

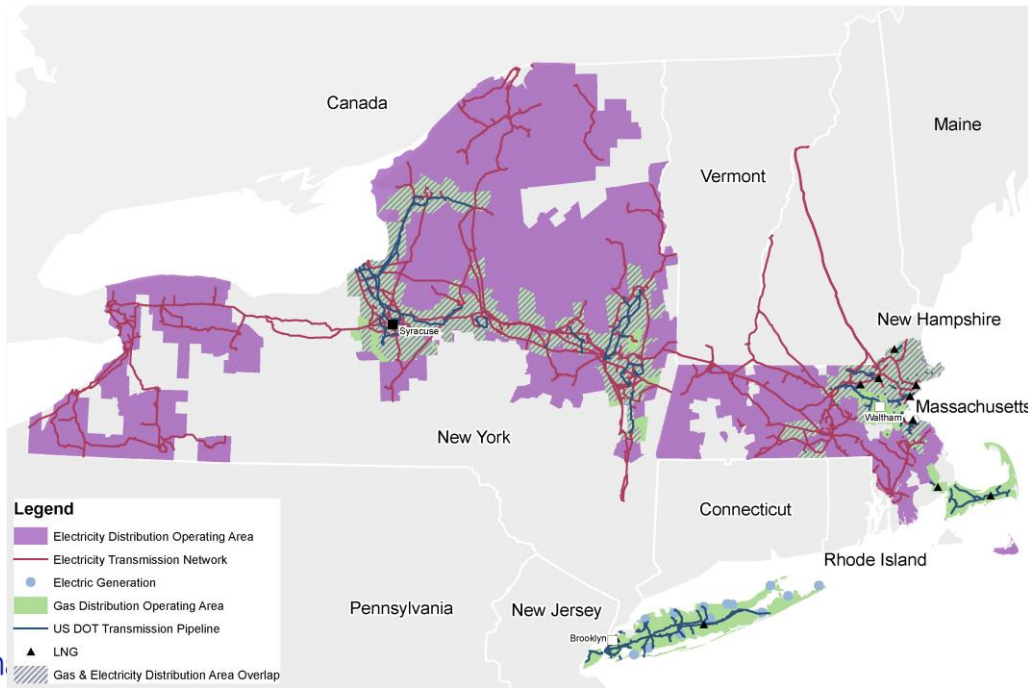
Workforce Optimization

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nationalgrid



We are one of the largest investor-owned energy companies in the US — serving more than 20 million people throughout New York and Massachusetts.



Serving 20 million people

- Nearly 18,000 employees
- 3.4 million gas customers
- 2.9 million electric customers

Customers by region:



2.2 million



UNY 2.2 million
LI 0.6 million
NYC 1.3 million

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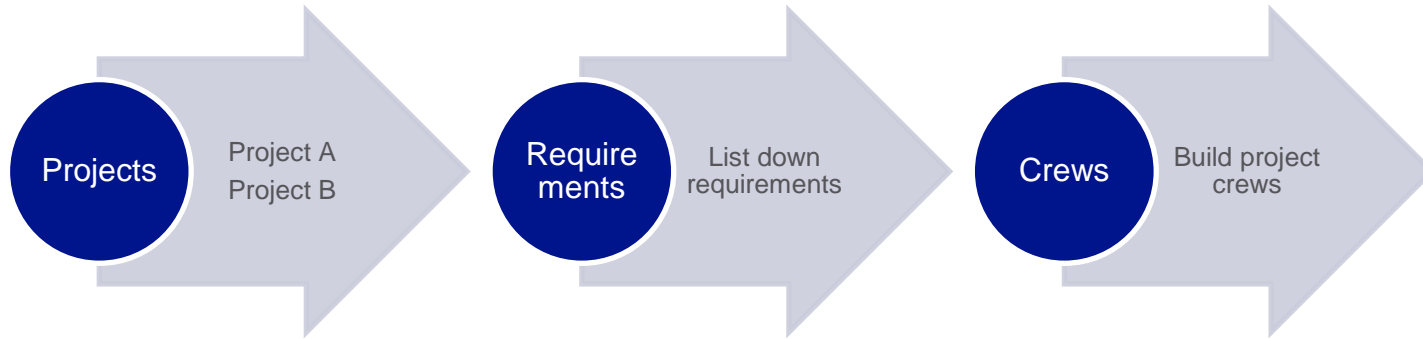
01

Background

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Background



Projects
Project A
Project B

Project A	
Job group	# of workers
Electrician	1
Welder	1

Project A crew
Michael Wilson
Peter Parker

↕ Match Job requirement to job title

Workers	
Name	Job description
Michael Wilson	Electrician 1/c
Peter Parker	Welder
John Doe	Welder

