Improving Advisor Placement in IQP Centers via Matching

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Challenge

- The IQP is an interdisciplinary project completed by every WPI undergraduate student
  - One of the most distinctive elements of the WPI Plan
  - Each IQP requires one or two advisors

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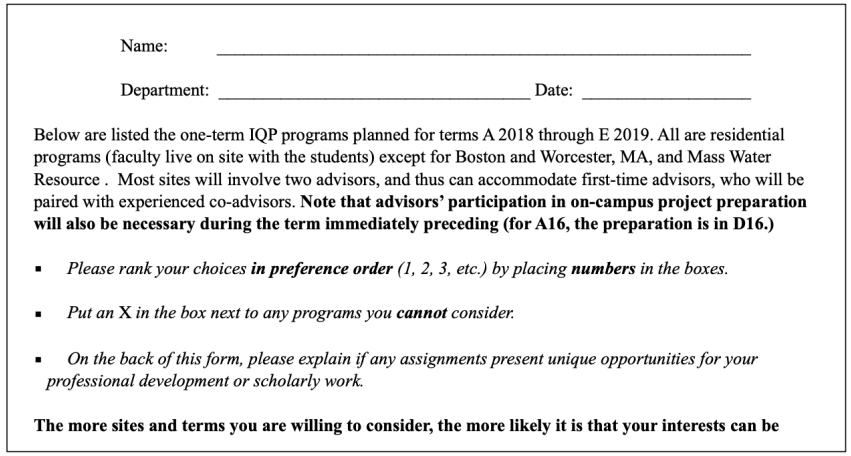
  - Each IQP requires one or two advisors
- Optimally match IQP advisors to project sites
  - Maximize number of matches made
  - Prioritize solutions that maximize advisor satisfaction
- Create a tool that will:
  - Collect advisor applications and site information
  - Consider skills of specific advisors
  - Output pairings of advisors to IQP sites
  - Be interactive for the user

Drawbacks of Current Process

- Paper application
  - Varying responses
- Data manually entered into a decision matrix in Excel
- Matches made by hand
  - About 90 applicants and 50 site-term combinations
- Applicants not numerous enough and not interested in enough sites to fill spots
  - Need to bring back retired faculty each year



Name: _____

Department: _____ Date: _____

Below are listed the one-term IQP programs planned for terms A 2018 through E 2019. All are residential programs (faculty live on site with the students) except for Boston and Worcester, MA, and Mass Water Resource . Most sites will involve two advisors, and thus can accommodate first-time advisors, who will be paired with experienced co-advisors. **Note that advisors' participation in on-campus project preparation will also be necessary during the term immediately preceding (for A16, the preparation is in D16.)**

- *Please rank your choices **in preference order** (1, 2, 3, etc.) by placing **numbers** in the boxes.*
- *Put an X in the box next to any programs you **cannot** consider.*
- *On the back of this form, please explain if any assignments present unique opportunities for your professional development or scholarly work.*

The more sites and terms you are willing to consider, the more likely it is that your interests can be

A term	B term	C term	D term	E term
Boston, MA	Cape Town, South Africa	Bangkok, Thailand	Asuncion, Paraguay	Bar Harbor, Maine
Copenhagen, Denmark	Cuenca, Ecuador	Cuenca, Ecuador	Copenhagen, Denmark	Beijing, China
Moscow, Russia	Hangzhou, China	Hong Kong, China	London, England	London, England
Panama City, Panama	Kyoto, Japan	Eilat, Israel	Mass.Water Resource Outreach, MA	Worcester, MA
Santa Fe, New Mexico	Melbourne, Australia	Monteverde, Costa Rica	Mandi, India	
Switzerland	Nantucket, MA	Rabat, Morocco	Melbourne, Australia	
Windhoek, Namibia	San Juan, Puerto Rico	San Jose, Costa Rica	Thessaloniki, Greece	
	Tirana, Albania	Wellington, New Zealand	Windhoek, Namibia	
	Venice, Italy	Worcester, MA	Worcester, MA	

Importance

- Contribute to work in combinatorial optimization
- Impact real people at WPI
  - Reduce the workload of GEO stakeholders
  - Allow IQP advisor matches to be announced earlier

The Global Experience Office (GEO)

- Met with GEO stakeholders to discuss the factors they take into account when making advisor-site matches:
  - Advisors cannot advise during back-to-back terms
  - Preferably at least one advisor at each site has advising experience
  - Specifications for particular sites
    - Number of advisors
    - Directors
    - Language requirements
- GEO stakeholders want the ability to interact with the output to prevent certain matches and force others

Mathematical Modeling

- Integer optimization: find most effective way to complete tasks
  - Represented with mathematical models containing:
    - Decision variables - represent the decisions to make
    - Objective function - dictates what is maximized or minimized
    - Constraint inequalities - restrict decisions that can be made
  - Assignment problems: a type of optimization problem that assigns items in one category to items in another category

