382.0	501.0
Std. Deviation of Org. Equity	140.0	93.6	157.0	168.5	108.5	108.3	155.3	155.3	178.9	110.6	99.8
Manually Assigned Requirements	R2	R2	R2	R2	R2	R2	R2	R2	R2	R2	R2
	R6	R6	R6	R6	R6	R6	R6	R6	R6	R6	R6
	R8	R8	R8	R8	R8	R8	R8	R8	R8	R8	R8
	R12	R12	R12	R12	R12	R12	R12	R12	R12	R12	R12
RASE Assigned Requirements	R3	R4	R13	R31	R20	R20	R4	R4	R1	R4	R5
	R4	R11	R29	R32	R23	R25	R9	R9	R9	R11	R11
	R11	R20			R26	R33	R11	R11	R11	R14	R20
	R15	R23			R30		R20	R20		R20	R21
	R23	R24			R32		R23	R23		R23	R26
	R24	R30					R24	R24		R24	R34
	R38	R34					R30	R30		R30	
		R36								R34	
		R38								R36	

Decision Support and Analysis Center



1. MINIMUM LOADING STRATEGY

A. Binding Resource heuristic - With this approach, the following steps are used to assign resources to CNO requirements:

- a) Mark all CNO requirements as "not resourced" by setting $X_i = 0$
- b) The resources required for each requirement "i" for each resource type "k" is summed across all requirements to estimate $S_k = \sum r_{ik}$
- c) The degree of loading (e.g. binding) for each resource type will be the fraction of available resources that is needed (normalized by available resources), computed as: $\Delta_k = S_k / R_k$ for each k
- d) The probable (but not assured) binding resource will be the index defined by $RB = \text{MAX}[\Delta_k]$
- e) Sort requirements from smallest to largest resources needed for resource type RB.
- f) Set $RL_k = R_k$
- g) Go to the next CNO requirement on the sorted list (if this is the first time, go to the first requirement on the sorted list).
- h) For this requirement, compute $RL_k = RL_k - r_{ik}$ for all "k"
- i) If $RL_k \geq 0$ for all "k", then mark this requirement as resourced by setting $X_i = 1$, then go to step 1.g, otherwise continue to step 1.j
- j) For the resource type "k" that went below zero in step 1.i, all available resources have been allocated and the resource allocation process is complete.

Decision Support and Analysis Center

1. MINIMUM LOADING STRATEGY

B. Proportional Impact heuristic - With this approach, the following steps are used to assign resources to CNO requirements:

- a) Mark all CNO requirements as "not resourced" by setting $X_i = 0$
- b) Set $RL_k = R_k$ for all "k"
- c) The fraction of the totally available resources that are needed by each requirement is computed as: $P_i = \sum r_{ik} / RL_k$ (summed across index "k")
- d) Sort requirements from smallest to largest values of P_i
- e) Select the top CNO requirement on the sorted list that was not previously selected.
- f) For this requirement, compute $RL_k = RL_k - r_{ik}$ for all "k"
- g) If $RL_k \geq 0$ for all "k", then mark this requirement as resourced by setting $X_i = 1$, then go to step c, otherwise continue to step h
- h) For the resource type "k" that went below zero in step 1.g, all available resources have been allocated and the resource allocation process is complete.

Decision Support and Analysis Center

2. MAXIMUM LOADING STRATEGY

A. Binding Resource heuristic - With this approach, the following steps are used to assign resources to CNO requirements:

- a) Mark all CNO requirements as "not resourced" by setting $X_i = 0$
- b) The resources required for each requirement "i" for each resource type "k" is summed across all requirements to estimate $S_k = \sum r_{ik}$
- c) The degree of loading (e.g. binding) for each resource type will be the fraction of available resources that is needed (normalized by available resources), computed as: $D_k = S_k / R_k$ for each k
- d) The probable (but not assured) binding resource will be the index defined by $RB = \text{MAX}[\Delta k]$
- e) Sort requirements from largest to smallest resources needed for resource type RB.
- f) Set $RL_k = R_k$
- g) Go to the next CNO requirement on the sorted list (if this is the first time, go to the first requirement on the sorted list).
- h) For this requirement, compute $RL_k = RL_k - r_{ik}$ for all "k"
- i) If $RL_k \geq 0$ for all "k", then mark this requirement as resourced by setting $X_i = 1$, then go to step 2.g, otherwise continue to step 2.j
- j) For the resource type "k" that went below zero in step 2.i, all available resources have been allocated to large requirements. If there are still requirements on the list, it is possible that one may require resources less than what is currently left over (since we sorted from highest to lowest). For this reason, we allow the algorithm to continue checking the sorted list all the way to the end. If this is the end of the list, then stop. If not, then for all "k" set $RL_k = RL_k + r_{ik}$ (e.g return the resources that we removed from the last requirement that would not fit) and go to step g.