02

Problem

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Problem

Project requirements

Project	Location	Electrician	Welder
Project A	Waltham	1	1
Project B	Worcester	2	0

Final assignment

Project	Worker	Job group	Cost (\$)
Project A	Michael Wilson	Electrician	12
	Peter Parker	Welder	6
Project B	William Martin	Electrician	9
	Bruce Wayne	Electrician	8

Total cost: \$ 35

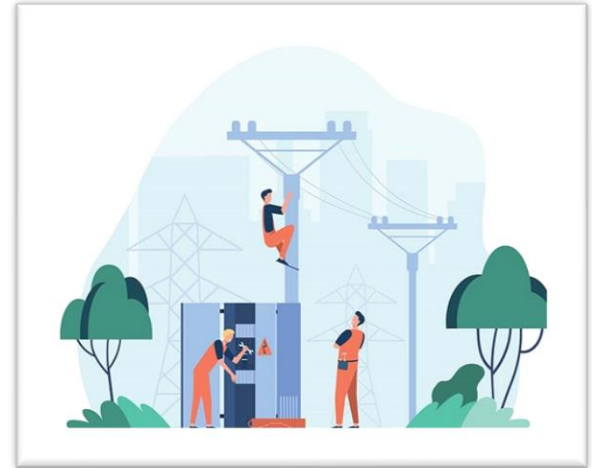
Available workers

Worker	Homebase	Job description
John Doe	N. Andover	Welder
Peter Parker	Waltham	Welder
Mark Anderson	Lowell	Welder
Bruce Wayne	Reading	Electrician 2/c
Michael Wilson	Reading	Electrician 1/c
William Martin	Beverly	Electrician 2/c
Robert Moore	Malden	Electrician 1/c

Can we improve crew formation?

Would it make sense to optimize on reimbursement cost?

Can we use mathematical optimization?



03

Solution

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Mathematical Optimization

Yes, we can!



Mathematical Optimization – Linear sum assignment

Task	Electrician 2/c	Electrician 2/c	Electrician 1/c	Welder
Project A Electrician	\$5	\$9	\$3	-
Project A Welder	-	-	-	\$6
Project B Electrician	\$6	\$10	\$12	-
Project B Electrician	\$8	\$7	\$8	-

Manual assignment

Cost: \$35

Optimized assignment

Cost: \$22

Objective: Assign every employee a distinct task such that total cost is **minimal**, and every task gets exactly one worker and vice versa.

Python package: OR-Tools

Mathematical Optimization – Linear sum assignment

Context:

- For optimization formulation we only consider ‘**available**’ workers.
- A ‘**job group**’ consists of multiple job descriptions which are interchangeable.
- A project can have requirements for different job groups with multiple workers required for a job group.
- We define a ‘**task**’ to be a single job group requirement within a project.
 - If a project requires 2 electricians and a welder, then that project has **3 tasks**.

Mathematical Optimization – Linear sum assignment

Notation:

$$x_{wt} = \begin{cases} 1 & \text{if worker } w \text{ is assigned to task } t, \\ 0 & \text{otherwise} \end{cases}$$

c_{wt} : Cost if worker w is assigned to task t .

Therefore, the optimization problem is:

Minimize

$$\sum_{w,t} c_{wt} x_{wt}$$

Mathematical Optimization – Linear sum assignment

Constraint 1:

A task t must only be assigned to a single worker w

For every task t :

$$\sum_w x_{wt} = 1$$

Mathematical Optimization – Linear sum assignment

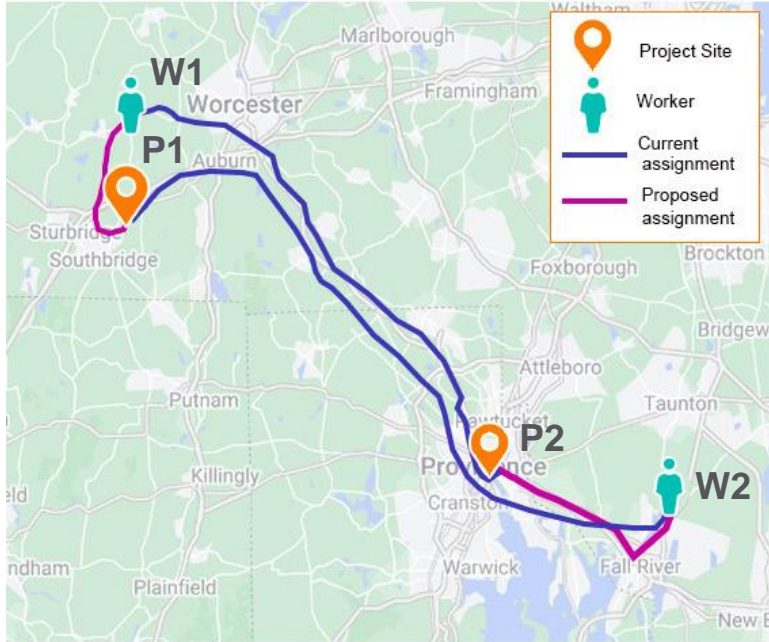
Constraint 2:

A **worker** w can only perform one **task** t at a time.