Mathematical Modeling

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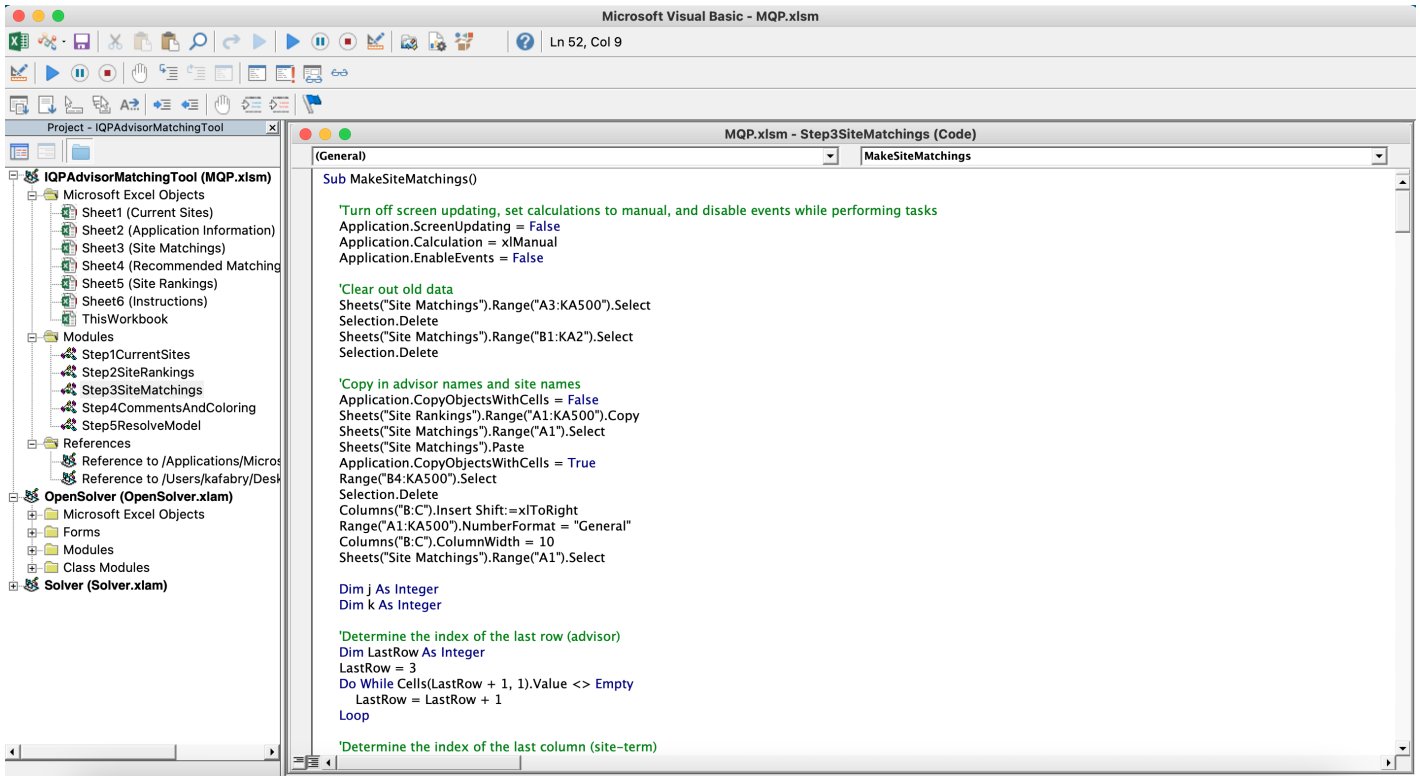
  - Assignment problems: a type of optimization problem that assigns items in one category to items in another category
- Decision Support System (DSS): a tool that helps people make better decisions based on quantitative data
  - User: provides input data
  - DSS: finds and displays the best solution in a clear and simple way

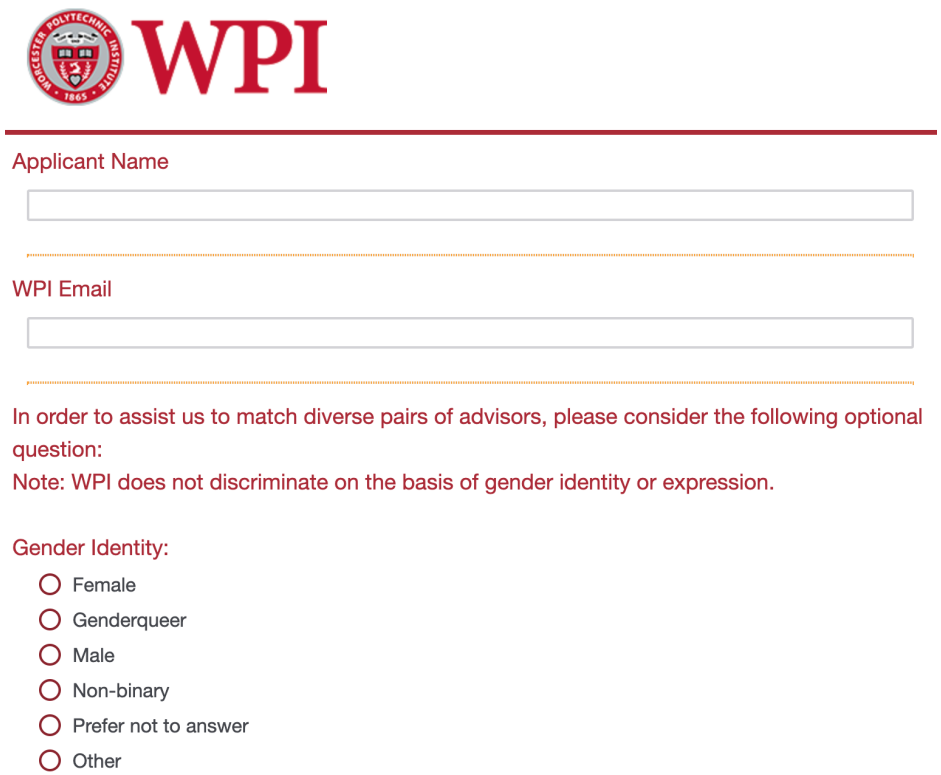
Visual Basic for Applications (VBA)

- VBA: a programming language in Excel
  - Allows users to create a spreadsheet-based optimization model
- We will develop a DSS in VBA to help the GEO match advisors to IQP sites using data collected through the advisor application



Qualtrics Survey

- Used to learn applicant's:
  - Name
  - Email
  - Gender identity
  - Employment status
  - Department affiliation
  - Director status
  - Experience level
  - Term availability
  - Language abilities
  - Site-term preferences



WPI

Applicant Name

WPI Email

In order to assist us to match diverse pairs of advisors, please consider the following optional question:
Note: WPI does not discriminate on the basis of gender identity or expression.