Decision Support and Analysis Center

2. MAXIMUM LOADING STRATEGY

B. Proportional Impact heuristic - With this approach, the following steps are used to assign resources to CNO requirements:

- a) Mark all CNO requirements as "not resourced" by setting $X_i = 0$
- b) Set $RL_k = R_k$ for all "k"
- c) The fraction of the totally available resources that are needed by each requirement is computed as: $P_i = S_{rik} / RL_k$ (summed across index "k")
- d) Sort requirements from largest to smallest values of P_i
- e) Select the top CNO requirement on the sorted list that was not previously selected.
- f) For this requirement, compute $RL_k = RL_k - rik$ for all "k"
- g) If $RL_k \geq 0$ for all "k", then mark this requirement as resourced by setting $X_i = 1$, then go to step c, otherwise continue to step h
- h) For the resource type "k" that went below zero in step 2.g, all available resources have been allocated to large requirements. If there are still requirements on the list, it is possible that one may require resources less than what is currently left over (since we sorted from highest to lowest). For this reason, we allow the algorithm to continue checking the sorted list all the way to the end. If this is the end of the list, then stop. If not, then for all "k" set $RL_k = RL_k + rik$ (e.g return the resources that we removed from the last requirement that would not fit) and go to step e.

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3. BALANCED LOADING STRATEGY

With this approach, the following steps are used to assign resources to CNO requirements:

- a) Mark all CNO requirements as "not resourced" by setting $X_i = 0$
- b) The resources required for each requirement "i" for each resource type "k" is summed across all requirements to estimate $S_k = \sum r_{ik}$
- c) The degree of loading (e.g. binding) for each resource type will be the fraction of available resources that is needed (normalized by available resources), computed as: $\Delta_k = S_k / R_k$ for each k
- d) The probable (but not assured) binding resource will be the index defined by $RB = \text{MAX}[\Delta_k]$
- e) Using resource type RB as your criteria, sort the CNO requirements from smallest to largest. Set the small counter $S=1$ and the large counter $N = \text{number of requirements}$.
- f) Set $RL_k = R_k$
- g) Go to the CNO requirement on the sorted list corresponding to S
- h) For this requirement, compute $RL_k = RL_k - r_{Sk}$ for all "k"
- i) If $RL_k \geq 0$ for all "k", then mark this requirement as resourced by setting $X_S = 1$, then go to step 2.j, otherwise STOP.
- j) If $S \geq N$, STOP (all requirements have been resourced). Otherwise, go to the CNO requirement on the list corresponding to N
- k) . For this requirement, compute $RL_k = RL_k - r_{Nk}$ for all "k"
- l) If $RL_k \geq 0$ for all "k", then mark this requirement as resourced by setting $X_N = 1$, also set $S=S+1$ and $N=N-1$, then go to step 2.g. Otherwise continue
- m) If $S > N$, then STOP. Otherwise continue.
- n) For the resource type "k" that went below zero in step 2.l, all available resources have been allocated to large requirements. If there are still requirements on the list, it is possible that one may require resources less than what is currently left over (since we sorted from highest to lowest). For this reason, we allow the algorithm to continue checking the sorted list all the way to the end. If this is the end of the list, then stop. If not, then for all "k" set $RL_k = RL_k + r_{ik}$ (e.g return the resources that we removed from the last requirement that would not fit) and go to step g.

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4. EQUITY BASED STRATEGY

With this approach, the following steps are used to assign resources to CNO requirements:

- a) Separate all requirements into J lists (represented by Λ) where each list represents requirements associated with each organization.
- b) Mark all CNO requirements as "not resourced" by setting $X_{ij} = 0$
- c) The resources required for each requirement "ij" for each resource type "k" is summed across all requirements to estimate $S_k = \sum r_{ik}$
- d) The degree of loading (e.g. binding) for each resource type will be the fraction of available resources is needed (normalized by available resources), computed as: $\Delta k = S_k / R_k$ for each k
- e) The probable binding resource will be the index defined by $RB = \text{MAX}[\Delta k]$
- f) Set the list counter $j = 1$ and $RL_k = R_k$.
- g) If sub objective = "utility based", sort CNO requirements in each Λ_j list from highest to lowest utility score.
- h) If sub objective is not = "utility based", then sort each Λ_j list of CNO requirements from smallest to largest resources needed for resource type RB.
- i) If sub objective is not = "balanced", then go to step k.
 - i. Set low counter $L_j = 1$ and the high counter $H_j =$ number of requirements for organization j for all J.
 - ii. Go to the CNO requirement on the sorted list L_j corresponding to L_j
 - iii. If $XL_{jj} = 1$ then go to step j.5. Otherwise, for this requirement, compute $RL_k = RL_k - r_{Ljk}$ for all "k"
 - iv. If $RL_k \geq 0$ for all "k", then mark this requirement as resourced by setting $XL_{jj} = 1$, and go to step j.5. Otherwise STOP
 - v. If $L_j > H_j$, go to step j.9 (all requirements for this organization are resourced). Otherwise, go to next requirement on the list corresponding to H_j
 - vi. If $XH_{jj} = 1$ then go to step j.8. Otherwise, for this requirement, compute $RL_k = RL_k - r_{Hjk}$ for all "k"
 - vii. If $RL_k \geq 0$ for all "k", then mark this requirement as resourced by setting $XH_{jj} = 1$, then go to step j.8. Otherwise: set $RL_k = RL_k + r_{Hjk}$ for all k, set $L_j = L_j + 1$, $H_j = H_j - 1$. If $L_j > H_j$ then go to step j.9. Otherwise go to step j.2.
 - viii. Set $L_j = L_j + 1$, and $H_j = H_j - 1$. If $L_j \leq H_j$, Go to step j.2. Otherwise continue.
 - ix. Set $j = j + 1$. If $j > J$ set $j = 1$. Go to step j.2
- j) The sub objective is = "utility based", so perform the following steps:
 - i. Set counter $L_j = 1$ for organization j for all J.
 - ii. Go to the CNO requirement on the sorted list L_j corresponding to L_j
 - iii. For this requirement, compute $RL_k = RL_k - r_{Ljk}$ for all "k"
 - iv. If $RL_k \geq 0$ for all "k", then mark this requirement as resourced by setting $XL_{jj} = 1$, and go to step k.9. Otherwise continue.
 - v. Set $RL_k = RL_k + r_{Hjk}$ for all k.
 - vi. Set $L_j = L_j + 1$. If $L_j \leq$ Number of requirements for this organization, then go to step k.2. Otherwise continue.
 - vii. Set $j = j + 1$. If $j > J$ set $j = 1$. If all $X_{ij} = 1$ then STOP, otherwise go to step k.2

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5. UTILITY BASED STRATEGY

With this approach, the following steps are used to assign resources to CNO requirements:

- a) Mark all CNO requirements as "not resourced" by setting $X_i = 0$
- b) Sort CNO requirements from highest utility score to lowest score, and set $S=1$.
- c) Set $RL_k = R_k$
- d) Go to the CNO requirement on the sorted list corresponding to S
- e) For this requirement, compute $RL_k = RL_k - rSk$ for all "k"
- f) If $RL_k \geq 0$ for all "k", then mark this requirement as resourced by setting $X_S = 1$, then go to step 2.g, otherwise continue to step 2.h
- g) Set $S=S+1$, and go to step d
- h) For the resource type "k" that went below zero in step 2.f, all available resources have been allocated and the resource allocation process is complete.

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6. OPTIMAL SEARCH STRATEGY

With this approach, the following steps are used to assign resources to CNO requirements:

- a) An objective function is created to guide the search process. The objective function takes the following form based on which sub objective was selected:
 1. If sub objective = "Maximum requirements", then the Objective function is defined as: $\text{Max } \sum X_i$
 2. If sub objective = "Utility based", then the Objective function is defined as: $\text{Max } \sum u_i X_i$
- b) A constraint is formulated for each resource type, using the general form: $\sum \sum r_{ijk} X_{ij} < R_k$ for each k (summation is across i and j)

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RASE – Algorithm Terminology

i = An index used to designate a specific CNO requirement

j = An index used to designate a specific organization

k = An index used to indicate a type of resource (funds, people, etc) needed to support requirement **i**

k = The index of the resource selected by the user to achieve an equitable distribution of resources across organizations (e.g. "funds")

P_i = The proportion of the available resources (across all "k" types of resources) that is needed by CNO requirement "i" for organization "j"

r_{ijk} = The resources of type k needed to execute requirement "i" for organization "j"

R_k = The amount of resource type k that is available and can be allocated across the CNO requirements.

RL_k = The amount of available resources left over as each requirement is allocated its necessary resources

X_{ij} = A decision variable indicating whether requirement ij has been chosen to be resourced

u_{ij} = The benefit (utility) of assigning resources to requirement "ij"

L_j = List of requirements associated with organization j

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