In other words, for every **worker** w , we have:

$$\sum_t x_{wt} = 1$$

Solution - example



Manual vs optimized assignment

W1 to P2 (round-trip) - \$135

W2 to P1 (round-trip) - \$135

Total - \$270

W1 to P1 (round-trip) - \$23

W2 to P2 (round-trip) - \$23

Total - \$46

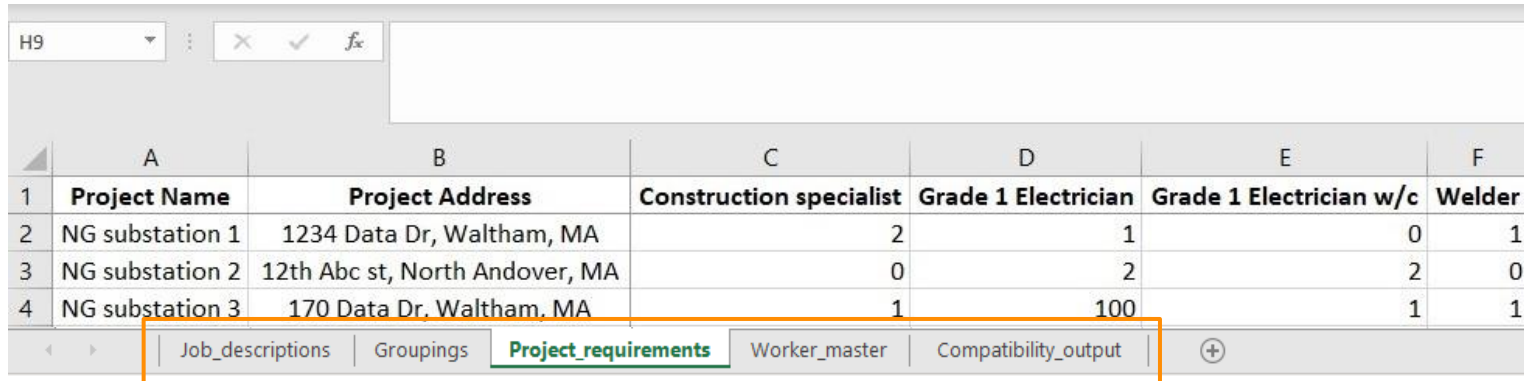
04

Input walkthrough

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Input template



The screenshot shows an Excel spreadsheet with a table containing project data. The table has columns for Project Name, Project Address, Construction specialist, Grade 1 Electrician, Grade 1 Electrician w/c, and Welder. The sheet tab bar at the bottom is highlighted with an orange box, showing tabs for Job_descriptions, Groupings, Project_requirements (selected), Worker_master, and Compatibility_output.

	A	B	C	D	E	F
1	Project Name	Project Address	Construction specialist	Grade 1 Electrician	Grade 1 Electrician w/c	Welder
2	NG substation 1	1234 Data Dr, Waltham, MA	2	1	0	1
3	NG substation 2	12th Abc st, North Andover, MA	0	2	2	0
4	NG substation 3	170 Data Dr, Waltham, MA	1	100	1	1

Input sheets

Job description

Job titles used across organization

	A	B	C
1	Job Descriptions		
2	Construction specialist		
3	Grade 1 Electrician		
4	Grade 1 Electrician w/c		
5	Welder		
6			

Job_descriptions | Groupings | Project_requirements | Worker_master | Compatibility_output

Grouping

	A	B	C
1	Group	Member 1	Member 2
2	Electrician	Grade 1 Electrician	Grade 1 Electrician w/c

Job_descriptions | **Groupings** | Project_requirements | Worker_master | Compatibility_output | (+)

Allows the job titles to be interchangeable

Project Requirements

Job titles auto-populated from job descriptions sheet

	A	B	C	D	E	F
1	Project Name	Project Address	Construction specialist	Grade 1 Electrician	Grade 1 Electrician w/c	Welder
2	NG substation 1	1234 Data Dr, Waltham, MA	2	1	0	1
3	NG substation 2	12th Abc st, North Andover, MA	0	2	2	0
4	NG substation 3	170 Data Dr, Waltham, MA	1	100	1	1
5						