Gender Identity:

- Female
- Genderqueer
- Male
- Non-binary
- Prefer not to answer
- Other

. . .

Mathematical Model: Set Definitions

- L: set of all languages, indexed by ℓ

Mathematical Model: Set Definitions

- L: set of all languages, indexed by ℓ
- A: set of all advisors, indexed by i
  - Subset A_{FT} are full-time faculty members
  - Subset A_{GEO} are GEO faculty members
  - Subset A_E are experienced advisors
  - Subset A_ℓ are advisors who speak language ℓ
  - Subset A_{DP} are advisors who are scheduled to advise D term of the previous year
  - Subset A_{DY} are directors who want to advise at their site

Mathematical Model: Set Definitions

- L: set of all languages, indexed by ℓ
- A: set of all advisors, indexed by i
- S: set of all site-terms, indexed by j
  - Subsets S_ℓ are site-terms that have language restrictions, needing language $S\ell$
  - Subsets S_E, S_A, S_B, S_C, and S_D contain all site-terms for terms E, A, B, C, and D
  - Subsets $S_{DY,i}$ are site-terms where advisor i is a director for that site
  - Subsets $S_{NI,i}$ are site-terms advisor i is not interested in

Mathematical Model: Parameter Definitions

- $\lambda \in [0, 1]$, weight of advisor preferences (default $\lambda = 0.05$)
  - λ closer to 0 will give preference to the first component of the objective function
- $\mu \in [0, 1]$, weight of experienced advisor constraint (default $\mu = 0.05$)
  - μ closer to 0 will give preference to the first component of the objective function
- $a_{ij} \in \{0, 1, 2\}$, advisor i's preference of going to site j
  - 0 if not interested, 1 if interested, and 2 if very interested
- $c_j \in \{1, 2\}$, advisor capacity of site j

Mathematical Model: Variable Definitions

- $x_{ij} \in \{0, 1\}$, 1 if advisor i is matched to site-term j, 0 if they are not
- $z_j \in \{0, 1\}$, 0 if there is at least one experienced advisor at site j, 1 if there is not

Mathematical Model

- Objective function (1) maximizes:
  - 1. the total number of matches made
  - 2. the number of matches to sites preferred by advisors
  - 3. the number of site-terms with at least one experienced advisor
- Constraint set (2) ensures that there are no more advisors per site-term than the capacity of that site-term
- Constraint set (3) ensures that GEO faculty are assigned to advise for at least one site-term each year
- Constraint set (4) prioritizes having at least one experienced advisor matched to each site-term
- Constraint set (5) indicates the language requirements for necessary sites

Mathematical Model

$$\text{maximize} \quad \sum_{i \in A_{FT}} \sum_{j \in S} x_{ij} + \lambda * (\sum_{j \in S} \sum_{i \in A} a_{ij} x_{ij}) - \mu * (\sum_{j \in S} z_j), \qquad (1)$$

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$$\text{subject to} \quad \sum_{i \in A} x_{ij} \leq c_j, \ j \in S, \tag{2}$$

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$$\text{subject to} \quad \sum_{i \in A} x_{ij} \leq c_j, \ j \in S, \tag{2}$$

$$\sum_{j \in S} x_{ij} \geq 1, \ i \in A_{GEO}, \tag{3}$$

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$$\sum_{j \in S} x_{ij} \geq 1, \ i \in A_{GEO}, \tag{3}$$

$$\sum_{i \in A_E} x_{ij} \geq 1 - z_j, \ j \in S, \tag{4}$$

- Constraint set (5) indicates the language requirements for necessary sites

Mathematical Model

$$\text{maximize} \quad \sum_{i \in A_{FT}} \sum_{j \in S} x_{ij} + \lambda * (\sum_{j \in S} \sum_{i \in A} a_{ij} x_{ij}) - \mu * (\sum_{j \in S} z_j), \tag{1}$$

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$$\sum_{i \in A_\ell} x_{ij} \geq 1, \ j \in S_\ell, \tag{5}$$

Mathematical Model

- Constraint sets (6) - (11) prevent an advisor from being assigned more than once in the same term and in back to back terms

Mathematical Model

$$\sum_{j \in S_A \cup S_B} x_{ij} \leq 1, i \in A, \tag{6}$$

$$\sum_{j \in S_B \cup S_C} x_{ij} \leq 1, i \in A, \tag{7}$$

$$\sum_{j \in S_C \cup S_D} x_{ij} \leq 1, i \in A, \tag{8}$$

$$\sum_{j \in S_E} x_{ij} \leq 1, i \notin A_{DP}, \tag{9}$$

$$\sum_{j \in S_A} x_{ij} \leq 1, i \notin A_{DP}, \tag{10}$$

$$\sum_{j \in S_E \cup S_A} x_{ij} = 0, i \in A_{DP}, \tag{11}$$

Mathematical Model

- Constraint set (12) ensures that project center directors who want to advise at their site-term are automatically matched there
- Constraint set (13) prevents advisors from being matched to site-terms they ranked as not interested
- Constraint sets (14) and (15) ensure that x_{ij} and z_j are binary variables

Mathematical Model

$$x_{ij} = 1, i \in A_{DY}, j \in S_{DY,i}, \tag{12}$$

- Constraint set (13) prevents advisors from being matched to site-terms they ranked as not interested
- Constraint sets (14) and (15) ensure that x_{ij} and z_j are binary variables

Mathematical Model

$$x_{ij} = 1, i \in A_{DY}, j \in S_{DY,i}, \tag{12}$$

$$\sum_{j \in S_{NI,i}} x_{ij} = 0, i \in A, \tag{13}$$

- Constraint sets (14) and (15) ensure that x_{ij} and z_j are binary variables

Mathematical Model

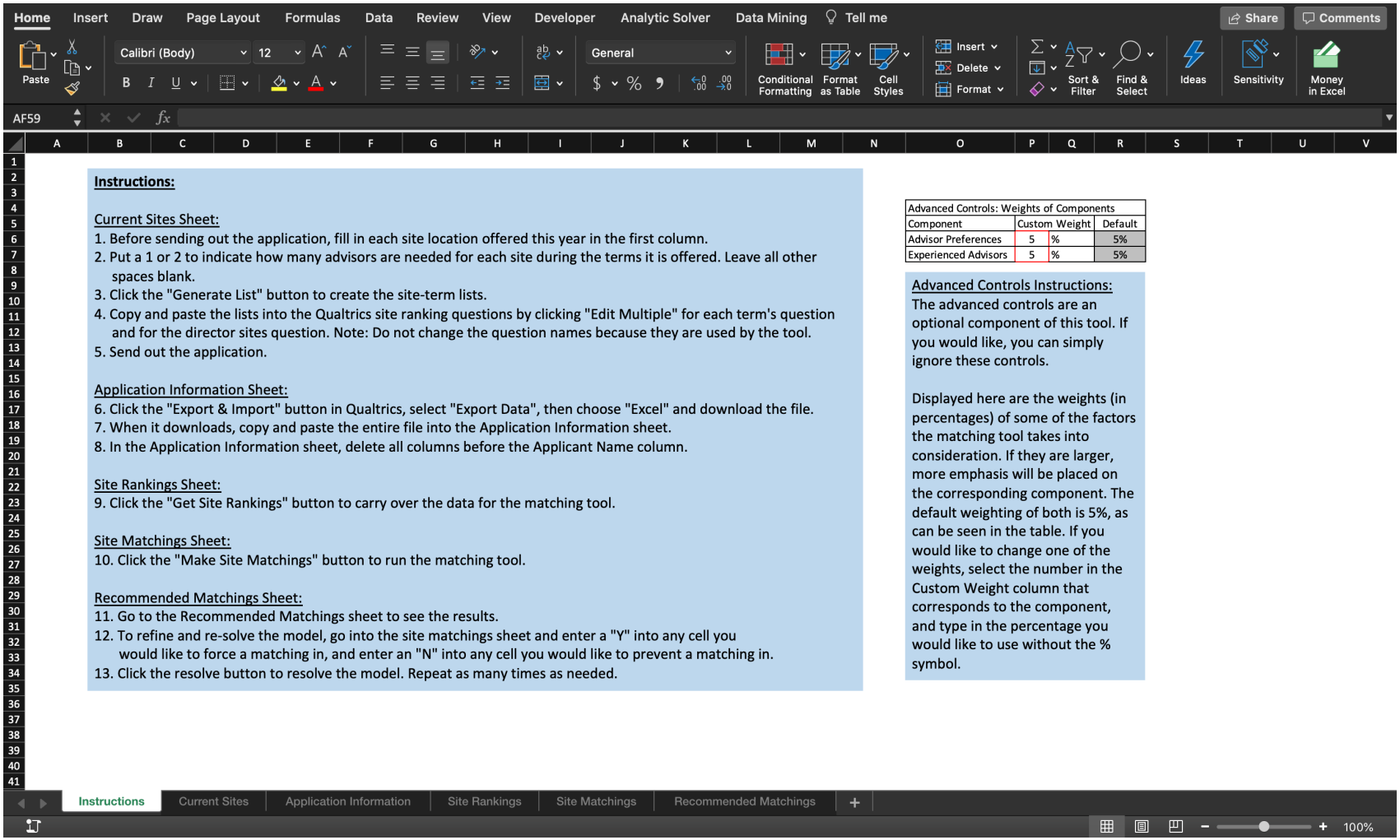
$$x_{ij} = 1, i \in A_{DY}, j \in S_{DY,i}, \tag{12}$$

$$\sum_{j \in S_{NI,i}} x_{ij} = 0, i \in A, \tag{13}$$

$$x_{ij} \in \{0, 1\}, i \in A, j \in S, \tag{14}$$

$$z_j \in \{0, 1\}, j \in S \tag{15}$$

Matching Tool in Excel: Instructions



Instructions:

Current Sites Sheet:
1. Before sending out the application, fill in each site location offered this year in the first column.
2. Put a 1 or 2 to indicate how many advisors are needed for each site during the terms it is offered. Leave all other spaces blank.
3. Click the "Generate List" button to create the site-term lists.
4. Copy and paste the lists into the Qualtrics site ranking questions by clicking "Edit Multiple" for each term's question and for the director sites question. Note: Do not change the question names because they are used by the tool.
5. Send out the application.

Application Information Sheet:
6. Click the "Export & Import" button in Qualtrics, select "Export Data", then choose "Excel" and download the file.
7. When it downloads, copy and paste the entire file into the Application Information sheet.
8. In the Application Information sheet, delete all columns before the Applicant Name column.

Site Rankings Sheet:
9. Click the "Get Site Rankings" button to carry over the data for the matching tool.

Site Matchings Sheet:
10. Click the "Make Site Matchings" button to run the matching tool.