Job_descriptions | Groupings | **Project_requirements** | Worker_master | Compatibility_output | (+)

Worker sheet

	A	B	C	D	E	F	G	H
1	Personnel Number	First Name	Last Name	Job Description	Home Base	Available	Can be reassigned	Current Project
2	1	John	Doe	Construction specialist	North Andover	yes	yes	NG substation 2
3	2	Mark	Wayne	Construction specialist	Waltham	yes	yes	NG substation 2
4	3	Jane	Doe	Construction specialist	Lynn	yes	no	NG substation 3
5	4	Jack	Craig	Construction specialist	Lowell	no	yes	NG substation 3
6	5	David	Smith	Grade 1 Electrician	North Andover	yes	yes	NG substation 1
7	6	Benjamin	Johnson	Grade 1 Electrician	Worcester	yes	yes	NG substation 2
8	7	Thomas	Jones	Grade 1 Electrician	Reading	yes	yes	NG substation 3
9	8	James	Davis	Grade 1 Electrician	Waltham	yes	yes	NG substation 3
10	9	William	Martin	Grade 1 Electrician	Worcester	yes	yes	NG substation 3
11	10	Michael	Wilson	Grade 1 Electrician w/c	Lynn	yes	no	NG substation 1
12	11	Robert	Campbell	Grade 1 Electrician w/c	Lowell	no	yes	NG substation 2
13	12	Micahel	Carter	Grade 1 Electrician w/c	Reading	yes	yes	NG substation 1
14	13	Robert	Moore	Welder	Medford	yes	yes	NG substation 2
15	14	Matthew	Parker	Welder	Billerica	yes	yes	NG substation 2

Navigation tabs: Job_descriptions | Groupings | Project_requirements | **Worker_master** | Compatibility_output (+)

05

Input validity

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Valid Input

The screenshot shows the Microsoft Excel interface with a custom ribbon titled "Workforce Optimization". On this ribbon, there are two buttons: "Validate Input" (with a green icon) and "Save to remote" (with a blue icon). The "Validate Input" button is highlighted with a red box. Below the ribbon, the formula bar shows "I11". The main grid contains data for project specifications:

	A	B	C	D	E	F	G
1	Project Name	Project Address	Construction specialist	Grade 1 Electrician	Grade 1 Electrician w/c	Welder	
2	NG substation 1	1234 Data Dr, Waltham, MA	2	1	0	1	
3	NG substation 2	12th Abc st, North Andover, MA	0	2	2	0	
4	NG substation 3	170 Data Dr, Waltham, MA	1	0	1	1	
5							
6							
7							
8							
9							
10							
11							
12							
13							

A dialog box titled "Microsoft Excel" is open, displaying the message "Compatible input file" and an "OK" button. The dialog box is highlighted with a green border.

Excel customizations via VB script

Invalid Input

The screenshot shows the Microsoft Excel interface with the 'Workforce Optimization' ribbon selected. The 'Validate Input' button is highlighted with a red box. Below the ribbon, the formula bar shows 'H4'. The spreadsheet contains the following data:

	A	B	C	D	E	F	G
1	Project Name	Project Address	Construction specialist	Grade 1 Electrician	Grade 1 Electrician w/c	Welder	
2	NG substation 1	1234 Data Dr, Waltham, MA	2	1	0	1	
3	NG substation 2	12th Abc st, North Andover, MA	0	2	2	0	
4	NG substation 3	170 Data Dr, Waltham, MA	1	100	1	1	
5							
6							
7							
8							
9							
10							
11							
12							
13							

An error dialog box is displayed over the spreadsheet with the following text:

Microsoft Excel

Unequal project requirements and workers or invalid project name

OK

Compatibility sheet – why is it invalid?

File Home Insert Draw Page Layout Formulas Data Review View Developer Help Workforce Optimization

Validate Save to Input remote

G8

	A	B	C	D	E	F
1	Job Group	Project Requirement	Available Workers			
2	Grade 1 Electrician	106	7			
30						

Job_descriptions Groupings Project_requirements Worker_master **Compatibility_output** (+)