Recommended Matchings Sheet:
11. Go to the Recommended Matchings sheet to see the results.
12. To refine and re-solve the model, go into the site matchings sheet and enter a "Y" into any cell you would like to force a matching in, and enter an "N" into any cell you would like to prevent a matching in.
13. Click the resolve button to resolve the model. Repeat as many times as needed.

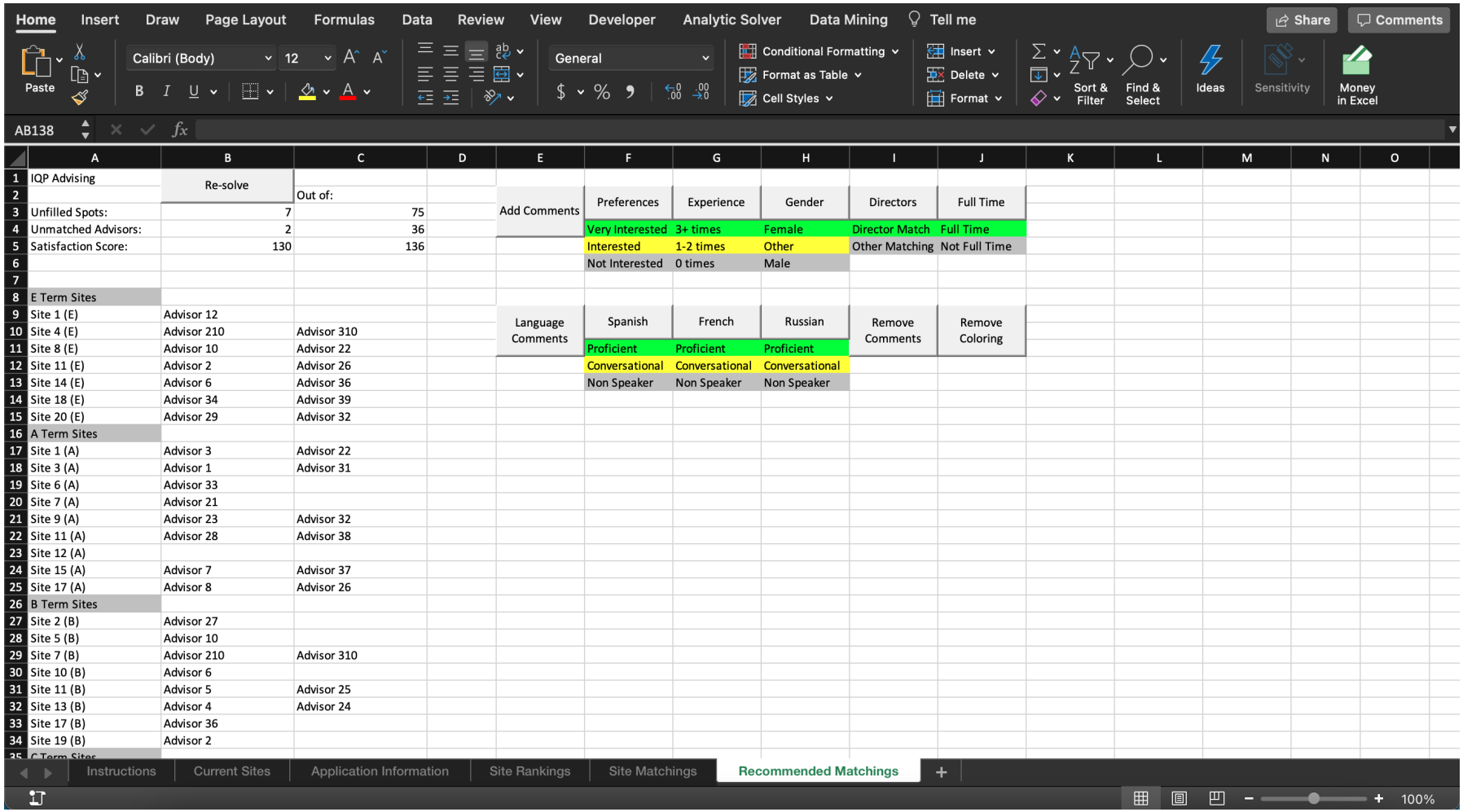
Advanced Controls: Weights of Components			
Component	Custom Weight		Default
Advisor Preferences	5	%	5%
Experienced Advisors	5	%	5%

Advanced Controls Instructions:
The advanced controls are an optional component of this tool. If you would like, you can simply ignore these controls.

Displayed here are the weights (in percentages) of some of the factors the matching tool takes into consideration. If they are larger, more emphasis will be placed on the corresponding component. The default weighting of both is 5%, as can be seen in the table. If you would like to change one of the weights, select the number in the Custom Weight column that corresponds to the component, and type in the percentage you would like to use without the % symbol.

- The tool's first sheet has detailed instructions on its use

Matching Tool in Excel: Output



	A	B	C
1	IQP Advising	Re-solve	
2			Out of:
3	Unfilled Spots:	7	75
4	Unmatched Advisors:	2	36
5	Satisfaction Score:	130	136
6			
7			
8	E Term Sites		
9	Site 1 (E)	Advisor 12	
10	Site 4 (E)	Advisor 210	Advisor 310
11	Site 8 (E)	Advisor 10	Advisor 22
12	Site 11 (E)	Advisor 2	Advisor 26
13	Site 14 (E)	Advisor 6	Advisor 36
14	Site 18 (E)	Advisor 34	Advisor 39
15	Site 20 (E)	Advisor 29	Advisor 32
16	A Term Sites		
17	Site 1 (A)	Advisor 3	Advisor 22
18	Site 3 (A)	Advisor 1	Advisor 31
19	Site 6 (A)	Advisor 33	
20	Site 7 (A)	Advisor 21	
21	Site 9 (A)	Advisor 23	Advisor 32
22	Site 11 (A)	Advisor 28	Advisor 38
23	Site 12 (A)		
24	Site 15 (A)	Advisor 7	Advisor 37
25	Site 17 (A)	Advisor 8	Advisor 26
26	B Term Sites		
27	Site 2 (B)	Advisor 27	
28	Site 5 (B)	Advisor 10	
29	Site 7 (B)	Advisor 210	Advisor 310
30	Site 10 (B)	Advisor 6	
31	Site 11 (B)	Advisor 5	Advisor 25
32	Site 13 (B)	Advisor 4	Advisor 24
33	Site 17 (B)	Advisor 36	
34	Site 19 (B)	Advisor 2	

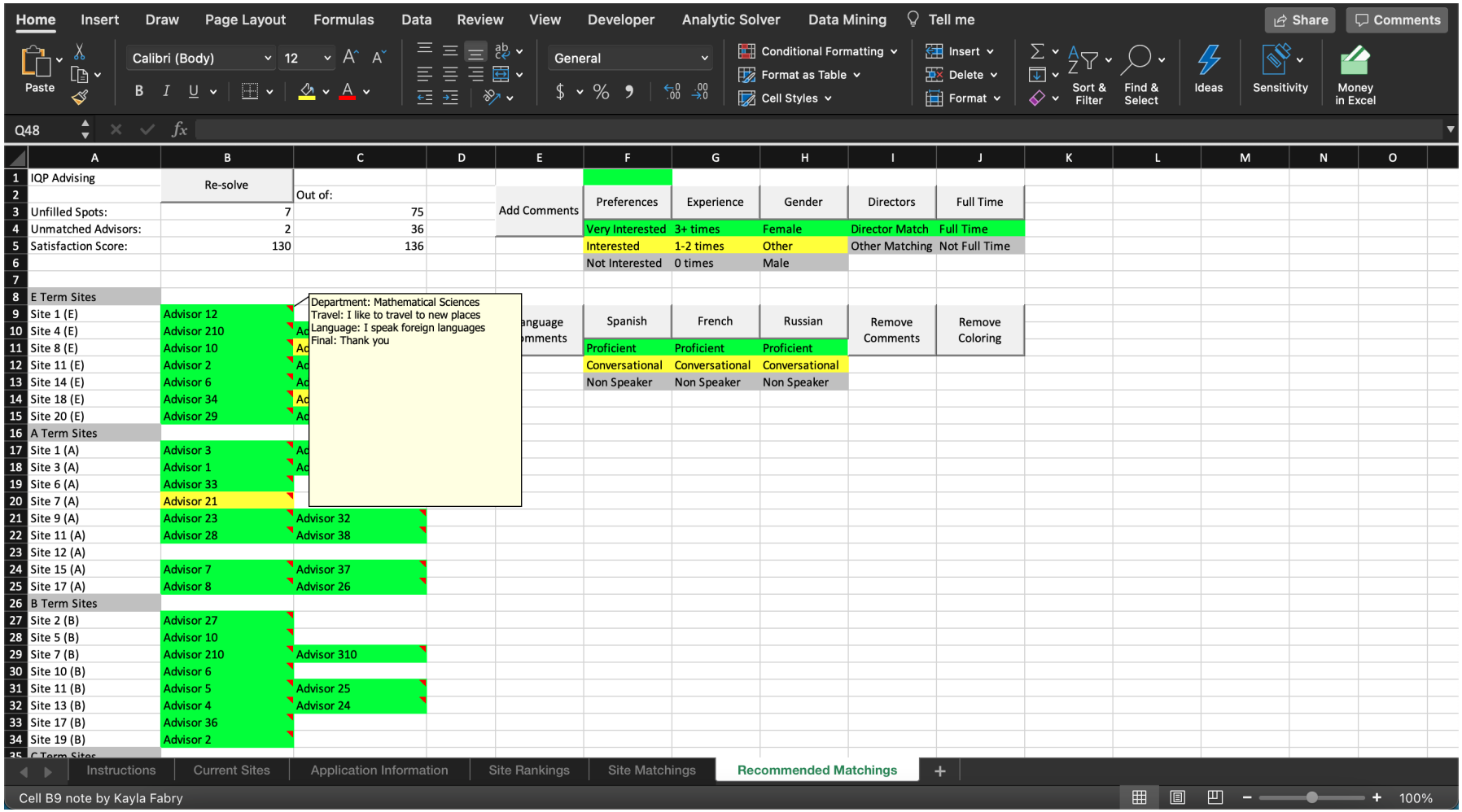
Add Comments	Preferences	Experience	Gender	Directors	Full Time
	Very Interested	3+ times	Female	Director Match	Full Time
	Interested	1-2 times	Other	Other Matching	Not Full Time
	Not Interested	0 times	Male		

Language Comments	Spanish	French	Russian	Remove Comments	Remove Coloring
	Proficient	Proficient	Proficient		
	Conversational	Conversational	Conversational		
	Non Speaker	Non Speaker	Non Speaker		

Instructions | Current Sites | Application Information | Site Rankings | Site Matchings | Recommended Matchings

- This is what the tool's output looks like with our sample data

Matching Tool in Excel: Interpreting Output



	A	B	C	D	E	F	G	H	I	J
1	IQP Advising	Re-solve								
2			Out of:							
3	Unfilled Spots:	7	75		Add Comments	Preferences	Experience	Gender	Directors	Full Time
4	Unmatched Advisors:	2	36			Very Interested	3+ times	Female	Director Match	Full Time
5	Satisfaction Score:	130	136			Interested	1-2 times	Other	Other Matching	Not Full Time
6						Not Interested	0 times	Male		
7										
8	E Term Sites									
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10	Site 4 (E)	Advisor 210								
11	Site 8 (E)	Advisor 10								
12	Site 11 (E)	Advisor 2								
13	Site 14 (E)	Advisor 6								
14	Site 18 (E)	Advisor 34								
15	Site 20 (E)	Advisor 29								
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32	Site 13 (B)	Advisor 4	Advisor 24							
33	Site 17 (B)	Advisor 36								
34	Site 19 (B)	Advisor 2								