06

Output

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Output

	A	B	C	E	F	G
1	Personnel Number	First Name	Last Name	Job Group	Current Project	Current Cost
2	3	Jane	Doe	Construction specialist	NG substation 3	68
3	10	Michael	Wilson	Electrician	NG substation 1	79
4	1	John	Doe	Construction specialist	NG substation 2	5
5	2	Mark	Wayne	Construction specialist	NG substation 2	79
6	5	David	Smith	Electrician	NG substation 1	95
7	6	Benjamin	Johnson	Electrician	NG substation 2	260
8	7	Thomas	Jones	Electrician	NG substation 3	40
9	8	James	Davis	Electrician	NG substation 3	5
10	12	Micahel	Carter	Electrician	NG substation 1	55
11	13	Robert	Moore	Welder	NG substation 2	55
12	14	Matthew	Parker	Welder	NG substation 2	40
13						781

Current Assignment

	H	I
1	Optimal Project	Optimal Cost
2	NG substation 3	68
3	NG substation 1	79
4	NG substation 1	95
5	NG substation 1	5
6	NG substation 2	5
7	NG substation 3	148
8	NG substation 2	5
9	NG substation 2	79
10	NG substation 2	5
11	NG substation 1	68
12	NG substation 3	40
13		597

Optimal Assignment

Modified Assignment

	J	K	L
1	New Project	New Cost	Cost difference
2	NG substation 3	68	0
3	NG substation 1	79	0
4	NG substation 1	95	-90
5	NG substation 1	5	74
6	NG substation 2	5	90
7	NG substation 2	260	0
8	NG substation 2	5	35
9	NG substation 3	5	0
10	NG substation 2	5	50
11	NG substation 1	68	-13
12	NG substation 3	40	0
13		635	146

Cost difference = Current cost – New cost

07

Benefits & Future steps

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Our method



Minimize cost



Immediate feedback
on the feasibility



Ability to mark an
employee unavailable



Mark employees as
unchangeable



Flexibility to make manual
changes in the output with
costs calculated at runtime

Benefits

- Potential cost savings of ~20% on the per diem expenses
- Overall travel time reduced
- Improved safety
- Improved employee satisfaction

Achieving Success

- Working sessions with users
- Verify generated assignments are usable
- Analyze usability of provided features
- Identify areas for improvement to increase quality

08

Appendix

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Output

How do we update cost, duration and distance dynamically?

- Pre-calculated lookup table
- Nested Index Match formula

	A	B	C	D	E
1	Personnel Number	NG substation 1_Construction specialist	NG substation 1_Electrician	NG substation 1_Welder	NG substation 2_Electrician
2	1	9500	-1	-1	-1
3	2	500	-1	-1	-1
4	3	7900	-1	-1	-1
5	5	-1	9500	-1	500
6	6	-1	14800	-1	26000
7	7	-1	5500	-1	500
8	8	-1	500	-1	7900
9	9	-1	14800	-1	26000
10	10	-1	7900	-1	5500
11	12	-1	5500	-1	500
12	13	-1	-1	6800	-1
13	14	-1	-1	6800	-1
14					

Invalid
combination

Lookup table for cost (in cents)

Solution – Optimized assignment

Manual assignment*

Project	Worker	Job	Cost (\$)
Project A	John Doe	Electrician	128
	Peter Parker	Welder	45
	Mark Anderson	Construction Specialist	202
	Bruce Wayne	Electrician	35

Total cost: \$ 410

Optimized assignment*

Project	Worker	Job	Cost (\$)
Project A	David Price	Electrician	18
	Peter Parker	Welder	45
	Neil Vincent	Construction Specialist	57
	Andy Jordan	Electrician	16

Total cost: \$ 136

* The above scenario is using a toy data

Input template

Validity check and
remote save

Custom menu bar

The screenshot displays an Excel spreadsheet with a custom menu bar. The menu bar includes 'File', 'Home', 'Insert', 'Draw', 'Page Layout', 'Formulas', 'Data', 'Review', 'View', 'Developer', 'Help', and a custom item 'Workforce Optimization' which is highlighted with a red box. Below the menu bar, a 'Validate' button (green square) and a 'Save to Input remote' button (blue square) are highlighted with a purple box. The spreadsheet shows a table with columns A through F and rows 1 through 4. The table data is as follows:

	A	B	C	D	E	F
1	Project Name	Project Address	Construction specialist	Grade 1 Electrician	Grade 1 Electrician w/c	Welder
2	NG substation 1	1234 Data Dr, Waltham, MA	2	1	0	1
3	NG substation 2	12th Abc st, North Andover, MA	0	2	2	0
4	NG substation 3	170 Data Dr. Waltham. MA	1	100	1	1

At the bottom of the spreadsheet, a tab bar shows several input sheets: 'Project_requirements' (highlighted with an orange box), 'Worker_master', 'Job_descriptions', 'Compatibility_output', and 'Groupings'. A plus sign icon is visible to the right of the tabs.

Input sheets

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