Department: Mathematical Sciences
Travel: I like to travel to new places
Language: I speak foreign languages
Final: Thank you

Spanish	French	Russian	Remove Comments	Remove Coloring
Proficient	Proficient	Proficient		
Conversational	Conversational	Conversational		
Non Speaker	Non Speaker	Non Speaker		

- Buttons allow the user to interpret matches

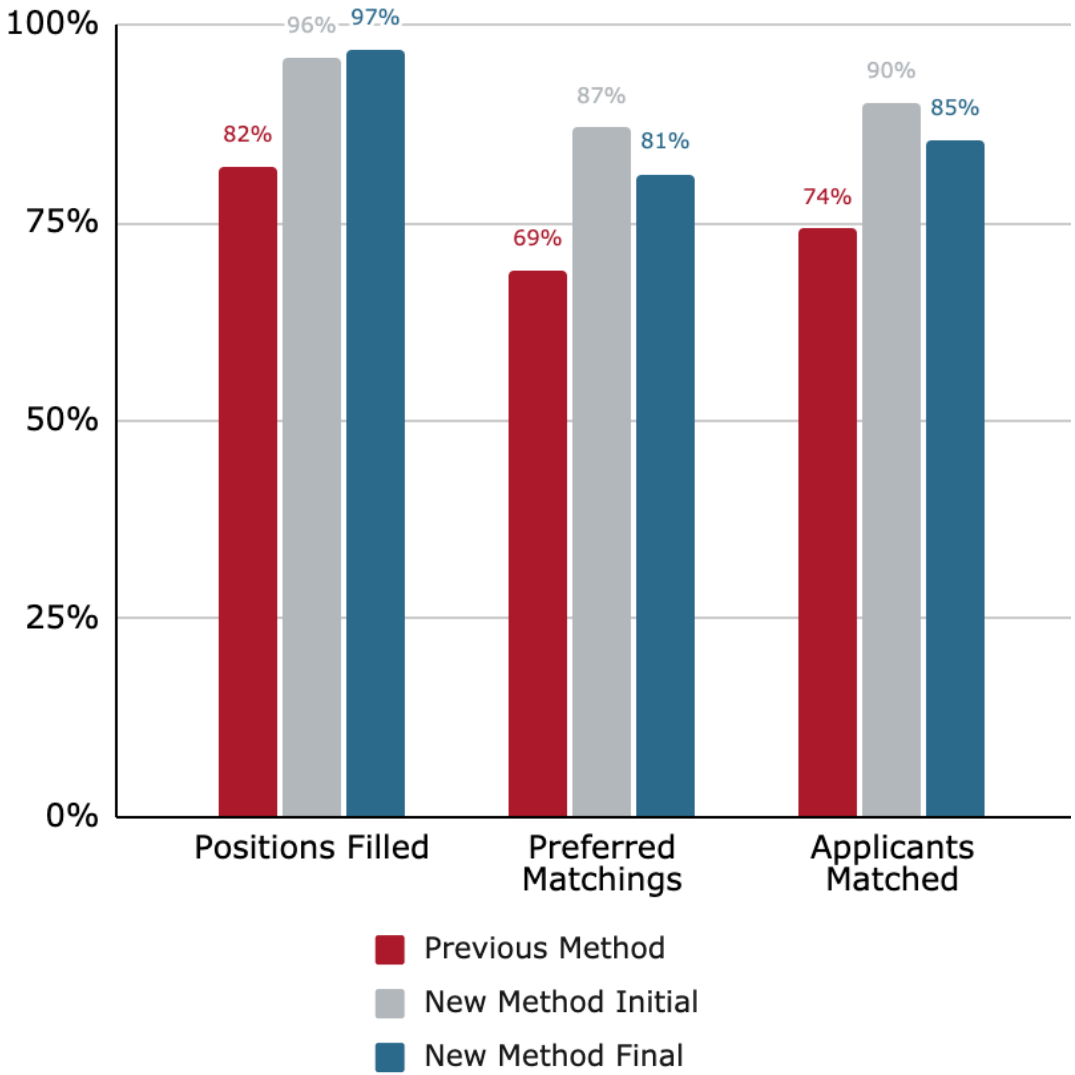
Matching Tool in Excel: Interactivity

	A	B	C	D	E	F	G	H	I
1	Make Site Matchings	Assigned Advisors:		1	2	1	2	2	2
2		Maximum Advisors:		1	2	2	2	2	2
3	Applicant Name	Assigned Ter	Maximum A:	Site 1 (E)	Site 4 (E)	Site 8 (E)	Site 11 (E)	Site 14 (E)	Site 18 (E)
4	Advisor 1	2	2	0	0	0	0	0	0
5	Advisor 2	3	5	0	0	0	1	0	0
6	Advisor 3	2	2	0	0	0	0	0	0
7	Advisor 4	1	1	0	0	0	0	0	0
8	Advisor 5	2	2	0	0	0	0	0	0
9	Advisor 6	3	5	0	0	0	0	1	0
10	Advisor 7	2	2	0	0	0	0	0	0
11	Advisor 8	2	2	0	0	0	0	0	0
12	Advisor 9	1	2	0	0	Y	0	0	0
13	Advisor 10	2	5	0	0	N	0	0	0
14	Advisor 11	1	2	0	0	0	0	0	0
15	Advisor 12	1	1	1	0	0	0	0	0
16	Advisor 21	2	2	0	0	0	0	0	0
17	Advisor 22	3	5	0	0	1	0	0	0
18	Advisor 23	2	2	0	0	0	0	0	0
19	Advisor 24	1	1	0	0	0	0	0	0
20	Advisor 25	2	2	0	0	0	0	0	0
21	Advisor 26	3	5	0	0	0	1	0	0
22	Advisor 27	2	2	0	0	0	0	0	0
23	Advisor 28	2	2	0	0	0	0	0	0
24	Advisor 29	2	2	0	0	0	0	0	0
25	Advisor 210	3	5	0	1	0	0	0	0
26	Advisor 211	1	2	0	0	0	0	0	0
27	Advisor 212	0	1	0	0	0	0	0	0
28	Advisor 31	2	2	0	0	0	0	0	0
29	Advisor 32	3	5	0	0	0	0	0	0
30	Advisor 33	2	2	0	0	0	0	0	0
31	Advisor 34	1	1	0	0	0	0	0	1
32	Advisor 35	1	2	0	0	0	0	0	0
33	Advisor 36	3	5	0	0	0	0	1	0

Instructions | Current Sites | Application Information | Site Rankings | Site Matchings

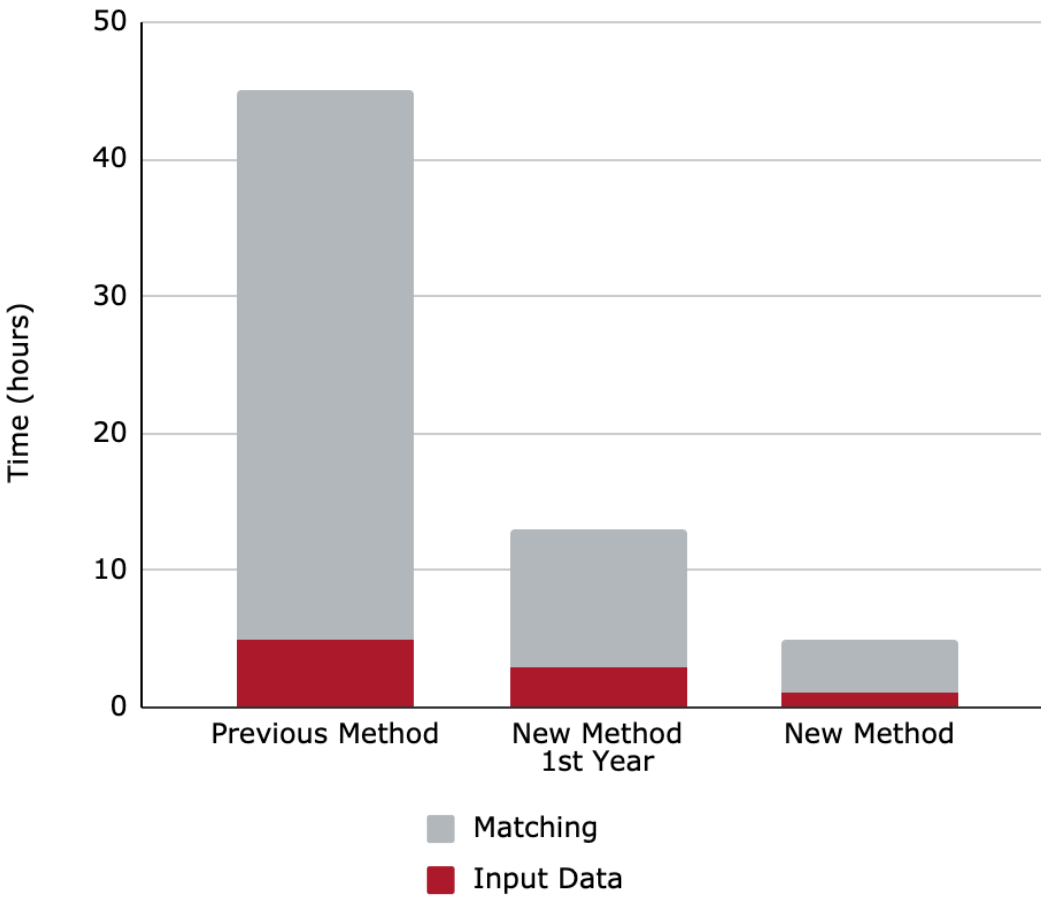
- The tool's output is interactive
  - The user can enter a "Y" or "N" into any cell corresponding to a match they want to force or prevent
  - Then re-solve
- Ex: want Advisor 9 to advise at Site 8 (E) instead of Advisor 10

Impact: Optimal Matching



- 15% more advisor positions filled
- 12% more matches to sites preferred by applicants
- 11% more applicants matched to at least one site

Impact: Time Savings



- Previous: about 5 hours to input application data and 40+ hours to match
- 1st year: about 3 hours to input data and 10 to match
- New future years: predict 5 hours in total
- 89% reduction in time
  - GEO stakeholders will gain back some free time in their weekends

Takeaways

- Utilized VBA to
  - Develop knowledge of the programming language
  - Apply binary integer optimization techniques to a real problem
  - Expand upon critical thinking and decision making skills

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- Utilized VBA to
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  - Apply binary integer optimization techniques to a real problem
  - Expand upon critical thinking and decision making skills
- Developed understanding of the needs of GEO stakeholders to
  - Learn how to tailor designs towards a specific goal
  - Understand importance of an interactive interface
- Future Applications
  - Advisor placement for other travel abroad programs
  - Professor assignments for teaching courses
  - Course matches to classrooms and lecture halls

Thank you

Thank you

-

Questions?